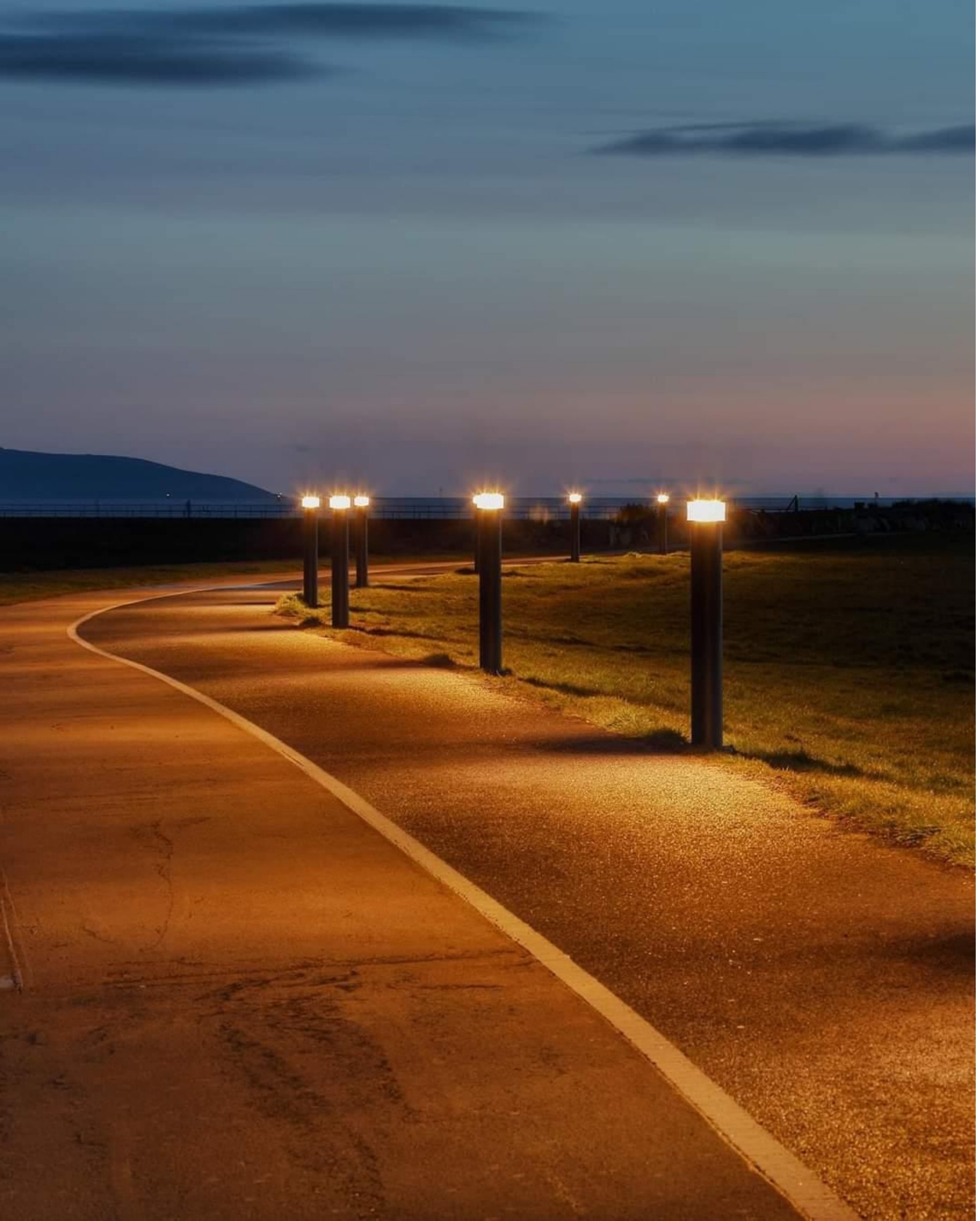
Comhairle Cathrach na Gaillimhe
Galway City Council

Galway City Council

Galway City Emissions Inventory Baseline



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1 Introduction

Without urgent action climate impacts have the potential to result in catastrophic and irreversible consequences for nature, human-life and eco-systems worldwide. Climate action is essential, and a top priority on the Irish Government's agenda to ensure alignment with climate science and goals set out in the Paris Agreement. The policy targets, outlined in Section 2, set out a proactive and forward-thinking approach to reduce the impacts of climate change.

To best determine a course of action, assessments of historic and predicted energy use, and their resulting emissions is vital. Developing these assessments for local areas enables an understanding of how national targets for energy use and greenhouse gas (GHG) emissions can be met.

Local authorities, such as Galway City Council (GCC), have a responsibility to meet the 2030 target of a 51% reduction in GHG emissions compared to 2018, which has been set out in national policy. National climate change policy in Ireland is focused on Ireland's Climate Action Plan and Low Carbon Development (Amendment) Act 2021, which detail the local and regional actions necessary to meet this target and tackle climate change. This includes the requirement for local authorities to:

- Prepare and develop a Climate Action Plan, containing both mitigation and adaption measures, every five years.
- Select and develop a designated Decarbonisation Zone (DZ) within the local authority area. This zone will be the central focus for a range of climate mitigation, adaptation and biodiversity measures.

In line with these requirements, GCC are engaged with Arup to prepare the following items:

- GHG baseline emissions inventory for Galway City and the DZ (the subject of this report);
- Energy Masterplan for Galway City with Spatial Energy Demand Analysis; and
- Implementation Plan for the Galway City DZ.

Developing an understanding of Galway City's energy use and associated carbon emissions resulting from activities across sectors is vital to the realisation of Galway City Council's objectives and commitments for the transition to a low carbon economy.

2 Policy Context: European

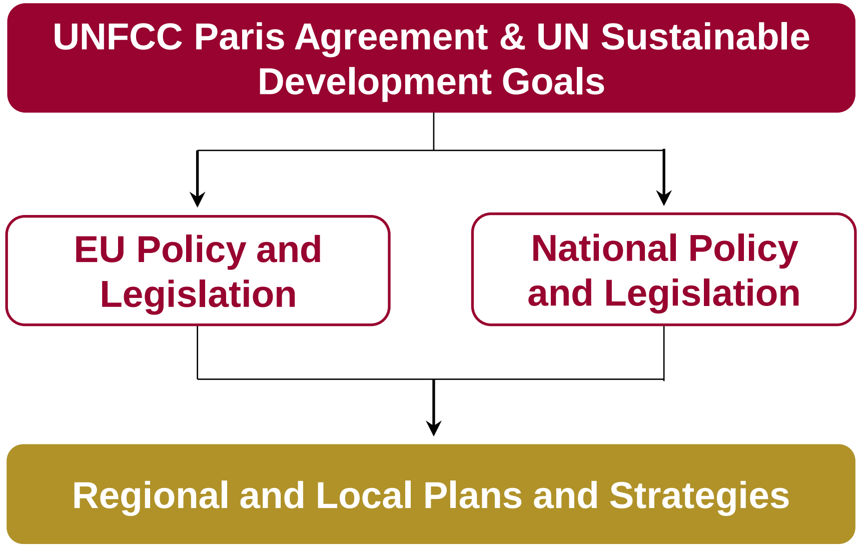
Over the past decade, policies encouraging a just transition to a more sustainable, energy efficient and low carbon society have been developed globally, across the EU and locally. This section outlines the policy context which is privy to the policy driving emissions reductions within local authorities, detailed in Section 1.

The UNFCCC's Paris Agreement is a legally binding international treaty on climate change, which was adopted in 2015 to limit global warming to 1.5 degrees Celsius. Similarly, the UN's Sustainable Development Goals (SDGs) which comprises 17 Goals that integrate the economic, social and environmental dimensions of sustainable development are heavily incorporated into Ireland's national policy such as the National Planning Framework (NPF) and the Regional Spatial and Economic Strategy (RSES).

Across the EU, The European Green Deal, aims to achieve EU climate neutrality through the conservation of biological life, reducing pollution and helping ensure a just and inclusive transition to clean energy. The EU Fit for 55 Package requires that the EU reduce greenhouse gas (GHG) emissions by 55% by 2030 compared to 1990 levels, utilising different policies, tools, regulations, and changes to standards.

The Emission Trading System (ETS) and the EU Effort Sharing Regulation (ESR), which are being updated as part of the Fit for 55 package, aim to strategically help reduce GHGs in a cost-effective manner. The Renewable Energy Directive (RED), the updated RED II (will be RED III under Fit for 55) is the most important legislation influencing the growth of renewables in the European Union (EU) and Ireland. The RED sets out mandatory targets for renewable energy in Ireland.

The REPowerEU Plan, developed by the EU Commission, is the plan to make Europe independent from Russian fossil fuels before 2030, while also supporting the transition to low carbon fuels to tackle the on-going climate crisis. The measures set out in the REPower EU Plan intend to respond to these ambitions through energy saving, diversification of energy supplies and accelerated roll-out of renewable energy across all sectors.



