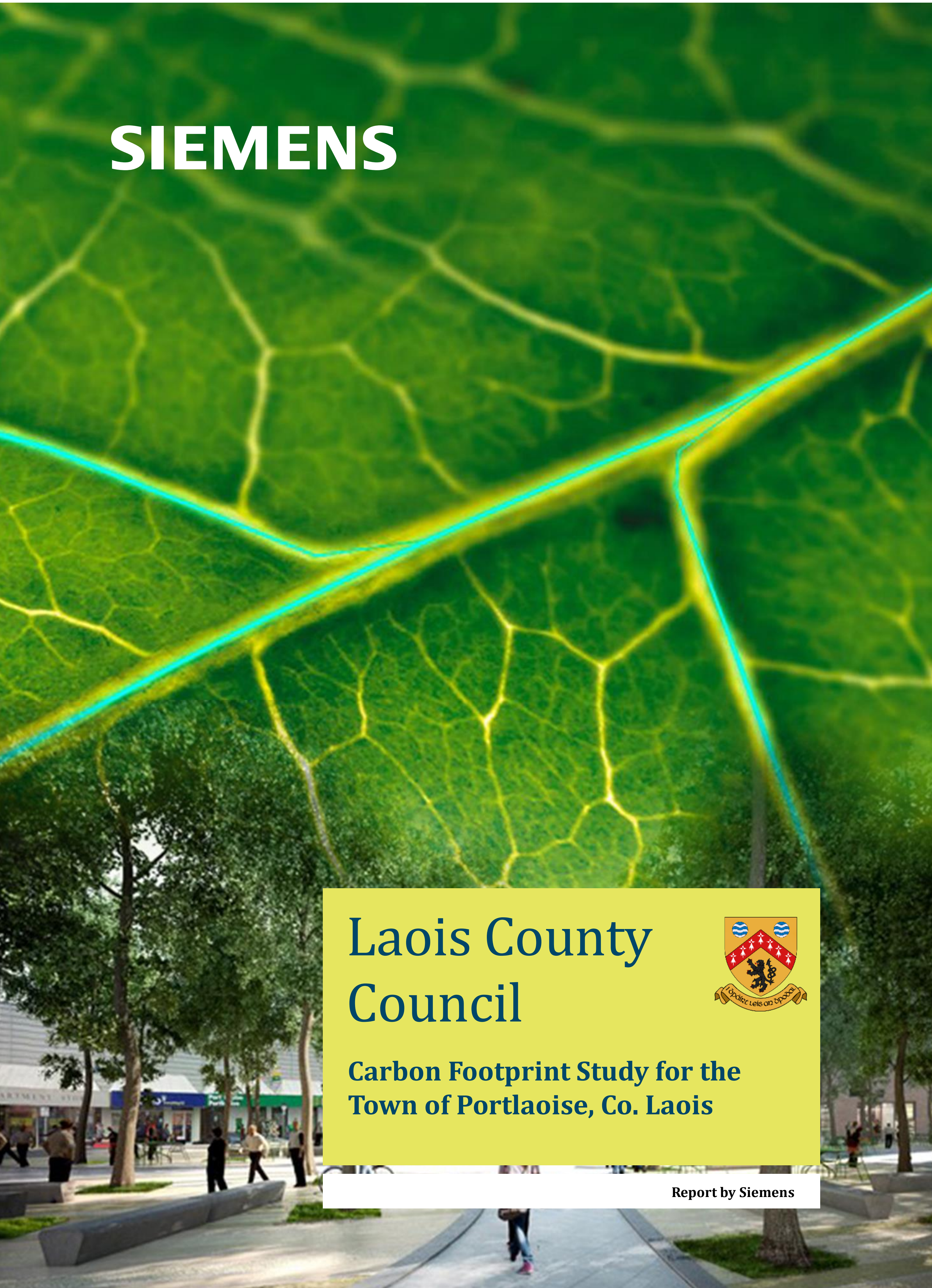

SIEMENS

Laois County Council

Carbon Footprint Study for the Town of Portlaoise, Co. Laois

Report by Siemens

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1 EXECUTIVE SUMMARY

The Carbon Footprint Study report for Town of Portlaoise is designed to provide Laois County Council with a detailed assessment of its existing Carbon footprint and the potential to reduce its impact through identifying suitable reduction opportunities.

In the first phase, a Baselining of Portlaoise Carbon footprint exercise was conducted. This focused on three categories – the impact from electricity demand, heating needs and prevalent transportation modes within the boundaries of Portlaoise. As Portlaoise does not have its own electricity generation, the impact assessment was done assuming that the electricity mix supplied to the town is similar to that of the national electricity grid mix. The heating needs for both residential and non-residential sectors were analysed considering the mix of the fuel source used and the housing age. Based on this analysis, the overall electricity demand for Portlaoise (without Heating) is 80,666 MWh p.a. while the overall thermal energy demand (incl. Electricity for Heating) is 141,736 MWh p.a. Overall emissions related to the transportation sector were determined for both passenger and freight modes. Overall fuel consumption (across all fuel sources) for passenger and freight was ~6,000 Tons p.a.

Based on the above assessment, the overall Carbon Footprint baseline for the Town of Portlaoise is tabulated below:

	Scope 1,2		Scope 1,2 & 3	
Sector	**CO_2 Emissions (tons)**	**GHG (tons of CO_2e)**	**CO_2 Emissions (tons)**	**GHG (tons of CO_2e)**
Residential	32,888	32,962	35,084	36,567
Non-Residential	29,791	29,861	31,438	32,652
Passenger Transport	16,107	16,221	19,200	19,569
Freight Transport	8,490	8,536	10,158	10,371
Total	**87,276**	**87,580**	**95,879**	**99,159**

To reduce the Carbon Footprint for Portlaoise, a detailed assessment of Renewable Potential in the region was conducted. Both wind and solar potential was assessed for multiple historical weather patterns (2012, 2015, 2017). The assessment included development of scenarios for onshore wind farms considering the proximity to transmission networks, distance from the town for five combinations of turbine capacity and height. Overall, there is a potential for onshore renewable generation of up to 15,169 GWh/a in Portlaoise. Similarly, scenarios were developed for roof top PV potential considering 15 combinations of orientation and inclination of the panels. Depending on the chosen configuration, the annual electricity output could reach up to 177 GWh/a.

To model the actual impact of the above renewables option, 3 use cases were developed – renewables, heating, and transportation. The **Renewables Use Case** comprised of scenarios considering the onshore wind potential supplied indirectly via National Grid (Option 1A), directly to the town (Option 1B) and with Rooftop PV (Option 2). The **Heating Use Case** focused upgrading the Energy Efficiency especially of the older residential setups. Finally, the **Transportation Use Case** focused on the impact replacing 5% of conventional cars to electric vehicles charged from the national grid electricity. The impact of each Use Case was assessed in comparison to the Baseline Carbon Footprint tabulated earlier.

Use Case	**Details**	**Reduction of CO_2 emissions vs Baseline**
Renewable: Option 1A	Onshore wind supplied via Grid	3%
Renewable: Option 1B	Onshore wind supplied directly to town	34%
Renewable: Option 2	Rooftop PV	18%
Heating	Retrofit legacy residential units	16%
Transportation	Replace 5% conventional vehicles with EV	1%

2 INTRODUCTION

The Ireland 2040 Plan identifies the town of Portlaoise as a national demonstration project for implementing sustainable and community driven urban renewal. Furthermore, Portlaoise has been allocated funding to advance towards the status of 'Low Carbon Town' as part of the Ireland 2040 demonstration project.

Laois County Council went out to tender in November 2019, to prepare the baseline carbon footprint of the town and understand the potential opportunities to reduce the overall carbon footprint. Siemens was awarded the contract for this project in August 2020. The resulting report covers the four key topics identified in the Tender document:

1. Footprint:
    a. To provide a "Carbon Footprint" for the town of Portlaoise; this carbon footprint must be capable of being recalibrated in future years (under a separate contract) so as to provide a "progress achieved" measure.
    b. Provide a baseline of total and sectoral energy usage in Carbon tonnes by fuel and energy-related CO2 emissions for the Study Area, including for Scope 1, 2 and 3 Emissions as per the GHG Protocol, while also having regard to the six GHG's listed in the Kyoto Protocol.
2. Provide an estimate of the renewable energy potential for the Study Area
3. Establish a register of opportunities for the reduction of energy demand and the transition to renewable energy supply.
4. Identify organisations (including State companies) that can support Portlaoise during transition

This report provides a primary carbon footprint study. The scope of this study is limited to emissions from direct energy consumption and does not include secondary emissions from consumption of products.

3 BASELINING PORTLAOISE'S CARBON FOOTPRINT

The Carbon Footprint Study in Portlaoise targets emissions which are caused by energy use in the electricity, building and transport sector within Portlaoise's administration boundaries. With this study, Laois County Council has brought transparency into its energy related carbon footprint and other greenhouse gas emissions (listed in the Kyoto Protocol: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6)). This is the starting point of their approach to become Ireland's first Low Carbon Town in accordance with Action 165 of the Climate Action Plan.

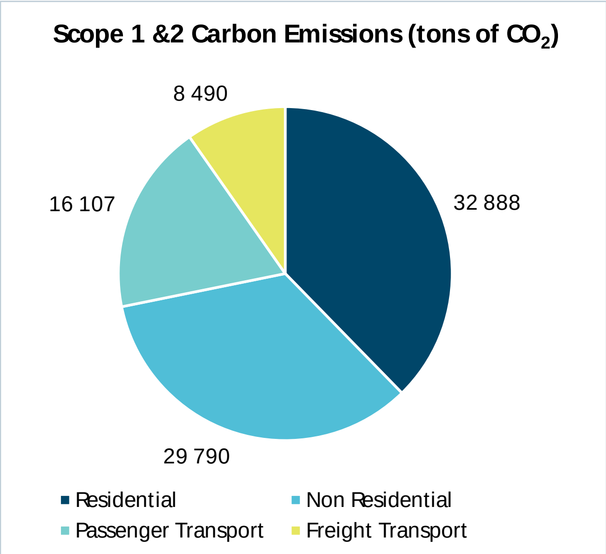


Figure 1: Scope 1 & 2 carbon emission

Overall, around 4 tons of Scope 1 and 2 CO_2 are emitted per capita. Most of the emissions (~70%) are due to energy related activities such as heating, lighting, operating appliances in residential and non-residential buildings. Transport of passengers and goods is responsible for ~ 30%.

The next sections of the study provide insights into the baseline emissions using local statistics ([1] – [4]) and a deep dive into the GHGs of the different scopes. The emission baseline of Portlaoise was built by calculating the energy demand within the Portlaoise's boundary based on the latest public available Census data of the Central Statistics Office (CSO), enhanced by national travel surveys and traffic counting information for heavy duty vehicles and the underlying Sustainable Energy Authority Ireland (SEAI) energy system data for electricity.

This approach provides a reasonable coverage and understanding of the emissions, by ensuring consistency in data use and reporting as well as enables an easy update of the carbon footprint baseline with a limited amount of additional data. For updating & monitoring the Carbon Footprint an easy to use excel workbook ("Carbon footprint baselining") is made available separately to the County Council.

3.1 Overview of system boundaries, data acquisition, availability

The study covers the settlement of Portlaoise as marked with a red outline in the map below.

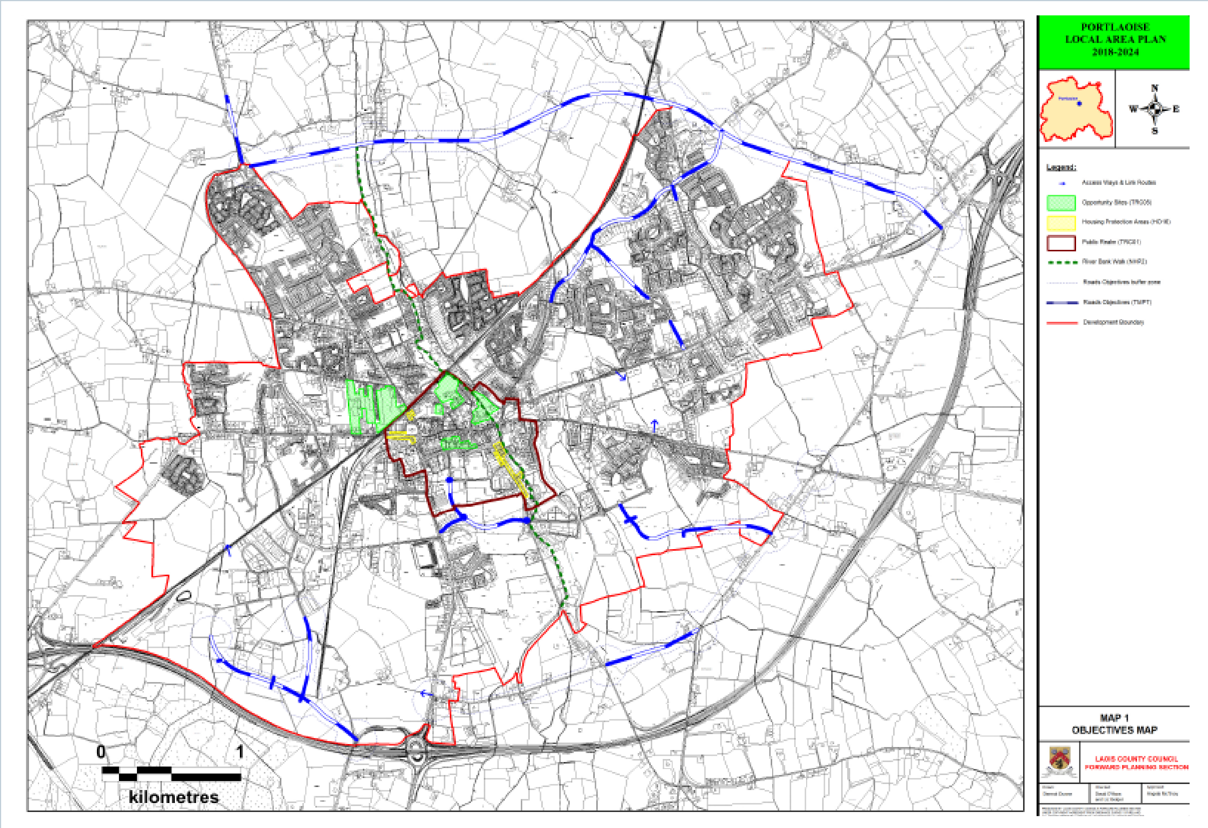
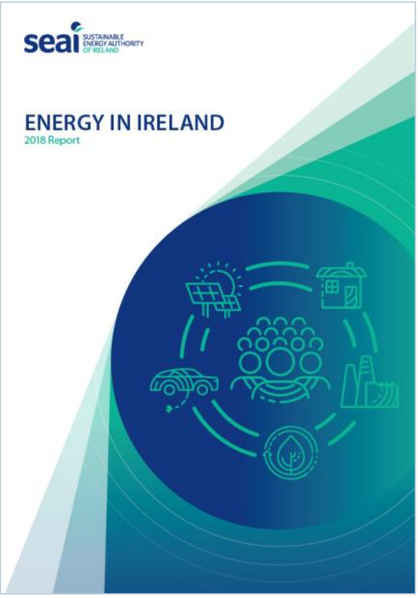


Figure 2: Map of Portlaoise town

Portlaoise's settlement considered for this study covers ca 13.71 square kilometers represented in the map. The population consists 22,050 inhabitants in 7,547 households. The town has a good transport connectivity to the rail system as well as a ring road motorway outside the boundary which reduces transit traffic. The town offers a good mix of residential and commercial development which offers job opportunities at short distances. However, there is still a significant amount of individual motorized transport in the town. The plan for two public town bus lines and the "2040 and Beyond: A Vision for Portlaoise Strategy for a Better Town Centre" targeting for example a walkable, green and recreational town center as well as the reconnection of the old and new town are positive activities that would foster the reduction of individual motorized transport.

