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Developing a regional energy plan for two counties in Ireland

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ABSTRACT

Developing a sustainable energy supply will most likely require a transition from large-scale centralised plants to decentralised distributed generation. Consequently, local planning authorities will play a more important role in energy planning in the coming years, as more decentralised energy facilities begin to develop. In this paper, a regional energy plan is begun for two counties located on the west coast of Ireland to identify how they can reduce their overall CO₂ emission by 20% by the year 2020. The two counties in question are called Limerick and Clare, which have a combined population of approximately 296,000 people over an area of approximately 6,200 km². Two primary objectives were set to create the energy plan. Firstly, an energy balance is developed here for the region based on the year 2020 using the existing consumption of energy and national energy projections. The results indicate that fossil fuels supplied over 90% of the energy in the two counties in 2009 which cost the local economy over M€300. In addition, even with the implementation of national energy efficiency and renewable energy policies, the region will still supply over 80% of its demands using fossil fuels. The energy balance here will form the basis for the second key objective, which is the creation of a new regional energy strategy using the energy-systems-analysis tool, EnergyPLAN.

KEYWORDS

Local; energy planning; energy balance; emissions balance; fuel costs.

INTRODUCTION

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” [1]. 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). 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.* [2], 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 of the dynamics of the energy system, especially when integrating renewable energy generation or distribution grids 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.
- Assess the feasibility of various proposals considering the following:
 - 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 [1] and abroad [2], 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 1):

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 1, 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.

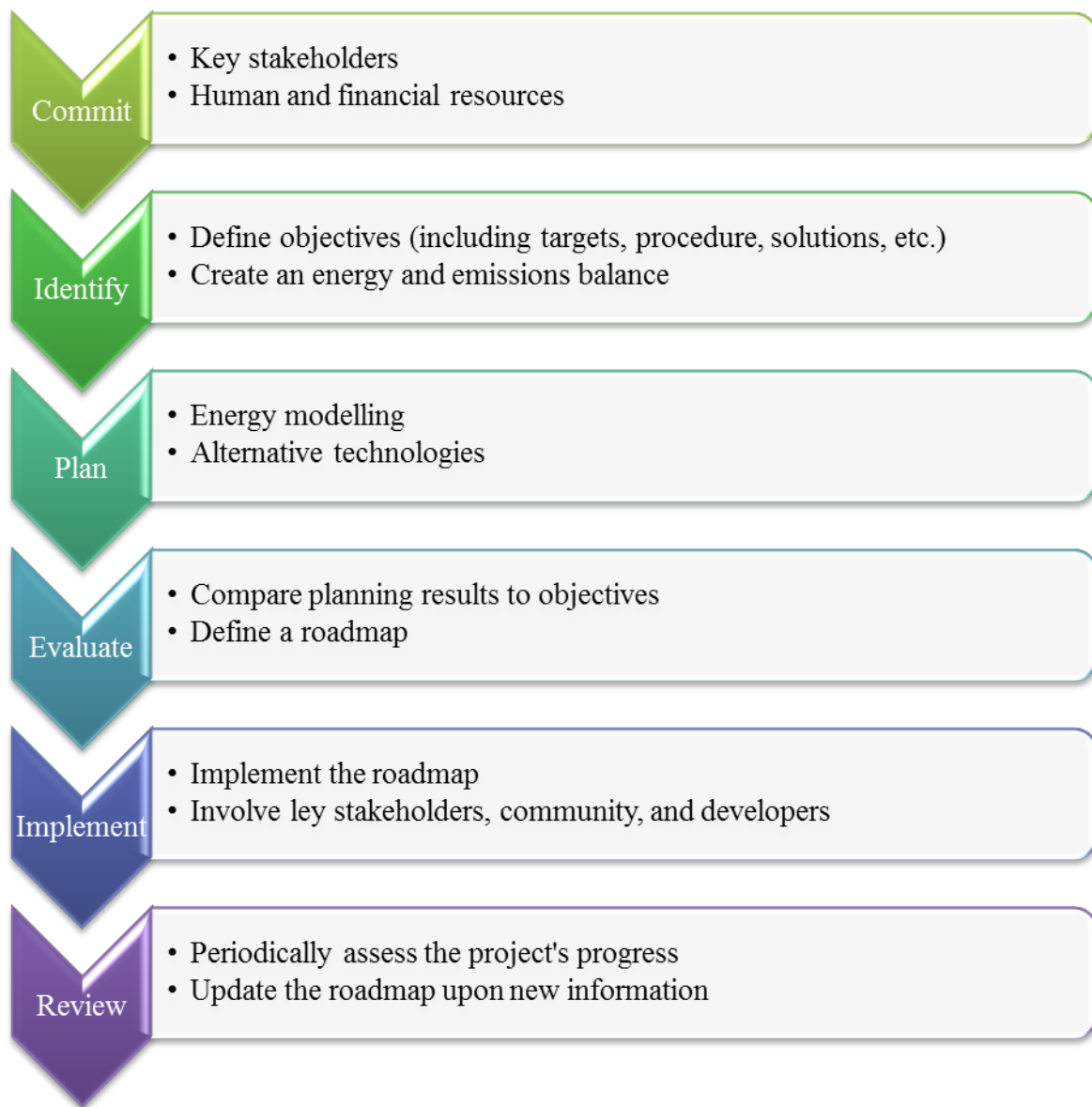


Figure 1: Steps and corresponding manpower required to develop and implement a local energy plan [1-3].

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 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. In this paper, the results from the first part of the LCEP are presented, which is the Energy and Emissions Balance. Existing methodologies

were reviewed, data was collected, and an energy balance was created for the Limerick-Clare Region (LCR).

Ireland itself is an island located on in the North-West of Europe, which is divided up into a number of regions for planning policies. As outlined in Figure 2, 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 2. County Clare has a total area of 3449 km², County Limerick an area of 2735 km², and Limerick City an area of 21 km². 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. Since this research is being carried out by the Limerick Clare Energy Agency [4], it primarily relates to the Limerick Clare region as a whole.

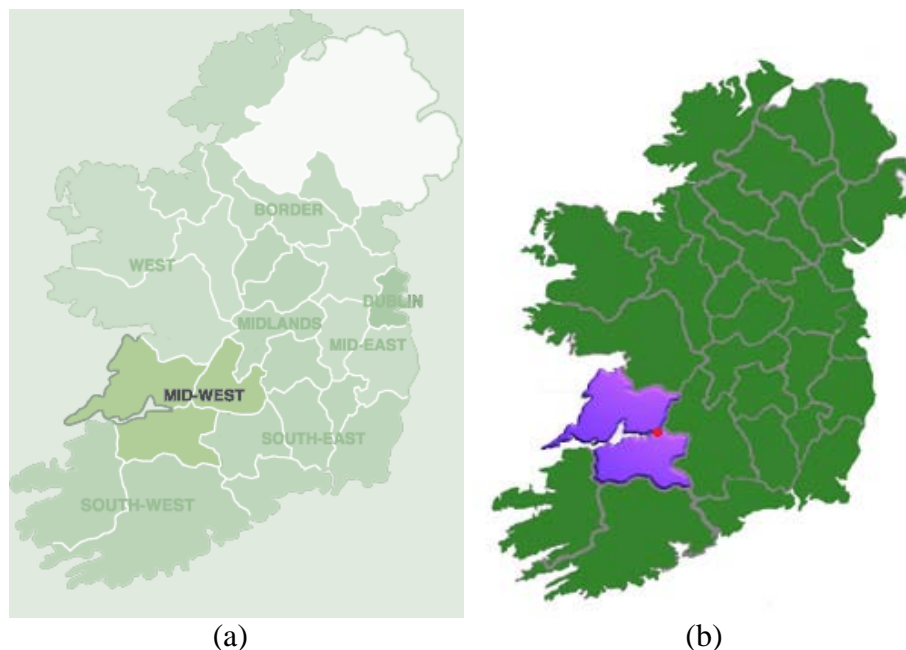


Figure 2. (a) Mid-West regional authority and (b) Limerick-Clare region in Ireland [5, 6].