2 Policy Context: National

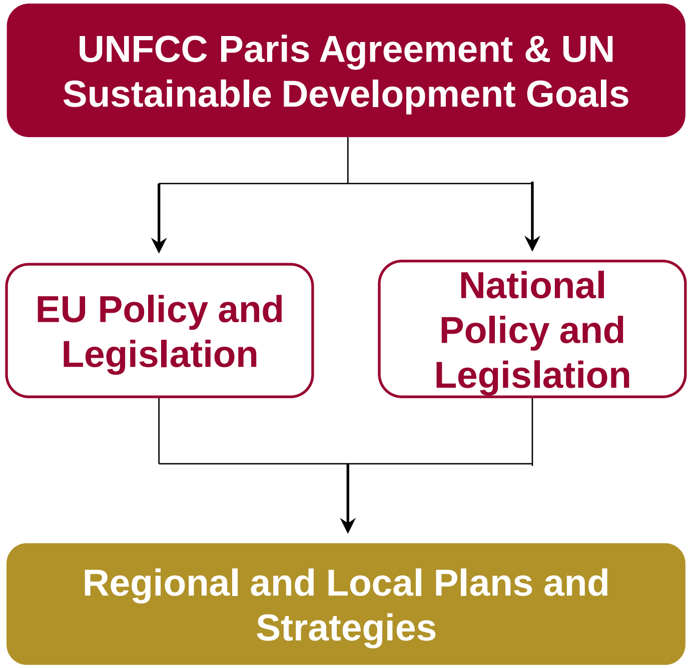
The National Climate and Energy Plan (2021-2030) builds on previous national strategies and sets out Ireland's objectives regarding decarbonisation, energy and innovation. In Ireland carbon budgets act as a means of implementing the national emissions reductions targets, which will enable compliance with European targets.

The Climate Action and Low Carbon Development (Amendment) Act 2021 is the crucial instrument for implementing national decarbonisation measures and establishes a legal framework comprising carbon budgets to achieve a 51% reduction in overall GHG emissions by 2030 and net-zero emissions by 2050. Local authorities are expected to "lead by example" in implementing these emissions reduction targets, as detailed in Section 1.

The National Planning Framework: Project Ireland 2040, which aims to facilitate the increase in Ireland's population by 2040, sets out the National Planning Framework (NPF) and National Development Plan (NDP). The NPF provides the objectives and strategy for Ireland's national development to 2040, while the NDP sets out various investment strategies to achieve the ambitions of Project Ireland 2040. Both plans detail the essential role and measures that spatial and land use planning have in relation to actions on climate change.

In line with actions set out in national policies, local authorities are required to produce and develop their own climate actions plans. Each local authority will prepare a *Local Authority Climate Action Plan* (LACAP) and update them every five years. Plans will be required to align to their respective development plans. The delivery of these will aid in creating healthy places and promoting sustainable communities, while supporting the implementation of the National Planning Framework, as well as other relevant policies and objectives set out by Government. The work being carried out, as presented in this report, will feed into the development and delivery of Galway City's Climate Action Plan.

This policy overview demonstrates that the Galway City Baseline Emissions Inventory will set the context to allow Galway City Council (GCC) to take action towards achieving EU and national targets. Understanding the policy context across multiple levels is important to execute an effective strategy for Galway City, and subsequent plans based on this inventory will also refer to the policy context.



3.1 Methodology: Overview

For Galway City Council to prepare an Energy Masterplan and Implementation Plan for the city and DZ respectively, an Emissions Inventory must be prepared to determine the baseline against which actions can be measured. Arup was appointed by Galway City Council to undertake this Baseline Emissions Inventory. Both a top-down and bottom-up emissions inventory were prepared, covering all economic sectors, to proportion the energy consumption and GHG emissions data to Galway City.

The top-down approach comprises an indicative representation of energy consumption and associated GHG emissions within Galway City, based on scaling factors applied to national data. Applying this methodology, the top-down energy consumption and GHG emissions for Galway City will reflect the energy and emissions balance for Ireland.

A bottom-up approach is considered a more accurate methodology as it encompasses more granular data which can account for local conditions. This provides a stronger benchmark compared to the top-down inventory which allows planners to measure the implications of city-level actions. Therefore, the bottom-up baseline is used to benchmark the subsequent measures proposed as part of the Energy Masterplan and DZ Implementation Plan. It should be noted that given the scale of the study exact ground-level measurements could not be undertaken for most sectors; therefore, some assumptions are still contained within the bottom-up approach.

The top-down emissions inventory has been used to set a precedence for the bottom-up emissions inventory, providing an initial starting point to determine approximate emissions proportions. While the top-down results can be considered indicative, the bottom-up results provide a better representation of the City and are used for the resulting plans; therefore, the bottom-up results are the focus of this report.

It should be noted that the accuracy of the Baseline Emissions Inventory results should be taken in the context of its purpose. The fundamental application of this energy and emissions inventory is to represent a baseline for evaluating alternatives to include in local action plans. The Baseline Emissions Inventory provides a representation of what and how energy is consumed in Galway, to inspire action for improvement. The source of data used was primarily taken from publicly available information online, supplemented with data collected directly from stakeholders (refer to Section 3.3).

A 2018 baseline year was used for both emissions inventories in keeping with requirements set out in the Climate Action Plan (refer to Section 2). Where data was not available for 2018 (baseline year), the figures were interpolated. The assumptions and uncertainties for each sector are detailed in later sections.

Summary

- A top-down and bottom-up emissions inventory were prepared for a baseline year of 2018.
- The top-down inventory should be considered indicative.
- The bottom-up inventory is more accurate and used to benchmark the Energy Masterplan and DZ Implementation Plan.

3.2 Methodology: Scope

This Baseline Emissions Inventory report includes an assessment of Galway City local authority area only. The Galway City boundary is shown in **Figure 1** below and comprises a population of upwards of 79,900 (in 2018).

The results of the inventory are provided for Galway City in its entirety, in addition to results extracted for the DZ area in isolation.

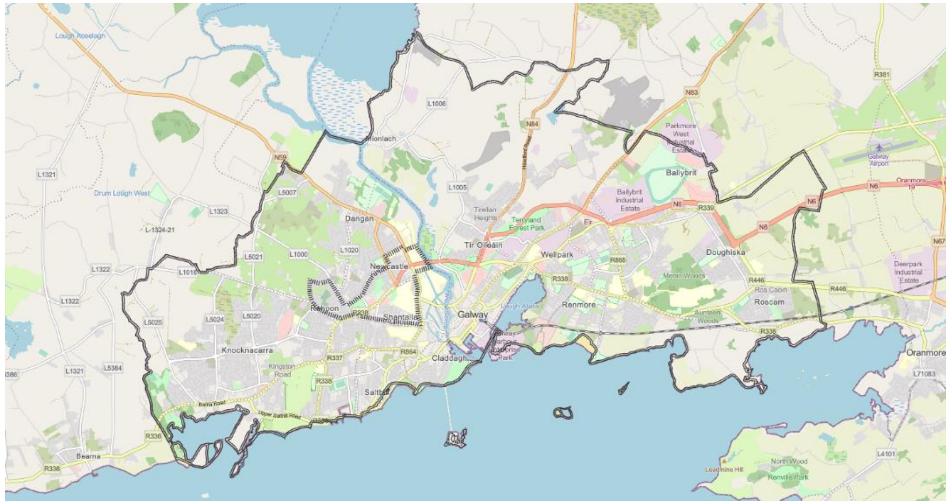


Figure 1: Galway City Boundary

The GCC has selected the "Westside" Area for the DZ. This area meets the requirements of a DZ in terms of size, feasible pathway to 51% reduction in greenhouse gases over the decade, the potential influence of the Council, and collaboration with stakeholders. This selection was made in response to a request from Central Government to all local authorities to select a DZ and prepare an Implementation Plan for the zone.

It should be noted that this Baseline Emissions Inventory does not consider the potential for Galway City's population to grow as it is based on the 2018 baseline year only. However, the subsequent Energy Masterplan and DZ Implementation Plan incorporate population growth projections for future years. The emissions have been determined on a sectoral basis, with the inventory including all economic sectors as follows: residential, social housing, municipal, transport, agriculture, commercial (including industry), waste and wastewater. The approach to determine energy consumption and emissions for each sector is detailed in later sections.