Data is key for baselining Portlaoise's carbon and greenhouse gas emission. However, there must be a balance between data collection effort, timely provision of results, reproducibility of results, and updatability.

Several initiatives and reporting schemes are already in place to deliver the baseline data required to derive the energy demand data as well as the energy sources for serving the demand. As their study is focused on energy use and energy related carbon and other greenhouse gas emissions, the "Energy in Ireland" report of the Sustainable Energy Authority of Ireland (SEAI 2019) is a major underlying data source. It provides up-to-date and most frequently updated data of the national energy situation. Wherever possible, data has been scaled to the town specific situation.

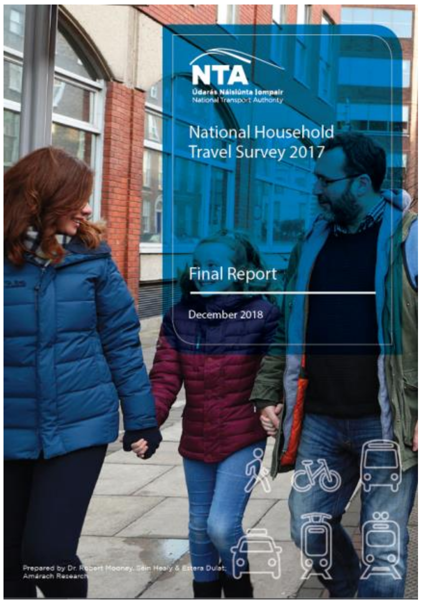


As there is no local electricity generation in Portlaoise, it has been assumed the electricity is supplied by national grid mix. The SEAI delivers the data for national electricity grid mix, which has been used to derive the emission factor of a unit electricity used in Portlaoise.

Energy sources for heat supply differ by region. Therefore, the share of permanent private households by central heating provided by CSO census data, has been used as Portlaoise' energy mix of heat sources. The emission factor per unit of heat used in Portlaoise have been derived by applying the Covenant of Mayors (CoM) Default Emission Factors (Version 2017).

Portlaoise itself, has no direct access to energy use data in residential sector nor in the commercial sector. Therefore, the national average of energy use per household for the residential sector and per employee for industry & commercial activities provided by SEAI have been used. However, the heat demand in residential sector depends significantly on building efficiency. Building Energy Rating (BER) data is a good source, however, is as yet not available for 100% of existing building stock. Therefore, building age provided by CSO has been used an indicator of building efficiency in Portlaoise. The building age profile has been mapped with indicative building energy rating grades for typical homes provided by SEAI.

Although the average energy use in residential sector is based on national data of 2018, the number of Portlaoise households and employee are based on CSO (2016) data. It has been decided to exclude a demand projection, as 2020 data will be collected by CSO and can be used for later updates during the ongoing monitoring phase.



Besides the residential and commercial building sector, the transport sector is a major cause of carbon dioxide and other greenhouse gas emissions. Although there are traffic monitoring counters in place to get real time information on the number of vehicles, it does not distinguish between the specific vehicle types and does not provide any information on transport demand of Portlaoise inhabitants in terms of mode, trip purpose and distance.

The CSO collects very specific information on the mode share used for commuting to school and work. However, this would consider only part of the transport demand. Therefore, the National Household Travel Survey has been used to fill the data gaps. The advantage of this survey is sub-regional breakdown based on the population size. Hence, data of large urban towns i.e., population greater than 10,000, is representative for Portlaoise's passenger transport. The combination of both data sources provides a good mode share of inhabitants' journeys.

Distances have been estimated based on distance per journey information and vehicle kilometers per mode. The numbers have been validated against the number of buses stops per day and distance of routes within the Portlaoise settlement.

Freight transport has been estimated by traffic counting information, such as annual average daily traffic (AADT) and share of Heavy Goods Vehicles (HGV), as well as estimated distance within the Portlaoise settlement.

3.2 Carbon intensity of energy sector

Electricity:

According to the SEAI national energy report and key statistics in 2018 the **carbon intensity of electricity fell from 441 to 375 gCO_2/kWh**. This was mainly due to large reduction in coal use and an increase in wind generation. However, the SEAI Energy in Ireland report 2019 showed that in 2018, >66% of electricity is still generated by fossil fuels, mainly natural gas. It is expected that going forward, the transition of the national electricity generation mix to more renewables would help reduce the carbon footprint of Portlaoise.

There is a significant difference in the shares of electricity by fuel for end use, compared to the fuel inputs as represented in the energy flow for electricity generation in the graph below. This is due to the differing efficiencies in electricity generating processes. Electricity transformation losses accounted for 42% of all fuel inputs in 2018. This means that 58% of all the energy used to generate electricity ends up as electricity. The efficiencies of the generation processes are already covered in the emission factors applied to the energy used.

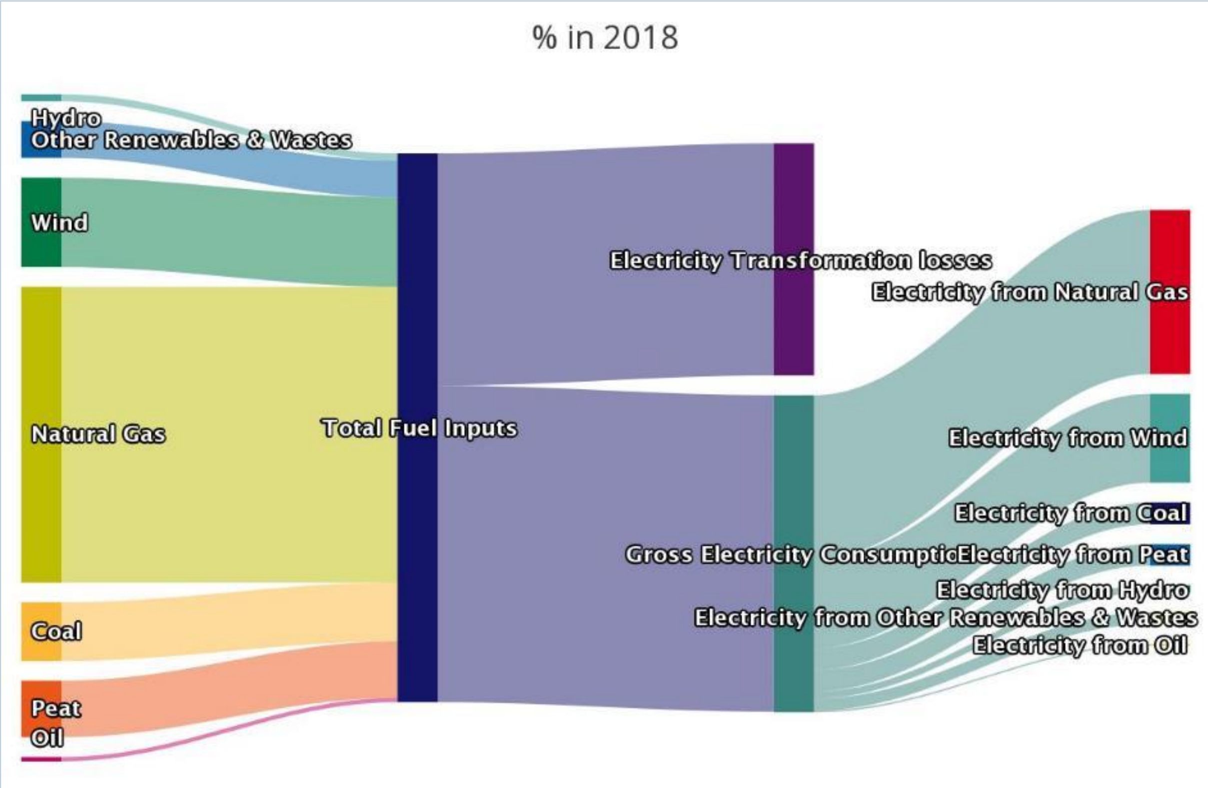


Figure 3: Electricity mix 2018 – based on national grid SEAI [6]

Heat:
According to the CSO census 2016, the statistics of heat sources for housing shows that most of houses are heated with natural gas. Nationally, there is a significant share of oil heating which is of a higher carbon intensity compared to natural gas. However, the share of high carbon intensive heat sources such as oil, coal, and peat of Portlaoise's heating mix is only around 2/3 of the national average.

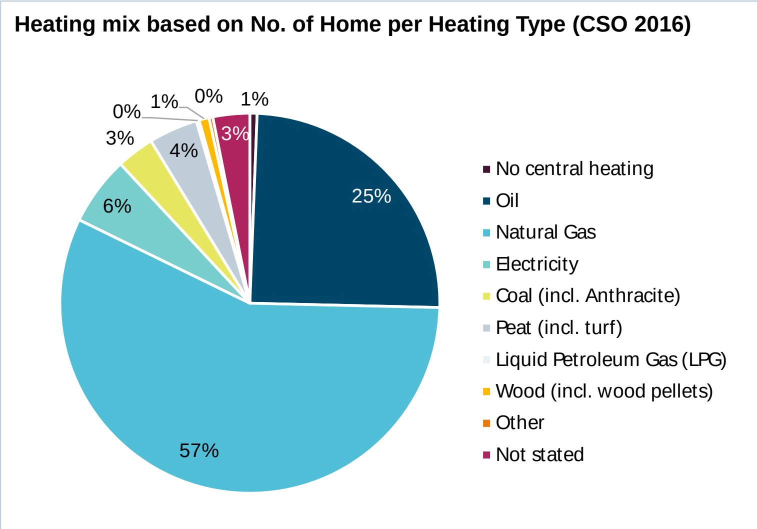


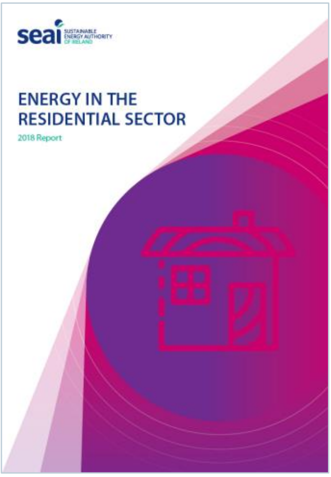
Figure 4: Heating mix based on number of homes per heating type

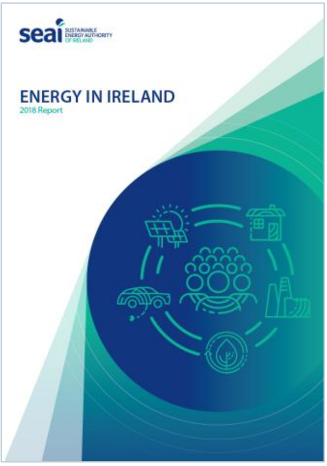
It is assumed that the average thermal demand per house is in similar proportion to the type of heating stated. The emission impact of houses heated with electricity is included in the "electricity assessment" and hence excluded from heating analysis to avoid duplication. Assuming the distribution of households with unspecified heat source to be like the rest of the town, the carbon intensity of **thermal energy of Portlaoise is estimated at 235 gCO_2/kWh**. Typically, private households and building owners will not replace the existing infrastructure unless its end of lifetime of the heating system in the building. Hence, it is assumed that the 2016 data relating to heat sources in homes is still valid.

3.3 Energy demand in the building sector

Residential:

Due to the lack of detailed data on energy use in the local residential sector, the SEAI 2018 "Energy in the residential sector" report has been used to estimate the energy demand and efficiency in Portlaoise [5], [6].





Laois County Council agreed to use the energy use of a typical home as a starting point.

In relation to housing, the typical consumption of 18,560 kWh/yr on a national level is made up of 13,885kWh/yr for thermal and 4,675kWh/yr for electrical energy in 2018 according to the SEAI Energy in Ireland 2019 report. It is assumed that the appliances use pattern for lighting, cooking, etc. is similar to the national average.

However, thermal demand depends on a building's energy efficiency. The existing building stock in Portlaoise is newer compared to the National stock, as observed by comparing the average age of buildings in Portlaoise and Ireland. Around a half of Portlaoise's housing was built after 2000, whereas on the national level only a quarter was built in the same period.

