Limerick Clare Energy Plan

Energy and Emissions Balance 2010 and 2020

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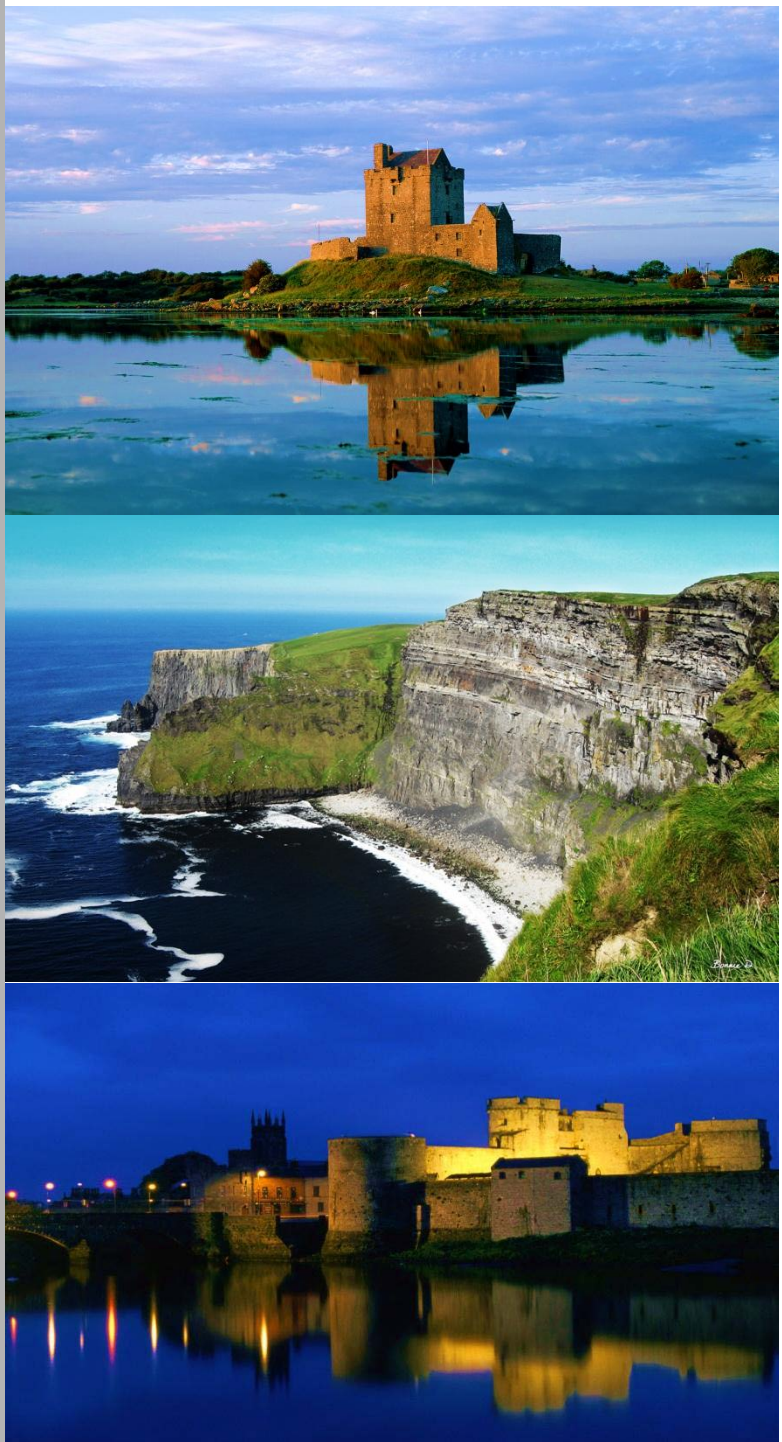
LIMERICK CLARE
energy agency



Limerick Clare Energy Plan: Energy and Emissions Balance 2010 and 2020

Clare Local Development Company

Ballyhoura Development Limited

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

West Limerick Resources

The Limerick Clare Energy Agency (LCEA) was established in 2005 through the joint investment of Limerick and Clare County Councils.

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Executive Summary

Considering the security of supply concerns relating to the Irish energy system at present and the significant renewable energy resource available, many initiatives and policies have been developed to encourage the transition to renewable energy. These objectives are almost exclusively set at a national level, but they need to be supplemented by local plans also, since the most successful renewable energy projects to date are at a local level. For example, it is evident from the transition to renewable energy in Denmark, that 100% renewable energy systems can already be implemented at a local level. Hence, by initiating local action, national targets can be met and exceeded, while also creating a template for a wider transition to renewable energy. Accordingly, the primary goal of the project is:

To develop a local energy plan for Limerick and Clare which is based on a quantified assessment of different sustainable energy measures, in terms of costs, fuel, and carbon dioxide emissions.

The project has been subdivided into two sections: the Energy & Emissions Balance and the Climate Change Strategy. In this report, the Energy & Emissions Balance, the key goal is to develop a local energy balance for the Limerick Clare Region (LCR), which can subsequently be used in the Climate Change Strategy.

This report includes a review of existing legislation which affects the LCR at EU, national, regional, and local level. In addition, other local energy balances in Ireland are assessed to establish the different methodologies currently utilised in Ireland for local energy balances. From this review, the key difference identified is the use of a top-down or a bottom-up approach. Typically large areas with more than 10,000 inhabitants use a top-down approach to create an energy balance whereas smaller areas use a bottom-up approach based on actual energy consumption data. For the LCR, it was concluded that a top-down approach would therefore be the most suitable.

While creating the energy balance for the LCR, a number of key challenges were experienced. Below is a brief overview of these challenges along with some recommendations:

1. It is important for local authorities and local communities to begin recording their electricity, heat, and transport demands in the region. One option is for the Irish government to make if mandatory for energy suppliers to provide data to local county councils on energy consumption.
2. A heat atlas should also be created for the region. The heat atlas is a fundamental tool for assessing the feasibility of new energy networks, such as district heating and the expansion of the gas grid.
3. The methodology developed in this report should not be considered as a final solution for estimating energy consumption at a regional level. Instead it should be developed and improved over time as more contributors offer their knowledge and insights into energy consumption in the region.
4. More information should be collected about the type of boilers used within the region.

Even though there were many barriers during this study, the accuracy of this methodology should be taken in the context of its purpose. It is clear that the proportioning top-down methodology utilised will not produce exact figures, but the principal purpose of the energy balance is to form an indicative picture of what and how energy is consumed within a region. The fundamental application of the energy balance is to act as a baseline for evaluating alternatives (in the Climate Change Strategy) and so exact data is not necessary. In addition, the recent recession in Ireland has outlined the unpredictability of the economy and

hence the unpredictability of future energy consumption. Therefore, even if actual bottom-up data is available in the future in the LCR, it will still be difficult to accurately forecast an energy balance for the future. As a result, this methodology fulfils the objective which it needs to meet: it is a relatively simple methodology which provides an indicative representation of energy consumption within the LCR now and for 2020.

Another major challenge in this study, which will exist no matter what data is available, is the definition of boundaries. For the LCR, this was particularly difficult in relation to the consumption of energy in industry and the local electricity mix. Hence, new methodologies have been developed to consider these concerns in this study, which can be replicated by other counties in Ireland also. For industry, two energy balances were created: the primary one which proportioned national consumption to the local region based on the number of jobs in the region and a second one for a sensitivity analysis, which used the actual energy consumption in the region. In relation to the electricity mix, the key challenge was defining a mix which rewarded the local implementation of renewable energy, instead of it being lost in national statistics. Hence renewable energy production in the region is allocated first and the remainder is met by the average national fossil fuel mix.

Using these new methodologies, the energy consumption (Figure 1 and Figure 2), energy-related greenhouse gas emissions (Figure 3), and fuel costs (Figure 4) are estimated for the LCR. These results have also been estimated for County Clare, County Limerick, and Limerick City individually in the main report.

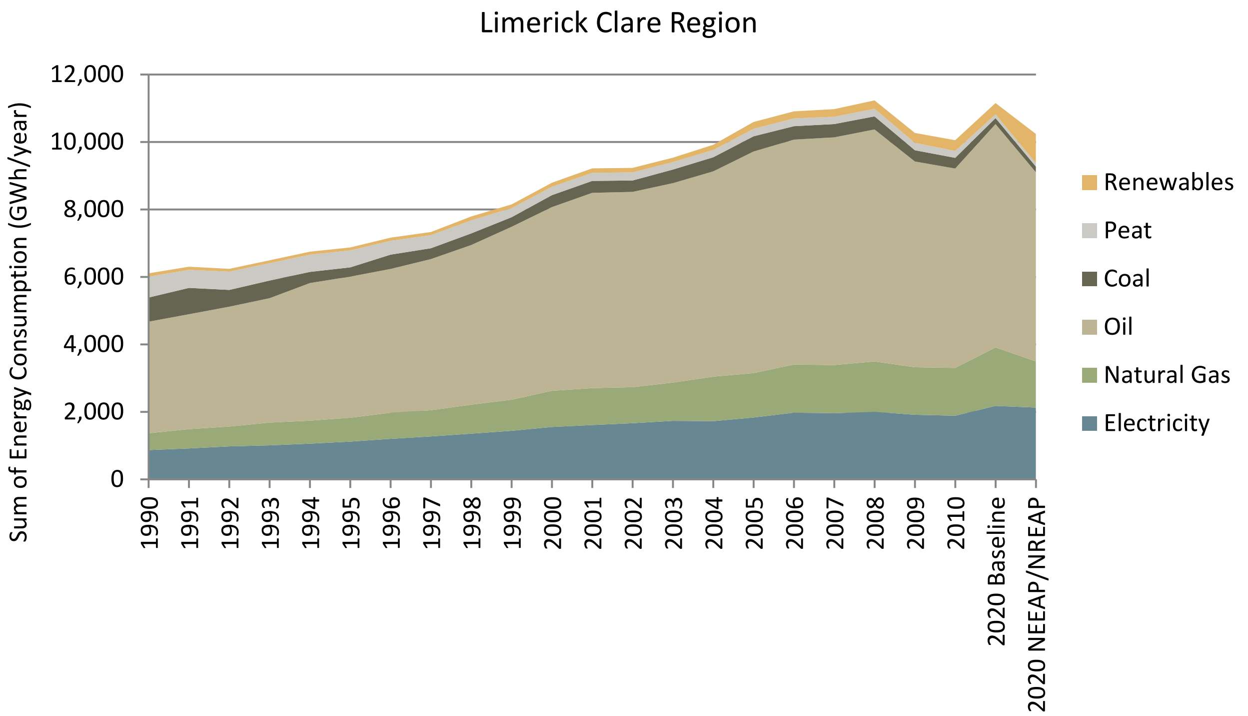

Figure 1: Energy consumed in the LCR by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

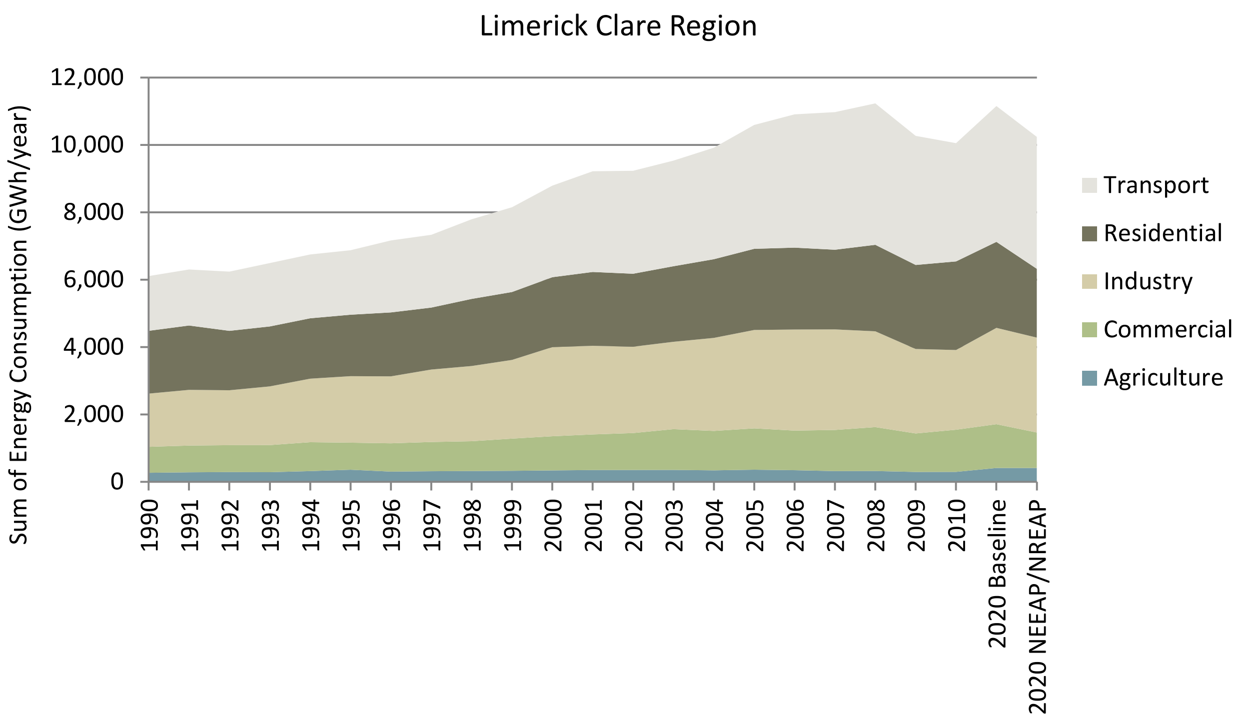

Figure 2: Energy consumed in the LCR by sector from 1990-2010 and forecasted for 2020 excluding LEUs.

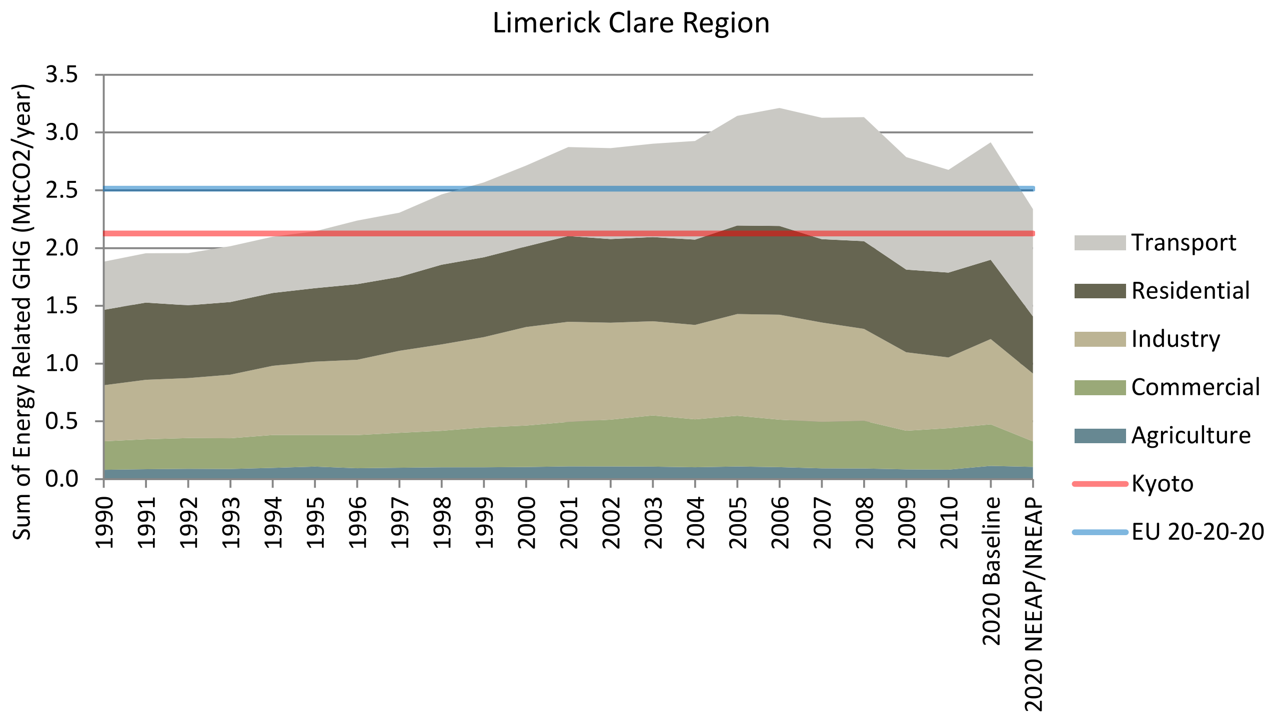

Figure 3: Energy related GHG emissions in the LCR by sector from 1990-2010 and forecasted for 2020 excluding LEUs.

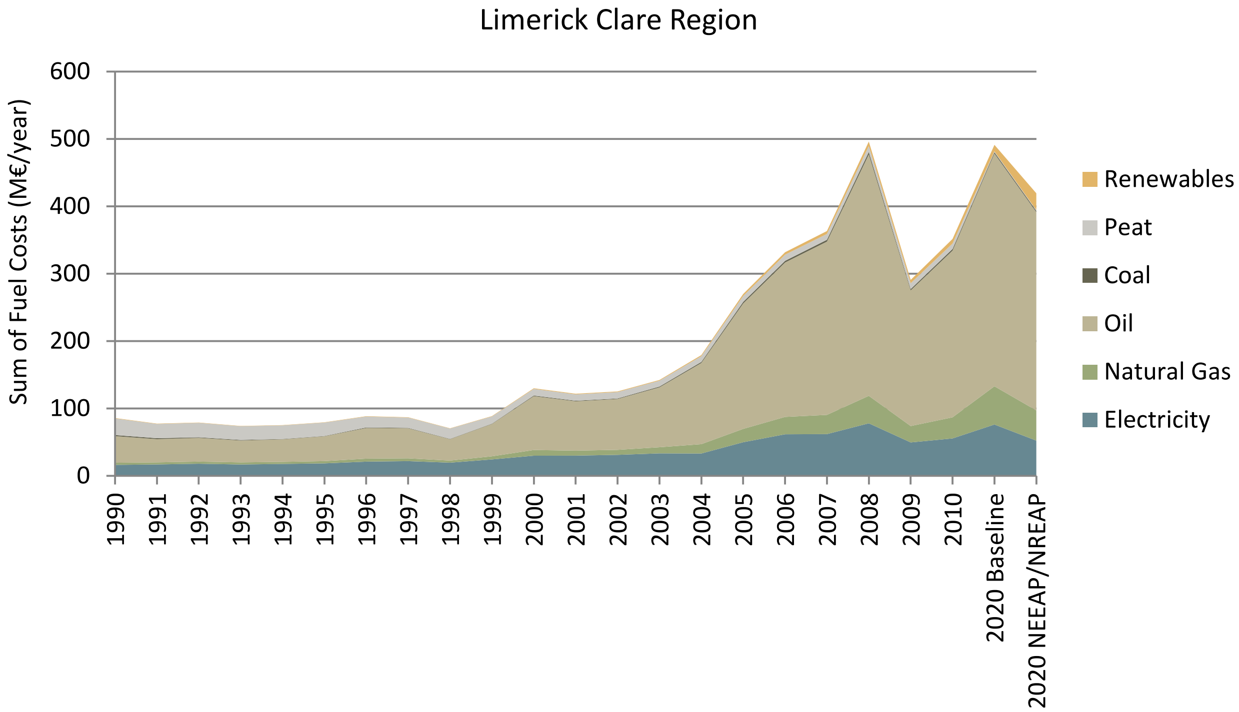

Figure 4: Fuel costs in the LCR by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

It is evident from the results that the LCR is heavily dependent on fossil fuels which cannot be found within the region. This can be clearly illustrated in the summary of the results in Table 1 and Table 2, which indicates that in 2010 approximately M€350 was spent on fuel for the region. However, if the government policies proposed in the NEEAP/NREAP scenarios are implemented, then the overall energy consumption in the LCR will only increase by 2% compared to 11% in a business-as-usual scenario. Also, implementing these polices will ensure that Ireland's greenhouse gas emission targets for both Kyoto and EU 20-20-20 targets will be met in 2020 and the cost of fuel in the region will be M€70/year instead of M€140/year. Approximately 20% and 10% of the energy savings required by 2020 will come from buildings and the public sector respectively. Therefore, the LCEA can play a key role on behalf of the county councils at implementing and coordinating these savings.

Table 1: Summary of energy demand, energy related GHG emissions, and fuel costs in 2010.

2010	Energy Demand (GWh)	Energy related GHG (Mt CO_2)	Fuel Costs (M€)
Ireland	140,106	41.7	5,335.9
Clare County	3,670	1.0	130
Limerick City	1,730	0.5	60
Proportioned LEUs			
Limerick County	4,640	1.2	162
Limerick-Clare Region	10,040	2.7	352
With All LEU's Energy			
Limerick County	9,180	2.4	296
Limerick-Clare Region	14,360	3.8	482

Table 2: Summary of energy demand, energy related GHG emissions, and fuel costs in 2020 if government policies are implemented.

2020 NEEAP/NREAP	Energy Demand (GWh)	Energy related GHG (Mt CO_2)	Fuel Costs (M€)
Ireland	139,000	35.4	6,200
Clare County	3,640	0.8	150
Limerick City	1,660	0.4	69
Proportioned LEUs			
Limerick County	4,950	1.1	201
Limerick-Clare Region	10,250	2.3	420
With All LEU's Energy			
Limerick County	10,200	2.4	406
Limerick-Clare Region	15,250	3.6	622

Naturally these energy, greenhouse gas emission, and fuel cost reductions will require a number of investments. Hence, the next step in this research is to input the energy balance developed in this study into the energy-systems-analysis tool, EnergyPLAN, to assess if these investments will be socio-economically viable for the LCR. This will be carried out in the Climate Change Strategy, which also includes an assessment of the renewable energy potential in the LCR. The final output is a local energy strategy which identifies how the LCR can utilise more of this renewable energy, with the final goal of becoming a 100% renewable energy region.

Limerick Clare Energy Agency

This report has been prepared for the Limerick-Clare Energy Agency (LCEA) [1]. The LCEA was established in 2005 with equal investment from Limerick County Council and Clare County Council. The agency is also fortunate to enjoy the support of the LEADER groups in Clare, West-Limerick and Ballyhoura; in addition to The University of Limerick and Aerobord Ltd.

The LCEA aims to provide energy solutions for sustainable development in the region. The agency provides energy services to all economic sectors and the general public, promoting and facilitating efficiency and sustainability in the production and consumption of energy. The top ten areas of interest for the agency are:

1. Promote Public Awareness of Energy & Climate Change Issues.
2. Evaluate Energy Consumption in Clare & Limerick.
3. Evaluate Energy Related Emissions for Clare & Limerick.
4. Develop an Energy & Emissions Balance for Clare & Limerick.
5. Support & Develop Renewable Energy Production, Distribution & Training Programmes.
6. Conduct Energy Audits & Benchmarking of Public Buildings and Facilities in Clare & Limerick.
7. Promote Cooperation and Links to Community Groups (LEADER etc.)
8. Promote Research & Development Partnerships with Third Level Education Bodies.
9. Promote Energy Efficiency and Environmental Awareness to all Commercial Energy Consumers.
10. Promote the Establishment of Low Carbon Commerce.

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Nomenclature

Abbreviation	Description
AEB	Actual Energy Balance
BER	Building Energy Rating
CER	Commission for Energy Regulation
CSO	Central Statistics Office (Ireland)
DoEHLG	Department of Environment, Heritage, and Local Government (Ireland)
EMP	Energy Master Planning (Tool)
ESB	Electricity Supply Board
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse Gas (Emissions)
IEA	International Energy Agency
LCEA	Limerick Clare Energy Agency
LCEP	Limerick Clare Energy Plan
LCR	Limerick Clare Region
LEU	Large Energy User
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
MOU	Memorandum of Understanding
MRSO	Meter Registration System Operator
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical classification of economic activities in the European Community)
NEEAP	National Energy Efficiency Action Plan
NREAP	National Renewable Energy Action Plan
POWCAR	Place of Work Census of Anonymised Records
REB	Responsible Energy Balance
SEAI	Sustainable Energy Authority of Ireland
SEP	Sustainable Energy Project
SEZ	Sustainable Energy Zone
TSO	Transmission System Operator

1 Introduction

Over the last 150 years, global energy supplies have been increasingly dependent on fossil fuel that has led to a variety of significant global problems including climate change and security of supply. It has thus become a global objective to transition from a fossil fuel to a renewable energy based system, which by its definition is a sustainable and environmentally friendly form of creating energy. The generic actions required to make this transition are well documented and consist of energy efficiency, renewable energy generation, and the electrification of transport. However, the specific technologies that each country should incorporate are dependent on local resources, infrastructure, and objectives. As a result, many studies focus specifically on the future of the Irish energy system.

From these studies, it is evident that Ireland has a number of positive and negative issues relating to its energy system. On the negative side, Ireland's current energy system is inefficient and fossil fuel intensive. Hence, Ireland had the 39th highest energy consumption per person in the world in 2008 and the 24th highest CO_2 emission per person (out of 137 countries). Magnifying this issue is the fact that Ireland has very little indigenous fossil fuel production and hence Ireland imported over 90% of its energy in 2008, as displayed in Figure 5. Due to dramatically increasing fossil fuel prices in the last decade there has also been a dramatic rise in the price of importing fuel in Ireland which exceeded €6 billion in 2008 [2]: this has a substantial cost on Ireland's balance of payments.

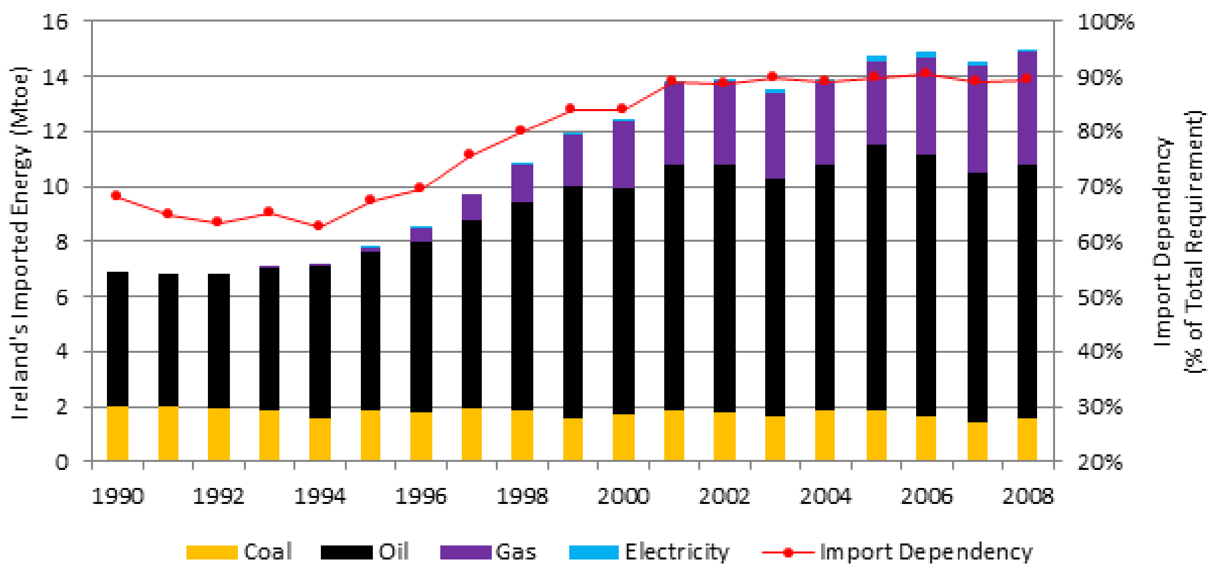

Figure 5: Ireland's imported energy by fuel and dependency from 1990 to 2008 [3-5].

In contrast to the current situation, Ireland has a range of positive issues for the future energy system. Most significantly is the vast renewable resource available in Ireland. Looking at a range of studies which have evaluated the economic resource in Ireland [6-10], it is evident from Figure 6 that over 200% of Ireland's electricity consumption could be supplied from intermittent renewable energy in 2020. Not only is this a substantial renewable resource, but the wind and wave resources available are among the best in the world. Hence, Ireland should be a world-leading installed and developer of these technologies.

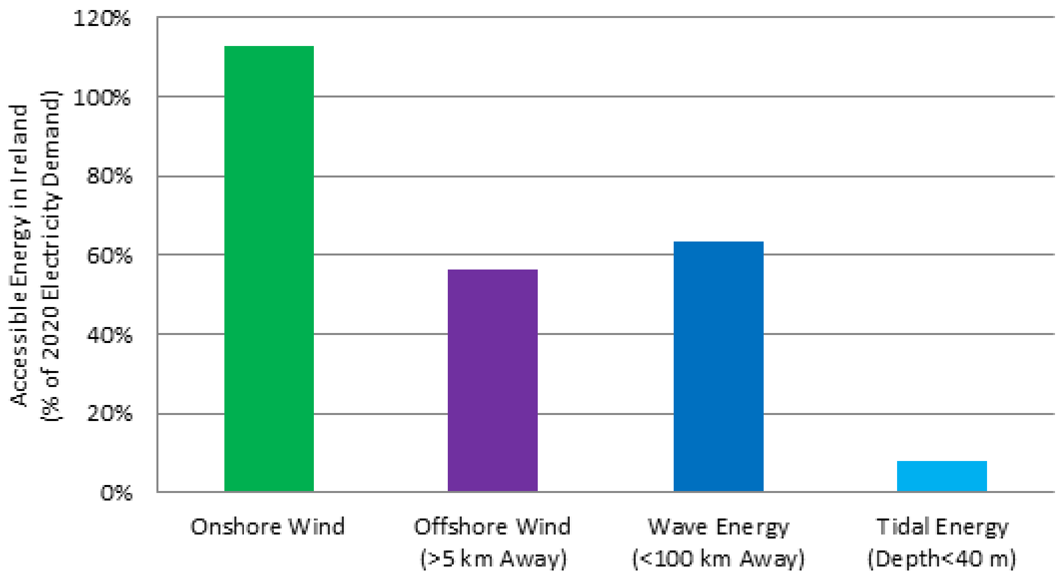

Figure 6: Accessible intermittent renewable energy resource in Ireland relative to forecasted 2020 electricity consumption [6-10].

Considering the vulnerable position of the Irish energy system at present and the significant renewable energy resource available, many initiatives and policies have been developed to encourage the transition to renewable energy (for more details see Appendix I). These objectives are almost exclusively set at a national level, but they need to be supplemented by local plans also. It is evident based on the transition to renewable energy in Denmark, that 100% renewable energy systems can be fully implemented at a local level over a relatively short timeframe of 5-10 years [11, 12]. Hence, by initiating local action, national targets can be met and exceeded, while also creating a template for a wider transition to renewable energy. As outlined by O'Hora "national policy sets the direction for sustainable development, but it is practical action at local level that makes that development real" [13]. Accordingly, the objective of this project is to develop a local energy plan for the counties of Limerick and Clare in Ireland, which will subsequently be referred to as the Limerick-Clare Energy Plan (LCEP). The primary goal of the project is:

To develop a local energy plan for Limerick and Clare which is based on a quantified assessment of different sustainable energy measures, in terms of costs, fuel, and carbon dioxide emissions.

To understand the context and contribution of this report, it is important to understand the process of developing and implementing a local energy plan. As stated by Steidle *et al.* [14], it is important that a local energy planning framework includes the following attributes:

- Considers the entire energy system (electricity, heat, and transport) from both a demand and supply perspective.
- Accounts for the dynamics of the energy system, especially when integrating renewable energy generation or distribution girds such as district heating and gas.
- Uses a long-term time horizon which allows for changes to energy infrastructure in the region.
- Involves all key stakeholders.
- It is a continuous process where information is improved based on experience.
- Establishes a method of measurement for evaluating progress.

- Be completed from a socio-economic perspective because the plan must consider:
    - A variety of interests from local groups.
    - Energy infrastructure has a very long lifetime: 25-50 years.
    - There are many different options and alternatives to be considered.
    - Interdependent subsystems which need to act with one another, especially when integrating renewable energy.
    - Need to be able to compare the demand and supply sides with one another i.e. a demand reduction is often cheaper than a generation expansion.
    - Individual projects are often dependent on socio-economic factors i.e. energy prices, taxes, laws.
    - Energy is often co-ordinated with planning in other fields such as waste management, transportation, etc.

Based on previous experiences in both Ireland [13] and abroad [14-16], it is evident that these issues can be accounted for by completing a local energy plan using the following key steps (which are also displayed in Figure 7):

1. **Committing:** key stakeholders must commit their time and resources to the energy planning project. They must come from all sectors of society and include the local Authority, local politicians, local planners, public and private bodies, developers, businesses, energy suppliers, service providers, technical experts, educational institutions, residents associations, householders. The resources required are time, human (i.e. administrative and technical expertise), and financial. After various stakeholders have committed to the project, than a project management team can be establish to drive the project forward.
2. **Identifying:** system boundaries, planning approach, urgent energy problems, long-term objectives, technical solutions, potential benefits of plan, decision makers, historic development, on-going activities, areas which can be influenced, financing options. Typically, this results in an energy and emissions balance for the region, a planning methodology, an outline of the institutional setup, and some clear objectives (which can be updated as the project progresses)
3. **Planning:** due to the complexity of modern energy systems, energy tools are necessary to account for the complex interactions between supply and demand as well as the numerous financial parameters that need to be considered. In this step, the energy balance developed is inputted into the chosen energy tool. Afterwards, various alternatives are defined and assessed in the energy tool so they can be evaluated in relation to costs, fuel consumption, and emissions.
4. **Evaluating:** here the results from the planning phase are assessed and compared to the initial objectives of the energy plan. Specific actions and projects are identified for implementation and therefore, the final step in the energy plan is to establish how these can be executed under the existing institutional framework in place.
5. **Implementing:** once the energy plan has defined, it must be implemented. At this point it becomes essential to involve the community, developers, and other key stakeholders in the process. As outlined in Figure 7, this will require the most significant human and financial resources.
6. **Reviewing:** It is essential that the energy planning framework in place is flexible and periodically updated. This ensures that assumptions, objectives, and the alternatives identified can be reconsidered as new information becomes available.

Figure 7: Steps and corresponding manpower required to develop and implement a local energy plan [13-15].

In line with this approach, the project presented here will primarily relate to tasks 2, 3, and 4, which are identifying, planning, and evaluating respectively. Hence, the most important objective in this work is develop the flexible energy planning framework which can be utilised by Limerick and Clare county councils to create and update their energy strategy in the future. Developing this process and identifying attractive alternatives for the future will enable the local authorities to identify and involve key stakeholders going forward. Therefore, the methodologies and tools created in this project can be continuously updated by the local authority as the energy system in the Limerick-Clare region (LCR) evolves. In addition, the methodology has been created so that it can be repeated by other local authorities also, by using generic data and freely available energy planning tools.

This specific project has been divided into two separate workstreams:

1. Energy and Emissions Balance (**identifying**)

2. Climate Change Strategy (**planning** and **evaluating**)

As outlined in Figure 8, the primary goal of the Energy and Emissions Balance is to develop a methodology for creating a local energy balance. This methodology will then be used to analyse the historical (1990-2010) and future (2020) consumption of energy in the LCR.

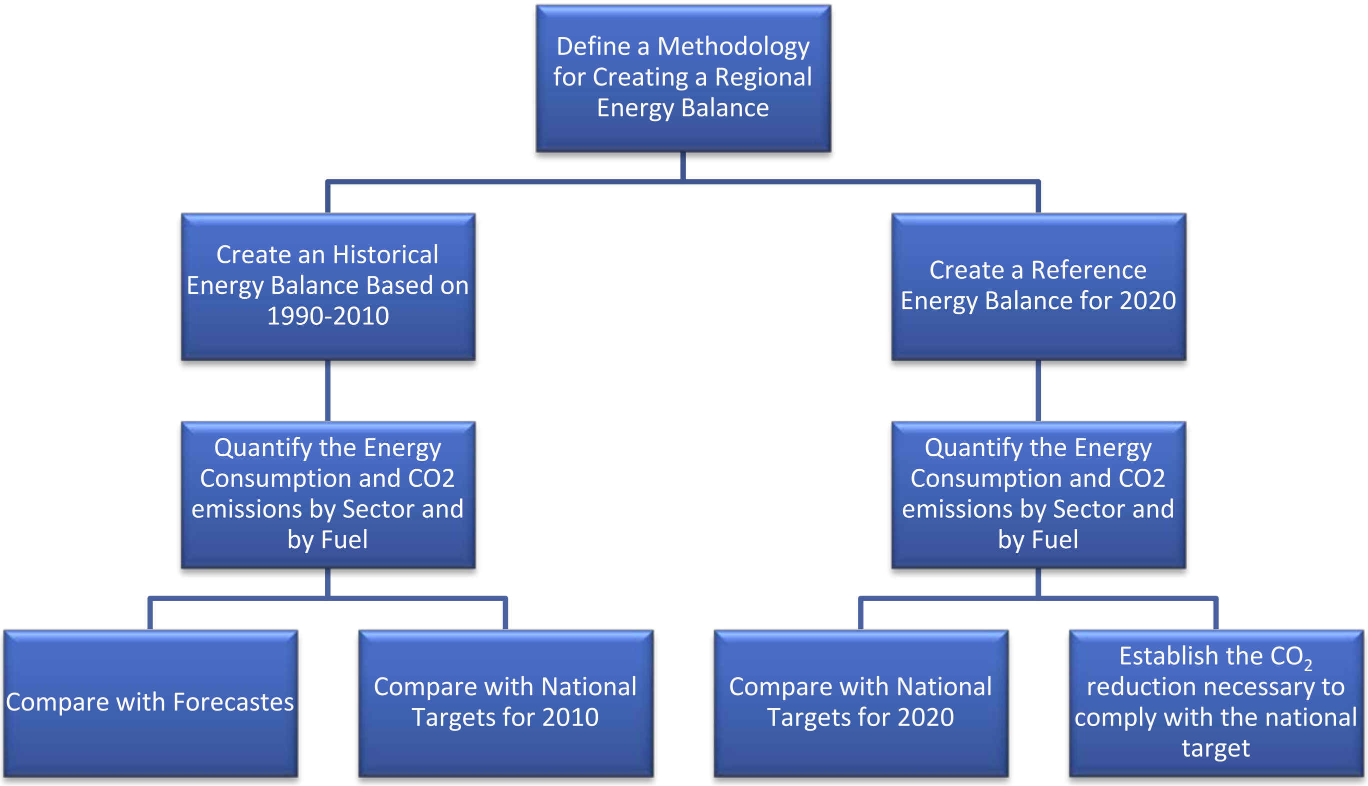

Figure 8: Tasks to be completed within Workstream 1: Energy and Emissions Balance.

In Workstream 2, the Climate Change Strategy, a model of the local energy system will be created in an energy-system-analysis tool to evaluate the economic, energy, and CO_2 implications of various energy alternatives for the region.

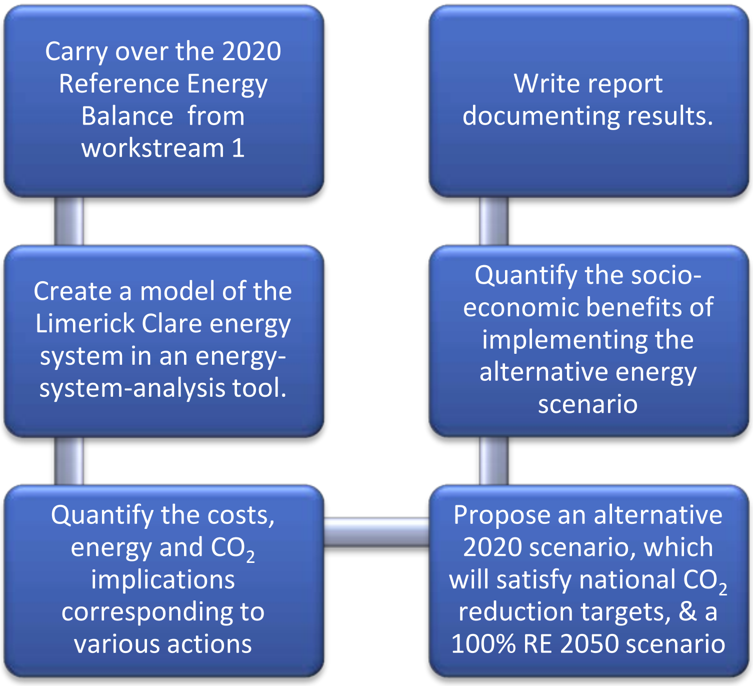

Figure 9: Tasks to be completed within Workstream 2: Climate Change Strategy.