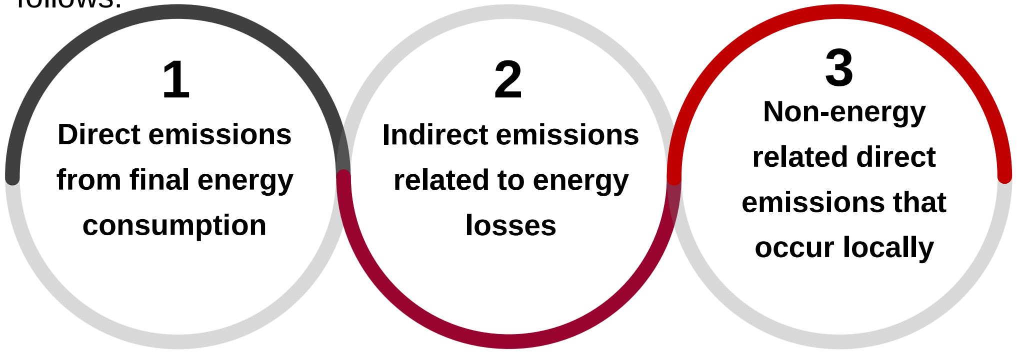
The top-down inventory has been undertaken following the Covenant of Mayors (CoM) Methodology, which provides a common reporting framework developed by multi-disciplinary experts for cities to assess GHG emissions applying a standardised approach enabling international comparability. The top-down assumptions and results for each sector are summarised in Appendix 1 of this report.

The development of the bottom-up inventory has been based on the Codema Guidance (2017) *"Developing CO2 Baselines: A Step-by-step Guide for your Local Authority"* developed in partnership with the Sustainable Energy Authority of Ireland (SEAI). This inventory was developed prior to the development of the CARO Local Authority Guidance and was deemed the preferrable approach for the Irish context at the time of preparation. However, the Codema methodology has been adjusted as appropriate, given availability of data, to ensure a comprehensive analysis where potential gaps were identified. Crucially, this approach has been supported by stakeholder engagement and 'direct-data' gathering. The differences between the approach applied by Arup and the Codema methodology are noted for each sector in later sections of this report.

3.3 Methodology: General Approach

The emissions across the various sectors are calculated using emission factors, fuel type, and energy consumption. The energy emissions are based on total final consumption (TFC), which is the energy harnessed by end-users (and recorded on utility bills and meters), and SEAI emission factors which account for losses in energy conversion. The total primary energy requirement (TPER) is included for sectoral energy totals as a reference.

The 3 main types of GHG emissions included in the inventory are as follows:



The energy emissions provided in the baseline include both direct and indirect emissions. The three main long-lived greenhouse gases are considered: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The emissions reporting unit is tonnes CO_2 equivalent (tCO_2eq). This unit is used to compare the emissions from the various GHGs based on their global-warming potential (GWP). The GWP assumptions are taken from the IPCC as shown in Table 1.

Table 1: Global Warming Potentials (Source: IPCC)

Greenhouse gas	100 Year Period	20 Year Period
CO2	1	1
CH4 (fossil origin)	29.8	82.5
CH4 (non fossil origin)	27.2	80.8
N2O	273	273

3.3 Methodology: General Approach

Data sources identified in the selected bottom-up methodology were utilised to develop the granular level of detail required for the bottom-up approach. If data was not available from expected sources, stakeholder engagement has been relied upon to fill data gaps for the bottom-up baseline inventory.

Stakeholder engagement has been carried out throughout the development of the Baseline Emissions Inventory.

Stakeholder scanning was carried out in order to determine key stakeholders across the city and DZ. Following this, a stakeholder survey was sent out to the identified high-energy users to gain information on energy use for the baseline year (2018). This 'direct data' obtained from high-energy users has been fed into the bottom-up baseline, providing a further level of granularity to the results for the bottom-up approach.

Data collection, and engagement with stakeholders has been captured using the Landowner Engagement Management System (LEMS). LEMS is used to provide a tracking mechanism of all stakeholder correspondence, including an action register, throughout the lifecycle of projects. Figure 2 depicts a snapshot of the LEMS tool used to track the engagements for the development of this baseline inventory. This system will continue to be used for subsequent plan making.

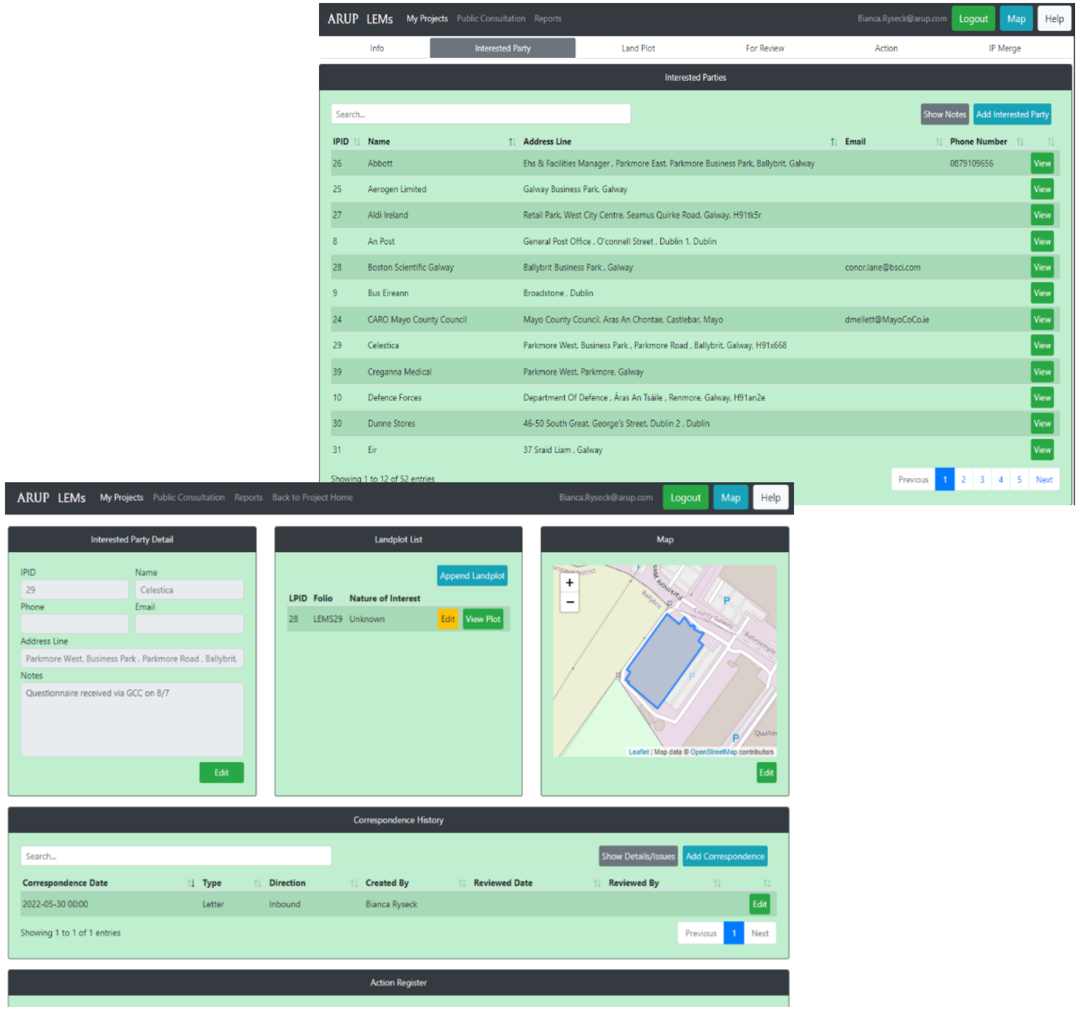


Figure 2: LEMS Stakeholder Engagement Tracking

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4.1 Bottom-Up Inventory: Approach

The bottom-up inventory uses a variety of data sources across the sectors supplemented with data collection where feasible. The data sources per sector are outlined in Table 2 below.

Table 2: Bottom-up inventory data sources

Sector	Data Source
Residential	CSO Census 2016 SEAI Energy in Ireland (2018) BER Research Tool
Municipal	SEAI M&R
Commercial	Building stock survey 2015 (SEAI) Survey Data
Industry	Energy in Ireland 2019 (SEAI) Survey Data
Transport	ENEVAL Western Regional Model (2016-2019) National Transport Survey (2018) EPA National Greenhouse Gas Inventory (2018)
Agriculture	CSO Agriculture Census (2020) Codema / SEAI Energy Benchmarks (2018) IPCC Emission Factors (Ch10)
Waste	NWCPO Permits EPA Waste Licencing (Annual Reporting) Facility Data Records
Wastewater	Facility Data Records SEAI M&R

The population figure is based on CSO data (extrapolated from census data) for the baseline year (2018), totaling 79,924 within the local authority boundary, which is the same as the top-down inventory.

The methodology employed was largely based on the Codema Guidance, as noted in Section 3.2, with divergences specified. As noted in Section 3.1, where feasible data was collected directly from facilities through surveys and provision of data records was incorporated to relevant sectors.

