DUBLIN CITY BASELINE EMISSIONS REPORT

2016

Comhairle Cathrach Bhaile Átha Cliath
Dublin City Council

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

codema Dublin's Energy Agency

Report prepared by Codema on behalf of Dublin City Council, with support from the Sustainable Energy Authority of Ireland.

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Executive Summary

Codema conducted this analysis in order to advance energy and CO_2 emission baseline methodologies in Ireland, so that they may be replicated by other local authorities. This report follows on from Codema's summary report 'Dublin Region's Baseline Emissions Inventory 2016', which was funded under the Sustainable Energy Authority of Ireland (SEAI), Research, Development and Demonstration (RD&D) 2017 programme.

This baseline report aims to raise awareness of climate change and the impact that different sectors in the Dublin region have on Ireland's overall carbon emissions. It provides local authorities with the necessary information to make decisions on climate change actions to lower the city's carbon emissions.

This is a city-wide baseline and will be used as part of Dublin City Council's Climate Change Action Plan, which details the actions that are planned in order to curtail energy consumption and CO_2 emissions in the Dublin City region. This assessment is part of the commitment that the Dublin Local Authorities (DLAs) have made as signatories to the European Union's Covenant of Mayors for Climate and Energy Initiative. This involves the monitoring of city-level energy consumption and CO_2 emissions, and reporting on the progress of energy and emission actions which affect the local authority area.

The baseline year for this analysis is 2016, except for transport, which was based on 2012 data from the National Transport Authority (NTA), and projected up to 2016. The sectors that have been included in this analysis are: residential, commercial, transport, social housing, municipal, waste, and wastewater.

Codema found that the total emissions from various sectors in Dublin City total the equivalent of 2,810,800 tonnes of CO_2, which is the equivalent to 5.1 tCO_2eq per capita. The sectors that produced the most emissions were residential, commercial and transport, producing 35%, 33% and 25% respectively, of the total emissions in Dublin City. From this analysis, these three sectors should be the main targets of energy and emission initiatives.

Codema also calculated the total energy use in Dublin City to be 9,771 gigawatt hours (GWh). This energy figure excludes energy use from waste and wastewater, since a total CO_2 equivalent was estimated for these sectors. It should be noted that energy from renewables only contributed 2% to the total fuel mix in Dublin City. Of this renewable energy, 1.1% came from biomass sources.

This report also shows that the total energy use in the housing sector (both the residential and social housing sectors) decreased by 12% from 2011 to 2016. Energy use per dwelling reduced from 21.8 megawatt hours (MWh) in 2011 to 18.9 MWh in 2016. This change in energy is due to better energy ratings in the housing sector. In 2011, the most common Building Energy Rating (BER) for a Dublin City dwelling was a very poor 'G' rating; however, this has since improved somewhat to a D2 rating in 2016.

From 2011 to 2016, energy use in the commercial sector increased by 9%. The highest increase in energy within this sector came from services (10%), followed by the industrial activities at 5%. This increase in energy use may be attributed to an increase in floor areas by different commercial properties, namely industrial uses and retail (warehouses and shops).

Over the same period, Dublin City Council reduced its own energy use by 12%. This energy reduction comes mainly from the council's buildings and facilities, which reduced their energy use by 19% in total. Meanwhile, energy increased in public lighting from 26 GWh in 2011 to 27 GWh in 2016.

Residential

- Total residential emissions were 974,000 tonnes of CO_2 in 2016
- Total delivered energy for the residential sector in Dublin City for 2016 was 3,596 GWh
- 43% of the housing stock was C3 or better, with D2 the most common rating
- Terraced houses made up 37% of the total residential housing stock, followed by apartments (33%), semi-detached (24%) and detached houses (6%), respectively
- Apartments were the least carbon intensive type of housing, emitting 4.20 tCO_2/apartment

- Detached houses were the most carbon intensive type of housing, emitting 9.46 tCO_2/detached house

Commercial

- Total emissions in 2016 were 934,000 tonnes of CO_2; 806,700 tonnes of CO_2 from services sector and the remaining 127,300 tonnes of CO_2 came from the industrial sector
- Total final energy used in 2016 in the commercial sector was 2,976 GWh
- Industrial uses (32%), retail (26%), offices (17%) and hospitality (17%) contributed the most to CO_2 emissions
- Hospitality and leisure held the highest emissions per property, 230.5 tCO_2 and 230.6 tCO_2 respectively
- Utility, miscellaneous uses and offices had the lowest emissions per property, 13.2 tCO_2, 14.3 tCO_2 and 20.0 tCO_2, respectively

Transport

- Total final emissions from transport were 697,700 tonnes of CO_2
- Total energy use in transport was 2,672 GWh
- Dublin City's modal split was made up of 43% private and commercial transport, public transport, 20%, walking, 30%, and cycling 7%
- Transport emissions came from diesel (75%), gasoline (25%), electricity (0.2%) and LPG (0.1%)

Social Housing

- Total final emissions from social housing were 94,000 tonnes of CO_2 in Dublin City
- Total delivered energy in 2016 was 396 GWh for social housing in Dublin City
- 30% of the social housing stock in Dublin City was rated C3 or better, with F being the most common BER type
- The majority of social housing units were apartments and terraced houses, making up 47% and 35% respectively of the total social housing stock, followed by semi-detached (17%) and detached (1%)
- Apartments were the least carbon intensive type of housing, emitting 2.92 tCO_2 per unit
- Detached, semi-detached and terraced houses were the highest emitters per dwelling, at 3.47, 3.93 and 3.97 tCO_2/house, respectively

Municipal

- Total final emissions produced by Dublin City Council in 2016 were 38,800 tonnes of CO_2
- Total final energy used in 2016 in DCC was 117 GWh
- Buildings and facilities contributed 55% of total emissions in DCC, followed by public lighting at 33%, and municipal fleet at 12%

Waste

- Total emissions from landfills in Dublin City were estimated at 52,700 tonnes of CO_2eq
- Methane made up 85% of total CO_2 equivalent emissions from landfills

Wastewater

- Total emissions from wastewater in Dublin City was 12,700 tonnes of CO_2eq
- Wastewater emissions per person per annum were estimated to be 23$KgCO_2eq$

Introduction

Codema has produced the following report on behalf of Dublin City Council (DCC) and outlines the methodologies and results of Dublin City's energy use and emissions in different sectors.

Codema conducted this analysis, in order to advance energy and CO_2 emission baseline methodologies in Ireland, so that they may be replicated by other local authorities. This report follows on from Codema's summary report 'Dublin Region's Baseline Emissions Inventory 2016' which was funded under the Sustainable Energy Authority of Ireland (SEAI), Research, Development and Demonstration (RD&D) 2017 programme.

This baseline report aims to raise awareness of climate change and the impact that different sectors in Dublin City have on Ireland's overall carbon emissions and energy use. It provides DCC with the necessary information to make decisions on climate change actions to lower the city's carbon emissions in the areas they have responsibility for.

Context

Climate Change Challenges

Climate change is widely recognised as the greatest environmental challenge of our time. The evidence of this can be seen globally; in Ireland this is demonstrated by rising sea levels, extreme weather events and changes in the eco-system.

A multitude of evidence and research-based reports have shown an irrefutable indication that greenhouse gas (GHG) emissions are responsible for climate change, and it is imperative to act now in order to reduce the amount of irreversible damage caused by these emissions.

The Intergovernmental Panel on Climate Change (IPCC) stated that GHG emissions have increased by 70% between 1970 and 2004, due to human activity (IPCC, 2007), meaning that human activity is the driving factor for climate change.

Ireland has committed to reduce its emissions by the year 2020 and 2030 (relative to 2005 levels). The significance of Dublin City in the Irish economy means that it is imperative to plan and commit to energy saving and CO_2 reductions at a local and regional level, in order to meet national level targets from a bottom-up approach.

It is particularly important for urban regions to focus on their reduction in emissions, as more than 70% of global emissions are caused by activities in urban areas, such as manufacturing, transportation and energy demand (Shaoqing et al. 2015). Carbon sinks tend to be limited in cities, given the amount of built-up areas, and the limited amount of natural eco-systems, which have the ability to absorb CO_2.

The National Transport Authority (NTA) conducted National Travel Surveys in 2014 and found that 67% of domestic travel conducted by Irish residents in 2014 was in the Dublin region. Therefore, cities are one of the main sources of carbon emissions and may be the solution to leading a low-carbon economy and sustainable future.

There are many significant additional benefits to reducing CO_2 levels and increasing the share of renewable energies. These include a decrease in dependency on fossil fuels, which in turn results in a higher security of energy supply, better health, lower energy costs, an increase in the city's competitiveness, and a more sustainable economy.

Changes in the Irish economy

Ireland experienced a deep economic recession between 2008 and 2011, which led to significant changes in economic activity. The downturn had an effect, as later analysed, on energy in all sectors, particularly in commercial and transport. The unemployment rate rose by 221%, when compared to 2006 levels (Central Statistics Office, 2011). Energy consumption per household also fell by 18% from 2006 levels (SEAI, 2013).

The economic recession also had an adverse effect on the amount of equity available in the public and private sector to invest in energy-saving and renewable energy projects.

Since 2011, Ireland has been slowly recovering from the recession with unemployment figures decreasing from 295,700 at the start of 2011 to 172,900 at the end of September 2016. This represents a reduction of 41% in unemployment (Census 2011, 2016).

GDP and construction have both increased nationally, by 5.1% and 15.1% respectively, when compared to

2015 (Census 2016). Activity in Irish roads and infrastructure is once again growing. The Luas line in Dublin has recently been extended and is in operation since the end of 2017 (Luas Cross City), accommodating an additional 10 million passenger journeys per year.

All the evidence from national surveys point towards a growing economy that is still, however, recovering from an economic recession.

Energy and Emission Targets

2020 Energy & Emission Targets

The EU has set out targets for 2020 for all its member states. The 2020 targets for climate change and energy are:

- 20% increase in energy efficiency
- 20% of energy to be supplied by renewables
- A reduction of 20% in greenhouse gas emissions from 2005 levels

Different targets are given to different countries, depending on their energy use and amount of renewables. Therefore, the overall 2020 target for Ireland is 16% of total final energy use to come from renewable energy. This target will have to be reached by making use of renewable energy in electricity, transport and energy for both heating and cooling.

2030 Emission Reduction Targets

The 2030 Emission Reduction Targets were set by the Covenant of Mayors for Climate and Energy, of which DCC is a signatory. The 2030 target is a 40% reduction in emissions from the baseline year

The Covenant of Mayors for Climate and Energy is a voluntary initiative made by local and regional authorities, which will implement EU targets, namely the 40% GHG reduction target by 2030. All EU states which are signatories to the CoM share the common goal of decarbonising their countries or region by 2050. Signatories are also expected to integrate approaches to tackle climate change through mitigation and adaptation, and to increase their ability to adapt to the impacts of climate change.

Changes in Energy Use in Dublin City

This report focuses on energy use and emissions from different carbon-emitting sectors. As part of this study, energy use in 2016 from the housing, commercial and municipal sectors were compared to energy use in 2011.

From this report, Codema found that the total energy use in the housing sector (both residential and social housing) decreased by 12% over the five year period. Energy use per dwelling reduced from 21.8 MWh in 2011 to 18.9 MWh in 2016. This change in energy can be attributed to better energy ratings in the housing sector. The most common energy rating in housing was a G rating in 2011; however, in 2016, this average rating had improved somewhat to a D2.

From 2011 to 2016, energy use in the commercial sector increased by 9%. The highest increase in energy came from the services sector at 10%, followed by the industry sector at 5%. This increase in energy use may be attributed to an increase in floor areas by different commercial properties, namely industrial uses and retail (warehouses and shops).

Over the same period, Dublin City Council reduced its own energy use by 12%. This energy reduction comes mainly from its buildings and facilities, which reduced their energy use by 19%. Meanwhile, energy increased in public lighting from 26 GWh in 2011 to 27 GWh in 2016.

A more comprehensive analysis of the change in energy use in these sectors may be found in the following chapter: 2016 Energy Use in Comparison with 2011.

Emission Sectors

This section outlines the methodologies used to update and estimate the energy consumption and associated CO_2 emissions in different sectors in Dublin City.

This study has been conducted for different energy-consuming and GHG-emitting sectors for the year 2016, namely residential, commercial, transport, social housing, municipal, waste and wastewater.

2016 was chosen as the baseline year, mainly due to the 2016 national Census. The national Census is the base of most of the methodologies developed by Codema.

Codema analysed the available data for each sector in order to identify the most suitable methodology for the calculations. This took into account the fact that these methods must be accurate, simple and easy to replicate, in order to allow regular updates in the future and facilitate the adaptation of this methodology across Ireland. The analysis focused on the current energy demand and fuels that are used to provide energy, and the associated CO_2 emissions and GHG emissions related to activities (waste and wastewater) within Dublin City.

Emission Factors

Emission factors are used to convert energy use to CO_2 emissions. The emission factors are dependent on the type of fuel used, as different fuels have different emission factors. For example, renewable energy like photovoltaics would have an emission factor of zero; this means that the total energy from renewables, when converted to CO_2 emissions, would yield no emissions. In other words, if energy use in a sector remains the same, but more energy is supplied by renewable energy, then the emissions in that sector will be lower than if the energy was sourced from fossil fuels, or non-renewables. Table 16 found in Appendix B - Emissions, lists all the different types of fuels and their corresponding emissions.

Figure 1 below illustrates the emission factors for different fuel types. It should be noted that electricity has the highest emission factor, as it has the highest emissions in $kgCO_2$ for every 1 kWh of energy use.

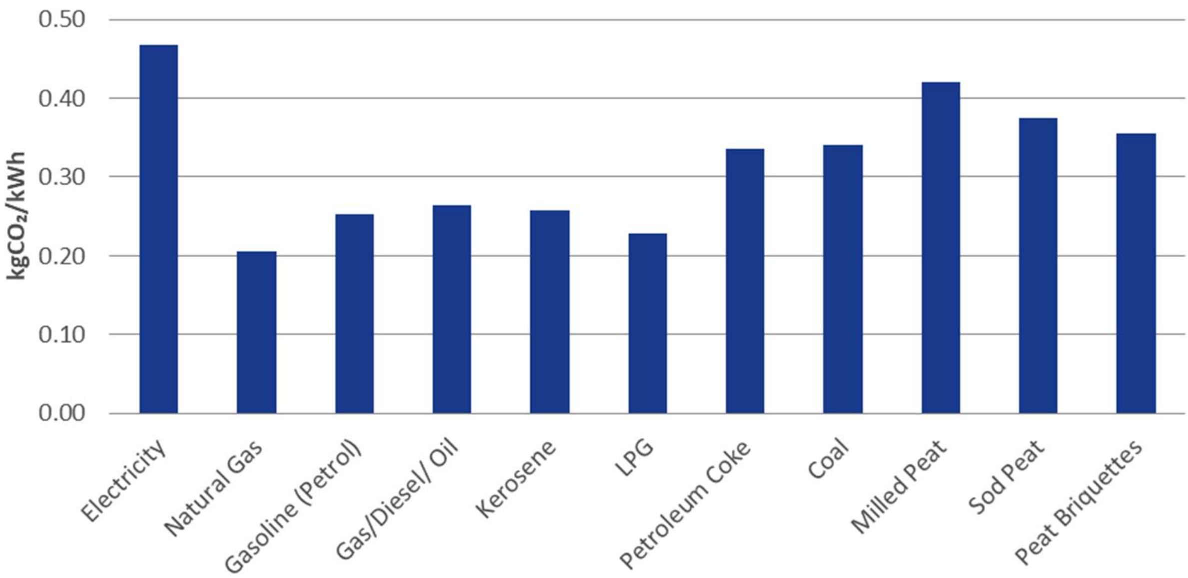

Figure 1 Emission Factors for Different Fuel Types

Residential

This section looks at the emissions arising from the residential sector. It excludes social housing units, as social housing is analysed separately in the Social Housing Section.

In Ireland, the residential sector accounted for 24% of overall energy consumption in 2015 (SEAI, 2016). Nationally, this is the second largest energy user after transportation, thus monitoring energy use and emissions in this sector is crucial.

Methodology

This methodology is based on two main data sources: Census 2016 and the Building Energy Rating (BER) Research Tool.

The Census data for the entire Dublin City residential sector was provided by the Central Statistics Office (CSO). This data was broken down into: location, type of housing and period built. This was then applied to the averages calculated from the BER database, which were broken down into four dwelling types and seven periods, providing a total of 28 subsets. Residential units were broken down into:

- Detached
- Semi-detached
- Terraced
- Apartments

This breakdown allows a higher level of accuracy when applying the averages to all housing.

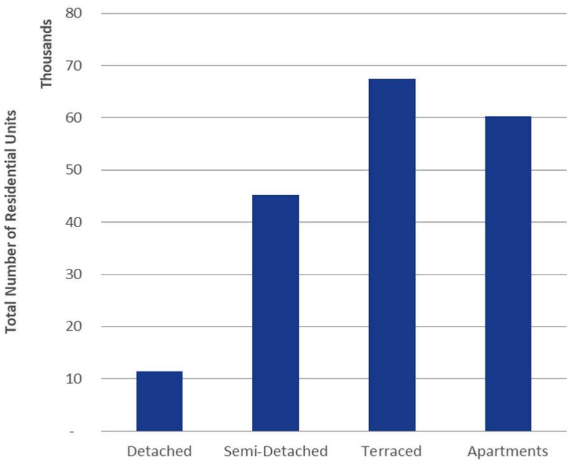

Figure 2 Total Number of Residential Units in Dublin City

The BER Research Tool was developed by SEAI and is used in this analysis for the calculation of energy required for normal use of space heating, hot water, ventilation and lighting per metre squared area of a residential unit. The final energy rating given to a household is in kWh/m^2/year and an energy efficiency scale from A to G. It also provides an insight into other data, such as type of household, year of construction, location, floor area and fuel use.

The BERs analysed in this report were broken down by location and included the BERs pertaining to Dublin City. This was done by filtering the data by postcode and was then broken down further by type of dwelling (detached, semi-detached, terraced and apartments) and period built. These categories were defined as such to match the information available from the Census for the entire residential housing stock in Dublin City. As can be seen in Figure 3, there is a high representation of BERs for each housing type.

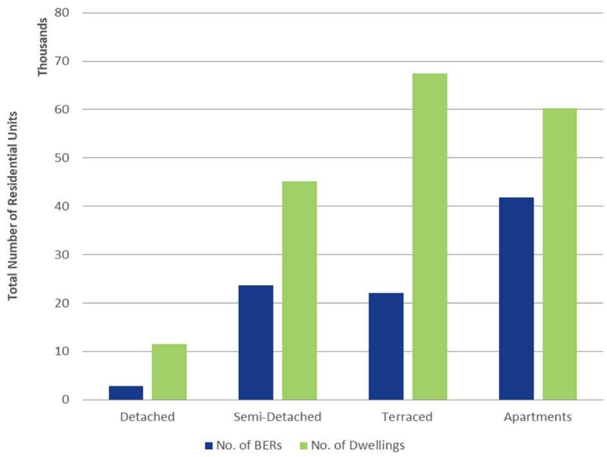

Figure 3 Representation of Dublin City's Residential Households in BER Database

The drawback of the BER is that a certificate is only required if a house is being sold or rented out after January 1st 2009. This means that it will not give a complete representation of all the housing stock in Dublin City. However, Dublin City will have a higher percentage of sales and rentals than any other local authority area, especially given the current housing and rental market. In Dublin City, Codema analysed a total of 90,399 BERs.

A disadvantage of using the BER as a main dataset is that it does not differentiate between different users and their energy use and does not account for electrical energy used by appliances. This is because the BER is an asset-based rating rather than an operational rating. A detailed list of assumptions and limitations may be found in Appendix A - Assumptions & Limitations.

Analysis

At a regional level, the number of dwellings constructed in the period between 2012 and 2016 accounted for 2% of the total residential units in Dublin City. This was a 6% decrease in residential construction when compared to the period between 2006 and 2011. This reduction in construction was directly related to the economic recession in 2008, as the construction industry was one of the worst to be affected.

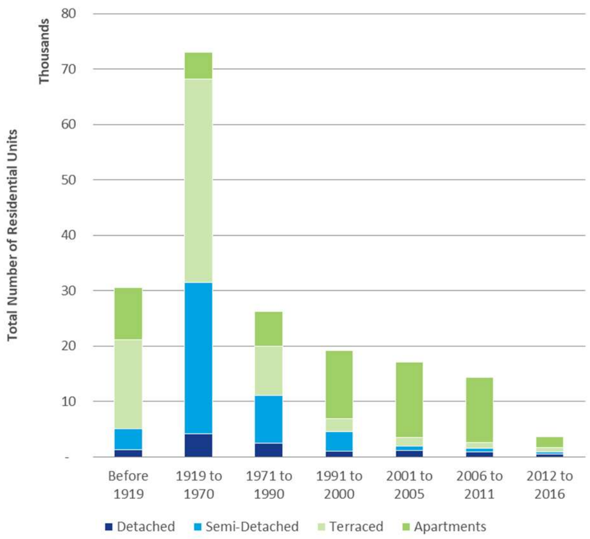

Figure 4 Dublin City's Total Residential Stock by Type and Period Built

As can be seen from Figure 4, the majority of residential units were built in the period between 1919 and 1970. From 1991 onwards, it is clear that apartments were the main type of housing built.

In 2016, the largest share of residential units were terraced houses; they made up 37% of the total residential housing stock in Dublin City. This was followed closely by apartments at 33%, while the lowest share of housing type was detached, comprising of just 6% of Dublin City's housing stock.

The city's residential sector emitted a total of 974,000 tonnes of CO_2 in 2016. Figure 5 depicts the total emissions by different dwelling types. Terraced houses had the highest emissions, accounting for 331,900 tonnes of CO_2. This was followed by semi-detached houses, apartments and detached houses, all of which accounted for 280,200, 253,200 and 108,700 tonnes of CO_2 respectively of the total residential sector emissions in 2016.

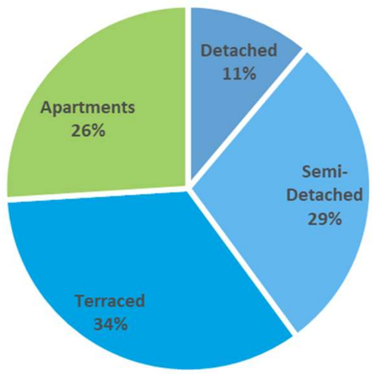

Figure 5 Dublin City's Residential Emissions by Dwelling Type

Figure 6 shows the share of emissions produced by the different types of dwellings and the corresponding number of residential units.