As illustrated in Figure 3, the population has been increasing steadily in both Limerick and Clare counties since 1990, but Limerick City has remained relatively stable. Overall, the total population in the LCR reached approximately 296,000 in 2009, which is 6.7% of the population in the Republic of Ireland.

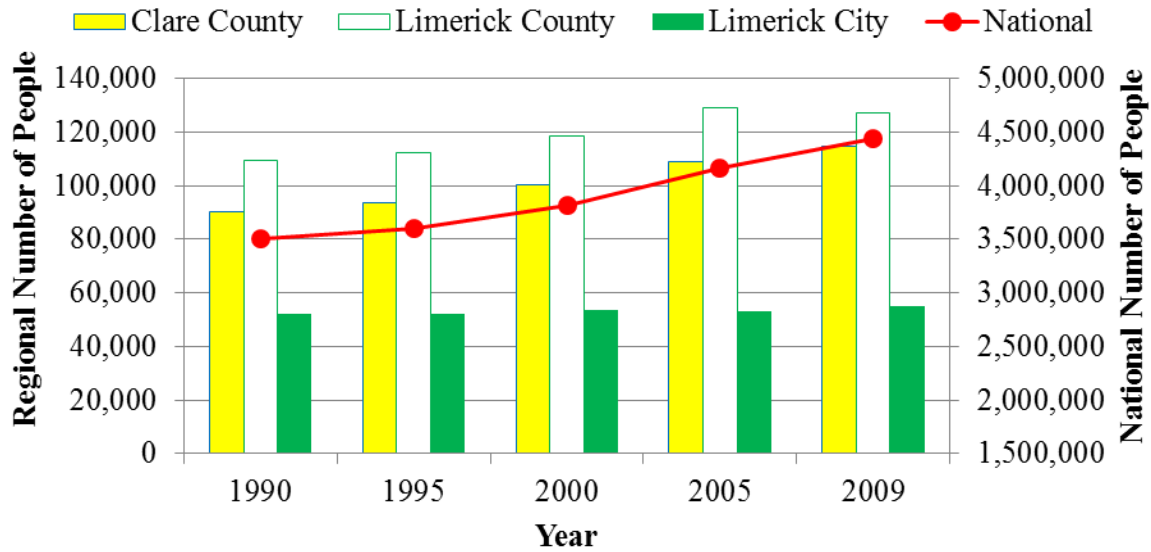


Figure 3. Population of County Clare, County Limerick, and Limerick City from 1990-2009.

REVIEW OF METHDOLOGIES

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 1990-2009 based on historical data and for the year 2020 based on projected data. However, before developing the energy balance for the LCR, the first step was to carry out a literature review to identify how other energy balances were constructed. From this review, a range of different energy balances were identified which included: national historical energy balances for each year from 1990-2009, 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.

A national energy balance is developed each year by the Energy Policy Statistical Support Unit in the Sustainable Energy Authority of Ireland (SEAI). 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 (along 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 [7, 8]. Although less detailed than the historical energy balance, it contains data on all the primary consumers and producers in Ireland. 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.

In 2008, Codema developed an energy balance for Dublin City local authority [9] which formed the basis for developing the Dublin City Sustainable Energy Action Plan 2010-2020 [10]. 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 m² terraced house with a 100 m² exposed wall area and a window area of 24 m². 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. 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. 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.

In 2006, the Limerick Clare Energy Agency (LCEA) made an energy balance for the LCR also, which included separate energy balances for County Clare, County Limerick, and Limerick City [11]. This study used a top-down approach for all sectors by proportioning the national energy balance data to a local balance 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. 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.

An energy balance was also created for County Wexford in Ireland based on the year 2006 [12]. 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. 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. In the residential sector, the number of private households was used to proportion national coal, peat, and LPG consumption data to a local level.

An energy balance was also developed for county Mayo in Ireland by the Sustainability Institute [13]. 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. For example, 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.

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 [1]. 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 [14]. Hence, this tool was used to create the Dundalk energy balance. 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 the transport and agriculture sectors 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. Hence, the significant drawback of this approach is the level of resources required to do this. For example, the number of houses alone in the LCR is 102,435 [15]. Therefore, although the bottom-up approach is suitable for 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, an energy balance was also developed for the Clonakilty District using a bottom-up approach by creating an energy audit [16]. 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, but the authors outlined that 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.

Overall, it is evident that local energy planning is a very new and developing area in Ireland. However, it is also evident from this literature review that a wide range of local energy planning has evolved since 2008. Many of the characteristics outlined in Table 1 and approaches outlined in Table 2 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 km² 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 km² with 491,555 people and 190,984 households in urban areas only. Therefore, different methodologies were taken from each of the local energy balances completed in Ireland and applied to the LCR in this study.

Table 1. Key statistics for each region which has developed an energy balance in Ireland [17-20].

| Region | Population | Area Covered | | Population Density (pop./km ²) | Permanent Households | Industrial Units |
|---------------------------|------------|--------------------------|-------------------------|--|----------------------|------------------|
| | | Type | Size (km ²) | | | |
| Ireland | 4,581,269 | Urban & Rural | 70,182 | 65 | 1,462,296 | 5400 |
| Dublin City | 491,555 | Urban | 118 | 4176 | 190,984 | 588 |
| Limerick Clare Region | 289,932 | Urban & Rural Separately | 6205 | 47 | 102,525 | 404 |
| Wexford County | 130,518 | Urban & Rural | 2370 | 55 | 45,096 | 219 |
| Mayo County | 121,680 | Urban & Rural | 5589 | 22 | 43,431 | 170 |
| Dundalk Town [#] | 28,749 | Urban | 25 | 1164 | 10,186 | Not Available |
| Clonakilty District | 14,678 | Urban & Rural Separately | 331 | 44 | 4,879 | Not Available |

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

Table 2. Approach used to estimate the energy consumed in each sector by the different studies.

| Energy Balance | Industry | Transport | Residential | Services | Agriculture |
|--------------------------|-----------|--|--|-----------|---------------------------|
| Dublin City [9] | Top-Down | Top-Down | Bottom-Up: based on a DEAP simulation | Top-Down | n/a |
| Limerick-Clare [11] | Top-Down | Top-Down | Top-Down | Top-Down | Top-Down |
| County Wexford [12] | Top-Down | Top-Down | Top-Down | Top-Down | Top-Down |
| County Mayo [13] | Top-Down | Top-Down: modified on personal judgement | Top-Down: modified on personal judgement | Top-Down | Top-Down |
| Dundalk SEZ [1] | Bottom-Up | n/a | Bottom-Up | Bottom-Up | Bottom-Up: buildings only |
| Clonakilty District [16] | Bottom-Up | n/a | Bottom-Up | Bottom-Up | Bottom-Up |

METHODOLOGY

Based on the energy balance methodologies reviewed above, it was 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 developed 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 [1]. Considering the number of houses alone in the LCR is 102,435 [15], a top-down approach was chosen here.

Another important issue which needed to be considered in this report was the historical and future energy demand within the Limerick-Clare region. By outlining historical consumption, the local authorities could assess the CO₂ 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 1990-2009, 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 2 while the yellow 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.

Industry

At a national level, accounting for industry is relatively straight forward, since the boundary is defined by the country's boundaries. However, at a local level, it is much more complicated to define where exactly the boundary of an industry is.

Defining the boundary for industry at a local level is particularly complicated in the LCR due to the scale of industry located in the region. As outlined in Figure 4, four of the top fifteen industrial GHG emitters in Ireland are located in the LCR. These industrial facilities are so large it would be unfair to designate their consumption entirely to the LCR, especially since it is not only the local economy but also the national economy which benefits from their existence. Conversely though, it is inaccurate to exclude these facilities from the local energy

balance since this would excuse local regions from the consumption that is occurring in large-scale industrial facilities. As a compromise, it was concluded that the fairest way to document industrial consumption in a local energy balance is to create a national average consumption.