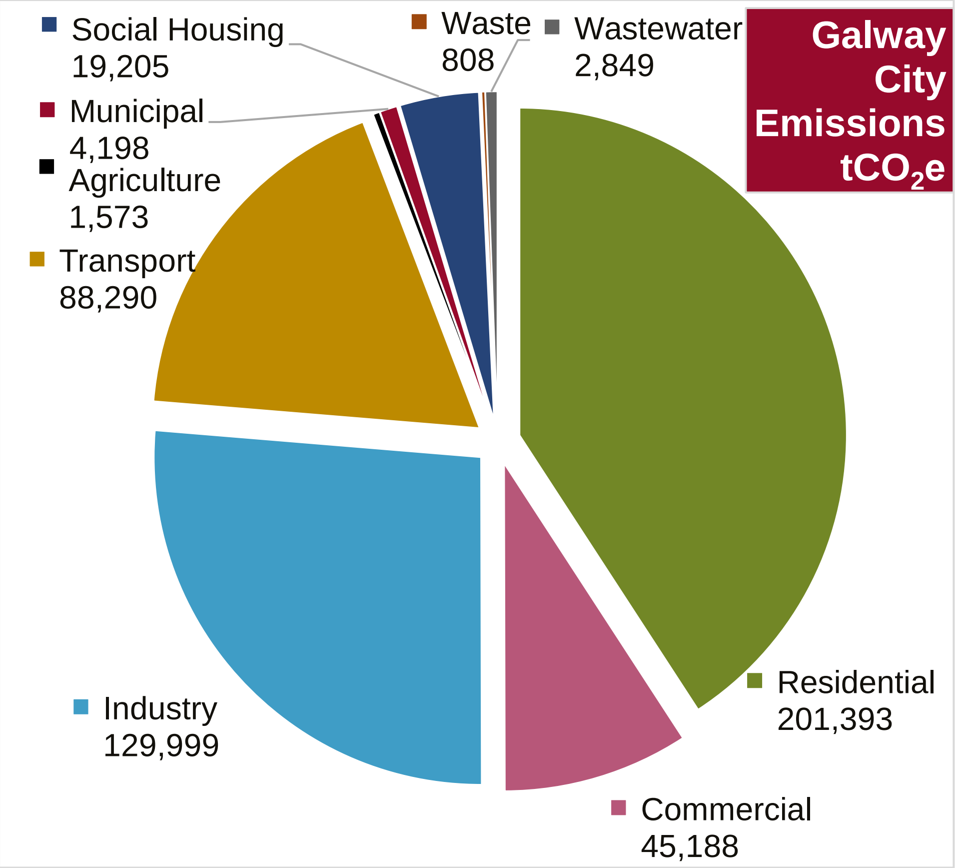
A spatial analysis was undertaken to record the locations associated with the energy consumption and emissions data within the local authority boundary. The mapping includes small area boundaries for most sectors except the agricultural sector which uses Electoral Divisions (ED's). The Decarbonization Zone can be delineated from rest of the city through this spatial analysis, which is detailed in Section 5. A screenshot of the map is shown in Section 4.3.

4.2 Bottom-Up Inventory: Results Summary

The energy and emissions data per sector is shown in Table 3 below. The emissions distribution is shown in the pie chart. The methodology for each sector (based on the Codema approach) is detailed in the proceeding sections. The primary energy is discussed in Section 5.12.

Table 3: Bottom-up inventory results

Sector	Energy (MWh)	Emissions (tCO_{2eq})
Residential	731,829	201,393
Commercial (incl. Industry)	593,526	175,187
Transport	-	88,290
Agriculture	704	1,573
Municipal	13,591	4,198
Social Housing	10,959	19,205
Waste	2,686	808
Wastewater	10,525	2,849
Total		**493,503**



4.3 Bottom-Up Inventory: Spatial Analysis

The bottom-up inventory results were mapped using GIS to demonstrate the spatial distribution of emissions and energy consumption as discussed in Section 3, screen captures of the web map are shown in Figure 3 and 4.

This spatial analysis was undertaken according to small area boundaries, as noted in Section 3, and required specific sectoral assumptions to enable mapping which can be summarised as follows:

- Small area locations from the BER Research Tool were used for the residential sectors.
- Social housing data was spread across small area locations based on spatial assumption using area size (which holds a greater degree of uncertainty). Specific locations of social housing properties were not available on a small area basis.
- Data according to Electoral Divisions was used for the agriculture sector.
- Transport links, that are GIS based, were take from the ENEVAL model.
- Industrial and commercial locations were based on a mixture of direct data and a spatial assumption using the size of the small area boundaries. Top-down data was used to supplement direct data, which required a spatial assumption (which holds a greater degree of uncertainty).
- Municipal, waste, and water sectors used direct data location points per building or per facility.

Whilst the spatial analysis provides an indication of the energy and emissions distribution across the city it should be noted that the exact locations have not been determined - this spatial analysis is representative only to assist further plan making, rather than to define specific locations.

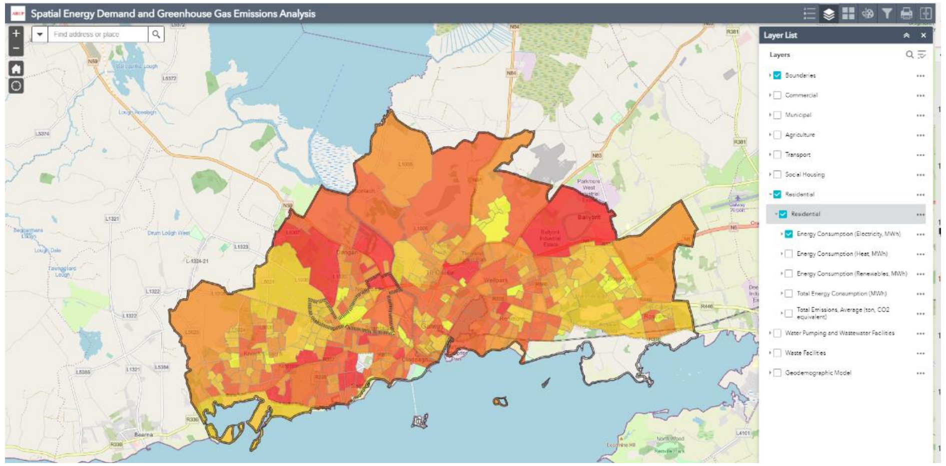


Figure 3: Spatial Energy and GHG Emissions Analysis Web-Map

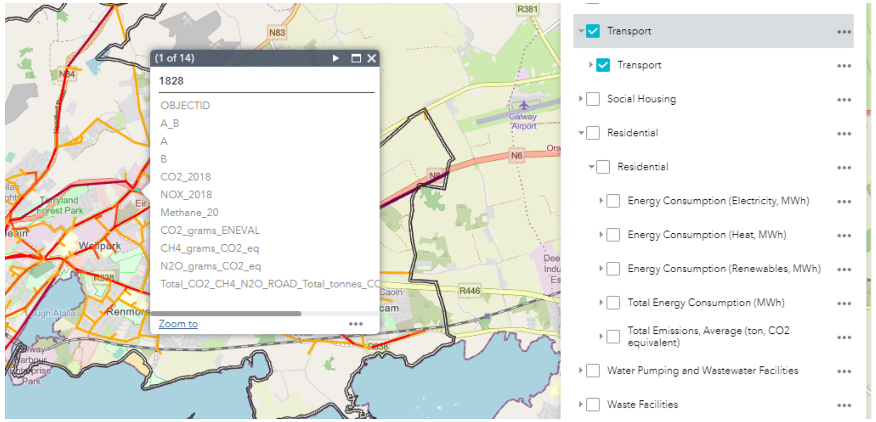


Figure 4: Web-Map Emissions Breakdown per Sector

4.4 Bottom-Up Inventory: Residential

The residential sector was identified as the greatest contributing sector to overall GHG emissions in Galway City, contributing over 40% of emissions in the baseline year 2018. Table 4 summarises the results.

Table 4: Residential Sector Results

Residential Sector	Tonnes CO_{2eq}
Residential emissions	201,393
Total	**201,393**

This section details the boundary, approach, limitations and uncertainties utilised for the calculation of energy use and associated emissions from the residential sector for 2018.

4.4.1 Assessment Boundary

Local authority data was utilised for calculation of emissions from this sector. Census data and the BER Research Tool allowed for the results to be filtered for Galway City Council. Boundaries were therefore pre-determined from the use of these datasets.

According to the Codema methodology, Social Housing is an individual sector. Social housing is captured within Census data and quantities were therefore removed from census data prior to the interpolation stage.

4.4.2 Approach

The Codema methodology was followed for the residential sector. A combination of data from the Central Statistics Office (CSO) and from the SEAI developed BER Research Tool have been used as the key data sources for the sector.

The following categories were used to estimate associated energy use and emissions from Galway City's housing stock in 2018:

- Persons/properties per housing type
- Persons/properties per built-period

In order to estimate the make-up of housing stock and built-period for 2018 in Galway City, census data from 2011 and 2016 were extrapolated. The extrapolated population data for 2018 was further utilised to scale the data and increase accuracy of the results.