It can be seen that apartments have the least emissions per unit, at 4.20 tCO_2 per apartment. This is followed by terraced, semi-detached and detached houses, emitting 4.92, 6.21 and 9.46 tonnes of CO_2 per dwelling, respectively.

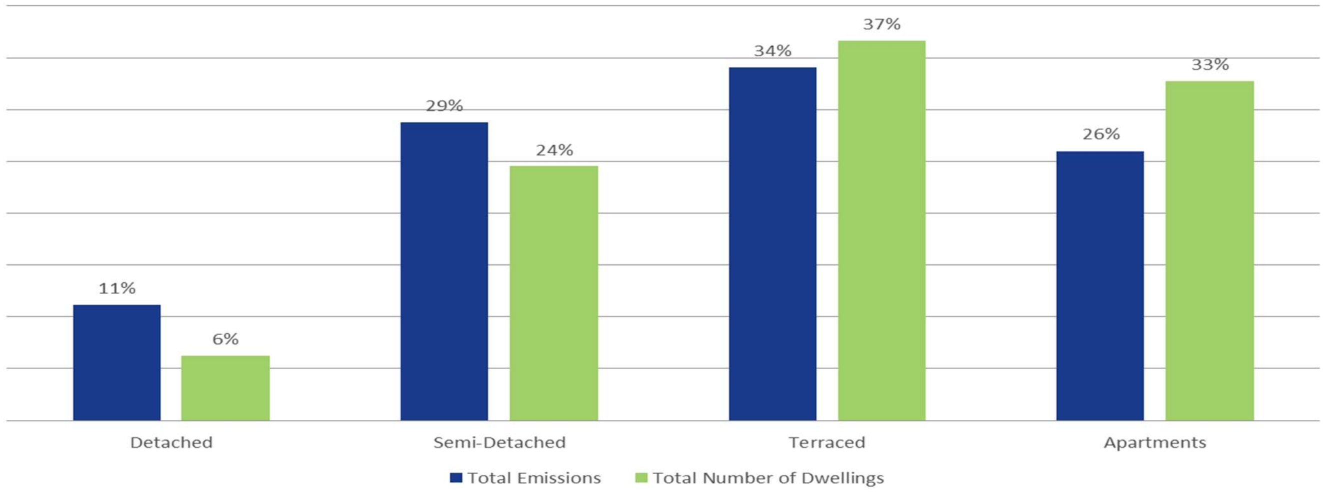

Figure 6 Share of Total Emissions and Number of Residential Units for Each Housing Type

Therefore, in terms of CO_2 per unit, apartments performed the best, while detached houses performed the worst.

The reasons for these findings are that apartments have less exposed areas when compared to detached or semi-detached houses. They are also the type of dwellings which have been built most recently, resulting in more efficient buildings due to modern materials and new building energy regulations. Detached, semi-detached and terraced houses make up the majority of the housing stock built before 1991 in Dublin City.

Figure 7 shows the total emissions for the residential sector in Dublin City, grouped by fuel and dwelling type.

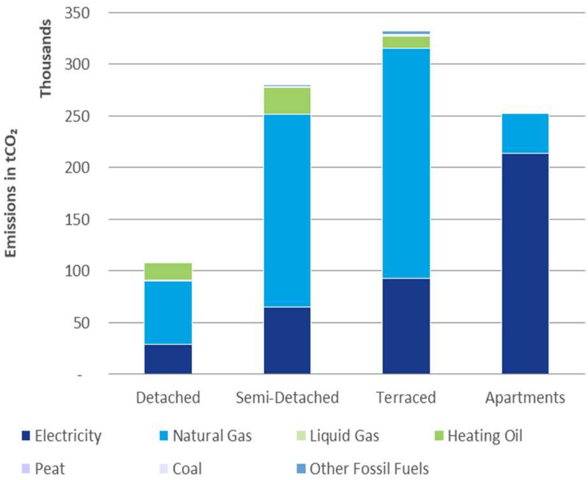

Figure 7 Total Emissions in tCO_2 in the Residential Sector by Fuel Mix and Dwelling Type

The highest emissions in the residential sector come from natural gas and electricity, which contribute 52% and 41% respectively. There was very little peat and coal used in the residential sector, only contributing to 0.21% of total emissions. Other fossil fuels include multi-fuel stoves that have no particular specified fuel for use, accounting for 1% of total residential emissions.

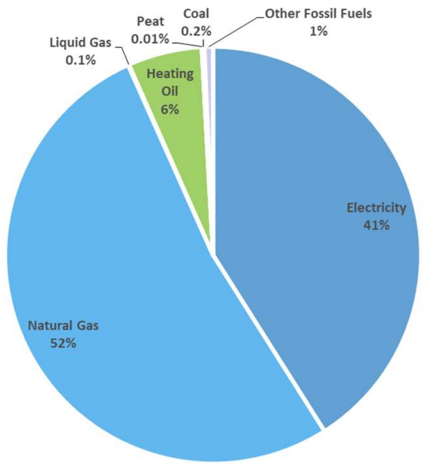

Figure 8 Share of Total Emissions in the Residential Sector by Fuel Type

Total energy use in the residential sector was 3,596 GWh. The residential fuel split mainly comes from natural gas, which makes up 69% of the total energy use in Dublin City due to the density of the gas grid in this region. Electricity is the second highest fuel in demand, making up 24% of the fuel mix, followed by oil at 6%.

Total renewable fuels only accounted for 0.04% of the final energy consumption. The majority of this came from biomass sources (mainly wood).

Figure 9 shows the total final energy use broken down into the different energy demand areas. Most of the energy used was for space heating. Space heating had by far the highest energy demand, accounting for 64% of the total. This is followed by water heating at 20%. Heating overall in the residential sector has the highest energy demand by far and creates potential for heat recovery from waste heat and district heating as a way of catering for this high heat demand. Lighting and pumps/ fans are the least energy intensive, making up just 3% and 1% of the total demand, respectively.

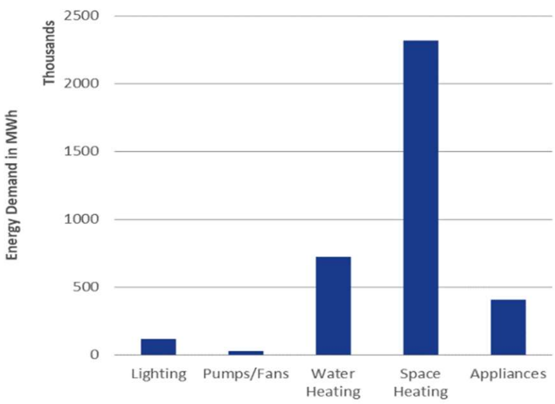

Figure 9 Residential Energy Demand in MWh in Dublin City

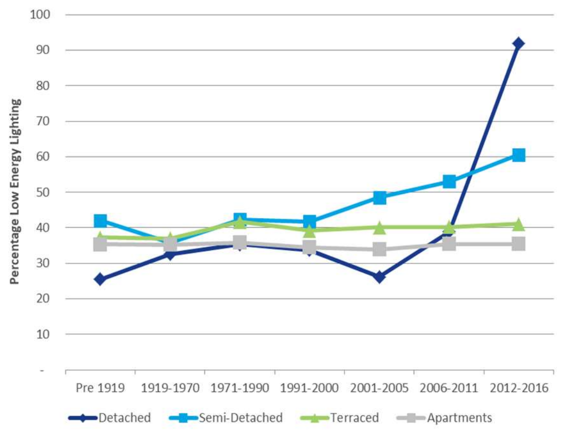

Figure 10 Percentage of Low Energy Lighting by Building Type and Period Built

Figure 10 shows the percentage of low energy lighting analysed from the BER research tool, and broken down by house type and period built. The overall average percentage of low energy lighting in Dublin City's residential sector is 36%, with newer built dwellings having higher levels. The highest percentage is found in newly built detached houses at 92%. This shows that there is still room for improvement for the other dwelling types.

Figure 11 and 12 show the total building energy ratings for all residential housing in Dublin City, after the averages for each dwelling type and period built were applied to the entire housing stock.

The most common rating was D2, and 55% of the housing stock in 2016 were rated D1 or better. The majority of better ratings (i.e. A and B ratings) came from newly built or refurbished apartments.

There were 1,535 A2 and A3 rated residential units in the city (of which only 0.2% were A2 rated). However, no A1 dwellings could be identified in the residential sector in 2016.

The residential housing stock in Dublin City is ageing, and as a result, newly built or refurbished dwellings would generally perform better.

16% of the housing stock was F or G rated, mainly comprising of terraced houses that were constructed in the period between 1919 and 1970.

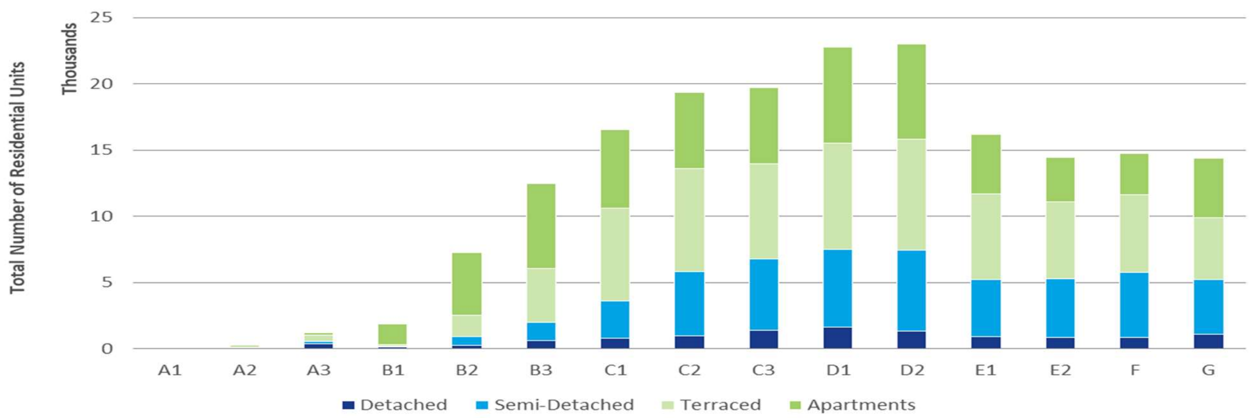

Figure 11 Building Energy Ratings for all the Dublin City's Residential Stock by Dwelling Type

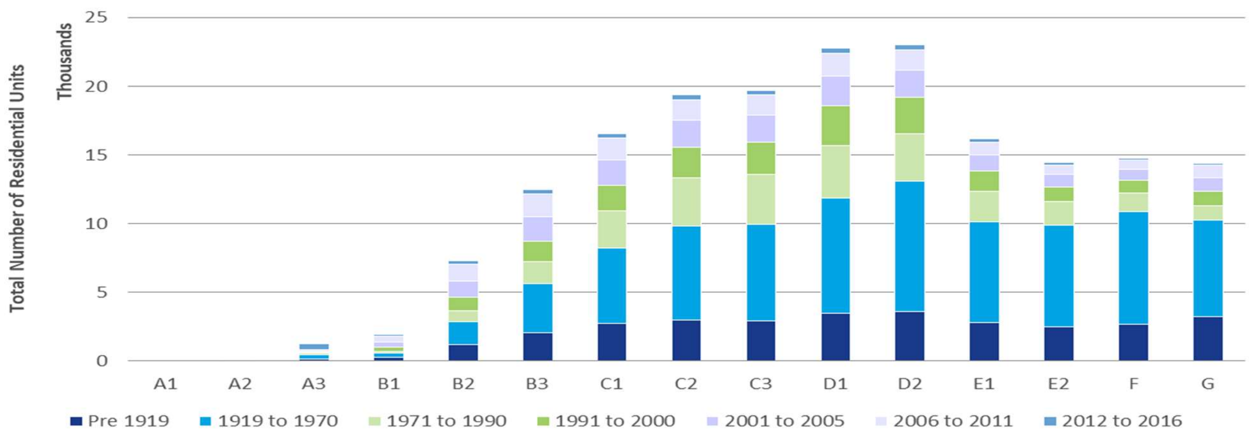

Figure 12 Building Energy Ratings for all Dublin City's Residential Units by Construction Period

Key Finding

- Total residential emissions were 974,000 tonnes of CO_2 in 2016
- Total delivered energy for the residential sector in Dublin City for 2016 was 3,596 GWh
- The majority of residential units were constructed between 1919 and 1970
- Apartments were the least carbon intensive type of housing, emitting 4.20 tCO_2/apartment
- Detached houses were the most carbon intensive type of housing, emitting 9.46 tCO_2/detached house
- Construction of new residential developments for the period between 2012 and 2016 made up 2% of the total housing stock
- 43% of the housing stock was C3 or better, with D2 being the most common rating
- Terraced houses make up 37% of the total housing stock, followed by apartments (33%), semi-detached (24%) and detached houses (6%) respectively
- Terraced houses produced 34% of total residential emissions in Dublin City, followed by semi-detached, apartments and detached houses, which make up 29%, 26% and 11% respectively, of total residential emissions
- 52% of residential emissions came from natural gas and 41% from electricity
- Space heating had the highest energy demand in the residential sector at 64% of total energy demand
- The highest percentage of low energy lighting was for newly built detached houses, at 92%
- 69% of the residential fuel mix was made up of natural gas, followed by electricity at 24%

Table 1 Dublin City's Residential Inventory; Energy and CO_2 Emissions

Residential Sector	Electricity	Fossil Fuels						Renewable Energies		Total
		Natural Gas	Liquid Gas	Heating Oil	Peat	Coal	Other Fossil Fuels	Biofuel	Other Biomass	
Detached (MWh)	61,632	300,337	811	67,469	-	528	2,650	-	-	433,427
Semi-Detached (MWh)	137,801	912,922	1,010	100,348	123	2,151	8,062	-	196	1,162,613
Terraced (MWh)	197,887	1,086,213	579	48,118	124	2,675	13,630	-	343	1,349,568
Apartments (MWh)	457,004	188,429	829	2,340	-	77	490	16	773	649,956
Total Energy (MWh)	**854,324**	**2,487,901**	**3,228**	**218,275**	**247**	**5,430**	**24,832**	**16**	**1,312**	**3,595,564**
Detached (tCO_2)	28,813	61,479	186	17,340	-	180	699	-	-	108,696
Semi-Detached (tCO_2)	64,422	186,875	232	25,789	44	733	2,128	-	-	280,222
Terraced (tCO_2)	92,512	222,348	133	12,366	44	911	3,597	-	-	331,911
Apartments (tCO_2)	213,650	38,571	190	601	-	26	129	-	-	253,168
Total Emissions (tCO_2)	**399,397**	**509,273**	**740**	**56,097**	**88**	**1,849**	**6,553**	**-**	**-**	**973,997**

Commercial

The commercial sector includes both the services and the industrial sector. The changes in the Irish economy, briefly described in the introduction, have had a large impact on commercial activity in Ireland. As the Irish economy recovers, new businesses are once again emerging across Dublin City.

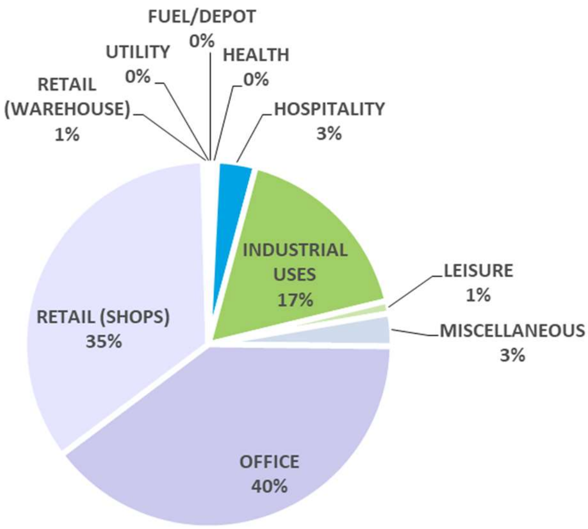

Figure 13 Dublin City's Commercial Properties by Category

Three quarters of commercial properties can be categorised as offices and retail outlets, with only 17% of properties accounting for industrial operations. This is likely due to the high demand and rates for property in Dublin City, which favours numerous smaller retail-type businesses with a smaller floor area.

Methodology

The methodology used for the calculation of the commercial baseline includes two main data sources - data from the Valuation Office and energy consumption benchmarks from the Chartered Institution of Building Services Engineers (CIBSE).

The Valuation Office provided a list of all the commercial properties and their respective floor areas in Dublin City. These properties were also broken down into different categories, type of use, and location.

Currently, there is no energy data available for commercial properties, as there is no formal energy reporting required. Therefore, in order to assign energy use to each property, Codema used energy benchmarks from the UK CIBSE Guide F: Energy Efficiency and TM46 (CIBSE, 2012). These sources provide typical energy usage per square metre of floor area for different business categories, amalgamated from numerous UK surveys. A detailed list of assumptions and limitations may be found in Appendix A - Assumptions & Limitations.

Codema matched the property uses provided by the Valuation Office with the building descriptions given in the CIBSE guides. The floor areas listed by the Valuation Office were based on the different business requirements. This can be found in the Valuation Office's Code of Measuring Practice (Valuation Office Ireland, 2009). If the measured floor area from the Valuation Office did not match that in the CIBSE guides (gross floor area to net floor area), then a conversion factor was applied.

Codema then applied energy figures to all the commercial properties, according to their use. There were over 230 different property types listed in Dublin City.

The CIBSE energy figures are only split into either fossil fuels or electricity. Therefore, due to a lack of data at a local level, the 2011 national breakdown of fossil fuels and electricity for energy use in the industrial sector was used instead (SEAI, 2012). However, this presents a limitation as it is not an accurate representation of fuel use in the commercial sector in Dublin City.

The advantage of using CIBSE energy benchmarks is that they are based on a large sample set, and as Irish building regulations follow the UK regulations, the energy figures are applicable in the Irish context. There are certain limitations, however; climate in the UK is more severe than in Ireland and can affect results when applied to the Irish sector. Most of the benchmarks used by CIBSE guides are outdated, with some surveys dating back to 1992. Therefore, these figures might not reflect energy efficiency measures and buildings complying with new building regulations.

Analysis

The different commercial property categories outlined in this section are:

- Fuel/Depot
- Health
- Hospitality
- Industrial Uses
- Leisure
- Miscellaneous

- Office
- Retail
- Retail (Warehouse)
- Utility

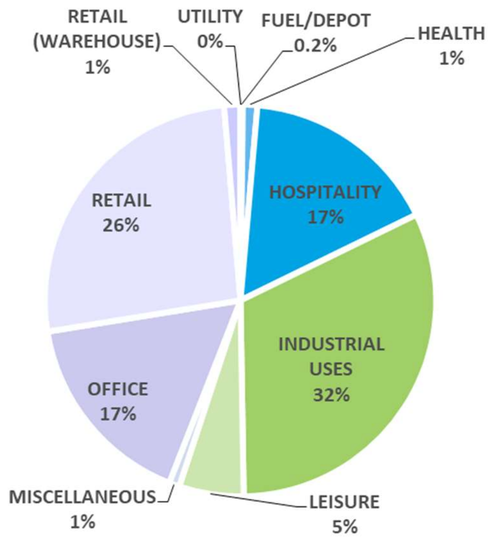

Figure 14 Commercial Emissions by Property Category

Total emissions from the commercial sector in 2016 were calculated at 934,000 tonnes of CO_2.

As can be seen from Figure 14, the commercial properties that produced the most emissions were:

- Industrial uses: 298,200 tCO_2
- Retail: 244,500 tCO_2
- Offices: 154,100 tCO_2
- Hospitality: 153,000 tCO_2

Figure 15 gives an indication of emissions in comparison to the number of buildings for different commercial properties in Dublin City.

Hospitality, industrial uses, offices and retail are the main CO_2 emitters, as altogether they make up 91% of the commercial sector's total emissions. From this analysis, these four categories should be the main targets of energy and emission reduction initiatives within the commercial sector.

By comparing buildings of different uses to their total emissions and number of businesses in each category, a clearer picture can then be gained of the businesses with the highest and lowest emissions per property.

When comparing emissions to the number of commercial properties, the hospitality and leisure sectors had the highest shares of emissions at 230.5 tCO_2 and 230.6 tCO_2 per building, respectively. On the other hand, utility, miscellaneous uses and offices had the lowest emissions per commercial property, at 13.2 tCO_2, 14.3tCO_2 and 20.0 tCO_2, respectively.