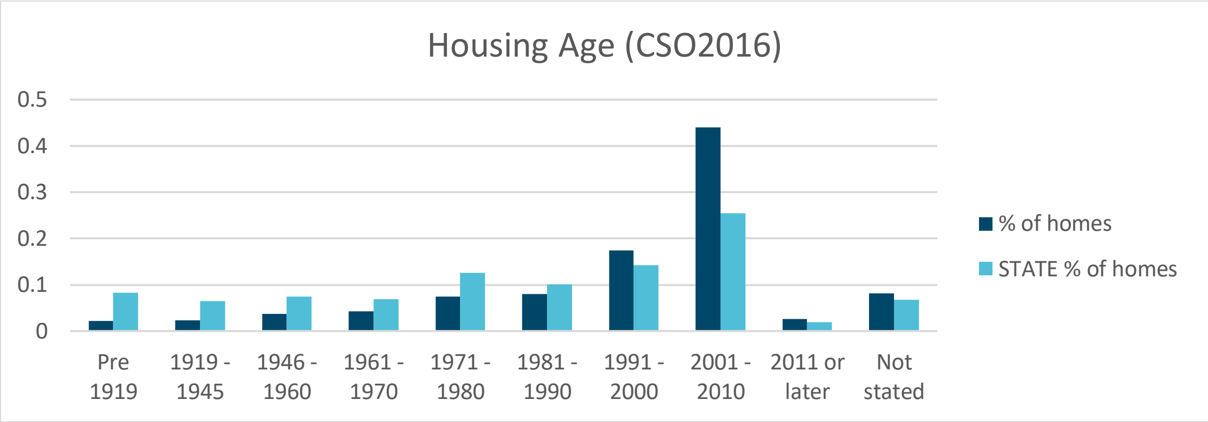


Figure 5: House aging

Considering this significant difference, the thermal energy demand was adapted using the SEAI Building Energy Rating grades of typical homes for their year of construction and type of heating.

Table 1: Indicative Building Energy Rating grades for typical homes

Oil/gas central heating		Standard electric heating		Solid fuel central heating	
Year of construction	Typical energy rating	Year of construction	Typical energy rating	Year of construction	Typical energy rating
2012+	A3	2012+	A3	2012+	A3
2010-2011	B1	2010-2011	B1	2010-2011	B1
2008-2009	B3	2008-2009	C3	2008-2009	B3
2005-2007	C1	2005-2007	D1	2005-2007	C2
1994-2004	C3	1994-2004	E1	1994-2004	D1
1978-1993	D1	1978-1993	E2	1978-1993	D2
Pre 1978	D2/E1/E2	Pre 1978	G	Pre 1978	F

These tables indicate the typical BER rating for houses by age for various fuel types. The data reflects typical Building Regulations and practices at the time of construction.

Table 2: Indicative annual CO_2 emissions and running costs for different rating bands for space and water heating

Rating	2 Bed Apartment		3 Bed Semi-D		4 Bed Semi-D		Detached House		Large house	
	Area (m²)	75	Area (m²)	100	Area (m²)	150	Area (m²)	200	Area (m²)	300
	Tonnes CO_2	Cost (€)	Tonnes CO_2	Cost (€)	Tonnes CO_2	Cost (€)	Tonnes CO_2	Cost (€)	Tonnes CO_2	Cost (€)
A1	0.4	€140	0.5	€190	0.8	€280	1.1	€400	1.6	€600
A2	0.8	€280	1.1	€380	1.6	€560	2.2	€800	3.2	€1,100
A3	1	€350	1.4	€470	2	€700	2.7	€900	4.1	€1,400
B1	1.3	€440	1.7	€590	2.5	€900	3.4	€1,200	5	€1,800
B2	1.6	€570	2.2	€800	3.3	€1,100	4.3	€1,500	6.5	€2,300
B3	2	€700	2.7	€900	4	€1,400	5.3	€1,900	8	€2,800
C1	2.4	€800	3.1	€1,100	4.7	€1,600	6.3	€2,200	9.4	€3,300
C2	2.8	€1,000	3.7	€1,300	5.5	€1,900	7.4	€2,600	11	€3,900
C3	3.2	€1,100	4.2	€1,500	6.3	€2,200	8.4	€2,900	12.7	€4,400
D1	3.7	€1,300	5	€1,700	7.5	€2,600	10	€3,500	14.9	€5,200
D2	4.4	€1,500	5.8	€2,000	8.8	€3,100	11.7	€4,100	17.5	€6,100
E1	5	€1,800	6.7	€2,300	10.1	€3,500	13.4	€4,700	20.1	€7,000
E2	5.7	€2,000	7.6	€2,600	11.4	€4,000	15.1	€5,300	22.7	€7,900
F	6.8	€2,400	9.1	€3,200	13.6	€4,700	18.2	€6,300	27.2	€9,500
G	8.5	€3,000	11.3	€4,000	17	€5,900	22.7	€7,900	34	€11,900

This table gives estimated annual fuel cost and CO_2 emissions on the basis of typical occupancy and heating the entire dwelling to a comfortable level.

The Tables above are based on fuel and electricity factors from February 2014.

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Ireland's EU Structural Funds Programmes 2007 - 2013

Co-funded by the Irish Government and the European Union

EUROPEAN UNION STRUCTURAL FUNDS

The Sustainable Energy Authority of Ireland is partly financed by Ireland's EU Structural Funds Programme funded by the Irish Government and the European Union.

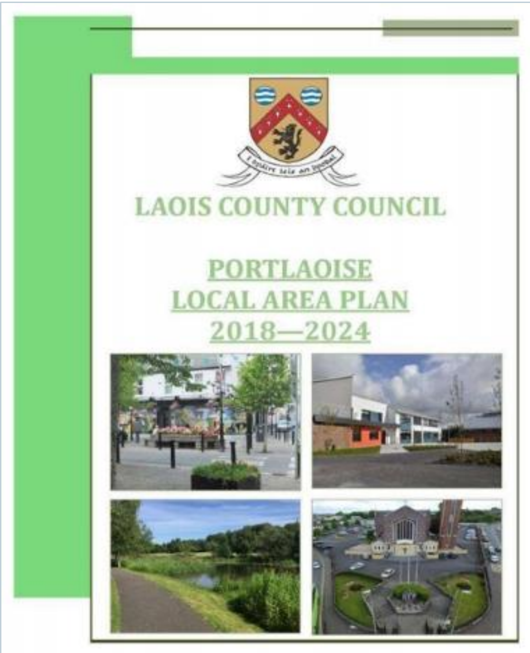
Figure 6: SEAI guidelines for buildings

This assessment leads to Portlaoise's buildings being ~18% more efficient than the national average. Hence, the typical consumption of Portlaoise's homes is 11,386kWh/yr for thermal and 4,675kWh/yr for electrical energy.

According to CSO 2016, Portlaoise has 7,547 households. Thus, the overall energy use in residential sector is 35,275 MWh/yr of electrical and 85,928 MWh/yr of thermal demand. Thermal demand accounts for ~70% of overall energy demand and must be in focus for any energy efficiency improvement program.

Non-Residential:
The non- residential sector consists of a multitude of commercial business, public sector bodies and other industries. Although there is energy measurement system in place for publicly owned buildings on the county level, it covers only a limited part of the non-residential activities within the settlement of Portlaoise. The SEAI did an extensive survey of the commercial buildings stock in the Republic of Ireland looking at building types and energy demand of different commercial applications. However due to the lack of detailed data on Portlaoise's building stock and energy use in local commercial and public sector, an alternative approach using number of employees was chosen to simulate to energy use in alignment with Laois County Council and the energy consultant ORS. Additionally, several initiatives already implemented or planned are incorporated in this section supporting the overall decarbonization activities in Portlaoise.

According the SEAI Energy in Ireland 2018 [7], the consumption per employee in commercial and public services is available. Based on state average [8], [9], the consumption per employee in commercial and public service is assumed to be 4,228 kWh/a of electrical demand per employee and 5,198 kWh/a of thermal demand per employee


LAOIS COUNTY COUNCIL

PORTLAOISE
LOCAL AREA PLAN
2018—2024

The CSO 2016 report on 10,736 employees within Portlaoise settlement [10]. The employees count for the commercial and public sector includes all commercial activities in Portlaoise such as retail, hotels, etc., as well as public buildings and utilities including education, water & waste management, etc. This number of employees is also used in Portlaoise Local Area Plan 2018 to 2024 and therefore aligned with other studies. Further, there is no significant energy intensive industry within the area under consideration.

Overall, the energy use in commercial and public sector is 45,392 MWh/yr of electrical and 55,808MWh/yr of thermal demand.

The electricity demand of commercial and public sector exceeds the electricity demand of residential sector, therefore should be a focus for energy efficiency programs.

Summary of energy demand in building sector:
Based on the number of inhabitants, households, and employees in commercial and public services in 2016, the overall energy demand resulted in about 81 GWh of electricity energy and 142 GWh of thermal energy.

Electricity use in the residential sector is around 25% lower compared to the non-residential needs, whereas the thermal energy demand is more than 50% higher compared to non-residential sector.

Discussion of selected public services and potential initiatives

Portlaoise is host to several public facilities that were investigated as part of baselining the carbon footprint of non-residential sector. These included community premises, sports facilities, hospitals, and prison system. Based on our experience, these public services have a low impact on the overall carbon footprint. Specifically, in case of Portlaoise, the energy demand of these services is relatively low compared to the overall energy demand. The subsequent discussion validates this assumption and the overall analysis.

Public stadium: O'Moore Park is a stadium with capacity of 22,000 individuals (6,500 seated), primarily used for Gaelic football and hurling. The stadium includes floodlights facility. As part of the Green Stadium Initiative, Laois GAA (authority responsible for the stadium), has plans of converting the floodlights and stadium lighting to LED. The funding for these plans is already secured and implementation is in progress. It is estimated that the initiative would lead to an annual saving of € 12,000 /year in electricity and would result in reduction of ~18 tons of greenhouse gas [11] (assuming an energy price of 24 Eurocent per kWh). Overall, the base energy consumption and the impact of initiatives for these sports facilities would likely account for <1% of Portlaoise's overall GHG footprint.

Hospitals consume a lot of energy - both electricity and heat. A comparison of 90 hospital in Germany [12] provided an average energy consumption of a hospital under normal conditions, both climatic and operational, of 0.27 MWh/m2, 14.37 MWh/worker, and 23.41 MWh/bed. It turns out that the energy consumption per bed is similar to the average energy consumption per household. Considering this assumption to be applicable in Portlaoise as well, the 200-bed hospital in Portlaoise would be comparable to ~3% of energy consumption in residential sector.

Prisons: Portlaoise has 2 prisons – Midlands Prison and Portlaoise Prison – with a cumulative capacity of ~1,100 prisoners. It also has an Irish Prison Service College responsible for training facilities. The Irish Prisons annual report [13] shows that at the national level there were ~9,000 prisoners across all facilities in Ireland whose total energy demand was 82 Million kWh (electricity and heating). According to the capacity of Portlaoise prisons, the fraction would translate to ca. 9% of overall electricity demand of Portlaoise and 10% of heating demand. This service has a much higher energy intensity per employee compared to the consumption per employee in commercial and public services based on state average according to the SEAI Energy in Ireland 2018 [7]. Therefore, the prison service should be monitored for energy efficiency levers.

Council Buildings: In 2019, Laois County Council Premises in Portlaoise consumed 1.1 GWh electricity and 2.6GWh of Gas (thermal energy). As can be seen in comparison to the overall demand, the specific council building demand is ~2%.

The LIEN (Large Industry Energy Network) which is run by SEAI is a good source on how to improve energy efficiency in industrial operations [14]. Additionally, a fund for community energy projects across Ireland was launched recently. The scheme supports substantial investment in energy upgrades to homes, community, and commercial buildings. This includes rented properties, businesses, sports and community facilities, public sector buildings and schools. The Sustainable Energy Authority of Ireland (SEAI) are managing the new scheme, which is an enhanced version of the previous Better Energy Communities Scheme [15].

Agriculture

There a few farms within the settlement covering <25 hectares. Significant energy related activities play a role at dairy farms only. In terms of electricity consumption per dairy cow milked, the figures varied from 4 kWh/cow/week to 7.3 kWh/cow/week according to TEAGASC [16]. Even in the worst-case scenario, the electricity consumption of the dairy farm activities is far below 1% of the overall energy consumption of the town. Although the energy related carbon emissions of the dairy farm are negligible on the town level, there are numerous studies focusing on the energy efficiency and climate actions of dairy farms. The following are usually recommended for enabling a positive transformation [17, 18, 19]:

- Record usage at various intervals
- Switch to a better tariff
- Make staff aware of energy saving aspirations
- Switch off equipment and lights where appropriate
- Insulate water heaters and pipework to minimise losing heat you are paying for
- Use cheaper night-time electricity where possible, especially for water heating
- Consider investing in energy saving devices
- Heat recovery and optimize plate cooling
- Replace old equipment with energy efficiency model

Looking at the default values of diesel consumption, there is a primary energy use of fuels reported by literature of 0.7MJ/kg ECM (energy corrected milk) [20]. Applying an average of 22kg ECM/day/cow [21], for a herd size of <150 cows over the few farms, the resulting diesel consumption of ~15000 kg diesel per year significantly below 1% of overall Portlaoise's diesel consumption (see next Section for overall Diesel consumption). Hence, impact of agriculture on carbon assessment is ignored in the reminder of the report.

3.4 Transport sector

Passenger

Transport pattern within towns and urban areas are very diverse depending on the town's geography, available infrastructure and socio-economic activities occurring within the town boundaries. To address this complexity, we need to consider modes of transport, number of trips, reasons for trips and distance of trips.

CSO collects data for commuting to work and education. However, these trips cover a part of the overall transport profile.