The results from Workstream 1 are documented in this report, while the results from Workstream 2 are documented in a separate report. Section 2 summarises the key findings from a literature review of existing energy balances in Ireland while the methodology developed here for creating a local energy balance is discussed in section 3. Energy production is discussed in section 4, which includes a summary of existing infrastructure and a description of the methodology for creating a local energy mix. The historical (1990-2010) and future (2020) energy balances are portrayed and discussed in section 5 and section 6. Finally, the conclusions from this report are outlined in section 7. It is important to note that the energy balances developed in this report form the basis for the energy modelling work completed in the Climate Change Strategy (Workstream 2).

2 Existing Energy Balances

The objective of an energy balance is to identify the energy used within a region and to categorise it by sector and by fuel. For this project, the objective was to develop an energy balance for the LCR for the years 1990-2010 based on historical data and for the year 2020 based on projected data. Before developing the LCR, the first step was to carry out a literature review to identify how other energy balances are constructed. From this review, a range of different energy balances were identified which included: national historical energy balances for each year from 1990-2010, national forecasted energy balances for the year 2020, regional energy balances for Dublin City, the LCR, Wexford, Mayo, and local energy balances for Dundalk and Clonakilty. Below is a summary of the key methodologies and results from these results, which were used to develop the methodology in this study.

2.1 National Energy Balance

A national energy balance is developed each year by the Energy Policy Statistical Support Unit in the Sustainable Energy Authority of Ireland (SEAI). As displayed in Table 3, the national energy balance outlines how energy was consumed in Ireland by sector, including industry, transport, residential, services, and agriculture, as well as by fuel type including coal, peat, oil, natural gas, renewables, and electricity (a more detail version is also available with many sub-divisions of each). In addition, the national energy balance also outlines how much and what type of energy is consumed and produced by energy conversion facilities such as power plants, CHP facilities, briquetting plants, and oil refineries.

Similarly, the Energy Modelling Group in the Sustainable Energy Authority of Ireland creates a forecasted energy balance for Ireland for the year 2020 [10, 17]. Although less detailed than the historical energy balance, it contains data on all the primary consumers and producers in Ireland. For example, in the historical energy balance industrial energy consumption is categorised by different NACE sectors, but in the forecasted energy balance it is categorised by industry as a whole.

Overall, the national energy balance is an ideal platform for developing a regional energy balance, due to the historical documentation since 1990, the forecasted balance for 2020, and the breakdown of consumption by sector and by fuel.

Table 3: 2009 national energy balance for Ireland [18, 19].

2009 kilo tonnes of oil eqivalent (ktoe)	COAL	PEAT	OIL	NATURAL GAS	RENEWABLES	ELECTRICITY	TOTAL
Indigenous Production	-	584	-	319	606	-	1,522
Imports	1,331	-	9,041	3,989	59	81	14,501
Exports	5	5	959	-	0	15	984
Mar. Bunkers	-	-	98	-	-	-	98
Stock Change	-113	277	24	1	1	-	190
Primary Energy Supply (incl non-energy)	**1,214**	**856**	**8,008**	**4,309**	**665**	**66**	**15,130**
Primary Energy Requirement (excl. non-energy)	**1,214**	**856**	**7,745**	**4,309**	665	**66**	**14,867**
Transformation Input	**852**	**694**	**3,074**	**2,759**	**43**	**58**	**7,479**
Public Thermal Power Plants	852	564	210	2,515	34	-	4,174
Combined Heat and Power Plants	-	9	6	244	9	-	268
Pumped Storage Consumption	-	-	-	-	-	50	50
Briquetting Plants	-	120	-	-	-	-	120
Oil Refineries & other energy sector	-	-	2,859	-	-	9	2,868
Transformation Output	**-**	**108**	**2,864**	**-**	**16**	**2,084**	**5,072**
Public Thermal Power Plants	-	-	-	-	13	1,896	1,909
Combined Heat and Power Plants - Electricity	-	-	-	-	3	157	160
Combined Heat and Power Plants - Heat	-	-	-	-	-	-	-
Pumped Storage Generation	-	-	-	-	-	31	31
Briquetting Plants	-	108	-	-	-	-	108
Oil Refineries	-	-	2,864	-	-	-	2,864
Exchanges and transfers	**19**	**-**	**-21**	**-**	**-347**	**347**	-2
Electricity	-	-	-	-	-347	347	-
Heat	-	-	-	-	-	-	-
Other	19	-	-21	-	-	-	-2
Own Use and Distribution Losses	**-**	**28**	**108**	**65**	**-**	**281**	483
Available Final Energy Consumption	**381**	**242**	**7,669**	**1,485**	**291**	**2,158**	**12,238**
Non-Energy Consumption	**-**	**-**	**263**	**-**	**-**	**-**	**263**
Final non-Energy Consumption (Feedstocks)	-	-	263	-	-	-	263
Total Final Energy Consumption	**368**	**272**	**7,580**	**1,578**	**289**	**2,147**	**12,248**
Industry*	**112**	**1**	**703**	**531**	**140**	**716**	**2,215**
Non-Energy Mining	-	-	74	11	-	58	143
Food, beverages and tobacco	18	-	190	117	39	142	507
Textiles and textile products	-	-	4	0	-	7	12
Wood and wood products	-	-	9	2	85	33	130
Pulp, paper, publishing and printing	-	-	2	2	-	16	21
Chemicals & man-made fibres	3	-	52	68	1	118	242
Rubber and plastic products	-	-	9	6	-	36	51
Other non-metallic mineral products	88	-	165	36	16	81	398
Basic metals and fabricated metal products	-	-	139	168	-	42	349
Machinery and equipment n.e.c.	0	-	7	7	-	18	31
Electrical and optical equipment	-	-	40	107	-	103	251
Transport equipment manufacture	3	-	1	4	-	6	14
Other manufacturing	-	1	10	2	-	55	68
Transport	**-**	**-**	**4,994**	**-**	**77**	**4**	**5,075**
Road Freight	-	-	810	-	-	-	810
Road Private Car	-	-	2,369	-	77	-	2,446
Public Passenger Services	-	-	215	-	-	-	215
Rail	-	-	40	-	-	4	44
Domestic Aviation	-	-	33	-	-	-	33
International Aviation	-	-	735	-	-	-	735
Fuel Tourism	-	-	122	-	-	-	122
Unspecified	-	-	670	-	-	-	670
Residential	**257**	**272**	**1,209**	**625**	**52**	**685**	**3,099**
Commercial/Public Services	**-**	**-**	**462**	**423**	**19**	**683**	**1,586**
Commercial Services	-	-	300	185	16	490	991
Public Services	-	-	162	237	3	193	595
Agricultural	-	-	212	-	0	60	272
Statistical Difference	**12**	**-30**	**-174**	**-93**	**2**	**11**	**-273**

2.2 Local Energy Balances

Before creating the energy and emissions balance in this report, other methodologies applied to local areas were reviewed. In total six previous local energy balances were found for regions within Ireland:

- Dublin City
- Limerick and Clare Region
- County Wexford
- County Mayo
- Dundalk Town
- Clonakilty District

A detailed description of the methodologies used in each of these reports is provided in Appendix II. Here, the important characteristics of each region and the methodologies applied are presented. As outlined in Table 4, the previous energy balances in Ireland have been completed for very different types of regions. For example, the Dublin City energy balance included a relatively small urban area of 118 km^2 with almost 500,000 while the Mayo energy balance consisted of a large 5589 km^2 area with approximately 120,000 people. Therefore, to establish how this diversity was accommodated, the key characteristics of each methodology were defined and compared, as displayed in Table 5. These key characteristics were then used to define the methodology utilised in this study.

Table 4: Key statistics for each region which has developed an energy balance in Ireland [20-23].

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Population</th><th colspan="2">Area Covered</th><th rowspan="2">Population Density (pop./km²)</th><th colspan="2">Permanent Households</th><th rowspan="2">Industrial Units</th></tr>
<tr><th>Type</th><th>Size (km²)</th><th>Total</th><th>% with central heating</th></tr>
<tr><td>Ireland</td><td>4,581,269</td><td>Urban & Rural</td><td>70,182</td><td>65</td><td>1,462,296</td><td>90%</td><td>5400</td></tr>
<tr><td>Dublin City</td><td>491,555</td><td>Urban</td><td>118</td><td>4176</td><td>190,984</td><td>88%</td><td>588</td></tr>
<tr><td>Clare County*</td><td>108,331</td><td>Urban & Rural</td><td>3449</td><td>31</td><td>38,210</td><td>89%</td><td>165</td></tr>
<tr><td>Limerick City*</td><td>51,886</td><td>Urban</td><td>21</td><td>2494</td><td>19,550</td><td>84%</td><td rowspan="2">239</td></tr>
<tr><td>Limerick County*</td><td>129,715</td><td>Urban & Rural</td><td>2735</td><td>47</td><td>44,765</td><td>89%</td></tr>
<tr><td>Limerick Clare Region*</td><td>289,932</td><td>Urban & Rural Separately</td><td>6205</td><td>47</td><td>102,525</td><td>88%</td><td>404</td></tr>
<tr><td>Wexford County</td><td>130,518</td><td>Urban & Rural</td><td>2370</td><td>55</td><td>45,096</td><td>88%</td><td>219</td></tr>
<tr><td>Mayo County</td><td>121,680</td><td>Urban & Rural</td><td>5589</td><td>22</td><td>43,431</td><td>89%</td><td>170</td></tr>
<tr><td>Dundalk Town#</td><td>28,749</td><td>Urban</td><td>25</td><td>1164</td><td>10,186</td><td>94%</td><td>Not Available</td></tr>
<tr><td>Dundalk SEZ</td><td></td><td>Urban</td><td>4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Clonakilty District</td><td>14,678</td><td>Urban & Rural Separately</td><td>331</td><td>44</td><td>4,879</td><td>81%</td><td>Not Available</td></tr>
</table>

***More detailed regional statistics for Limerick and Clare are provided in Appendix III.**

#This data is for Dundalk town as the data was not available for the Dundalk Sustainable Energy Zone.

Table 5: Assumptions used to estimate the energy consumed in each sector by the different studies.

Energy Balance	Industry	Transport	Residential	Services	Agriculture
Dublin City [24]	Proportioned national data based on NACE Rev 1.1. employee numbers.	Number of vehicles, average annual mileage, specific fuel consumption, & contacted other transport operators.	Identified a typical house, constructed a model using DEAP and project based on year of construction.	Proportioned national data based on NACE Rev 1.1. employee numbers.	Not Applicable
Limerick-Clare [25]	Proportioned national data based on employee numbers.	Proportioned national data based on number of private cars.	Proportioned national data based on number of private households.	Proportioned national data based on employee numbers.	Proportioned national data based on area farmed.
County Wexford [26]	Proportioned national data based on industrial units, used annual expenditure on oil, and got electricity consumption from the CER.	Used number of vehicles, average annual mileage, & specific fuel consumption for road transport. Contacted transport operators for others. Only accounted for fuel supplied in the region.	Proportioned national data based on number of private households for coal, peat, and LPG. Number of oil boilers in the region and average household consumption for oil, and electricity demand from the CER.	Electricity consumption from the CER. Proportioned other fuels based on ratio to electricity at a national level.	For oil, Proportioned national annual expenditure based on farm numbers and size, found average oil price over time period, then used specific fuel consumption of tractors to estimate oil. Got electricity demand from the CER.
County Mayo [27]	Proportioned national data based on employee numbers.	Compared residential statistics at a national and regional level, then made a personal judgement on the per capita consumption locally compared to the national average.	Compared residential statistics at a national and regional level, then made a personal judgement on the per capita consumption locally compared to the national average.	Proportioned national data based on employee numbers.	Proportioned national data based on employee numbers.
Dundalk SEZ [13]	Profile of buildings made using the EMP tool based on benchmark or real data.	Not Applicable	Profile of buildings made using the EMP tool based on benchmark or real data.	Profile of buildings made using the EMP tool based on benchmark or real data.	Not Applicable
Clonakilty District [28]	Energy audit distributed	Energy audit distributed	Energy audit distributed	Energy audit distributed	Energy audit distributed

3 Energy Consumption Methodology

Based on the energy balance methodologies reviewed in Appendix II, it is clear that there are two primary approaches for creating a regional energy balance: bottom-up and top-down. The first clear conclusion for this study was that the Limerick-Clare energy balance should be made using a top-down approach. The energy balances completed for Dundalk town and the Clonakilty district do indicate that the bottom-up approach is a more accurate methodology: it accounts for local deviations from national averages, it enables the planners to identify opportunities for energy efficiency and renewable energy, and it acts as a benchmark for monitoring the implications of local actions taken. However, a significant drawback for the bottom-up approach is the level of resources required to complete it, especially over a region as large as Limerick and Clare. For example, the bottom-up EMP tool develop by SEAI to create an energy balance for Dundalk town requires approximately 15 inputs per building about details such as location, bills, the heating system, energy efficiency measures, and energy generation on-site [13]. Considering the number of houses alone in the LCR is 102,435 [29], a top-down approach was chosen here.

Another important issue which needed to be considered in this report was the historical and future energy consumption within the Limerick-Clare region. By outlining historical consumption, the local authorities could assess the CO_2 emissions in the region compared to the targets set under the Kyoto Protocol, which were based on 1990 levels. Projecting an energy balance forward is important so the implications of the current energy system can be assessed for the Greenhouse Gas Emissions (GHG) reduction targets set for 2020. In addition, the future energy system acts as a baseline for evaluating the feasibility of alternatives in the region. By using a top-down approach, it is relatively easy to project historical and future energy demand within the LCR, based on the national energy balances developed by SEAI for 1990-2010, and forecasted for the year 2020. Since a top-down approach was deemed more suitable for this study, this eliminated the methodologies highlighted in grey in Table 4 and Table 5, while the blue cells outline the methodologies which were chosen.

To use the top-down approach, ratios needed to be developed for each sector which was indicative of the energy consumed at a local level, compared to a national level, for that sector. Once a ratio was identified for that sector, then the coal, peat, oil, natural gas, renewable, and electricity demand for that sector could be found based on the data in the national energy balance. Below is a more detailed explanation of the reasoning and the methodologies used to identify the ratios used for each sector for the LCR. The same methodologies could be applied to other counties or regions in Ireland.

3.1 Services

The services sector covers the NACE sectors G-O, which includes workplaces such as retail, hotels, business, real estate, public administration, and many more. Typically, the services sector does not contain any significant large energy users. Hence, it was concluded that the number of employees in this sector should be indicative of the energy consumed in this sector. Therefore, national energy consumption in the services sector was proportioned based on the number of workers in NACE sectors G-O.

$$Services\ Ratio = \frac{Services\ Workers\ (NACE\ Rev\ 1.1\ Sectors\ G-O)\ in\ Region}{Sevices\ Workers\ (NACE\ Rev\ 1.1\ Sectors\ G-O)\ in\ Ireland}$$

3.2 Residential

For the residential sector, the number of private houses was used to proportion national energy demand to a local level. This data can be obtained from the Irish census for the years 1991, 1996, 2002, and 2006 [30, 31], so the figures were linearly interpolated for the years between. For 2007 onwards, the number of houses could be projected based on annually updated data online [32].

$$Residetnial\ Ratio = \frac{Number\ of\ Private\ Houses\ in\ Region}{Number\ of\ Private\ Houses\ in\ Ireland}$$

An effort was also made to proportion this data based on local conditions such as house size, age of the houses, age of the occupants, and income of the occupants. However, after reviewing the literature in this area [33-35] it was evident that houses with older people, lower incomes, and older houses have less energy savings measures installed. However, houses with younger people, higher incomes, and new houses have more energy consuming appliances. In addition, "research conducted by Codema [36] has shown that for a group of identical apartments, with similar types of domestic appliances, annual energy use may differ by as much as a factor of 3" [24]. As a result, no local adjustment factor was applied after proportioning national data based on the number of private houses due to too much uncertainty.

Finally, it should be noted that both bottom-up approaches utilised by Codema for Dublin City [24] and especially SEAI's approach for Dundalk Town [13] would be account for local variations more accurately than proportioning national data. Therefore, the Irish government should legislate that energy consumption data is provided by energy suppliers to local authorities to improve the residential section of the energy balance. This would ensure that actual demands are used instead of models and statistics.

3.3 Transport

Transport is an unusual category: firstly, since it contains a wide variety of different modes which use the same type of fuel and secondly, because there is no distinct point of consumption for transport so it is difficult to define a boundary.

At a national level, oil accounted for 99.7% (average) of the total fuel consumed by transport between 1990 and 2010. Although this has slowly decreased in recent years to 97.9% in 2010, it is evident that oil will continue to be the dominant fuel for transportation for many years to come. However, unlike other sectors, oil consumption in transport can be subdivided into a distinct set of subcategories. For national data, the subcategories recorded are road, aviation, rail, fuel tourism, and unspecified. Figure 10, illustrates the demand within these sectors in Ireland for 1990-2010, from which it is evident that road transport is the primary consumer of oil in Ireland. However, even across each of these subcategories, different types of oil are commonly share: primarily petrol and diesel. This interaction between mode and fuel means the methodology for proportioning national transport data to a local level becomes more complex than for the other sectors. Overall, the following steps were necessary for each mode:

1. Divide each mode of transport by subcategory at a national level.
2. Divide each subcategory by the type of fuel consumed at a national level.
3. Proportion the demand to a local level based on a ratio for that subcategory of transport.
4. Add the consumption of each fuel across each the various subcategories of transport.

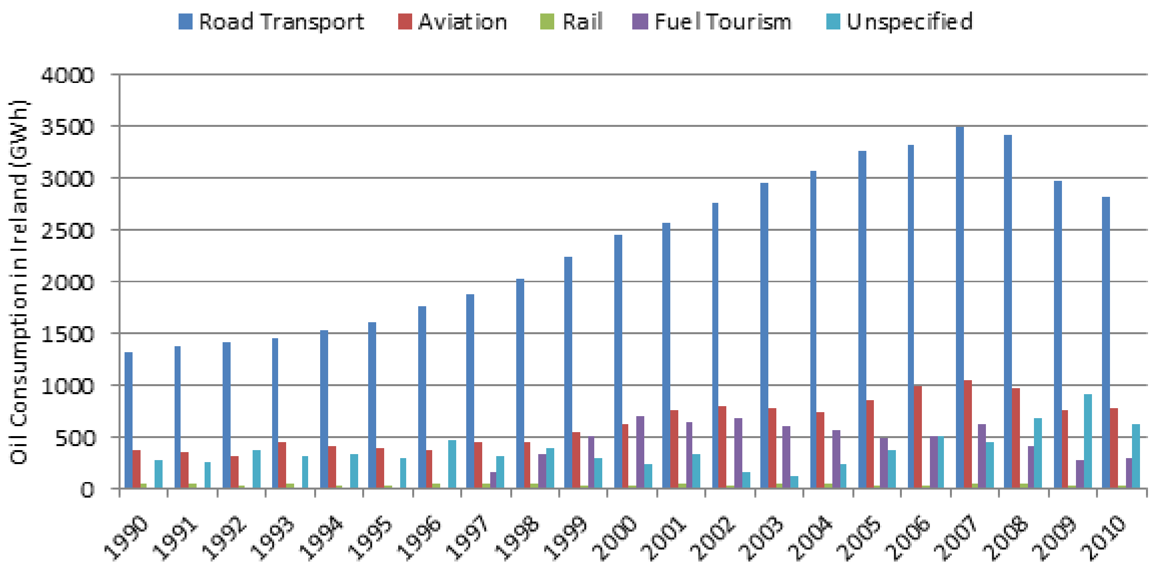

Figure 10: Oil demand in Ireland by mode of transport from 1990 to 2010.

In addition to this complex proportioning procedure, the second key issue was defining a boundary. It is difficult to define a border for transport since it is very easy for people to purchase fuel in one region and use it in another. To overcome this Curtin [26] assumed that only energy actually provided in the county of Wexford was defined as consumption. In the previous Limerick-Clare energy balance [25], all national consumption was simply proportioned based on the number of private cars. Hence, the transport sector was not refined to the specifics of the local area, but instead the same ratio of consumption between fuels at a national level was simply proportioned to the local area (based on the number of private cars). For Dublin City [24], the boundaries for transport were defined based on the statistics which could be obtained: the number of cars could be obtained for Dublin City alone, but road freight was based on Dublin City and County. Bus consumption was based on the consumption of energy by the entire Dublin Bus fleet and rail was based on consumption by the LUAS tram and the DART train. Finally, for the Mayo energy balance [27], transport was distributed on per capita basis along with a local adjustment factor: for example, rail consumption for a Mayo citizen was assumed to be 50% than the national average since most rail journeys are long-distance to Dublin. Overall, a variety of methodologies have been used to define the transport border for a region. Therefore, considering this and the more complex procedure for proportioning transport energy demand, each mode is discussed separately below.

3.3.1 Road

In line with the methodology outlined previously, the first step is to divide road transport into its subcategories. As outlined in Figure 11, these are private cars, road freight, and public passenger vehicles.

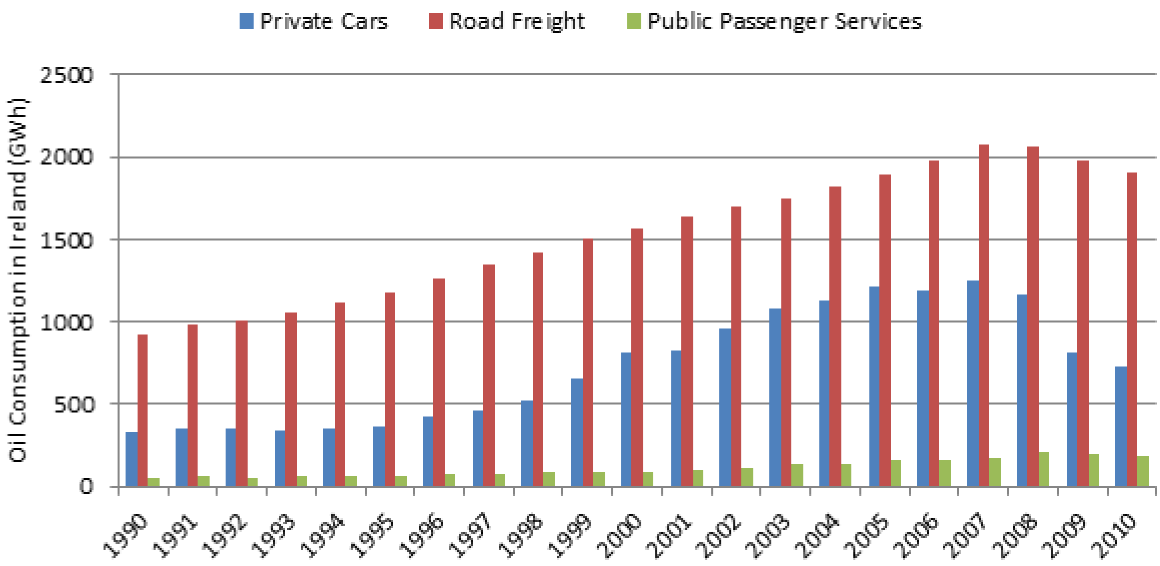

Figure 11: Oil consumed in Ireland by mode of road transport from 1990-2010.

The fuels used for private cars in Ireland are primarily petrol and diesel, with relatively small proportions of biofuel and LPG. For each of these fuels, national data was localised based on the number of private cars registered in the local region:

$$Private\ Cars = \frac{Number\ of\ Private\ Cars\ Registered\ in\ Region}{Number\ of\ Private\ Cars\ Registered\ in\ Ireland}$$

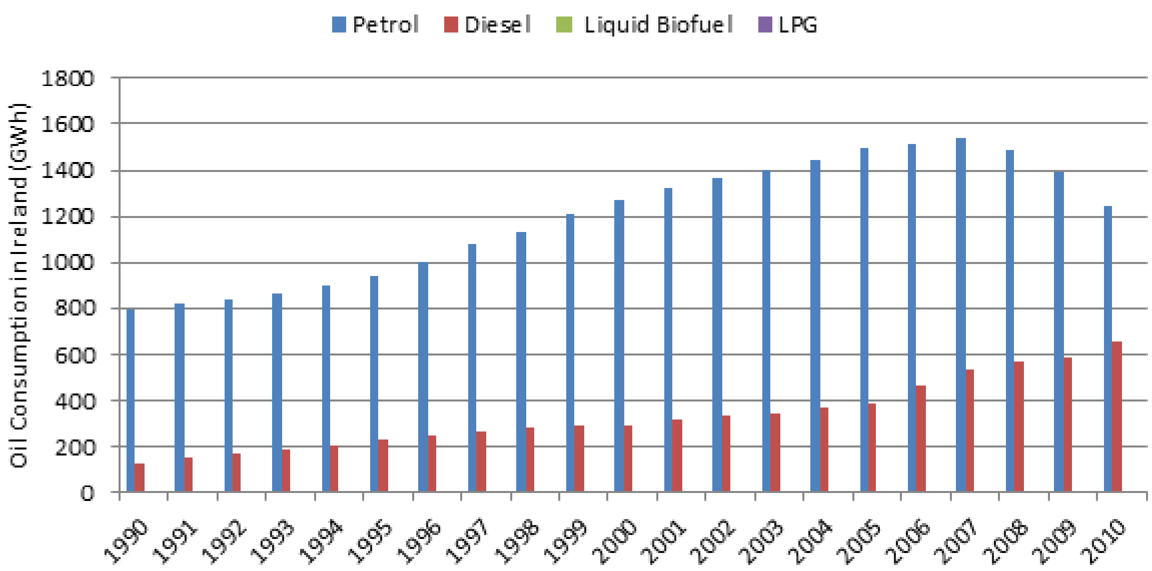

Figure 12: Type of fuel consumed by private cars in Ireland from 1990-2010.

For road freight, the only fuel consumed was diesel. Therefore, this was proportioned from a national to a local level based on the number of heavy goods vehicles over 2 tonnes registered in the region:

$$Road\ Freight = \frac{Number\ of\ Heavy\ Goods\ Vehicles\ Over\ 2\ Tonne\ Registerd\ in\ Region}{Number\ of\ Heavy\ Goods\ Vehicles\ Over\ 2\ Tonne\ Registerd\ in\ Ireland}$$

The public passenger service vehicles use both petrol and diesel, which is displayed in Figure 13. In the annual Irish transport statistics [37-48], public passenger vehicles are recorded as both small (which includes taxis, hackneys, and limousines) and large (which includes buses). Therefore, the petrol in the public passenger service sector was proportion based on the number of small vehicles and the diesel was proportioned based on the number of large vehicles:

$$Public\ Passenger\ Service\ Petrol\ Ratio = \frac{Number\ of\ Small\ Public\ Passenger\ Service\ Vehicles\ in\ Region}{Number\ of\ Small\ Public\ Passenger\ Service\ Vehicles\ in\ Ireland}$$

$$Public\ Passenger\ Service\ Diesel\ Ratio = \frac{Number\ of\ Large\ Public\ Passenger\ Service\ Vehicles\ in\ Region}{Number\ of\ Large\ Public\ Passenger\ Service\ Vehicles\ in\ Ireland}$$

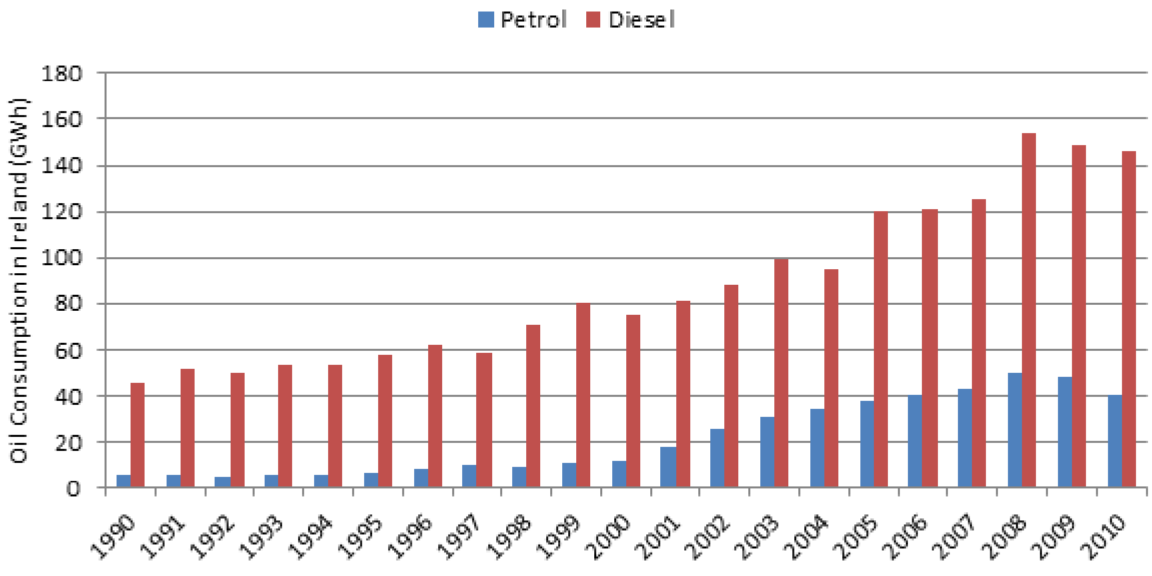

Figure 13: Type of fuel consumed by public passenger service vehicles in Ireland from 1990-2010.

Once the fuels in the private car, road freight, and public passenger service sectors are proportioned separately, they can then be added back together to obtain the total demand for petrol and diesel within the local region.

3.3.2 Rail

There are no local rail networks in Limerick or Clare and hence, the intercity network is the only one which operates in both counties. Based on the methodology proposed by Curtin [26], only the fuel which was actually provided in the region was allocated to that region. Iarnród Éireann's Limerick dispatch office estimated that approximately 10,000 litres of diesel is supplied weekly in Limerick City at the refuelling depot in Roxboro [49]. Conversion factors from litres of diesel to kWh were then found from [50]: 1 litre of gas oil diesel, which is used for rail, equates to 10.3 kWh. Therefore, the 10,000 litres consumed weekly in Limerick City equates to approximately 103 MWh, which corresponds to approximately 5.4 GWh per year. This was the only rail demand assumed in the energy balance. It should be noted that rail only accounted for 1% of transport on average between 1990-2010 (see Figure 10) and hence, it has only played a minor role in the past.

3.3.3 Aviation

Proportioning data on a per capita basis similar to that utilised in the Mayo energy balance [27], seems very useful for distributing the energy consumed by national transport assets such as airports. Even though airports and ports are located in specific locations, typically only a small proportion of the energy is consumed by residents of that county. Therefore, by proportioning these pieces of infrastructure on per capita basis, responsibility is shared amongst everyone in Ireland and so a per capita ratio was used:

$$Aviation\ Ratio = \frac{Number\ of\ People\ in\ Region}{Number\ of\ People\ in\ Irealnd}$$

3.3.4 Fuel Tourism

Fuel tourism occurs when there is a lower price for fuel in Ireland compared to other countries, particularly in Northern Ireland and Britain. When this happens cars and trucks from other countries will fill their vehicles with petrol or diesel just before leaving Ireland: hence the consumption actually occurs outside of Ireland. Typically this will happen along the border of Ireland and Northern Ireland, or else at the major road freight ports in Ireland: Dublin and Rosslare. Since the Northern Irish border is approximately 200 km from the LCR, and there is no major port for road freight in Limerick or Clare, it was assumed that there is no fuel tourism in the transport sector for the region.

3.3.5 Unspecified

The unspecified sector covers motorcycles, service vehicles, construction vehicles, exempt vehicles (such as ambulances, police vehicles, etc.), and shipping, as well as differences in the estimates of energy consumption for private cars, public passenger vehicles, and road freight. Since there is no data available to break this data down further, it has been proportioned on a population basis, similar to aviation.

$$Unspecified\ Transport\ Energy\ Ratio = \frac{Number\ of\ People\ in\ Region}{Number\ of\ People\ in\ Irealnd}$$

3.4 Agriculture

A number of key agricultural statistics are gathered by the CSO at a national and local level approximately every 10 years in the “Census for Agriculture”, which was most recently completed in 1991 [51] and 2000 [52]. These include the number the number of farms, type of farms, economic size of farms, and many more. Similar to methodology used in the previous Limerick-Clare energy balance [25], the area farmed was deemed to be the most appropriate way to proportion national data to a local level.

$$Agriculture\ Ratio = \frac{Area\ Farmed\ in\ Region}{Area\ Farmed\ in\ Ireland}$$

3.5 Industry

The energy demand for industry in the LCR was firstly calculated using a similar methodology to that in the previous LCR energy balance [25]. Here, national industrial energy consumption is proportioned to a regional level based on the number of industrial workers in the Nomenclature générale des Activités économiques dans les Communautés Européennes (NACE) sectors 13-37. NACE is used to identify the primary function of an industry and hence employee numbers are categorised under these sectors by the CSO. To date, there have been four major versions of the NACE classification: NACE in 1961, NACE Rev 1 in 1990, NACE Rev 1.1 in 2002, and NACE Rev 2 in 2006. For the national energy balance in Ireland created by SEAI [18], industry convers any organisation under the NACE Rev 1.1 sectors 13-37 and hence these sectors were used here also.

$$Industry\ Ratio = \frac{Industrial\ Workers\ (NACE\ Rev\ 1.1\ Sectors\ 15-37)\ in\ Region}{Industrial\ Workers\ (NACE\ Rev\ 1.1\ Sectors\ 15-37)\ in\ Ireland}$$

Proportioning the total industrial demand in Ireland based on the number of workers creates an average energy demand per employee and a total industrial energy demand based on the total number of people employed in the region. However, after assessing the industrial profile in the LCR, it was clear that the LCR has a significant number of Large Energy Users (LEUs). As outlined in Figure 14, four of the top fifteen industrial GHG emitters in Ireland are located in the LCR. This created a significant issue in relation to the boundary condition: by using an average consumption based on the number of employees, it is unlikely that the actual energy consumed by industry in the LCR is being accounted for. To investigate this concern, the four companies displayed in Figure 14 which are in the LCR were contracted to obtain their total energy consumption for the years 2005, 2007, and 2009.

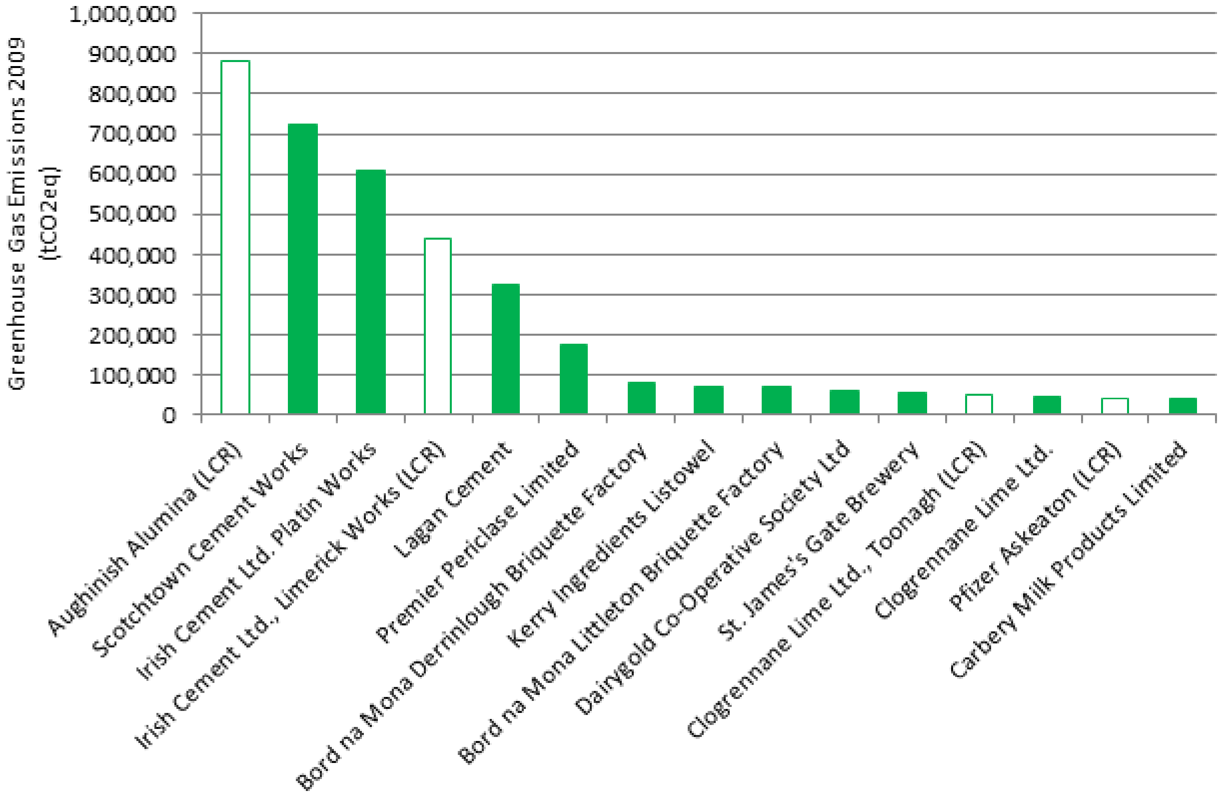

Figure 14: Top 15 industrial greenhouse gas emitters in Ireland in 2009 [53].

The results demonstrate the issues surrounding the boundary condition for industry. As displayed in Figure 15, the energy consumed by these four LEUs is approximately double the energy calculated for the LCR based on the proportioning methodology. As expected, this verified that the proportioning methodology does not account for the actual energy consumption in industry in the LCR. However, this raises another important discussion: should the LCR region be entirely responsible for the energy consumed by these large industries?

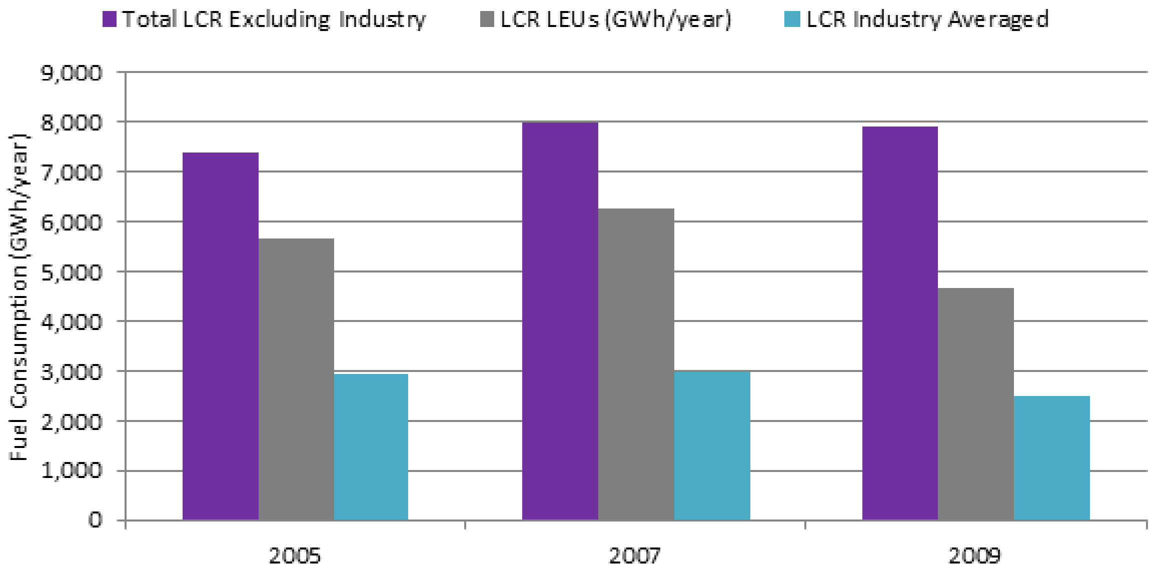

Figure 15: Energy consumption in the LCR excluding industry, by LEUs in LCR, and by industry in the LCR when average across Ireland for 2005, 2007, and 2009.

It could be argued that the LCR should be responsible for the energy consumed by these LEUs since these companies are located in that region. Hence, it reflects the 'actual' energy consumed within the region. However, it could also be argued that the LCR should only be allocated the average industrial consumption because:

1. At a national level, accounting for industry is relatively straight forward since all of industry contributes towards the same national economy. In contrast, at a local level some industries are so large that they don't just contribute to the local economy, but the wider national economy also.
2. As outlined in Figure 15, the energy consumed by the four LEUs in the LCR is approximately 70% of the total energy in the LCR (excluding industry) over the years 2005, 2007, and 2009. Hence, by allocating the energy demand from these LEUs to the citizens of the LCR, then the actions of the collective community could be dwarfed by the actions of these four industries. This would mean that any resulting energy strategy for the LCR could primarily be an energy strategy for these four companies, which would counteract the objectives of developing local energy plans.
3. Finally, the LEUs are already part of the EU Emissions Trading Scheme (ETS), which means they are responsible for their CO2 emissions within a separate accounting system to the local economy.