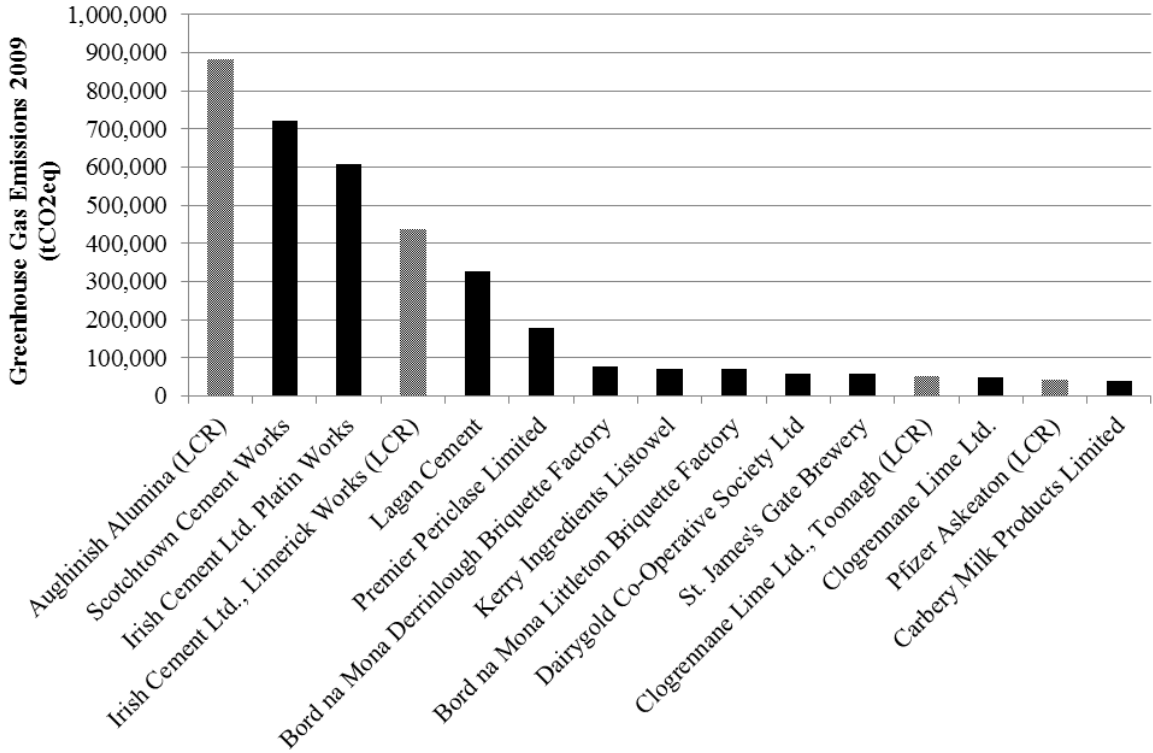


Figure 4. Top ten industrial greenhouse gas emitters in Ireland in 2009 [21].

Looking at the various metrics available, the number of industrial workers in the Nomenclature générale des Activités économiques dans les Communautés Européennes (NACE) sectors 13-37 was used to proportion national industrial energy consumption to a regional level. NACE is used to identify what the primary function of any 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 [22], industry converts any organisation under the NACE Rev 1.1 sectors 13-37 and hence these sectors were used here also. By averaging the total industrial demand in Ireland based on the number of workers, each local region is accepting an even proportion of responsibility for the consumption in large-scale industrial facilities.

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 significantly 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.

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 [23, 24], 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 [25].

An effort was also made to adjust this data based on local conditions such as house size, age of the houses, age of the occupants, and income of the occupants. However, the literature in this area [26-28] indicated that houses with older people, lower income households, and older houses have less energy saving measures installed, but houses with younger people, higher incomes, and new houses have more energy consuming appliances. In addition, “research conducted by Codema [29] 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” [9]. As a result, no significant relationship was identified in the literature which related key characteristics of a house to energy consumption and so, no local adjustment factor was applied after proportioning national data based on the number of private houses. In the future, if more detailed research reports the actual electricity and heat consumption based on the characteristics of a house, a local adjustment factor could be reassessed.

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 99.8% (average) of the total fuel consumed by transport between 1990 and 2009. Although this has slowly decreased in recent years to 98.4% in 2009, 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 5, illustrates the demand within these sectors in Ireland for 1990-2009, 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 shared: 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.

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 [12] assumed that only energy actually provided in the county of Wexford was defined as consumption. In the previous Limerick-Clare energy balance [11], 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 [9], 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 [13], 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.

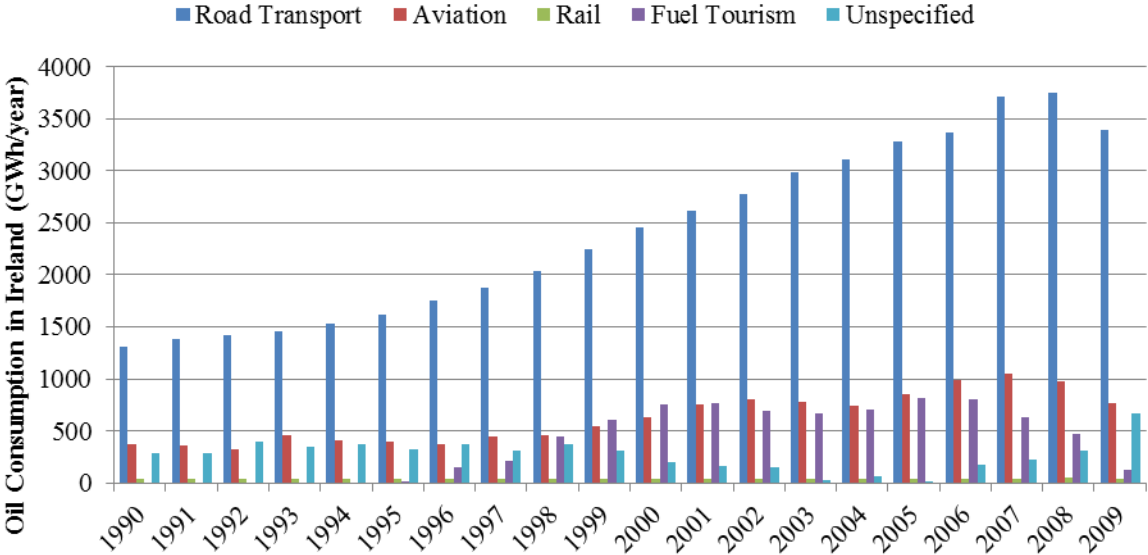


Figure 5. Oil demand in Ireland by mode of transport from 1990 to 2009.

Road. In line with the methodology outlined previously, the first step is to divide road transport into its subcategories. As outlined in Figure 6, these are private cars, road freight, and public passenger vehicles.

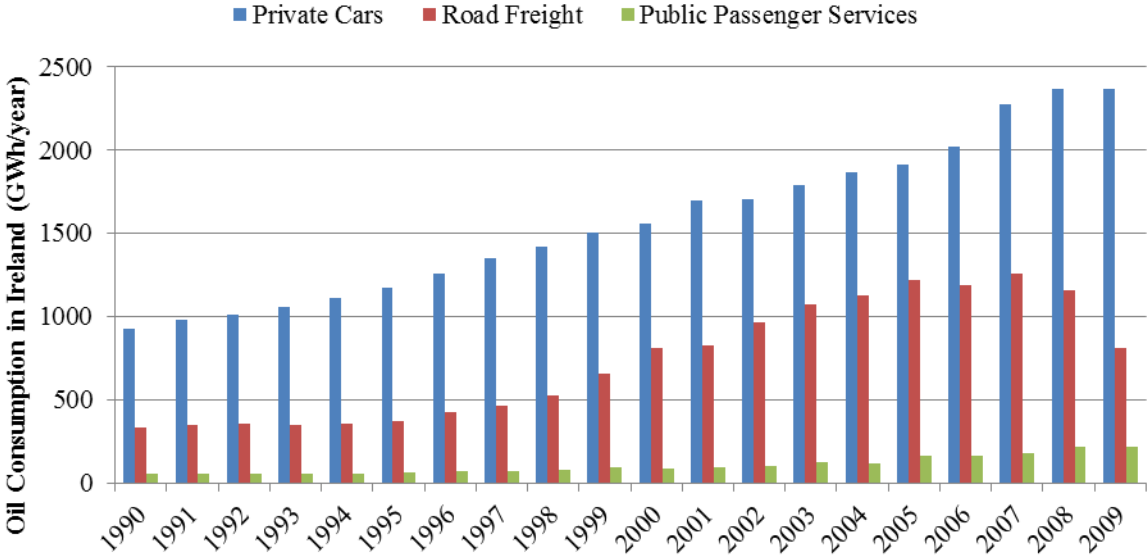


Figure 6. Oil consumed in Ireland by mode of road transport from 1990-2009.