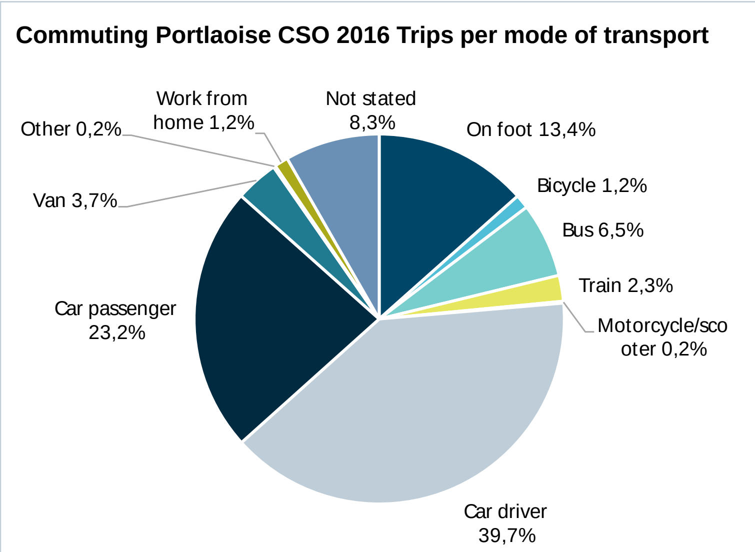


Figure 7: Trips by mode in Portlaoise

The National household Travel Survey in 2017 (NTA) provides an overview on the passenger transport demands [22]. Fortunately, the study distinguishes between six architypes to assess the diversity in transport patterns. Portlaoise falls in the "Larger Urban Town" category representing towns with >10,000 inhabitants. Compared to the national average,

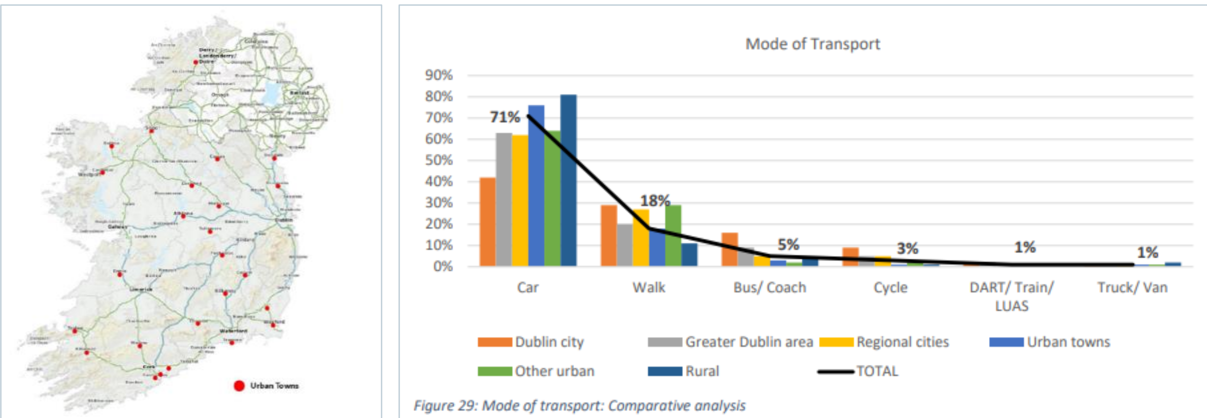


Figure 29: Mode of transport: Comparative analysis

Figure 8: Mode of transport in major Irish cities

these towns have more trips and more car usage. As there has been no significant change in the socio-economic profile since 2017, it is assumed that the transport pattern is still valid for creating the baseline impact for Portlaoise.

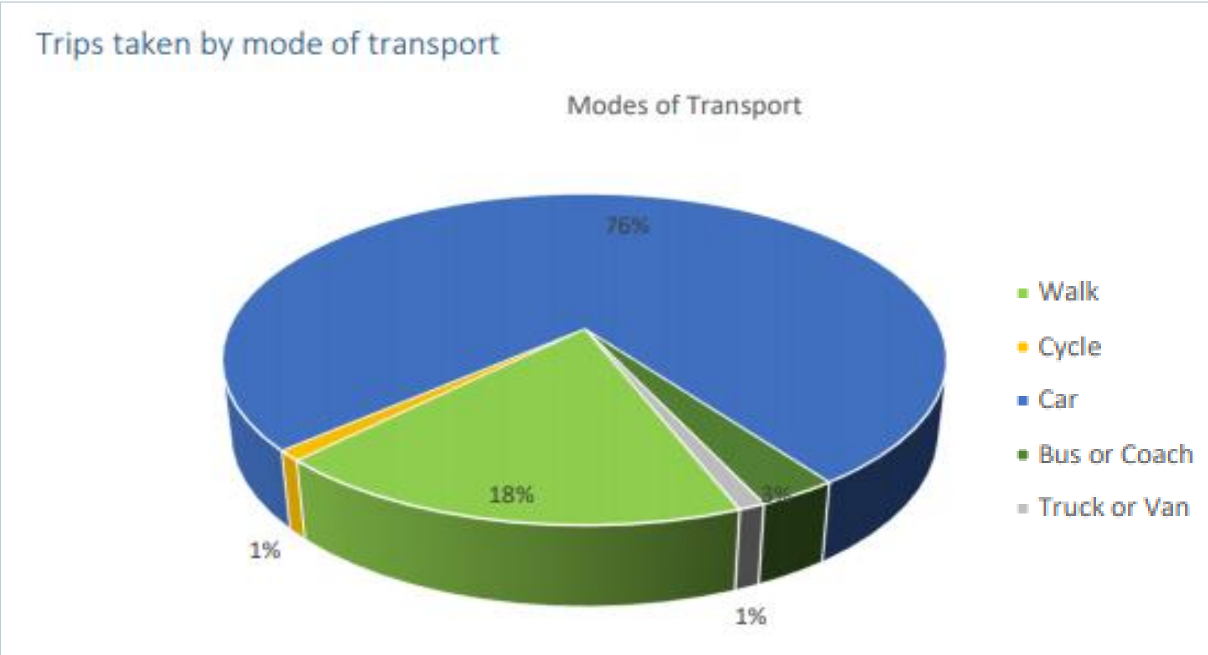


Figure 9: Trips taken by mode

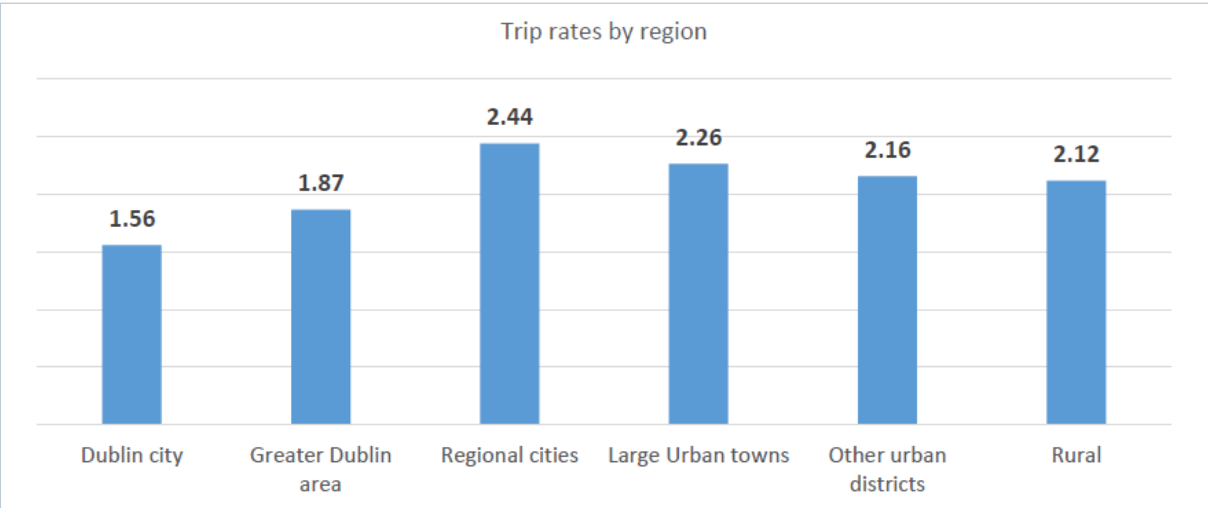


Figure 10: National daily trip rates by region

According to the NTA (Figure 13), on the "Reason for trip excluding the return home trips", around 54% are trips commuting to work or school. This share of trips can be calculated on town specific information using the modes taken from the CSO 2016. The mode of transports taken for the rest of the trips are allocated according to the NTA "Large Urban Town" mode categories.

The Portlaoise specific mode share for community, shows less car use and much more bus and train service use compared to the NTA Large Urban Town average. This contributes to less emissions for passenger transport per person. The combination of national survey and town specific information for commuting delivers the final mode shares taken per trip presented in Figure 12.

Looking at the final mode shares taken per trip nearly three quarters of the trips are taken by car. However, to judge the fuel consumption and the related GHG emissions, the trips taken by mode of transport must be aligned to the share of distances taken by mode of transport.

The CSO also delivers a deeper view on the distance of trips taken. On average, the distance per trip is ~8 km and the average distance is ~18 km per day per person. The CSO also provides a view on the mode of transport by duration of journey and the average vehicle speed. Based on this, we derive the default values of average distance per mode and trip. Finally, mode shares by distance in passenger kilometer (pkm) is presented in Figure 11: Portlaoise trips taken by mode of transport. The mode share by distance shows higher proportion for car use as typical trip distance by car is much higher than walking or cycling. The average use of car for driver or passenger is >16km per day per person. According to the CSO journey statistics the average number of persons per car is ~1.58.

According to the national statistics concerning vehicles licensed for the first time in the last ten years, we derived the fuel type per mode of transport vehicles in use. Cars and van are dominated by diesel fuel (70%), follow by 26% of petrol vehicles and 4% of hybrid vehicle. Electric cars are still negligible, below 1%, at present. Bus and train services run entirely on diesel. The detailed calculation for energy demand of transport is available in the excel workbook provided to the County Council

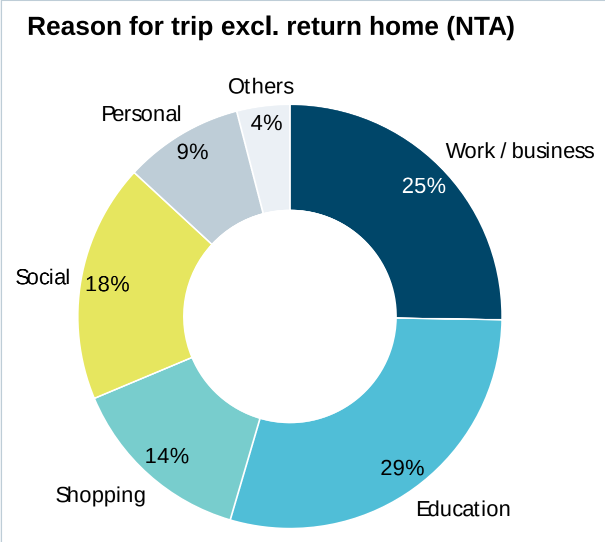


Figure 13: Reason for trip excl. return to home trips

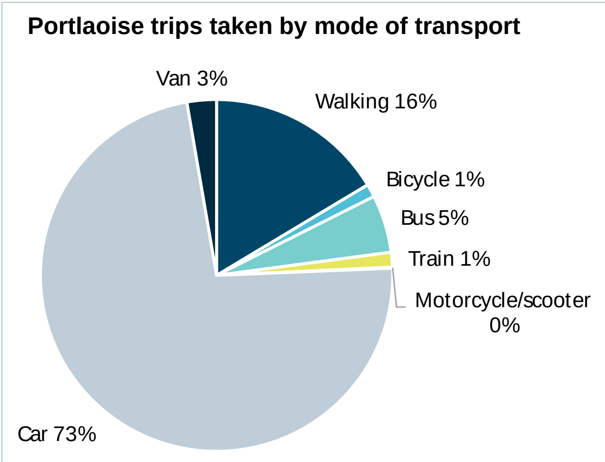


Figure 11: Portlaoise trips taken by mode of transport

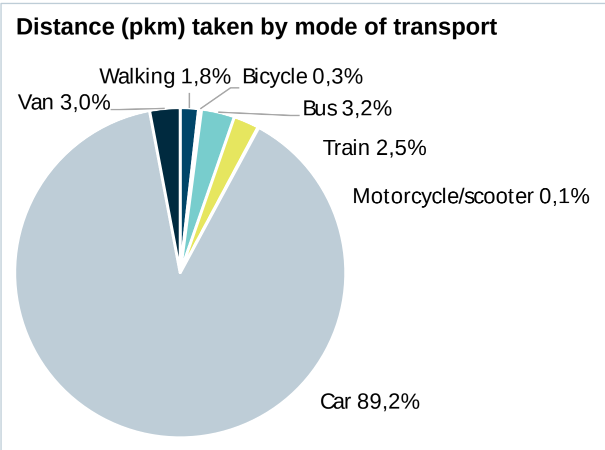


Figure 12: Distance taken by mode of transport

	Vehicles per day (AADT)	Share of HGV	No. of HGV per day
N77 Abbeyleix Road into Portlaoise	10598	8%	848
N80 from Stradbally into Portlaoise	7183	13%	934
N80 Mountmellick Rd into Portlaoise (Provided by LCC)	13128	9%	1182
R445 Dublin Rd into Portlaoise	15369	3%	461
M7 Junction 17 exit off the motorway	20497	14%	2870
M7 Junction 16 exit off the motorway	22894	12%	2724
		total	**9018**
		w/o M7 junc.	**3424**
	Vehicles per day (AADT)	**w/o N77, R445**	**7709**
Deviation of freight depending on the traffic counter considered		**best case**	**-56%**
		worst case	**17%**

In conclusion, at present, ~1,560 tons of petrol and ~3,470 tons of diesel are used for passenger transport per annum in the zone.

Freight

Freight transport within the Portlaoise settlement is done entirely by road as there is no rail freight in the town. As national statistics do not consider the town specific situation, this study uses the traffic counter monitoring data of the main junctions and roads to Portlaoise.

The average annual daily traffic data delivers the number of vehicles and the share of heavy good vehicles (HGV). However, as few traffic counters are outside Portlaoise settlement, the destination of all vehicles is not necessarily Portlaoise, and vehicles may be counted multiple times due to crossing of several counters, the present assessment in built on few assumptions discussed here. We excluded through traffic from the R445 and N77 exits off the motorway. On average, we assume 7,709 HGVs per day with an average distance of 5km within the Portlaoise settlement (estimated based on East-West and North-South dimensions & road network).

The deviation of HGV data in a best case is -56% HGV and in a worst case is +17% of HGV, depending on the traffic counters considered. Hence, the selected approach is a conservative estimation of freight traffic within Portlaoise settlement.

Based on the above assessment and the latest HGV traffic counting numbers, ~100 tons of diesel per annum are required for freight transport within the Portlaoise settlement.

3.5 Summary of energy use and GHG emissions

The following table presents the annual energy demand of Portlaoise

Sector	Electricity demand (w/o heating) [MWH/a]	Thermal Energy Demand Incl. Electricity for heating [MWH/a]
Residential	35,275	85,928
Non-Residential	45,392	55,808
Total (Buildings)	80,666	141,736

Transport Passenger	Fuel demand [kg]	
Diesel	3,368,702	
Petrol	1,562,367	
Rail (Diesel)	102,748	
Transport Freight		
Diesel	953,907	

Based on Portlaoise energy demand in residential, commercial & public sector as well as passenger and freight transport, the GHG emissions are calculated in four different levels of granularity.