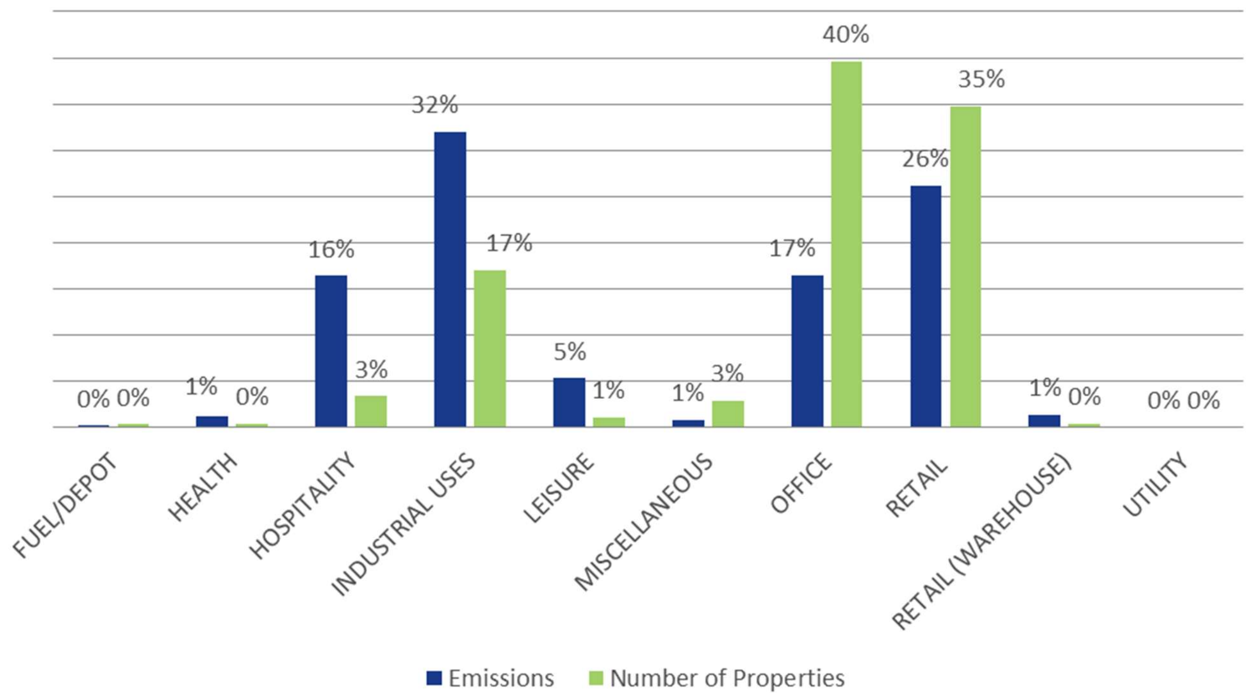

Figure 15 Share of Total Emissions and Number of Commercial Properties in Dublin City

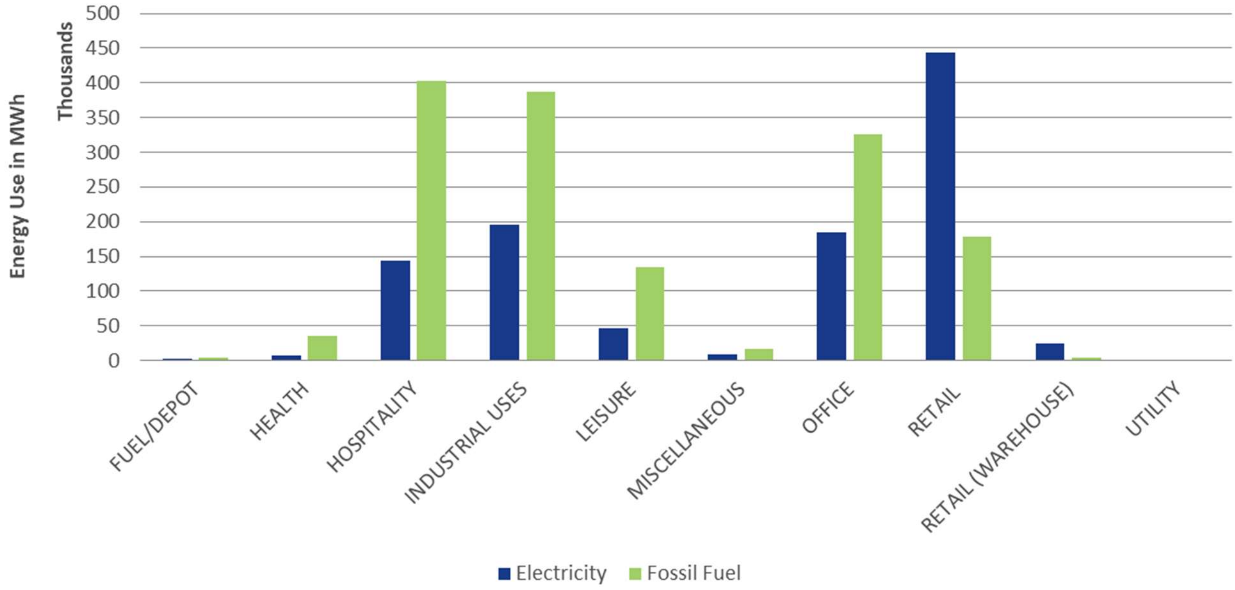

Figure 16 Dublin City's Electricity and Fossil Fuel Use in MWh in the Commercial Sector by Category

Figure 16 shows the electricity and fossil fuel consumption of commercial buildings by category. These figures are representative of the CIBSE energy benchmark fuel breakdown. Hospitality holds the highest share of fossil fuels at 27%, while retail has the highest share of electricity use (42%). The high electricity consumption figure for retail could be due to the widespread use of electric air heating/cooling ventilation systems, and the high volume of lighting required in retail units.

CIBSE only breaks down fuel use into fossil fuels and electricity. However, for this study, the fuel use has been further broken down using the SEAI national fuel split for the services and industrial sectors.

Services Sector

The biggest energy users in the services sector are:

- Hospitals
- Hotels
- Large entertainment theatres

In the case of the services sector, Codema calculated the electricity use using CIBSE energy figures. The remaining energy split is based on national figures, as there is currently no data available specifically for the Dublin region.

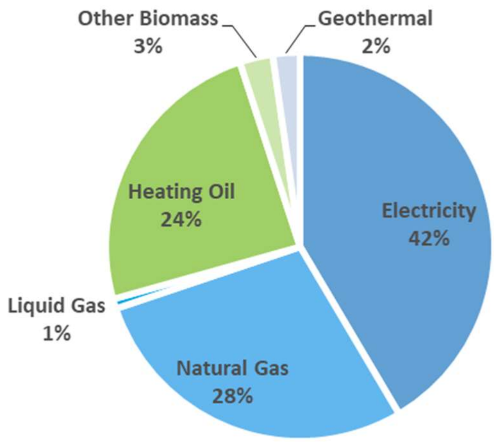

Figure 17 Percentage Energy Use in the Services Sector

The total energy used by the services sector was calculated at 2,550 GWh. This energy mostly comes from electricity at 1,058 GWh and natural gas at 723 GWh. Heating oil also has a high energy use in the services sector, making up 620GWh of the total energy mix.

Renewables contribute to 128 GWh of the total fuel mix, split into 70 GWh of biomass and 58 GWh of geothermal energy.

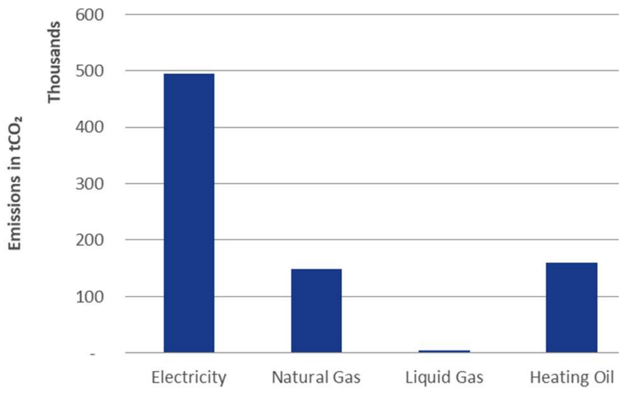

Figure 18 Total Emissions in the Services Sector in tCO_2

The services sector emitted 806,700 tonnes of CO_2 in total. Figure 18 shows that highest emissions came from electricity (61%) heating oil (20%) and natural gas (18%) within the services sector.

Industrial Sector

Industrial buildings and their processes consume a high share of both electricity and fossil fuels. The main industrial property uses in Dublin City are:

- Factories
- Stores
- Workshops
- Warehouses

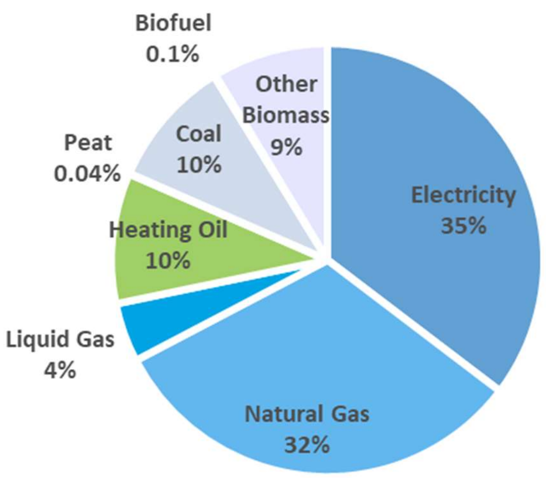

Figure 19 Percentage Energy Use in the Industrial Sector

The total energy used in the industrial sector was 426 GWh. Electricity (151 GWh) and natural gas (136 GWh) accounted for the main share of this energy use. The industrial sector had a high use of renewables, with biofuel and biomass making up 38 GWh of the total fuel mix.

Total emissions from the industrial sector were 127,300 tonnes of CO_2. As can be seen from Figure 20, electricity accounts for the largest share of the total emissions (55%), followed by natural gas at 22%. Coal and heating oil also produce significant emissions, contributing 11% and 9% to the total, respectively.

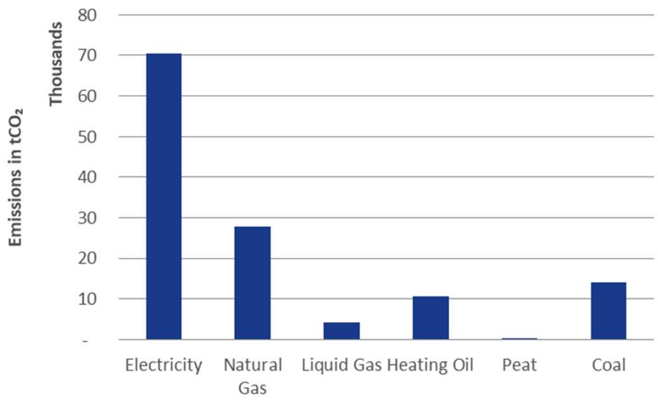

Figure 20 Total Emissions in the Industrial Sector in tCO_2

Electricity and gas were the main energy sources for both the services and the industrial sector. However, as the statistics used on the fuel split were not specific to Dublin, gas would probably hold a larger share in reality, due to the prevalence of the gas grid in the city.

Key Findings

- Total emissions in 2016 were 934,000 tonnes of CO_2 - 806,700 tonnes of CO_2 from services and 127,300 tonnes of CO_2 from industrial sector
- Total final energy used in 2016 in the commercial sector was 2,976 GWh
- Three quarters of commercial properties were offices and retail outlets
- Industrial uses (32%), retail (26%), offices (17%) and hospitality (17%) contributed the most to CO_2 emissions
- Hospitality and leisure held the highest emissions per property, at 230.5 tCO_2 and 230.6 tCO_2 respectively
- Utility, miscellaneous uses and offices had the lowest emissions per property, 13.2 tCO_2, 14.3 tCO_2 and 20.0 tCO_2, respectively
- 42% of total commercial sector electricity is used by retail outlets
- Hospitality accounted for 27% of total commercial fossil fuel use
- Electricity (61%), heating oil (20%) and natural gas (18%) were the main contributors to CO_2 emissions in the services sector
- Electricity (55%) and natural gas (22%) were the highest contributors to CO_2 emissions in the industrial sector

Table 2 Dublin City's Commercial Inventory; Energy and CO_2 Emissions

Commercial Sector		Fossil Fuels						Renewable Energies			Total
	Electricity	Natural Gas	Liquid Gas	Heating Oil	Peat	Coal	Other fossil fuels	Biofuel	Other Biomass	Geothermal	
Services Sector (MWh)	1,057,927	723,341	20,667	620,006	-	-	-	-	70,267	57,867	2,550,075
Industry Sector (MWh)	150,540	136,321	18,840	41,590	178	40,879	-	533	36,969	-	425,849
Total Energy (MWh)	**1,208,467**	**859,662**	**39,507**	**661,596**	**178**	**40,879**	**-**	**533**	**107,236**	**57,867**	**2,975,924**
Services Sector (tCO_2)	494,581	148,068	4,739	159,342	-	-	-	-	-	-	806,729
Industry Sector (tCO_2)	70,377	27,905	4,320	10,689	63	13,923	-	-	-	-	127,277
Total Emissions (tCO_2)	**564,958**	**175,973**	**9,059**	**170,030**	**63**	**13,923**	**-**	**-**	**-**	**-**	**934,007**

Transport

In 2014, the transport sector was responsible for the largest share of energy consumption than any other sector in the Irish economy (SEAI, 2014). The Central Statistics Office (CSO) recently published 'Census 2016, Commuting in Ireland', which shows that commuting has increased nationally, and is in line with the changes and growth in the Irish economy.

Comparing 2016 and 2011 Census data, the number of people commuting to work increased by 11%. Nationally, commuting by car increased by 8%, public transport rose by 21%, walking increased by 3%, and cycling (which had the highest recorded increase) was up by 43% in 2016.

The increase in cycling may be due to factors such as the Dublin Bike scheme that was launched by Dublin City Council. In 2015, the number of journeys on Dublin Bikes increased to 4.1 million, compared to 1.2 million in 2010 (Department of Transport, 2016). The Cycle-to-Work Scheme also influenced the increased number of cyclists in the city, as the scheme allows employees to claim tax relief up to 52% on the purchase of bicycles and accessories. So far, the Cycle-to-Work scheme has contributed towards 5,000 bikes in Ireland (Cyclescheme.ie, 2017).

Significant improvements have been made to the sustainability of the transport system in recent years, both nationally and at a regional level in Dublin. The national vehicle road tax system was revised, and as of July 2008, the system moved away from assessing vehicles based on their engine size to one that is based on CO_2 emissions per kilometre. In 2016, the number of new vehicles registered in Ireland increased by 17.5%, when compared to 2015 data (SIMI, 2016). Around 67% of new cars in 2014 were rated in the A band, which means that their emissions would be less than 110g of CO_2 per kilometre (SEAI, 2014).

Methodology

Codema contacted the National Transport Authority (NTA) to assess the CO_2 and GHG emissions associated with transportation in Dublin. The NTA provided Codema with data that included total emissions in different road links in Dublin and the transportation mode used. This data is a part of Appraisal Modules, which form part of the Regional Modelling System (RMS) for Ireland. A detailed list of assumptions and limitations may be found in the Appendix section.

The RMS was developed using a wide range of data sources to represent travel demand and patterns as accurately as possible. 2012 was used as the base year for the data. This is determined by the CSO Census, which is used to calculate population growth and travel patterns. The data sources used to develop the RMS may be found in the table below.

Table 3 Data Sources Used by the NTA's RMS

RMS Data Sources	
The CSO Census	Port Passenger Data
The NTA National Household Travel Survey	MyPlan Landuse Database
The GeoDirectory	Over 6,000 Traffic Counts - NTA, TII, Local Authorities Nationwide
The Valuation Office Parking data	Journey Time Data
CSO HGV Data	Automatic Vehicle Location Data for Public Transport
NTA Ticketing Data	Public Transport Surveys
NTA Airport Surveys	GTFS Public Transport Network Data
HERE Road Network Data	NAPTAN Bus Stop Database
Traffic Signal Data from a Range of Urban Traffic Control Systems	

The RMS consists of three main components:

- National Demand Forecasting Model
- Five Regional Multimodal Models
- Appraisal Modules

The **National Demand Forecasting Model** (NDFM) provides demand forecasts which were inputted into the Regional Multimodal Model. This model makes use of planning data to predict levels of travel demand at the smallest spatial data available (known as a Census Small Area). NDFM produces an average 24-hour weekday demand, and also forecasts travel patterns for Heavy Goods Vehicles (HGVs).

The **Regional Multimodal Models** (RMMs) are multi-modal network-based transport models, including all modes of transport (car, bus, light rail, rail, cycling and walking). The five Regional Multimodal Models are made up of five main cities: Dublin, Cork, Galway, Limerick and Waterford.

The NDFM produces travel demand outputs that are used in the RMM for iteration through assignment modules.

The RMM converts the 24-hour demand into time, mode and destination. In addition to typical trip behaviours (time, destination and mode), this model also includes impacts that affect decision-making, such as availability and costs of parking.

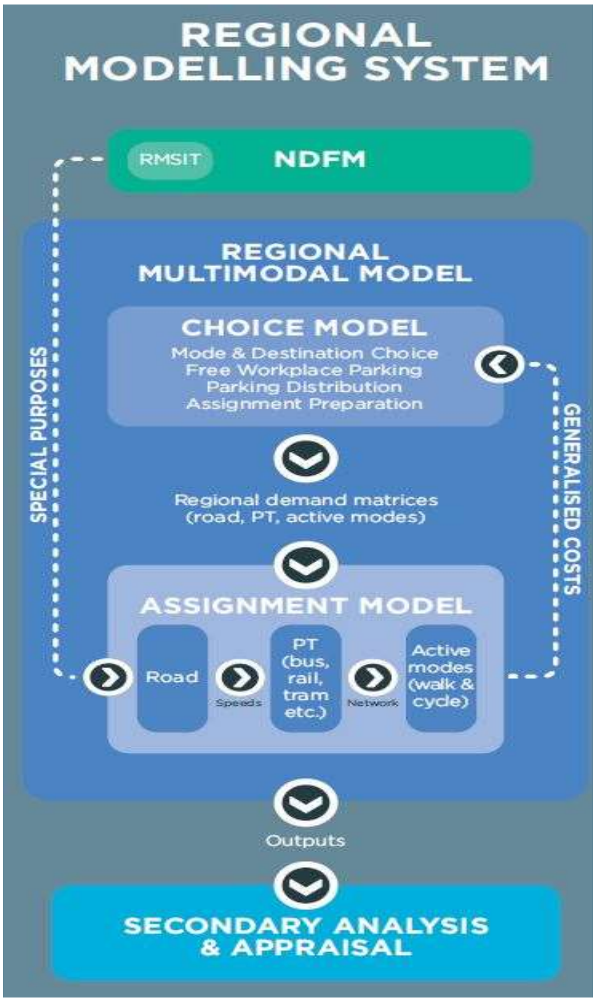

Figure 21 RMM Structure. Source : NTA, 2017

The Appraisal Modules work in conjunction with the Regional Multimodal Model as they provide appraisal tools in line with national guidelines. This model uses RMM outputs needed to appraise schemes, policies and strategies.

The transportation model includes impacts on:

- Emissions of local air quality pollutants
- Emissions of global GHG gasses

The emissions which are estimated by the Appraisal Modules are the following:

- Nitrogen Oxides (NO_x)
- Nitrogen Dioxide (NO_2)
- Particulate Matter (PM10)
- Fine Particulate Matter (PM 2.5)
- Hydro Carbons (HC)
- Carbon Monoxide (CO)
- Carbon Dioxide (CO_2)
- Benzene (C_6H_6)
- Methane (CH_4)
- Butadiene (C_4H_6)

The model is a Geographical Information System (GIS) based process for automating the process of calculating link proportions. The emissions tool uses three main variables to estimate emissions: fleet type, vehicle type and link type. To appraise the emissions, the software would also need the modelled year, annualisation factors to combine emissions from different time periods, and speed-based emissions by vehicle type and emission category.

Emissions of all pollutants may be displayed by link (includes all the links in the model), by zone and by grid (a default national 1km^2 grid along with a used defined grid).

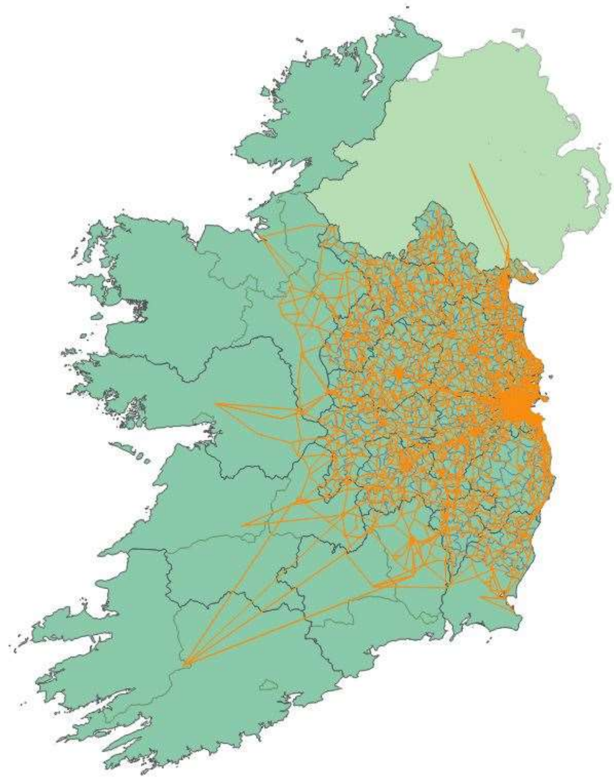

Figure 22 East Regional Model in GIS, Including all the Different Road Links

Analysis

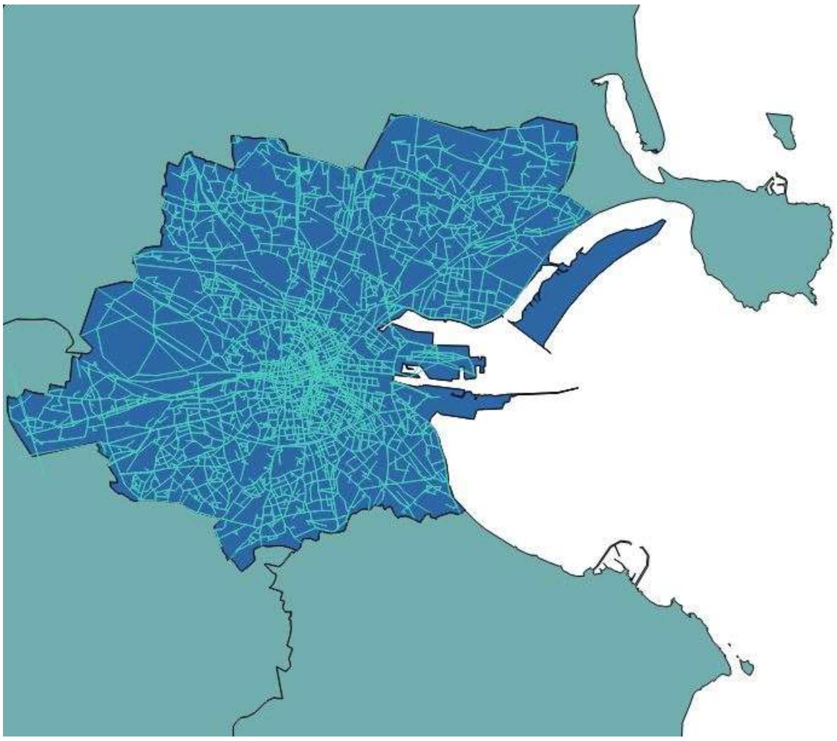

Figure 23 Dublin City Road Links

From the GIS model provided by the NTA, the total GHGs were extracted for different road links in Dublin City. Figure 23 above, shows all the different road links in Dublin City. Some road links might be located in more than one local authority area; for example, a road link might be in both Fingal and Dublin City. The road links were attributed to a local authority area depending on the length of the road link in the respective area. Road links were also attributed to Dublin City if they started and ended in the local authority area.

The GIS models provided by the NTA included projections of transportation emissions and fuel mix for different transportation modes. Projections are based on the 2012 data and are projections for the year 2018 and 2035.

From the GIS model, the total GHGs were extracted and then converted to CO_2 equivalent, to find the total emissions from the transport sector.