Upon reflection it was concluded that both of these approaches could be validated. Therefore, two energy balances were created for the industrial sector. In the first energy balance it uses the proportioning methodology discussed based on the number of employees, so it accounts for the share of industrial energy which the LCR is responsible for under the condition that large-scale industry is not just a local asset, but a national asset. This has been assigned the name 'Responsible Energy Balance' (REB). The second energy balance allocates the energy consumed by the four LEUs to the LCR in addition to the industrial energy in the REB. Hence, this represents the actual industrial energy consumed in the LCR and so it has been named the 'Actual Energy Balance' (AEB). An attempt was made to use the CSO's POWCAR dataset [54] to estimate the industrial energy demand in the LCR (based on the methodology in the Dublin City energy balance [24]), but it was not possible to extract the data required within the timeframe of this study. In the end, any proportioning methodology is only an approximation and since sufficient data is not yet available to determine which statistic will be most accurate, the industrial worker statistics was deemed adequate for this study. In addition, the two energy balances (REB and AEB) considered represent two extremes which are likely to impact the results more than the choice of proportioning statistic.

3.6 Ratios for 2020

All of the ratios developed above were proportioned based on historical data. Therefore, to proportion national data from Ireland's energy forecasts [17], two methodologies were used

1. Where no trend was evident in the historical ratio between 1990 and 2010, then the average over this timeframe was used to proportion 2020 statistics.
2. Where a trend was evident from the historical ratio between 1990 and 2010, then this was continued to the year 2020 and applied to the statistics. For example, the proportion of people employed in County Limerick has been growing at 0.1%/year since 2002 and so this was continued to the year 2020.

For the AEB, it was assumed that the energy consumed by the LEUs in 2009 will be the same energy consumed by the LEUs in 2020.

3.7 Summary

The methodology developed above was designed to be:

1. Top-down so it could use historical and forecasted national data.
2. Repeatable so it could be used by other counties in Ireland.
3. Account for local deviations from the national average by proportioning data on statistics indicative of energy consumption and by developing two energy balances for the industrial sector.

The accuracy of this methodology should be taken in the context of its purpose. It is clear that this methodology will not produce exact figures, but the principal purpose of the energy balance is to form an indicative picture of what and how energy is consumed within a region. The fundamental application of the energy balance is to act as a baseline for evaluating alternatives (in the Climate Change Strategy) and so exact data is not necessary. In addition, the recent recession in Ireland has outlined the unpredictability of the economy and hence the unpredictability of future energy consumption. Therefore, even if actual bottom-up data was gathered for the LCR, it would still be difficult to accurately forecast an energy balance for the future. As a result, this methodology fulfils the objective which it needs to meet: it is a relatively simple methodology which provides an indicative representation of energy consumption within the LCR now and for 2020.

In the future however, there are a number of issues which could be improved. Firstly, creating an energy balance is not a scientific issue, but a data collection issue and hence, it is essential to start recording data at a local level in Ireland. During this study, it became apparent that local energy data is not available or not accessible in Ireland. For example, for the Wexford energy balance [26] the CER were able to provide the electricity consumption at a local level for each sector: industry, services, residential, and services. However, after discussions with the CER, EirGrid, ESB Networks, and the MRSO (Meter Registration System Operator), it was not possible to get this data for Limerick and Clare. This indicates that there is one of two problems: either nobody is responsible for gathering data at a local level or else, nobody is providing data at a local level. It is essential that this data becomes available so that accurate local energy balances can be established and subsequently local authorities can become responsible for their own energy planning, which has proven to be the most successful approach in other parts of the world [11, 12, 55]. It is important to point out that due to lack of local energy data at present, it is not possible to even define if a statistic is a good representation of local energy consumption or not. For example, if more time was allocated by the local authority to find more detailed statistics to create the LCR energy balance, due to the absence of actual energy data at a local level, it would not be possible to define which statistics are more or less accurate. Therefore, ensuring that energy suppliers provide energy data to the local authorities is the only accurate solution available. Hence the most important recommendation from this study is that, the Irish government should legislate that actual energy consumption data is provided by energy suppliers to local authorities to improve local energy balances. This would ensure that actual demands are used instead of models and statistics which are the only possibilities at present. This would follow a similar law imposed in Denmark in the 1970s which required local authorities to quantify the energy consumed in their region [56, 57].

Finally, in the absence of actual local energy data, it is highly recommended that a detailed bottom-up energy balance is developed in smaller exemplar zones in Limerick and Clare by the local authorities. SEAI's EMP tool and guidelines [13] could be used as a template for this work. However, it is not only important to quantify the amount of energy consumed in a region, it is also important to identify the location of the consumption, especially for heat (i.e. this is essential when analysing large-scale infrastructure such as a gas grid and district heating). Therefore, a heat atlas could also be created similar to those recently developed for Denmark [58] and London [59].

4 Energy Production

The energy balance needs to account for the supply of energy as well as energy demand. This section describes the existing and planned energy infrastructure in the LCR between now and 2020. Afterwards, the methodology used to create a local energy mix for the LCR is presented.

4.1 Energy Infrastructure

Overall, energy infrastructure usually consists of a production facility and distribution network such as power plants and the electricity grids, boilers and district heating networks, and cars and road networks. In the section, the energy infrastructure considered in this study for the LCR is described, along with the developments expected between now and 2020.

4.1.1 Electricity

In relation to renewable energy, there was 123.3 MW of wind power installed in the LCR in 2010. Table 6 illustrates how this capacity increased over time and also outlines that in 2011, the total installed wind power had increased to 150.3 MW [60]. The only large-scale (> 1 MW) hydroelectric plant in the region is Ardnacrusha, which has a capacity of 86 MW. The final significant renewable energy plant is the Gortadroma landfill gas facility with an electricity generating capacity of 1 MW, which began producing electricity in June 2009.

Table 6: Cumulative installed wind power capacity in Limerick and Clare [60].

Name	Year of Completion	Capacity	Cumulative Capacity
County Clare			
Moanmore	2004	12.6	12.6
Booltiagh	2005	19.5	32.1
County Limerick			
Tournafulla	2007	7.5	7.5
Knockawarriga	2008	22.5	30
Tournafulla	2008	17.2	47.2
Knockastanna	2009	7.5	54.7
Dromada	2009	28.5	83.2
Slievereagh	2009	3	86.2
Carrons	2010	4.99	91.2
Rathcahill	2011	12.5	103.7
Grouse Lodge	2011	15	118.7
	Total in the LCR		
Total	2004	12.6	12.6
Total	2005	32.1	32.1
Total	2006	0	32.1
Total	2007	7.5	39.6
Total	2008	39.7	79.3
Total	2009	39	118.3
Total	***2010***	***4.99***	***123.3***
Total	2011	27.5	150.3

Forecasting forward, EirGrid is predicting an installed capacity of 440 MW for wind power and 75 MW for wave power by 2025 [61]. A time series outlining how this capacity will be reached under the gate 3 connection process was recently produced by EirGrid [62]. It was assumed that all wind farms expected to connect to a substation in the LCR or with a specified address in the LCR are located in the LCR. Using this assumption, a list of the wind farms expected to connect in the LCR between now and 2023, along with their expected connection date are outlined in Table 7. Here it is evident that an installed wind capacity of 330.2 MW can be expected in the LCR by 2020, which is the assumption used in this study. EirGrid's programme for firm access connections under gate 3 did not specify any connections for wave or tidal energy and hence, it was assumed here that their capacity was 0 MW in 2020. In summary, the existing and expected electricity generating capacities in the Limerick-Clare region for 2010 and 2020 respectively are outlined in Table 8.

Table 7: Forecasted wind power connected in the LCR (in line with those in the 'Gate 3' process) [62].

Name	Substation (110 kV)		Capacity (MW)	Connection Year	Cumulative Capacity (MW)
	Name	Location			
		Total Cumulative Capacity Installed in 2011			150.8
Boolynagleragh	Booltiagh	Clare	33	2013	183.8
Boolynagleragh	Booltiagh	Clare	3.98	2014	187.8
Lissycasey	Booltiagh	Clare	6	2014	193.8
Boolynagleragh (2)	Booltiagh	Clare	11.64	2014	205.4
Carrownaweelaun	Tullabrack	Clare	4.6	2014	210.0
Cahermurhpy	Booltiagh	Clare	6	2014	216.0
Glenmore	Booltiagh	Clare	30	2014	246.0
Garvoghil	Ennis	Clare	6	2014	252.0
Kiltumper	Booltiagh	Clare	5	2014	257.0
Tullabrack	Tullabrack	Clare	13.8	2014	270.8
Toonagh	Ennis	Clare	0.9	2014	271.7
Toonagh WF	Ennis	Clare	0.499	2014	272.2
Askeaton	Aughinish	Limerick	20	2018	292.2
Coolrus	Charleville	Cork*	3	2018	295.2
Ballagh	Trien	Kerry*	9	2020	304.2
Athea (4)	Athea-2	Limerick	25	2020	329.2
Athea Extension	Athea-2	Limerick	1	***2020***	***330.2***
Knockathea	Athea-2	Limerick	33.9	2021	364.1
Knocknagornagh	Athea-2	Limerick	43.7	2021	407.8

***Address of this wind farm was specified as County Limerick.**

There is also some fossil fuel electricity generation in the LCR. This includes Moneypoint power station, which is the largest power plant in Ireland with a rated power capacity of 847.5 MW, which is expected to still be present in 2020 [63]. Since its primary fuel source is coal, Moneypoint is actually the largest GHG emitter in Ireland and accounts for approximately 7.5% of all energy-related GHG emissions [19, 53]. In addition to Moneypoint, there is also a 161 MW CHP plant located at the Aughinish Alumina refinery plant on Aughinish Island in Limerick. Electricity and heat generated by the facility is consumed onsite, but excess electricity is exported to the grid. There is also a relatively small 6.2 MW industrial CHP plant located at Wyeth Nutritionals (Pfizer) in Askeaton, Limerick. To date, no additional conventional generation is expected to be constructed in the LCR by 2020 [63].

Table 8: Energy generating facilities in the LCR in 2010 and 2020 [63].

Plant Type	Name	Fuel	Installed Capacity (MW)	
			2010	2020
Power Plant	Moneypoint	Coal	847.5	847.5
Industrial CHP	Aughinish Alumina	Natural Gas	161	161
Industrial CHP	Wyeth Nutritionals	Natural Gas	6.2	6.2
Wind	Total	Wind	123.3	330.2
Hydro	Ardnacrusha	Water	86	86
Waste	Gortadroma	Landfill Gas	1	1
Tidal*	Total	Water	0	0
Wave*	Total	Water	0	0

***This is the expectations in the business-as-usual scenario only. As outlined in the Climate Change Strategy, there is approximately 370 GWh/year of tidal and 25.5 TWh/year of wave energy feasible in the LCR respectively.**

Due to the significant amount of electricity generation in the LCR, which was discussed previously in section 4.1.1, the region has one of the best electricity infrastructures in Ireland. As outlined in Figure 16, there are two existing 400 kV lines passing through the region, which extend all the way to the east of Ireland. These two lines are capable of carrying between 1400 MW and 1700 MW each, depending on the time of year [64]. In addition, there is an extensive 220 kV network in both Limerick and Clare, which circles the Shannon estuary region. Most of these lines can carry proximately 450 MW of electricity, while the remaining 110 kV lines can carry approximately 120 MW.

The Irish Transmission System Operator (TSO), EirGrid, plans to invest approximately €315m on the network in the region by 2025. As outlined in Figure 17, this will be used to upgrade the power lines supplying the large urban centres of Ennis and Limerick, to upgrade over 250 km of existing networks to facilitate higher capacity power flows, and to strengthen the transmission capacity across the Shannon Estuary [61].

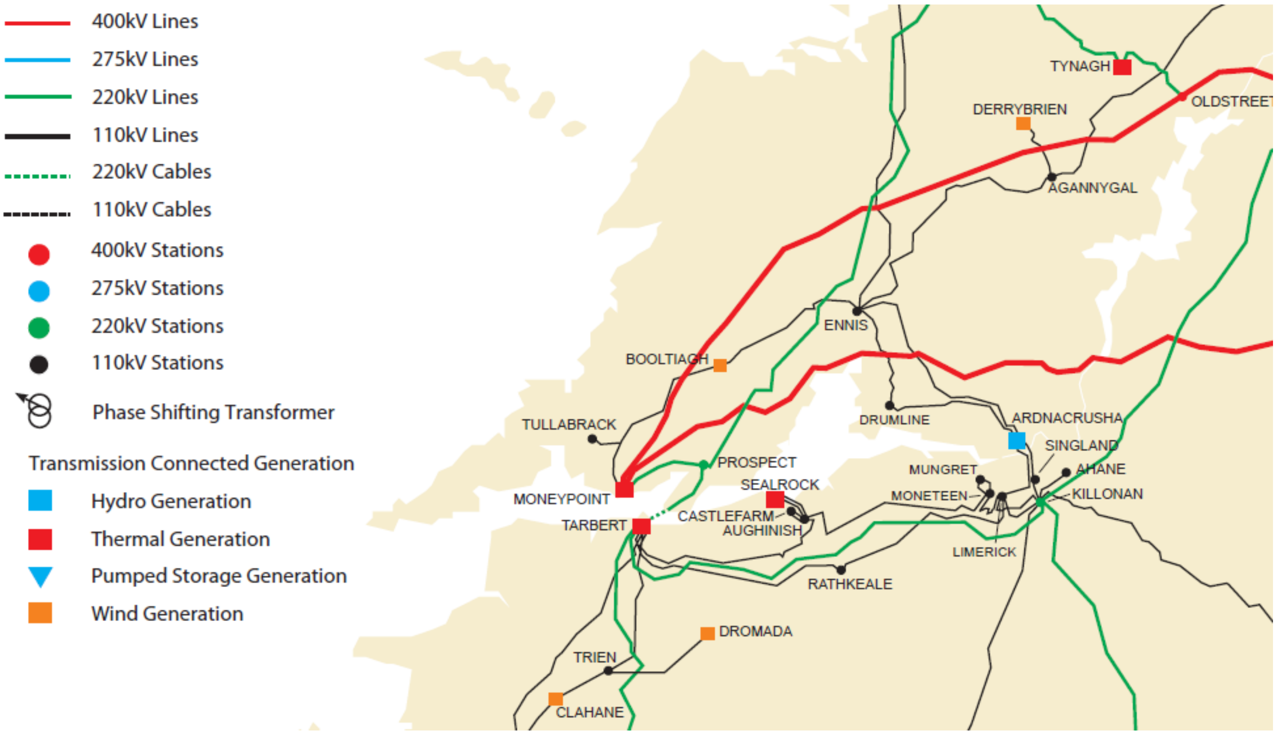

Figure 16: Electricity grid in the Limerick-Clare region in January 2011 [65].

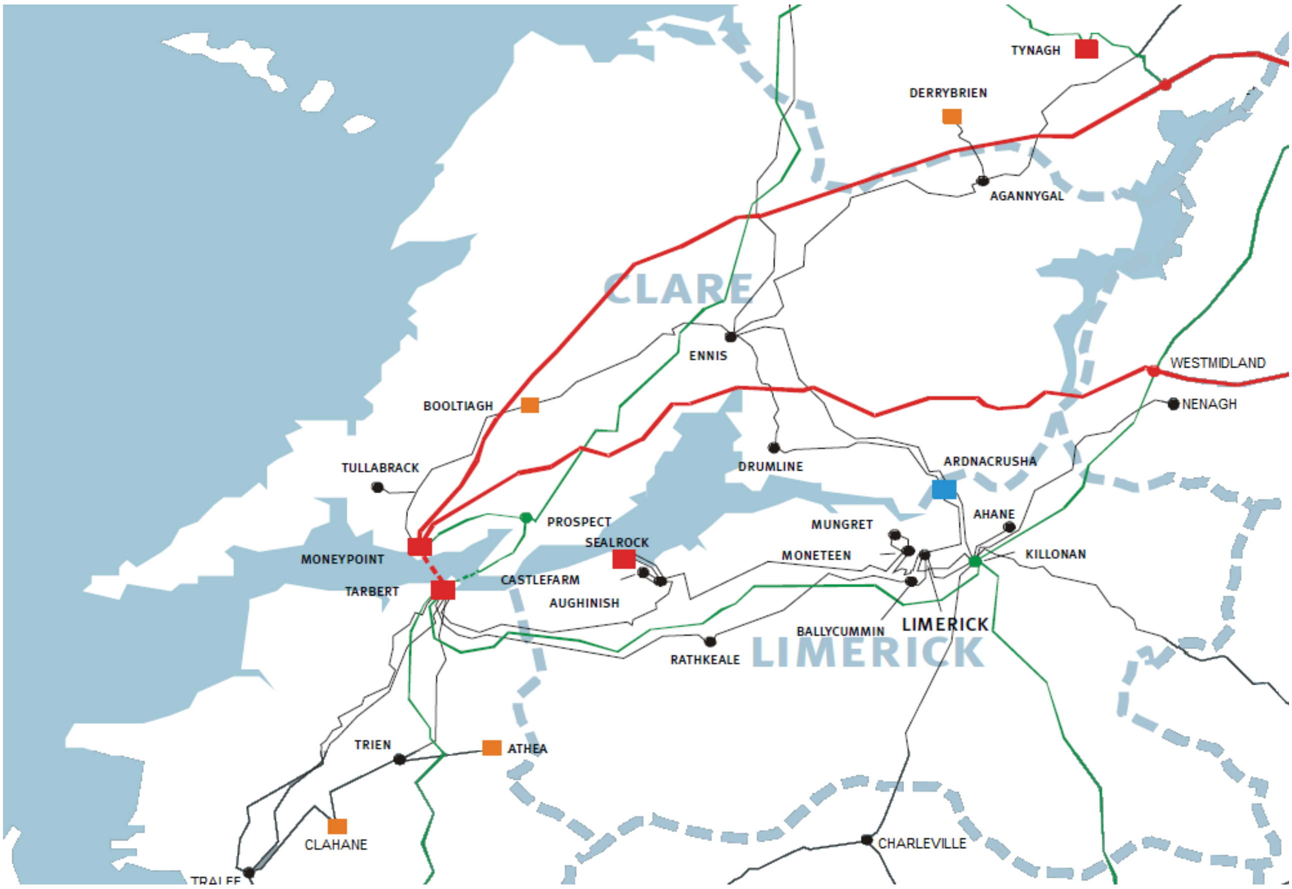

Figure 17: Electricity grid in Limerick and Clare by 2025 (legend displayed in Figure 16) [61].

4.1.2 Gas

There is also a well-establish gas grid in the LCR, as outlined in Figure 18. There are currently seven towns in County Clare which are connected to the gas grid (Bunratty, Clarecastle, Cratloe, Ennis, Killaloe, Meelick, Shannon, and Sixmilebridge) and six towns in County Limerick (Adare, Annacotty, Ballyneety, Castleconnell, Castleroy, Clarina, and Patrickswell) as well as Limerick City.

Figure 18: Gas network on the Island of Ireland [66].

A key development which could occur in the LCR in the coming years will is the introduction of the Shannon Liquefied Natural Gas (LNG) facility [67] in Kilcolgan, County Kerry, which is only 6 km from County Limerick. Shannon LNG will be capable of supplying gas to the Irish gas network. As displayed in Figure 19, this will Ireland's fourth source of gas supply along with the Kinsale and Corrib gas fields, as well as the gas interconnectors to Scotland. If this LNG facility is built, it is likely that that gas network will expand in the LCR, which will increase the dependency on natural gas in the LCR. It is important to consider the long-term implications of this, as a gas grid does not increase the flexibility in an energy system and hence it does not enable larger penetrations of fluctuating renewable energy. In contrast, district heating is an alternative heating infrastructure that does enable larger penetrations of fluctuating renewable energy [68], so developing a natural gas grid in the LCR now may not be beneficial in the long-term.

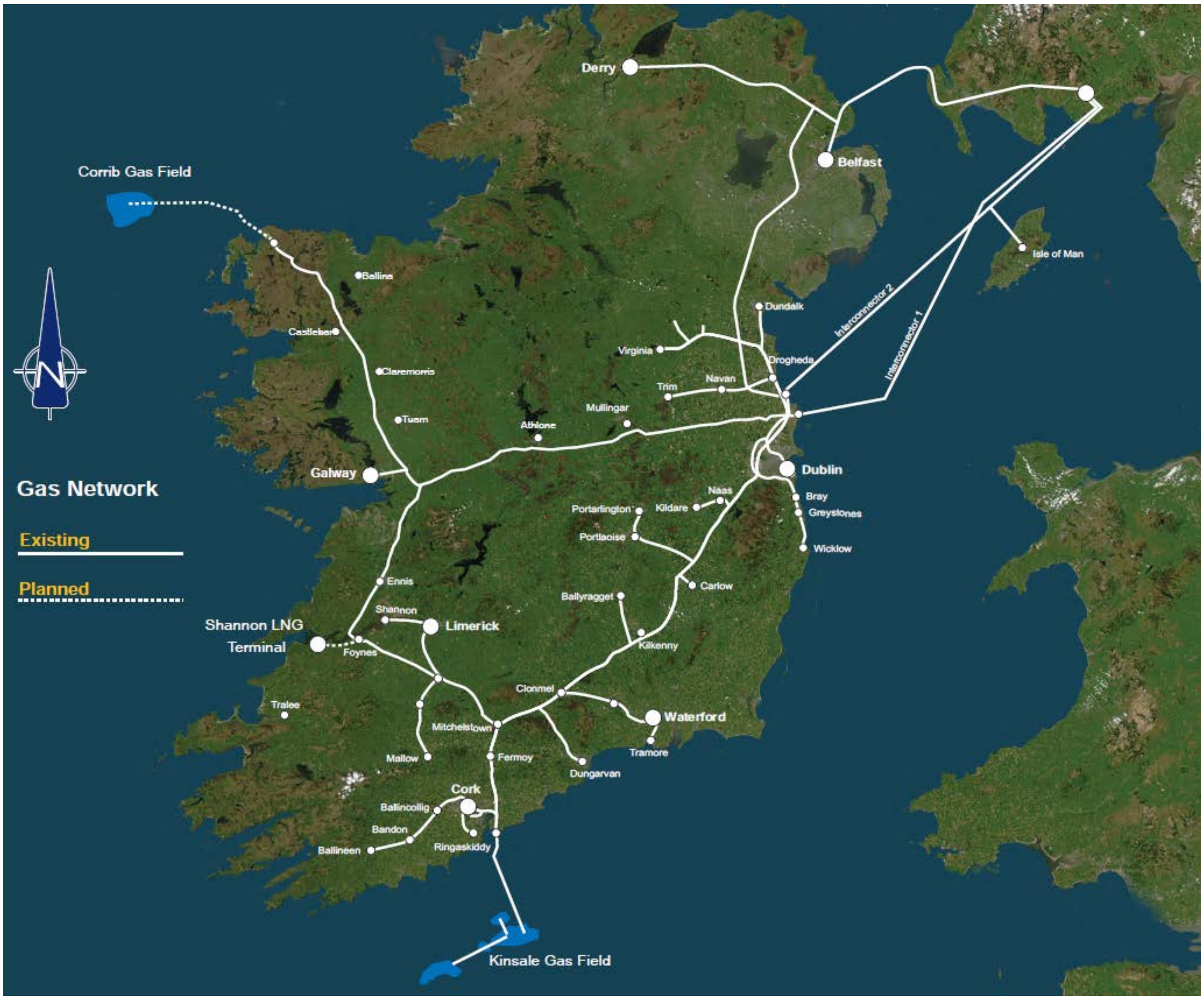

Figure 19: Shannon LNG facility and the Irish gas network [69].

4.1.3 District Heating

It is worth nothing that there is currently no significant district heating network installed in the LCR. As a result, the waste heat from the power stations, industrial CHP and cement factories in the region, as well as the waste cooling load from the proposed Shannon LNG facility are sent into the Shannon estuary. Therefore, there is a significant resource of surplus heat and cooling available in the region also.

4.1.4 Transport

In this study, the infrastructure relating to transport in the LCR was not included. However, in future studies this should be added, as previous work has indicated that infrastructure savings due to demand reductions and modal shifts can be more economical than simply replacing oil with renewable based oils in the transport sector [70].

4.2 Local Energy Mix

Defining the energy mix is very complex at the local level. Overall, two key options are available: using the national energy mix or creating a unique local energy mix. The argument for using the national mix is based on the fact that energy networks are national systems. For example, Moneypoint power station in the LCR is a key 'security of supply' asset for the entire island of Ireland. However, by using national energy mixes, the actions taken at a local level are not fully accounted for since they become diluted by actions in other regions. This is a significant issue as the implementation of renewable energy will require a transition from a centralised to a decentralised energy system, so action at a local level is essential and must be rewarded [11, 12]. As a result, it was deemed essential in this study to create a local mix that reflects renewable energy actions at the local level. A number of key issues were identified when designing the methodology for constructing a local energy mix. These are listed below along with a brief description of the action taken to account for it:

1. **Issue:** it must reflect the impact of implementing renewable energy at a local level in terms of energy production and GHG emissions. **Action:** This will be accounted for by assuming that local renewable energy is allocated to the local energy mix first. For the electricity sector, this could also be argued from a technical point of view. At present there is a priority dispatch procedure used on the Irish electricity market for renewable electricity generation [71]. Therefore, any renewable electricity constructed will be used to displace fossil fuels and so, the local community responsible for constructing this capacity should be allocated with this renewable energy: for example, if all of the electricity in the LCR is supplied using wind turbines, then these will be prioritised and used to displace a fossil fuel power plant somewhere else.
2. **Issue:** the methodology has to be repeatable for another region in Ireland, keeping in mind that this could be an importer or exporter of electricity, without double accounting or excluding any energy production. **Action:** after the local renewable energy has been allocated, the remaining demand will be met by a national average fossil fuel mix. Therefore, renewable energy is allocated on a location specific basis, but responsibility for fossil fuels is shared.
3. **Issue:** it should encourage local regions to create options for the integration of intermittent renewable electricity, instead of just using the national electricity grid as a balancing tool. This is an important issue as local energy strategies should contribute to the overall design of the national energy system and not simply use the national grid for short-term gain. Although the final responsibility for balancing the electricity grid rests with the national TSO, local regions should provide options for the national system to accommodate more intermittent renewable energy. **Action:** only renewable energy consumed in the region is allocated to the region. In other words, if the LCR produces more electricity from wind energy than it consumes the excess, this will not be allocated to the LCR.

To illustrate how these actions are applied, each sector is discussed separately.

4.2.1 Electricity (Intermittent Renewables)

The renewable energy penetration target for the electricity sector in Ireland is 40% by 2020, compared to 12% and 10% for the heat and transport sectors respectively (see Figure 54). In addition, it is not possible to define the point of consumption for renewably produced electricity. Therefore, the electricity sector was the most considered and challenging when allocating renewable electricity production to a local region in this study. An example is presented here to illustrate how the allocation procedure worked.

The total electricity demand in the LCR in 2010 was 1890 GWh and the total renewable electricity generated in the LCR was 648 GWh. Based on the principals outlined above, if the local produced renewable energy is allocated to the LCR first, then there is 1242 GWh of electricity which still needs to be met. As displayed in Figure 20, power plants in Ireland consumed coal, peat, oil, and gas to produce electricity in 2010. The corresponding percentage of each fuel consumed was 19% for coal, 13% for peat, 5% for oil, and 63% for gas. Therefore, this breakdown was used to estimate the mix of fossil fuels plants which met the remaining 1349 GWh of electricity in the LCR. As displayed in Figure 21, the 1349 GWh difference was thus met by 19% coal (240 GWh), 11% peat (136 GWh), 2% oil (29 GWh), and 67% natural gas (837 GWh). Hence, when creating the local electricity mix, renewable electricity generated in the LCR is prioritised first followed by the national average fossil fuel mix.

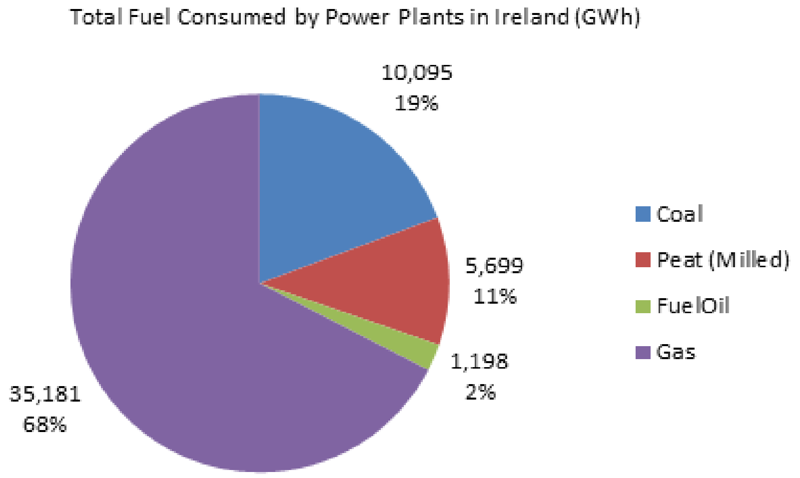

Figure 20: Fuel consumed for electricity generation in Ireland in 2010 (GWh).

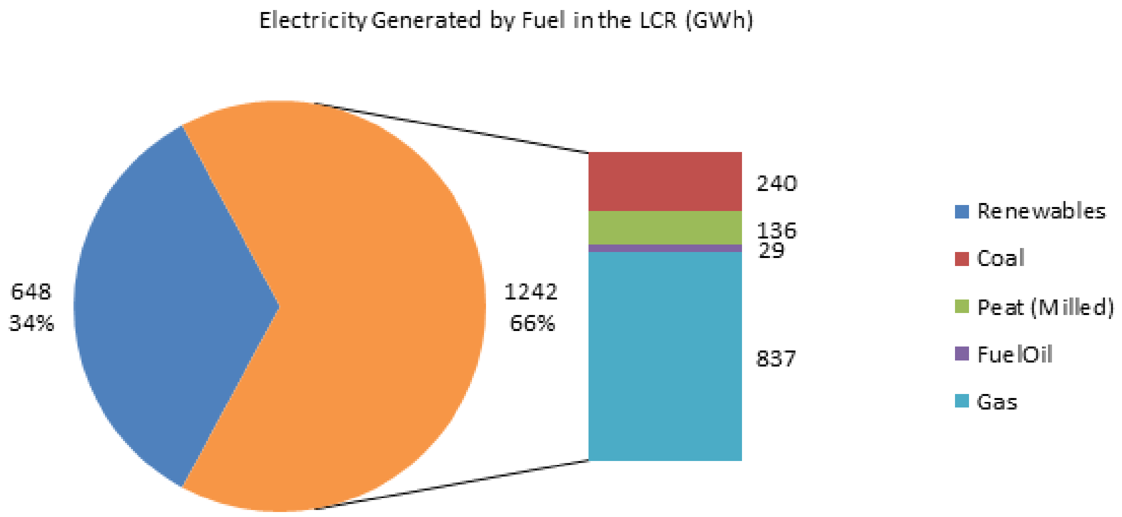

Figure 21: Source of electricity generation in the LCR for 2010 (GWh).

It is also important to mention that with this methodology, counties which have an excess supply of renewable electricity cannot credit it to the region unless the consumption is in the region and in the form of electricity. This is to maintain the principal that national assets are shared and also to one of the key issues outlined in this methodology i.e. to encourage local regions to develop flexible technologies which aid the integration of intermittent renewable energy. Identifying these technologies will be the primary goal in the next stage of this research, which will be documented in the Climate Change Strategy report.

This approach also ensures that counties are not solely responsible for large-scale power plants located within their boundaries. This is particularly relevant in this study, sine the largest power station in Ireland, Moneypoint, is located in the LCR. As displayed in Figure 22, if Moneypoint's consumption was allocated to the LCR, it would increase the total energy consumption in the region by anything from approximately 100% to 333%. As already mentioned about LEUs in industry in section 3.5, allocating a national asset to a one particular region does not reflect the fact that the asset is there for the national system. Hence, the electricity mix methodology developed here was deemed more appropriate.

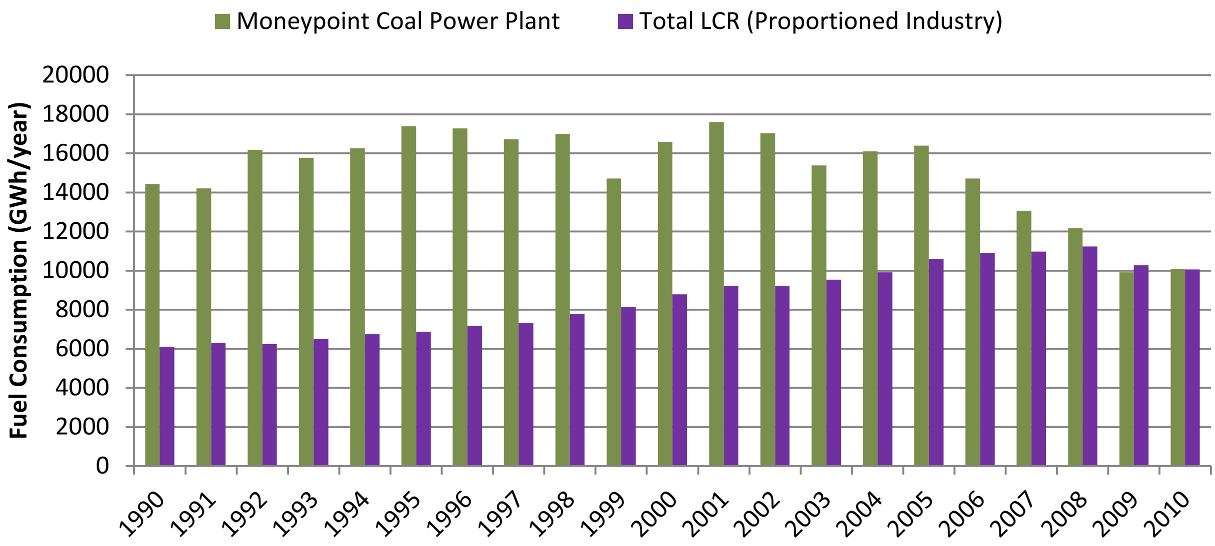

Figure 22: Total fuel consumed by Moneypoint power station and the LCR from 1990 to 2010 [18].

Finally, after defining this methodology, a CO_2 emission factor could be calculated for the LCR based on the emission factors in 0. The resulting emission factors are displayed in Figure 23, where they are compared to the national emission factor recorded. These results further demonstrate why a local energy mix is warranted for local energy planning. As displayed in Figure 23, throughout the 1990s, the national electricity system was reducing its carbon footprint by moving towards more efficient forms of electricity generation such as gas, as well as increasing the capacity of renewable energy such as wind power. In contrast, at a local level no additional renewable electricity generation was added between 1990 and 2003, so the local CO_2 emission factor remained stable during this period. However, as outlined previously in Table 6, wind power began to develop rapidly in the LCR from 2004 onwards and correspondingly the local electricity CO_2 emission factor then began to reduce. This clearly demonstrates how a local energy mix reflects the actions taken within the LCR.

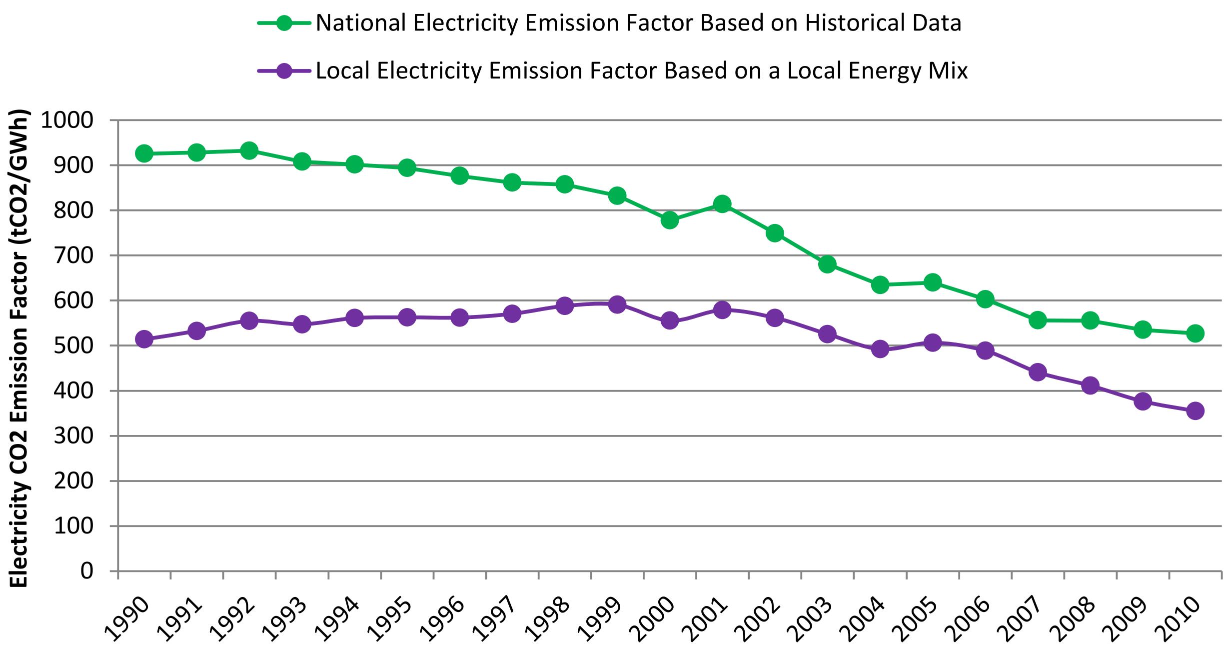

Figure 23: Electricity CO_2 emission factor at a national and local level from 1990-2010 [18, 19].

4.2.2 Heat (Biomass)

Unlike electricity, it is possible to define a physical location for the consumption of renewable fuel (i.e. biomass) used in the heating sector. However, no data which documented the exact consumption of biomass on a county basis in Ireland could be obtained. As a result, it is assumed that the fuel consumption documented as 'renewables' in the Irish energy balance [19] in the industrial, commercial, and residential sectors is biomass for heating purposes. Using the proportioning methodologies described in section 3, the biomass consumed in the LCR is calculated. Although this is a crude approximation of the biomass consumed for heating in the LCR, it needs to be considered in the context of current consumption. For example, in 2010, 'renewables' only accounted for approximately 5% of the 'heating' fuel consumed in the industrial, commercial, and residential sectors in Ireland, which will only increase to 12% if government targets are achieved (see Figure 54). Since biomass does not currently represent a significant proportion of the heat demand, this approximation was deemed sufficient for this study.

4.2.3 Transport (Biofuel)

Like the heating sector, no data was identified which outlined the biofuel consumption in Ireland for individual counties. Therefore, it was assumed that all 'renewables' consumed in the transport sector of the Irish energy balance [19] is biofuel for transport purposes. Once again, it is worth noting that under this assumption biofuels only represented approximately 2% of the energy consumed in transport in Ireland for 2010. Therefore, like biomass in the heating sector, biofuels do not currently represent a significant proportion of the transport demand and so this approximation was deemed sufficient for this study.

5 Energy and Emission Balances

An energy and emissions balance has been constructed for the LCR for each year from 1990-2010. In addition, two energy balances were also created for the year 2020 based on the 'Baseline' and 'NEEAP/NREAP' scenarios created in the 2010 version of SEAI's forecasts [17]. The Baseline scenario includes all energy-related government policies and measures legislated for up to the end of 2010. It is a hypothetical scenario developed by SEAI to represent the consequences of no further action. The 'NEEAP/NREAP' scenario represents the energy consumption in Ireland assuming a 'low growth' economic recovery along with the implementation of both the National Energy Efficiency Action Plan (NEEAP) [72] and the National Renewable Energy Action Plan (NREAP) [73] for 2020.