	Scope 1,2	Scope 1,2	Scope 1,2 & 3	Scope 1,2 & 3
Sector	**Carbon Dioxide Emissions (tons of CO_2)**	**Greenhouse Gas Emissions (tons of CO_2e)**	**Carbon Dioxide Emissions (tons of CO_2)**	**Greenhouse Gas Emissions (tons of CO_2e)**
Residential	32,888	32,962	35,084	36,567
Non-Residential	29,791	29,861	31,438	32,652
Passenger Transport	16,107	16,221	19,200	19,569
Freight Transport	8,490	8,536	10,158	10,371
Total	**87,276**	**87,580**	**95,879**	**99,159**

In the table above, the first column considers the Scope 1 and 2 carbon emissions, covering CO_2 emissions caused due to the local combustion e.g., heating systems or vehicles tank to wheel emissions, electricity used in Portlaoise. The second column considers CO_2 and other greenhouse gases listed in the Kyoto Protocol (Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF6)) expressed in carbon dioxide equivalents (CO_2e). As carbon dioxide is most of the combustion emissions, the difference between scope 1 and 2 in CO_2 and CO_2e is <1%.

Pre-processing of energy sources to be used in the energy generation process e.g., fuels also cause GHG emissions. This is considered as scope 3 emissions and is highlighted in Column 3 and 4 in the Table above. This adds around 10% of CO_2 emission and 14% to CO_2e of the overall GHG emissions.

Overall, the root causes of GHG emissions present a similar view at all levels of granularity - 70% of the energy related emissions is caused by Residential & Non-Residential sector, around 10% by freight traffic and 20% by passenger transport.

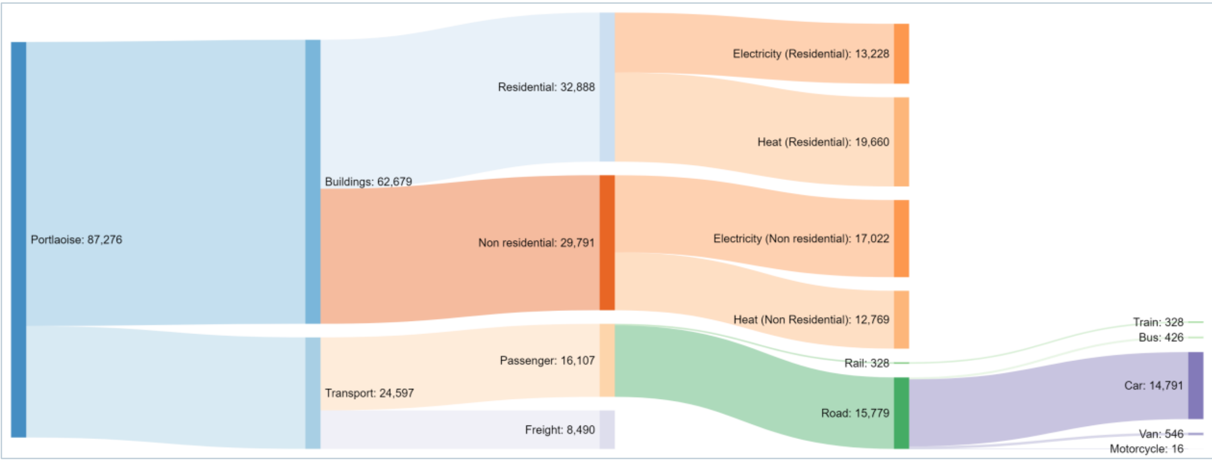


Figure 14: Sankey diagram for Portlaoise CO_2 emissions

The Sankey diagram in Figure 14 presents the **energy related Scope 1&2 CO_2 emissions of buildings & transport sector (tons of CO_2).**

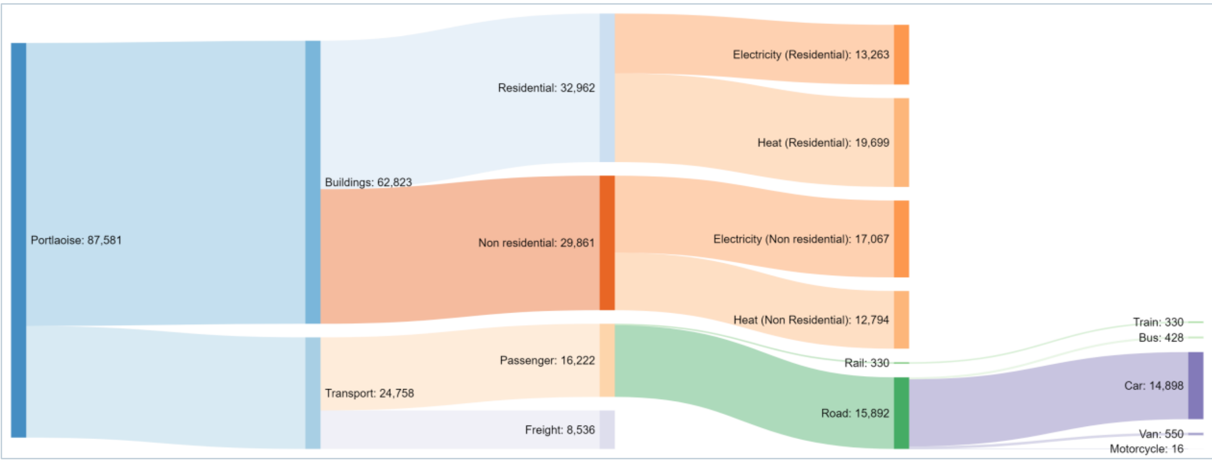


Figure 15: Sankey diagram for Portlaoise GHG emissions

The Sankey diagram in Figure 15 presents the **energy related Scope 1&2 greenhouse gas emissions of buildings & transport sector (tons of CO_2e).**

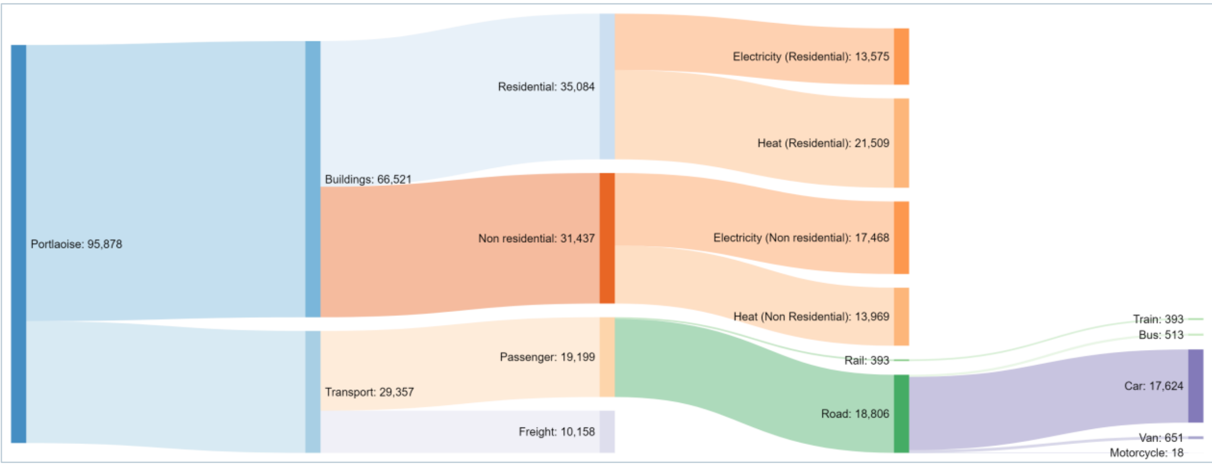


Figure 16: Sankey diagram for Portlaoise CO2 emissions (incl. Scope 3)

The Sankey diagram in Figure 16 presents the **energy related Scope 1, 2 & 3 carbon dioxide emissions of buildings & transport sector (tons of CO_2).**

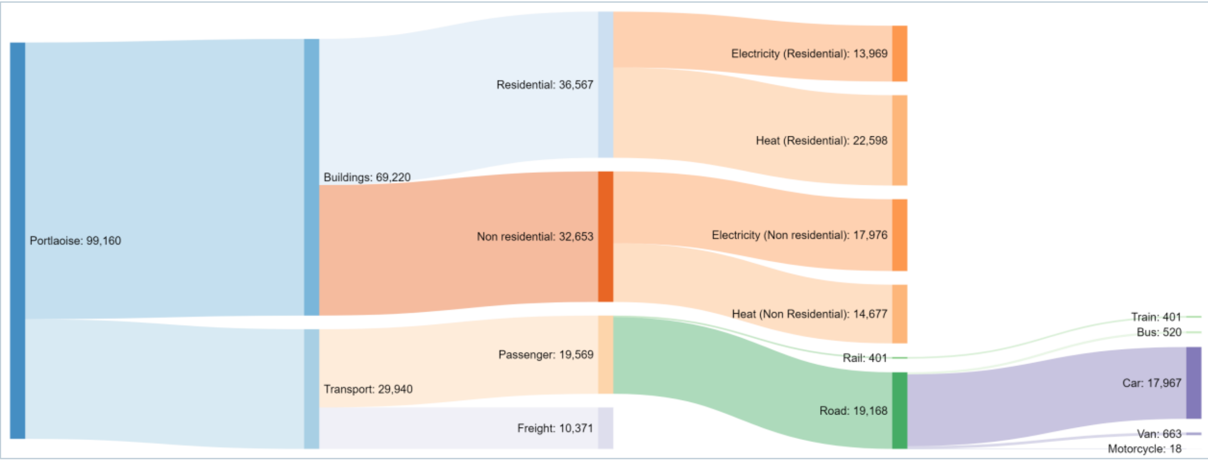


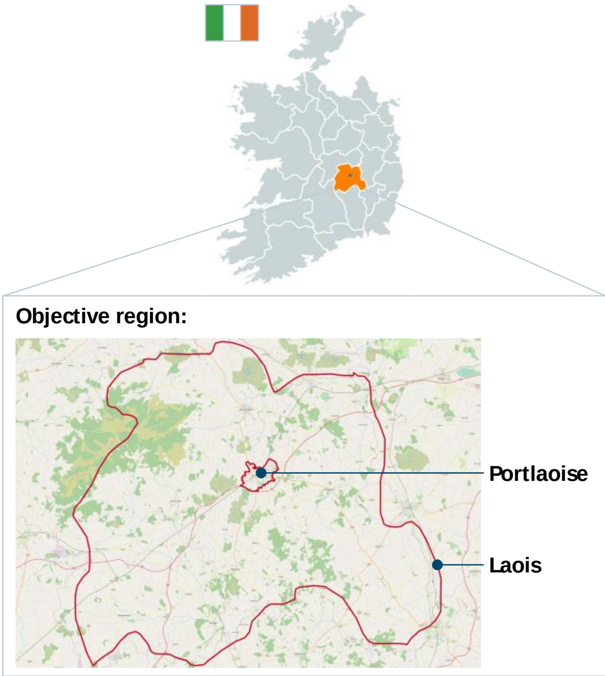
Figure 17: Sankey diagram for Portlaoise GHG emissions (incl. Scope 3)

The Sankey diagram in Figure 17 presents the **energy related Scope 1, 2 & 3 greenhouse gas emissions of buildings & transport sector (tons of CO_2e).**

4 RENEWABLE POTENTIAL

Renewable potential analysis

In this section, the renewable potential is assessed for the town of Portlaoise. The renewable generation sources e.g., wind and PV, can potentially help to reach the sustainability goals of a zero-carbon town. For a precise analysis of the generation potential, a spatial observation of the region is required. The objective area is the town Portlaoise, although a thorough consideration of the entire area of County Laois, is used for scenario construction.



The goals of this analysis are:

1. Evaluate the hourly profile of wind and PV generation and determine its variance based on a number of input factors such as change in weather pattern over years
2. Determine the area which is available within the town itself or in the county, to expand wind and PV generation for potential local use
3. Calculate the investment costs (preliminary assessment) and assess the impact on current electricity demand in Portlaoise

ESM Global Database

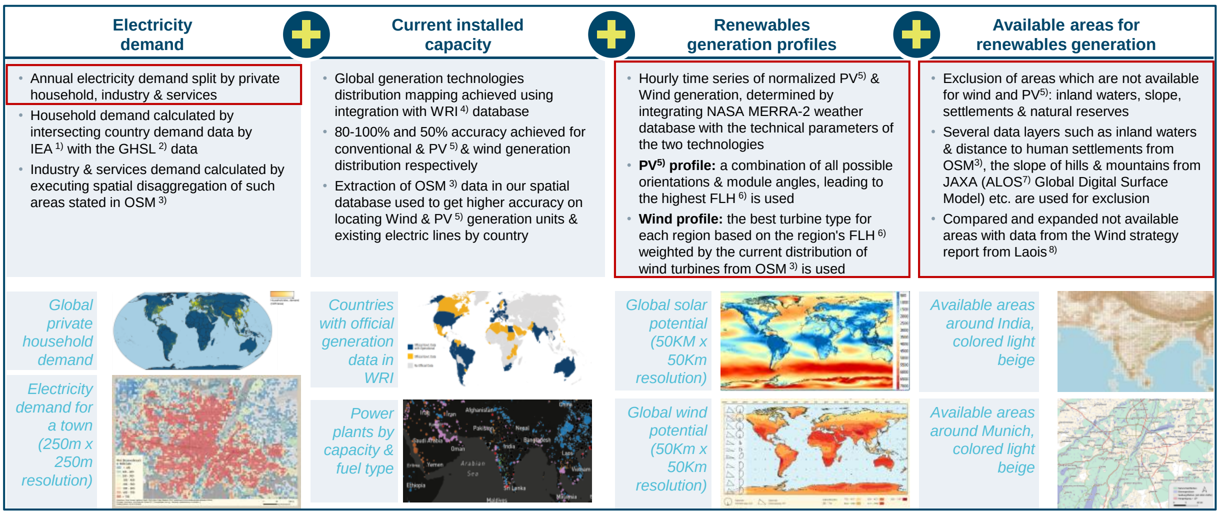


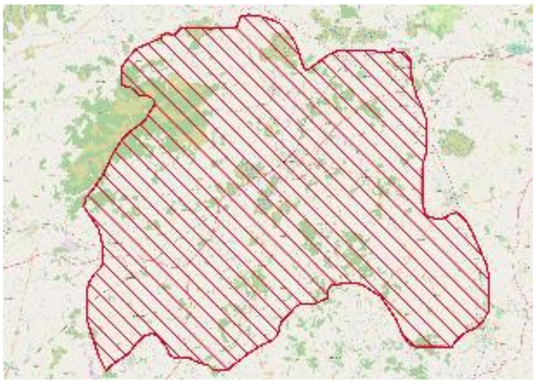
Figure 18: Energy modelling

The ESM global database at Siemens (Figure 18), offers a variety of information sources, all referenced with spatial information. The analysis of the renewable potential makes use of the combined electricity demand from private households and commerce, trade, service and industry. The weather data with windspeed and solar irradiation is used to calculate, along with several reference generation plants, a cumulative generation potential. For a more precise assumption of the renewable potential in a region, the weather conditions are considered and restricted areas for generation plants are taken into account. The restricted areas are divided in different subcategories. Natural reserve, inland waters, slope areas (above 10 percent inclined) and settlement areas with a distance zone of either 600 or 1000m are available and feed into the analysis of economically usable potential.