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. Also, although no notable electricity consumption has been used for private cars in the past, this is likely to change in the future. Therefore, the local demand for electric transport was also obtained from national forecasts for 2020 using the ratio for the number of private cars.

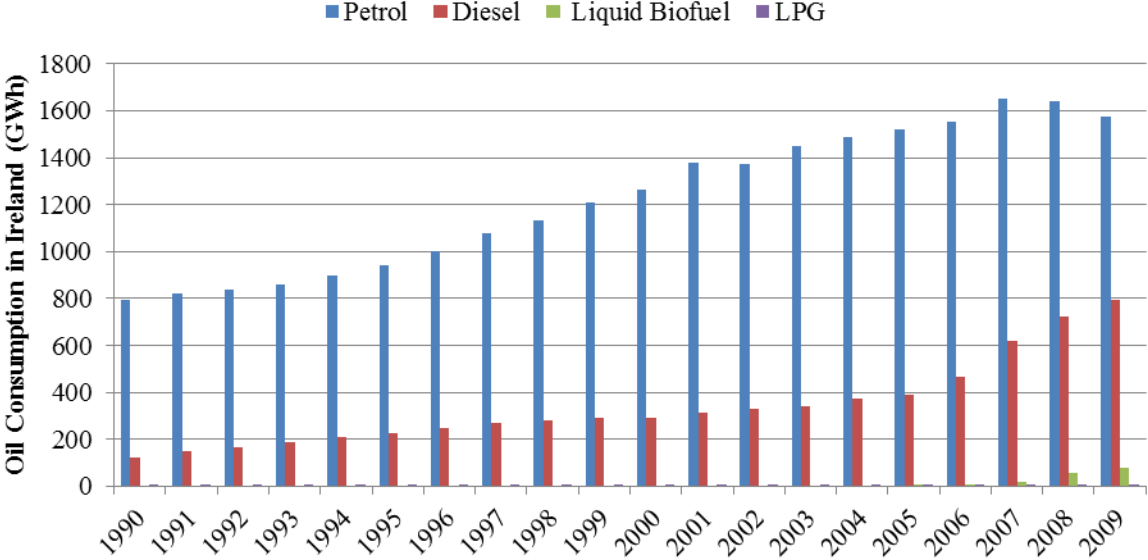


Figure 7. Type of fuel consumed by private cars in Ireland from 1990-2009.

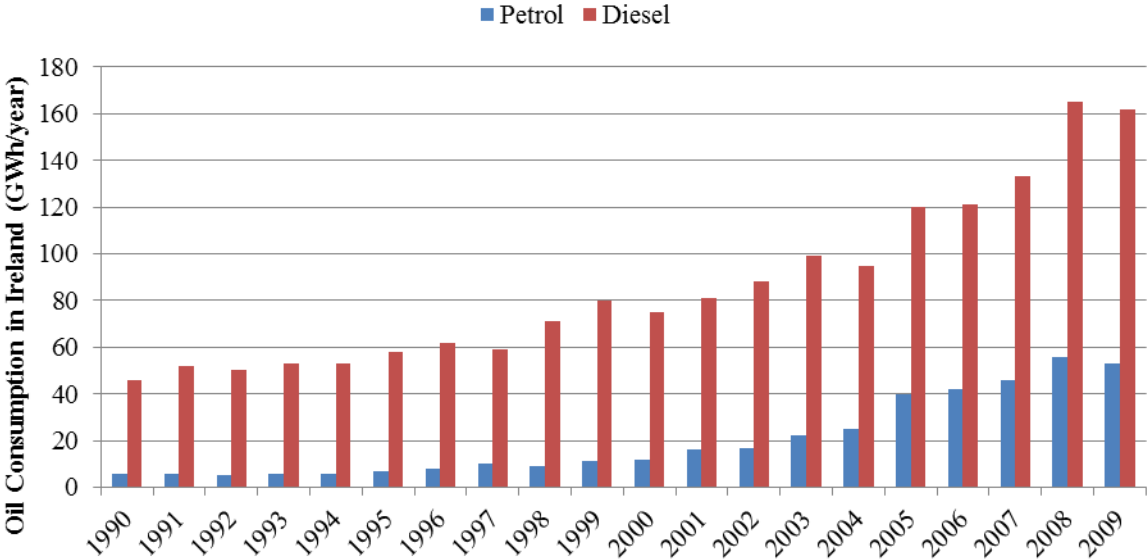


Figure 8. Type of fuel consumed by public passenger service vehicles in Ireland from 1990-2009.

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.

The public passenger service vehicles use both petrol and diesel, which is displayed in Figure 8. In the annual Irish transport statistics [30-41], 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.

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

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 [12], 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 [42]. Conversion factors from litres of diesel to kWh were then found from [43]: 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 1990-2009 (see Figure 5) and hence, it has only played a minor role in the past.

Aviation. Proportioning data on a per capita basis similar to that utilised in the Mayo energy balance [13] 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 municipality. Therefore, by proportioning these pieces of infrastructure on per capita basis, responsibility is taken for that energy in a fair way and so a per capita ratio was used.

Fuel Tourism. This 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.

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.

Agriculture

A number of key agricultural statistics are gathered by the Central Statistics Office of Ireland (CSO) at a national and local level approximately every 10 years in the "Census for Agriculture", which was most recently completed in 1991 [44] and 2000 [45]. 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 [11], the area farmed was deemed to be the most appropriate way to proportion national data to a local level.

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 [8], two methodologies were used. Firstly, where no trend was evident in the historical ratio between 1990 and 2009, then the average over this timeframe was used to proportion 2020 statistics. Secondly, where a trend was evident from the historical ratio between 1990 and 2009, 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.

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.

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 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 and so it is not necessary that it produces exact data. In addition, the recent recession in Ireland has outlined the unpredictability forecasting forward 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.

RESULTS AND DISCUSSION

Using the methodology above, an energy and emissions balance was developed for the LCR. Since the national energy balance in Ireland has been completed for each year since 1990, a local energy balance could also be developed for the LCR for each of these years. Since SEAI also forecast energy demand in Ireland for the year 2020 [7, 8], an energy balance was also developed for the LCR for the year 2020. This was based on the NEEAP/NREAP scenario created in the 2010 version of SEAI's forecasts [8], which 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) [46] and the National Renewable Energy Action Plan (NREAP) [47] for 2020. As outlined in Figure 9, energy consumption in Ireland has grown from approximately 84 TWh in 1990 to almost double that at 157 TWh in 2008. Over this timeframe, coal and peat consumption has been reduced, while all other fuels have increased, primarily oil.