The BER Research Tool is a public tool which allows statistical data from the Building Energy Rating (BER) scheme to be accessed. The tool details BER certification from across the country, including annual energy usage and carbon dioxide emissions associated to dwellings which have undergone a BER assessment.

Using the BER database, energy usage (kWh) has been summarised based on housing type (apartment, detached, semi-detached or terraced) and built period, using BER ratings. This data has been scaled to the entire building stock calculated for 2018.

Using percentage breakdowns of final energy consumption by fuel type for the residential sector in 2018 published by the SEAI, energy consumption for each category was determined. The SEAI conversion factors were applied to determine the total CO2eq.

4.4 Bottom-Up Inventory: Residential

Arup applied the Codema methodology for the residential sector. However, it should be noted that some of the databases and tools set out in the methodology were not as developed as described.

The BER Research Tool required an extensive review. Rather than an online tool, the current version of the BER Research Tool is an excel spreadsheet and therefore calculations were conducted manually through the excel spreadsheet rather than through the various filters described in the Codema methodology.

4.4.3 Limitations and uncertainties

While BER ratings provide an assessment of the primary energy consumption of an assessed property, the rating is not totally indicative of the actual energy usage of the property.

Calculation of energy consumption was from BER assessed properties. Not all properties are BER assessed in the city boundary, and therefore scaling was carried out in order to determine overall emissions from the entire sector. This is an identified limitation with the available data and therefore there will be a level of uncertainty in the results.

It is noted that both population increase, and housing stock increase is not linear. Population increase has therefore been calculated according to the CSO method to ensure most accurate results. Additionally, calculations have been carried out based on housing stock values from 2011 and 2016, extrapolated to 2018. In order to get a best estimate for the housing stock increase to 2018, population data was also utilised to scale the data to minimise uncertainty in the non-linear housing stock increase.

Photographer Credit: Chaosheng Zhang

4.5 Bottom-Up Inventory: Commercial and Industrial

The commercial sector results are made up of the top-down calculated energy use and associated emissions from the industrial and tertiary sectors combined, as well as primary data obtained through stakeholder engagement. This section details the boundary, approach, limitations and uncertainties utilised. Table 5 summarises the results.

Table 5: Commercial and Industry Sector Results

Commercial Sector	Tonnes CO_{2eq}
Top-Down Industry	45,188
Top-Down Tertiary (Non-municipal)	129,999
Total	**175,187**

4.5.1 Assessment boundary

The commercial sector includes all tertiary, non-municipal buildings and industrial buildings located within the local authority area; however, excludes facilities captured under the water and wastewater sectors. Data from stakeholders are within the boundary for the local authority area. Data utilised from the top-down approach is assumed to be within the administrative area/boundary of the city, based on population interpolation.

4.5 Bottom-Up Inventory: Commercial and Industrial

4.5.2 Approach

The Codema methodology proposed the utilisation of data from the Valuation Office and CIBSE energy benchmarks for the commercial sector. This data however, would not be made available until 2023, and therefore the Codema methodology could not be used for the commercial and industrial sectors at the time of this baseline report.

Energy use for the identified high energy users in Galway City was collected through stakeholder surveys. High energy users were identified through a stakeholder scanning exercise, and from information gathered by GCC, as noted in Section 3. Data collected through this method has been captured within the results for the industrial sector. Top-down data for the commercial and industrial sectors has been used to supplement stakeholder data which comprises national level figures scaled to Galway City.

4.5.3 Limitations and uncertainties

Data could not be obtained from the Valuation Office as per the Codema methodology. Therefore, a combination of stakeholder data obtained through engagement, as well as the top-down baseline inventory results have been utilised as a best estimate in place. There will therefore be associated uncertainties in the emissions calculated from the commercial sector until more accurate data is provided.

4.6 Bottom-Up Inventory: Transport

This section details the boundary, approach, limitations and uncertainties utilised for the calculation of emissions from the transport sector for 2018. Table 6 summarises the results.

Table 6: Transport Sector Results

Transport Sector	Tonnes CO_{2eq}
Road	87,963
Rail	355
Total	**88,290**

4.6.1 Assessment boundary

The boundary applied to the assessment encompassed road and rail emissions within the local authority area only. The road links with over 50% of their link length within the local authority area were included and railway lines were included up to the local authority boundary. Maritime transport was excluded as this is considered as being outside the local authority boundary. There are no airports within the local authority area, so aviation was also excluded.

4.6.2 Approach

The National Transport Authority (NTA) Appraisal Module known as the Environmental Evaluation Model (ENEVAL) is a GIS model which estimates emissions based on fleet type, vehicle type and link type and was utilised for the transport inventory. The Western Regional Model (WRM) was used, with relevant links extracted for Galway City. This appraisal module accounts for varying time periods and speed-based emissions across road links.

The outputs from the model include two out of the three primary greenhouse gases included in the inventory (CO_2 and CH_4). N_2O emissions could not be obtained directly from the model (omitted from Codema guidance) so an interpolation factor was determined from national transport emissions data. However, it should be noted the CO_2 is the dominant GHG for this sector.

The GWP factor was applied to CH_4 and N_2O data to determine tonnes of CO_{2eq} (refer to Section 3.3). This was added to the CO_2 emissions to determine total tonnage CO_{2eq} for road transport.

The inclusion of rail emissions was not encompassed in the Codema methodology which only included road emissions. The emissions from rail were calculated according to the Transport Infrastructure Ireland (TII) Carbon Tool (Version 2.1) which provides an emission factor for CO_{2eq} emissions per rail passenger kilometre. The rail length within the local authority area was measured and the passenger data was obtained from the NTA National Heavy Rail Census Report (2018). The passenger kilometres were determined based on this, and the emissions factor applied to determine the tCO_{2eq} from rail.

4.6 Bottom-Up Inventory: Transport

4.6.3 Limitations and uncertainties

The ENEVAL model uses built-in assumptions to estimate emissions to a reasonable degree of accuracy. This is the most detailed transport model available in Ireland, however, there is a slight degree of uncertainty associated with the model assumptions as it does not contain direct measurement.

The ENEVAL data was only readily available for the years 2016 and 2019, as such, the emissions were interpolated to 2018 using this data. The interpolation of data was key to this assessment whereby there is an associated level of uncertainty.

It should be noted that given the strategic nature of the model, the minor residential roads within housing estates are not included. Therefore, it is likely this inventory includes a slight underestimate of actual transport emissions. However, given that the decarbonisation measures will target national, regional, and local roads rather than minor residential roads, this is deemed appropriate for the purposes of this baseline which is to inform plan making.

4.7 Bottom-Up Inventory: Agriculture

This section details the boundary, approach, limitations and uncertainties utilised for the calculation of energy use and associated emissions from the agriculture sector for 2018. **Table 7** summarises the results.

Table 7: Agriculture Sector Results

Transport Sector	Tonnes CO_{2eq}
Energy emissions	205
Livestock emissions	1,368
Total	**1,573**

4.7.1 Assessment boundary

Data according to Electoral Divisions (ED's) is utilised within the local authority area only. The assessment includes mobile machinery used on farms (off-road), whilst transport to and from the farm (on-road) is captured within the transport sector. The assessment does not account for transportation further afield, outside of the local authority boundary. This assessment excludes fisheries, land-use and forestry (emissions from forestry within Galway City are considered negligible).

4.7.2 Approach

Data from the CSO Census of Agriculture (2020) which provides information on animal farming, livestock, crop farming, and hectares of land-use was utilised. Energy benchmarks, compiled by Codema, were applied to the CSO data to determine energy consumption (including electricity, heating and mobile machinery) for the various farming activities. The CO_{2eq} emissions were determined from the energy consumption using SEAI emission factors. Methane emissions (CH_4) from livestock (manure and enteric fermentation) were calculated using IPCC emission factors which are dependent on livestock type and location. This was converted to CO_{2eq} using the GWP factor. Methane emissions from livestock were not included in the Codema methodology. Emissions from land management were excluded from this assessment including potential for both sequestration and emissions derived from management activities (such as fertilization and soil carbon).

The CSO data was only available for 2010 and 2020. It was determined that 2020 data would be most suitable to represent 2018. A check using 2010 data was undertaken showing very little difference compared to 2020 emissions. CSO data was used for both livestock and crop farming whereas the Codema methodology uses the Land Parcel Identification System for crops. This system was not deemed suitable in this instance as it was out of date.

4.7.3 Limitations and uncertainties

Assumptions were made when applying the energy benchmarks compiled by Codema if direct benchmarks were not available, which incurs a level of uncertainty; however, the assumptions can be deemed conservative and appropriate. The 'Livestock Units' were taken for the 2020 livestock data, in the absence of more granular data by species. Emission factors were generalised for heating, electricity, and mobile machinery in accordance with the Codema methodology, which incurs a level of uncertainty. The interpolation of data was key to this assessment which causes an associated level of uncertainty as it is not direct data.