From these projections, Codema could estimate Dublin City's transport emissions for 2016, and these were also broken down by different GHG emissions.

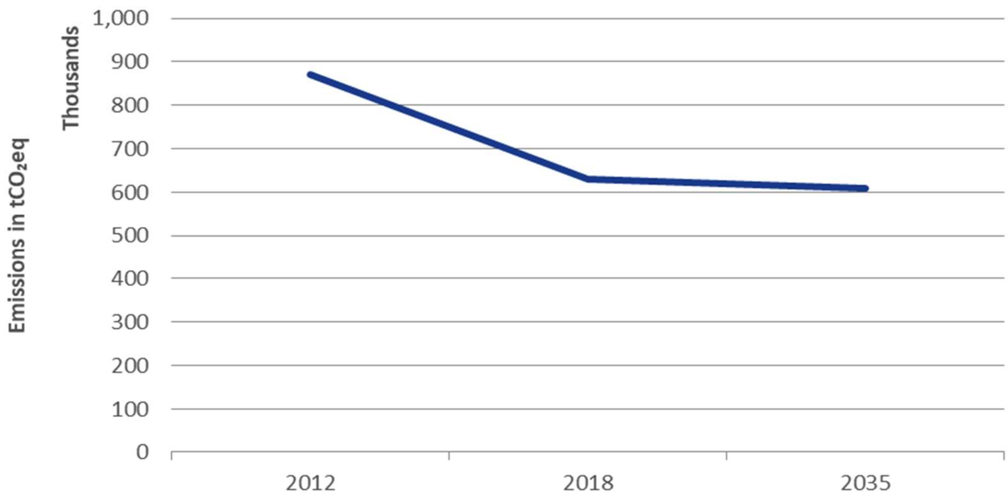

Figure 24 GHG Emission Projections for Dublin City's Transport

Based on the 2012 data, the modal split for Dublin City was calculated. 37% of total journeys were made by cycling and walking, which have no emissions attributed to them. The rest of the city's transportation needs (63%) were met by public transport and private/ commercial transport.

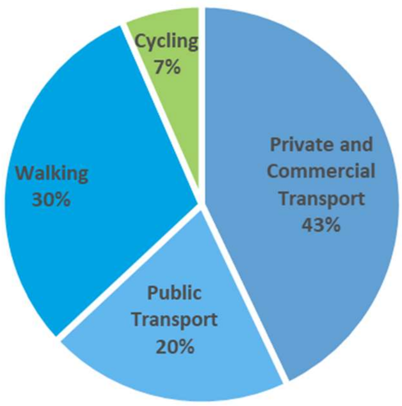

Figure 25 Dublin City's Transport Modal Split in Journeys

From SEAI's 'Energy in Ireland 1990 – 2016, Share of Emissions in Transport' a breakdown of fuel use in Ireland in 2016 was found. The 2016 fuel mix and the CO_2 emissions from the GIS maps were used to find the associated energy use from transportation.

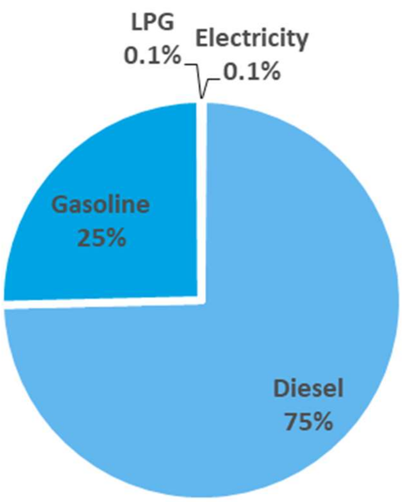

Figure 26 Dublin City's Transport Energy Use

The total energy use from the transport sector in Dublin City, amounted to 2, 672 GWh. This energy mainly came from diesel (1,991 GWh) and gasoline (676 GWh). Electricity and LPG only made up 0.2% of the total energy use, which is equivalent to 4.6 GWh.

The total emissions from transport in 2016 were the equivalent of 697,700 tonnes of CO_2, and were made up of carbon dioxide, methane and nitrous oxide.

Diesel was the main fuel source for both public and private transport, accounting for 75% of total emissions. This was followed by petrol/ gasoline at 25%, and electricity at 0.2% of total emissions.

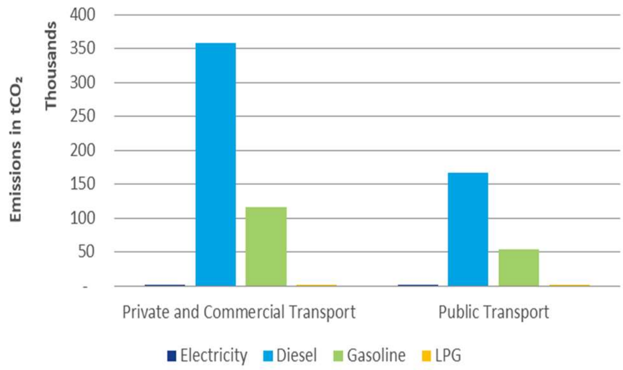

Figure 27 Dublin City's CO_2 Emissions from Transportation

It is good to note that the data available in the timeframe of this report was for 2012 and projections for 2016 were made from this data. This report will be updated once the 2016 model is made available, including the emissions, energy use and modal split in Dublin City.

Key Findings

- Total final emissions from transport were 697,700 tonnes of CO_2
- Total energy use in transport was 2,672 GWh
- Dublin City's modal split was made up of 43% private and commercial transport, public transport, 20%, walking, 30% and cycling, 7%
- Transport emissions came from diesel (75%), gasoline (25%), electricity (0.2%), and LPG, (0.1%)

Table 4 Dublin City's Transport Inventory, Energy and CO_2 Emissions

Transport Sector	Electricity	Fossil Fuel				Renewable Energies	Total
		Natural Gas	Diesel	Gasoline	LPG	Biofuel	
Private and Commercial Transport (MWh)	1,945	-	1,356,476	460,824	1,209	-	1,820,454
Public Transport (MWh)	910	-	634,331	215,496	565		851,302
Total Energy (MWh)	2,855	-	1,990,807	676,320	1,774	-	2,671,756
Private and Commercial Transport (tCO_2eq)	909	-	358,110	116,128	277	-	475,423
Public Transport (tCO_2eq)	425	-	167,463	54,305	129	-	222,323
Total Emissions (tCO_2eq)	1,335	-	525,573	170,433	406	-	697,747

Social Housing

Dublin City Council (DCC) is responsible for the general maintenance and refurbishment of social housing in the city. This means that much of the energy consumption and emission reductions of Dublin City's social housing stock are dependent on the upgrades and retrofitting that the local authority has carried out in recent years. The behaviour of social housing tenants is also a factor in this energy consumption, as they are responsible for the amount of energy that they consume.

Methodology

This methodology, similar to the residential sector's methodology, is based on two main data sources: DCC's social housing database and the Building Energy Rating (BER) Research Tool. A detailed list of assumptions and limitations may be found in Appendix A - Assumptions & Limitations.

The social housing data for the entire Dublin City housing stock was provided by DCC. This data was broken down into location, type of housing, period built and energy rating. This breakdown allows a higher level of accuracy; social housing was divided into seven periods and four dwelling types, adding up to a total of 28 subsets. Social housing units were broken down into the following categories:

- Detached
- Semi-detached
- Terraced
- Apartments

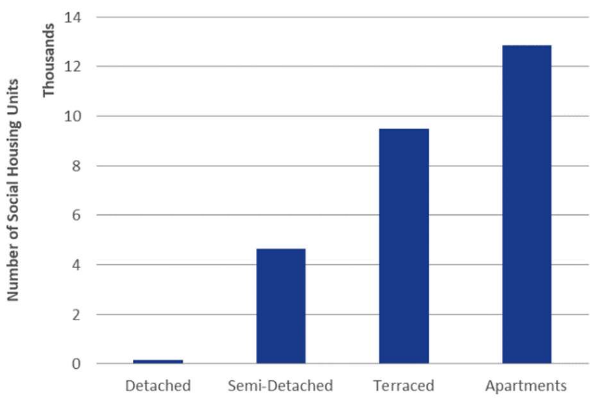

Figure 28 Breakdown of Total Social Housing Units by Construction Type in Dublin City

The energy rating of each housing unit (obtained from DCC's database), along with the floor area of each social housing unit, was used to find an average energy use. The average energy use for each household for normal use was obtained from the BER Research Tool. This provides data on energy use for space heating, hot water, ventilation and lighting per metre squared area of a residential unit. The final energy rating given to a household is in kWh/m^2/year and an energy efficiency scale from A to G. Furthermore, it also provides information into other data such as type of household, year of construction, location, and fuel use.

The BERs analysed in this chapter only represent social housing. The data was filtered by postcode to obtain location-specific data for Dublin City and social housing. The data was then broken down by type of dwelling (detached, semi-detached, terraced and apartments), period built and energy rating (A-G). These categories were defined as such to match the information available from the local authority for the entire social housing stock in Dublin City. Depending on the energy rating (A1, A2, etc.) of each social housing unit, the BERs' average energy use was then applied to each unit.

Analysis

At a regional level, the greatest number of social housing units were built in Dublin City in the period between 1919 and 1970. The period between 206 and 2016 accounted for only 4% of the total social housing dwellings. The decrease in social housing units over this period may be related to the economic downturn.

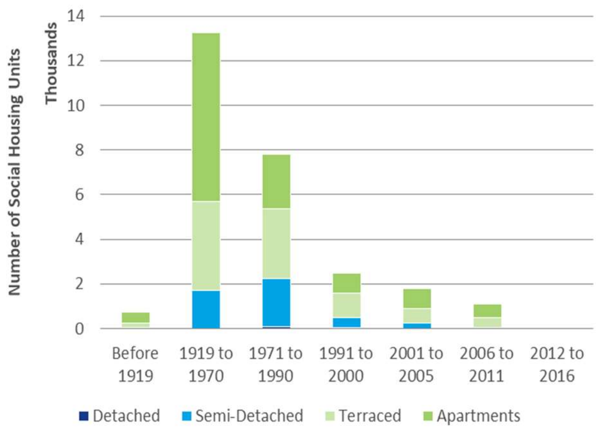

Figure 29 Dublin City's Total Social Housing Stock by Type and Period Built

From 1971 onwards, the main types of housing built were terraced houses and apartments.

In 2016, the majority of social housing dwellings were apartments, which made up 47% of the total social housing stock. Terraced houses accounted for 35% of the total housing stock, followed by semi-detached at 17%. The least type of housing were detached, contributing only 1% to the total social housing stock in Dublin City.

Total emissions from the social housing sector in Dublin City amounted to 94,000 tonnes of CO_2 in 2016. As can be seen from Figure 30, terraced houses and apartments had the highest emissions (each representing 40% of total emissions), followed by semi-detached and detached houses, contributing 19% and 1% to the total emissions in 2016, respectively.

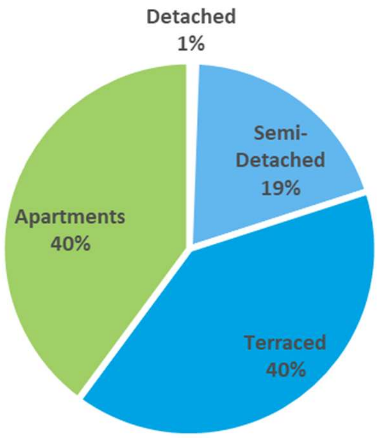

Figure 30 Dublin City's Social Housing Emissions by Dwelling Type

Figure 31 shows the share of emissions produced by different dwelling types and the corresponding share of social housing units.

Apartments produced the least emissions per unit, at 2.92 tCO_2 per apartment. These were followed by detached, semi-detached and terraced houses, emitting 3.47, 3.93 and 3.97 tonnes of CO_2 per dwelling, respectively.

Therefore, from this analysis, apartments were the least CO_2 emitting type of dwelling. Meanwhile, terraced houses produced the most CO_2 per dwelling type in 2016.

Apartments are more efficient as they tend to lose less energy from the building envelope, and therefore produce fewer emissions. Similarly, houses such as terraced, semi-detached and detached houses, which have more exposed areas, will typically have higher energy losses.

As explained above, apartments were the most common type of housing built from 1971 onwards, and thus this would result in modern building techniques, more efficient materials and new building regulations.

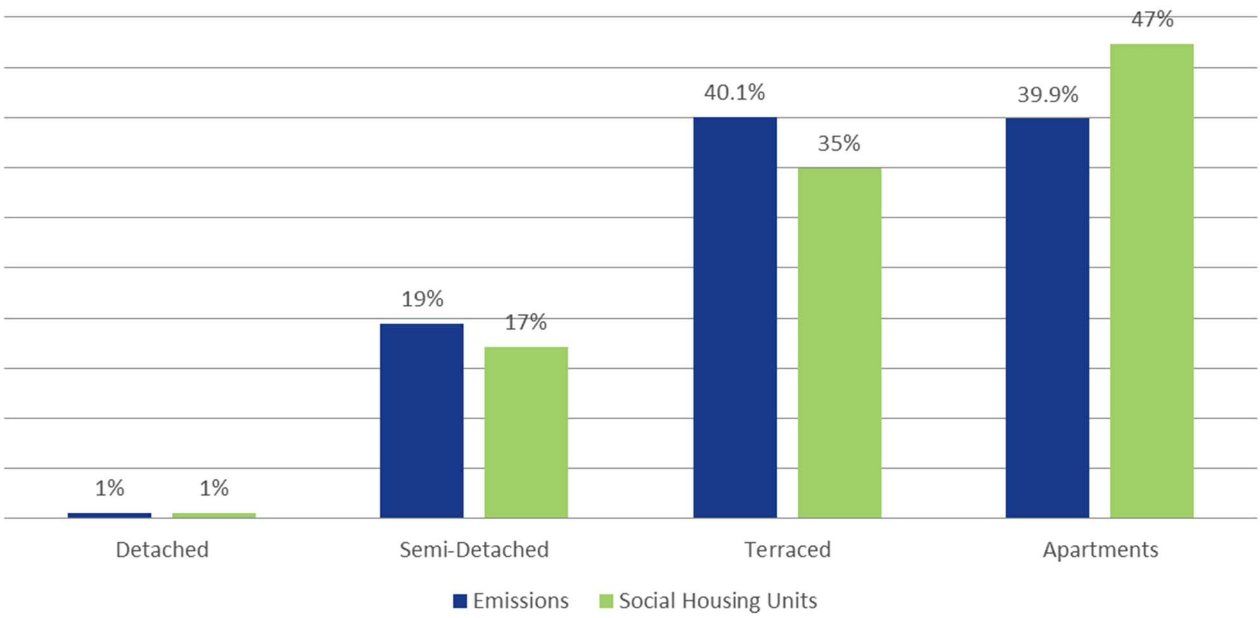

Figure 31 Share of Total Emissions and Number of Units for Each Social Housing Type in Dublin City

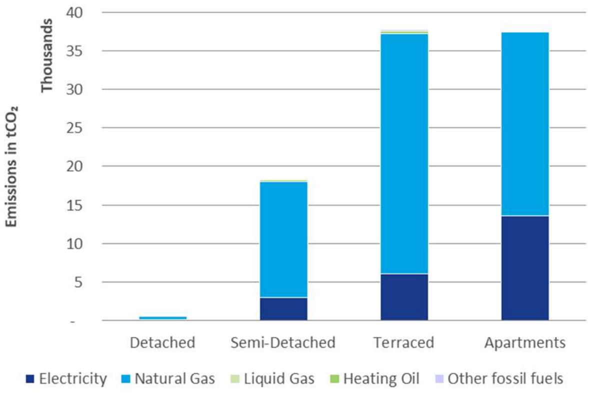

Figure 32 Total Emissions in tCO_2 in the Social Housing Sector by Fuel Mix and Dwelling Type

Figure 32 shows the total emissions for the social housing sector in Dublin City, grouped by fuel and dwelling type.

The highest percentage of emissions came from natural gas and electricity, which accounted for 75% and 24% of the total, respectively. Liquid gas, heating oil and other fossil fuels contributed to 1.4% of total emissions. Other fossil fuels include multi-fuel stoves that have no particular fuel specified, and account for only 0.3% of the fuel mix.

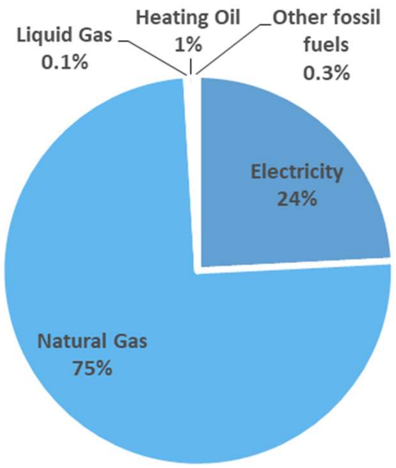

Figure 33 Share of Total Emissions from Social Housing by Fuel Type

Total energy used in Dublin City's social housing sector amounted to 396 GWh in 2016. The majority of energy used in social housing was from natural gas, accounting for 87% of the total fuel use. This may be due to the density of the gas grid in Dublin. Electricity contributed 12% to the fuel mix, which made it the second highest type of energy used.

Liquid gas, oil and other fossil fuels made up 1.35% of the energy use, which is a very minimal amount.

From this analysis, peat, coal, biofuel and biomass have no contribution to the fuel mix in social housing.

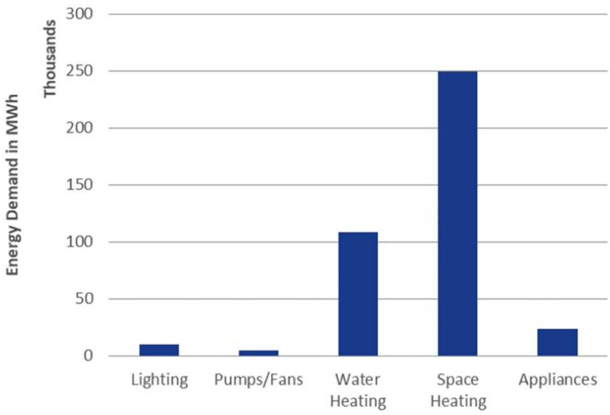

Figure 34 Social Housing Energy Demand in MWh in Dublin City

Figure 34 shows that most of the energy used was for space heating. At 63%, space heating had the highest energy demand, followed by water heating (27%). This shows that most of the energy use is for heating generally (i.e. both space and water heating). Lighting and pumps/ fans are the least energy intensive, making up 3% and 1%, respectively, of the total energy demand.

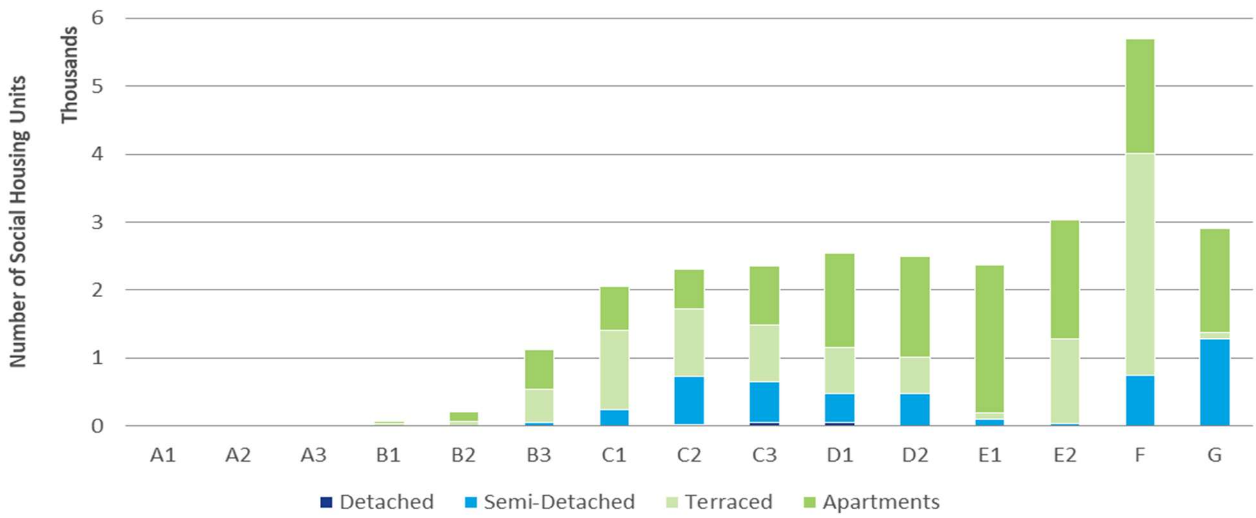

Figure 35 Building Energy Ratings for all the Dublin City's Social Housing Stock by Dwelling Type

Figure 35 shows the total building energy ratings for all the social housing in the city, for each dwelling type and period built.

We can see that the most common rating was F, which makes up 21% of the total social housing stock in Dublin City. The majority of buildings with an F rating were constructed between 1919 and 1970.

Seven social housing units in the city had an A rating, and 30% of the social housing stock is rated C3 or better. The social housing stock in Dublin City is ageing and as a result, newly built or upgraded dwellings would usually perform better.

Figure 36 depicts changes in the BERs over an eight year period from 2009 to 2016. In June 2013, DCC initiated a Fabric Upgrade Programme and is continually upgrading the social housing stock to make it more efficient.

To date, these actions have resulted in a 15% reduction in CO_2 emissions. These upgrades have caused a shift away from E, F and G ratings, to better B and C ratings.