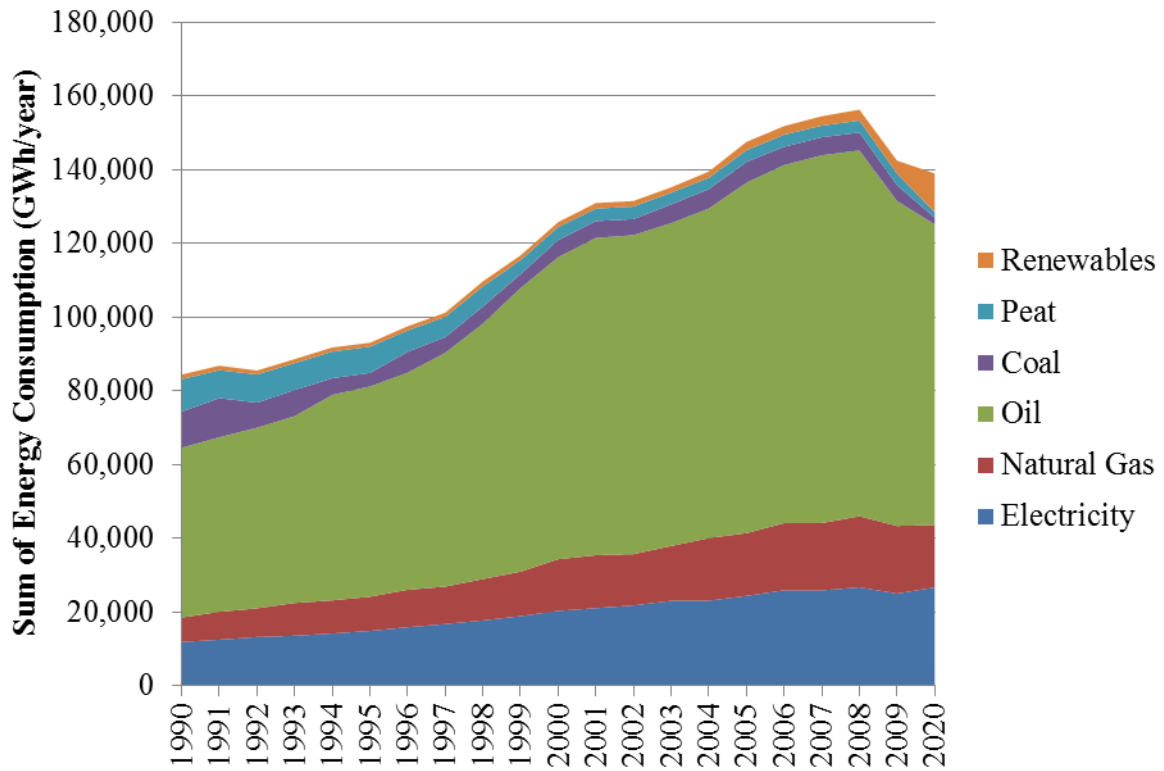


Figure 9. Historical energy consumption by fuel in Ireland from 1990-2009 and forecasted consumption to 2020 [8, 22].

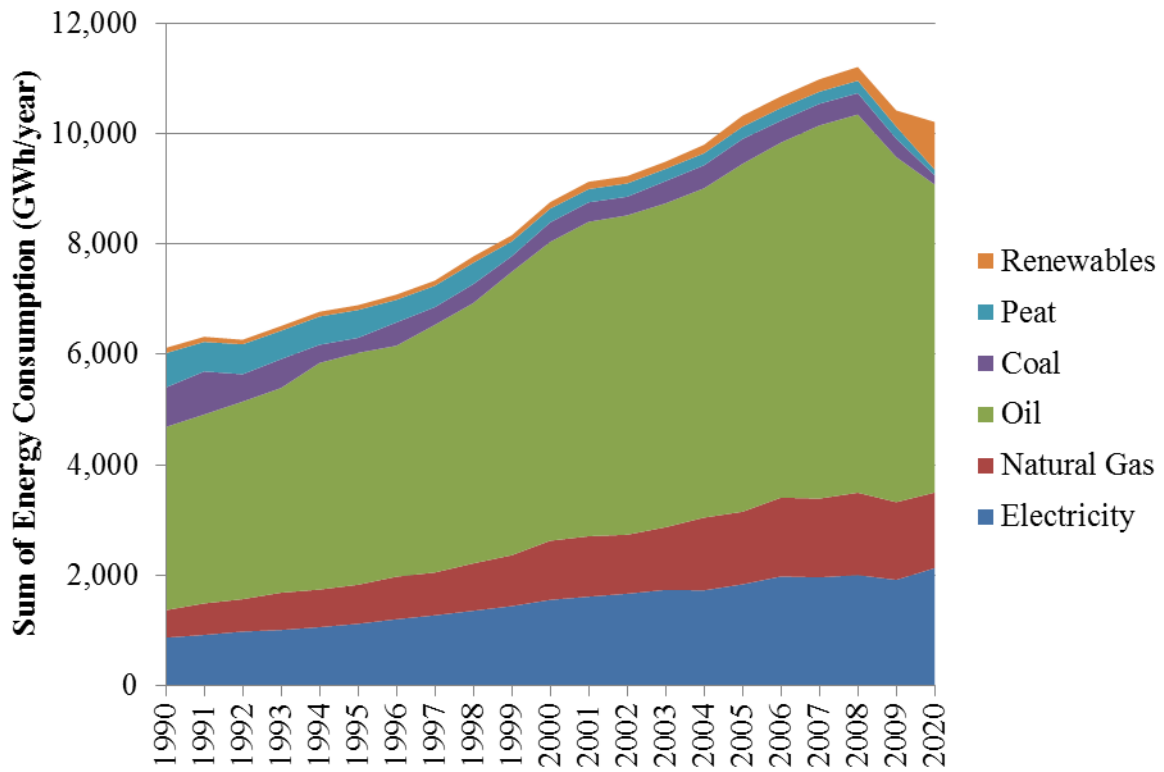


Figure 10. Energy consumption by fuel in the LCR from 1990-2009 and 2020.

These trends have been mirrored at a local level in the LCR, which had a peak energy consumption of approximately 11 TWh in 2008. Over the entire period from 1990-2009, the LCR had an total energy consumption between 7-7.4% of the national energy demand. In addition, oil was the primary fuel which supplied this growth in energy demand in the LCR. Looking at the energy consumption by sector in Figure 11, it is clear that transport is the primary contributor to the growth in energy demand between 1990 and 2009. This demonstrates why oil has also grown so rapidly, since it is currently the only widespread liquid fossil fuel available.

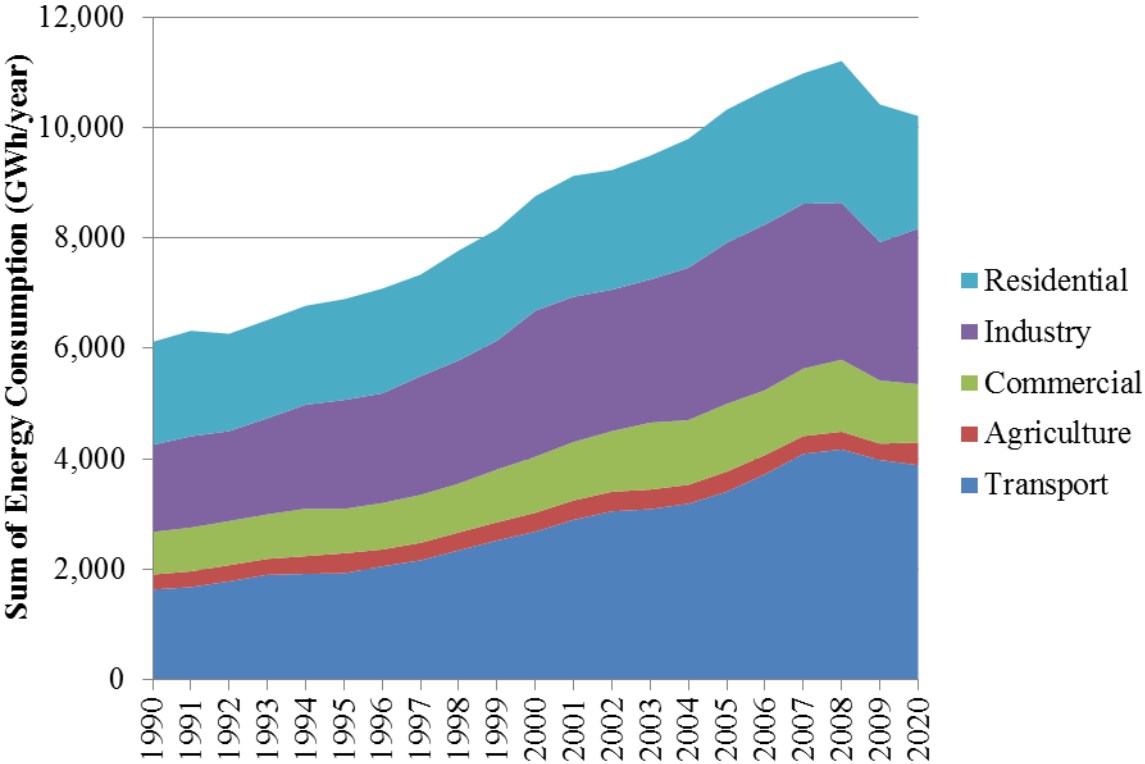


Figure 11. Energy consumption by sector in the LCR from 1990-2009 and 2020.