In relation to energy production, the baseline scenario assumes that those units which have secured a grid-connection agreement and can avail of the Renewable Energy Feed-In Tariff (REFIT) will be connected. This amounts to a total renewable electricity capacity of 3,500 MW by 2020 as compared to around 1,500 MW at the end of 2010. The NEEAP/NREAP assumes that the "16% of total energy consumption from renewable sources by 2020" target set in the Renewable Energy Directive (28/EC/2009) is met, by implementing the following sub-targets:

- 40% share of renewable energy in electricity (RES-E)
- 10% share of renewable energy in transport (RES-T)
- 12% share of renewable energy in heat (RES-H)

To reach these targets, the following renewable energy production technologies are implemented in Ireland in the NEEAP/NREAP (note that the capacities assigned to the LCR are illustrated in Table 8):

- Expansion of biomass electricity-generating capacity to 153 MW through the implementation of co-firing plans in Edenderry power station,
- Construction of two waste-to-energy units
- Landfill-gas electricity generation
- Small-scale biomass CHP, which is supported by new REFIT tariffs for biomass CHP
- Development of at least 75 MW of wave energy
- Expansion of both onshore and offshore wind capacity
- Upgrade of the transmission network

In addition to these energy production measures, there are a range of energy savings measures in both the 2020 baseline and 2020 NEEAP/NREAP scenarios. These are listed in Table 9 along with the estimate savings associated with each action (note that these estimates are from the 2011 version of SEAI's energy forecasts [74]). From Table 9, it is evident that energy efficiency improvements in buildings will provide the most significant savings by 2020, since they account for 50% of all savings achieved. In particular, the Better Energy Homes scheme which primarily concerns the retrofitting of houses with insulation, accounts for almost 21% of all the savings achieved. The public sector and large industries also make a significant contribution, with each accounting for approximately 10% of the total savings.

Table 9: Energy savings in in the Baseline and NEEAP/NREAP scenarios [74].

Energy Savings (GWh)				
Sector	2020 Baseline	Additional in NEEAP/NREAP	2020 NEEAP/NREAP Total	2020 NEEAP/NREAP % of Total
Public Sector	821	2,419	3,240	11.3%
Green Public Procurement (via ACA)	287		287	1.0%
CHP (public sector)	183		183	0.6%
Public Sector Building Demonstration Programme	140		140	0.5%
ReHeat (public sector)	123		123	0.4%
SEEEP and EERF (public sector)	88		88	0.3%
Public Sector Programme		1,261	1,261	4.4%
Better Energy (public sector)		1,000	1,000	3.5%
Public transport efficiency		158	158	0.5%
Business Sector	4,815	1,000	5,815	20.2%
SEAI Large Industry Programmes	2,728		2,728	9.5%
ACA (private sector)	688		688	2.4%
SEAI SME Programme	506		506	1.8%
CHP (private sector)	428		428	1.5%
ReHeat (private sector)	288		288	1.0%
SEEEP and EERF (private sector)	177		177	0.6%
Better Energy (Commercial sector)		1,000	1,000	3.5%
Buildings	6,703	7,682	14,385	50.0%
2008 Building Regulations -Dwellings	2,110		2,110	7.3%
2002 Building Regulations -Dwellings	1,279		1,279	4.4%
Energy efficient boiler regulation	1,200		1,200	4.2%
Domestic Lighting (Eco-Design Directive)	1,200		1,200	4.2%
Home Energy Saving (HES) scheme	365		365	1.3%
2005 Building Regulations – Buildings other than dwellings	300		300	1.0%
Warmer Homes Scheme (WHS)	130		130	0.5%
Greener Homes Scheme (GHS)	119		119	0.4%
Better Energy Homes (residential retrofit)		6,000	6,000	20.9%
2011 Building Regulations -Dwellings		833	833	2.9%
Smart Meter roll-out		624	624	2.2%
Building Regulations - Nearly Zero Energy Dwellings		225	225	0.8%
Mobility-Transport	3,924	1,401	5,325	18.5%
Improved fuel economy of private car fleet (EU Regulation)	3,014		3,014	10.5%
Vehicle registration tax (VRT) and annual motor tax (AMT) rebalancing	657		657	2.3%
Aviation efficiency	253		253	0.9%
More efficient road traffic movements		713	713	2.5%
Electric vehicle deployment		688	688	2.4%
TOTAL	**16,263**	**12,502**	**28,765**	100%

In this section, the resulting energy consumed, energy-related GHG emitted, and the fuel costs for Ireland, Clare County, Limerick City, Limerick County, and the LCR are presented separately for each historical year between 1990 and 2010, as well as for the two forecasted scenarios in 2020 (baseline and NEEAP/NREAP). For Limerick County and the LCR, a second set of results is also included, in which the LEUs are added to represent the actual energy consumption instead of the responsible energy consumption as defined earlier in section 3.5.

5.1 Ireland

Here the overall trends in energy consumption, GHG emissions, and fuel costs in Ireland are discussed for the period 1990-2010 and for the forecasts to 2020. Due to the proportioning methodology used in this study to estimate the energy consumption in the local regions, as discussed in section 3, the overall trends at a local level are the same as those at the national level. Hence, these trends will be reflected in the Limerick and Clare energy balances also.

The energy consumed in Ireland is displayed in Figure 24, which is sub divided by six different types of fuel; renewable energy, peat, coal, oil, natural gas, and electricity.

It is important to note that electricity consumed is produced by a variety of different fuels, which is not reflected in Figure 24. Since the electricity sector has Ireland's largest renewable energy penetration target, a lot of the renewables are hidden in this data. However, a detailed breakdown of this is available in SEAI's annual historical [75] and forecasting reports [74].

The overall energy consumed in Ireland has grown steadily between 1990 and 2008 at approximately 3%/year. Due to the economic recession, in 2009 there was a 9% drop followed by a 2% drop in 2010. However, even with this drop the energy consumed in 2010 was still 166% of the 1990 energy consumed in Ireland. The 2020 Baseline will result in a 9% increase while the 2020 NEEAP/NREAP will cause a 9% decrease in energy consumption. The actions related to this reduction in the NEEAP/NREAP scenario are outlined in Table 9.

It is evident from Figure 24 that oil is the main type of fuel consumed in Ireland: in 1990 oil represented 55% of the total energy consumed which grew to 61% in 2010. Under the baseline scenario the share of oil will continue to rise to 62.5%, but if government policy is implemented, then this will drop to 59%. As outlined in Figure 25, the increase in oil is strongly associated with an increasing demand for energy in the transport sector. Hence, the government's commitments to higher efficiency standards for new cars and the implementation of 10% electric vehicles are most likely responsible for the reduction in oil consumed in the 2020 NEEAP/NREAP scenario.

Since fuels used for electricity production are not represented in Figure 24 and Figure 25, it is evident that only a small proportion of consumption is met by renewable energy, coal, and peat which account for 3%, 3%, and 2% of the final energy consumption respectively. By 2020 coal and peat will have reduced to 1% which renewable energy is expected to remain at 3% in the Baseline and increase to 8% in the NEEAP/NREAP scenario. This suggests that significant increases of renewable energy is feasible for the heat sector since in 2010, 28 TWh of bioenergy was produced in Denmark of which 11 TWh was used in the final energy consumption [76].

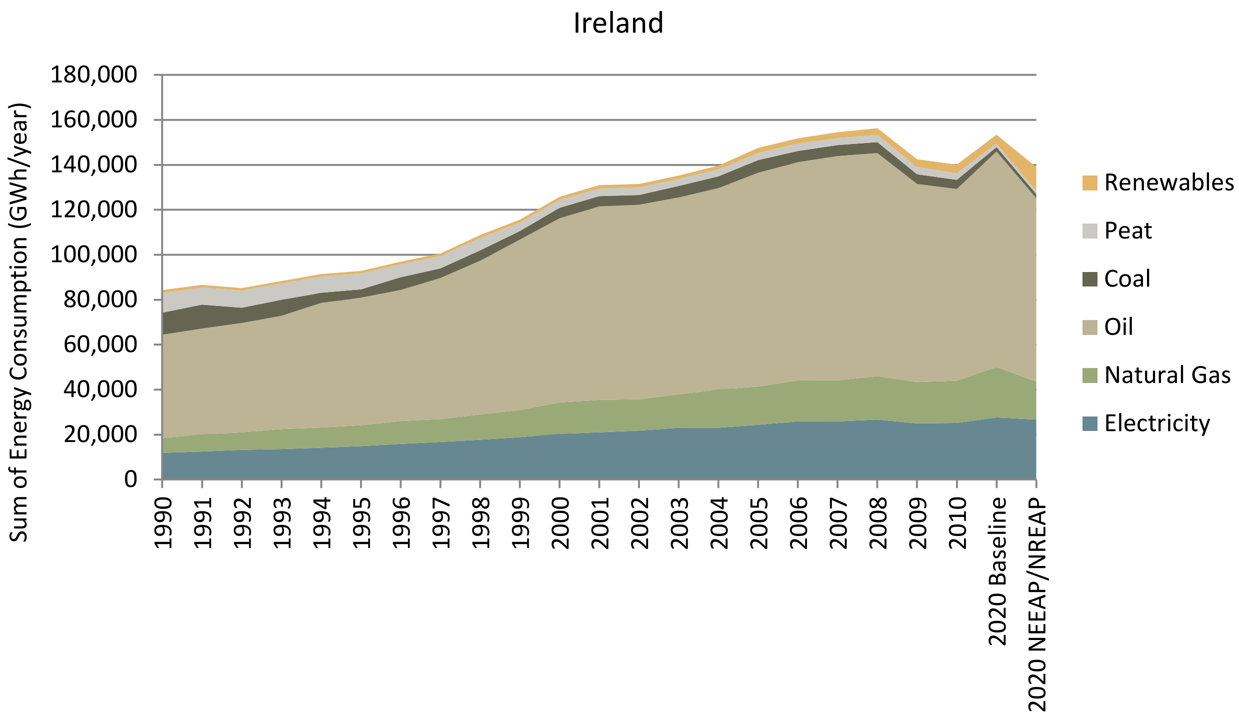

Figure 24: Energy consumed in Ireland by fuel from 1990-2010 and forecasted for 2020.

The energy consumption can also be sub divided by sector. In line with national statistics reported by SEAI, five different sectors are used here: transport, residential, industry, commercial, and agriculture.

Figure 25 indicates that every sector in Ireland has experienced an increase in energy consumption between 1990 and 2010. As discussed previously transport has been the primary cause for the overall increase in energy consumed in Ireland, which was 133% more in 2010 than in 1990. The commercial sector has experienced the second largest relative increase since 1990, with 2010 consumption 73% higher. The residential sector grew by 45%, industry by 22%, and agriculture by 9%.

Looking forward, it is also evident from Figure 25 that the agriculture sector is set to experience the largest relative increase between 2010 and 2020. In both the Baseline and the NEEAP/NREAP scenarios there is a 39% increase in energy consumption in agriculture. In the Baseline there is a 6% increase in the commercial sector, a 10% increase in industry, a 17% increase in transport, and a 3% drop in residential energy consumption. For the NEEAP/NREAP scenario both commercial and residential energy consumption decrease by 14% and 22%, while the industry and transport sectors increase by 9% and 13% respectively. This represents the significant contribution from buildings to the energy savings required by 2020 as outlined in Table 9.

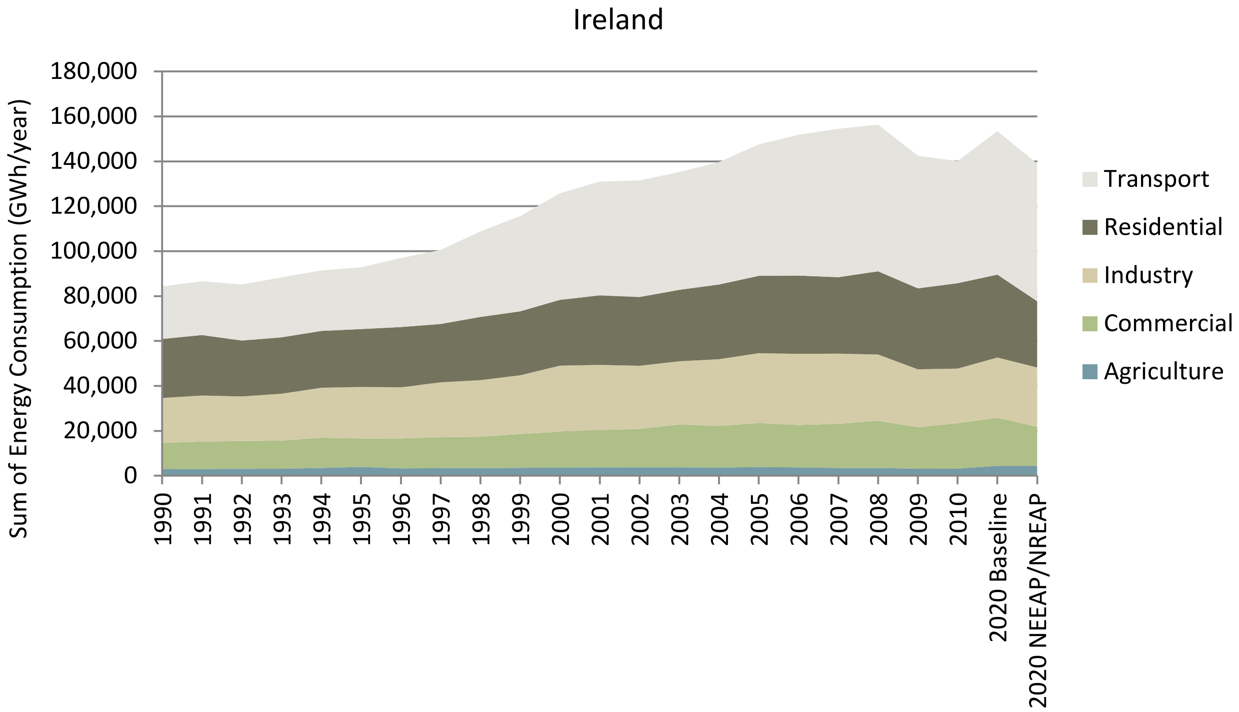

Figure 25: Energy consumed in Ireland by sector from 1990-2010 and forecasted for 2020.

In relation to energy related GHG emissions, Figure 26 indicates that the trend in historical emissions between 1990 and 2010 are similar to the trends experienced in total energy consumption. Therefore, by 2010 the energy related CO2 emissions were 135% of those in 1990. However, due to an increasing penetration of renewable energy in the electricity sector, the GHG emissions in the baseline do not increase in line with the forecasted increase in energy consumption, but they remain the same as 2010. Since 16% of the primary energy supply is forecasted to be supplied by renewable energy in the NEEAP/NREAP scenario by 2020 and approximately 29 TWh of energy savings are due to be implemented (see Table 9), there is a 15% drop in GHG emissions by 2020.

In relation to existing targets, the Kyoto protocol set a limit on Irish GHG emissions which was 13% above 1990 levels over the period 2008-2012. Over the three years between 2008 and 2010, Ireland was on average 26% above this limit and if the Baseline scenario is continued, Ireland will be 20% above this limit in 2020. However, if government policies are implemented as set out in the NEEAP/NREAP scenario, then the Kyoto target can be considered met since the results show a shortfall of only 1.5%.

The other binding target for CO2 emissions in Ireland relates to the EU 20-20-20 targets under the EU directives 2009/29/EC for ETS participants and 406/2009/EC for non-ETS participates. Both of these require a GHG reduction of approximately 20% compared to 2005 levels. As illustrated in Figure 26, if government targets are implemented this target will not only be met, but surpassed. Therefore, the policies established in the NEEAP/NREAP are effective for meeting Ireland's energy-related GHG obligations.

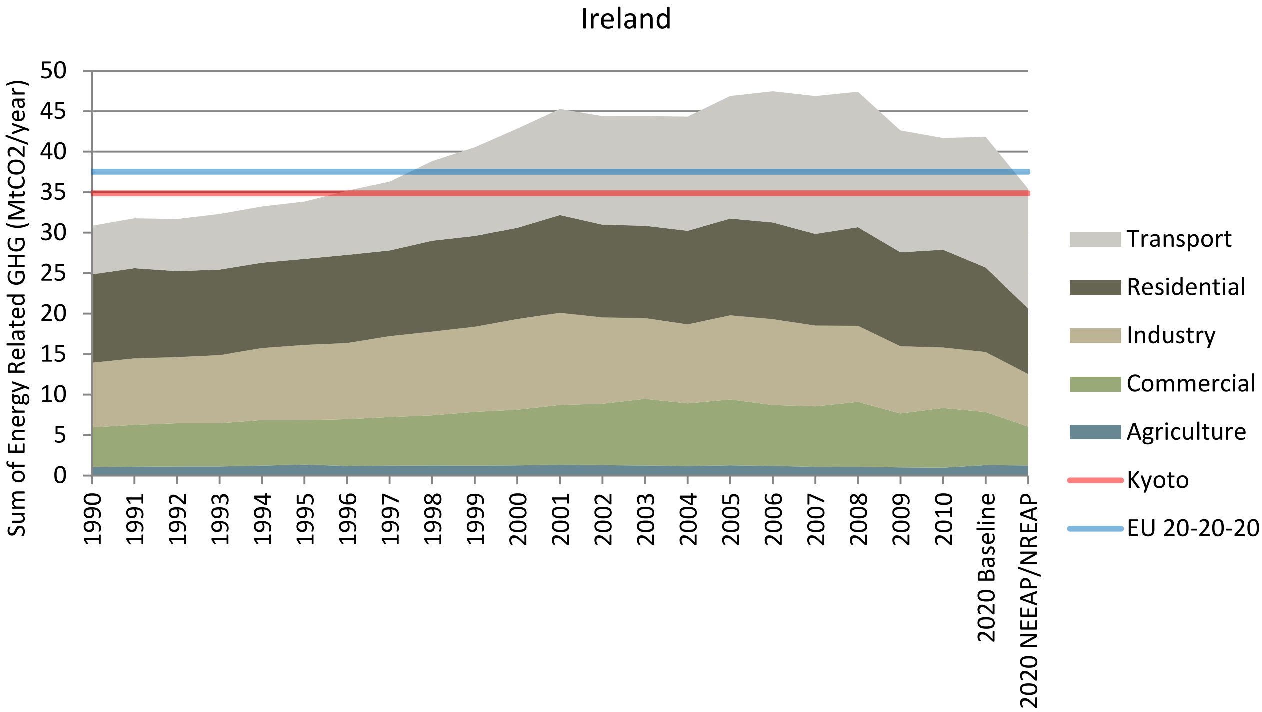

Figure 26: Energy related GHG emissions in Ireland by sector from 1990-2010 and forecasted for 2020.

Like energy consumption and GHG emissions, Figure 27 the cost of Ireland's energy has also grown between 1990 and 2010, but with a few unique trends. Firstly, in the 1990s, energy costs increased by an average of only 1%/year, but by an average of 16%/year in the 2000s. Secondly, the variation from one year to the next is much more unpredictable than for energy consumption and GHG emissions. As outlined in Figure 28, the cost of energy in Ireland varied by extremes of +48% and -41% between 1991 and 2010, while the total energy consumption only varied by extremes of +/-9%. Thirdly, the cost of fuel is set to increase by 16% in the NEEAP/NREAP scenario for 2020 compared to 2010, even though there is a 1% decrease in energy consumption: this is due to forecasted increases in the price of fuel by the IEA [77].

In total, the cost of fuel in Ireland peaked in 2008 at €7.4 billion, while in 2020 this will be €7 billion in the Baseline and €6.2 billion in the NEEAP/NREAP scenario. Naturally this reduction in fuel costs requires corresponding investments on both the demand and production side as discussed previously. In the Climate Change Strategy, these investments are quantified but here only the fuel costs are illustrated.

Oil accounts for the largest cost throughout the period between 1990 and 2010. Similar to the amount of oil consumed, the costs for oil also increasingly dominated the overall picture throughout this period. In 1990, oil represented 40% of the total costs, but by 2010 it represented 67%. Similarly in the Baseline oil accounts for 71% of the costs and in the NEEAP/NREAP scenario it is 69% of the total. This demonstrates the Ireland's significant dependence on oil for transport and the importance of developing new alternatives in the future. Hence, new liquid fuel technologies are assessed in the Climate Change Strategy which will enable the LCR to become a first mover in this area. The electricity cost is responsible for approximately 16% of the fuel costs in the NEEAP/NREAP scenario while natural gas makes up 9% and renewables 5%. Peat and coal are negligible in terms of the overall fuel costs in 2020.

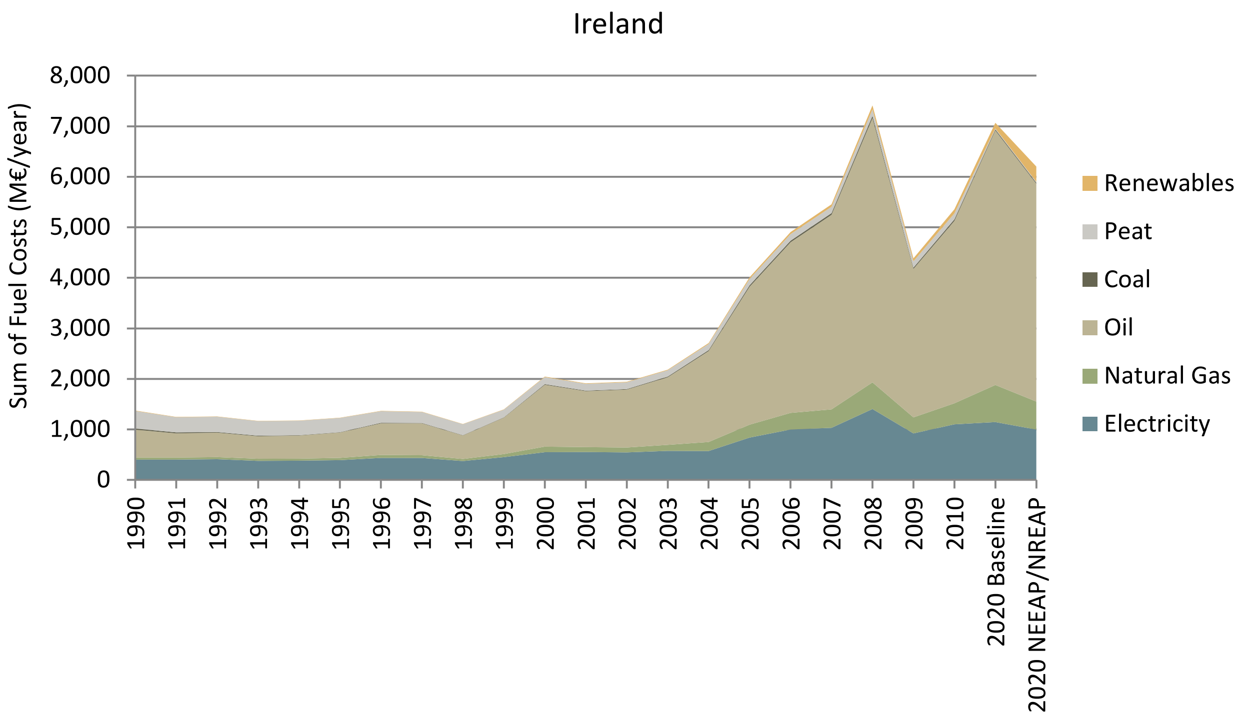

Figure 27: Fuel costs in Ireland by fuel from 1990-2010 and forecasted for 2020.

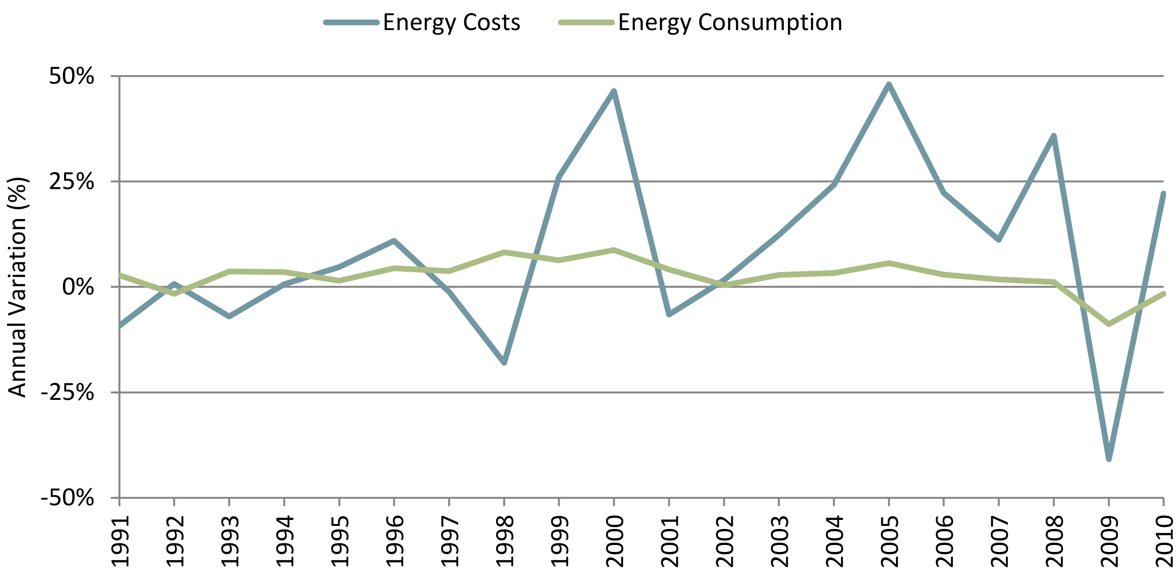

Figure 28: Annual variation in energy costs and energy consumption in Ireland between 1991 and 2010.

Overall this brief overview of the key trends in energy consumption, energy related GHG emissions, and fuel costs in Ireland demonstrated the importance of transitioning to more sustainable forms of energy and the implementation of energy savings. With the implementation of the policies outlined by the Irish government, in 2020 the energy consumption will decrease, GHG emission targets will be met, and fuel costs will be approximately 13% lower than a business-as-usual scenario. A more detailed breakdown of the historical and forecasted energy consumption and production in Ireland can be found in SEAI's annual reports [17, 74, 75].

5.2 Limerick-Clare Region

This section presents the energy consumption, energy related GHG emissions, and fuel costs for the LCR for the 'responsible' (excluding LEUs) and 'actual' (including LEUs) methodologies. The same results are available in for County Clare, County Limerick, and Limerick City separately in section 6.

5.2.1 Excluding Large Energy Users

Due to the proportioning methodology used in this study to estimate the energy consumption in Limerick-Clare Region, as discussed in section 3, the overall trends and energy mix at a local level is practically the same as those discussed in section 5.1 for Ireland. The only difference is the electricity mix used at a national level compared to the local level, which has been discussed in detail in section 4.1.1. Hence, the trends and energy mix will not be the focus here, but instead the magnitude of energy, GHG, and fuel costs associated with Limerick-Clare Region.

Figure 29 and Figure 30 indicate that the energy consumption in Limerick-Clare Region was approximately 6,100 GWh in 1990 and peaked at 11,200 GWh in 2008. In 2020, if a business as usual scenario is followed, then the total energy consumption will return to the peak in 2008, but if the NEEAP/NREAP scenario is implemented then it will reduce to 10,200 GWh.

Figure 31 indicates that Limerick-Clare Region's energy related GHG emissions peaked in 2006 at approximately 3.21 Mt compared to 1.88 Mt in 1990. In recent years this has been reducing and in 2010 it was 2.67 Mt, but under a business-as-usual scenario they will increase again to 2.91 Mt in 2020. However, with the implementation of government policies, the recent reduction will continue and by 2020 it will be 2.33 Mt, which is below the EU 20-20-20 targets, but still approximately 9% above the Kyoto target.

Finally, the fuel costs for Limerick-Clare Region are outlined in Figure 32. Like the national picture, fuel costs are the most volatile metric recorded in this study over the period 1990-2010 and for 2020. In 1990, the total fuel costs for the region was approximately M€86, which increased dramatically in the 2000s to a peak of M€496 in 2008: this is 580% of 1990 expenditure. Although there has been a reduction in fuel costs in recent years compared to the peak in 2008, trends suggest that fuel costs are beginning to increase once again. For example, even though energy consumption dropped by 2% between 2009 and 2010, the cost of fuel in the LCR increased by M€60. Under a business-as-usual situation, this increase is forecasted to continue so that in 2020 the cost of fuel would be M€492. In contrast under the NEEAP/NREAP scenario, fuel costs decline to M€420. Naturally, this reduction in fuel costs will require investments in cleaner energy production technologies and a range of energy savings, which are outlined in Table 9. Assessing the tradeoff between these investments and the corresponding reductions in fuel costs will thus be the key focus of the Climate Change Strategy.

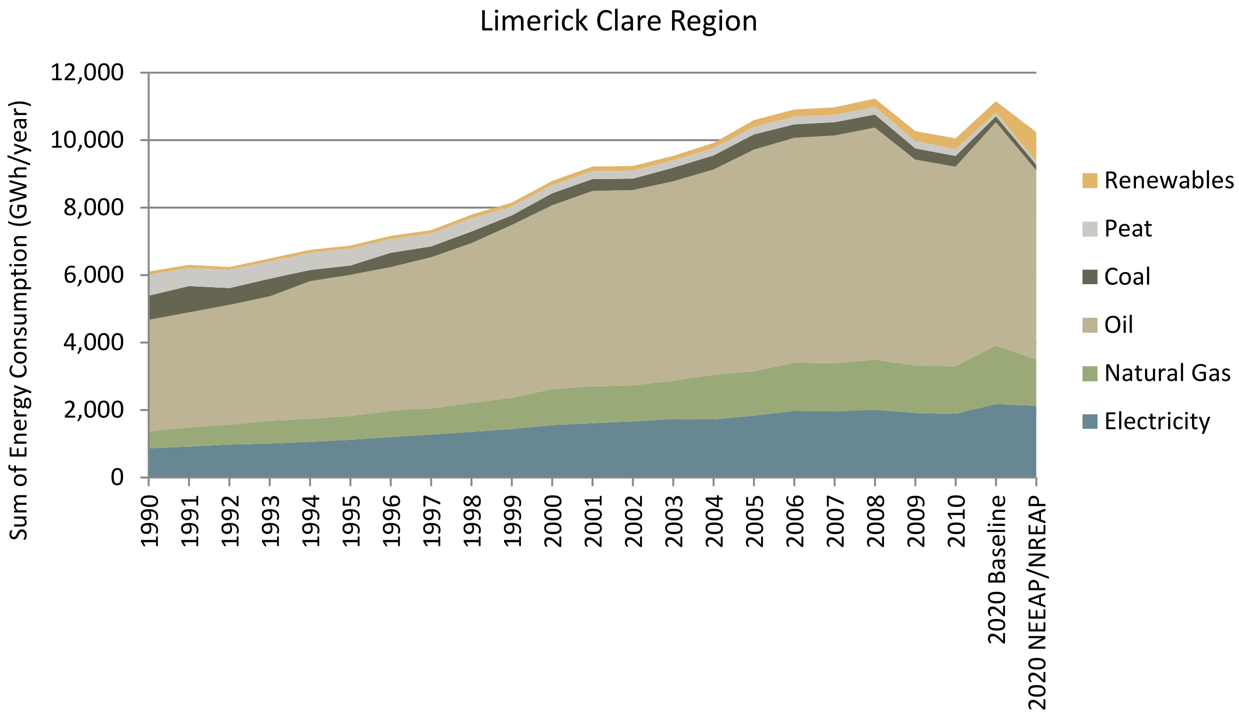

Figure 29: Energy consumed in the LCR by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

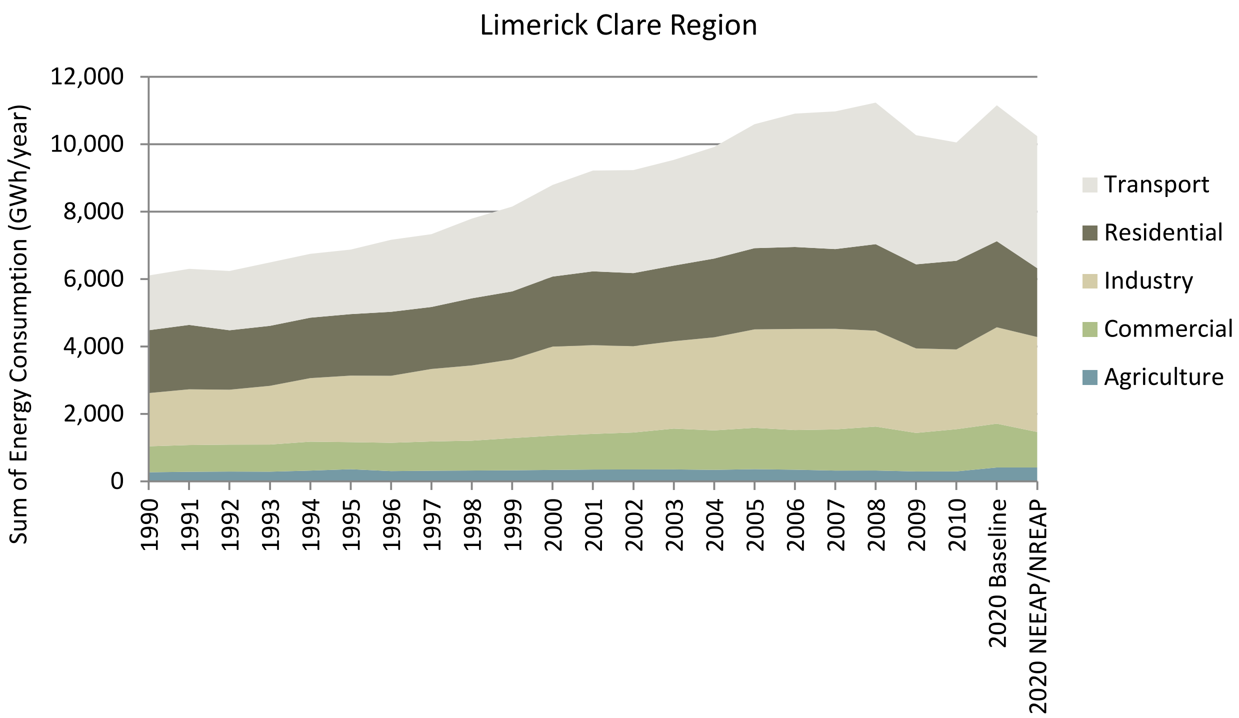

Figure 30: Energy consumed in the LCR by sector from 1990-2010 and forecasted for 2020 excluding LEUs.

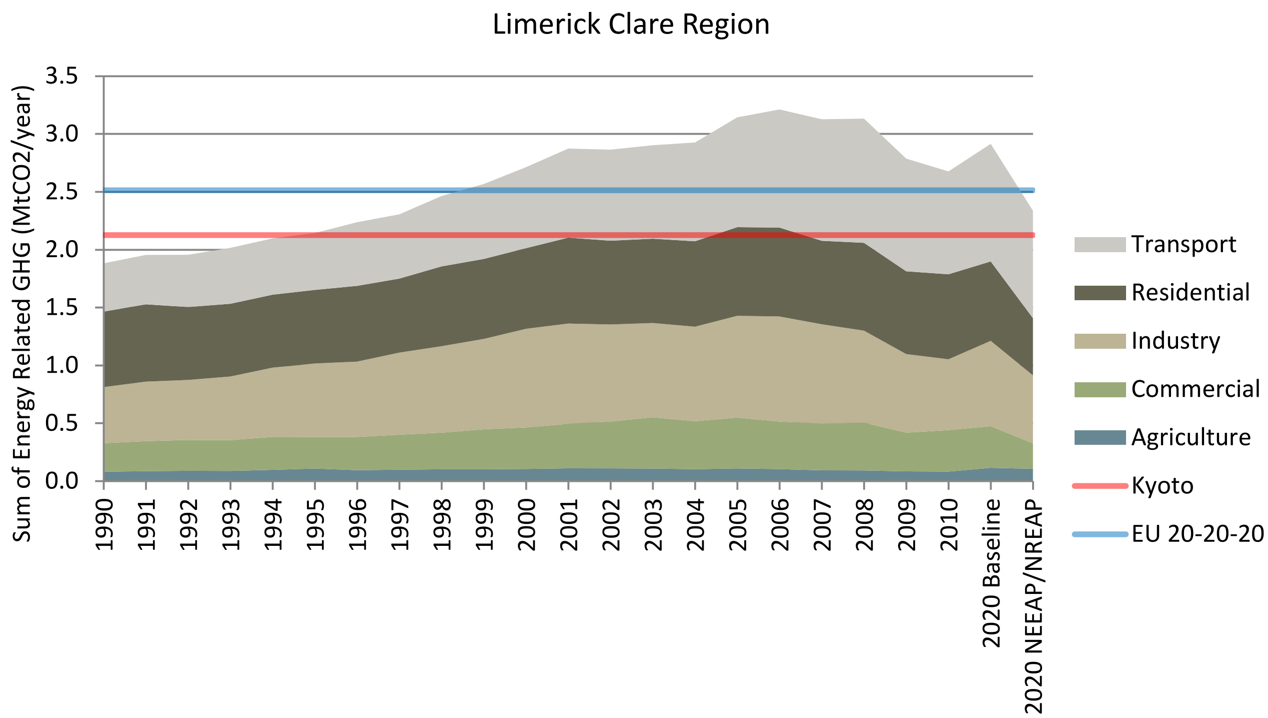

Figure 31: Energy related GHG emissions in the LCR by sector from 1990-2010 and forecasted for 2020 excluding LEUs.

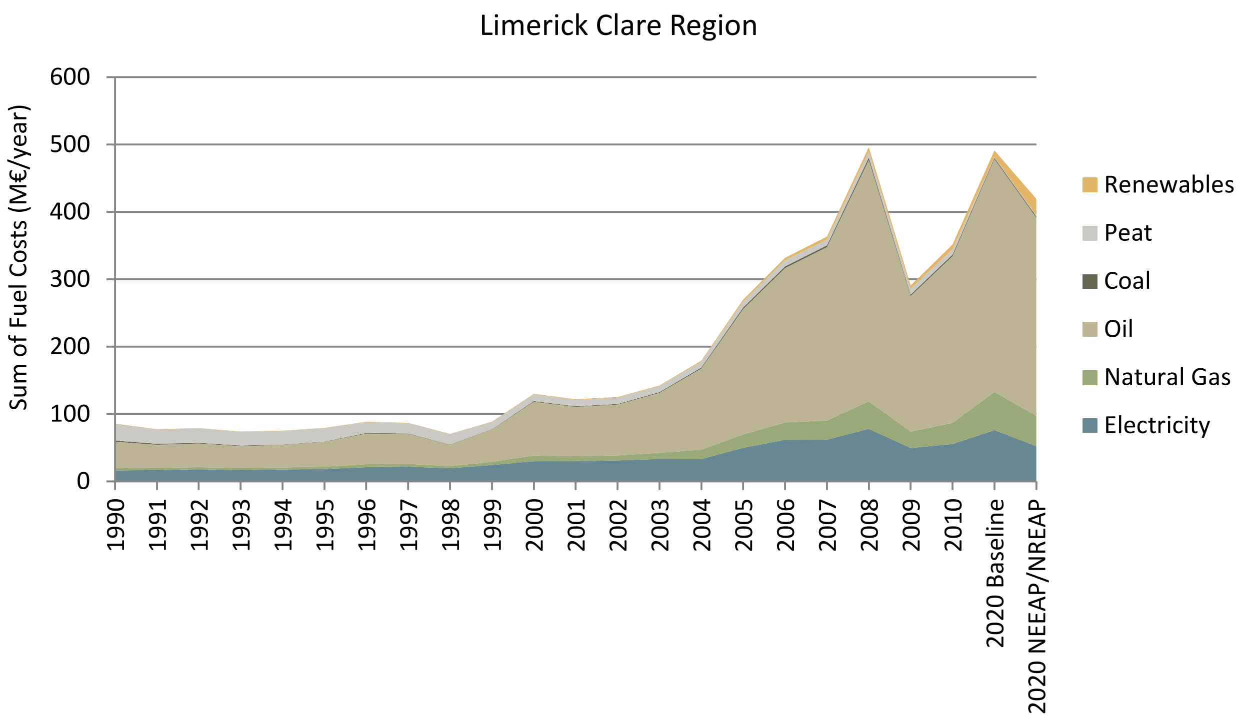

Figure 32: Fuel costs in the LCR by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

5.2.2 Including Large Energy Users

The results presented here represent the 'actual' energy consumption in Limerick-Clare Region instead of the 'responsible' energy consumption. As outlined earlier in section 3.5, County Limerick contained 4 out of the top 15 industrial GHG emitters in Ireland in 2009. Hence, it was deemed unfair to allocate all of this energy consumption solely to the region and so the 'responsible' methodology was utilised instead. However, for completeness, the results here for Limerick-Clare Region do include the energy consumed by these large industries to illustrate how they affect the overall picture.