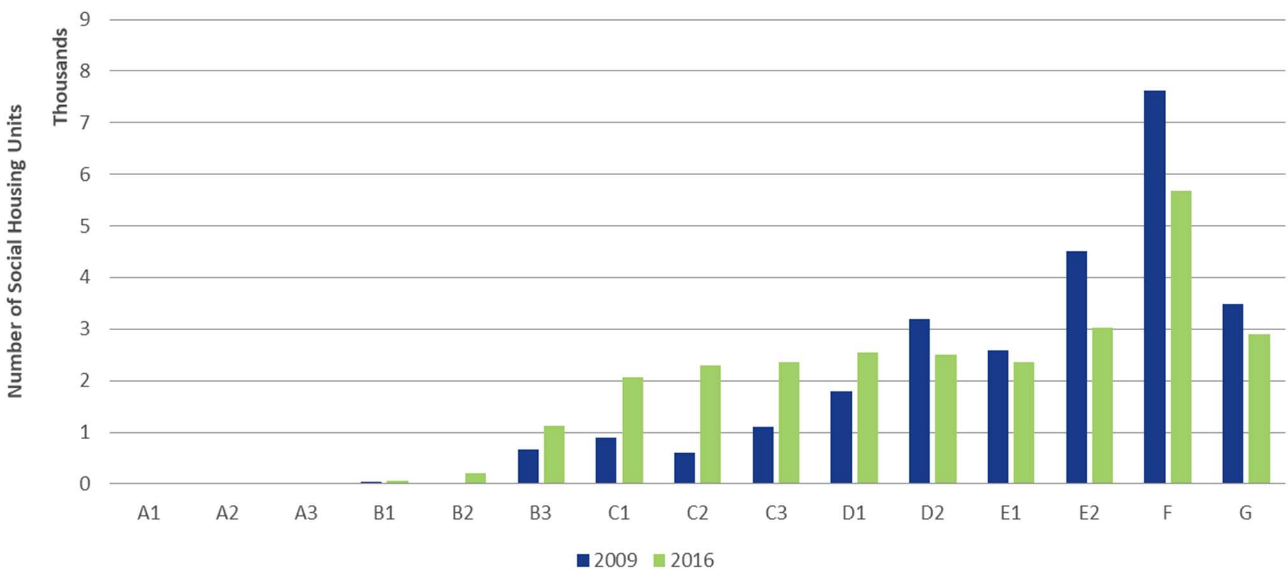

Figure 36 Building Energy Ratings for all the Dublin City Social Housing Stock in 2009 and 2016

Key Findings

- Total final emissions from social housing were found to be 94,000 tonnes of CO_2 in Dublin City
- Total delivered energy in 2016 amounted to 396 GWh for social housing in Dublin City
- Construction of social housing in Dublin City was the highest between 1919 and 1970
- Apartments were the least carbon intensive type of housing, emitting 2.92 tCO_2 per unit
- Detached, semi-detached and terraced houses were the highest emitters per dwelling, at 3.47, 3.93 and 3.97 tCO_2/house, respectively
- 30% of the social housing stock in Dublin City were rated C3 or better, with F being the most common BER type
- The period between 2009 and 2016 showed a 15% reduction in CO_2 emissions in DCC's social housing stock, due to continuous upgrades
- The majority of social housing units were apartments (47%) and terraced houses (35%), followed by semi-detached (17%) and detached (1%)
- Terraced houses and apartments had the highest emissions, each emitting 40% of total emissions, followed by semi-detached and detached houses, contributing 19% and 1% to total emissions, respectively
- Natural gas accounted for 75% of total social housing CO_2 emissions in Dublin City, followed by electricity at 24%
- Space heating and water heating had the highest energy demand, accounting for 63% and 27% of total energy demand, respectively
- Natural gas accounted for 87% of total energy consumption, followed by electricity at 12%

Table 5 Dublin City's Social Housing Inventory; Energy and CO_2 Emissions

Social Housing	Electricity	Fossil Fuels						Renewable Energies		Total
		Natural Gas	Liquid Gas	Heating Oil	Peat	Coal	Other fossil fuels	Biofuel	Other Biomass	
Detached (MWh)	203	2,092	-	16	-	-	-	-	-	2,312
Semi-Detached (MWh)	6,369	73,354	162	916	-	-	139	-	-	80,941
Terraced (MWh)	12,990	152,123	71	1,135	-	-	686	-	-	167,006
Apartments (MWh)	29,108	116,335	246	-	-	-	104	-	-	145,792
Total Energy (MWh)	**48,670**	**343,905**	**479**	**2,068**	**-**	**-**	**929**	**-**	**-**	**396,050**
Detached (tCO_2)	95	428	-	4	-	-	-	-	-	527
Semi-Detached (tCO_2)	2,978	15,016	37	236	-	-	37	-	-	18,303
Terraced (tCO_2)	6,073	31,140	16	292	-	-	181	-	-	37,702
Apartments (tCO_2)	13,608	23,814	56	-	-	-	27	-	-	37,505
Total Emissions (tCO_2)	**22,753**	**70,397**	**110**	**532**	**-**	**-**	**245**	**-**	**-**	**94,037**

Municipal

Dublin City Council (DCC) is responsible for the energy use and emissions from its buildings and facilities, its public lighting, and also its vehicle fleet[1].

Methodology

In Ireland, public sector bodies are required to report on their annual energy use and performance to the Sustainable Energy Authority of Ireland (SEAI). This is done through the Monitoring and Reporting system (M&R), which is used to track the local authorities' progress towards an energy efficiency improvement target of 33% by 2020, compared to the baseline year.

From the M&R system, Codema was able to extract the energy consumption for DCC, which was broken down by type of energy use - electricity, thermal (LPG, natural gas, kerosene, gas oil and wood) and transport (diesel, petrol and biofuels). The energy use was then converted into the different energies' corresponding CO_2 emissions, which may be found in Appendix B - Emissions.

The energy use was then broken down into three categories:

- Municipal Buildings / Facilities
- Public Lighting
- Municipal Fleet

Analysis

From the results obtained from the M&R system, DCC's total energy use in 2016 was 117 GWh. The council's buildings and facilities were the highest energy consumers, accounting for 62% of the council's overall consumption. This is mainly due to the large number of council-owned buildings. Public lighting was the second highest energy consumer, accounting for 23% of the total energy consumption, while municipal fleet accounted for 15% of the total energy use.

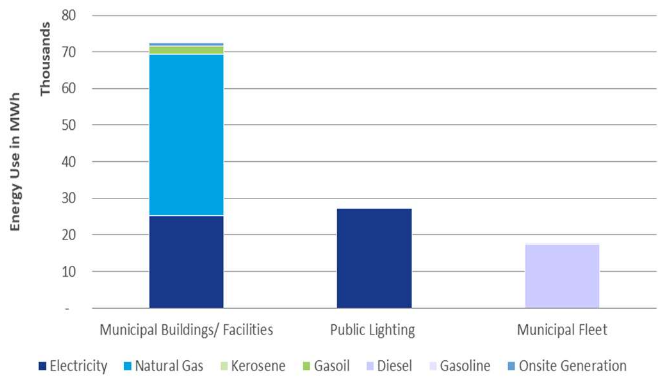

Figure 37 Energy Use in DCC Grouped by Category and Fuel Use

The highest share of fuel used by the council in 2016 was electricity (45%), followed by natural gas (37%). Diesel, which makes up part of the energy used for the vehicle fleet, contributes 15% to the total fuel mix. Renewables, namely onsite generation energy sources, amounted to 1% of the total energy mix throughout the council.

When energy use was converted into emissions, the council's total emissions amounted to 38,800 tonnes of CO_2. Buildings and facilities were the highest contributors, accounting for 55% of these total emissions. This was followed by public lighting and the municipal fleet, each contributing 33% and 12% to the council's CO_2 emissions, respectively.

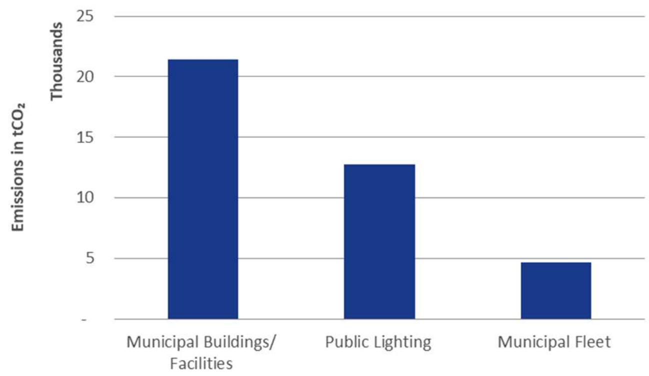

Figure 38 Emissions in tCO_2 by Sector in the Municipality

[1] Emissions from water supply, mainly pumping water from source to the destination (residential, commercial properties, etc.) are no longer part of the municipality's remit, and have been removed. However, these emissions are still part of the city and have been included with the City's total emissions which may be found in the Conclusions Chapter.

Similarly, when the local authority's energy use was converted into emissions, the highest emissions came from electricity at 63%, followed by natural gas and diesel, each emitting 23% and 12%, respectively.

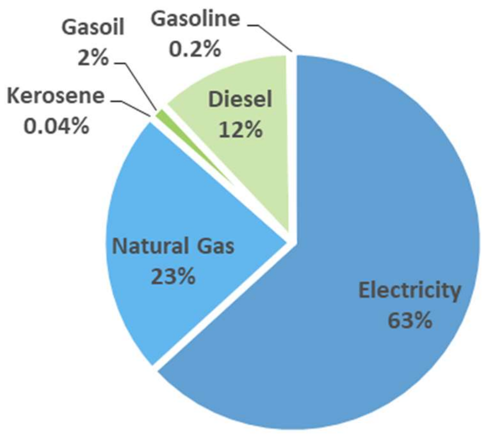

Figure 39 DCC's Emissions by Fuel Type

Key Findings

The key findings from the municipal sector are summarised below.

- Total final emissions produced by DCC in 2016 were 38,800 tonnes of CO_2
- Total final energy used in 2016 in DCC was 117 GWh
- Buildings and facilities were the largest consumers of energy in the municipality. They make up 62% of the total energy consumption
- Buildings and facilities contributed 55% to total emissions in DCC, followed by public lighting, (33%), and municipal fleet (12%)
- Electricity accounted for 63% of DCC's total carbon emissions, followed by gas (23%) and diesel (12%)

Table 6 Dublin City's Municipal Inventory, Energy and CO_2 Emissions

Municipal Sector	Electricity	Fossil Fuel							Renewable Energies				Total
		Natural Gas	Liquid Gas	Heating Oil		Diesel	Gasoline	Other Fossil Fuels	Biofuel	Other Biomass	Onsite Generation	Solar Thermal	
				Kerosene	Gasoil								
Municipal Buildings/ Facilities (MWh)	25,285	44,081	-	59	2,143	-	-	-	-	-	844	-	72,412
Public Lighting (MWh)	27,270	-	-	-	-	-	-	-	-	-	-	-	27,270
Municipal Fleet (MWh)	-	-	-	-	-	17,350	376	-	-	-	-	-	17,726
Total Energy (MWh)	**52,555**	**44,081**	**-**	**59**	**2,143**	**17,350**	**376**	**-**	**-**	**-**	**844**	**-**	**117,409**
Municipal Buildings/ Facilities (tCO_2)	11,820.74	9,023.38	-	15.15	565.76	-	-	-	-	-	-	-	21,425
Public Lighting (tCO_2)	12,748.77	-	-	-	-	-	-	-	-	-	-	-	12,749
Municipal Fleet (tCO_2)	-	-	-	-	-	4,580	95	-	-	-	-	-	4,675
Total Emissions (tCO_2)	**24,570**	**9,023**	**-**	**15**	**566**	**4,580**	**95**	**-**	**-**	**-**	**-**	**-**	**38,849**

Waste and Wastewater

This section analyses the CO_2 emissions from landfill waste and wastewater; namely emissions from collection, wastewater treatment and disposal.

Waste

Since 2012, government policies have focused on dealing with waste as a resource, as well as reducing or eliminating landfilling (EPA, 2017). Waste management practices currently promote the recovery of residual waste, rather than disposing into landfills.

In 2013, segregation and separate collection of domestic food waste was legislated and as a result, municipal waste recycling and composting increased. This has resulted in the reduction of landfill disposal. In the Dublin Region most landfills are inactive, and only six landfills sites are active across the whole of Ireland (EPA, 2017)[2]. Municipal waste in Ireland consists of domestic, commercial and other waste.

Methodology

The emissions data from landfills were obtained from two main data sources: the EPA 2017 Waste Application Licences and environmental information from landfill annual reports. A detailed list of assumptions and limitations may be found in the Appendix section.

The EPA 2017 Waste Applications provided Codema with a list of all licensed landfills in the Dublin region. The licensed landfills are listed by name and location. From the names and location, the annual reports for each landfill can be found, which contain a Pollutant Release and Transfer Register (PRTR). The PRTR is a reporting system of emissions and lists more than 350 industrial facilities that are involved in environmentally hazardous activities. Each service or facility listed must provide information regarding the amount of pollutant releases to air, water and wastewater.

From the PRTR of each landfill licenced in the Dublin region, Codema calculated the total emissions released to the air. The PRTR lists the different GHGs that are released annually, and these were then converted into CO_2 equivalent emissions. This allowed the calculation of the total CO_2 emissions from landfill for the Dublin region However, in order to calculate the landfill emissions for Dublin City, the population number for each Dublin area was obtained from the 2016 Census of Population, this was done to divide the total emissions by population for each local authority area.

Analysis

Even though most of the landfills in Dublin are inactive, they still emit GHG emissions. Figure 40 depicts the breakdown of landfill emissions in terms of tCO_2eq; this makes them comparable and it is easier to understand their effect on emissions.

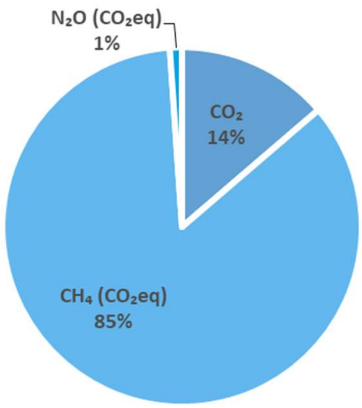

Figure 40 Landfill CO_2eq Breakdown

As may be seen from the figure above, most of the GHG emissions are made up of methane gas (CH_4), and due to the toxic content of methane, their impact is much larger even though methane might only be a small proportion of landfill emissions. Therefore, methane gas contributes to more CO_2eq gas than CO_2 does.

Table 7 Landfill Emissions in Dublin City

	Total Landfill Emissions in Dublin in tCO_2eq	Total population in Dublin	Population in Dublin City	Landfill Emissions in Dublin City in tCO_2eq
Calculating Landfill Emissions	128,047	1,345,402	553,165	**52,647**

[2] The Waste to Energy plant began operations in Ringsend in 2017, and may affect future waste analysis.

Wastewater

As the population in Dublin keeps growing, the amount of wastewater generated also increases. Currently, the wastewater treatment plant in Ringsend serves the population of the Greater Dublin Area (GDA), which includes the Dublin region and commuting towns of Meath, Kildare and Wicklow. The increase in population and the large area covered by the treatment plant have led authorities to seek a new facility and develop a National Wastewater Sludge Management Plan, published in 2016, to take some of the pressure off of the Ringsend facility.

Methodology

Ideally, emissions from wastewater would have been collected from Celtic Anglian Water (CAW), as they are the operators of the plant at Ringsend. However, CAW was unable to provide wastewater data within the timeframe of this study, and as such, a case study was used to estimate emissions from Ringsend's wastewater collection, treatment and disposal. A detailed list of assumptions and limitations can be found in Appendix A - Assumptions & Limitations

This case study showed an example of two wastewater treatment plants (WWTP) in Vienna, Austria, which involved a carbon footprint analysis to calculate the emissions from sewage sludge treatment, anaerobic digestion and sludge dewatering (Parravicini, et al., 2016).

Table 8 shows the emission sources from wastewater that were considered in this case study.

Table 8 Direct and Indirect Emissions from Wastewater

Emissions from Wastewater	
Direct GHG emissions	**Indirect GHG emissions**
Wastewater collection (sewer system)	Electricity supply
Wastewater treatment (WWTP)	Transportation (sewage sludge)
Wastewater discharge in water bodies	Use of chemicals & additives
	Disposal/reuse of residuals

Emissions that were considered in this study at different treatment stages were methane and nitrous oxide.

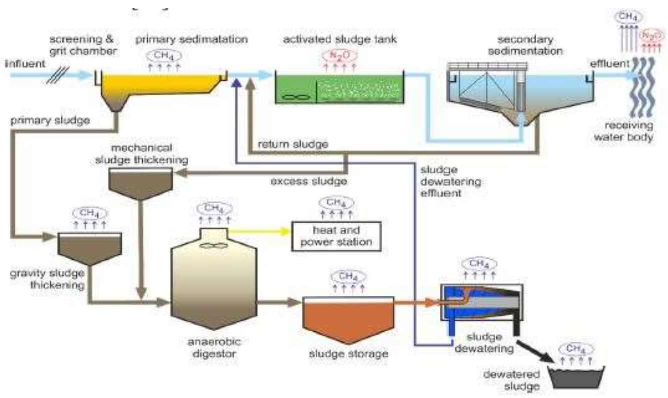

Figure 41 GHG Emissions at WWTP Source : Parravicini et al. (2016)

The carbon footprint analysis of the two WWTPs resulted in GHG emissions per population served, which was then broken down into GHG emissions per capita per annum. In a final step, the GHG emissions were then converted into CO_2 equivalents.

Comparing the findings of this case study with the Ringsend WWTP, which has similar characteristics to the two Austrian sites analysed, the CO_2 emissions could be calculated and were found to be 23kgCO_2eq per capita, per annum.

Codema applied the CO_2 equivalent per capita to the population of Dublin City, to get the total emissions in Dublin City from wastewater. This has been shown in Table 9 below.

Analysis

A detailed analysis of wastewater was not conducted as the data used in this report to calculate wastewater emissions were taken from a case study and not the actual emissions from the Ringsend WWTP. Once the data is made available, a more in-depth analysis will be provided.

Table 9 Wastewater Emissions in Dublin City

	Emissions per capita in kgCO_2/PE/a	Population in Dublin City	Wastewater Emissions in Dublin City in tCO_2eq
Calculating Wastewater Emissions	23	553,165	**12,723**

Key Findings

Waste

- Total emissions from landfills in Dublin City was found to be 52,700 tonnes of CO_2eq
- Methane made up 85% of total CO_2eq emissions in landfills
- CO_2 contributes to 14% of total CO_2eq emissions in landfills

Wastewater

- Total emissions from wastewater in Dublin City was found to be 12,700 tonnes of CO_2eq
- Wastewater emissions per person per annum were estimated to be 23KgCO_2eq

Table 10 Dublin City's Waste Emissions Inventory.

Waste Emissions in Dublin City	Landfill Waste	Wastewater
Total Emissions in tCO_2eq	52,652	12,723

2016 Energy Use in Comparison with 2011

This chapter analyses and compares energy use for Dublin City in 2011 and 2016. 2011 energy use figures for the housing and commercial sectors came from Codema's '*Dublin City Sustainable Energy Action Plan – Monitoring and Progress Report 2014*'. This 2014 report, is an assessment of the progress of Codema's 'Dublin City Sustainable Energy Action Plan 2010-2020', as part of DCC's commitment to the EU Covenant of Mayors initiative. This assessment was carried out in 2014, so was based on the CSO's 2011 Census.

For the municipal sector, data for 2011 was found directly from the M&R System and is further analysed in Appendix D - Municipal Emissions Projection.

In Codema's 2014 report, energy use and emissions from transport were analysed. However, a comparison between the two could not be made, as the methodologies differ from one to the other. Once the 2016 Census has been analysed by the NTA and the 2016 transport data has been received, then a comparison between 2011 and 2016 energy use and emissions (gathered by the NTA for both years) may be carried out. In this report, energy and emissions for 2016 are based on figures provided by the NTA and are based on projections of the 2012 transportation data.

Housing

Over the five year period between 2011 and 2016, Dublin City's housing units increased by 1.75%. It is important to note that housing in 2011 and 2016 include both residential and social housing. In the previous chapters in this report, residential and social housing have been split into separate sectors, however for the purpose of comparing energy use between 2016 and 2011, both sectors have been combined.

As we can see from Figure 42, terraced houses and apartments accounted for the greatest increase in housing units during this five-year period. Meanwhile, detached houses had the smallest change in units (an increase of just 461 housing units).

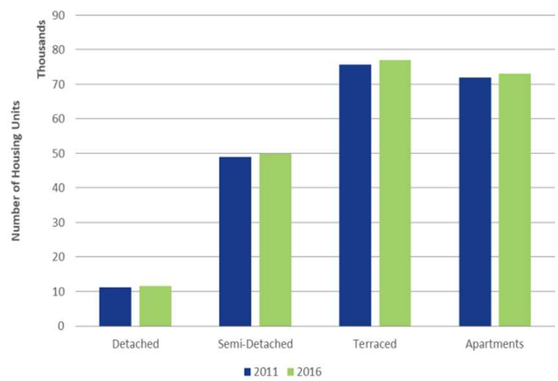

Figure 42 Total Number of Housing Units in Dublin City; 2011 and 2016

Total energy use in housing decreased by 12% from 2011 to 2016, with the highest reductions coming from terraced houses and semi-detached houses. From all the dwelling types, detached houses had the lowest change in energy use for the same period.

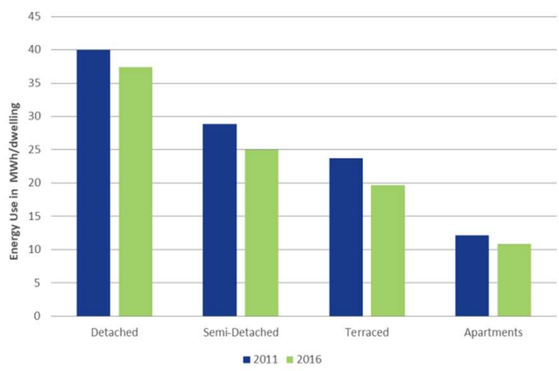

Figure 43 Energy Use per Dwelling in Dublin City's Housing Sector by Type- 2011 and 2016

SEAI's '*Energy Efficiency in Ireland, 2016 Report'*, showed that between 2000 and 2006, the residential sector consumed between 23 and 25 MWh per dwelling nationally, and 17.6MWh per dwelling in 2014. Codema's analysis shows that in 2011, Dublin City's residential sector consumed 21.8MWh per unit, whilst in 2016, energy use per dwelling decreased to 18.9 MWh.

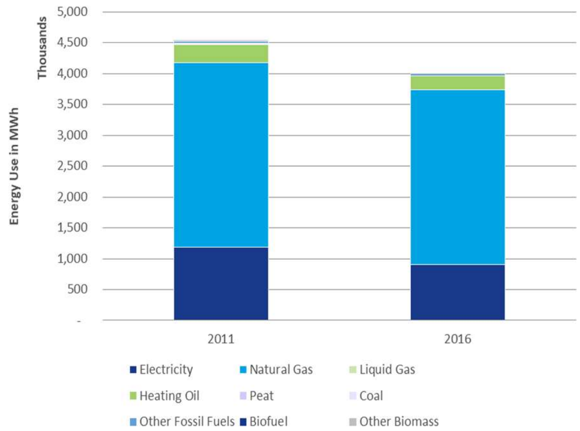

Figure 44 Total Energy Use in MWh in the Housing Sector by Fuel Mix; 2011 and 2016

Figure 44 illustrates the energy use in 2011 and 2016, according to fuel type. It can be seen that the most common fuel for both periods was natural gas, followed by electricity. The largest change in fossil fuel between the two periods was for peat, which went from 967 MWh in 2011 to 247 MWh in 2016; this was closely followed by coal and other fossil fuels. Meanwhile, biofuels increased their energy use from 6 MWh in 2011 to 16 MWh in 2016.