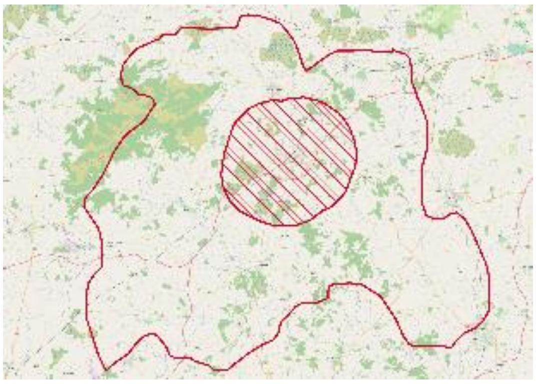
Renewable generation
The global database offers several different time series for wind and photovoltaic (PV) generation plants. Annual data from 2012, 2015 and 2017 was used in the different generation scenarios. Five different wind turbines and 15 solar orientations are considered for each year.

Chosen scenarios:
To analyse the renewable potential from PV and wind, different objective areas were derived. The wind potential analysis was built using four scenarios, with each scenario taking in account the restricted areas (natural reserve, slope areas, inland waters and 600 or 1000m distance to settlement areas). An overview can be seen in the graphics below. The scenario "*Laois County Council*" observes the whole area available in Laois County, only restricted areas are neglected. In "*Portlaoise w/ 10km zone*" a buffer zone of 10km around the objective map from Portlaoise is observed. The area (1km buffer) around the 110kV electricity grid lines is investigated in the "*Laois County Council Grid*" scenario. In "*Laois County Council grid w/ 1km zone*" only the area within the 1 km buffer zone around Portlaoise from the "*Laois County Council G*rid" scenario is observed.

Laois County
Full council area potential



Portlaoise within 10km zone
A zone of 10km around Portlaoise



Laois County Grid
1km around the 110kV power lines in Laois

Laois County grid within 1km zone
1km around the 110kV power lines in the buffer zones around Portlaoise

Wind Potential
To evaluate the renewable potential from wind, five different turbine types are used:
- Turbine ID 101: (140 m [hub height], 3 MW [output power]
- Turbine ID 102: (120 m [hub height], 2.5 MW [output power]
- Turbine ID 103: (100 m [hub height], 2 MW [output power]
- Turbine ID 104: (80 m [hub height], 3.02 MW [output power]
- Turbine ID 105: (100 m [hub height], 3.6 MW [output power]

With these turbines the weather data can be transferred to an electrical power output. Figure 19 shows that the output performance of these turbines. A turbine's performance can be compared based on its full load hours (FHL). Overall, for the observed years the Turbine 101 generates the most electrical energy, due to its highest hub height. As seen in Figure

20, apart from Turbine 104, FLH from over 3500h can be achieved for all Turbine configurations for most years under consideration.

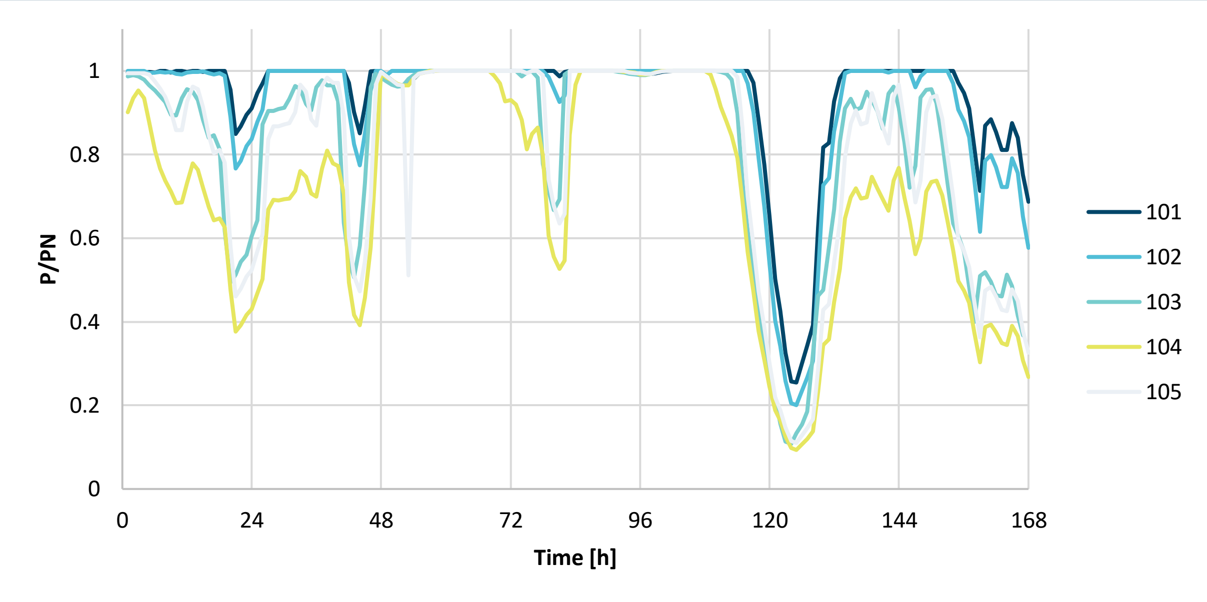


Figure 19: Output variation by turbine profile

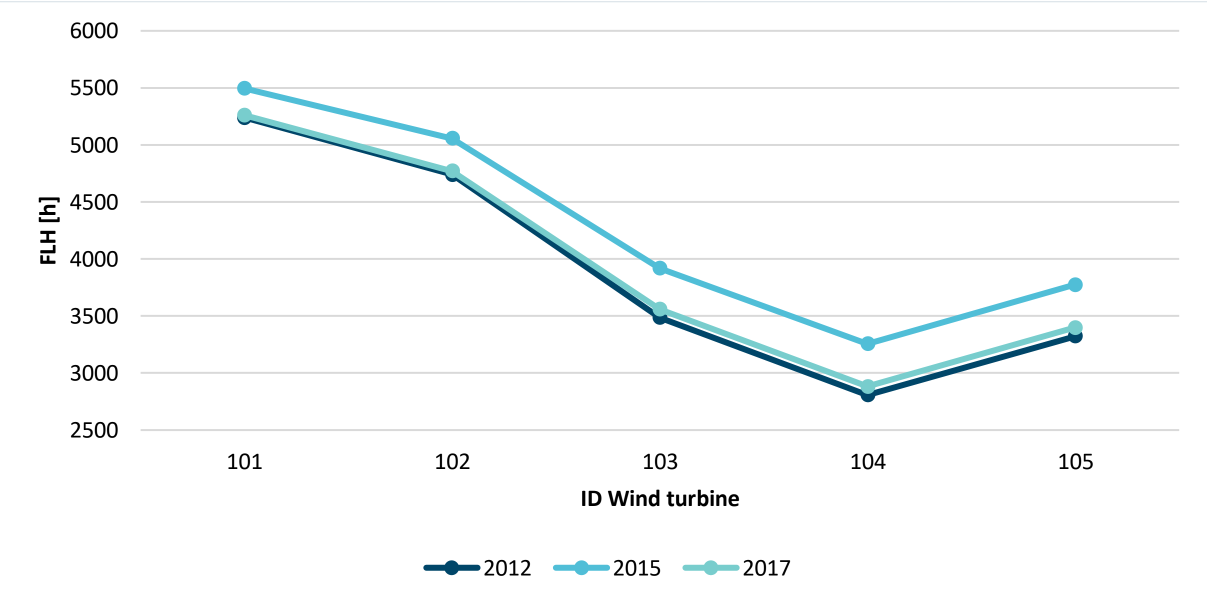
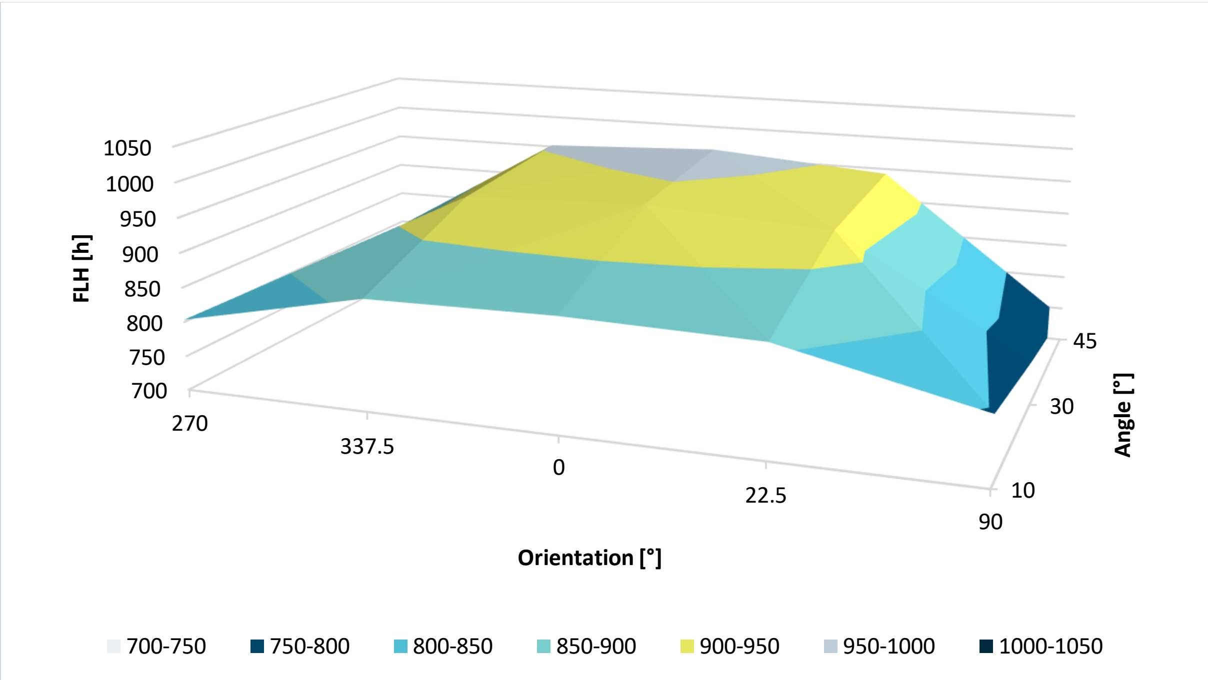


Figure 20: Output variation by year

Photovoltaic Potential
To derive electrical data from the radiation data (merra2 [23]) a reference generation module is required. Within the study, the orientations 0°(South), 22.5°, 90°(West), 270°(East) and 337.5 along with the angles 10°, 30° and 45° were considered. Orientation and angle play major roles for the utilization rate of the modules. In Portlaoise, a south orientation with a mounting angle of 45° generates the most energy output (Figure 21). As the comparison shows, the annual weather difference plays a minor role (maximum annual FLH delta of 7%) compared with module mounting. A south orientation (337.5°, 0°, 22.5°) with an angle of 30° and above will deliver over 900 FLH.



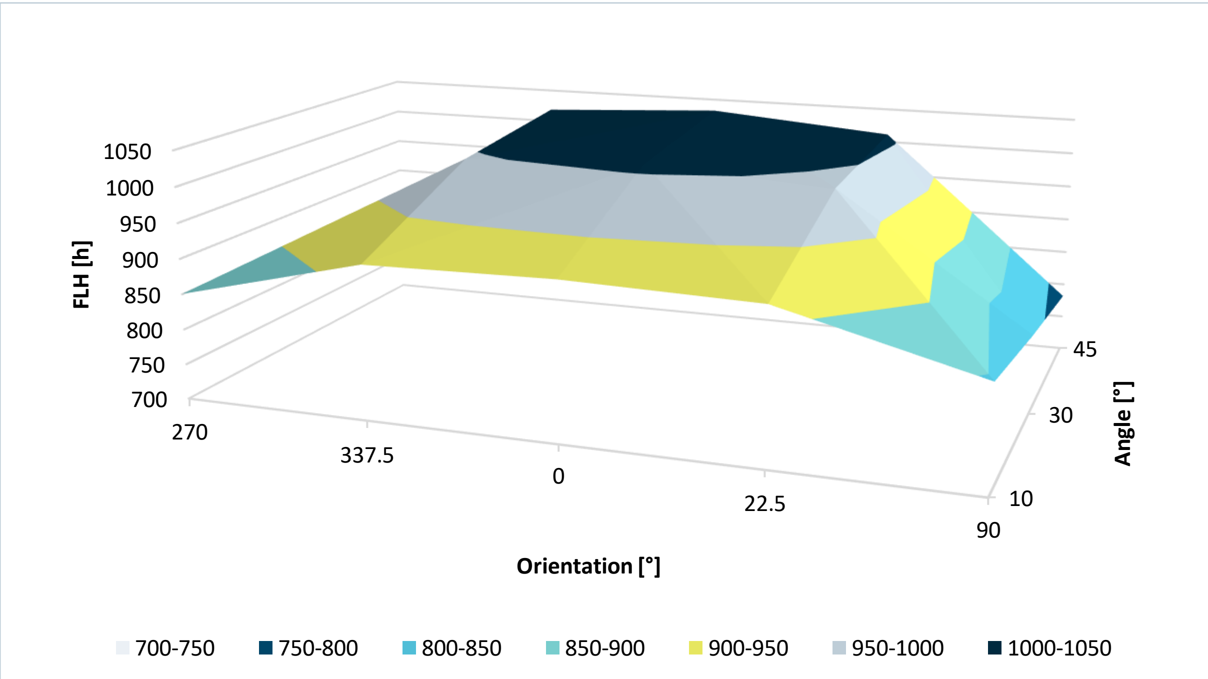


Figure 21: Output profile for PV with different orientation and angle

Wind analysis

The available area for wind generation plants, calculated with a minimum distance of 600m to inhabited areas is:

- Laois County 948.5 km^2
- Portlaoise w/ 10km zone 176.8 km^2
- Laois County Grid 71.9 km^2
- Laois County grid w 1/km 23.9 km^2

With the assumption of 3 MW installable wind turbine capacity per square kilometer, this results in the following potential capacity by scenario:

- Laois County 948.5 MW
- Portlaoise w/ 10km zone 530.7 MW
- Laois County Grid 215.7 MW
- Laois County grid w 1/km 71.7 MW

The Turbine (101-105) determines the energy output from this installed capacity. To reduce the graphic complexity different cases are defined. A combination of distance to inhabited areas (600m or 1000m) and the Turbine (101 or 105) is used to define the cases, E.g., The case "Max 600m" calculates the energy output with turbine 101 and the available area at 600 m distance to settlement areas. As Figure 22 shows, the variance within one scenario (depending on the case) is around factor 2. **Across all scenarios, an overall annual energy output between 189 GWh/a and 15,169 GWh/a is possible**.