Based on energy forecasts for 2020, it is evident from Figure 10 that the LCR’s dependence on oil will remain, as it will continue to be the most prominent fuel in the energy mix. In addition, even when the actions in the NEEAP and the NREAP are implemented, Figure 10 indicates that overall consumption is only reduced by approximately 2% in the LCR, which Figure 11 indicates is primarily due to industry and transportation. However, after converting the energy balance to an emissions balance based on the data in Table 3, it was clear from Figure 13 that the carbon dioxide emissions are 30% lower in 2020 compared to 2009. This is primarily due to the increased supply of renewable energy in the electricity sector: especially the wind power capacity increase of 118 MW in 2009 to 330 MW in 2020. Once again, Figure 13 demonstrates the key concern with oil consumption and the transportation sector for the LCR in the future.

Table 3: Carbon dioxide intensity for each fuel [48].

| Fuel | Coal | Peat | Oil | Petrol | Diesel | Jet Fuel | Fuel Oil | LPG | Natural Gas |
|--------------------------|------|------|-----|--------|--------|----------|----------|-----|-------------|
| CO2 Emissions (tCO2/GWh) | 341 | 369 | 261 | 252 | 264 | 257 | 274 | 229 | 57 |

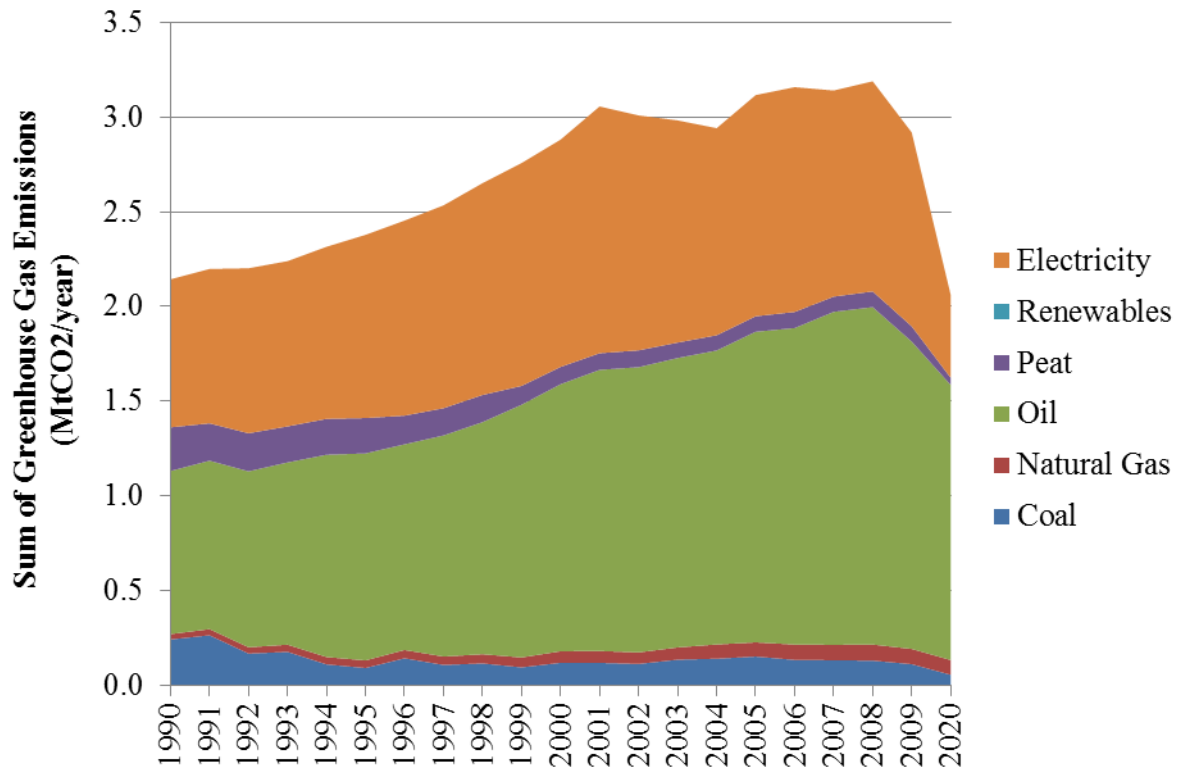


Figure 12. Energy-related greenhouse gas emissions in the LCR from 1990-2009 and for 2020.

Finally, 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 4, which correspond to an oil price of US\$60/barrel in 2009 and US\$105/barrel in 2020. In addition, the historical oil prices illustrated in Figure 13 were applied to their corresponding years using the same ratios as displayed in Table 4 to estimate the fuel costs from 1990-2008.

Table 4. Fuel prices assumed for 2009 and 2020 [49, 50].

| Year | Crude Oil US\$2009 / barrel | Fuel Prices (€2009/GJ) | | | | | | | | | |
|------|-----------------------------|------------------------|------|------|--------|--------|----------|----------|-----|-------------|------------|
| | | Coal | Peat | Oil | Petrol | Diesel | Jet Fuel | Fuel Oil | LPG | Natural Gas | Renewables |
| 2009 | 60 | 1.4 | 1.4 | 6.7 | 8.9 | 8.4 | 8.9 | 4.7 | 4.7 | 4.1 | 4.0 |
| 2020 | 105 | 2.6 | 2.6 | 12.6 | 16.8 | 15.8 | 16.8 | 8.8 | 8.8 | 7.8 | 7.5 |

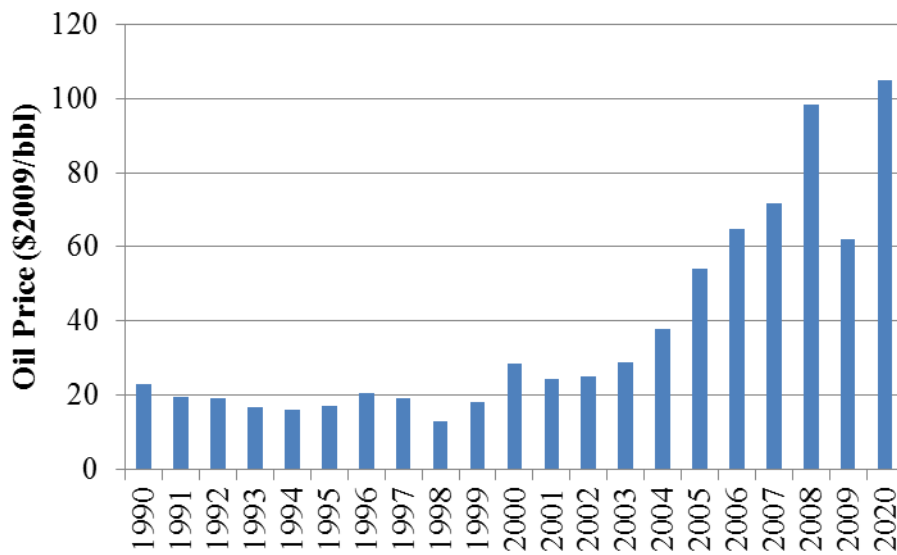


Figure 13. Historical oil price for 1990-2009 [51] and projected oil price for 2020 [50].