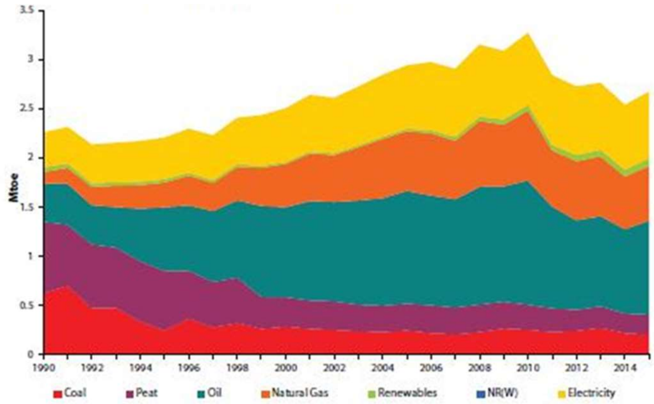

Figure 45 Residential Energy Use by Fuel. Source: SEAI Energy Statistics 1990-2015

The resulting decrease of overall energy, namely from fossil fuel sources and an increase in energy from certain renewable sources in Dublin City's housing stock, is in keeping with national findings. This can be seen from Figure 45, which has been extracted from SEAI's 2016 Report '*Energy Statistics 1990-2015'*, which shows energy reduction in the residential sector in million tonnes of oil equivalent (Mtoe). For the period between 2011 and 2015, coal and peat reduced nationally by 10% and 17% respectively. However, renewable energy increased for the same period, from 53Mtoe up to 76Mtoe in 2015.

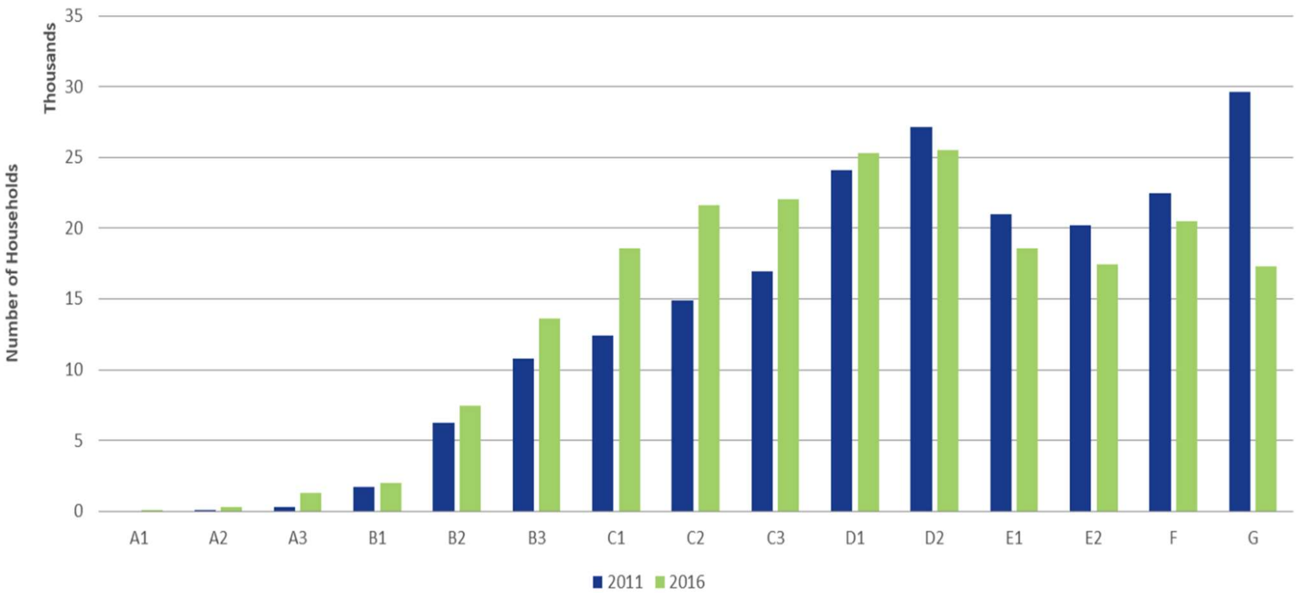

Figure 46 BERs for Dublin City Housing Stock; 2011 and 2016

Figure 46 shows an improvement in the BER ratings for the total housing stock in Dublin City, with the most common rating changing from a G in 2011 to a D2 in 2016. Furthermore, A and B ratings increased from 9% in 2011 to 12% in 2016.

As explained in both the Residential and Social Housing Sections, Dublin City has an old housing stock, and as a result, newly built or refurbished dwellings would generally perform better.

Overall, the housing stock in Dublin City had an improved Building Energy Rating, which may be due to a number of factors such as retrofitting work on social housing to upgrade the social housing stock, the Better Energy Home grants and the Deep Retrofit Program from SEAI.

Table 11 Dublin City's Housing Energy Use Inventory; 2011 and 2016

Residential Sector		Electricity							Renewable Energies		Total
			Natural Gas	Liquid Gas	Heating Oil	Peat	Coal	Other Fossil Fuels	Biofuel	Other Biomass	
2011	Detached (MWh)	55,187	310,434	490	78,189	-	826	1,850	-	-	446,976
	Semi-Detached (MWh)	193,258	1,061,244	1,085	139,549	397	5,083	12,170	-	492	1,413,279
	Terraced (MWh)	339,861	1,352,888	1,048	68,243	570	8,504	25,527	-	1,206	1,797,847
	Apartments (MWh)	594,690	264,667	2,074	8,042	-	385	763	6	1,859	872,486
	Total Energy (MWh)	1,182,997	2,989,232	4,697	294,023	967	14,798	40,310	6	3,557	4,530,588
2016	Detached (MWh)	61,835	302,429	811	67,485	-	528	2,650	-	-	435,739
	Semi-Detached (MWh)	144,170	986,276	1,172	101,264	123	2,151	8,202	-	196	1,243,554
	Terraced (MWh)	210,877	1,238,336	650	49,253	124	2,675	14,316	-	343	1,516,573
	Apartments (MWh)	486,112	304,764	1,074	2,340	-	77	594	16	773	795,749
	Total Energy (MWh)	902,994	2,831,806	3,707	220,343	247	5,430	25,761	16	1,312	3,991,615

Commercial

From 2011 to 2016, energy use in the commercial sector increased by 9%, from 2,730 GWh to 2,976 GWh in 2016. As can be seen from Figure 47, the highest increase in energy use was in the services sector; this increased by 10%, while energy use in the industry sector increased by 5% from 2011.

The services sector's biggest energy users are hospitals, hotels and large entertainment theatres. Meanwhile the industry sector's most energy-intensive users are factories, stores, workshops and warehouses.

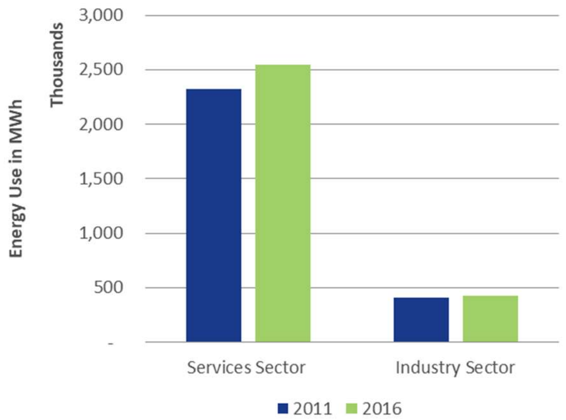

Figure 47 Total Energy Use in the Services and Industry Sector; 2011 and 2016

The increase in energy came mainly from natural gas and electricity; both fuels increased by 5% from 2011.

Renewables increased from 3% in 2011 to 6% in 2016, due to an increase in energy supply from geothermal and biomass sources. Meanwhile, energy use from heating oil in the commercial sector decreased by 12%, moving from 34% energy use in 2011 to 22% in 2016.

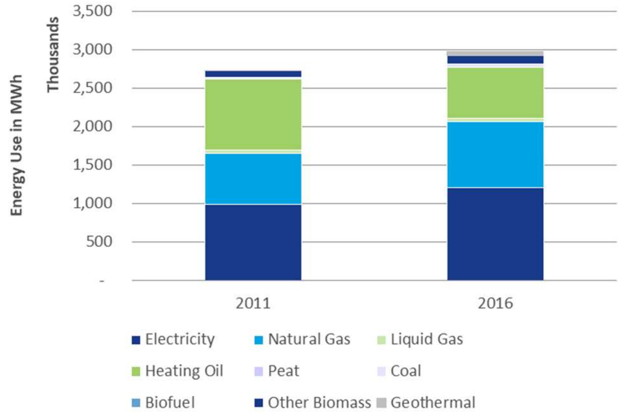

Figure 48 Total Energy Use in MWh in the Commercial Sector by Fuel Mix; 2011 and 2016

The number of businesses in 2011 decreased from 20,979 businesses to 19,606 businesses in 2016. The decrease in number of businesses mainly came from miscellaneous uses, retail (shops), utility and industrial uses. However, even though there was a decrease in number of businesses, industrial uses, retail (warehouses) and retail (shops) had an increase in floor area. From 2011, the floor area of the commercial sector increased by a total of 9%.

After further analysis, the energy increase in the commercial sector may be attributed to an increase in floor areas by different commercial properties. Since this methodology is based on CIBSE energy benchmarks per metre squared floor area (different energy benchmarks for different types of commercial properties as explained in the methodology for the Commercial Sector of this report), an increase in floor area may then result in an increase in energy use for the commercial sector.

From the 2016 Census results, it was found that the number of employed people in 2016 increased by 11% (over 2 million people) since 2011. Therefore, an increase in floor area, which would be needed to accommodate additional workers, may be a direct result of an increase in the workforce.

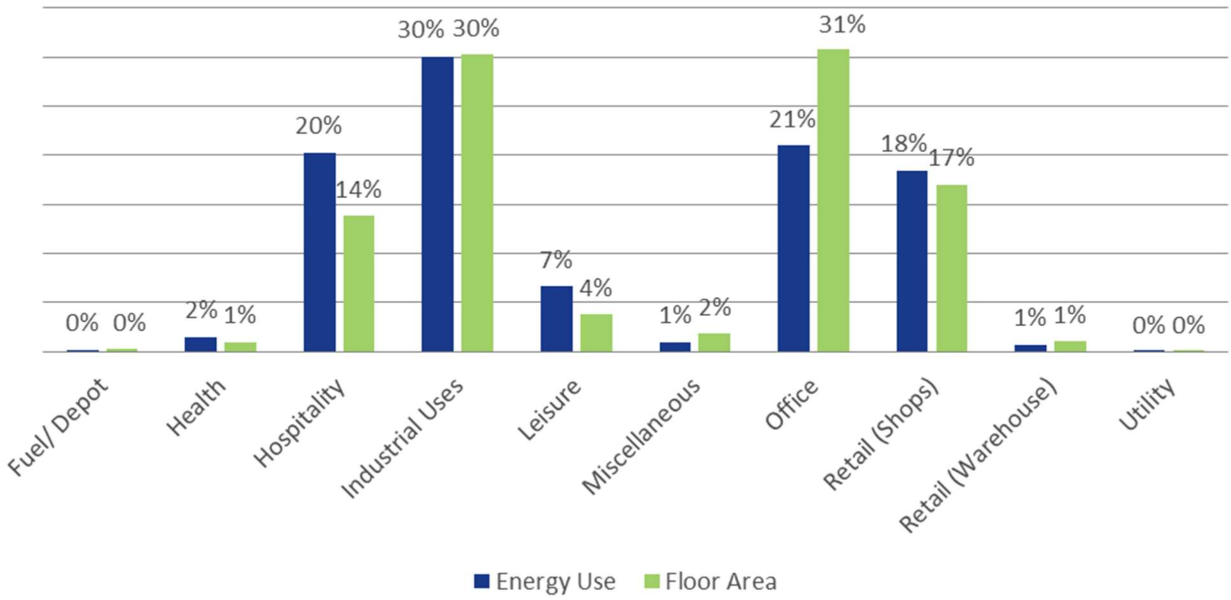

Figure 49 Share of Total Energy Use and Floor Area for Commercial Properties in Dublin City in 2011

Figure 49 and Figure 50 depict the share of energy use and floor area for each type of property in 2011 and 2016. By comparing energy use to floor area, one may gain a better understanding of energy use in kWh per metre squared of floor area.

The largest changes between 2011 and 2016 have been noted in the retail (warehouse) and miscellaneous sectors. Retail (warehouse) increased energy use from 4.17kWh/m^2 to 4.63kWh/m^2 in 2016 and miscellaneous uses increased by 0.41kWh/m^2, resulting in an energy use of 5.61kWh/m^2 in 2016. The energy use for the other property types remained relatively the same over the five year period, with only slight increases or decreases in energy use per metre squared.

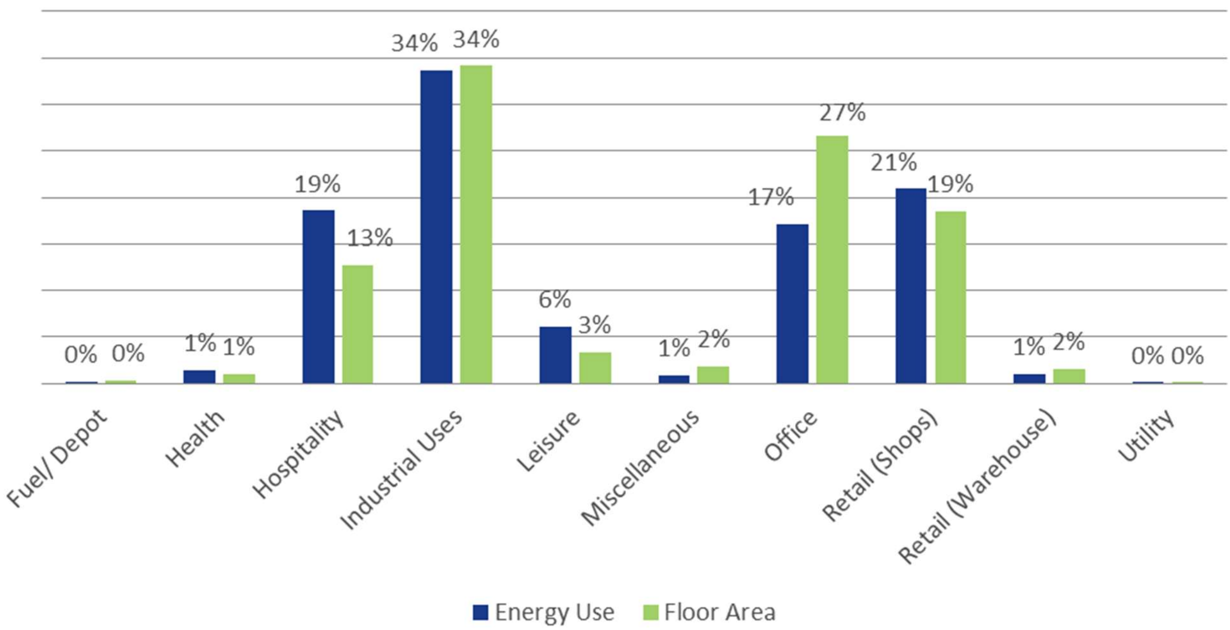

Figure 50 Share of Total Energy Use and Floor Area for Commercial Properties in Dublin City in 2016

Table 12 Dublin City's Commercial Energy Use Inventory; 2011 and 2016

Commercial Sector		Electricity	Fossil Fuels						Renewable Energies			Total
			Natural Gas	Liquid Gas	Heating Oil	Peat	Coal	Other fossil fuels	Biofuel	Other Biomass	Geothermal	
2011	Services Sector (MWh)	840,976	552,979	20,737	846,749	-	-	-	-	55,298	6,912	2,323,651
	Industry Sector (MWh)	146,765	112,232	17,806	73,742	-	25,900	-	899	28,598	-	405,941
	Total Energy (MWh)	987,741	665,211	38,543	920,491	-	25,900	-	899	83,895	6,912	2,729,592
2016	Services Sector (MWh)	1,057,927	723,341	20,667	620,006	-	-	-	-	70,267	57,867	2,550,075
	Industry Sector (MWh)	150,540	136,321	18,840	41,590	178	40,879	-	533	36,969	-	425,849
	Total Energy (MWh)	1,208,467	859,662	39,507	661,596	178	40,879	-	533	107,236	57,867	2,975,924

Municipal

From 2011 to 2016, Dublin City Council (DCC) reduced its energy use by 12%. As per the previous section, (Municipal Sector), the total energy use was broken down into three categories:

- Municipal Buildings/Facilities
- Public Lighting
- Municipal Fleet

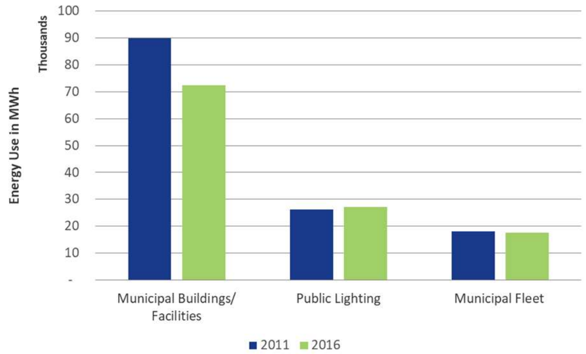

Figure 51 Energy Use by Sector in DCC; 2011 and 2016

A reduction in energy use was recorded for municipal buildings/facilities and the municipal fleet. Notably, buildings and facilities reduced their energy use by 19% from 2011 to 2016, while the council's fleet reduced its energy use by 2% over the same period. However, over the five year span, public lighting had an increase in energy use of 4%.

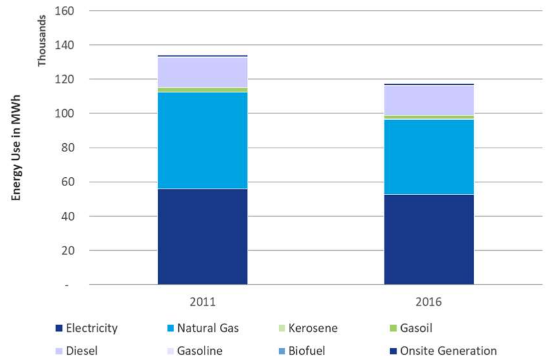

Figure 52 Total Energy Use in MWh in DCC by Fuel Mix; 2011 and 2016

Energy use was split by fuel type (as can be seen in Figure 52), and it may be noted that in both years (2011 and 2016), electricity and natural gas were the most common fuels used.

Natural gas reduced by 22% from 56 GWh in 2011 to 44 GWh in 2016, while energy use from electricity reduced by 6%. Heating oil (namely kerosene) decreased from 0.11 GWh to 0.06 GWh from 2011 to 2016, thus making it the energy use that reduced the most, with a reduction of 48%.

It is important to note that energy use from renewables also decreased, with onsite generation decreasing by 16% and biofuel was not used in 2016 as opposed to 4 MWh in 2011.

Table 13 Dublin City's Municipal Energy Use Inventory; 2011 and 2016

Municipal Sector		Electricity	Fossil Fuel							Renewable Energies				Total
			Natural Gas	Liquid Gas	Heating Oil		Diesel	Gasoline	Other Fossil Fuels	Biofuel	Other Biomass	Onsite Generation	Solar Thermal	
					Kerosene	Gasoil								
2011	Municipal Buildings/ Facilities (MWh)	29,950	56,247	-	113	2,508	-	-	-	-	-	1,009	-	89,828
	Public Lighting (MWh)	26,160	-	-	-	-	-	-	-	-	-	-	-	26,160
	Municipal Fleet (MWh)	-	-	-	-	-	17,662	489	-	4	-	-	-	18,155
	Total Energy (MWh)	56,110	56,247	-	113	2,508	17,662	489	-	4	-	1,009	-	134,143
2016	Municipal Buildings/ Facilities (MWh)	25,285	44,081	-	59	2,143	-	-	-	-	-	844	-	72,412
	Public Lighting (MWh)	27,270	-	-	-	-	-	-	-	-	-	-	-	27,270
	Municipal Fleet (MWh)	-	-	-	-	-	17,350	376	-	-	-	-	-	17,726
	Total Energy (MWh)	52,555	44,081	-	59	2,143	17,350	376	-	-	-	844	-	117,408

Conclusions

Total Energy Use & Emissions in Dublin City

This section examines the energy use and resulting total emissions from the different carbon emitting sectors in Dublin City.

The total energy use in Dublin City amounted to 9,771 GWh in 2016. At 38%, natural gas accounted for the greatest percentage of total energy consumption in Dublin City. This was followed by electricity (22%) and diesel (21%). It should be noted that energy from renewables only contributed 2% to the total fuel mix in Dublin City. Of this renewable energy, 1.1% came from biomass energy.

The total emissions from the various sectors in Dublin City total 2,810,900 tonnes of CO_2eq. Figure 54 below illustrates the total emissions by sector and fuel type; waste and wastewater were not broken down by fuel type, as the data provided was in terms of emissions.

From this analysis, Codema found that the commercial sector used the most electricity in Dublin City, and had the highest emissions from electricity (55%) as a result. As explained in the previous chapter (Emission Sectors, Commercial), this may be due to the number of retail and office outlets in Dublin City, which mostly use of electricity as their main energy source.

The residential sector had the highest CO_2 emissions for natural gas, accounting for 67% of the total gas emissions in Dublin City.

Meanwhile, the transport sector accounted for 99% of all diesel emissions in Dublin City.

It should be noted that the residential, commercial and transport sectors had the highest emissions and consume more fossil fuels than other sectors.

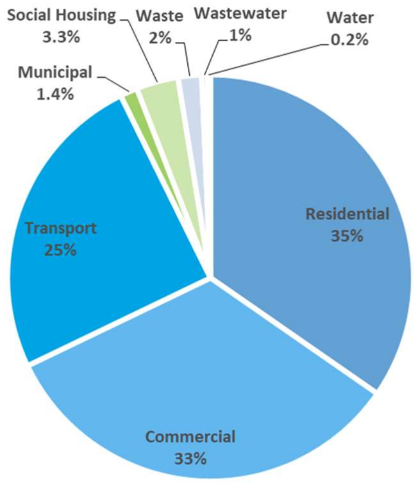

Figure 53 Share of Total Emissions in Dublin City

The sectors that produced the most emissions were residential, commercial and transport, producing 35%, 33% and 25% respectively, of total emissions in Dublin City. From this analysis, these three sectors should be the main targets of energy and emission reduction initiatives.