As illustrated in Figure 33 and Figure 34, the total energy consumed in 1990 in Limerick-Clare Region is now approximately 11,300 GWh instead of 6,100 GWh. Also, the peak in County Limerick with the LEUs occurred in 2007 and it was approximately 16,600 GWh whereas without the LEUs it was in 2008 at 11,000 GWh. Figure 34 also demonstrates the scale of energy consumed by industry in the region when compared to Figure 30 previously. For example, in 2010, industry represents approximately 63% of the total energy consumption when the LEUs are included, but without the LEUs industry only accounts for 26%. In addition, as illustrated in Figure 49, there was a dramatic switch from oil to natural gas within industry in County Limerick in 2006, which meant that the increase in GHG emissions from 2005 to 2006 is less when the LEUs are included in Figure 51 than when they were excluded in Figure 47.

Finally, the fuel costs are approximately double when LEUs are included, as displayed in Figure 36. Hence, each of these examples illustrate the influence that large industry has on the energy consumption and fuel mix in County Limerick if they are entirely allocated to the region. Hence, by doing this, local actions could be overshadowed and hence the 'responsible' methodology utilised earlier was use deemed more appropriate for this study.

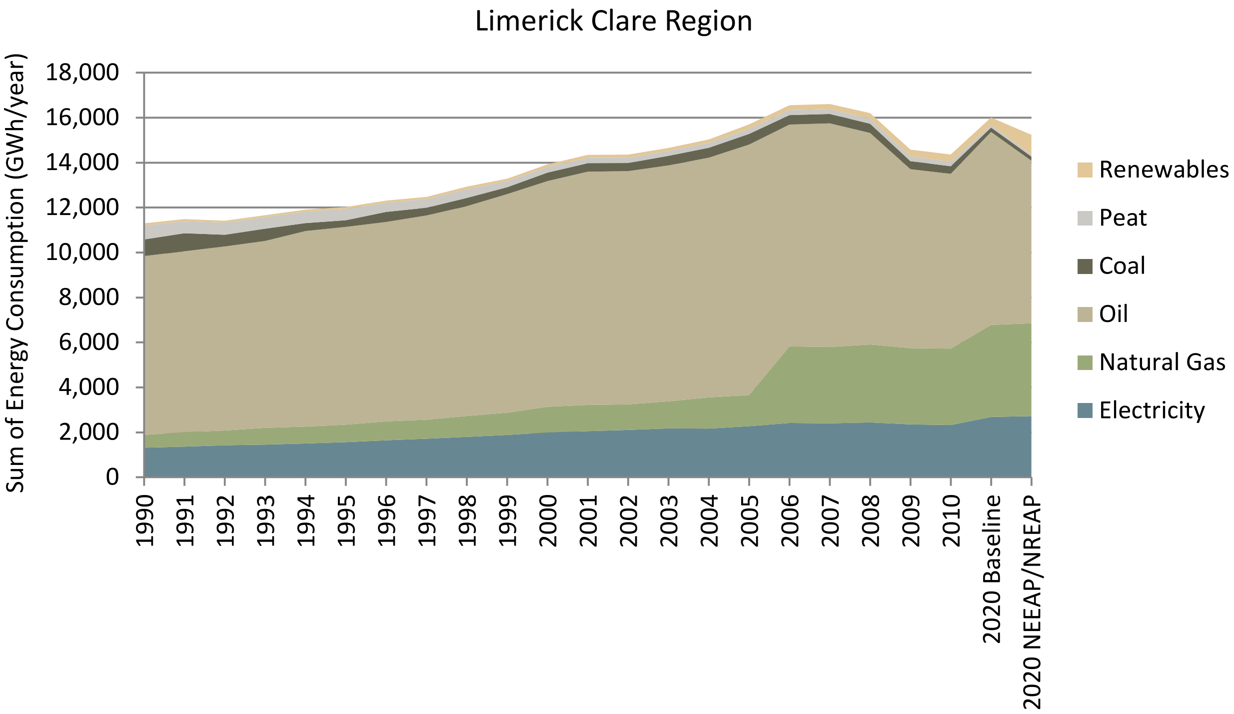

Figure 33: Energy consumed in the LCR by fuel from 1990-2010 and forecasted for 2020 including LEUs.

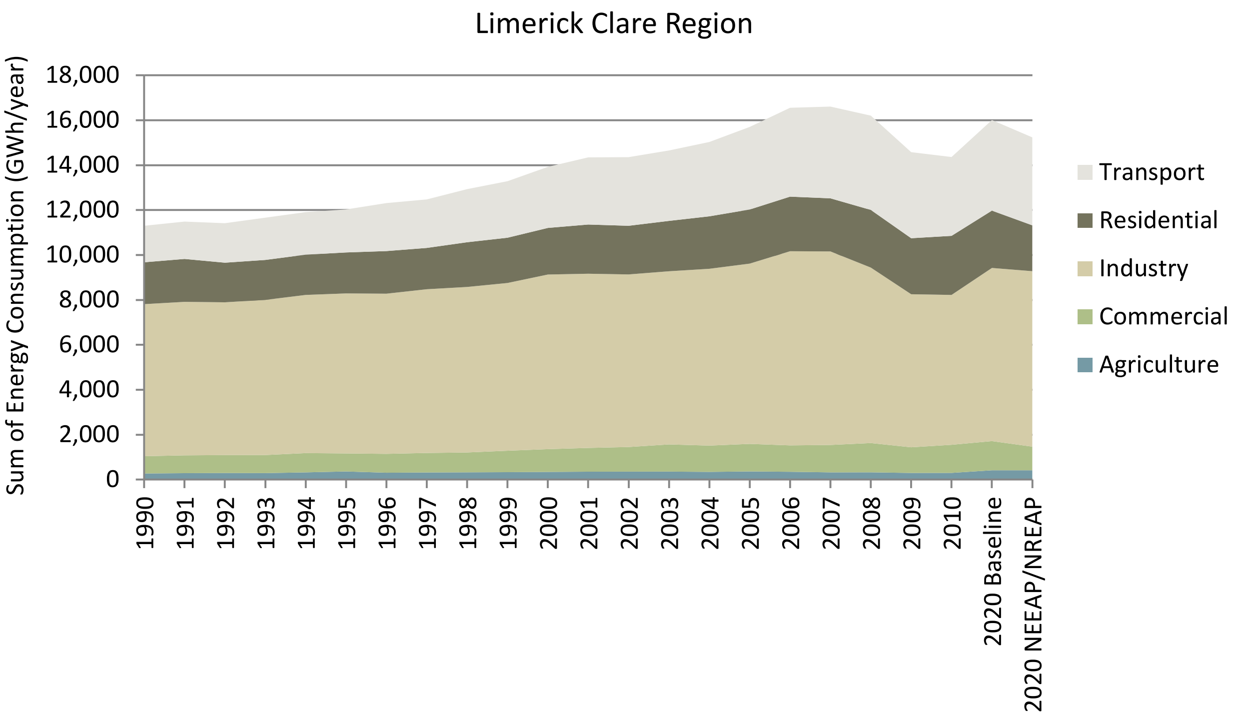

Figure 34: Energy consumed in the LCR by sector from 1990-2010 and forecasted for 2020 including LEUs.

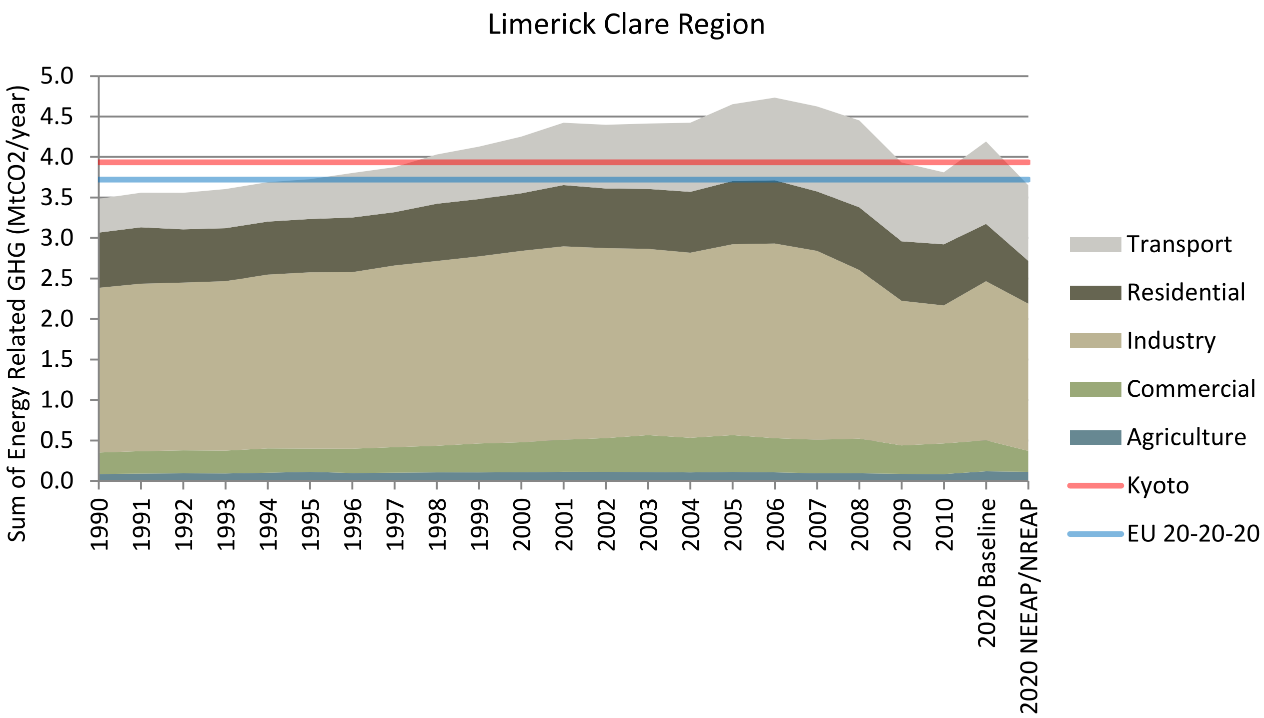

Figure 35: Energy related GHG emissions in the LCR by sector from 1990-2010 and forecasted for 2020 including LEUs.

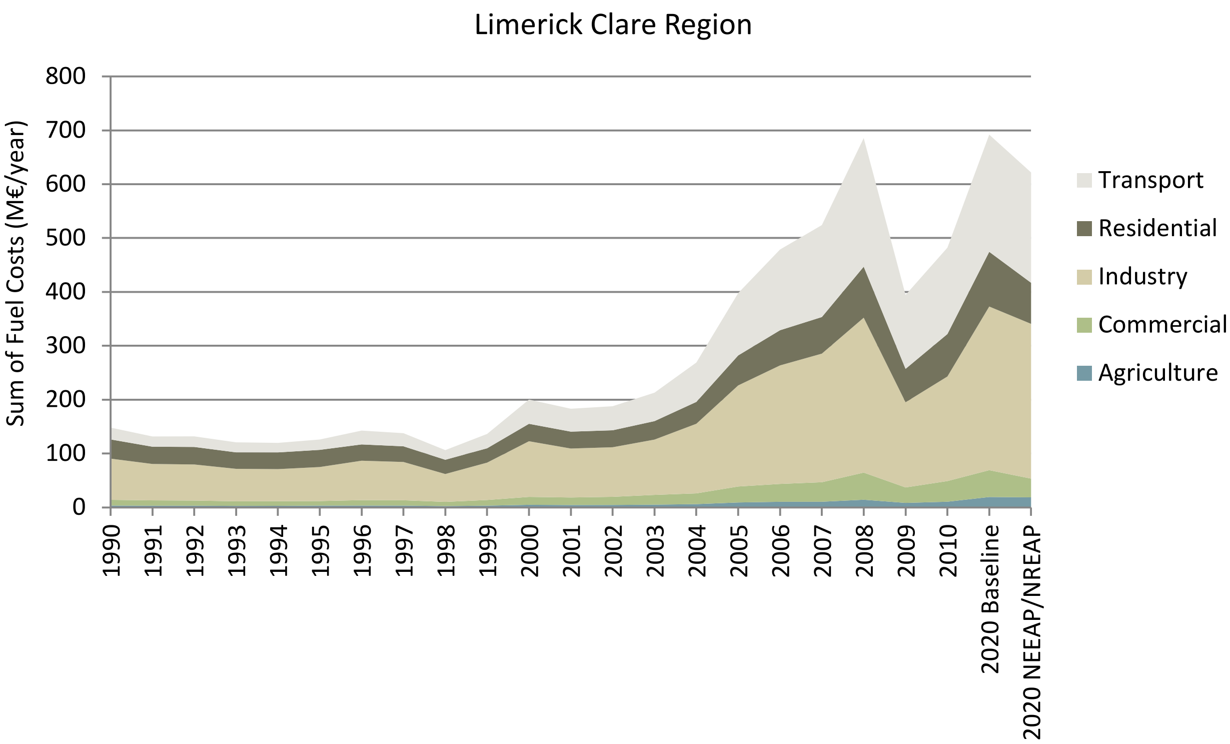

Figure 36: Fuel costs in the LCR by fuel from 1990-2010 and forecasted for 2020 including LEUs.

6 Energy and Emissions Balance by Local Authority

6.1 Clare County

Due to the proportioning methodology used in this study to estimate the energy consumption in County Clare, as discussed in section 3, the overall trends and energy mix at a local level is practically the same as those discussed in section 5.1 for Ireland. The only difference is the electricity mix used at a national level compared to the local level, which has been discussed in detail in section 4.1.1. Hence, the trends and energy mix will not be the focus here, but instead the magnitude of energy, GHG, and fuel costs associated with County Clare.

Figure 37 and Figure 38 indicate that the energy consumption in County Clare was approximately 2200 GWh in 1990 and peaked at 4000 GWh in 2008. In 2020, if a business as usual scenario is followed, then the total energy consumption will return to the peak in 2008, but if the NEEAP/NREAP scenario is implemented then it will reduce to 3600 GWh.

Figure 39 indicates that County Clare's energy related GHG emissions peaked in 2006 at approximately 1.16 Mt compared to 0.7 Mt in 1990. In recent years this has been reducing and in 2010 it was 0.97 Mt, but under a business-as-usual scenario they will increase again to 1.04 Mt in 2020. However, with the implementation of government policies, the recent reduction will continue and by 2020 it will be 0.8 Mt, which is below the EU 20-20-20 targets, but still approximately 8% above the Kyoto target.

Finally, the fuel costs for County Clare are outlined in Figure 40. Like the national picture, fuel costs are the most volatile metric recorded in this study over the period 1990-2010 and for 2020. In 1990, the total fuel costs for the region was approximately M€31, which increased dramatically in the 2000s to a peak of M€180 in 2008: this is 580% of 1990 expenditure. Although there has been a reduction in fuel costs in recent years compared to the peak in 2008, trends suggest that fuel costs are beginning to increase once again. For example, even though energy consumption dropped by 2% between 2009 and 2010, the cost of fuel in County Clare increased by M€12.5. Under a business-as-usual situation, this increase is forecasted to continue so that in 2020 the cost of fuel would be M€175. In contrast under the NEEAP/NREAP scenario, fuel costs decline to M€150. Naturally, this reduction in fuel costs will require investments in cleaner energy production technologies and a range of energy savings, which are outlined in Table 9. Assessing the tradeoff between these investments and the corresponding reductions in fuel costs will thus be the key focus of the Climate Change Strategy.

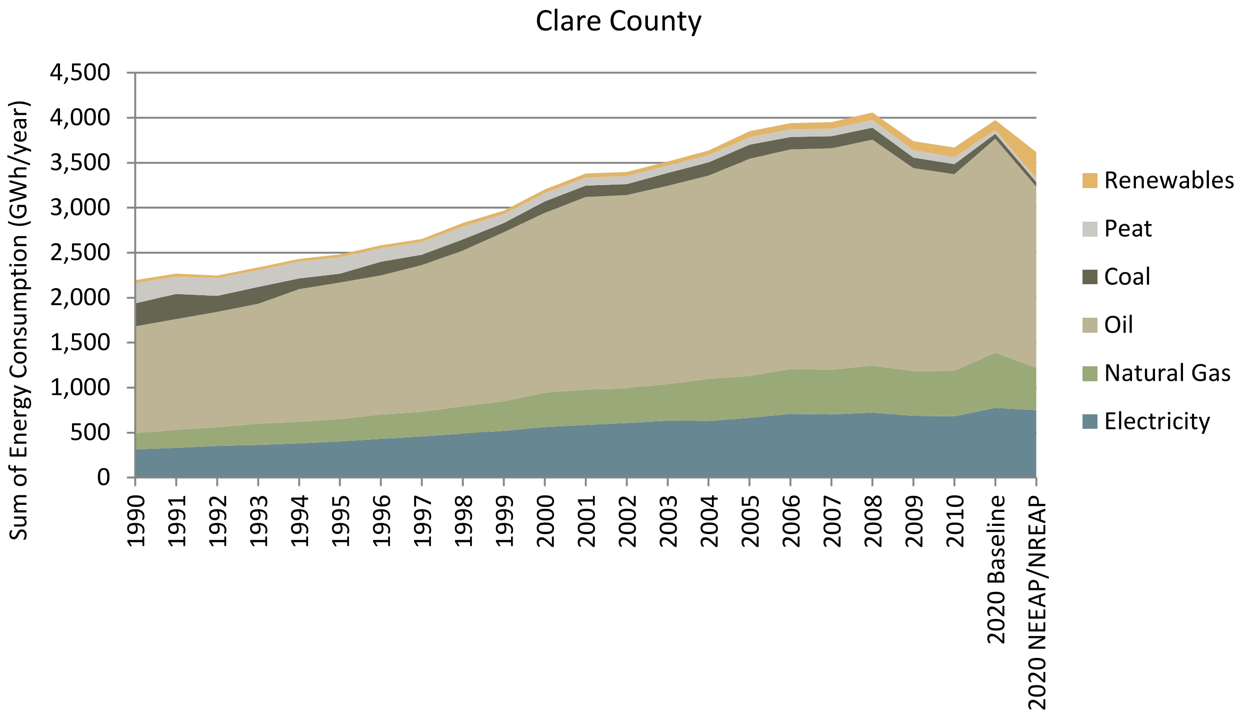

Figure 37: Energy consumed in Clare County by fuel from 1990-2010 and forecasted for 2020.

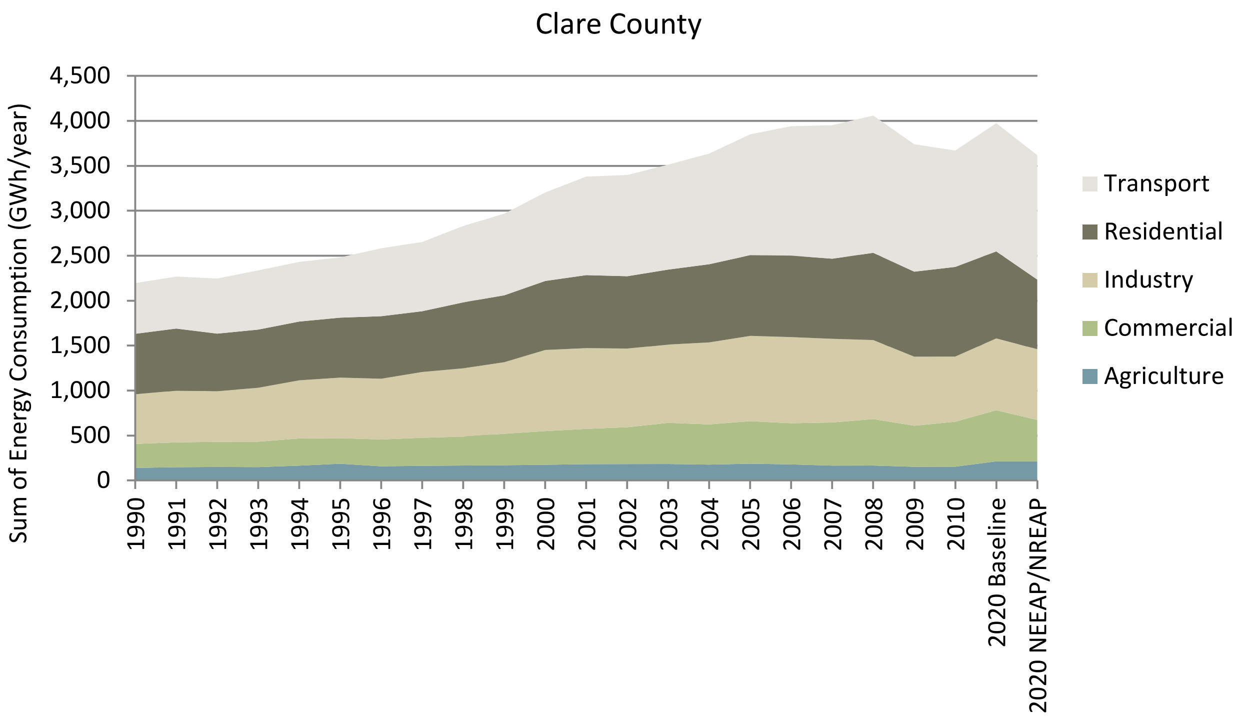

Figure 38: Energy consumed in Clare County by sector from 1990-2010 and forecasted for 2020.

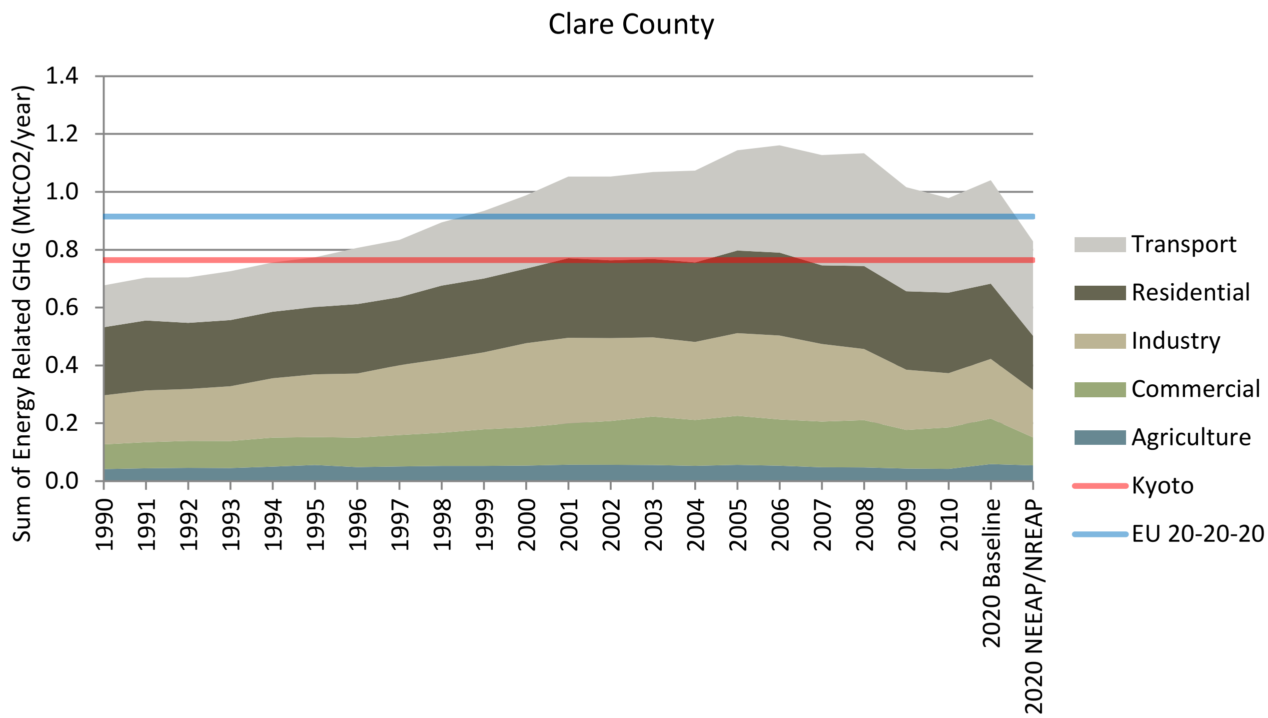

Figure 39: Energy related GHG emissions in Clare County by sector from 1990-2010 and forecasted for 2020.

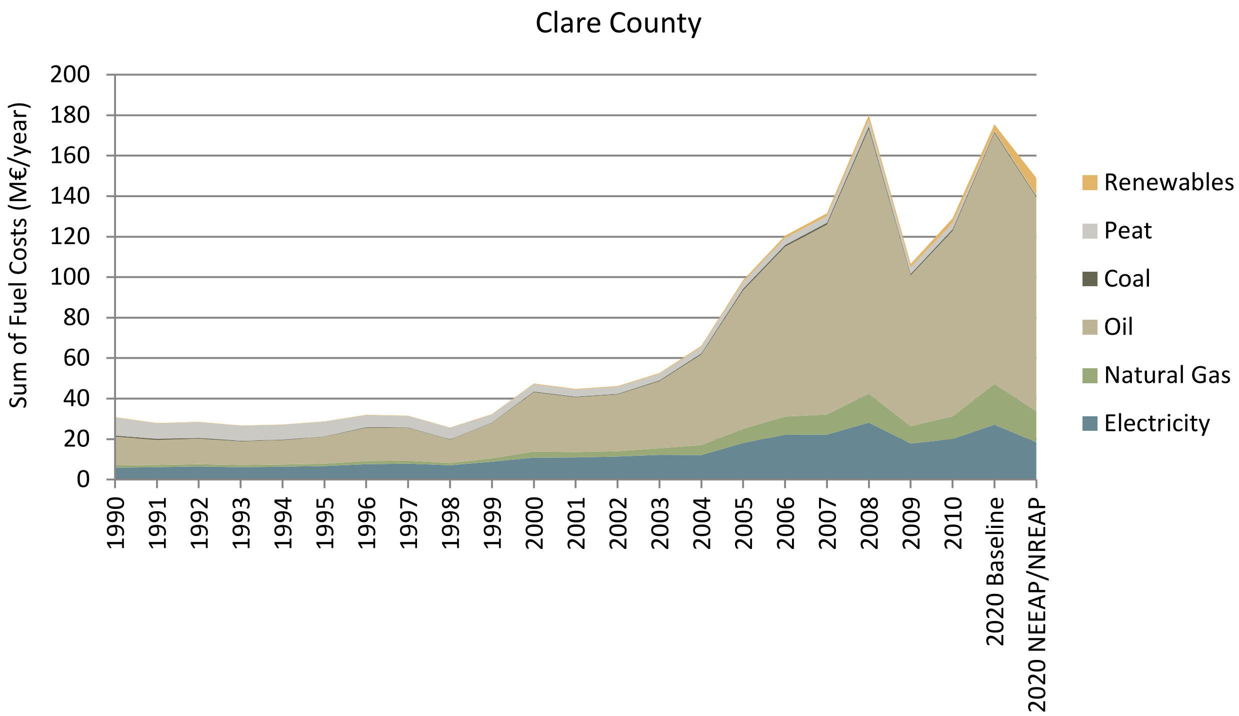

Figure 40: Fuel costs in Clare County by fuel from 1990-2010 and forecasted for 2020.

6.2 Limerick City

Due to the proportioning methodology used in this study to estimate the energy consumption in Limerick City, as discussed in section 3, the overall trends and energy mix at a local level is practically the same as those discussed in section 5.1 for Ireland. The only difference is the electricity mix used at a national level compared to the local level, which has been discussed in detail in section 4.1.1. Hence, the trends and energy mix will not be the focus here, but instead the magnitude of energy, GHG, and fuel costs associated with Limerick City.

Figure 41 and Figure 42 indicate that the energy consumption in Limerick City was approximately 1250 GWh in 1990 and peaked at 1950 GWh in 2008. In 2020, if a business as usual scenario is followed, then the total energy consumption will return to a level around 1800 GWH, but if the NEEAP/NREAP scenario is implemented then it will reduce to 1650 GWh.

Figure 43 indicates that Limerick City's energy related GHG emissions peaked in 2006 at approximately 0.55 Mt compared to 0.39 Mt in 1990. In recent years this has been reducing and in 2010 it was 0.46 Mt, but under a business-as-usual scenario they will increase again to 0.47 Mt in 2020. However, with the implementation of government policies, the recent reduction will continue and by 2020 it will be 0.38 Mt, which is below the EU 20-20-20 targets and the Kyoto target.

Finally, the fuel costs for Limerick City are outlined in Figure 44. Like the national picture, fuel costs are the most volatile metric recorded in this study over the period 1990-2010 and for 2020. In 1990, the total fuel costs for the region was approximately M€18, which increased dramatically in the 2000s to a peak of M€85 in 2008: this is 470% of 1990 expenditure. Although there has been a reduction in fuel costs in recent years compared to the peak in 2008, trends suggest that fuel costs are beginning to increase once again. For example, even though energy consumption dropped by 2% between 2009 and 2010, the cost of fuel in Limerick City increased by M€10. Under a business-as-usual situation, this increase is forecasted to continue so that in 2020 the cost of fuel would be M€80. In contrast under the NEEAP/NREAP scenario, fuel costs decline to M€69. Naturally, this reduction in fuel costs will require investments in cleaner energy production technologies and a range of energy savings, which are outlined in Table 9. Assessing the tradeoff between these investments and the corresponding reductions in fuel costs will thus be the key focus of the Climate Change Strategy.

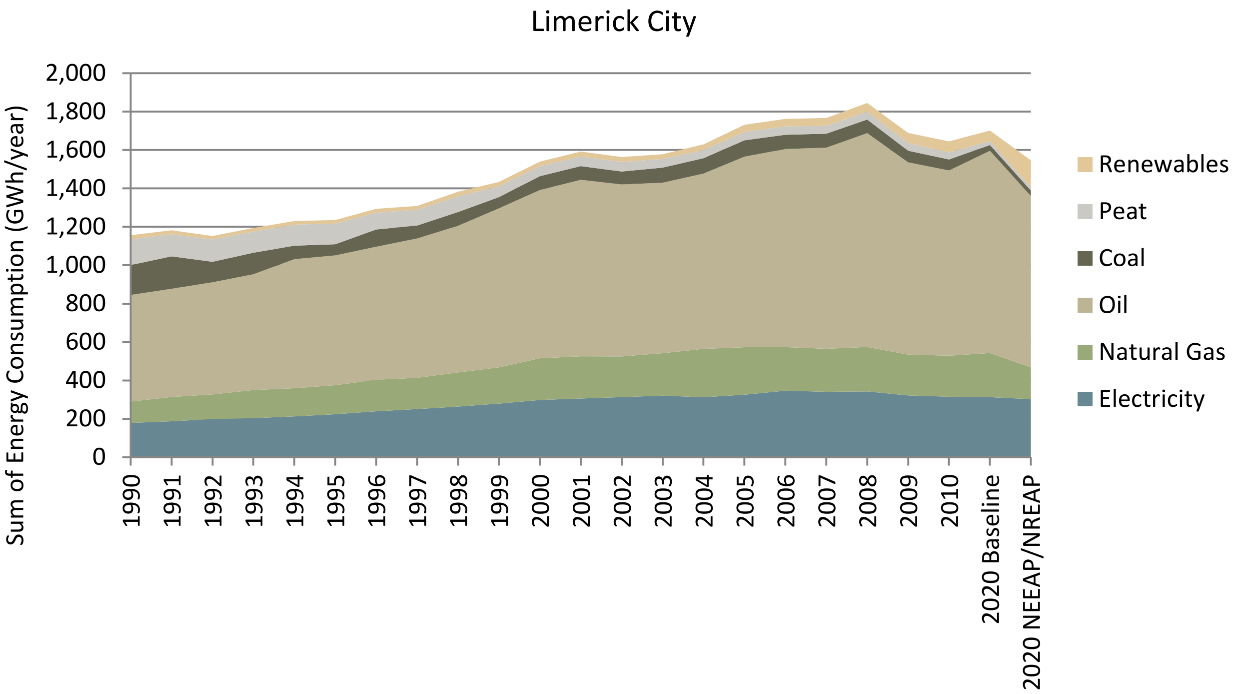

Figure 41: Energy consumption in Limerick City by fuel from 1990-2010 and forecasted for 2020.

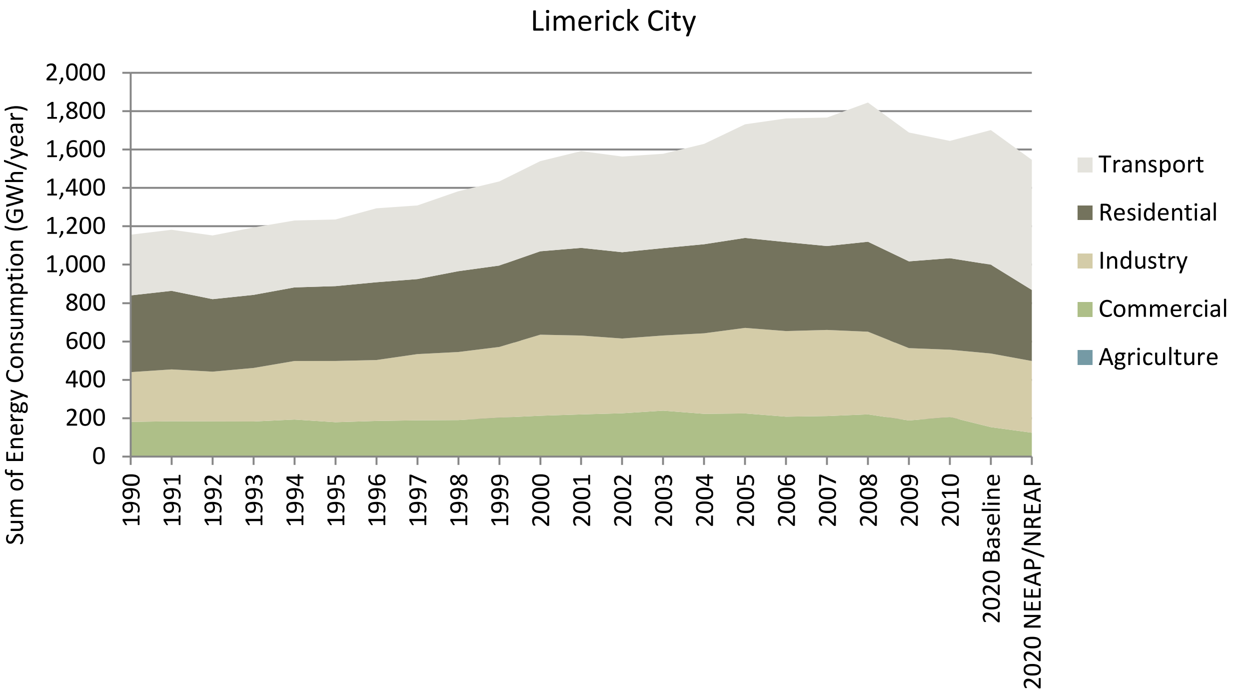

Figure 42: Energy consumed in Limerick City by sector from 1990-2010 and forecasted for 2020.

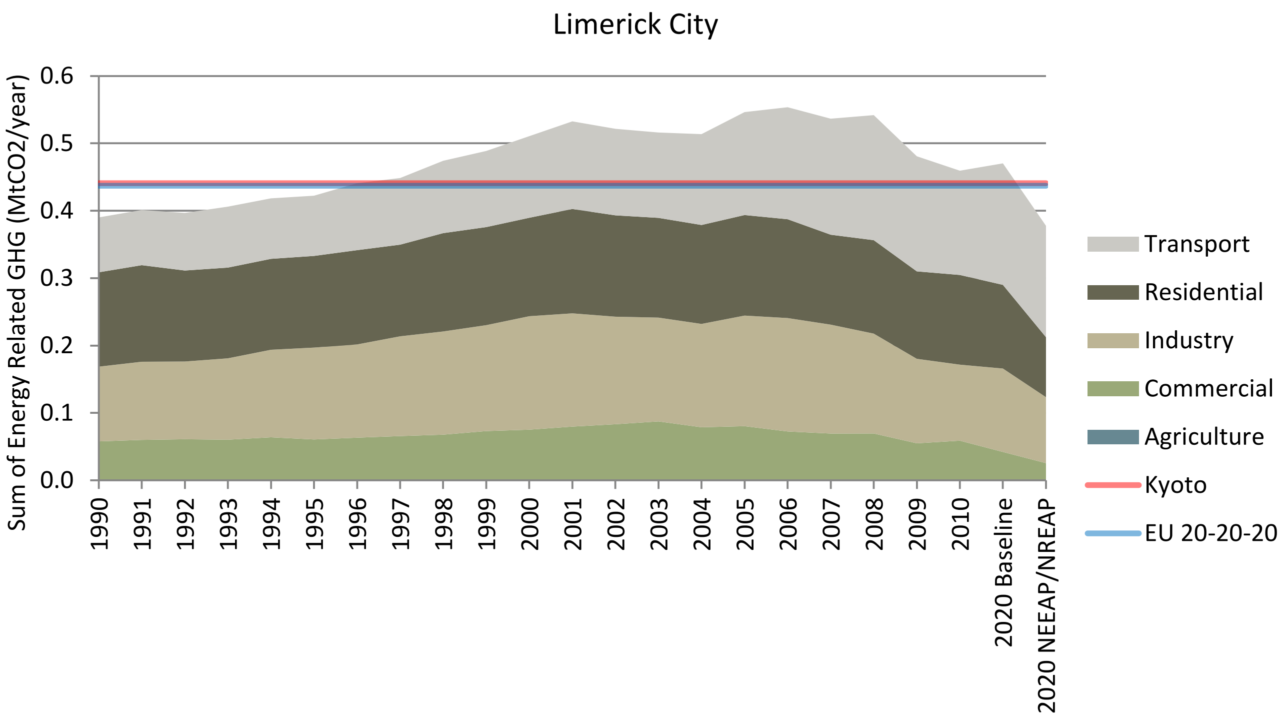

Figure 43: Energy related GHG emissions in Limerick City by sector from 1990-2010 and forecasted for 2020.

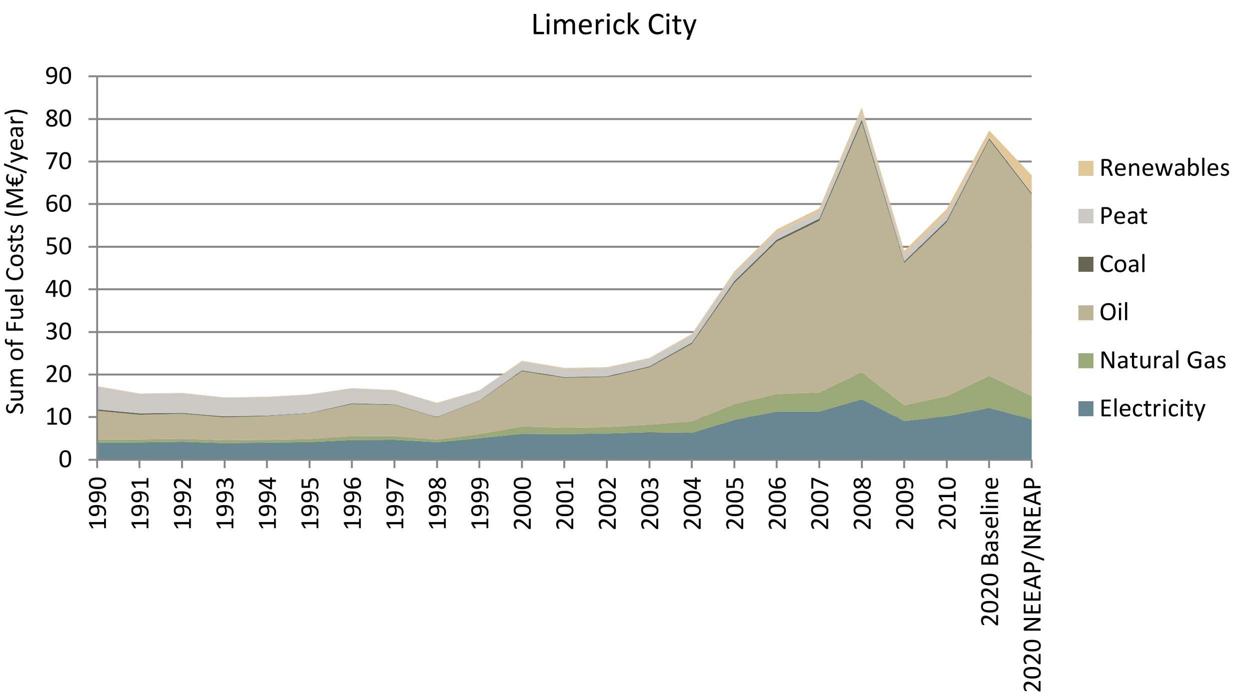

Figure 44: Fuel costs in Limerick City by fuel from 1990-2010 and forecasted for 2020.