Wind generation [GWh/a]

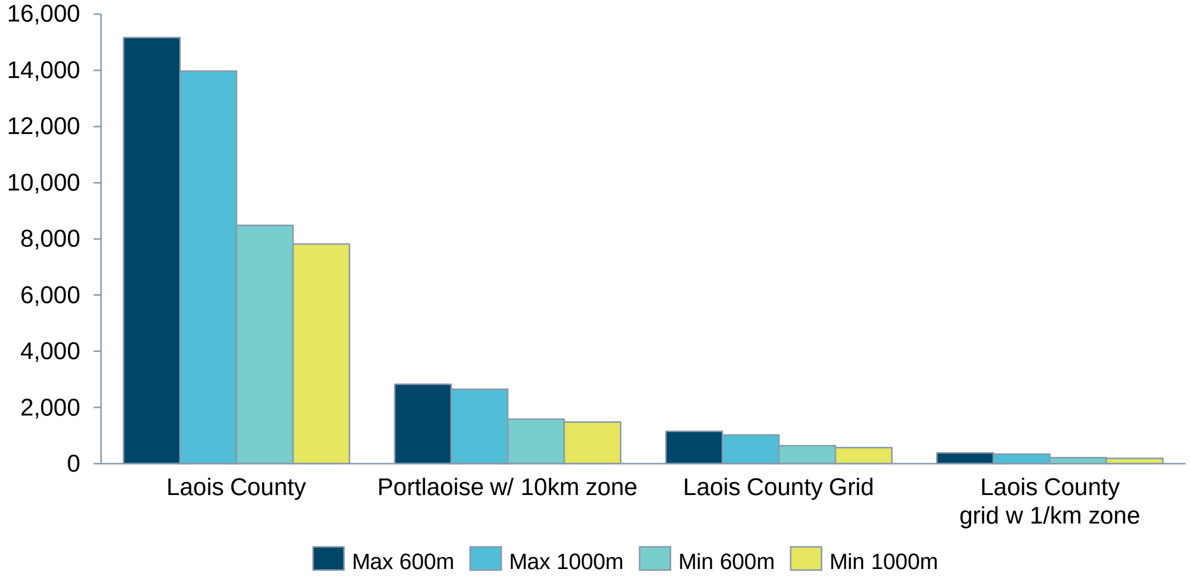


Figure 22: Wind output by scenarios

PV analysis

The available roof area in Portlaoise was calculated using Open Street Map (OSM [24]) data about buildings. By visual inspection of the OSM building data, some deficits were identified. A table with building information from Laois County Council was used to close the gap between OSM and satellite pictures of Portlaoise. The resulting area was reduced to a usage factor of 40%, since not all surfaces can be used for commercial purposes. As a result, 1.79km^2 are available for PV modules. Installable capacity for PV modules varies between 20 (Min Capacity Factor (CF)) and 100 MW/km^2 (Max Capacity Factor (CF)).

With a Module Orientation and Angle the energy output can be computed. The case MaxCF delivers the highest output with south orientation and 45° angle. For the South case a south orientation with the mean of all angles (10°, 30° and 45°) was evaluated. MinCF considers a west orientation with a mean angle. All cases were analyzed for the MinCF and MaxCF scenario.

Depending on the chose configuration, Figure 23 shows the annual electricity output will vary from 28 to 177 GWh/a.

PV generation [GWh/a]

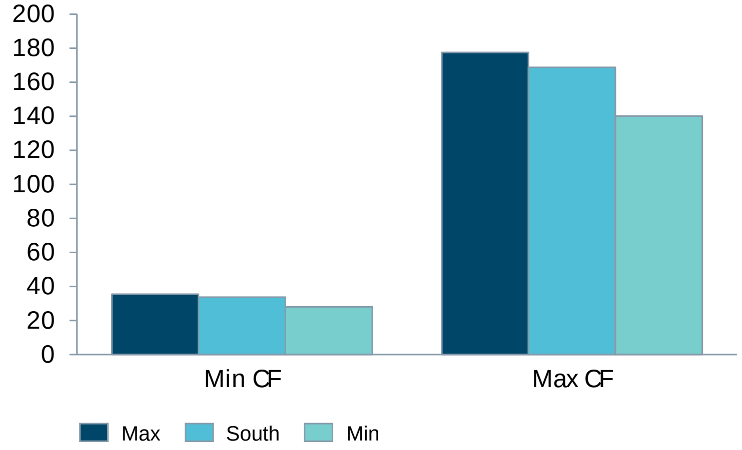


Figure 23: PV output scenarios

Renewable generation

Figure 24 compares the energy generation from wind and PV scenarios with the annual electricity demand of 80.6 GWh/a, from Portlaoise (dotted line). The significant capacity and utilization rate in all wind scenarios allow the wind turbines to cover the annual total demand of Portlaoise between 2 and 32 times. Despite the rather small area for roof top PV, around 0.4 to 2 times demand can be addressed, due to the high-capacity factor for PV modules. A combination of wind and PV indicates a high potential for renewable energy within Portlaoise. This can support decarbonization efforts going forward.

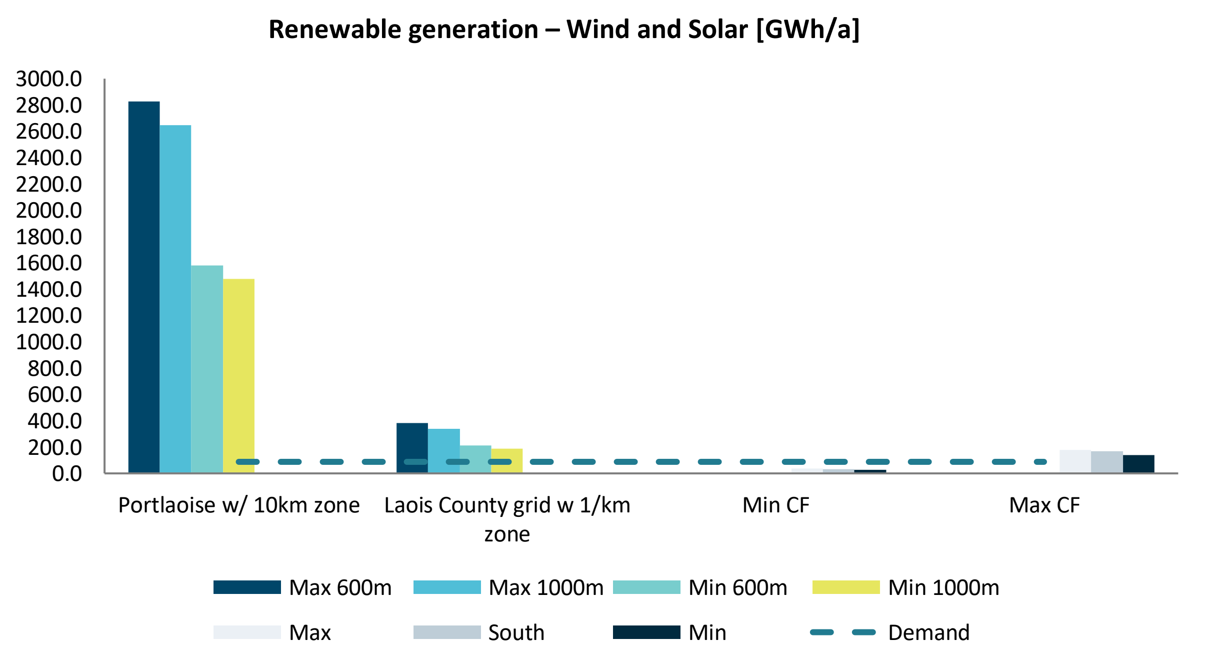


Figure 24: Comparison of renewable potential and present demand in Portlaoise

Economic evaluation

To evaluate the investment required, a simplified methodology is presented. The specific investment cost for Wind and PV are €1,567/kW [25] and €1,100/kWp [26]. These values are multiplied by corresponding installation capacity indicated in the different scenarios. The results are shown in Figure 25.

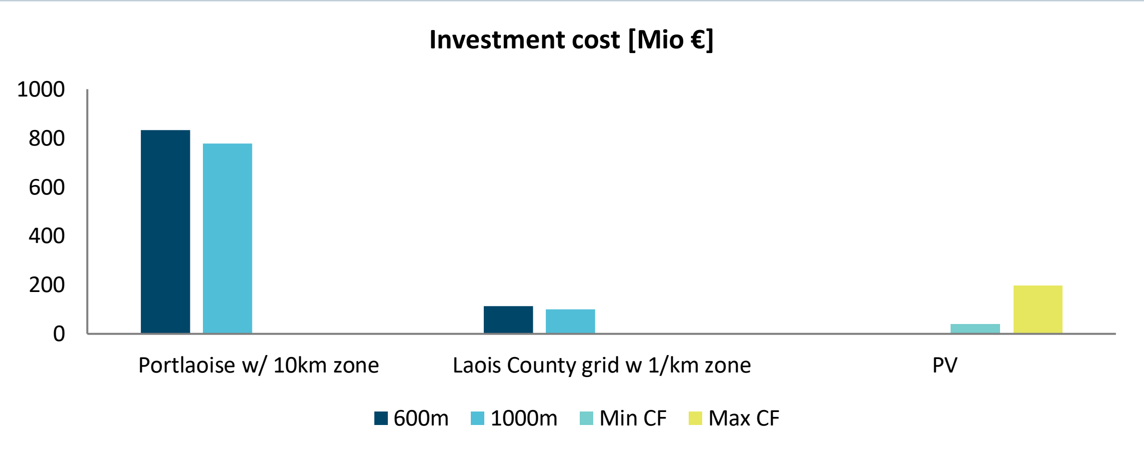


Figure 25: Investment cost for renewables across scenarios

The Wind scenario *Portlaoise w/ 10km zone* requires between €832 and €778 million of investment. This translates into 165 - 177 turbines of Type 101. If the area around the electricity grid lines is used (*Laois County Council grid w/ 1km*), investment requirement reduces to €100 - €112 million depending on the distance rule. This translates to installation of 21 - 24 Type 101 turbines.

PV investment depends mainly on the used Capacity Factor (CF) and the results reveal a potential investment range of between €39 and €197 million.

To compare the investments made both, for wind and PV, based on the electrical energy output, a simplified calculation is proposed. To calculate the specific investment cost the annual energy output is multiplied by the observation time and divided by the initial investment costs:

$$Specific\ cost = \frac{\left(\frac{Energy\ output}{year}\right) * 20\ years}{(Invetment\ cost)}$$

As seen, the technical lifetime of the generation unit is assumed to be 20 years. To reduce the complexity among all variations of potential scenarios, only the maximum and minimum case for wind and PV are investigated. Wind is represented for max with turbine Type 101 and min with Turbine type 104. PV max is a south orientation with 45° mounting angle, min is a west orientation with a mean mounting angle.

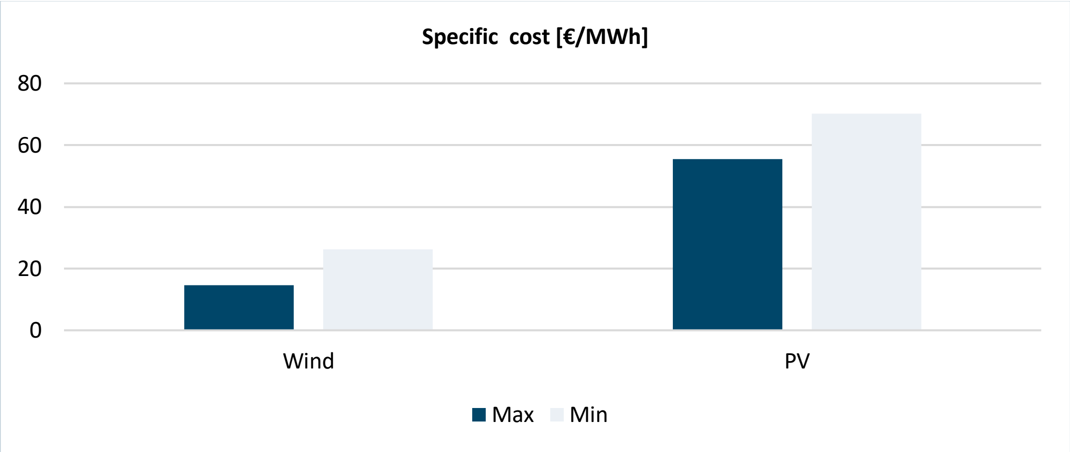


Figure 26: Specific cost for wind and solar

As seen in Figure 26, wind costs range from €14.7/MWh to €26.3/MWh, while PV is more expensive at €55.4/MWh to €70.2/MWh. The specific electricity costs for wind are lower as their high investment costs are balanced with a much better FLH.

5 REGISTER OF OPPORTUNITIES

In this Chapter, major levers including renewable energies, electric cars, upgraded energy efficiencies in buildings are thoroughly analyzed for their potential to reduce the overall carbon footprint within Laois County. The impact analysis shows CO_2 reductions by sector for Portlaoise, compared to the baseline (developed in Chapter 3).