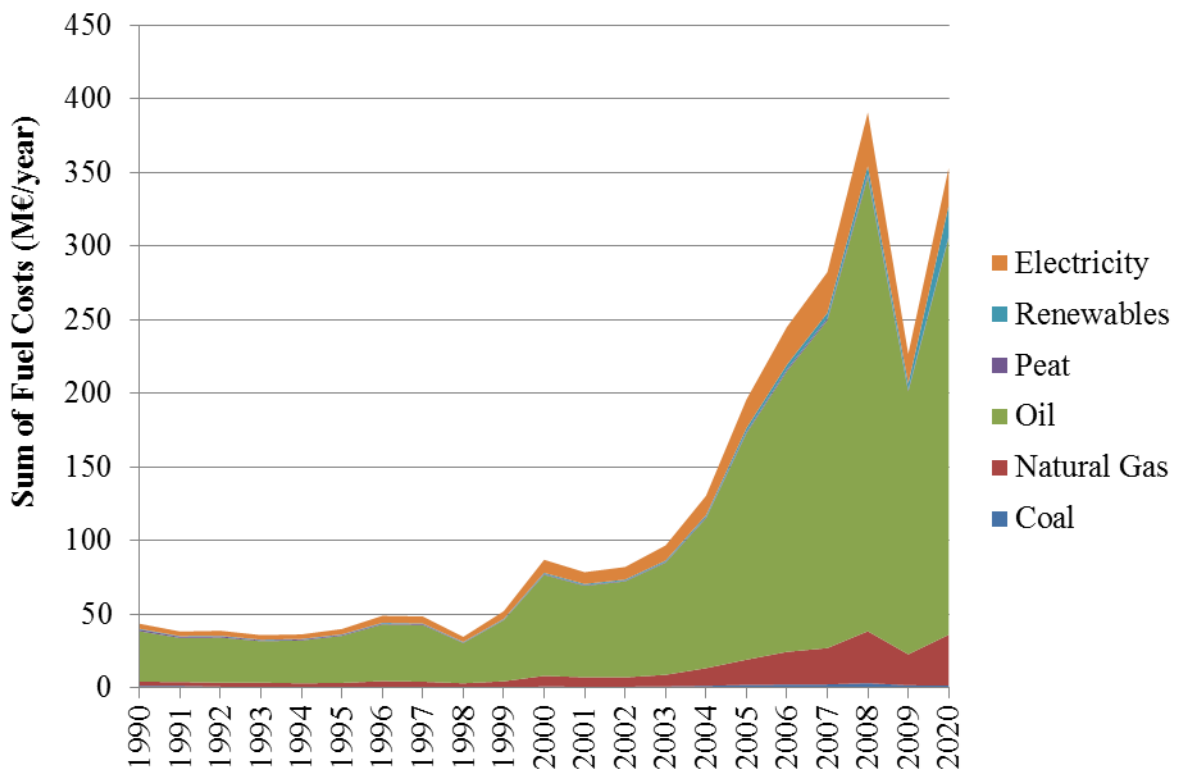


Figure 14. Expenditure on fuel in the LCR from 1990-2009 and for 2020.

Using these cost assumptions, Figure 14 illustrates the dramatic increase in the cost of fuel in the LCR since 1998. In fact, between 1998 and 2008, the cost of fuel in the LCR increased by approximately 29% on average each year, until eventually falling by 42% in 2009 due to the economic recession. As a result, the cost of fuel in the LCR grew from just under M€50/year throughout the 1990s to over M€350/year in 2008. Also as Figure 14 shows, with increasing fuel prices expected between now and 2020 [50], the cost of fuel in the LCR is expected to

reach M€350/year again in 2020, even with the implementation of all the actions in the NEEAP and the NREAP. Even more concerning is the fact that there is no oil, coal, or natural gas available in the LCR and since an estimated M€306/year will be spent on these fuels in 2020, it is clear that alternative sustainable sources must be identified in the region. Hence, this will be the primary future objective of this work, which will be completed by transferring the LCR energy balance into the energy-systems-analysis tool, EnergyPLAN [52]. With this model, various sustainable energy alternatives will be analysed to identify how the region can reduce its energy consumption and increase renewable energy generation in the most cost-effective manner.

CONCLUSION

It is evident from the results presented here that the LCR is heavily dependent on fossil fuels which cannot be found within the region. As a result, it has been estimated that over 80% of the LCR's energy demands will be met by fossil fuels in 2020 and at least M€300 will be spent on importing these fuels into the region. This is a very insecure and expensive scenario for the region. As a result, the next step in this research is to input the energy balance developed in this study into the energy-systems-analysis tool, EnergyPLAN. Subsequently, a local energy strategy can be created for the LCR, which identifies how the region can utilise more renewable energy and reduce its energy-related CO₂ emissions.

NOMENCLATURE

| Abbreviation | Description |
|--------------|---|
| CER | Commission for Energy Regulation (Ireland) |
| CSO | Central Statistics Office of Ireland |
| GHG | Greenhouse Gas |
| LCEA | Limerick Clare Energy Agency |
| LCR | Limerick-Clare Region |
| LEU | Large Energy User |
| NACE | Nomenclature générale des Activités économiques dans les Communautés Européennes (Statistical classification of economic activities in the European Communities). |
| NEEAP | National Energy Efficiency Action Plan |
| NREAP | National Renewable Energy Action Plan |
| SEAI | Sustainable Energy Authority of Ireland |

REFERENCES

- [1] O'Hara, A. Guidelines for a Sustainable Energy Community. *Sustainable Energy Authority of Ireland*, 2011. Available from: [http://www.seai.ie/SEC/Toolkit/Guidelines for a Sustainable Energy Community.pdf](http://www.seai.ie/SEC/Toolkit/Guidelines%20for%20a%20Sustainable%20Energy%20Community.pdf).
- [2] Steidle, T., Schelenzig, C., Vincenzo, C., Macchiato, M., Lavangno, E., Rydèn, B., Willemsen, S., Grevers, W., Jank, R. Advanced Local Energy Planning: A Guidebook. *International Energy Agency*, 2000. Available from: <http://www.iea-alep.pz.cnr.it/>.
- [3] UN-HABITAT. Sustainable Urban Energy Planning: A handbook for cities and towns in developing countries. *UN-HABITAT*, 2009. Available from: <http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2839>.