6.3 Limerick County

This section presents the energy consumption, energy related GHG emissions, and fuel costs for County Limerick for the 'responsible' (excluding LEUs) and 'actual' (including LEUs) methodologies.

6.3.1 Excluding Large Energy Users

Due to the proportioning methodology used in this study to estimate the energy consumption in County Limerick, as discussed in section 3, the overall trends and energy mix at a local level is practically the same as those discussed in section 5.1 for Ireland. The only difference is the electricity mix used at a national level compared to the local level, which has been discussed in detail in section 4.1.1. Hence, the trends and energy mix will not be the focus here, but instead the magnitude of energy, GHG, and fuel costs associated with County Limerick.

Figure 45 and Figure 46 indicate that the energy consumption in County Limerick was approximately 2650 GWh in 1990 and peaked at 5200 GWh in 2008. In 2020, if a business as usual scenario is followed, then the total energy consumption will return to the peak in 2008, but if the NEEAP/NREAP scenario is implemented then it will reduce to 5000 GWh.

Figure 47 indicates that County Limerick's energy related GHG emissions peaked in 2006 at approximately 1.5 Mt compared to 0.81 Mt in 1990. In recent years this has been reducing and in 2010 it was 1.23 Mt, but under a business-as-usual scenario they will increase again to 1.4 Mt in 2020. However, with the implementation of government policies, the recent reduction will continue and by 2020 it will be 1.12 Mt, which is below the EU 20-20-20 targets, but still approximately 22% above the Kyoto target.

Finally, the fuel costs for County Limerick are outlined in Figure 48. Like the national picture, fuel costs are the most volatile metric recorded in this study over the period 1990-2010 and for 2020. In 1990, the total fuel costs for the region was approximately M€37, which increased dramatically in the 2000s to a peak of M€231 in 2008: this is 620% of 1990 expenditure. Although there has been a reduction in fuel costs in recent years compared to the peak in 2008, trends suggest that fuel costs are beginning to increase once again. For example, even though energy consumption dropped by 2% between 2009 and 2010, the cost of fuel in County Limerick increased by M€28. Under a business-as-usual situation, this increase is forecasted to continue so that in 2020 the cost of fuel would be M€236. In contrast under the NEEAP/NREAP scenario, fuel costs decline to M€202. Naturally, this reduction in fuel costs will require investments in cleaner energy production technologies and a range of energy savings, which are outlined in Table 9. Assessing the tradeoff between these investments and the corresponding reductions in fuel costs will thus be the key focus of the Climate Change Strategy.

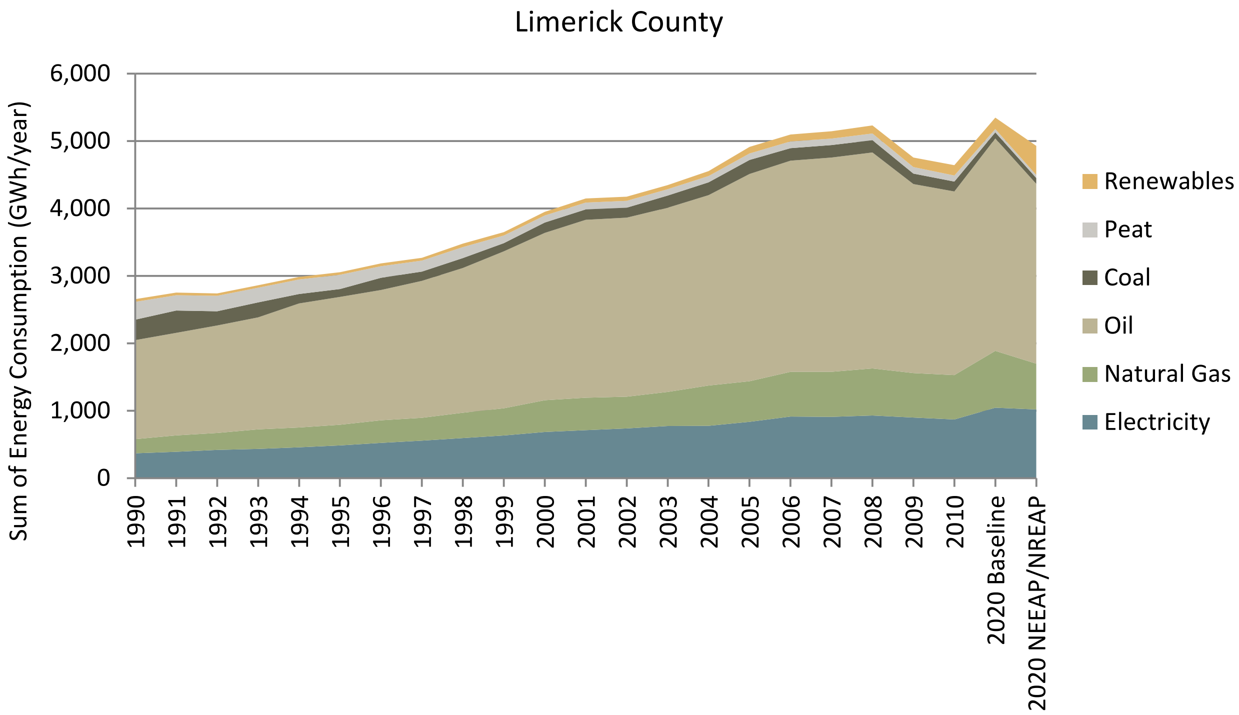

Figure 45: Energy consumed in County Limerick by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

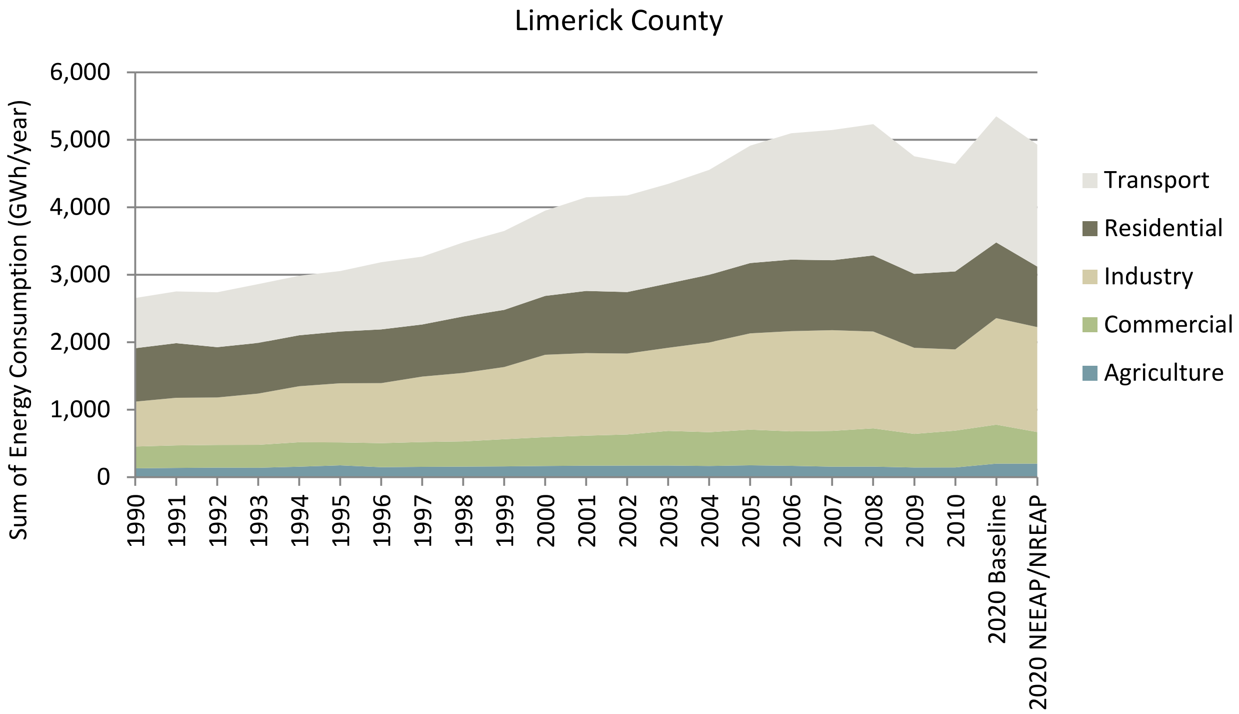

Figure 46: Energy consumed in Clare County by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

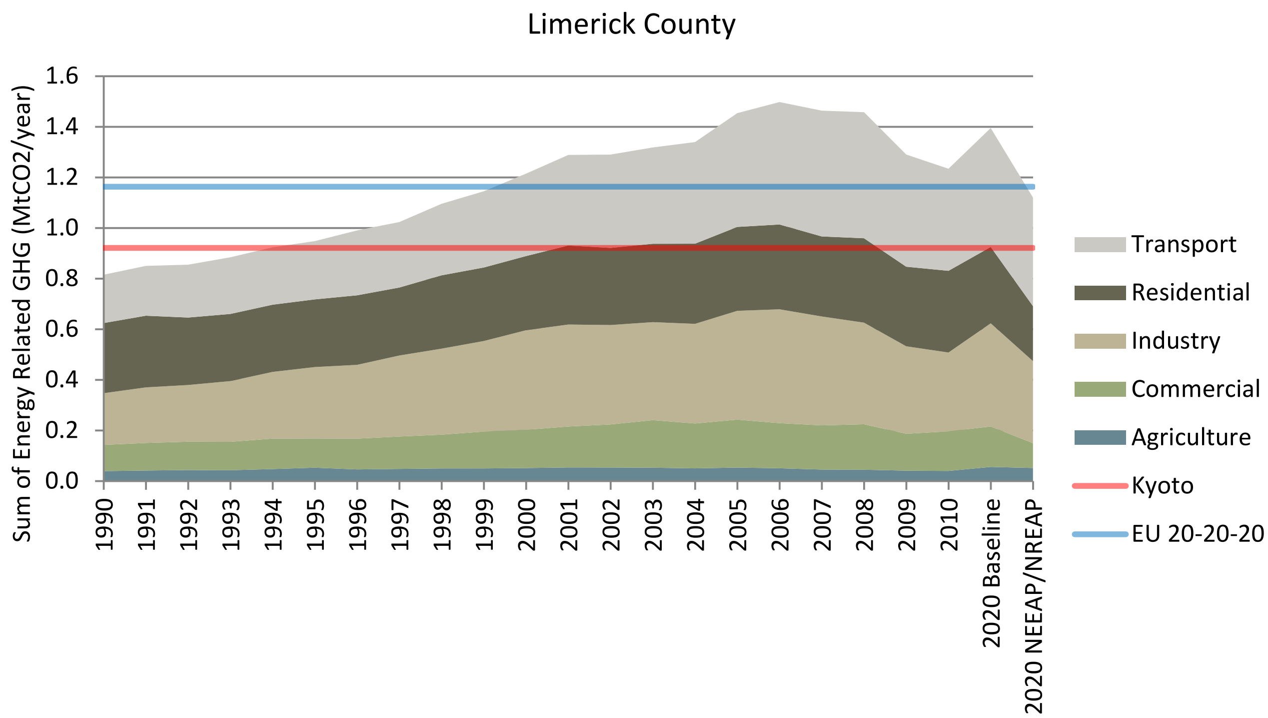

Figure 47: Energy related GHG emissions in County Limerick by sector from 1990-2010 and forecasted for 2020 excluding LEUs.

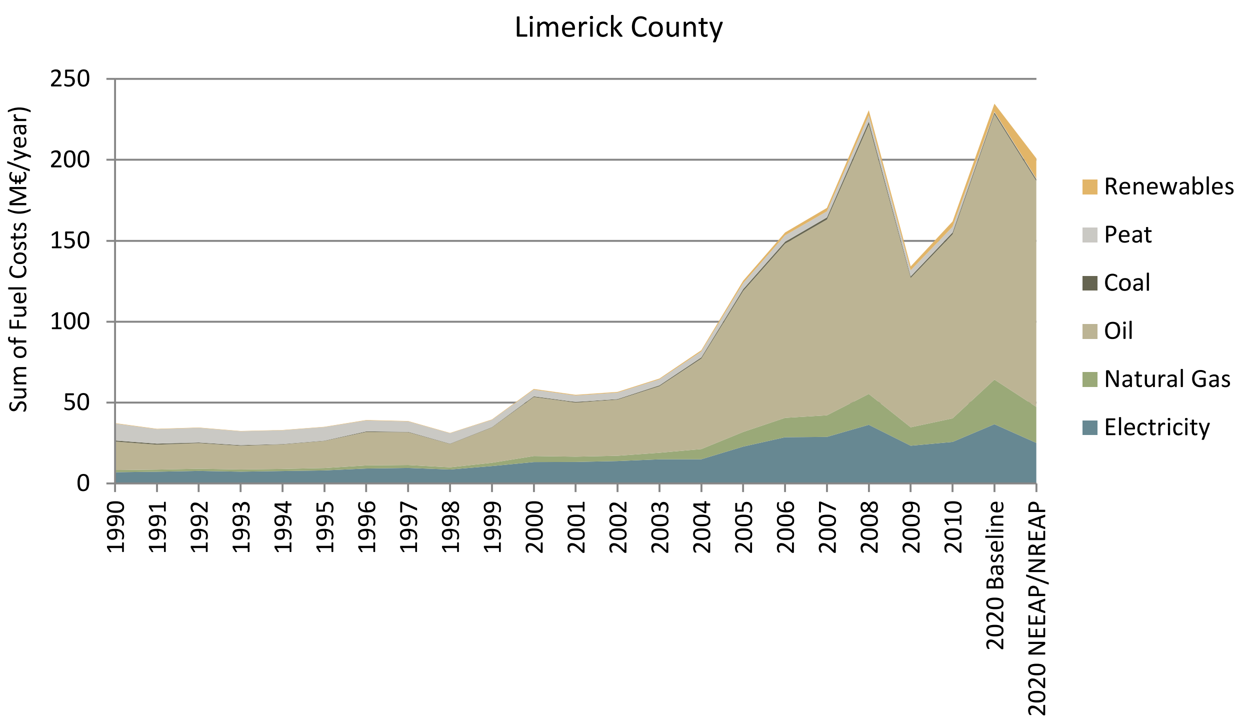

Figure 48: Fuel costs in County Limerick by fuel from 1990-2010 and forecasted for 2020 excluding LEUs.

6.3.2 Including Large Energy Users

The results presented here represent the 'actual' energy consumption in County Limerick instead of the 'responsible' energy consumption. As outlined earlier in section 3.5, County Limerick contained 4 out of the top 15 industrial GHG emitters in Ireland in 2009. Hence, it was deemed unfair to allocate all of this energy consumption solely to the region and so the 'responsible' methodology was utilised instead. However, for completeness, the results here for County Limerick do include the energy consumed by these large industries to illustrate how they affect the overall picture.

As illustrated in Figure 49 and Figure 50, the total energy consumed in 1990 in County Limerick is now approximately 8000 GWh instead of 2700 GWh. Also, the peak in County Limerick with the LEUs occurred in 2007 and it was approximately 11,000 GWh whereas without the LEUs it was in 2008 at 5200 GWh. Figure 50 also demonstrates the scale of energy consumed by industry in the region when compared to Figure 46 previously. For example, in 2010, industry represents approximately 63% of the total energy consumption when the LEUs are included, but without the LEUs industry only accounts for 26%. In addition, as illustrated in Figure 49, there was a dramatic switch from oil to natural gas within industry in County Limerick in 2006, which meant that the increase in GHG emissions from 2005 to 2006 is less when the LEUs are in included in Figure 51 than when they were excluded in Figure 47.

Finally, the fuel costs are approximately double when LEUs are included, as displayed in Figure 50. Hence, each of these examples illustrate the influence that large industry has on the energy consumption and fuel mix in County Limerick if they are entirely allocated to the region. Hence, by doing this, local actions could be overshadowed and hence the 'responsible' methodology utilised earlier was use deemed more appropriate for this study.

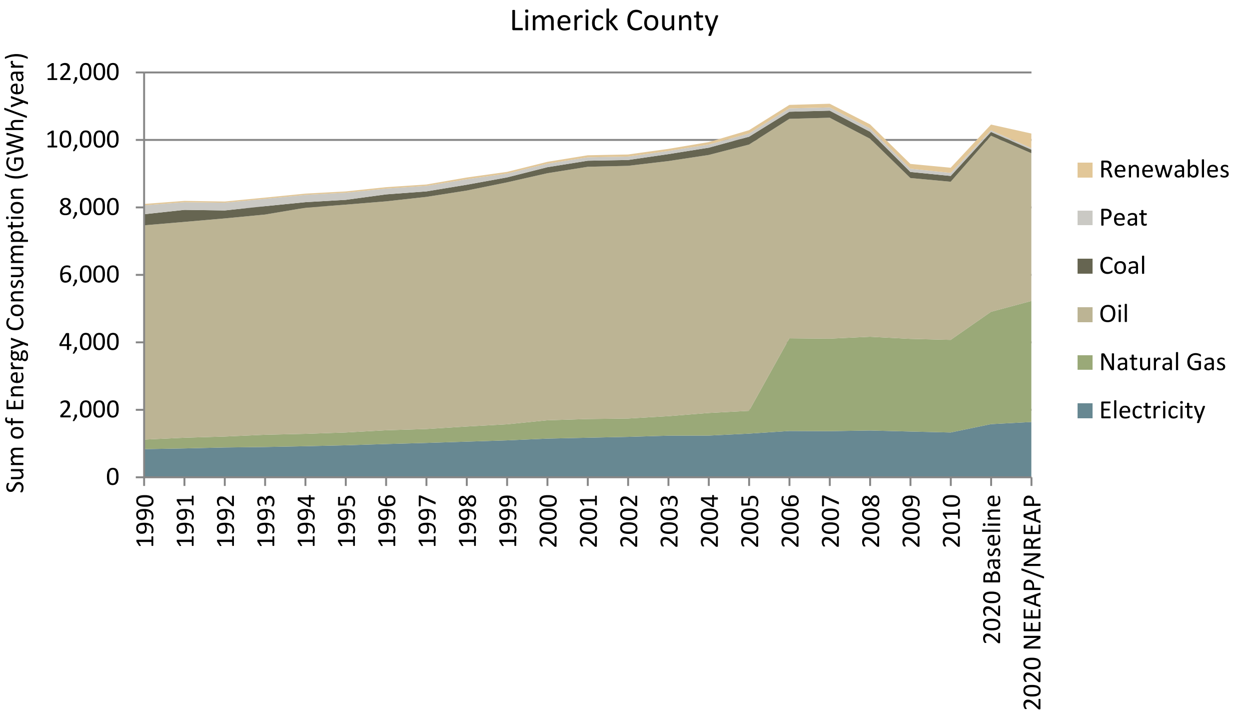

Figure 49: Energy consumed in County Limerick by fuel from 1990-2010 and forecasted for 2020 including LEUs.

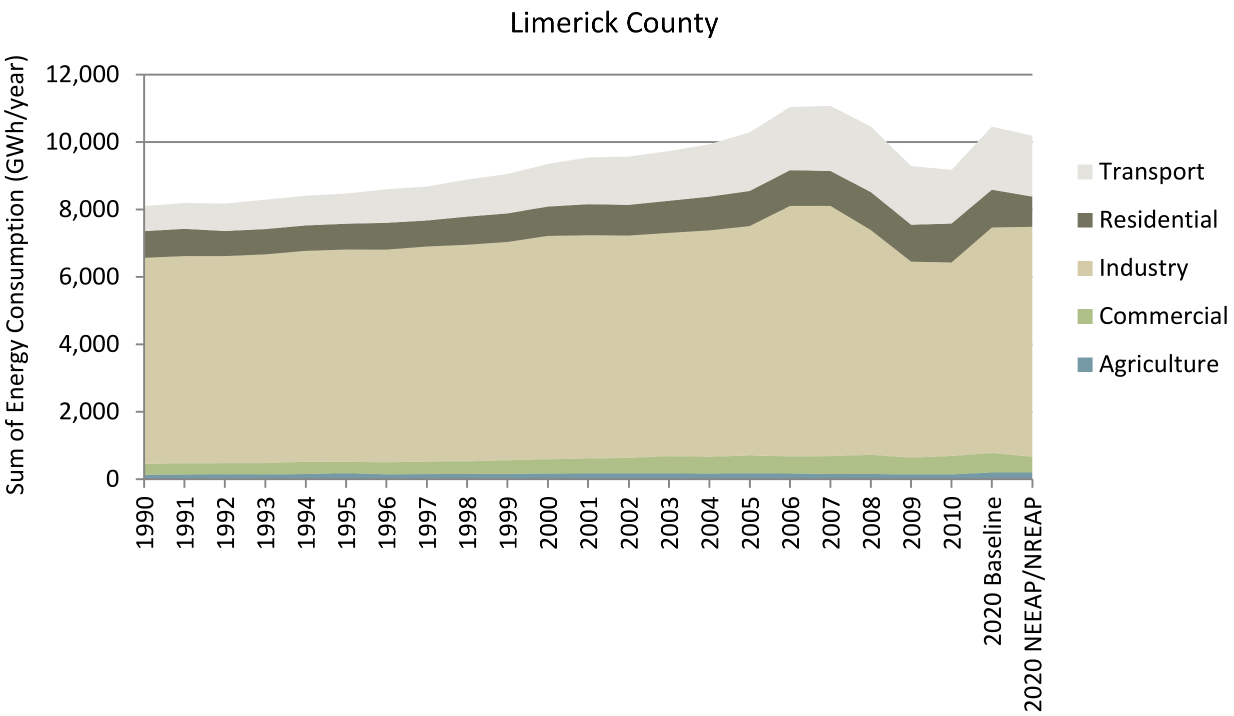

Figure 50: Energy consumed in County Limerick by sector from 1990-2010 and forecasted for 2020 including LEUs.

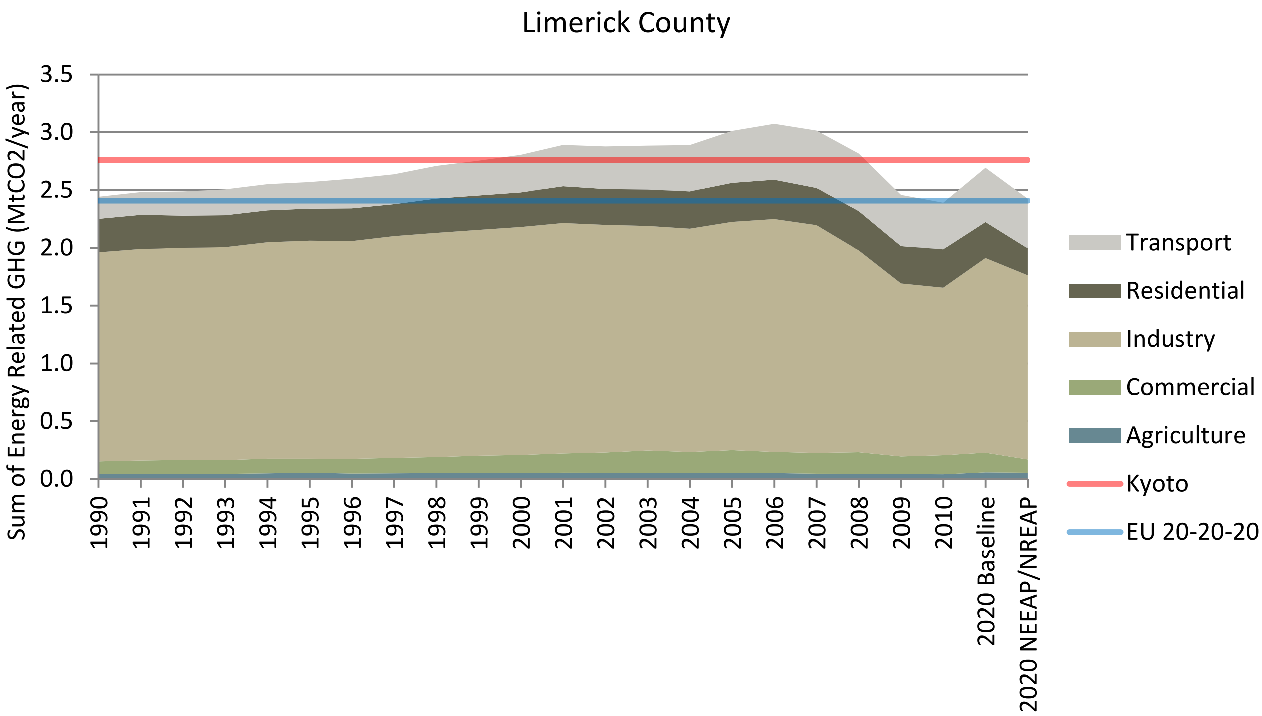

Figure 51: Energy related GHG emissions in County Limerick by fuel from 1990-2010 and forecasted for 2020 including LEUs.

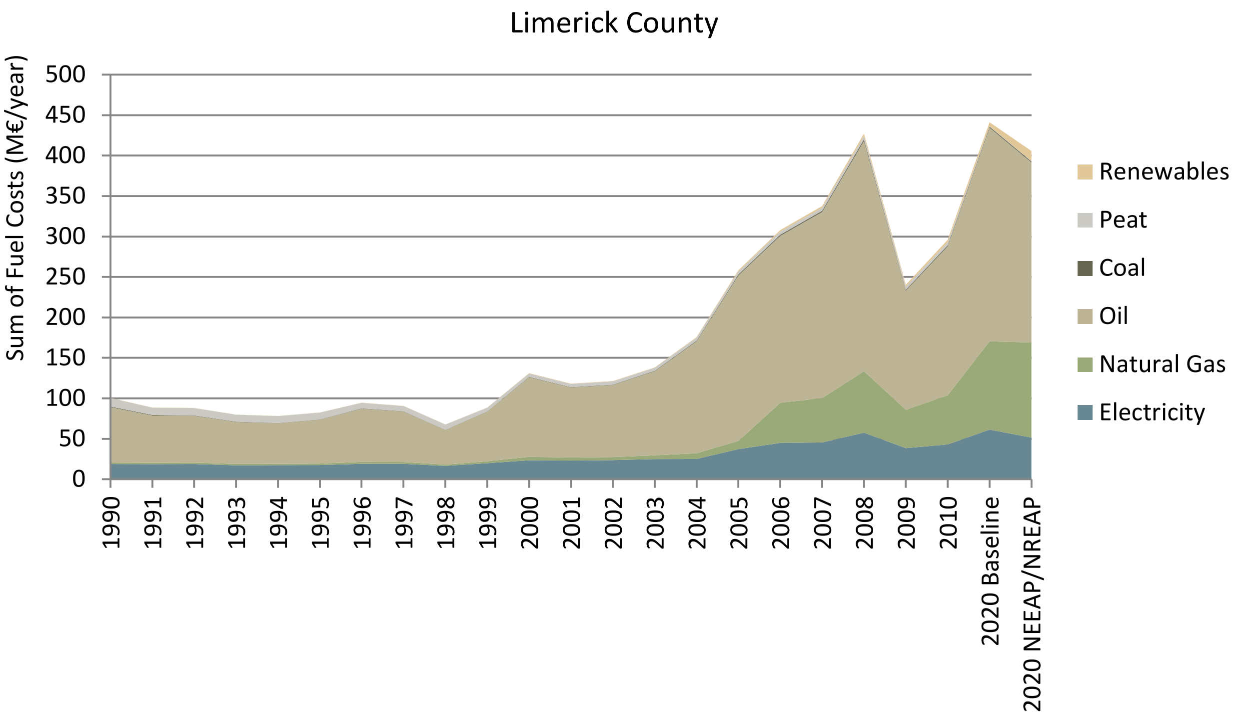

Figure 52: Fuel costs in County Limerick by fuel from 1990-2010 and forecasted for 2020 including LEUs.

7 Conclusions and Recommendations

A number of issues were raised while creating the energy and emissions balance in this report. Below is a list of recommendations which would make this process easier in the future:

1. During this process it was evident that there is a distinct lack of energy data recorded at a local level in Ireland and hence, this energy balance was developed by proportioning national data. Renewable energy projects have proven to be the most successful at a local level, with many small communities such as Samsø in Denmark [12] and Güssing in Austria [55] already using a net energy supply of 100% renewable energy. As a result, it is important for local authorities and local communities to begin recording the electricity, heat, and transport demands in the region. SEAI's Sustainable Communities program has developed a very thorough set of guidelines and an energy planning tool which could be used as a template to begin such a process [13]. Another alternative is for the national government to enforce energy suppliers to provide data to local county councils on energy consumption.
2. Further to quantifying the heat demand, it is also essential to create a heat atlas for the region. A heat atlas outlines the location of a building and its corresponding demand for heat, as well as potential suppliers of heat such as excess industrial process heat, waste incineration, CHP plants, and any other heat producing facility. The heat atlas is a fundamental tool for assessing the feasibility of new energy networks, such as district heating and expansion of the gas grid. Recently, heat atlases have been developed for Denmark [58] and London [59]. Therefore, similar methodologies and benchmark data could be used as a first step in developing a heat atlas for the Limerick-Clare region.
3. The methodology developed in this report should not be considered as a final solution for estimating energy consumption at a regional level. Instead it should be developed and improved over time as more contributors offer their knowledge and insights into energy consumption in the region. In line with this, the methodology reported here has built on the work completed in the 2006 Energy and Emissions Balance for the LCR [25].
4. It would be useful to have more information about the type of boilers used within the region. Since there is a gas network in the region and a well-established network of miscanthus farmers, the mix of boilers in the region could deviate from the national average. However, with no data available to assess this, the national average mix was assumed in this study.

Even though there were many barriers during this study, the accuracy of this methodology should be taken in the context of its purpose. It is clear that the proportioning methodology utilised will not produce exact figures, but the principal purpose of the energy balance is to form an indicative picture of what and how energy is consumed within a region. The fundamental application of the energy balance is to act as a baseline for evaluating alternatives (in the Climate Change Strategy) and so exact data is not necessary. In addition, the recent recession in Ireland has outlined the unpredictability of the economy and hence the unpredictability of future energy consumption. Therefore, even if actual bottom-up data is available in the future in the LCR, it will still be difficult to accurately forecast an energy balance for the future. As a result, this methodology fulfils the objective which it needs to meet: it is a relatively simple methodology which provides an indicative representation of energy consumption within the LCR now and for 2020.

Another major challenge in this study, which will exist no matter what data is available, is the definition of boundaries. For the LCR, this was particularly difficult in relation to the consumption of energy in industry and the local electricity mix. Hence, new methodologies have been developed to consider these concerns in this study, which can be replicated by other counties in Ireland also. For industry, two energy balances were created: the primary one which proportioned national consumption to the local region based on the number of jobs in the region and a second one for a sensitivity analysis, which used the actual energy consumption in the region. In relation to the electricity mix, the key challenge was defining a mix which rewarded the local implementation of renewable energy is not lost in national statistics. Hence renewable energy production in the region is allocated first and the remainder is met by the average national fossil fuel mix.

Using these new methodologies and estimating the energy consumption, energy related GHG emissions, and fuel costs for the LCR, it is evident from the results that the LCR is heavily dependent on fossil fuels which cannot be found within the region. This is illustrated in the summary of results in Table 10 and Table 11, which indicates that in 2010 approximately M€350 was spent on fuel for the region. However, if the government policies proposed in the NEEAP/NREAP scenarios are implemented, then the overall energy consumption in the LCR will only increase by 2% compared to 11% in a business-as-usual scenario. Also, implementing these polices will ensure that Ireland's GHG emission targets for both Kyoto and EU 20-20-20 targets will be met in 2020 and the cost of fuel in the region will be M€70/year instead of M€140/year. Approximately 20% and 10% of the energy savings required by 2020 will come from buildings and the public sector respectively. Therefore, the LCEA could play a key role on behalf of the county councils at implementing and coordinating these savings.

Table 10: Summary of energy demand, energy related GHG emissions, and fuel costs in 2010.

2010	Energy Demand (GWh)	Energy related GHG (Mt CO_2)	Fuel Costs (M€)
Ireland	140,106	41.7	5,335.9
Clare County	3,670	1.0	130
Limerick City	1,730	0.5	60
Proportioned LEUs			
Limerick County	4,640	1.2	162
Limerick-Clare Region	10,040	2.7	352
With All LEU's Energy			
Limerick County	9,180	2.4	296
Limerick-Clare Region	14,360	3.8	482

Table 11: Summary of energy demand, energy related GHG emissions, and fuel costs in 2020 if government policies are implemented.

2020 NEEAP/NREAP	Energy Demand (GWh)	Energy related GHG (Mt CO_2)	Fuel Costs (M€)
Ireland	139,000	35.4	6,200
Clare County	3,640	0.8	150
Limerick City	1,660	0.4	69
Proportioned LEUs			
Limerick County	4,950	1.1	201
Limerick-Clare Region	10,250	2.3	420
With All LEU's Energy			
Limerick County	10,200	2.4	406
Limerick-Clare Region	15,250	3.6	622

Naturally these energy, GHG, and fuel cost reductions will require a number of investments. Hence, the next step in this research is to input the energy balance developed in this study into the energy-systems-analysis tool, EnergyPLAN, to assess if these investments will be socio-economically viable for the LCR. In addition, the Climate Change Strategy includes an assessment of the renewable energy potential in the LCR and a local energy strategy which identifies how the LCR can utilise more of this renewable energy, with the final goal of becoming a 100% renewable energy region.

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9 Appendices

Appendix I. Relevant Energy Policy

There have been numerous policies developed in the last decade to encourage a transition to a more sustainable society. These are mainly formed at an EU, national, regional, and local level. In this section a brief overview of these policies is provided to demonstrate the context of the LCEP [13, 78].

EU Policy

The Kyoto Protocol[79] is an international agreement under the United Nations Framework which has set binding targets to reduce GHG emissions for 37 industrialised countries and the EU. The overall EU target is to reduce the average GHG emissions over the period 2008-2012 by 5% compared to those in 1990. These have been further broken down so that Ireland’s target is to limit GHG emission increases to 13% above 1990 emissions.

EU policy is driven by the EU Commission Strategic Energy Review [80]. This defined three key targets (20-20-20 targets) for the EU by 2020 (compared to the year 2005) which were:

1. 20% reduction in GHG emissions.
2. 20% increase in renewable energy production.
3. 20% improvement in energy efficiency.

The EU Directive 2009/28/EC [81] outlines how the 20% renewable energy target will be met for each member state. Overall, Ireland must reach a 16% renewable energy penetration by 2020. A compulsory target of 10% renewable energy in the transport sector has to be met by all member states, but otherwise each member states can decide how the overall renewable energy target will be met, across electricity, heat, and transport.

National Policy

In line with these EU targets, a number of plans, policies, studies, and targets have been established at a national level also.

The National Spatial Strategy 2002-2020 [82] is a 20 year plan for Ireland, which outlined the importance of a balanced development in Ireland across urban and rural regions, particularly for the national development of sectors such as renewable energy. The €184 billion National Development Plan 2007-2013 [83] promotes the use of renewable energy and energy efficiency through financial supports such as the Sustainable Energy Sub-Programme, which was allocated €276 million to fund the large-scale development of renewable energy (primarily wind). The National Climate Change Strategy 2007-2012 outlines how the Kyoto protocol can be implemented in Ireland. Until recently, Ireland was not on course to meet its Kyoto target, but as shown in Figure 53, due to the economic recession Ireland’s GHG emissions are predicted to fall below the Kyoto target in 2009. Since energy-related emissions account for 67% of the total, the National Climate Change Strategy concluded that harnessing more renewable energy and improving energy efficiency are integral parts of reducing GHG emissions in the future.

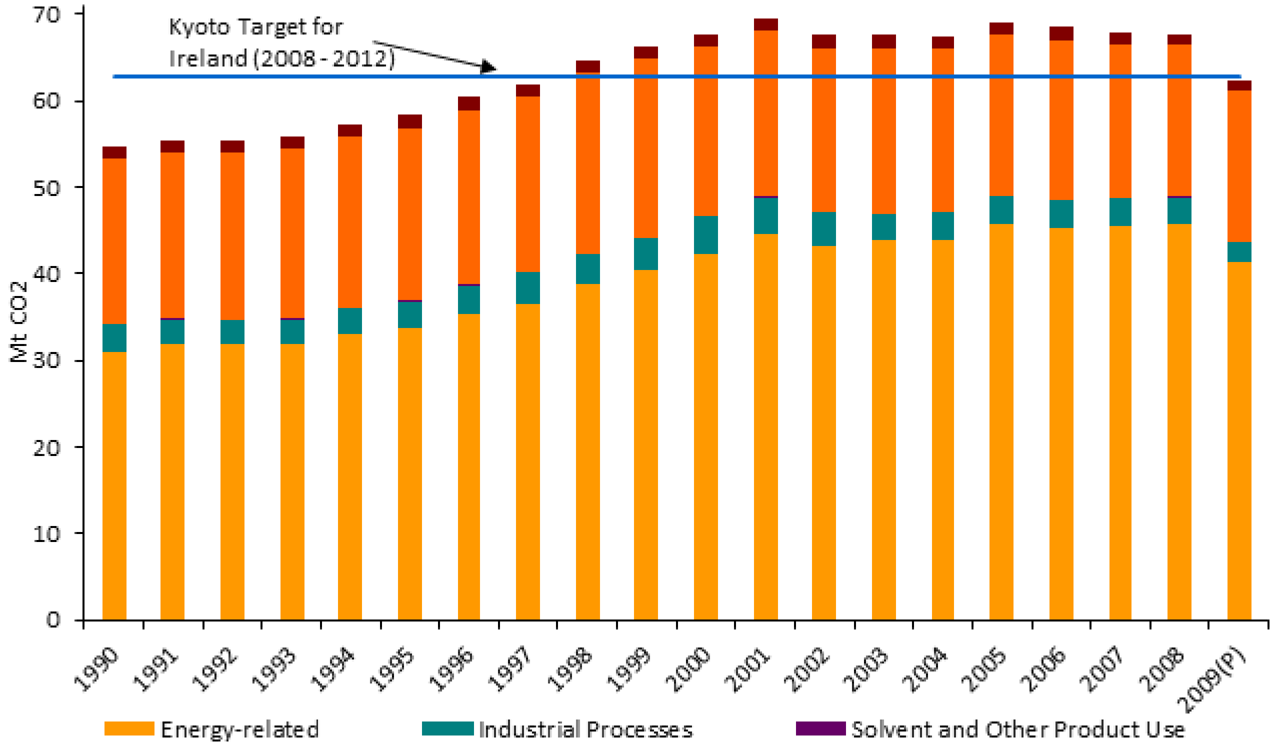


Figure 53: Greenhouse gas emissions by source in Ireland from 1990-2009 (provisional) [19].

More specifically in relation to renewable energy itself, the key overriding document at a national level is the 2007 Government White Paper: Delivering a Sustainable Energy Future for Ireland – The Energy Policy Framework 2007-2020 [84]. Recognising the large role that energy has to play in reducing GHG emissions, this document called for the alignment of energy and climate change in Ireland. It also set out the key targets for renewable energy in Ireland to meet the 16% overall renewable energy contribution required from the EU. As outlined in Figure 54, the 2020 renewable penetration targets are 40% for the electricity sector (increased from an original target of 33%), 12% for heat, and the minimum mandatory EU target of 10% for transport. In addition, some ambitious targets were set for specific technologies such as wind (primary contributor to 40% electricity sector target), ocean (500 MW i.e. wave or tidal energy), and CHP (800 MW). These objectives have also been endorsed by the newly elected government, who have outlined specific tasks in their Programme for Government for renewable energy, energy efficiency, and green jobs [85].