4.8 Bottom-Up Inventory: Municipal

This section details the approach, limitations and assumptions utilised for the calculation of energy use and associated emissions from the municipal sector for 2018. Table 8 summarises the results.

Table 8: Municipal Sector Results

Municipal Sector	Tonnes CO_{2eq}
Building/facility	2,286
Public Lighting	1,912
Total	**4,198**

4.8.1 Assessment boundary

The M&R system categorises energy use for buildings, public lighting, operations and the municipal fleet. Transportation emissions from across sectors have been captured within the Transport baseline, and therefore have been omitted from the emissions in the municipal sector. This is to ensure that there is no double counting of energy use and resulting emissions.

4.8.2 Approach

Energy use from municipal buildings are the responsibility of the Local Authority. Authorities report to the Monitoring and Reporting System (M&R) on energy use of all their assets enabling energy use from across their portfolio and operations to be determined. Data from the M&R system was used for the municipal sector inline with the methodology set out by Codema. Detailed data on electricity (MPRN) and gas (GPRN) consumption for GCC's municipal buildings and operations were obtained through this reporting system.

GCC additionally provided MPRN and GPRN data for a number of municipal properties located within Galway City that are under the jurisdiction of the council. Total energy consumption across defined categories (building/facility, public lighting and water processing) were summarised. The M&R system provides a breakdown of energy consumption by fuel type across the various categories. Based on this an overall breakdown of fuel consumption was determined. SEAI conversion factors were then applied to determine CO_{2eq} emissions resulting from sector categories and for the overall sector.

There were minimal deviations from the Codema methodology for the municipal sector. Differences in the methodology were largely in relation to the additional data provided by GCC and the exclusion of Municipal Fleet energy use.

4.8.3 Limitations and uncertainties

All municipal buildings captured on the M&R system are assumed to be within the local authority boundary. Galway County Council has a number of municipal buildings located within Galway City and data for these buildings have been provided and captured within the overall emissions for the sector.

The interpolation of data was key to this assessment; however, this does incur a level of uncertainty.

4.9 Bottom-Up Inventory: Social Housing

This section details the boundary, approach, limitations and uncertainties associated with the calculation of energy use and associated emissions from the social housing sector for 2018. Table 9 summarises the results.

Table 9: Social Housing Sector Results

Social Housing sector	Tonnes CO_{2eq}
Total	19,205

4.9.1 Assessment boundary

The data obtained through the Department of Housing is for Galway City, and therefore it can be assumed that the boundary for this sector covers only social housing properties within the local authority area.

4.9.2 Approach

The Codema methodology was followed for the social housing sector. To calculate emissions, a combination of local authority data, CSO census data, national fuel breakdowns and SEAI conversion factors were utilised. Social housing information for local authorities can be made available upon request from the local authority to the Department of Housing. Information on social housing quantities, property type, built periods and BER for the City for 2021 were provided.

Social housing BER data was filtered for properties between the years 2019 – 2021 and these results were subsequently removed.

The BER data available was categorised via built period and building type, and the overall energy consumption (kWh/year) was determined for each period and building type. Average energy consumption for each built period and property type were then calculated.

The percentage built-period for each property type was then determined and based on this the total number of properties by type and age was established. Estimated housing numbers were then multiplied by average energy consumptions. National fuel breakdowns for the residential sector in 2018 were then applied to the energy consumption to determine the fossil fuel and electricity breakdown. Finally, CO_{2eq} emissions were calculated using national conversion factors published by the SEAI.

For the social housing sector there were only minimal deviations from the methodology set out by Codema. The Codema methodology stated that data on social housing for the local authority would be made through a platform called iHouse. However, social housing data was instead obtained directly through the Department of Housing at the request of GCC.

4.9 Bottom-Up Inventory: Social Housing

4.9.3 Limitations and uncertainties

Census data from 2016 and the 2021 value from the provided data set were interpolated in order to determine the best estimate of social housing properties in Galway City in 2018, which incurs a level of uncertainty.

While BER ratings provide assessment of the primary energy consumption of an assessed property, the rating is not totally indicative of the actual energy usage of the property.

Not all properties are BER assessed in the City boundary, and therefore scaling was carried out in order to determine overall emissions from the entire sector. This was an identified limitation with the available data and therefore there will be a level of uncertainty in the results.

Photographer Credit: Chaosheng Zhang

4.10 Bottom-Up Inventory: Waste

This section details the boundary, approach, limitations and uncertainties utilised for the calculation of energy use and associated emissions from the waste sector for 2018. Table 10 summarises the results.

Table 10: Waste Sector Results

Waste sector	Tonnes CO_{2eq}
Total	**808**

4.10.1 Assessment boundary

The assessment includes waste facilities within the local authority area, however, there is one facility located outside the local authority area (managed by Galway City Council) which is included. The transportation of waste is excluded as this is included within transport sector emissions. Transportation outside the local authority boundary is excluded from the overall assessment, though it is acknowledged that waste is likely frequently transported outside of the City. There are some facilities with a waste license which were excluded as they are captured under the commercial sector (Section 4.5) and municipal sector (Section 4.8).

4.10.2 Approach

Data on the licensed and permitted facilities within the local authority area was obtained from the EPA Waste Licensing website and the National Waste Collection Permit Office (NWCPO). The facilities were screened to ensure their relevance and overlap with other sectors. Two licensed facilities and one permitted facility were included based on the screening exercise.

Energy consumption data was obtained from the EPA website (Annual Reports) for the licensed facilities. The permitted facility was contacted directly, and their energy consumption data provided. The emissions from energy consumption were determined using SEAI emission factors.

One licensed facility (a disused landfill) undertakes landfill gas flaring. The emissions data associated with this activity was obtained from the Annual Reporting and monitoring information provided directly by the facility.

The Codema methodology uses the Pollutant Release and Transfer Register (PRTR) information, however, there was a lack of relevant data on this system, as such, the EPA Annual Reports for energy consumption data were used instead.

The Codema methodology includes licensed facilities only whereas permitted facilities were also included in this inventory. The Codema approach focuses on data from landfills, however, as landfills are no longer the primary waste disposal mechanism in Ireland, this baseline inventory encompasses a broader suite of facilities.

4.10.3 Limitations and uncertainties

There were assumptions made when determining the emissions from landfill gas flaring (combustion and materials), which incurs a level of uncertainty; however, the assumptions can be deemed conservative and appropriate.

As noted, it is highly likely that a proportion of waste is frequently transported outside of the local authority area for processing or disposal; therefore, while the overall assessment covers waste facilities (and the transport sector covers road transport within the local authority boundary), not all end-of-life emissions from the waste generated within the local authority area are accounted for in this inventory.

4.11 Bottom-Up Inventory: Water

This section details the boundary, approach, limitations and assumptions utilised for the calculation of energy use and associated emissions from the water sector for 2018. This includes water processing/pumping and wastewater facilities. **Table 11** summarises the results.

Table 11: Water Sector Results

Wastewater sector	Tonnes CO_{2eq}
Wastewater	755
Water Processing	2,094
Total	**2,849**

4.11.1 Assessment boundary

The assessment includes the wastewater treatment at Mutton Island and the water processing at Terrylands Water Processing for the population of the local authority only and excludes additional capacity for areas outside Galway City.

4.11.2 Approach

There is one wastewater treatment facility that serves the entire population of Galway City. The details on energy consumption were obtained inline with the Codema methodology. The emissions were converted to CO_{2eq} utilising SEAI conversion factors, and subsequently totalled for the emissions resulting from the entire facility. Resulting CO_{2eq} emissions were then scaled to the population of Galway City, as the facility serves jurisdictions outside of the local authority boundary.

For water pumping and processing historic M&R data was interpolated based on population, and further scaled to reflect Galway City only.

The Codema methodology uses a wastewater report; however, in the absence of data in this format, data was obtained directly from the facility. Additionally, the Codema methodology does not include emissions of water treatment and water pumping despite wastewater treatment being included.

4.11.3 Limitations and uncertainties

Water pumping and treatment have historically been captured in the M&R system; however, energy consumption for the baseline year was not available. Emissions from water treatment and pumping is therefore being included within the wastewater section.

Extrapolation of data recorded for 2012 and 2013 was carried out in order to calculate energy consumption for water pumping and treatment for 2018. This method has assumed that population increase, and trends in previous consumption, are linear which incurs a level of uncertainty.

The biogas emission factor used assumes methane credit offsets any methane leakage in line with SEAI estimations for biogas CHP units.