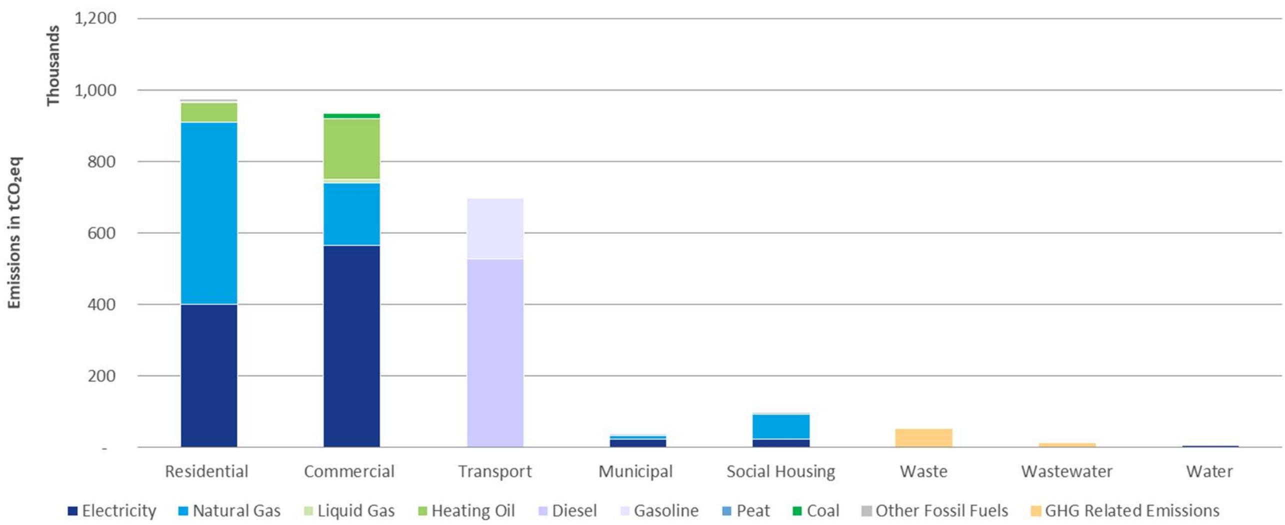

Figure 54 Total Emissions by Fuel Type in Different Sectors

Key Findings

2016 Emissions & Energy Use

Residential

- Total residential emissions were 974,000 tCO_2 in 2016
- Total delivered energy for the residential sector in Dublin City for 2016 was 3,596 GWh
- 43% of the housing stock was C3 or better, with D2 being the most common rating
- Terraced houses made up 37% of the total residential housing stock, followed by apartments (33%), semi-detached (24%), and detached houses (6%), respectively
- Apartments were the least carbon intensive type of housing emitting 4.20 tCO_2/apartment
- Detached houses were the most carbon intensive type of housing, emitting 9.46 tCO_2/detached house
- 52% of residential emissions came from natural gas and 41% from electricity

Commercial

- Total emissions in 2016 were 934,000 tCO_2; 806,700 tCO_2 from services and 127,300 tCO_2 from industrial sector
- Total final energy used in 2016 in the commercial sector was 2,976 GWh
- Industrial uses (32%), retail (26%), offices (17%) and hospitality (17%) contributed the most to CO_2 emissions
- Hospitality and leisure had the highest emissions per property, 230.5 tCO_2 and 230.6 tCO_2, respectively
- Utility, miscellaneous uses and offices had the lowest emissions per property, at 13.2 tCO_2, 14.3 tCO_2 and 20.0 tCO_2, respectively

Transport

- Total final emissions from transport were 697,700 tCO_2
- Total energy use in transport was 2,672GWh
- Dublin City's modal split was made up of 43% private and commercial transport, public transport, 20%, walking, 30% and cycling 7%
- Transport emissions came from diesel, 75%, gasoline, 25%, electricity, 0.2% and LPG, 0.1%

Social Housing

- Total final emissions from social housing amounted to 94,000 tCO_2 in Dublin City
- Total delivered energy in 2016 amounted to 396 GWh for social housing in Dublin City
- 30% of the social housing stock in Dublin City were rated C3 or better, with F being the most common BER type
- The majority of social housing units were apartments and terraced houses, making up 47% and 35% of the total social housing stock respectively, followed by semi-detached, 17%, and detached, 1%
- Apartments were the least carbon intensive type of housing, emitting 2.92 tCO_2 per unit
- Detached, semi-detached and terraced houses were the highest emitters per dwelling, 3.47, 3.93 and 3.97 tCO_2/house
- 75% of total social housing CO_2 emissions in Dublin City came from natural gas, followed by electricity, 24%

Municipal

- Total final emissions produced by DCC in 2016 were 38,800 tCO_2
- Total final energy used in 2016 in DCC was 117 GWh
- Buildings and facilities contributed 55% to total emissions in DCC, followed by public lighting, 33%, and municipal fleet, 12%
- Electricity accounted for 63% of DCC's total carbon emissions, followed by gas at 23% and diesel at 12%

Waste

- Total emissions from landfills in Dublin City amounted to 52,700 tCO_2eq
- Methane made up 85% of total CO_2 equivalent emissions in landfills

Wastewater

- Total emissions from wastewater in Dublin City amounted to 12,700tCO_2eq
- Wastewater emissions per person per annum were estimated to be 23KgCO_2eq

2016 Energy Use in Comparison with 2011

Housing

- Dublin City's housing units increased by 1.75%; terraced houses and apartments increased the most, 0.6% and 0.5% respectively
- Total energy use in housing decreased by 12%, the highest reductions came from terraced and semi-detached houses.
- Energy use per unit decreased from 21.8 MWh in 2011 to 18.9 MWh per unit in 2016
- BERs for the total housing stock in Dublin City improved from a G rating in 2011 to a D2 rating in 2016
- BERs with an A and B rating increased by 12% and 9% respectively from 2011

Commercial

- Energy use in the commercial sector increased by 9%; this increase came from the services sector (10%) and the industry sector (5%)
- From 2011, the floor area of the commercial sector increased by a total of 9%; this increase mainly came from industrial uses and retail (warehouses and shops)
- The largest changes between 2011 and 2016 were in the retail (warehouse) and miscellaneous sectors. Retail (warehouse) increased energy use from 4.17kWh/m^2 to 4.63kWh/m^2 in 2016 and miscellaneous uses increased by 0.41kWh/m^2
- The increase in energy was mostly from natural gas and electricity; both fuels increased each by 5% from 2011

Municipal

- From 2011 to 2016, DCC reduced its energy use by 12%
- Buildings and facilities reduced their energy use by 19% from 2011 to 2016; fleet reduced its energy use by 2% but public lighting had a 4% increase
- Natural gas and electricity consumption reduced by 22% and 6%, respectively
- Energy use from renewables decreased, with onsite generation decreasing by 16% and biofuel was not used in 2016 as opposed to 4 MWh in 2011

Table 14 Dublin City's Inventory; Energy and CO_2 Emissions

Dublin City	Electricity	Fossil Fuels									Renewable Energies				Total
		Natural Gas	Liquid Gas	Heating Oil	Diesel	Gasoline	LPG	Peat	Coal	Other Fossil Fuels	Biofuel	Other Biomass	Onsite Generation	Geothermal	
Residential (MWh)	854,324	2,487,901	3,228	218,275	-	-	-	247	5,430	24,832	16	1,312	-	-	3,595,564
Commercial (MWh)	1,208,467	859,662	39,507	661,596	-	-	-	178	40,879	-	533	107,236	-	57,867	2,975,924
Transport (MWh)	2,855	-	-	-	1,990,807	676,320	1,774	-	-	-	-	-	-	-	2,671,756
Municipal (MWh)	52,555	44,081	-	2,202	17,350	376	-	-	-	-	-	-	844	-	117,409
Social Housing (MWh)	48,670	343,905	479	2,068	-	-	-	-	-	929	-	-	-	-	396,050
Waste (MWh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wastewater (MWh)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water (MWh)	14,689	-	-	-	-	-	-	-	-	-	-	-	-	-	14,689
Total Energy (MWh)	**2,181,559**	**3,735,549**	**43,214**	**884,141**	**2,008,157**	**676,696**	**1,774**	**425**	**46,308**	**25,761**	**549**	**108,548**	**844**	**57,867**	**9,771,392**
Residential (tCO_2)	399,397	509,273	740	56,097	-	-	-	88	1,849	6,553	-	-	-	-	973,997
Commercial (tCO_2)	564,958	175,973	9,059	170,030	-	-	-	63	13,923	-	-	-	-	-	934,007
Transport (tCO_2eq)	1,335	-	-	-	525,573	170,433	406	-	-	-	-	-	-	-	697,747
Municipal (tCO_2)	24,570	9,023	-	581	4,580	95	-	-	-	-	-	-	-	-	38,849
Social Housing (tCO_2)	22,753	70,397	110	532	-	-	-	-	-	245	-	-	-	-	94,037
Waste (tCO_2eq)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52,647
Wastewater (tCO_2eq)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,723
Water (tCO_2)	6,874	-	-	-	-	-	-	-	-	-	-	-	-	-	6,874
Total Emissions (tCO_2/tCO_2eq)	**1,019,886**	**764,667**	**9,909**	**227,239**	**530,154**	**170,527**	**406**	**151**	**15,773**	**6,798**	**-**	**-**	**-**	**-**	**2,810,881**

Appendices

Acknowledgements

Codema would like to thank all the organisations and individuals consulted for this report who took the time to contribute to this work, in particular:

- Dublin City Council
- SEAI
- Environmental Protection Agency
- Barry Colleary, National Transport Authority
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- Pat Goucher, Valuation Office
- Pawel Bogacz, National Transport Authority
- Prof. Brian Ó Gallachóir, University College Cork

Appendix A - Assumptions & Limitations

Residential & Social Housing

- Locations of dwellings in the BER database are in terms of postcodes. This is done to preserve the identity of the home owners. However, there are certain cases were a postcode might overlap, meaning that the postcode might be the same for more than one local authority area. This might result in certain dwellings that are in other local authority regions to be placed in the Dublin City area as they share a common postcode
- BER certificates are only required if a house is being sold or rented. This results in a database that is not completely representative of all housing
- The BER dataset does not differentiate between different users and their energy use, nor does it account for energy use by appliances
- In the social housing sector, the energy rating for most of the households were provided by the local authority, however if an energy rating was not provided, then an energy rating (depending on the year of construction, type of household and characteristics of the housing unit) was assigned to the household

Commercial

- There are no energy benchmarks available in Ireland for commercial properties. Therefore, the UK CIBSE Guide was used, which is based on numerous surveys in the UK for different commercial property types
- Most of the benchmarks used by CIBSE are outdated, with some surveys dating back to 1992. This may not reflect the energy usage of the baseline year
- All energy figures used are 'Typical Practice' figures as described by CIBSE
- The energy use in retail is based on floor area used for sales. Therefore, no energy was allocated for storage or back of house uses
- All offices are assumed as 'naturally ventilated open plan', as described in CIBSE
- Hairdressing/salons are assumed as 'high street agencies' due to their higher energy use when compared to 'general retail'
- Any properties without a specific property use were considered as 'general retail'
- 80% space efficiency was assumed for conversion from net internal area to gross internal area
- All internal floor area to gross floor area conversions were based on a 95% conversion factor, given by CIBSE for 'Offices Naturally Ventilated'
- National breakdown of fossil fuel and electricity had to be used due to lack of data in CIBSE, as energy figures in CIBSE were either fossil fuel or electricity
- Data from the Valuation Office is subject to human error, as the area figures are entered by hand, which gives rise to errors

Transport

- The NTA model is based on the Census publications. When this report was produced, Census 2016 was not available to the NTA. Therefore, the main data used for this research was 2012 data provided by the NTA
- Fleet type was taken from Northern Ireland's databases, and it is assumed that the fleet makeup in Ireland will remain the same as the Northern Irish fleet
- Fuel split (petrol/diesel) of vehicles will remain unchanged over time
- It was assumed that no improvement in vehicle emission technology will be achieved, therefore future emissions will be overestimated
- Emissions were not adjusted to take into account the gradient links
- Projections for 2016 modal split assume that the modal split will remain the same as 2012, with only changes being the fuel mix for the different types of transport
- Projections for 2016 GHG emissions were based on 2012 projections for 2018 and 2035
- Breakdown of emissions for Dublin was assumed to be the same as SEAI's 2016 Energy in Ireland 1990 – 2016, Share of Emissions in Transport

Municipal

- Data for the municipality was gathered from the Monitoring & Reporting System, which is updated manually, which may give rise to errors

Waste & Wastewater

- Landfill emissions were the only type of waste considered
- Wastewater emissions were gathered from a case study in Austria for a WWTP with similar properties. However, this is not the measured figure of wastewater emissions in Dublin region, which might be slightly higher or lower than the quoted figures

Appendix B - Emissions

ETS and Non-ETS

The Emissions Trading System (ETS) was set in place by the European Union to reduce greenhouse gas emissions cost-effectively. A cap is set on the total GHG emissions that can be emitted by a company. Companies in the EU receive a set of emission allowances, or they may buy them and trade with other companies as needed. The cap is reduced over time so that the total emissions are reduced over time.

Emissions from ETS that are measured, reported and verified are carbon dioxide (CO_2), nitrous oxide (N_2O) and perfluorocarbons (PFCs). ETS sectors include:

- Power and heat generation
- Energy-intensive industry sectors which include oil refineries, steel works and production of iron, cement, lime, glass, ceramics, etc.
- Aviation
- Shipping
- Plants above a certain size

Non-ETS sectors include:

- Agriculture
- Buildings
- Energy
- Transport
- Services
- Small industries
- Waste

GHGs Considered

The emissions considered in this study follow the Environmental Protection Agency's (EPA) report entitled *Ireland's National Inventory Report 2015*. The EPA set up an inventory of total CO_2 and GHG emissions from different sectors as well as following the Intergovernmental Panel on Climate Change.

Table 15 GHG Emissions Considered for Each Sector

IPCC Level 2 Source Category		GHG
1.A.1	Energy Industries	CO_2
1.A.3	Transport	CO_2
3.A	Enteric Fermentation	CH_4
1.A.4	Other Sectors (Commercial/ Residential/ Agriculture)	CO_2
3.D	Agricultural Soils	N_2O
1.A.2	Manufacturing Industries and Construction	CO_2
3.B	Manure Management	CH_4
2.F.1	Refrigeration and air-con	HFC
2.A.1	Cement Production	CO_2
5.A	Solid Waste Disposal	CH_4

Emission Factors

As explained at the start of this report, emission factors are used to convert energy use to CO_2 emissions; these are dependent on the type of fuel used, so therefore different fuels have different emission factors. Unlike fossil fuels, which have different emission factors depending on the fuel type, renewable energy sources have an emissions factor of zero; this means that no emissions are attributed to energy sourced from renewables.

The national emission factors produced by SEAI were used throughout this study and may be found in Table 16 below.

Table 16 Emission Factors

Emission Factors	Electricity	Gas	Liquid Fuels					Solid Fuels and Derivatives				Renewable Energies				
		Natural Gas	Gasoline (Petrol)	Gas/Diesel/ Oil	Kerosene	LPG	Petroleum Coke	Coal	Milled Peat	Sod Peat	Peat Briquettes	Onsite Generation	Biogas	Solar Thermal	Biodiesel	Bioethanol
$kgCO_2/kWh$	0.468	0.205	0.252	0.264	0.257	0.229	0.335	0.341	0.420	0.374	0.356	0.000	0.000	0.000	0.000	0.000

CO_2 factors are used to convert GHG emissions to CO_2 equivalent. The CO_2 equivalents used, were from international approximations (Climate Change Connection, 2017), and may be found in the table below.

Table 17 CO_2 Equivalents

Greenhouse Gas	Symbol	100-year GWP (AR4)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulphur hexafluoride	SF_6	22,800
Hydrofluorocarbon-23	CHF_3	14,800
Hydrofluorocarbon-32	CH_2F_2	675
Perfluoromethane	CF_4	7,390
Perfluoroethane	C_2F_6	12,200
Perfluoropropane	C_3F_8	8,830
Perfluorobutane	C_4F_{10}	8,860
Perfluorocyclobutane	$c\text{-}C_4F_8$	10,300
Perfluoropentane	C_5F_{12}	13,300
Perfluorohexane	C_6F_{14}	9,300

Appendix C - Comparing Residential Housing and Social Housing

This section analyses and compares the emissions arising from both the residential and social housing sector. In 2016, Dublin City's housing (including both residential and social housing) accounted for 1,068,000 tCO_2, which is 38% of total emissions in Dublin City.

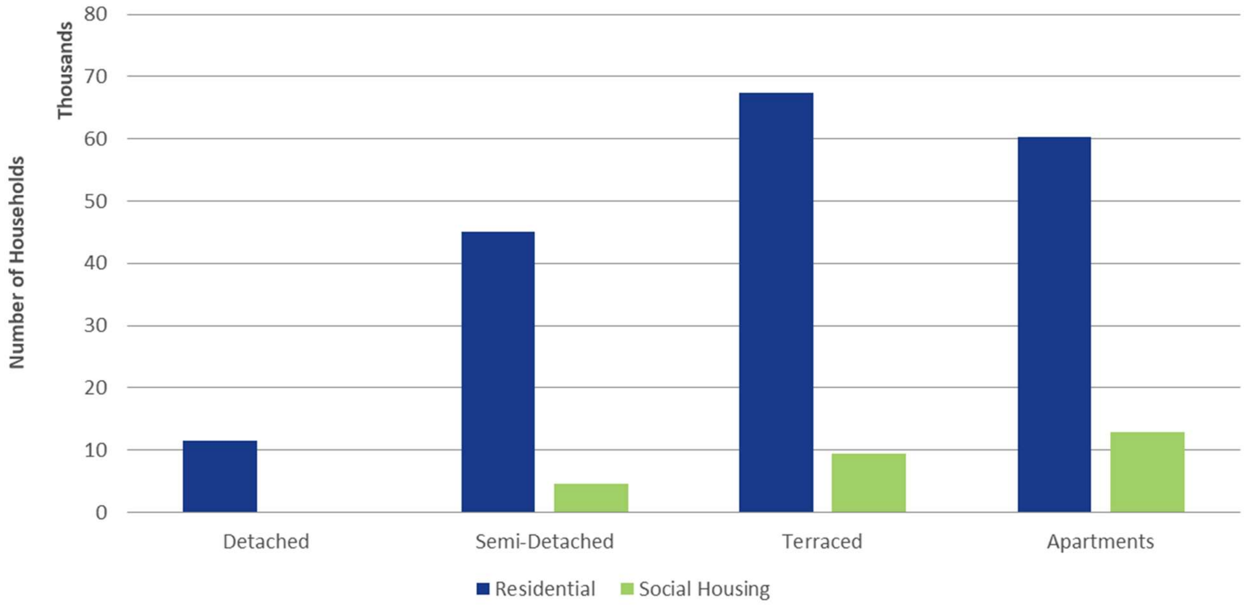

Figure 55 Total Number of Households by Type in Dublin City

As can be seen from Figure 55 and 56, social housing is a small percentage of the total households and floor area in Dublin City. Social housing accounts for 13% of total housing units and 9% of the total Dublin City housing floor area.

The most common type of dwelling in residential households was terraced housing, making up 37% of the total residential units in 2016. Terraced housing also had the highest residential floor area in Dublin City, at 38%. For social housing, the most common dwelling type were apartments, making up 47% of DCC's total social housing units. Terraced houses accounted for 43% of the total social housing floor area in Dublin City.

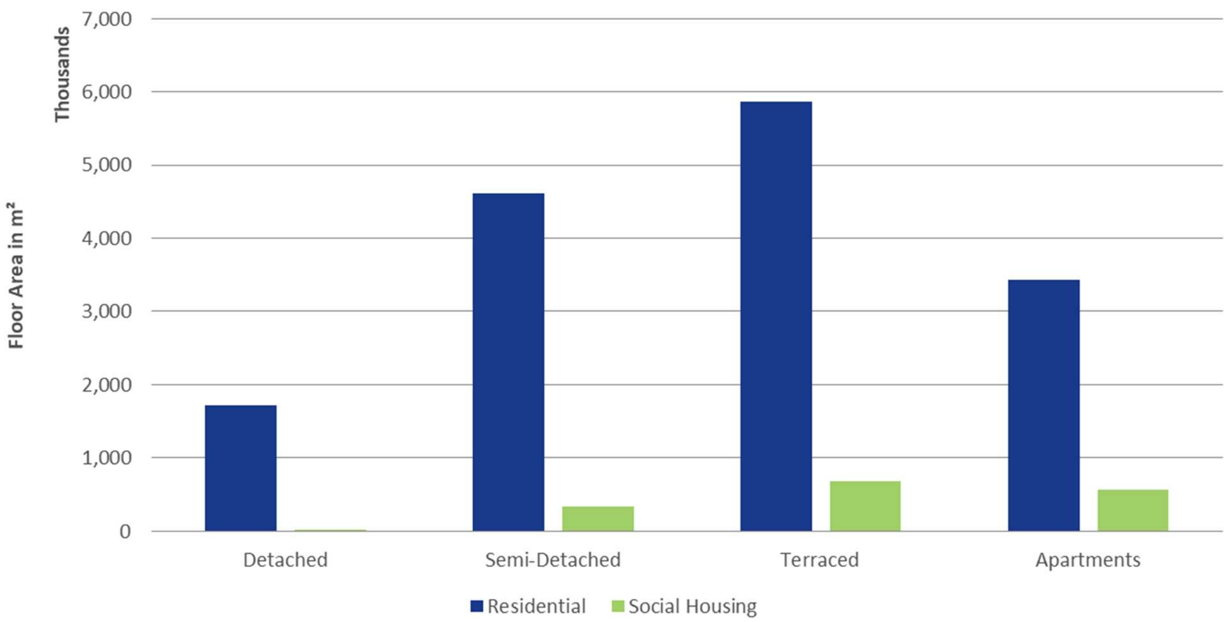

Figure 56 Total Household Floor Areas by Type of Dwelling in Dublin City

When comparing emissions per unit between social housing units and residential units, social housing units were found to emit fewer emissions per unit than residential units. Apartments for both the social housing and the residential sectors produced the least emissions from all the different dwelling types (detached, semi-detached, terraced and apartments).