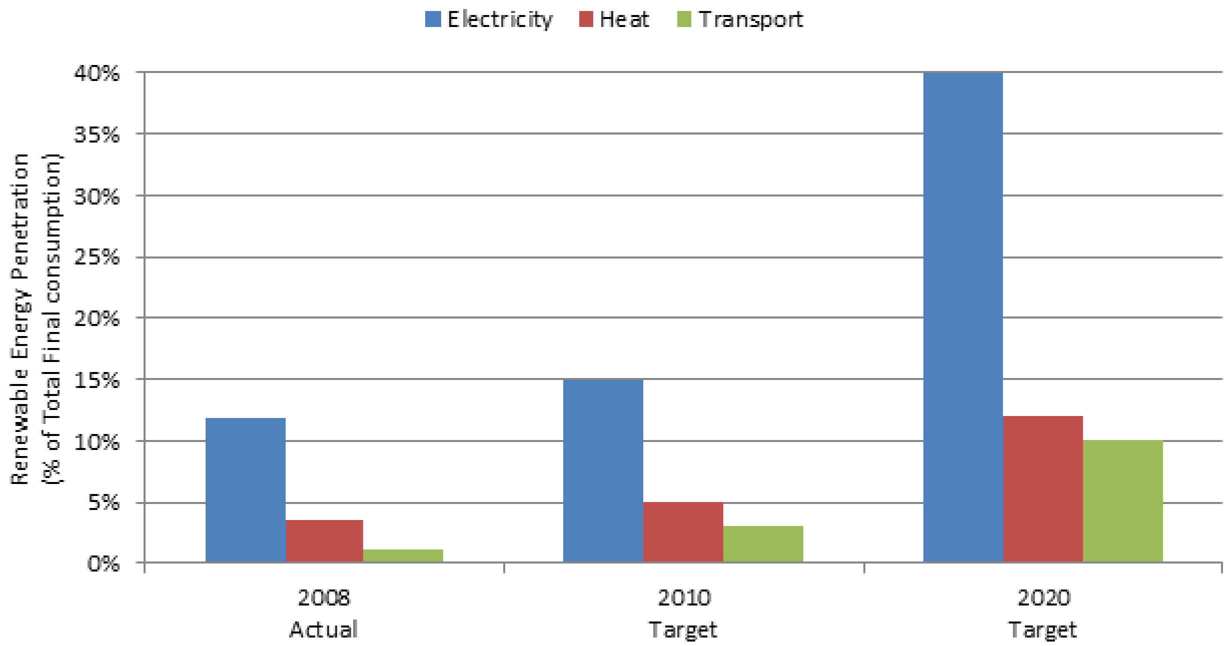


Figure 54: Renewable energy targets for Ireland [84].

Building on the foundations of the Government White Paper, numerous more specific studies and plans have been developed in recent years, which are summarised in Figure 55. The National Energy Efficiency Action Plan (NEEAP) defines the measures and policies required to reach the EU target of 20% improvement in energy efficiency by 2020, including a 33% target for the public sector [72]. The National Renewable Energy Action Plan (NREAP) outlines in detailed steps across electricity, heat, and transport, how Ireland will implement the EU target of 16% renewable energy by 2020 [73]. This is supported by the All-Island Grid Study which outlined the actions required for Ireland to reach a 40% renewable electricity target by 2020 [86], while Grid 25 presents the grid infrastructure measures which EirGrid believe are necessary to reach this target [61]. The Ocean Energy in Ireland [87] and the Draft Offshore Renewable Energy Development Plan from DCENR [88] discuss the research, incentives, and potential resource for offshore wind, wave, and tidal in Ireland. The Bio-Energy Action Plan [89] sets out targets for bioenergy, including a 10% penetration in the transport sector by 2020, while a memorandum of understanding (MOU) was signed between the Irish Government and key stakeholders for the development of electric vehicles in Ireland in 2010 [90].

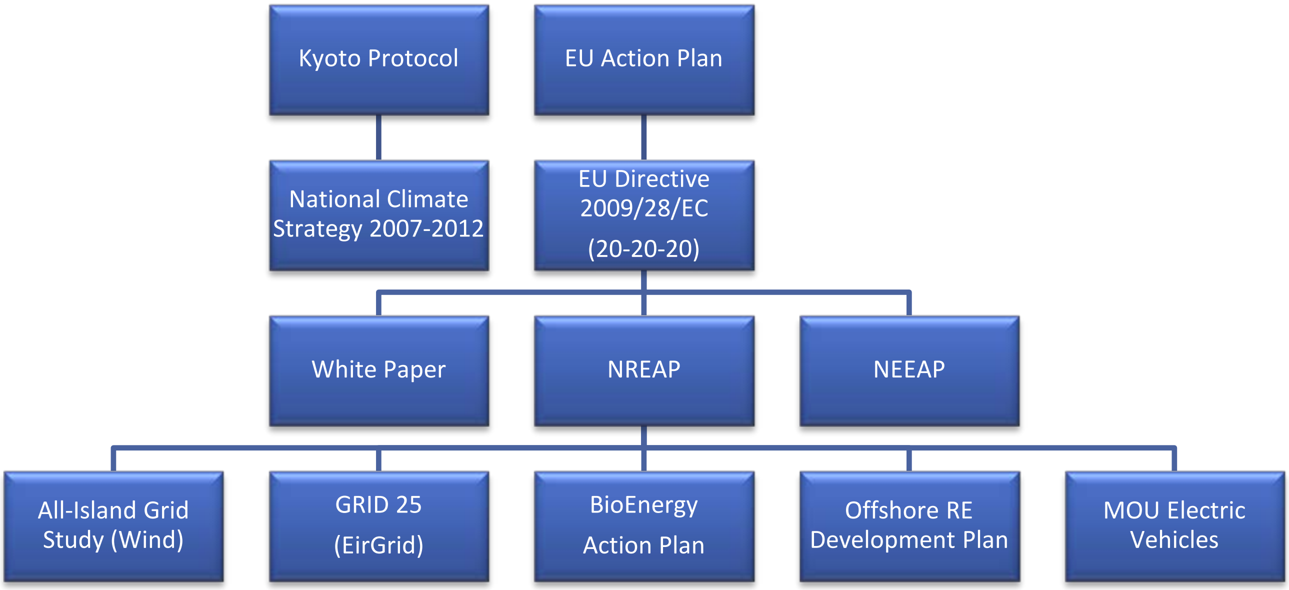
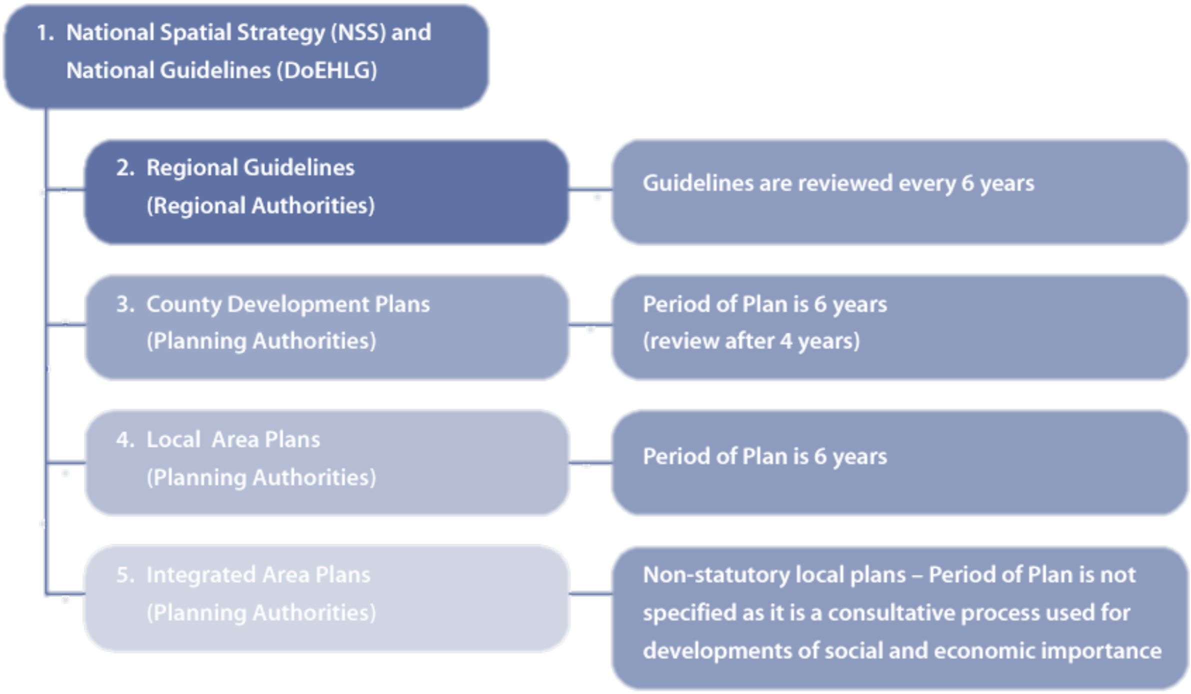


Figure 55: Relationship between EU and national policy on the development of sustainable energy in Ireland.

Local Policy

The format of local policies is greatly influenced by those implemented at a national level. Local planning in Ireland is coordinated by the Department of Environment, Heritage, and Local Government (DoEHLG) [91]. The guidelines created by the DoEHLG set the framework for regional, county, and local plans which are implemented by 8 regional authorities, 29 county councils, and 49 town councils on a period basis, as outlined in Figure 53. The Development Plan Guidelines which are created by the DoEHLG suggest that any energy should be included in the mandatory section “Infrastructure” of these development plans. Therefore, as outlined by SEAI’s Sustainable Communities Programme [13], these periodic local plans are an ideal platform for defining how local regions can transition to sustainable energy generation.

In addition, there are a number of more specific guidelines which can be used by local planning authorities for sustainable energy planning. The Guidelines for a Sustainable Energy Community developed by SEAI [13] outline how a local community can create, plan, and implement a sustainable energy zone. Since these are based on SEAI’s experience in Dundalk, they are an excellent framework for any local community in Ireland. The Quality Housing for Sustainable Communities [92] also outlines how to build sustainable communities, but with a specific focus on the actions required in the housing sector. The Wind Energy Development Guidelines [93] demonstrate how local authorities should assess wind farm applications and the Local Authority Climate Change and Energy Efficiency Measures [94] explains some best practice case studies for local authorities, which will enable the local authorities to meet the legislated target of 33% energy reduction by 2020.



Three key aspects of planning that could influence an SEC are:

1. Development Plans and Local Area Plan preparation
2. Implementation of the plans through the development management system
3. Enforcement of planning decisions

Figure 56: The planning system hierarchy for local authorities in Ireland [13].

Appendix II. Existing Energy Balances

The objective of an energy balance is to identify the energy used within a region and to categorise it by sector and by fuel. For this project, the objective was to develop an energy balance for the LCR for the years 1990-2010 based on historical data and for the year 2020 based on projected data. Before developing the LCR, the first step was to carry out a literature review to identify how other energy balances are constructed. From this review, a range of different energy balances were identified which included: national historical energy balances for each year from 1990-2010, national forecasted energy balances for the year 2020, regional energy balances for Dublin City, the LCR, Wexford, Mayo, and local energy balances for Dundalk and Clonakilty. Below is a summary of the key methodologies and results from these results, which were used to develop the methodology in this study.

National Energy Balance

A national energy balance is developed each year by the Energy Policy Statistical Support Unit in the Sustainable Energy Authority of Ireland (SEAI). As displayed in Table 3, the national energy balance outlines how energy was consumed in Ireland by sector, including industry, transport, residential, services, and agriculture, as well as by fuel type including coal, peat, oil, natural gas, renewables, and electricity (a more detail version is also available with many sub-divisions of each). In addition, the national energy balance also outlines how much and what type of energy is consumed and produced by energy conversion facilities such as power plants, CHP facilities, briquetting plants, and oil refineries.

Similarly, the Energy Modelling Group in the Sustainable Energy Authority of Ireland creates a forecasted energy balance for Ireland for the year 2020 [10, 17]. Although less detailed than the historical energy balance, it contains data on all the primary consumers and producers in Ireland. For example, in the historical energy balance industrial energy consumption is categorised by different NACE sectors, but in the forecasted energy balance it is categorised by industry as a whole.

Overall, the national energy balance is an ideal platform for developing a regional energy balance, due to the historical documentation since 1990, the forecasted balance for 2020, and the breakdown of consumption by sector and by fuel.

Table 12: 2009 national energy balance for Ireland [18, 19].

2009 kilo tonnes of oil eqivalent (ktoe)	COAL	PEAT	OIL	NATURAL GAS	RENEWABLES	ELECTRICITY	TOTAL
Indigenous Production	-	584	-	319	606	-	1,522
Imports	1,331	-	9,041	3,989	59	81	14,501
Exports	5	5	959	-	0	15	984
Mar. Bunkers	-	-	98	-	-	-	98
Stock Change	-113	277	24	1	1	-	190
Primary Energy Supply (incl non-energy)	**1,214**	**856**	**8,008**	**4,309**	**665**	**66**	**15,130**
Primary Energy Requirement (excl. non-energy)	**1,214**	**856**	**7,745**	**4,309**	665	**66**	**14,867**
Transformation Input	**852**	**694**	**3,074**	**2,759**	**43**	**58**	**7,479**
Public Thermal Power Plants	852	564	210	2,515	34	-	4,174
Combined Heat and Power Plants	-	9	6	244	9	-	268
Pumped Storage Consumption	-	-	-	-	-	50	50
Briquetting Plants	-	120	-	-	-	-	120
Oil Refineries & other energy sector	-	-	2,859	-	-	9	2,868
Transformation Output	**-**	**108**	**2,864**	**-**	**16**	**2,084**	**5,072**
Public Thermal Power Plants	-	-	-	-	13	1,896	1,909
Combined Heat and Power Plants - Electricity	-	-	-	-	3	157	160
Combined Heat and Power Plants - Heat	-	-	-	-	-	-	-
Pumped Storage Generation	-	-	-	-	-	31	31
Briquetting Plants	-	108	-	-	-	-	108
Oil Refineries	-	-	2,864	-	-	-	2,864
Exchanges and transfers	**19**	**-**	**-21**	**-**	**-347**	**347**	-2
Electricity	-	-	-	-	-347	347	-
Heat	-	-	-	-	-	-	-
Other	19	-	-21	-	-	-	-2
Own Use and Distribution Losses	**-**	**28**	**108**	**65**	**-**	**281**	483
Available Final Energy Consumption	**381**	**242**	**7,669**	**1,485**	**291**	**2,158**	**12,238**
Non-Energy Consumption	**-**	**-**	**263**	**-**	**-**	**-**	**263**
Final non-Energy Consumption (Feedstocks)	-	-	263	-	-	-	263
Total Final Energy Consumption	**368**	**272**	**7,580**	**1,578**	**289**	**2,147**	**12,248**
Industry*	**112**	**1**	**703**	**531**	**140**	**716**	**2,215**
Non-Energy Mining	-	-	74	11	-	58	143
Food, beverages and tobacco	18	-	190	117	39	142	507
Textiles and textile products	-	-	4	0	-	7	12
Wood and wood products	-	-	9	2	85	33	130
Pulp, paper, publishing and printing	-	-	2	2	-	16	21
Chemicals & man-made fibres	3	-	52	68	1	118	242
Rubber and plastic products	-	-	9	6	-	36	51
Other non-metallic mineral products	88	-	165	36	16	81	398
Basic metals and fabricated metal products	-	-	139	168	-	42	349
Machinery and equipment n.e.c.	0	-	7	7	-	18	31
Electrical and optical equipment	-	-	40	107	-	103	251
Transport equipment manufacture	3	-	1	4	-	6	14
Other manufacturing	-	1	10	2	-	55	68
Transport	**-**	**-**	**4,994**	**-**	**77**	**4**	**5,075**
Road Freight	-	-	810	-	-	-	810
Road Private Car	-	-	2,369	-	77	-	2,446
Public Passenger Services	-	-	215	-	-	-	215
Rail	-	-	40	-	-	4	44
Domestic Aviation	-	-	33	-	-	-	33
International Aviation	-	-	735	-	-	-	735
Fuel Tourism	-	-	122	-	-	-	122
Unspecified	-	-	670	-	-	-	670
Residential	**257**	**272**	**1,209**	**625**	**52**	**685**	**3,099**
Commercial/Public Services	**-**	**-**	**462**	**423**	**19**	**683**	**1,586**
Commercial Services	-	-	300	185	16	490	991
Public Services	-	-	162	237	3	193	595
Agricultural	-	-	212	-	0	60	272
Statistical Difference	**12**	**-30**	**-174**	**-93**	**2**	**11**	**-273**

Local Energy Balances

In total, six local energy balances were previously completed in Ireland. Although there are many local energy balances completed in other countries also, it is difficult to compare them with Irish energy balances due to the different sources of data available. Therefore, in this section only Irish energy balances are discussed.

9.1.1 Dublin City

In 2008, Codema developed an energy balance for Dublin City local authority [24] which formed the basis for developing the Dublin City Sustainable Energy Action Plan 2010-2020 [95]. During this project an energy balance was developed for the year 2006 and subsequently, forecasted energy balances were created for each year until 2020. Since it is an energy balance for the city, it includes industry, transport, residential and services, but not agriculture.

For the residential sector, the stock of existing houses in Dublin City was assessed based on dwelling type, floor area, age profile, and tenure type so that a typical home in Dublin could be created: this was defined as a 113 m^2 terraced house with a 100 m^2 exposed wall area and a window area of 24 m^2. Subsequently, the Building Energy Rating (BER) software developed by SEAI was used to model the energy demand in this typical house for a range of age profiles i.e. years of construction. The energy consumption identified for the sample house could then be multiplied by the number of houses in Dublin City of the corresponding age to predict the total demand for energy in the residential sector. This was an effective way of creating a generic bottom-up estimate of the energy consumed in the residential sector. After developing the 2006 energy balances, three scenarios were created for 2007-2020 to outline the consequences of various energy alternatives in the residential sector: once again by using the sample house as a baseline. Overall, this methodology consisted of some bottom-up and top-down assumptions which enabled the authors to consider some unique characteristics of the residential sector in Dublin, but still avoiding the resource-intensive data collection process of a pure bottom-up approach.

For the manufacturing and services sectors, the authors carried out a top-down approach by proportioning data from the national energy balance based on employee numbers. In 2006, the Central Statistics Office Ireland (CSO) carried out a census of Ireland which included a special POWCAR analysis: Place of Work Census of Anonymised Records. This dataset outlines the number of people employed in various NACE Rev 1.1 (Nomenclature statistique des activités économiques dans la Communauté européenne[1]) sectors at a national and local authority level in Ireland. Correspondingly, the national energy balance outlines the energy consumed in the industrial sector under these NACE rev 1.1 sector while a reported completed by SEAI outlines the energy consumed per employee in the services sector by NACE Rev 1.1 sector [96]. Therefore, national energy consumption data can be proportioned to a local level based on the proportion of employees in the region compared to the total employees in Ireland.

Since the transport sector is very inhomogeneous, several methodologies were used for different forms. For private cars, taxis, and exempt vehicles, the total energy consumed was based on the number of vehicles, the average annual mileage, the specific fuel consumption of an average vehicle, and a multiplication factor of 1.4 for city driving. For road freight, national data from the national energy balance was proportioned based on the tonne-km carried in Dublin City and County. For the bus, tram, and rail energy consumption, the operators were contacted directly which were Dublin Bus, Luas (RPA), and Iarnród Éireann respectively.

9.1.2 Limerick and Clare Region

In 2006, the Limerick-Clare Energy Agency commissioned an energy balance for the LCR also, which included separate energy balances for County Clare, County Limerick, and Limerick City [25]. This study

[1] Statistical classification of economic activities in the European Community

used a top-down approach for all sectors by proportioning the national energy balance data to a local using a representative statistic at both levels. For industry and services, the number of employees was used similar to Codema for the Dublin City energy balance. However, Codema separated industry and services into the various NACE Rev 1.1 sectors whereas here the total number of employees was used. For transport, national energy data was proportioned for private cars, road freight, bus, and rail based on the number of private cars in Clare County, Limerick County, and Limerick City compared to the national figure. For the residential sector national energy data was proportioned based on the number of private houses and for the agricultural sector data was proportioned based on the areas farmed.

The advantages of using this pure top-down approach is evident in this report as the authors were able to apply the proportions described above to all national energy balances between 1990 and 2004, thus creating a time series for energy consumption in each region. In addition, using this approach enables the methodology to be relatively easily used by other counties in Ireland also. However, the disadvantage of this approach is that it could fail to account for irregularities in a region.

9.1.3 County Wexford

An energy balance was also created for County Wexford in Ireland based on the year 2006 [26]. Once again a top-down approach was used for industry. However, instead of using national energy demand and employee numbers, the number of industrial units was used to proportion the total annual expenditure by industry on oil at a national to a local level. Afterwards, the total local expenditure was converted to energy based on the typical price for a kWh of oil. Liquid petroleum gas (LPG) in industry was proportioned based on the number of industrial units in Wexford compared to the total number of industrial units in all counties without access to the gas grid, while electricity in industry was obtained for Wexford from the Commission for Energy Regulation (CER).

Similarly, electricity consumption in the services sector was obtained from the CER. Using this as a starting point, the demand for other fuels was estimated based on the national relationship between that fuel and the electricity demand. Hence, it was assumed that the services sector in Wexford required the same ratio of fuels as the services sector at a national level.

For the transport sector, a similar approach was used to that for Dublin City: the total number of vehicles, average annual mileage, and specific fuel consumption was used to estimate the demand for private cars, road freight, and public service vehicles. Individual operators were contacted for rail and shipping energy used in the county. It is worth noting that only the fuel which was provided in the region was assumed to be part of the Wexford energy balance. For example, even though there is a rail network in Wexford, it was assumed that there was no demand since the train was refuelled in Dublin and not in Wexford.

In the residential sector, the number of private households was used to proportion national coal, peat, and LPG consumption data to a local level. However, only the houses in counties without a gas grid were considered for LPG. To estimate the oil consumed, the authors identified the average consumption by a house with an oil boiler in Ireland and the number of oil boilers in County Wexford. The electricity consumption in the residential sector for County Wexford was obtained from the CER:

Agriculture only consumes oil and electricity. For oil, national agricultural expenditure on oil in the agricultural sector was proportioned to a local level based on the number of farms and the average size of a farm in County Wexford. Subsequently, the specific fuel consumption was estimated for tractors so a annual energy demand for oil could be estimated. Electricity demand for the agricultural sector in Wexford was obtained from the CER.

9.1.4 County Mayo

An energy balance was also developed for county Mayo in Ireland by the Sustainability Institute [27]. Once again this study also followed a top-down approach. Similar to the Dublin City and Limerick and Clare reports, the authors in this study used employee numbers to proportion national energy data to a local level for industry and commerce. In addition, employee numbers were also used here to proportion agricultural data.

Unlike previous studies, the assumptions used for the residential and transport sectors incorporated a lot of personal judgement rather than specific facts. In the residential sector the authors noted that compared to the national average, Mayo had smaller houses, older houses, more houses without central heating, as well as wetter and windier weather. Considering each of these the authors assumed that the residential consumption per capita in Mayo would be 17-18% higher than the national average. Similar issues were considered for each form of transport and subsequently, a per capita consumption for Mayo was created compared to the national average. For example, for private cars the distance travelled to work, mode of transport, and number of tourists were assessed, which led to the assumption that Mayo has a 20% higher per capita private car consumption than the national average. Once again this top-down approach makes it easy to repeat the study over many years and other areas, but it is difficult to assess how accurate the assumptions developed for the residential and transport sectors are.

9.1.5 Dundalk Sustainable Energy Zone

SEAI are currently using Dundalk as an exemplar project for local communities in Ireland to introduce new energy efficiency measures and increase renewable energy generation. As part of this project, SEAI have developed guidelines for other communities based on experiences within Dundalk [13]. To supplement these guidelines, an Energy Master Planning (EMP) tool is available which enables communities to create a bottom-up energy balance of their region [97]. Hence, this tool was used to create the Dundalk energy balance.

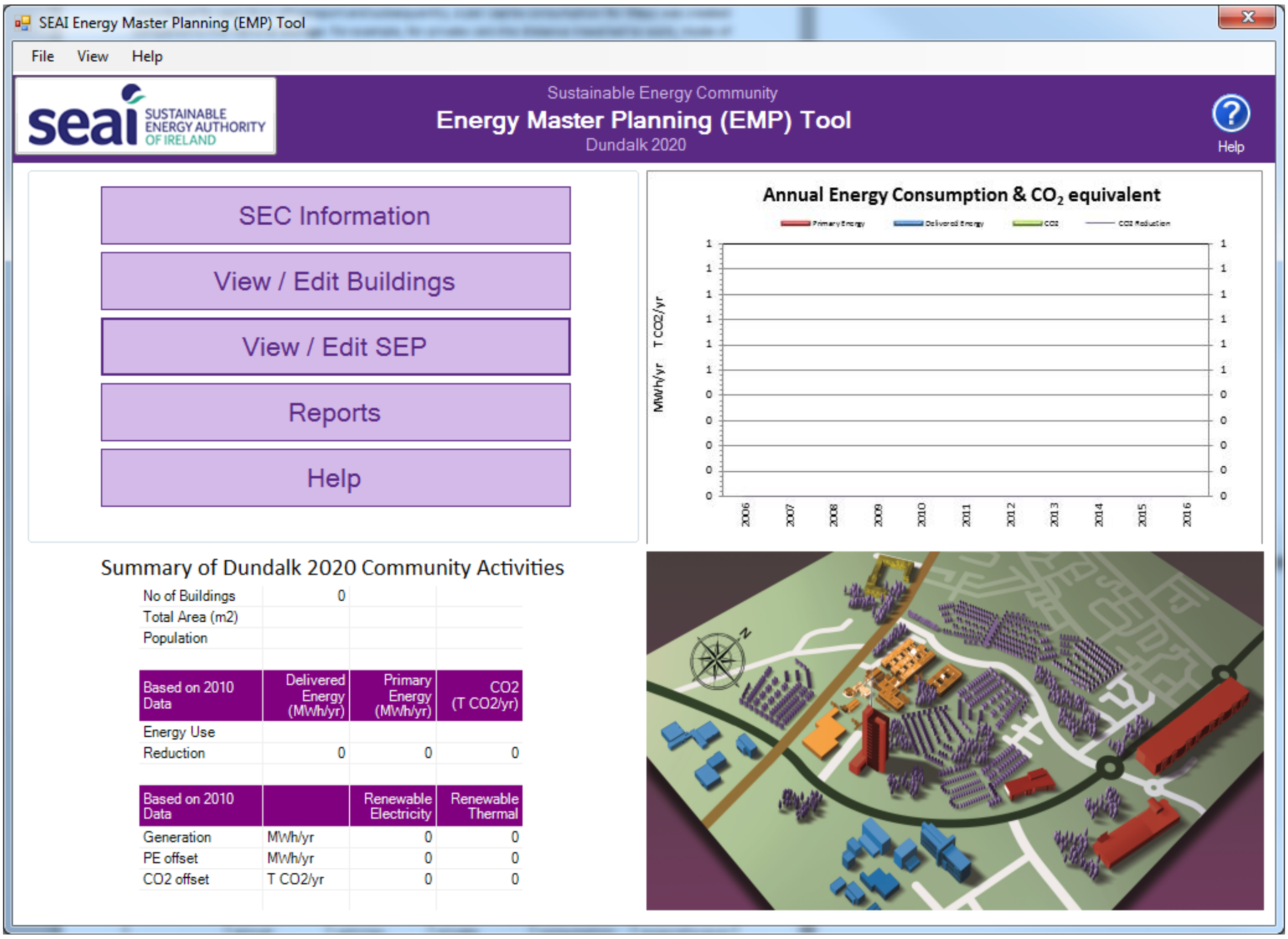


Figure 57: Interface of SEAI's Energy Master Planning tool [97].

The EMP tool is primarily focused on buildings and so it considers the industrial, services, residential and the building proportion of the agriculture sectors, but not the transport and agriculture are not included. The tool requires a lot of detail since each building has to be defined by category (15 options), stage of completion (5 options), type of use (44 options), and primary heating fuel (18 options), along with its address, floor area, and average weekly occupancy. Therefore, SEAI recommend a three phase approach when populating the tool with data: firstly using benchmark data, then real data, and final reviewing the data, which is outlined in Figure 58. This bottom-up approach enables the community to identify key stakeholders, opportunities for energy efficiency and renewable energy, as well as develop a very accurate representation of energy consumption in the region. However, the significant drawback is the level of resources required to do this. For example, the number of houses alone in the LCR is 102,435 [29]. Therefore, although the bottom-up approach can be applied to a refined urban area like Dundalk, it was concluded that based on the human resources required, it is not a suitable methodology for the LCR.

Finally, it should be noted also that the EMP tool also has the facility to add Sustainable Energy Projects (SEP) to a building including biogas, biofuel, biomass, solar, wind, and electrical/thermal energy efficiency projects. This enables the energy balance and energy plan to be developed in one tool, which could be advantageous for communities developing a long-term energy plan.

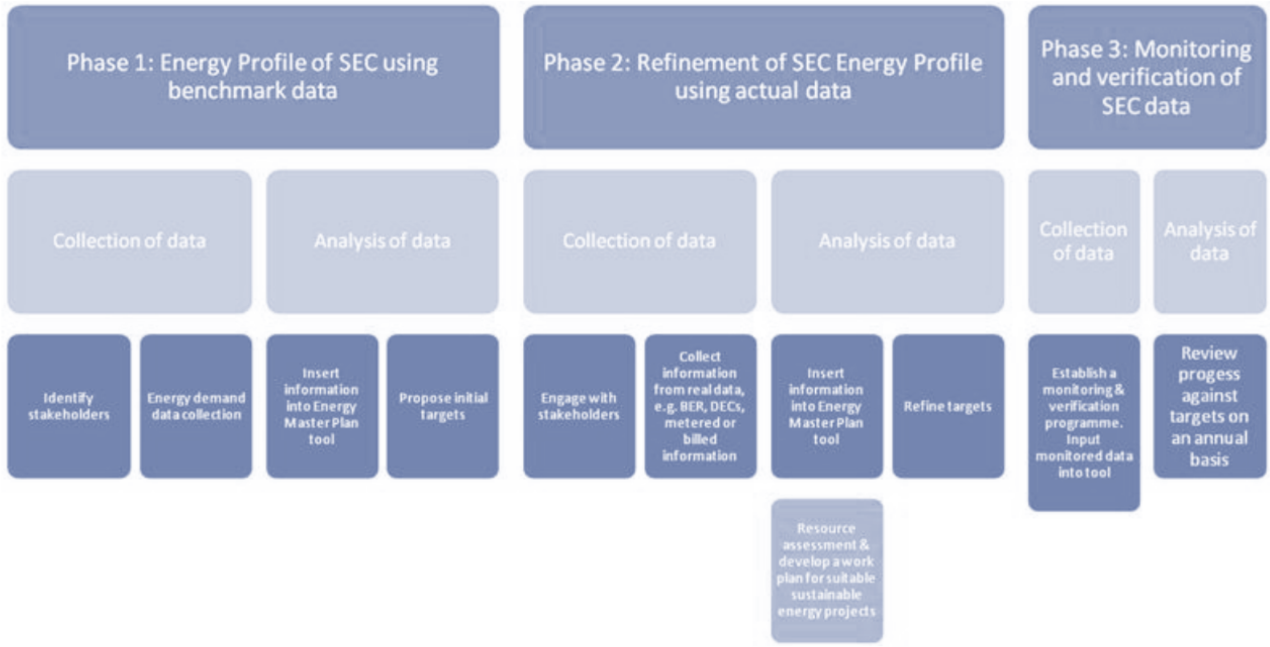


Figure 58: Three phase process for inputting data into SEAI's Energy Master Planning tool [98].

9.1.6 Clonakilty District

The energy balance developed for the Clonakilty District also used a bottom-up approach by creating an energy audit [28]. The audit was distributed to households and businesses to evaluate how much electricity, heating fuel, and transport fuel was used. The completion rate for the audit was not specified, the authors outlined that the some data had to be extrapolated for completeness. This was based on census data for households and the type of activity for businesses. As with the bottom-up methodology used by SEAI, the audit developed for Clonakilty would require too many resources to be completed over the LCR.

9.1.7 Summary

Local energy planning is a very new and developing area in Ireland. However, it is evident from this literature review that a wide range of local energy planning has evolved since 2008. Many of the characteristics outlined in Table 13 and approaches outlined in Table 14 demonstrate this diversity. For example, the Clonakilty District energy balance used a bottom-up approach to evaluate the energy consumed in an area of 331 km^2 with 17,678 people and 4,904 households in both urban and rural areas. In contrast, the Dublin City energy balance used a top-down approach to assess the energy consumed in an area of 115 km^2 with 491,555 people and 190,984 households in urban areas only. Therefore, to capture the diversity of methodologies, Table 15 was created outlining the primary assumptions used in each study. After assessing these assumptions, the methodology for the Limerick-Clare energy balance in this study was defined as outlined in the section 3.

Table 13: Key statistics for each region which has developed an energy balance in Ireland [20-23].

Region	Population	Area Covered		Population Density (pop./km^2)	Permanent Households		Industrial Units
		Type	Size (km^2)		Total	% with central heating	
Ireland	4,581,269	Urban & Rural	70,182	65	1,462,296	90%	5400
Dublin City	491,555	Urban	118	4176	190,984	88%	588
Clare County*	108,331	Urban & Rural	3449	31	38,210	89%	165
Limerick City*	51,886	Urban	21	2494	19,550	84%	239
Limerick County*	129,715	Urban & Rural	2735	47	44,765	89%	
Limerick Clare Region*	289,932	Urban & Rural Separately	6205	47	102,525	88%	404
Wexford County	130,518	Urban & Rural	2370	55	45,096	88%	219
Mayo County	121,680	Urban & Rural	5589	22	43,431	89%	170
Dundalk Town#	28,749	Urban	25	1164	10,186	94%	Not Available
Dundalk SEZ		Urban	4				
Clonakilty District	14,678	Urban & Rural Separately	331	44	4,879	81%	Not Available

***More detailed regional statistics for Limerick and Clare is provided in the Appendix III.**

#This data is for Dundalk town as the data was not available for the Dundalk Sustainable Energy Zone.

Table 14: Approach used to estimate the energy consumed in each sector by the different studies.

Energy Balance	Industry	Transport	Residential	Services	Agriculture
Dublin City [24]	Top-Down	Top-Down	Bottom-Up: based on a DEAP simulation	Top-Down	n/a
Limerick-Clare [25]	Top-Down	Top-Down	Top-Down	Top-Down	Top-Down
County Wexford [26]	Top-Down	Top-Down	Top-Down	Top-Down	Top-Down
County Mayo [27]	Top-Down	Top-Down: modified on personal judgement	Top-Down: modified on personal judgement	Top-Down	Top-Down
Dundalk SEZ [13]	Bottom-Up	n/a	Bottom-Up	Bottom-Up	Bottom-Up: buildings only
Clonakilty District [28]	Bottom-Up	n/a	Bottom-Up	Bottom-Up	Bottom-Up

Table 15: Assumptions used to estimate the energy consumed in each sector by the different studies.

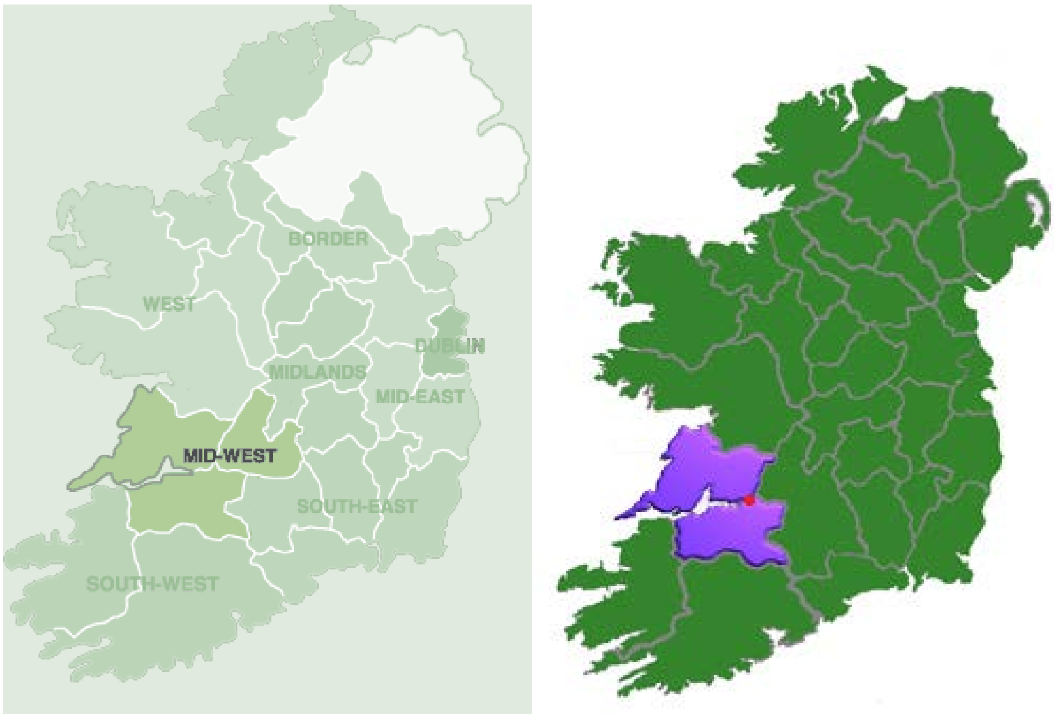
Energy Balance	Industry	Transport	Residential	Services	Agriculture
Dublin City [24]	Proportioned national data based on NACE Rev 1.1. employee numbers.	Number of vehicles, average annual mileage, specific fuel consumption, & contacted other transport operators.	Identified a typical house, constructed a model using DEAP and project based on year of construction.	Proportioned national data based on NACE Rev 1.1. employee numbers.	Not Applicable
Limerick-Clare [25]	Proportioned national data based on employee numbers.	Proportioned national data based on number of private cars.	Proportioned national data based on number of private households.	Proportioned national data based on employee numbers.	Proportioned national data based on area farmed.
County Wexford [26]	Proportioned national data based on industrial units, used annual expenditure on oil, and got electricity consumption from the CER.	Used number of vehicles, average annual mileage, & specific fuel consumption for road transport. Contacted transport operators for others. Only accounted for fuel supplied in the region.	Proportioned national data based on number of private households for coal, peat, and LPG. Number of oil boilers in the region and average household consumption for oil, and electricity demand from the CER.	Electricity consumption from the CER. Proportioned other fuels based on ratio to electricity at a national level.	For oil, Proportioned national annual expenditure based on farm numbers and size, found average oil price over time period, then used specific fuel consumption of tractors to estimate oil. Got electricity demand from the CER.
County Mayo [27]	Proportioned national data based on employee numbers.	Compared residential statistics at a national and regional level, then made a personal judgement on the per capita consumption locally compared to the national average.	Compared residential statistics at a national and regional level, then made a personal judgement on the per capita consumption locally compared to the national average.	Proportioned national data based on employee numbers.	Proportioned national data based on employee numbers.
Dundalk SEZ [13]	Profile of buildings made using the EMP tool based on benchmark or real data.	Not Applicable	Profile of buildings made using the EMP tool based on benchmark or real data.	Profile of buildings made using the EMP tool based on benchmark or real data.	Not Applicable
Clonakilty District [28]	Energy audit distributed	Energy audit distributed	Energy audit distributed	Energy audit distributed	Energy audit distributed

Appendix III. Key Regional Statistics

This section outlines some of the key statistics used when developing the local energy and emissions balances for Clare County, Limerick County, and Limerick City.

Geographic and Political Region

Ireland is divided up into a number of regions. As outlined in Figure 59, Limerick and Clare are located in the Mid-West region, which also includes North Tipperary. There are also separate local authorities in place for Limerick and Clare counties, as well as Limerick City, which are also highlighted separately in Figure 59. County Clare has a total area of 3449 km^2, County Limerick an area of 2735 km^2, and Limerick City an area of 21 km^2. As will be discussed in Appendix I, these geographic divisions are important for the purposes of planning in Ireland, as there are separate development plans created at a regional and local authority level.



(a) **(b)**

Figure 59: : (a) Mid-West regional authority and (b) Limerick-Clare region in Ireland [99, 100].

Climate

As outlined Table 16 by the weather data from Shannon airport, which is located in County Clare, it is evident that the Limerick-Clare region has a relatively moderate climate, with no extremely hot or cold periods. The monthly average temperature ranges from a low of approximately 5°C in January to 16°C in July. The region has an average 3.5 hours of sunshine each day and an average annual rainfall of almost 1 m.