Comhairle Cathrach na Gaillimhe
Galway City Council

4.12 Bottom-Up Inventory: Primary Energy

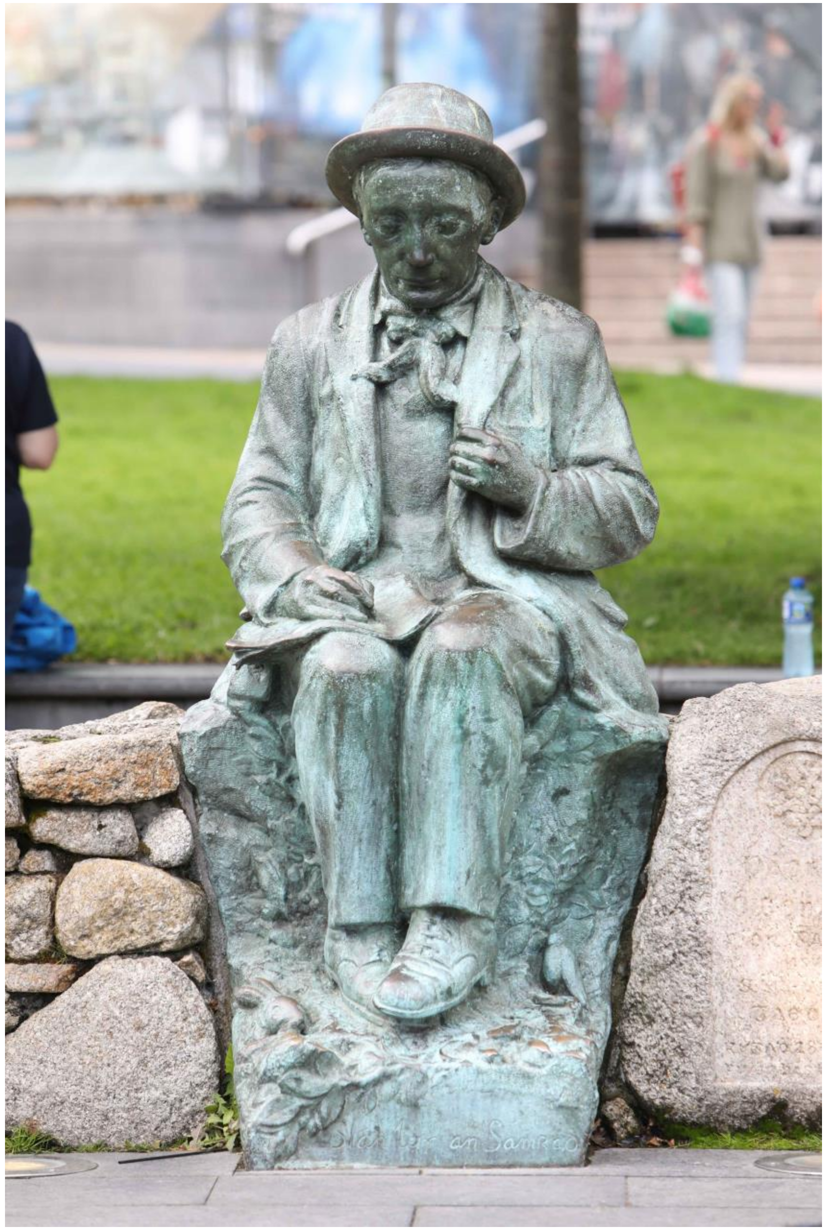
The total primary energy requirement (TPER) is presented to demonstrate the energy demand when considering conversion, transmission, and distribution losses, as noted in Section 3.3. TPER for each sector is included in Table 12.

The TPER estimates are for reference only as the total final energy consumption is the energy in control of the end user (as such, TFC is reported in the inventory and the focus for improvement in subsequent plans, refer to Section 4.2 for more details). As we move towards renewable electricity sources, the electrical losses on the grid will improve.

TPER was calculated using SEAI conversion factors. The primary energy was not calculated for transport as the SEAI conversion factors do not account for mechanical losses and would be typically based on fuel usage rather than MWh.

Table 12: Primary Energy

Sector	TPER (MWh)
Residential	7,800,283
Social Housing	19,205
Municipal	21,847
Commercial / Industry	883,823
Agriculture	919
Waste	3,217
Water	8,956
Total	**8,738,256**



4.13 Bottom-up Inventory: Discussion

The Baseline Emissions Inventory demonstrates the relative contribution of GHG emissions from the various sectors showing where the emissions hotspots are concentrated. It is evident from the spatial analysis generally where the GHG emissions are located. For example, residential emissions are concentrated centrally whereas industrial emissions sprawled on the outskirts of the City.

There are inevitable differences between the top-down and bottom-up inventories which can be attributed to the differences in the granularity of the data and the differences in the methodologies applied, as previously discussed. Despite this, both the top-down and bottom-up inventories result in the same top three sectors in terms of GHG emissions in the City.

The Baseline Emissions Inventory shows that the key focus sectors for GCC should be the residential, industrial, and transport sectors which are the largest contributing sectors in terms of greenhouse gas emissions in the Galway local authority area. This reflects the socio-economic structure of the City.

The bottom-up analysis incurs a level of uncertainty based on data availability and spatial assumptions. The commercial sector has the largest data gap whereby top-down data was used to fill this gap which led to greater uncertainties in the spatial analysis of this sector. There was also a higher level of uncertainty associated with the spatial analysis of the social housing sector as the housing unit locations could not be revealed for data protection reasons.

Despite some inherent uncertainty in the results, the assessment still proves fit for purpose with some clear trends identifiable. The inventory indicates what the emissions sources are and their associated locations enabling GCC to make better informed decisions in relation to decarbonisation.

The trends in the emissions and energy consumption demonstrate that the largest contributions are from the residential, industrial and transport sectors respectively, which is to be expected in a City location. Given that Galway is Ireland’s third largest city, there is substantial demand for housing within the local authority area. There is a strong local economy in Galway City with a large industrial sector that includes energy intensive manufacturing. There is still a heavy reliance on the private car (petrol/diesel) in Galway leading to considerable traffic related emissions. This is reflected in the findings of this Baseline Emissions Inventory.

5.1 Decarbonisation Zone: Overview

GCC has selected the "Westside" area as the DZ, as discussed in Section 3.2, for the inclusion in a focused Implementation Plan for decarbonisation and complementary sustainability measures. The selection of the DZ was based on selection criteria which included themes such as transport/active travel, the built environment, green spaces, demographics, air quality, community, social infrastructure and energy use. The "Westside" area emerged as the preferred DZ as result of an assessment using these themes, in addition to the existence of several strong partners such as University of Galway, and the Galway Energy Co-Operative Sustainable Energy Community.

The area covered comprises 167ha and encompasses a variety of public buildings, community facilities, commercial units and educational buildings. The wide variety of services within the DZ make it a useful location to act as a test bed of focused decarbonisation measures. The population figure within the DZ is supplied by GCC as being 5,541 (in 2021) covering two Electoral Divisions (ED's) and 22 small areas.

The baseline GHG emissions and energy consumption was required for the baseline year (2018), as discussed in Section 3, to enable the determination of measures specific to the area. The citywide bottom-up Baseline Emissions Inventory was used to determine the baseline for the DZ only through isolation of the data specific to the area.

The data for the city was mapped spatially (with GIS) and the data specific to the DZ was extracted using the boundary for the zone. Therefore, the methodology applied to the bottom-up inventory is consistent for the DZ. As such, the assessment boundary, approach, limitations and uncertainties for the various sectors, relevant to the DZ, are included in Sections 4.4-4.11 (as per the bottom-up inventory). The DZ boundary is shown in Figure 5 below.

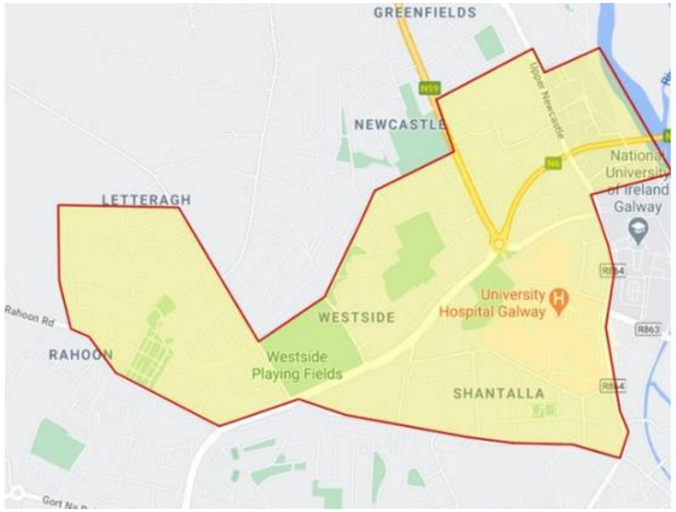


Figure 5 DZ Boundary

The DZ baseline results are summarised in Section 5.2.

The baseline for the DZ is used for the progression of the specific DZ Implementation Plan which is a more focused, area specific plan compared to the citywide Energy Masterplan.