In the residential sector, detached houses were the highest polluters at 9.46tCO_2 per unit, while in the social housing sector, terraced houses produced the most emissions, at 3.97tCO_2 per unit.

Detached houses in the residential sector would be the least efficient due to the way these dwellings are built; i.e. they have a larger floor area than other dwelling types and a larger building envelope - all these factors contribute to a higher energy use and thus higher emissions (unless renewables are used as a source of energy).

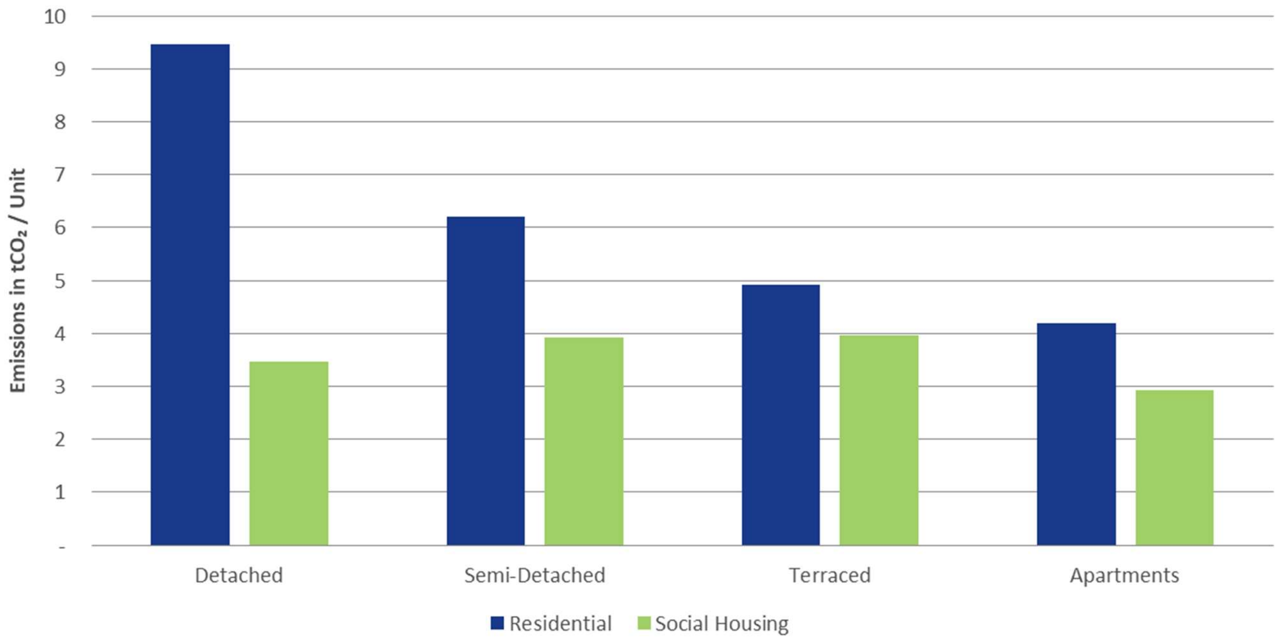

Figure 57 Emissions in tCO_2/unit for Residential and Social Housing

As for social housing, terraced houses and semi-detached houses (which had relatively similar emissions per unit) were found to be the highest emitters of CO_2 per unit. As can be seen from Figure 55 and 56, detached houses in the social housing sector are negligible as they only hold a fraction of the total units and floor area. Since detached units have little impact, semi-detached and terraced houses are the highest polluters. This is due to their type of construction, which is similar to detached houses. Houses usually have a larger floor area than apartments, which in turn leads to an increase in energy demand (space heating, for example). Semi-detached and terraced houses, similar to detached houses, would have more exposed façades than apartments, which leads to higher energy losses, resulting in an increase in energy demand.

It can be seen that overall emissions per unit in the social housing sector were much less than for the residential sector. Overall, social housing units produced 34% less emissions per unit than residential developments. These results reflect the ongoing retrofitting work that is being carried out by Dublin City Council to upgrade the less efficient social housing stock.

Appendix D - Municipal Emissions

Current Situation

Figure 58 shows the total CO_2 emissions from 2006 (baseline year) up to 2016. The baseline year is chosen by each local authority; this is dependent on the year which DCC started reporting their energy use and emissions on the M&R system.

As can be seen from Figure 58, the greatest emission reductions were between 2006 and 2013. From 2014 up to 2016, the emission reductions then started to even out. This might be the effect of the economic downturn on the activity levels of the local authority, or it might be due to the higher emission reduction actions, which would have been carried out in earlier years. These might be the easier emission reductions to achieve and yield a more drastic emission change. However, over the years these actions become harder to achieve, and therefore Dublin City Council must keep on striving to reach its targets and become a leader in emission reductions.

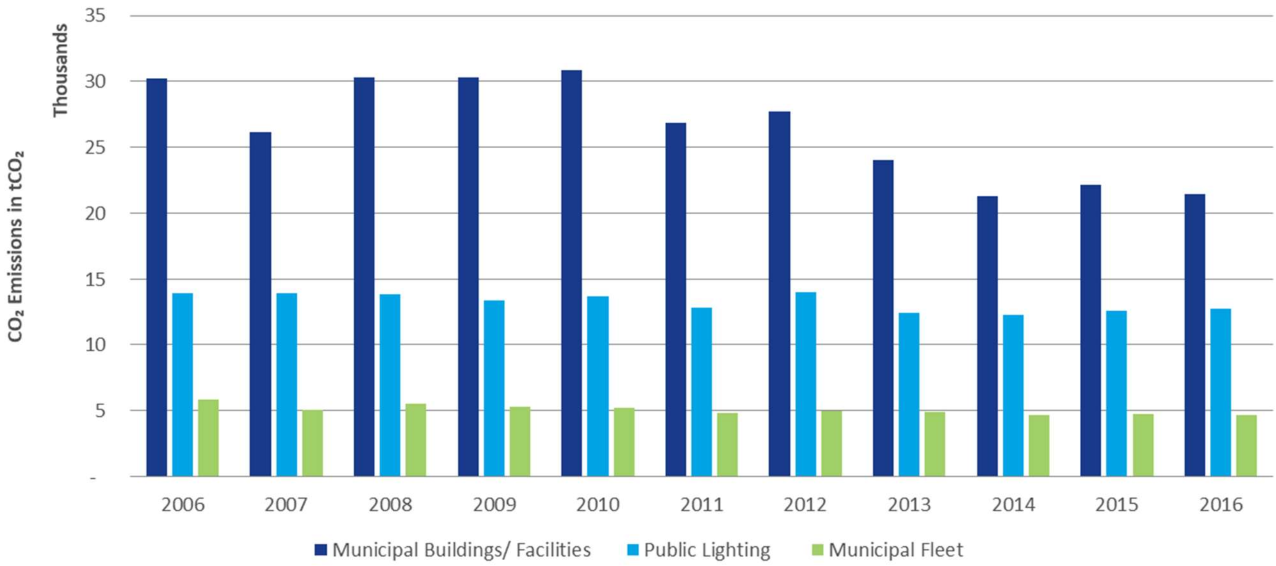

Figure 58 2006 – 2016 Emissions for DCC

Key Findings

- Buildings and Facilities have reduced their total emissions by 29%, however between the period 2014 and 2016, emissions increased on an annual basis
- Public Lighting emissions reduced by 9% from 2006 to 2016, but emissions have increased from 2014 to 2016
- Municipal fleet emissions decreased by 20% in 2016, however a negligible decrease was recorded for the period of 2014 to 2016

2030 Emission Reduction Targets

The 2030 Emission Reduction Targets were set by the Covenant of Mayors for Climate and Energy, of which DCC is a signatory. The 2030 target is a 40% reduction in emissions from the baseline year (2006).

The graph below illustrates the total emissions in DCC and the target glidepath (the emission target). It shows that in 2016, DCC was 18% away from meeting the 2030 target (40% emission reduction).

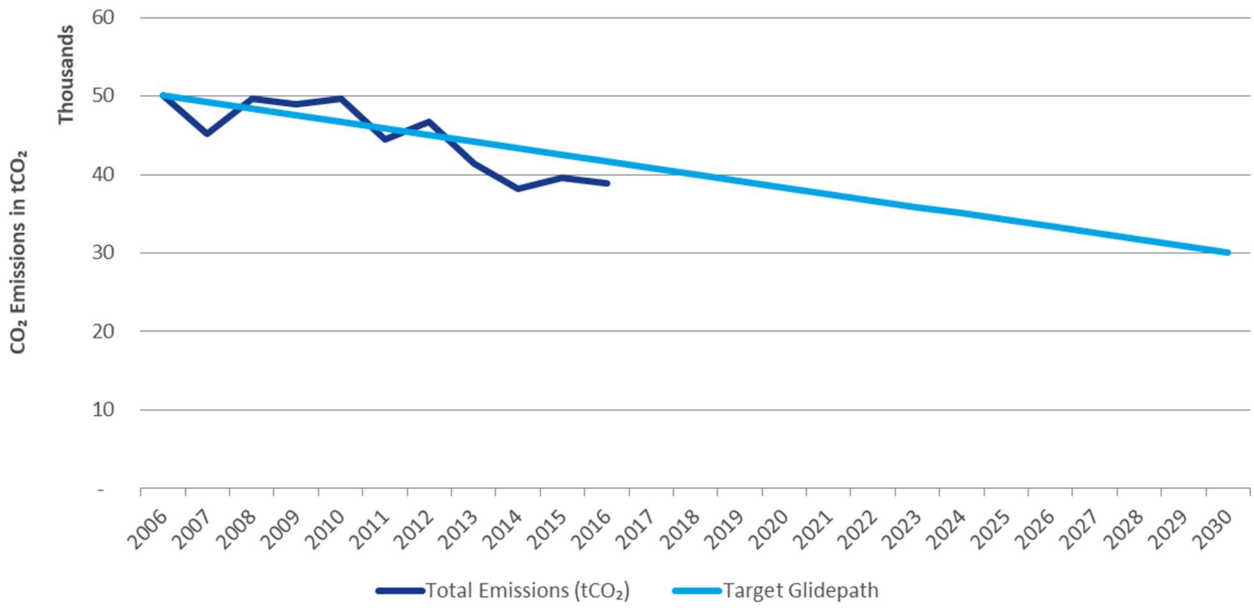

Figure 59 2030 Emissions Target for DCC

Appendix E - Dublin City's Energy and Emission Inventory in the Covenant of Mayors for Climate & Energy

Sector	FINAL ENERGY CONSUMPTION [MWh]															
	Electricity	Heat/cold	Fossil fuels								Renewable energies					Total
			Natural gas	Liquid gas	Heating oil	Diesel/Gas oil	Gasoline	Lignite	Coal	Other fossil fuels	Plant oil	Biofuel	Other biomass	Solar thermal	Geothermal	
BUILDINGS, EQUIPMENT/FACILITIES AND INDUSTRIES																
Municipal buildings, equipment/facilities	25,285	-	44,081	-	59	2,143	-	-	-	-	-	-	-	844	-	72,412
Tertiary (non municipal) buildings, equipment/facilities	1,057,927	-	723,341	20,667	620,006	-	-	-	-	-	-	-	70,267	-	57,867	2,550,075
Residential buildings	902,994	-	2,831,806	3,707	220,343	-	-	247	5,430	25,761	-	16	1,312	-	-	3,991,615
Public lighting	27,270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27,270
Industry – Non-ETS	165,229	-	136,321	18,840	41,590	-	-	178	40,879	-	-	533	36,969	-	-	440,537
Industry – ETS (not recommended)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	2,178,705	-	3,735,549	43,214	881,998	2,143	-	425	46,308	25,761	-	549	108,548	844	57,867	7,081,910
TRANSPORT																
Municipal fleet	-	-	-	-	-	17,350	376	-	-	-	-	-	-	-	-	17,726
Public transport	910	-	-	565	-	634,331	215,496	-	-	-	-	-	-	-	-	851,302
Private and commercial transport	1,945	-	-	1,209	-	1,356,476	460,824	-	-	-	-	-	-	-	-	1,820,454
Subtotal	2,855	-	-	1,774	-	2,008,157	676,696	-	-	-	-	-	-	-	-	2,689,482
OTHER																
Agriculture, Forestry, Fisheries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	2,181,559	-	3,735,549	44,988	881,998	2,010,300	676,696	425	46,308	25,761	-	549	108,548	844	57,867	9,771,392

Sector	CO_2 emissions [t] / CO_2 eq. emissions [t]															
	Electricity	Heat/cold	Fossil fuels								Renewable energies					Total
			Natural gas	Liquid gas	Heating Oil	Diesel/Gas oil	Gasoline	Lignite	Coal	Other fossil fuels	Plant oil	Biofuel	Other biomass	Solar thermal	Geothermal	
BUILDINGS, EQUIPMENT/FACILITIES AND INDUSTRIES																
Municipal buildings, equipment/facilities	11,821	-	9,023	-	15	566	-	-	-	-	-	-	-	-	-	21,425
Tertiary (non municipal) buildings, equipment/facilities	494,581	-	148,068	4,733	159,342	-	-	-	-	-	-	-	-	-	-	806,729
Residential buildings	422,150	-	579,671	849	56,628	-	-	88	1,852	6,798	-	-	-	-	-	1,068,034
Public lighting	12,749	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,749
Industry – Non-ETS	77,252	-	27,905	4,314	10,689	-	-	63	13,940	-	-	-	-	-	-	127,277
Industry – ETS (not recommended)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	1,018,544	-	764,667	9,896	226,673	566	-	151	15,791	6,798	-	-	-	-	-	2,043,087
TRANSPORT																
Municipal fleet	-	-	-	-	-	4,580	95	-	-	-	-	-	-	-	-	4,675
Public transport	425	-	-	129	-	167,463	54,305	-	-	-	-	-	-	-	-	222,323
Private and commercial transport	909	-	-	277	-	358,110	116,128	-	-	-	-	-	-	-	-	475,423
Subtotal	1,335	-	-	406	-	530,153	170,527	-	-	-	-	-	-	-	-	702,422
OTHER																
Agriculture, Forestry, Fisheries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER NON-ENERGY RELATED																
Waste management																52,647
Waste water management																12,723
TOTAL	1,019,886	-	764,667	10,302	227,239	530,154	170,527	151	15,773	6,798	-	-	-	-	-	2,810,881

References

Central Statistics Office, 2011, 2016. Live Register June 2011 and June 2016, Dublin: Stationary Office

Central Statistics Office, 2017. *Census of Population – Households and Families*

http://www.cso.ie/px/pxeirestat/Database/eirestat/Profile%201%20-%20Housing%20in%20Ireland/Profile%201%20-%20Housing%20in%20Ireland_statbank.asp?SP=Profile%201%20-%20Housing%20in%20Ireland&Planguage=0 (Accessed 17th May 2017)

Central Statistics Office, 2016. *Census 2016, Census of Population – Preliminary Actual and Percentage Change in Population 2011- 2016 by Sex, Province County or City, statistical Indicator and Census Year.*

Central Statistics Office, 2016 Census 2016, Commuting in Ireland

http://www.cso.ie/en/csolatestnews/presspages/2017/census2016profile6-commutinginireland/ (Accessed 21st September 2017)

Central Statistics Office, 2016 Census 2016, Commuting in Ireland – Persons cycling to work by electoral division, 2016

http://census.cso.ie/p6map21/ (Accessed: 21st September 2017)

CIBSE, 2012 *Guide F: Energy Efficiency in Buildings* 3rd edition. London: CIBSE Publications

CO_2 Equivalents, 2017 *Climate Change Connection* at

Available at: http://climatechangeconnection.org/emissions/co2-equivalents/ (Accessed 20th June 2017)

Codema 2013, *Dublin City Sustainable Energy Action Plan: Monitoring and Progress Report 2014,* Dublin

Cycle Scheme.ie, 2017

Available at: https://www.cyclescheme.ie/ (Accessed 23rd September 2017)

Department of Transport, Tourism and Sport, 2016 *Transport Trends an Overview of Ireland's Transport Sector* Dublin: Stationery Office

Dublin City Council, 2017 *Excel Database of Dublin City Social Housing Properties*. Dublin: Email Correspondence

Dùn-Laoghaire Rathdown County Council, 2008 *Ballyogan Landfill Facility and Recycling Park – Annual Environmental Report 2008*

http://www.epa.ie/licences/lic_eDMS/090151b2802c0904.pdf (Accessed 20th June 2017)

Environment, Heritage and Local Government, 2007 *Sustainable Urban Housing: Design Standards for New Apartments, Guidelines for Planning Authorities* Dublin, Government Publications

Environmental Protection Agency, 2006 *National Centre for Water and Wastewater Research and Demonstration 2007-2013.* https://aran.library.nuigalway.ie/bitstream/handle/10379/4106/STRIVE_78_web.pdf?sequence=1&isAllowed= (Accessed 29th June 2017)

Environmental Protection Agency, 2015 *Ireland's National Inventory Report –Greenhouse Gas Emissions 1990-2013*

http://coe.epa.ie/ghg/data/inventories/2015/IE_2015_NIR2.pdf (Accessed 18th April 2017)

Environmental Protection Agency, 2017 *Waste Applications, Licence or Environmental Information*

http://www.epa.ie/terminalfour/waste/waste-search.jsp?class=Landfill&status=Licensed&county=Dublin&Submit=Search+by+Combination (Accessed 29th June 2017)

Environmental Protection Agency, 2017 *Ireland's Environment – Waste*

http://www.epa.ie/irelandsenvironment/waste/ (Accessed 29th June 2017)

European Commission Climate Action, 2017 *The EU Emissions Trading System (EU ETS)*

https://ec.europa.eu/clima/policies/ets_en (Accessed 18th January 2018)

Fingal County Council, 2016 *Balleally Landfill, Balleally, Lusk, Co. Dublin – Annual Environmental Report 2015*

http://www.epa.ie/licences/lic_eDMS/090151b28059c411.pdf (Accessed 20th June 2017)

Fingal County Council, 2016 *Dunsink Landfill Annual Environmental Report 2015*

http://www.epa.ie/licences/lic_eDMS/090151b28059c33c.pdf (Accessed 20th June 2017)

IPCC, 2007 *The Physical Science Basis in: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge.

Murphy Environmental Hollywood Ltd, 2011 *Murphy Environmental Hollywood Ltd – Annual Environmental Report 2010*

http://www.mehl.ie/content/news/AER/AER2010.pdf (Accessed 20th June 2017)

National Transport Authority, *Regional Modelling System*

Available at: https://www.nationaltransport.ie/publications/ (Accessed 10th July 2017)

Parravicini, A., Svardal, K., Krampe, J., 2016 *Greenhouse Gas Emissions from Wastewater Treatment Plants.* Institute for Water Quality, Resources and Waste Management, Vienna, Austria

SEAI Building Energy Rating (BER), 2017 *SEAI National BER Register*

Available at: https://ndber.seai.ie/BERResearchTool/Register/Register.aspx (Accessed 17th April 2017)

SEAI Emission Factors.

Available at: http://www.seai.ie/Energy-Data-Portal/Emission_Factors/ (Accessed 18th April 2017)

SEAI, 2016 *Energy Efficiency in Ireland 2016 Report*

Available at: https://www.seai.ie/Publications/Statistics_Publications/Energy_Efficiency_in_Ireland/Energy-Efficiency-in-Ireland-2016-Report.pdf (Accessed 23rd April 2017)

SEAI, 2014 *Energy in Transport 2014 Report*

Available at: http://statistics.seai.ie/Publications/Statistics_Publications/Energy_in_Transport/Energy-in-Transport-2014-report.pdf (Accessed 23rd April 2017)

SEAI, 2016 *Energy-Related Emissions in Ireland, CO_2 Emissions form Fuel Combustion 2016 Report*

https://www.seai.ie/Publications/Statistics_Publications/Energy-related Emissions/CO2%20emissions%20from%20fuel%20combustion.pdf (Accessed 18th April 2017)

SEAI, 2017 *Monitoring and Reporting System*

https://psmr.seai.ie/Account/LogOn?ReturnUrl=%2f (Accessed 20th April 2017)

SEAI, 2016 *Energy Statistics 1990-2015 2016 Report*

https://www.seai.ie/resources/publications/Energy-Statistics-1990-2015.pdf (Accessed 23rd April 2017)

Shaoqing, C., Bin C.,, 2015 *Urban energy consumption: Different insights from energy flow analysis, input-output analysis and ecological network analysis.* Beijing Normal University, China.

SIMI, 2016 *National Vehicle Statistics – SIMI New Vehicle Registrations 2016*

http://www.simi.ie/Statistics/National+Vehicle+Statistics.html (Accessed 23rd April 2017)

Valuation Office, 2017*Excel Database of Dublin Commercial Properties.* Dublin: Email Correspondence

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Abbreviations

BER – Building Energy Rating

CAW – Celtic Anglian Water

CIBSE – Chartered Institution of Building Energy Services Engineers

CO_2eq – Carbon Dioxide Equivalent

CO_2 – Carbon Dioxide

CoM – Covenant of Mayors for Climate Change and Energy

CSO – Central Statistics Office

DCC – Dublin City Council

EPA – Environmental Protection Agency

ETS – Emissions Trading System

GDA – Greater Dublin Area

GDP – Gross Domestic Product

GHG – Greenhouse Gas

GIS – Graphical Information Science

HGV – Heavy Goods Vehicle

IPCC – Intergovernmental Panel on Climate Change

kWh – Kilowatt-hour

$ktCO_2$ – Kilo tonnes of Carbon Dioxide emissions

LUAS – Dublin's Light Rail System

MWh –Megawatt-hour

$MtCO_2$ – Mega tonnes of Carbon Dioxide emissions

Mtoe – Million tonnes of oil equivalent

NDFM – National Demand Forecasting Model

NHTS – National Household Travel Survey

NTA – National Transport Authority

PRTR – Pollutant Release and Transfer Register

RD&D – Research, Development and Demonstration

RMM – Regional Multi-modal Modes

RMS – Regional Modelling System

SEAI – Sustainable Energy Authority Ireland

SIMI – The Society of the Irish Motor Industry

tCO_2 – 1 tonne of Carbon Dioxide emissions

UCC – University College Cork

WWTP – Wastewater Treatment Plant

Comhairle Cathrach
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