- [4] *Limerick Clare Energy Agency*. Welcome to the Limerick Clare Energy Agency Website. Available from: <http://www.lcea.ie/> [accessed 23 August 2010].
- [5] *The Irish Regions Office*. Regions of Ireland: the Mid-West. Available from: http://www.iro.ie/midwest_region.html [accessed 11 September 2011].
- [6] *Funtrek*. Shannonside Ireland. Available from: <http://www.funtrek.com/ireland/maps/map-Shannon.htm> [accessed 11 September 2011].
- [7] Walker, N., Scheer, J., Clancy, M., Ó'Gallachóir, B. Energy Forecasts for Ireland to 2020. *Energy Modelling Group, Sustainable Energy Authority of Ireland*, 2009. Available from: http://www.seai.ie/Publications/Statistics_Publications/Energy_Modelling_Group/Energy_Forecasts_for_Ireland_to_2020.pdf.
- [8] Clancy, M., Scheer, J., Ó'Gallachóir, B. Energy Forecasts for Ireland to 2020. *Energy Modelling Group, Sustainable Energy Authority of Ireland*, 2010. Available from: http://www.seai.ie/Publications/Statistics_Publications/Energy_Modelling_Group/Energy_Forecasts_for_Ireland_to_2020-2010_report.pdf.
- [9] Wardell, G., Hayden, J., Kranzl, S., McCormac, D. Baseline Emission Inventory for Dublin City Sustainable Energy Action Plan 2010-2020. *Codema*, 2008. Available from: <http://www.codema.ie/report-article/date/2009/07/27/action-plan-on-energy-for-dublin-consultation-draft.html>.
- [10] Codema. Dublin City Sustainable Energy Action Plan 2010-2020. *Codema*, 2010. Available from: <http://www.codema.ie/report-article/date/2009/07/27/action-plan-on-energy-for-dublin-consultation-draft.html>.
- [11] Limerick Clare Energy Agency. Limerick and Clare Energy & Emissions Balance. *Limerick Clare Energy Agency*, 2006. Available from: <http://www.lcea.ie/Publications.asp>.
- [12] Curtin, R. An energy balance and greenhouse gas profile for county Wexford, Ireland in 2006, *Applied Energy*, Vol. 88, No. 11, pp 3773-3781, 2011.
- [13] Wilson, A., Lynch, P. Mayo Energy Audit 2009-2020. *Sustainability Institute*, 2008. Available from: <http://www.sustainability.ie/audit.html>.
- [14] *Sustainable Energy Authority of Ireland*. Energy Master Plan Tool. Available from: http://www.seai.ie/SEC/Toolkit/Energy_Master_Plan_Tool/ [accessed 10 August 2011].
- [15] Central Statistics Office Ireland. Census 2006: Housing. *Central Statistics Office Ireland*, 2007. Available from: <http://www.cso.ie/census/>.
- [16] Dubuisson, X., Kupova, D., Stuart, J. Renewable Energy Study 2011: A Roadmap Towards Energy Neutrality in the Clonakilty District by 2020. *Delap and Waller EcoCo, Sustainable Clonakilty, West Cork Development Partnership*, 2011. Available from: <http://www.sustainableclon.com/wb/wb/pages/renewable-energy-study-report-2011.php>.
- [17] *Central Statistics Office of Ireland*. Sap Map. Available from: <http://census.cso.ie/sapmap> [accessed 11 August 2011].
- [18] *Central Statistics Office of Ireland*. 2006 Sap Themes - Electoral Division, Province and County. Available from: http://census.cso.ie/censusasp/saps/Pages/Select_Theme_Table6_live.asp [accessed 10 August 2011].
- [19] Central Statistics Office Ireland. Census 2006: Areas. *Central Statistics Office Ireland*, 2006. Available from: http://www.cso.ie/census/census2006_volume_1.htm.

- [20] Central Statistics Office (Ireland). Census Population 2011: Preliminary Results. *Central Statistics Office (Ireland)*, 2011. Available from: http://www.cso.ie/census/2011_preliminaryreport.htm.
- [21] Environmental Protection Agency. Varified Emissions 2008-2010. *Environmental Protection Agency*, 2011. Available from: <http://www.epa.ie/whatwedo/climate/emissionstrading/etscheme/verifiedemissions2008-2010/>.
- [22] *Sustainable Energy Authority of Ireland*. 1990-2009 Energy Balances. Available from: http://www.seai.ie/Publications/Statistics_Publications/Energy_Balance/Previous_Energy_Balances/ [accessed 9 August 2011].
- [23] Central Statistics Office Ireland. Census 1991 Volume 3: Household Composition and Family Units. *Central Statistics Office Ireland*, 1994. Available from: http://cso.ie/census/census_1991_volume_3.htm.
- [24] *Central Statistics Office Ireland*. Census Interactive Tables for Censuses 1996, 2002, 2006. Available from: http://census.cso.ie/census/ReportFolders/ReportFolders.aspx?CS_referer=&CS_ChosenLang=en [accessed 12 August 2011].
- [25] *Department of the Environment, Heritage & Local Government*. House Completions (Number) by Local Authority, Year and Housing Sector. Available from: <http://www.cso.ie/px/DoEHLG/Dialog/varval.asp?ma=HSA11&ti=House+Completions+%28Number%29+by+Local+Authority,+Year+and+Housing+Sector&path=../Database/DoEHLG/Housing%20Statistics/&lang=1> [accessed].
- [26] Leahy, E., Lyons, S. Energy use and appliance ownership in Ireland, *Energy Policy*, Vol. 38, No. 8, pp 4265-4279, 2010.
- [27] O'Doherty, J., Lyons, S., Tol, R. S. J. Energy-using appliances and energy-saving features: Determinants of ownership in Ireland, *Applied Energy*, Vol. 85, No. 7, pp 650-662, 2008.
- [28] Watson, D., Williams, J. Irish National Survey of Housing Quality. *The Economic and Social Research Institute*, 2003. Available from: <http://www.esri.ie/UserFiles/publications/20100202150625/BKMNINT173.pdf>.
- [29] Hayden, J. Assessment of the Accuracy of the Heat Energy Rating. *M.Sc. Thesis*, Dublin Institute of Technology, Dublin, 2004.
- [30] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 1990. Available.
- [31] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 1995. Available.
- [32] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 2000. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [33] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 2001. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [34] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and*

- Local Government (Ireland)*, 2002. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [35] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 2003. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [36] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 2004. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [37] Department of Environment, Community and Local Government (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Environment, Community and Local Government (Ireland)*, 2005. Available from: <http://www.environ.ie/en/Publications/StatisticsandRegularPublications/VehicleDriverStatisticsBulletin/>.
- [38] Department of Transport (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Transport (Ireland)*, 2006. Available from: <http://www.transport.ie/roads/reports/index.asp?lang=ENG&loc=397>.
- [39] Department of Transport (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Transport (Ireland)*, 2007. Available from: <http://www.transport.ie/roads/reports/index.asp?lang=ENG&loc=397>.
- [40] Department of Transport (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Transport (Ireland)*, 2008. Available from: <http://www.transport.ie/roads/reports/index.asp?lang=ENG&loc=397>.
- [41] Department of Transport (Ireland). Irish Bulletin of Vehicle and Driver Statistics. *Department of Transport (Ireland)*, 2009. Available from: <http://www.transport.ie/roads/reports/index.asp?lang=ENG&loc=397>.
- [42] *Iarnród Éireann (Limerick District Regional Office)*, Average annual diesel fuel consumed in Limerick train station. Personal Communication, 2011. Received 18 August 2011.
- [43] AEA. Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. *UK Department of Energy and Climate Change (DECC) and the UK Department for Environment, Food and Rural Affairs (Defra)*, 2011. Available from: <http://archive.defra.gov.uk/environment/business/reporting/pdf/110707-guidelines-ghg-conversion-factors.pdf>.
- [44] Central Statistics Office Ireland. Census of Agriculture June 1991. *Central Statistics Office Ireland*, 1994. Available.
- [45] Central Statistics Office Ireland. Census of Agriculture Main Results June 2000. *Central Statistics Office Ireland*, 2002. Available from: http://www.cso.ie/releasespublications/pr_agrifishpubshardcopies.htm.
- [46] Department of Communications, Energy and Natural Resources (Ireland). Maximising Ireland's Energy Efficiency - The National Energy Efficiency Action Plan 2009 - 2020. *Department of Communications, Energy and Natural Resources (Ireland)*, 2009. Available from: <http://www.dcenr.gov.ie/Energy/Energy+Efficiency+and+Affordability+Division/National+Energy+Efficiency+Action+Plan.htm>.

- [47] National Renewable Energy Action Plan: Ireland. *Department of Communications, Energy and Natural Resources*, 2010. Available from: <http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/National+Renewable+Energy+Action+Plan.htm>.
- [48] Howley, M., Dennehy, E., Ó'Gallachóir, B. Energy in Ireland 1990 - 2009. *Energy Policy Statistical Unit, Sustainable Energy Authority of Ireland*, 2010. Available from: http://www.seai.ie/Publications/Statistics_Publications/Energy_in_Ireland/.
- [49] Mathiesen, B. V., Lund, H., Karlsson, K. The IDA Climate Plan 2050. *The Danish Society of Engineers and Aalborg University*, 2009. Available from: <http://ida.dk/News/Dagsordener/Klima/Klimaplan2050/Sider/Klimaplan2050.aspx>.
- [50] International Energy Agency. World Energy Outlook 2010. *International Energy Agency*, 2010. Available from: <http://www.iea.org/weo/2010.asp>.
- [51] British Petroleum. BP statistical Review of World Energy. *British Petroleum*, 2010. Available from: <http://www.bp.com/statisticalreview>.
- [52] *Aalborg University*. EnergyPLAN: Advanced Energy System Analysis Computer Model. Available from: <http://www.energyplan.eu/> [accessed 14th September 2010].