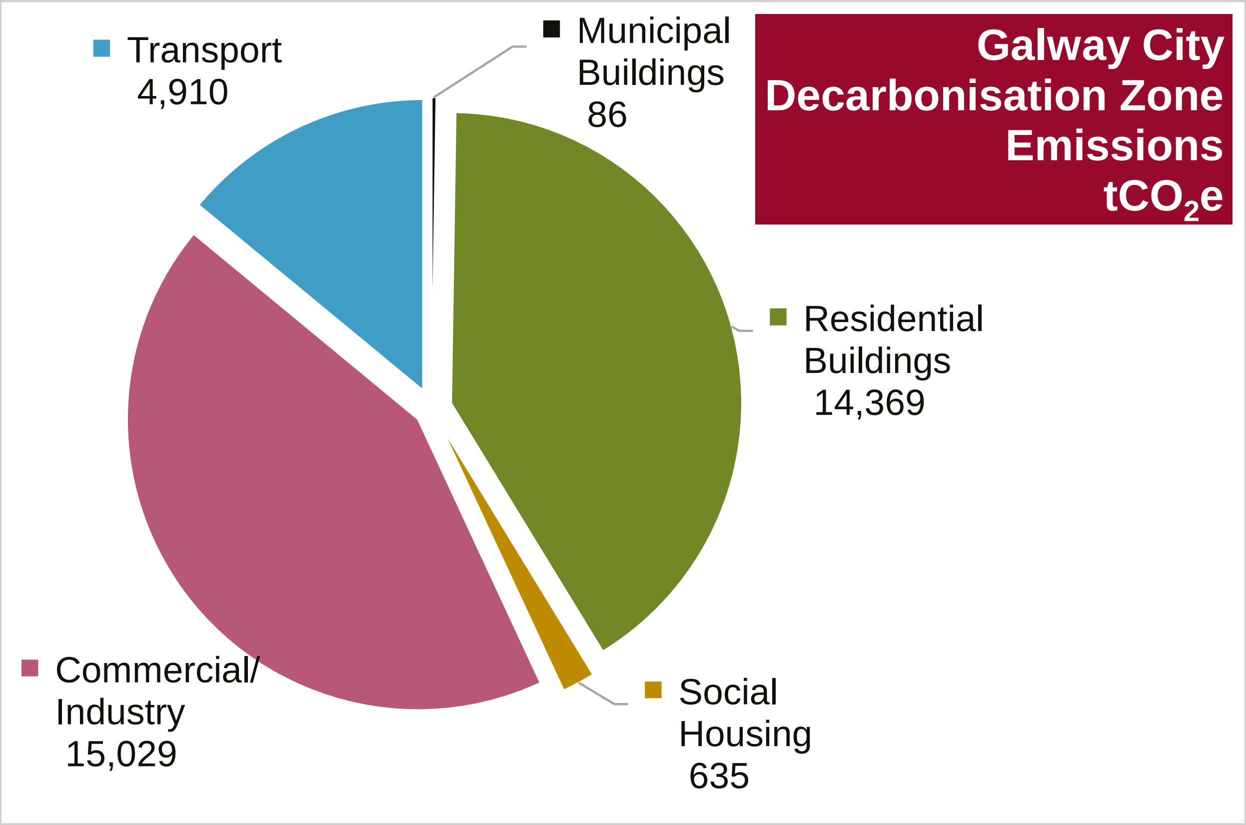
5.2 Decarbonisation Zone: Results Summary

The energy and emissions data per sector is shown in Table 13 below, which has been spatially extracted from the city-wide bottom-up baseline results. The emissions distribution is shown in the pie chart.

The DZ baseline inventory results in greatest emissions from the residential, commercial and transport sectors, consistent with the citywide baseline; however, the residential and commercial sectors account for a greater proportion of the total within the DZ. This is due to the area being a suburban location with a large number of residential dwellings and some large commercial energy users compared to the citywide proportions.

Table 13: Decarbonisation Zone inventory results

Sector	Energy (MWh)	Emissions (tCO_2eq)
Residential	50,527	14,369
Commercial (incl. Industry)	52,159	15,029
Transport	-	4,910
Municipal	278	86
Social Housing	2,219	635
Total		**35,029**



6 Conclusion

The primary purpose of the Baseline Emissions Inventory is to form an indicative picture of what and where emissions are derived in the City. The resulting application of the Emissions Inventory is to act as a baseline for evaluating alternatives and so precise data is not required.

The Inventory fulfils its objective by providing an indicative representation of the energy consumption and associated GHG emissions within Galway City for the baseline year (2018).

The results of this Baseline Emissions Inventory allows GCC to identify emissions hotspots and thus inform plan making going forward. This inventory will be used to assist decision making and focus attention on the sectors and locations where the greatest emissions savings can be made.

The Baseline Emissions Inventory is the first step in enabling GCC to reach its decarbonisation targets, by identifying the emissions hotspots within in the City and demonstrating focus areas for GCC – namely the residential, industrial, and transport sectors.

The next steps, following the Baseline Emissions Inventory, are summarized as follows:

- Firstly, a Register of Opportunities will be produced to identify potential actions to drive down emissions and meet reduction targets, outlined in Section 2, across all economic sectors.
- A Register of Opportunities will be produced for city wide actions as well as specifically for the DZ, noting that there are some overlap between city wide measures within the DZ.
- The actions identified in the Register of Opportunities will be modelled to 2030 and selected measures will be brought forward for inclusion in the subsequent Galway City Energy Masterplan and DZ Implementation Plan.
- These plans will drive emissions reduction and energy improvements in Galway City, with concentrated action in the DZ, which will enable the achievement of policy requirements and ensure that GCC lead the region on a sustainable development pathway.
- The stakeholder engagement initiated for the development of this Baseline Emissions Inventory, outlined in Section 3.3, will be continued throughout the development of the subsequent plans to ensure a diverse input and collaboration.

A1 Appendix: Top-Down Inventory Assumptions

The top-down inventory uses national energy reporting primarily undertaken by the SEAI. The specific reporting data per sector is outlined in Table 14 below.

Table 14: Top-down inventory data sources

Sector	Data Source
Residential	Energy in Ireland 2019 (SEAI)
Municipal	Building stock survey 2015 (SEAI)
Commercial	Building stock survey 2015 (SEAI)
Industry	Energy in Ireland 2019 (SEAI)
Transport	Energy in Ireland 2019 (SEAI)
Agriculture	Energy in Ireland 2019 (SEAI)
Waste	South Dublin Baseline Emissions Report 2016 (SEAI)
Wastewater	“Application of On-Site Wastewater Treatment in Ireland and Perspectives on Its Sustainability”

The population figure is based on CSO data (extrapolated) totaling 79,924 within the local authority boundary. The 2019 data was scaled to 2018 based on energy statistics for 2018. The top-down assessment included several assumptions to scale the data to the city-level, summarised as follows:

- For the residential sector, the energy data from the Energy in Ireland (2019) publication was scaled to Galway City using a factor based on housing per fuel type in the city, assuming the same proportions as national level.
- For the commercial and municipal sectors, the energy data from the building stock survey (2015) was scaled using a population-based factor, assuming the building stock did not considerably change between 2015 and 2018, and the fraction of administrative buildings compared to the total commercial stock is the same as national level.
- For the industrial sector, the energy data from the Energy in Ireland (2019) publication was scaled to Galway City using a population factor. This assumes that Environmental Protection Agency (EPA) industry data is representative, and fuel usage across the industrial sector in Galway City is the same as national level.
- For the transport sector, the energy data from the Energy in Ireland (2019) publication was scaled to Galway City using a factor based on motor vehicles in the city relative to the state, assuming fuel type used in the transport sector in Galway City is the same proportionally as national level.
- For the agriculture sector, the energy data from the Energy in Ireland (2019) publication was scaled using a factor based on the number of people working in agriculture in the city relative to the state, assuming fuel type used in the agriculture sector in Galway City is the same proportionally as national level.
- For the waste wand wastewater sector, the emissions were scaled to Galway City based on population, assuming emissions per capita for waste and wastewater management is the same as in South Dublin, and comparable to 2018, respectively.

A1 Appendix: Top-Down Inventory Results Summary

The energy and emissions data per sector is shown in Table 15 below. The emissions distribution is shown in the pie chart. The top-down analysis incurs a high level of uncertainty whereby the results are largely dependent on the scaling factors used. This top-down inventory should be considered indicative, to set a precedence for the bottom-up inventory. There are inevitable differences between the top-down and bottom-up inventories which can be attributed to the differences in the granularity of the data and the differences in the methodologies applied.

Table 15: Top-down inventory results

Sectors	Energy (MWh)	Emissions (tCO_2eq)
Municipal	2,286	778
Tertiary (Non-Municipal)	140,582	47,853
Residential	685,363	216,962
Industry	452,944	129,999
Transport	847,438	213,727
Waste	-	7,607
Wastewater	-	3,842
Agriculture	5,313	1,408
Non-energy emissions	-	11,449
Total		**633,625**