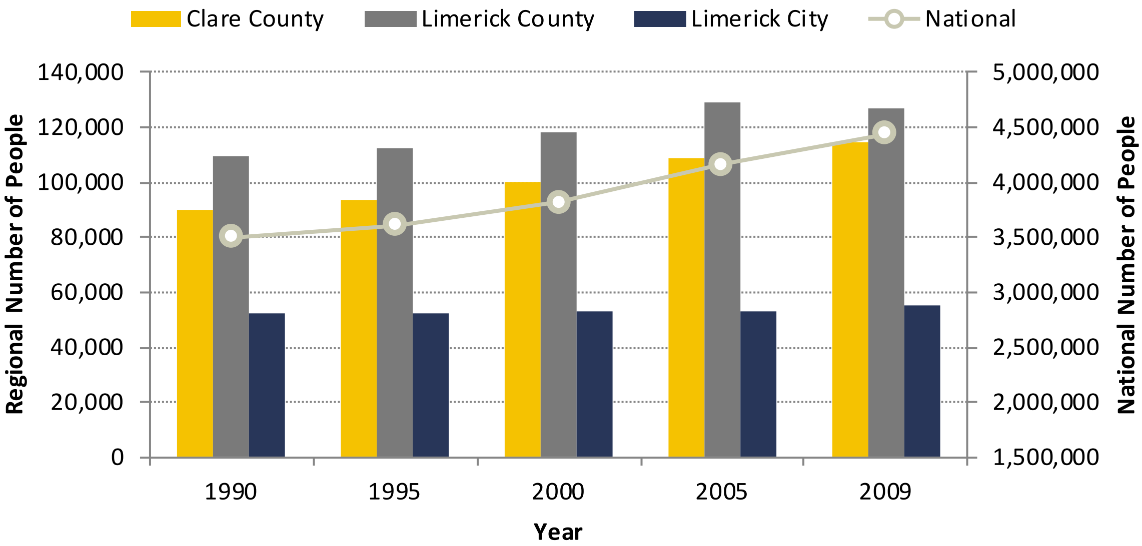
Table 16: Monthly and annual mean and extreme climate values at Shannon Airport in Co. Clare from 1961-1990 [101].

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
TEMPERATURE *(degrees Celsius)*													
mean daily max.	8.2	8.5	10.5	12.7	15.3	17.9	19	19.2	17.2	14.2	10.4	8.9	**13.5**
mean daily min.	2.6	2.7	3.6	4.8	7.3	10.1	12	11.7	10.1	8	4.5	3.6	**6.8**
mean	5.4	5.6	7	8.8	11.3	14	16	15.5	13.6	11.1	7.5	6.3	**10.1**
absolute max.	14	14.8	20.2	22.2	25.6	31.6	31	28.7	25.5	21.8	18.2	15.2	**31.6**
absolute min.	-11	-9.8	-7.8	-4.1	-0.9	1.5	5.2	2.9	1.3	-1.4	-6.1	-8.3	**-11.2**
mean no. of days with air frost	6.5	5.4	3.2	1.6	0	0	0	0	0	0.3	3.5	5	**25.4**
mean no. of days with ground frost	13.2	11	9.5	8.2	2.5	0.4	0	0	0.6	2.7	9.6	11	**68.6**
RELATIVE HUMIDITY *(%)*													
mean at 0900UTC	88	87	85	81	77	79	81	83	85	88	88	89	**84**
mean at 1500UTC	82	75	70	65	64	67	68	69	71	77	81	84	**73**
SUNSHINE *(hours)*													
mean daily duration	1.58	2.34	3.34	4.93	5.77	5.13	4.6	4.44	3.69	2.65	1.93	1.42	**3.48**
greatest daily duration	7.8	9.5	11.6	13.6	15.3	15.8	16	14.8	11.6	9.9	8.8	7.1	**15.8**
mean no. of days with no sun	10	7	5	3	2	2	2	2	3	6	8	11	**62**
RAINFALL *(mm)*													
mean monthly total	97.8	71.5	71.4	55.7	59.5	62.8	57	82.4	81.6	93.4	94.8	99	**926.7**
greatest daily total	29	33.5	28.5	29.6	27	29.7	43	35.9	35.5	33	33	50.4	**50.4**
mean no. of days with >= 0.2mm	20	16	19	16	17	16	15	18	18	20	19	20	**214**
mean no. of days with >= 1.0mm	16	12	14	11	13	11	10	13	13	15	15	16	**160**
mean no. of days with >= 5.0mm	7	5	5	4	4	4	4	5	6	6	7	7	**66**
WIND *(knots*)*													
mean monthly speed	10.9	11.1	11	9.5	9.5	8.9	8.7	8.6	9.6	10	9.6	10.5	**9.8**
max. gust	82	80	65	62	61	57	52	55	93	84	64	81	**93**
max. mean 10-minute speed	55	53	44	41	39	42	33	39	60	57	45	51	**60**
mean no. of days with gales	2.1	1.2	1.4	0.5	0.5	0.1	0	0.1	0.6	0.9	1	1.5	**9.8**
WEATHER *(mean no. of days with...)*													
snow or sleet	3.4	3.2	1.8	0.6	0.1	0	0	0	0	0.1	0.3	1.5	**10.9**
snow lying at 0900UTC	0.8	0.7	0.1	0	0	0	0	0	0	0	0.1	0.3	**2**
hail	3.7	3.1	4.3	2.5	1.7	0.2	0.1	0.2	0.3	1.1	1.8	2.7	**21.7**
thunder	0.9	0.5	0.4	0.3	0.4	0.8	0.8	0.5	0.4	0.4	0.4	0.4	**6.3**
fog	4.1	2	1.8	2.2	1.7	1.8	1.7	3.1	3	3.3	3.4	3.6	**31.8**

***1 knot = 0.514 m/s**

Population

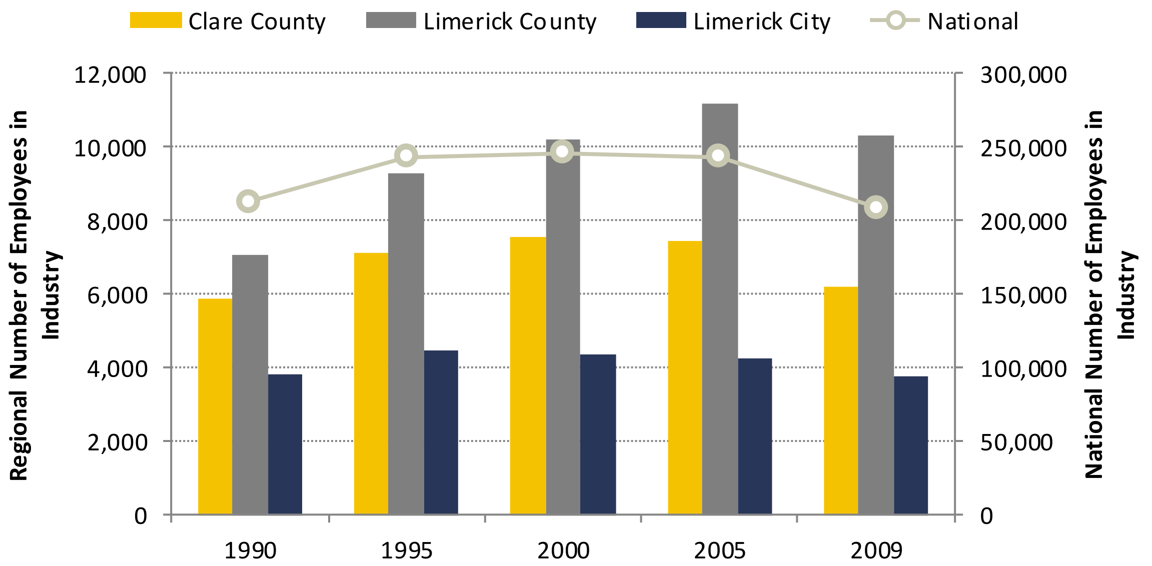
Region	Data	Year				
		1990	1995	2000	2005	2009
National	No. of People	3,505,645	3,606,013	3,820,164	4,159,187	4,444,701
Clare County	No. of People	90,300	93,388	100,187	109,032	114,511
	As % of National	*2.58%*	*2.59%*	*2.62%*	*2.62%*	*2.58%*
Limerick County	No. of People	109,247	112,377	118,522	128,957	127,165
	As % of National	*3.12%*	*3.12%*	*3.10%*	*3.10%*	*2.86%*
Limerick City	No. of People	52,092	52,048	53,362	52,910	55,083
	As % of National	*1.49%*	*1.44%*	*1.40%*	*1.27%*	*1.24%*
Limerick	No. of People	161,339	164,425	171,883	181,867	182,248
	As % of National	*4.60%*	*4.56%*	*4.50%*	*4.37%*	*4.10%*
LCR	No. of People	251,639	257,813	272,070	290,899	296,759
	As % of National	*7.18%*	*7.15%*	*7.12%*	*6.99%*	*6.68%*

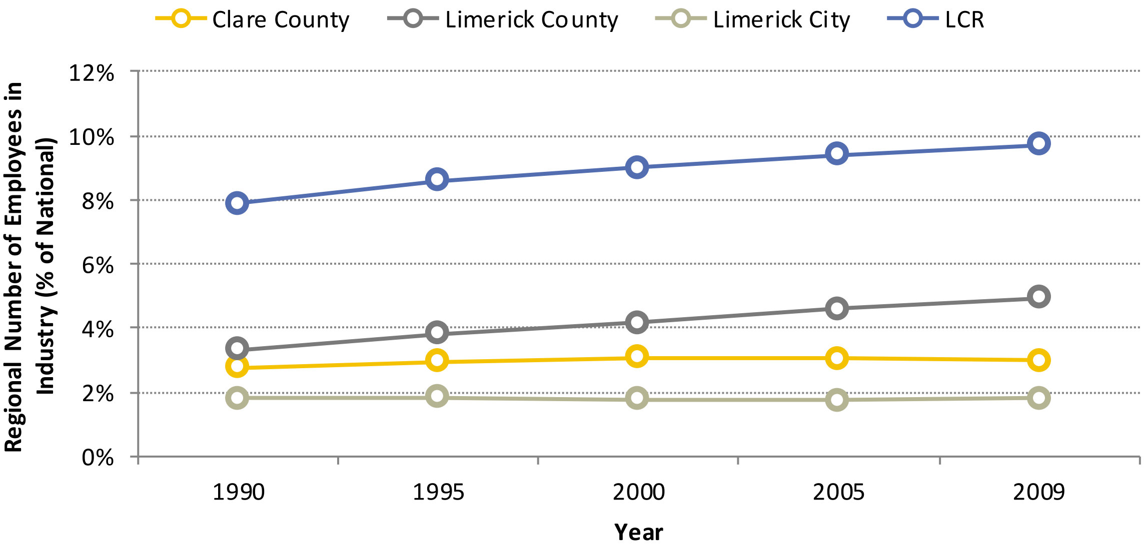


Employment

Industry

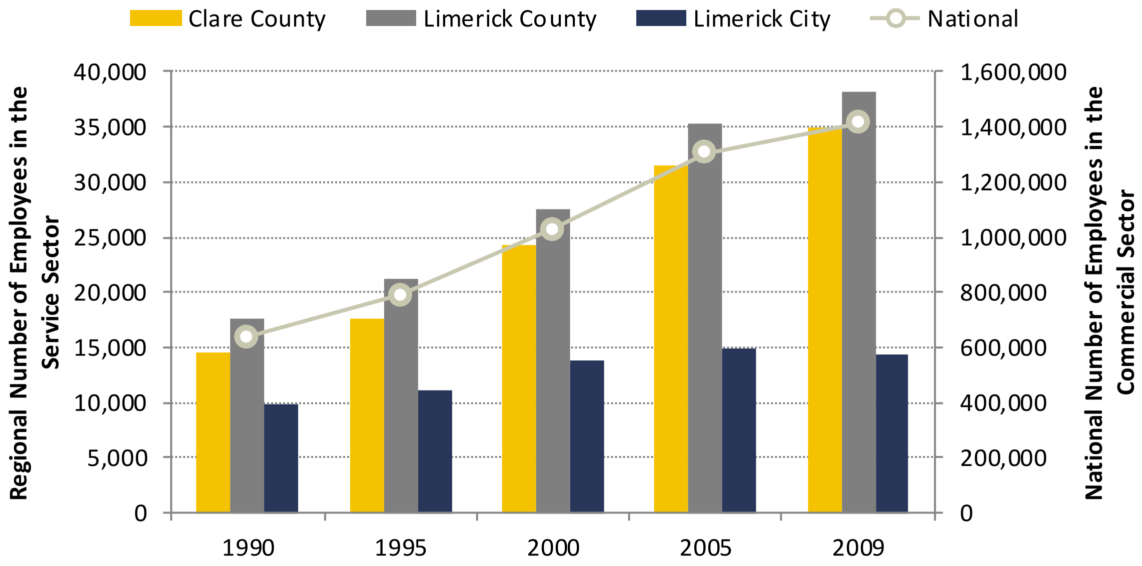
Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Workers	212,644	243,050	245,846	243,437	208,776
Clare	No. of Workers	5,874	7,143	7,539	7,426	6,222
	As % of National	*2.76%*	*2.94%*	*3.07%*	*3.05%*	*2.98%*
Limerick County	No. of Workers	7,077	9,292	10,199	11,170	10,336
	As % of National	*3.33%*	*3.82%*	*4.15%*	*4.59%*	*4.95%*
Limerick City	No. of Workers	3,844	4,491	4,367	4,264	3,750
	As % of National	*1.81%*	*1.85%*	*1.78%*	*1.75%*	*1.80%*
Limerick	No. of Workers	10,921	13,783	14,566	15,434	14,086
	As % of National	*5.14%*	*5.67%*	*5.92%*	*6.34%*	*6.75%*
LCR	No. of Workers	16,795	20,926	22,105	22,859	20,308
	As % of National	7.90%	8.61%	8.99%	9.39%	9.73%





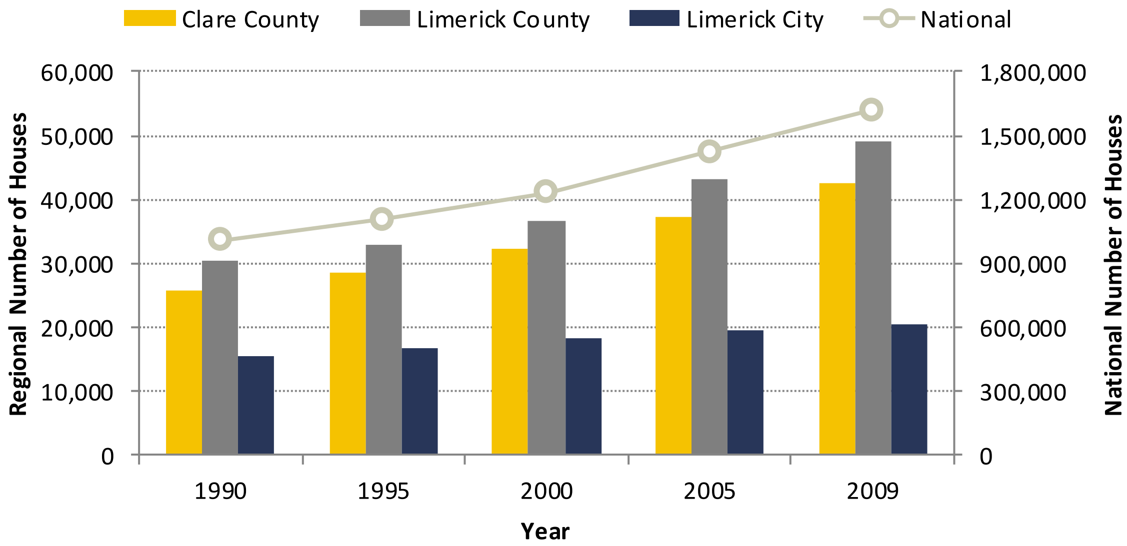
Services

Region	Data	1990	1995	2000	2005	2009
				Year		
National	No. of Workers	637,231	788,873	1,028,274	1,305,721	1,414,600
Clare	No. of Workers	14,523	17,695	24,194	31,578	35,007
	As % of National	*2.28%*	*2.24%*	*2.35%*	*2.42%*	*2.47%*
Limerick County	No. of Workers	17,577	21,164	27,622	35,276	38,183
	As % of National	*2.76%*	*2.68%*	*2.69%*	*2.70%*	*2.70%*
Limerick City	No. of Workers	9,815	11,122	13,734	14,975	14,393
	As % of National	*1.54%*	*1.41%*	*1.34%*	*1.15%*	*1.02%*
Limerick	No. of Workers	27,391	32,285	41,356	50,251	52,576
	As % of National	*4.30%*	*4.09%*	*4.02%*	*3.85%*	*3.72%*
LCR	No. of Workers	41,914	49,980	65,550	81,829	87,583
	As % of National	*6.58%*	*6.34%*	*6.37%*	*6.27%*	*6.19%*



Housing

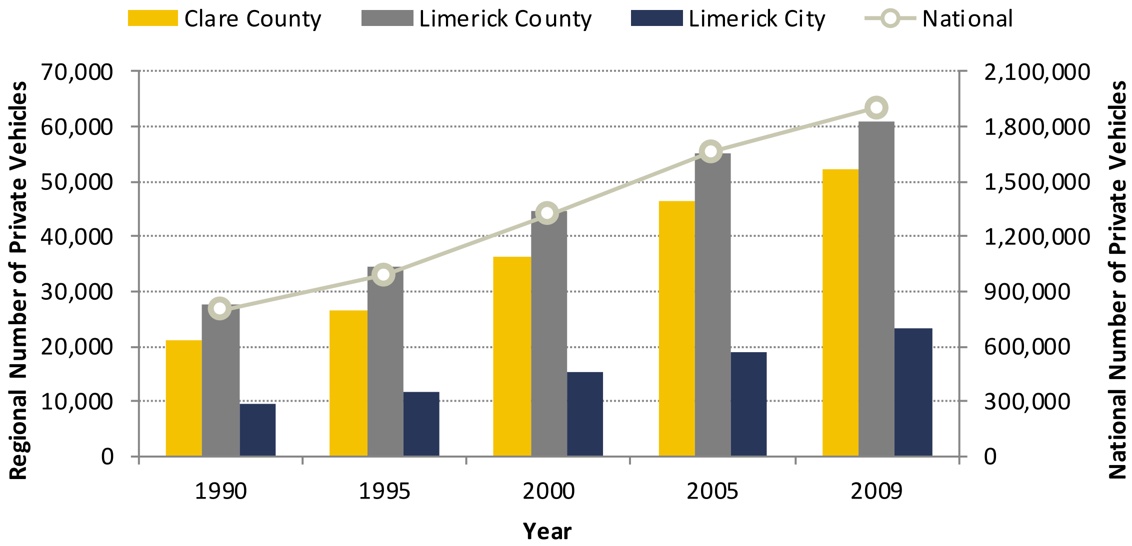
Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Houses	1,009,437	1,107,671	1,234,411	1,424,130	1,619,629
Clare	No. of Houses	25,831	28,678	32,332	37,126	42,478
	As % of National	*2.56%*	*2.59%*	*2.62%*	*2.61%*	*2.62%*
Limerick County	No. of Houses	30,414	32,974	36,747	43,101	49,236
	As % of National	*3.01%*	*2.98%*	*2.98%*	*3.03%*	*3.04%*
Limerick City	No. of Houses	15,367	16,773	18,315	19,399	20,323
	As % of National	*1.52%*	*1.51%*	*1.48%*	*1.36%*	*1.25%*
Limerick	No. of Houses	45,781	49,747	55,062	62,500	69,559
	As % of National	*4.54%*	*4.49%*	*4.46%*	*4.39%*	*4.29%*
LCR	No. of Houses	71,611	78,424	87,394	99,626	112,037
	As % of National	7.09%	7.08%	7.08%	7.00%	6.92%



Transport

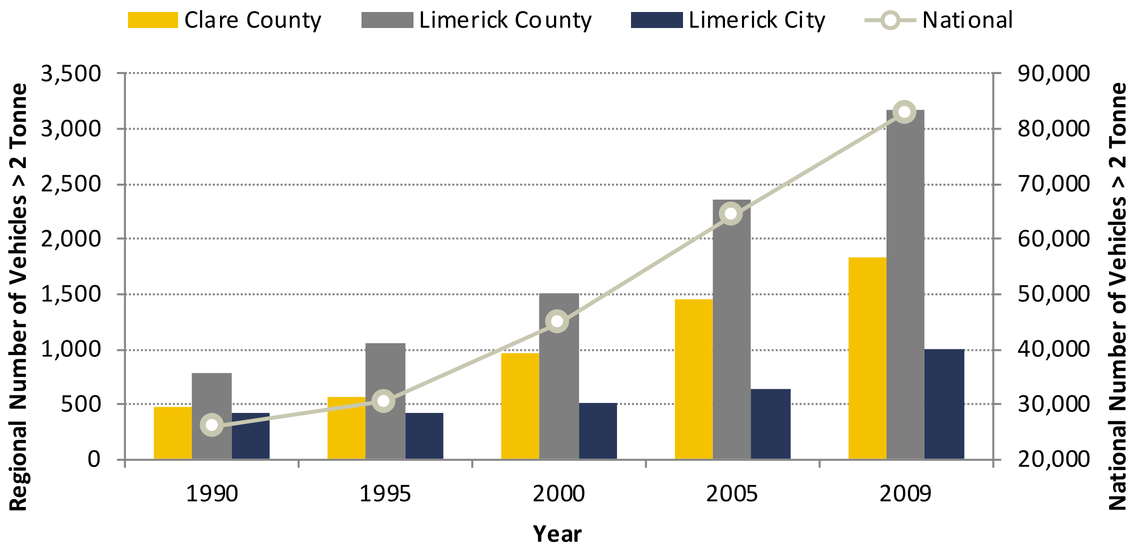
Private Vehicles

Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Vehicles	796,408	990,384	1,319,250	1,662,157	1,902,429
Clare	No. of Vehicles	21,052	26,560	36,339	46,404	52,199
	As % of National	*2.64%*	*2.68%*	*2.75%*	*2.79%*	*2.74%*
Limerick County	No. of Vehicles	27,717	34,347	44,448	55,202	61,032
	As % of National	*3.48%*	*3.47%*	*3.37%*	*3.32%*	*3.21%*
Limerick City	No. of Vehicles	9,687	11,548	15,305	18,933	23,138
	As % of National	*1.22%*	*1.17%*	*1.16%*	*1.14%*	*1.22%*
Limerick	No. of Vehicles	37,404	45,895	59,753	74,135	84,170
	As % of National	*4.70%*	*4.63%*	*4.53%*	*4.46%*	*4.42%*
LCR	No. of Vehicles	58,456	72,455	96,092	120,539	136,369
	As % of National	7.34%	7.32%	7.28%	7.25%	7.17%



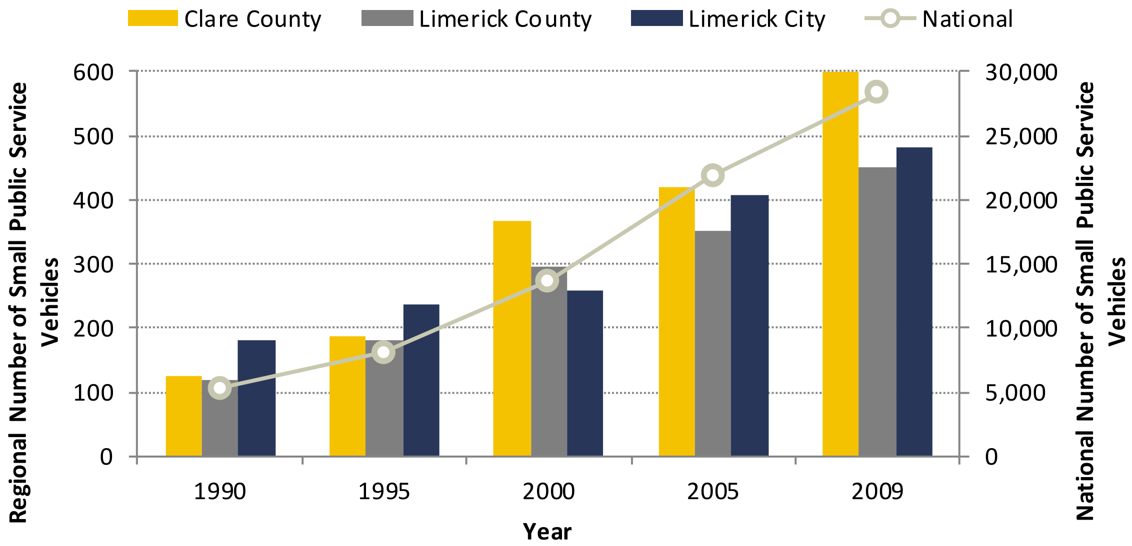
Vehicles Greater than 2 Tonne

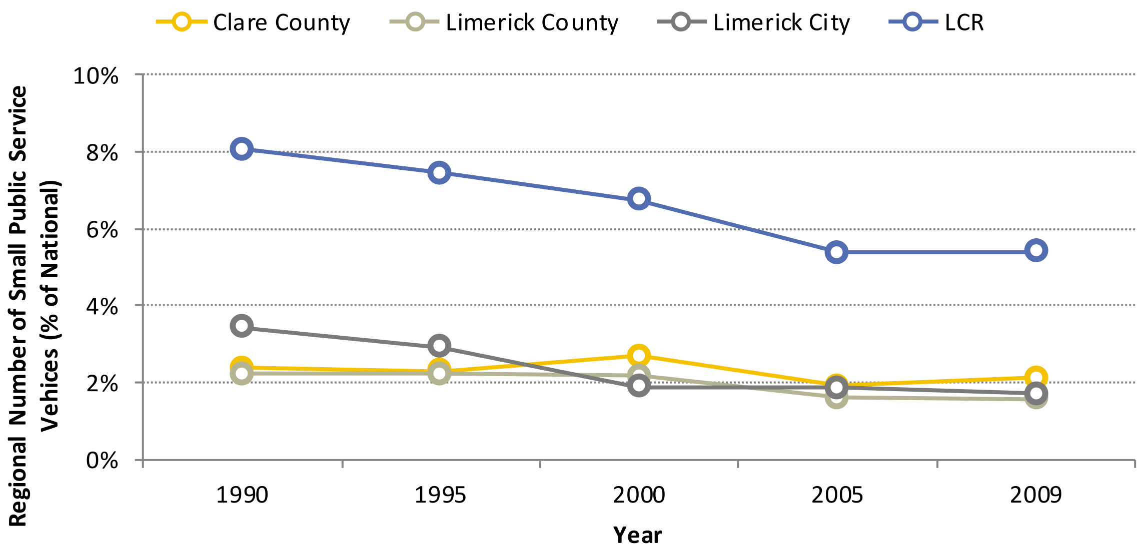
Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Vehicles	25,922	30,579	44,883	64,353	82,925
Clare	No. of Vehicles	482	562	960	1,452	1,839
	As % of National	*1.86%*	*1.84%*	*2.14%*	*2.26%*	*2.22%*
Limerick County	No. of Vehicles	788	1,053	1,502	2,356	3,167
	As % of National	*3.04%*	*3.44%*	*3.35%*	*3.66%*	*3.82%*
Limerick City	No. of Vehicles	424	427	514	639	999
	As % of National	*1.64%*	*1.40%*	*1.15%*	*0.99%*	*1.20%*
Limerick	No. of Vehicles	1,212	1,480	2,016	2,995	4,166
	As % of National	*4.68%*	*4.84%*	*4.49%*	*4.65%*	*5.02%*
LCR	No. of Vehicles	1,694	2,042	2,976	4,447	6,005
	As % of National	6.53%	6.68%	6.63%	6.91%	7.24%



Small Public Service Vehicles

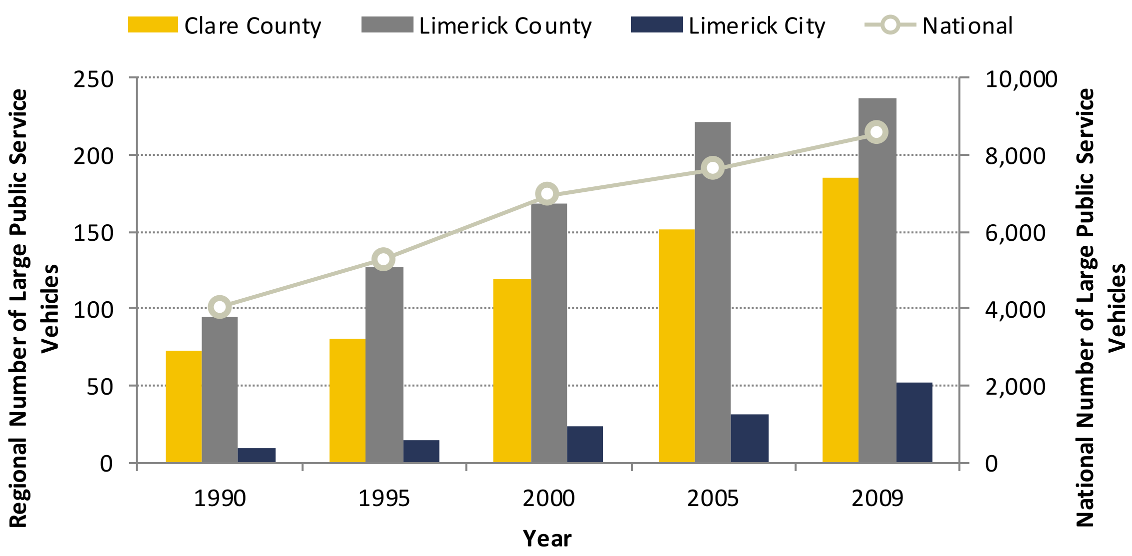
Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Vehicles	5,277	8,086	13,637	21,888	28,284
Clare	No. of Vehicles	126	186	367	419	599
	As % of National	*2.39%*	*2.30%*	*2.69%*	*1.91%*	*2.12%*
Limerick County	No. of Vehicles	118	180	296	353	450
	As % of National	*2.24%*	*2.23%*	*2.17%*	*1.61%*	*1.59%*
Limerick City	No. of Vehicles	182	236	257	408	482
	As % of National	*3.45%*	*2.92%*	*1.88%*	*1.86%*	*1.70%*
Limerick	No. of Vehicles	300	416	553	761	932
	As % of National	*5.69%*	*5.14%*	*4.06%*	*3.48%*	*3.30%*
LCR	No. of Vehicles	426	602	920	1,180	1,531
	As % of National	8.07%	7.44%	6.75%	5.39%	5.41%

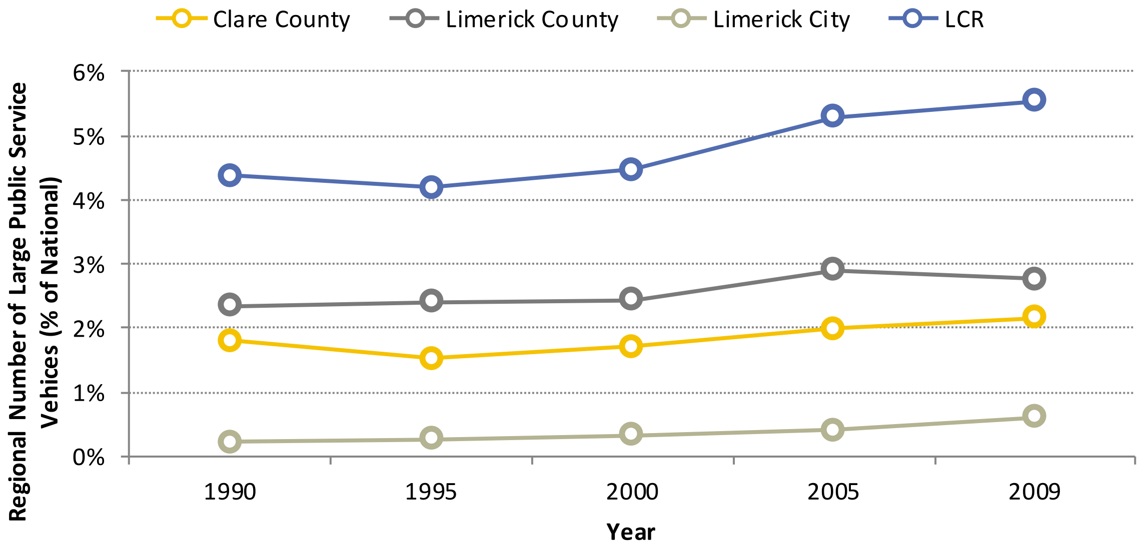

Clare County
Limerick County
Limerick City
National
Regional Number of Small Public Service Vehicles
National Number of Small Public Service Vehicles
600
500
400
300
200
100
0
30,000
25,000
20,000
15,000
10,000
5,000
0
1990
1995
2000
2005
2009
Year


Clare County
Limerick County
Limerick City
LCR
Regional Number of Small Public Service Vehicles (% of National)
10%
8%
6%
4%
2%
0%
1990
1995
2000
2005
2009
Year

Large Public Service Vehicles

Region	Data	Year 1990	1995	2000	2005	2009
National	No. of Vehicles	4,047	5,282	6,957	7,625	8,556
Clare	No. of Vehicles	73	80	119	151	185
	As % of National	*1.80%*	*1.51%*	*1.71%*	*1.98%*	*2.16%*
Limerick County	No. of Vehicles	95	127	169	221	237
	As % of National	*2.35%*	*2.40%*	*2.43%*	*2.90%*	*2.77%*
Limerick City	No. of Vehicles	9	14	23	31	52
	As % of National	*0.22%*	*0.27%*	*0.33%*	*0.41%*	*0.61%*
Limerick	No. of Vehicles	104	141	192	252	289
	As % of National	*2.57%*	*2.67%*	*2.76%*	*3.30%*	*3.38%*
LCR	No. of Vehicles	177	221	311	403	474
	As % of National	4.37%	4.18%	4.47%	5.29%	5.54%

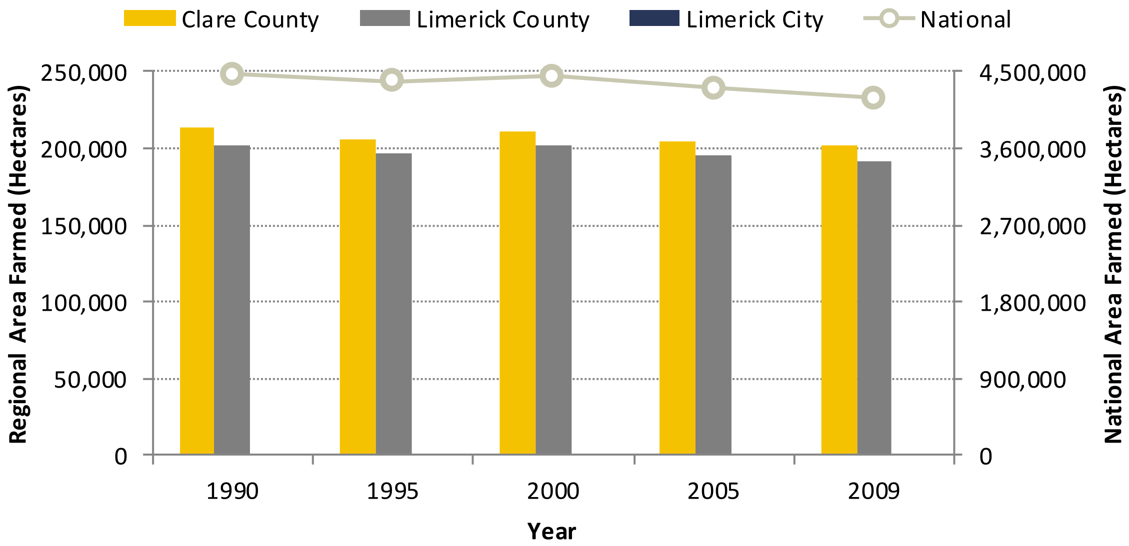




Agriculture

Region	Data	Year 1990	1995	2000	2005	2009
National	Hectares Farmed	4,470,310	4,388,500	4,443,100	4,302,000	4,189,900
Clare	Hectares Farmed	212,959	206,370	210,477	205,158	201,334
	As % of National	*4.76%*	*4.70%*	*4.74%*	*4.77%*	*4.81%*
Limerick County	Hectares Farmed	202,478	196,213	201,979	195,061	191,425
	As % of National	*4.53%*	*4.47%*	*4.55%*	*4.53%*	*4.57%*
Limerick City*	Hectares Farmed	0	0	0	0	0
	As % of National	-	-	-	-	-
Limerick	Hectares Farmed	202,478	196,213	201,979	195,061	191,425
	As % of National	*4.53%*	*4.47%*	*4.55%*	*4.53%*	*4.57%*
LCR	Hectares Farmed	415,436	402,583	412,456	400,219	392,759
	As % of National	9.29%	9.17%	9.28%	9.30%	9.37%

*Assumed there was no farming areas in Limerick City.



Clare County
Limerick County
Limerick City
National
Regional Area Farmed (Hectares)
250,000
200,000
150,000
100,000
50,000
0
National Area Farmed (Hectares)
4,500,000
3,600,000
2,700,000
1,800,000
900,000
0
1990
1995
2000
2005
2009
Year

Appendix IV. Key Data Assumptions

CO_2 emission factors and fuel costs needed to be assumed for the various fuels when completing the emissions balance and calculating fuel costs. The assumptions made and the sources used are outlined in this appendix.

Carbon Dioxide Emissions

Carbon dioxide emission factors are necessary to create an emissions balance. To be consistent with the work completed at a national level, the CO_2 emissions factors recommended by SEAI for the various fossil fuels were used, which are outlined in Table 17.

Table 17: Carbon dioxide intensity for each fuel [19].

Fuel	Coal	Peat (Milled)	Oil	Petrol	Diesel	Jet Fuel	Fuel Oil	LPG	Natural Gas
CO2 Emissions (tCO2/GWh)	341	420	261	252	264	257	274	229	204.7

It is worth noting that this report has quantified GHG emissions from energy related activities only and hence, it doesn't consider GHG emissions from cement factories, landfill waste, or agriculture.

Fuel Costs

The cost of fuel in the LCR over the period 1990-2009, as well as for 2020 has also been calculated based on the fuel prices outlined in Table 18, which correspond to an oil price of US$60/barrel in 2009 and US$105/barrel in 2020 [77, 102]. The 2020 price of US$105/barrel has been forecasted by the International Energy Agency (IEA) in the 2010 World Energy Outlook [77]. In addition, the historical oil prices illustrated in Figure 60 were applied to their corresponding years using the same ratios as displayed in Table 18 to estimate the fuel costs from 1990-2008.

Table 18: Fuel prices assumed for 2009 and 2020 [77, 102, 103].

Year	Crude Oil US$/barrel	Fuel Prices (€2009/GJ)									
		Coal	Peat	Oil	Petrol	Diesel	Jet Fuel	Fuel Oil	LPG	Natural Gas	Biofuel
2009	60	2.1	11	10	13.2	12.4	13.2	7	7	6.1	6.0
2020	107.4	3.1	11	13.4	15	15	16.1	12	9.4	9.1	8.0

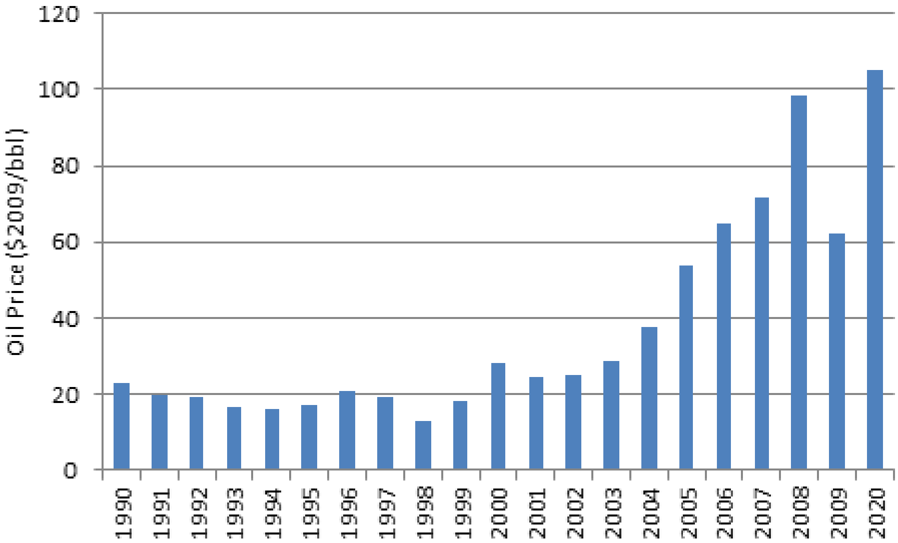


Figure 60: Historical oil price for 1990-2009 [104] and projected oil price for 2020 [77, 103].

Appendix V. Conversion Tables

Table 19: Energy unit conversions

To	toe	MWh	GJ
From		Multiply by	
toe	1	11.63	41,868
MWh	0.086	1	3.6
GJ	0.02388	0.2778	1

Table 20: Decimal prefixes

Prefix	Multiple	Symbol
Peta	10^{15}	P
Tera	10^{12}	T
Giga	10^{9}	G
Mega	10^{6}	M
Kilo	10^{3}	k