Our approach was to set up a digital model (ESDP=Energy System Development Plan) after defining project scope and acquiring requisite data. The modeling framework enables the optimization of a multi-vector energy system with respect to overall costs, while respecting environmental constraints such as CO_2 limitations. The model can compute the energy flows over different areas and for electricity, heat, and others where needed [27]. The ESDP model uses a wide array of technology assumptions to parametrize both the generation and supply side.

Given that demand needs to be met at all hours within the model and in the real-world scenario, the hourly time series for the thermal and electric demand is used within the study. The main purpose of this is to assure security of constant supply. Hourly demand data is taken from the Heat Roadmap for Europe study and thus incorporates local climate and weather conditions for Portlaoise.

The model has been intensively used in many studies, e.g., in a study on the decarbonization of all relevant sectors in Germany, leading to the Siemens' position on decarbonization [28]. Figure 27 depicts the modelling chosen approach:

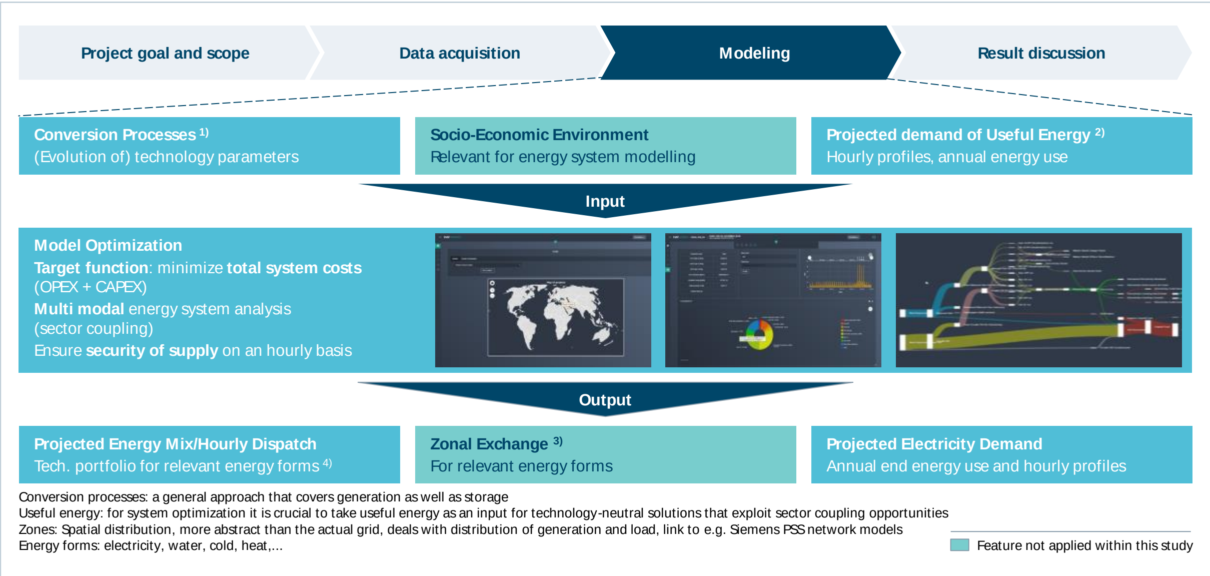


Figure 27: Energy modelling approach

In this study, the model has been calibrated to fit the demand characteristics and energy supply of Portlaoise. In different use cases, we showcase technology usage and market mechanism to decarbonize the town. The study starts by modelling all generation assets for Portlaoise. As of today, Portlaoise is entirely supplied from the national grid and so relies exclusively on Ireland's centralized power market and is therefore dependent on national efforts to decarbonize the Irish energy system. Therefore, the national supply side with its current energy mix is implemented in the model.

Given the demand for Portlaoise, the computations and use cases serve as decision support to roll out measures for achieving a lower carbon footprint in the town. In this report, local authorities (e.g., Laois County Council) will find impactful results as part of the analysis and may engage with various stakeholders to achieve local transitions to lower carbon footprints.

Efforts to reduce carbon footprints are chosen in a way that the impact is 'meaningful'. This implies that levers having a high impact on CO2 emission reductions for Portlaoise are generally preferred over the less impactful ones. Relevance of the use cases was assured by constructing the use cases of the town with Laois County Council, who actively engaged in the discussion. Figure 28 shows three use cases that were simulated.

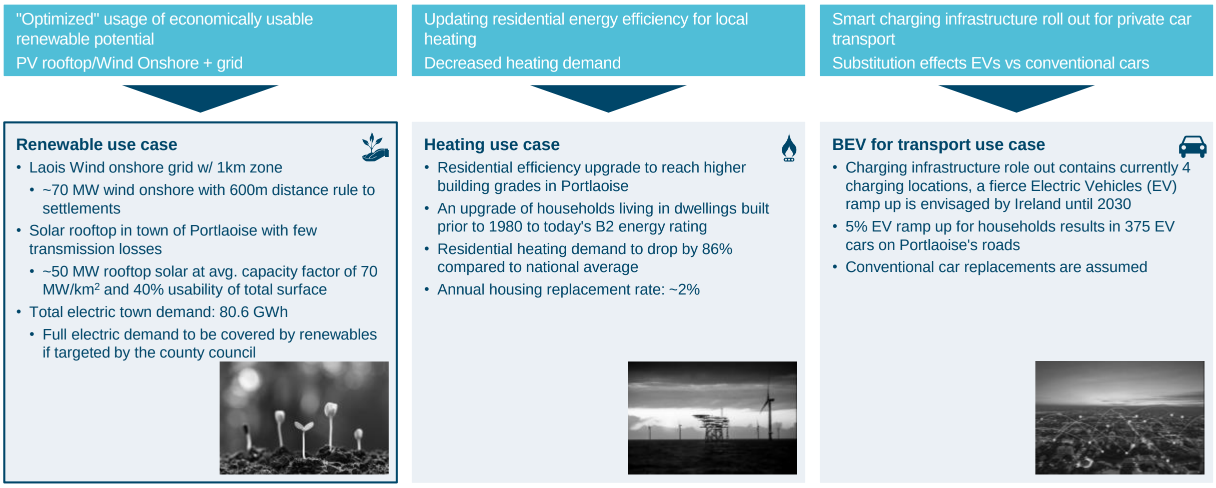


Figure 28: Use cases for CO2 emission reduction

All decarbonization efforts need careful consideration and more stakeholder involvement, when transitioning to a commercial phase. At the same time, acceptance may be achieved if politicians engage in stakeholder dialogue by building on the shown use cases. The shown use cases illustrate pathways to decarbonize the town at the local level.[1]

Making use of favorable local renewable locations seems to present a great opportunity for supplying the town with carbon free generation assets. A decreased carbon footprint for Portlaoise can be achieved by deploying wind generation assets or solar modules, in and around the urban area.

Electricity Use Case

The first use case (Option 1) considers onshore wind as decarbonization lever. All usable onshore wind potential in a 1km buffer zone around the town and around 110kV lines is considered. This results in 70 MW deployable onshore wind capacity. By default, the connected wind turbines will feed into the nation grid, thus resulting in an altered national energy mix that supplies grid electricity to the town. This use case, where the impact of wind is indirectly considered via the national grid, is referred to as Option 1A. As the impact of this technical onshore wind solution is small (70MW) compared to the total installed capacity of wind (>3.5GW), a market solution in form of a power purchase agreement between the town of Portlaoise and the wind farms results in a more rigorous decarbonization strategy (Option 1B). For the wind farm and the business to business to consumer solution (B2B2C), we have assumed 5 standard size wind turbines at average market cost (e.g., CAPEX Wind Onshore and CAPEX Solar [29]) and hub height - more precisely, a turbine with a 140-hub height. 115m rotors and a 3MW capacity being installed for electricity generation, using local Irish wind condition. If contracted, those 5 turbines impact the town decarbonization directly.

The second use case (Option 2) builds on the rooftop potential within the town of Portlaoise assuming no transmission losses due to a direct electrical connection to households. The study assumes a rooftop surface usability rate of 40% within cities, which considers that not all housing types qualify for rooftop PV rollout. By employing latest data-driven analytics for detailed geo-spatial analysis, rooftop areas are detected and evaluated. The analysis results in 50MW rooftop PV, with an assumed capacity installation factor of 70MW/sq. km that has, in contrast to the onshore wind use case (Option 1A), a direct effect on the town decarbonization.

Aggregated annual demands are estimated as shown in Chapter 3 for each sector. A "demand supply" matching is part of the algorithm within the energy system model. The renewable use case shown in Figure 29 (Option 1A) illustrates the use of 70 MW of wind turbines altering the national grid mix.

[1] Note: the simulated use cases do not claim to fully consider all interests of private and public stakeholders and all technical requirements needed for a commercial implementation.

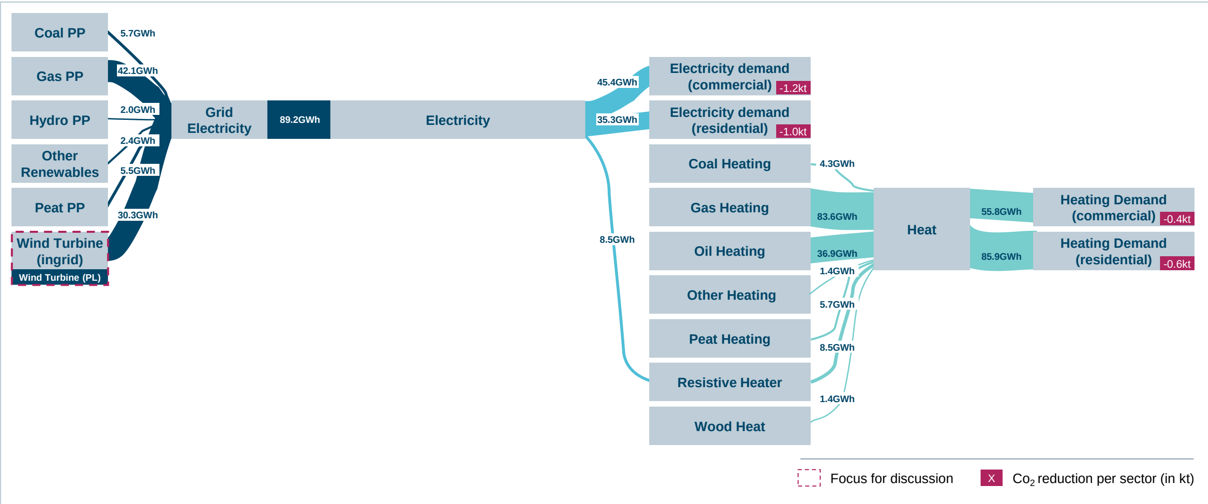


Figure 29: Option 1A considering additional wind available via National Grid

Compared to the national installed wind capacity, adding the 70 MWs onshore wind, has limited impact on the overall national generation mix. Note that the additional onshore wind capacity is assumed to replace the current installed energy mix in equal proportion. Thus, the algorithm of the model treats all technology replacement in the same manner and does not use a priority rule for proportional coal plant retirement.

The new energy mix results in an impact on the hourly CO_2 footprint of the grid electricity being lowered to 345g/kWh from 375g/kWh. This results in total cross sectoral lower footprint of about 3kt CO_2 on the town level which is equal to overall 3% lower CO_2 emissions versus today's baseline for the town. By sector, the emission reductions are 1.2 kt CO_2 Commercial Sector$_{electricity}$, 0.4 kt CO_2 Commercial Sector$_{heat}$, 0.6 kt CO_2 Residential Sector$_{heat}$, 1.0 kt CO_2 Residential Sector$_{electricity}$
Note: Passenger and freight transport not shown as electricity has limited impacted on transportation sector today.

Option 1B renewable use case for onshore wind illustrates the 'direct use' of 5 wind turbines for the town. Each turbine has a capacity of 3 MW with a 140 m hub height and a 115.7 m rotor. Given the contractual direct power delivery of the wind farm to the town, only a small amount of grid electricity is needed to back up the town energy supply. Gas-fired generation from the national energy fleet is one of the backup options to enable security of supply, as shown in Figure 30.

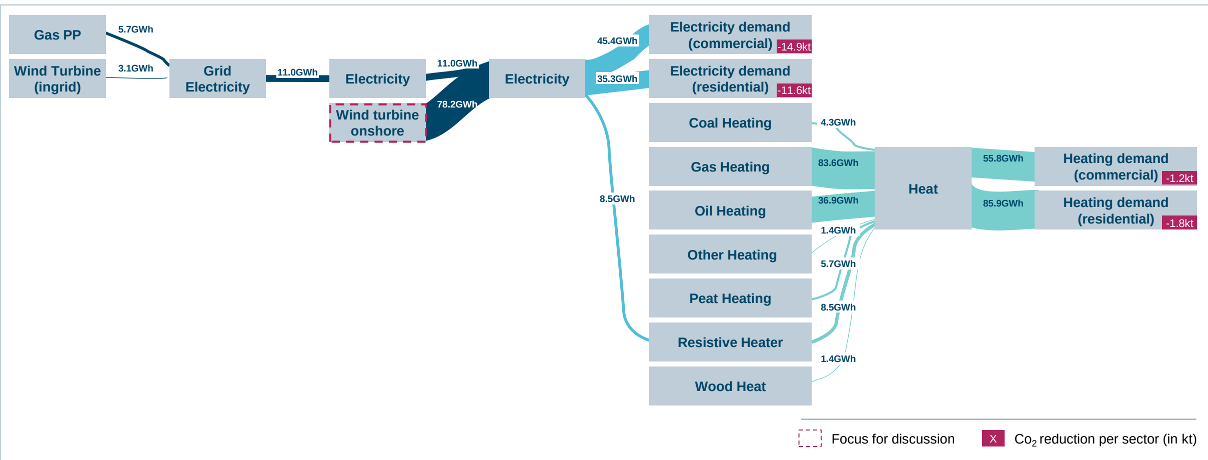


Figure 30: Option 1B onshore wind dedicated to Portlaoise

This use case achieves a significant reduction of CO_2, shown in the altered CO_2 intensity of the grid electricity. The CO_2 footprint of total electricity is only 48g/kWh in this scenario (vs 375g/kWh in baseline). The total cross sectorial CO_2 footprint is reduced to 58 kt CO_2 which is down by 29.3 kt CO_2 from the baseline. By sector, the emission reductions are

14.9 kt CO_2 Commercial Sector$_{electricity}$, 1.2 kt CO_2 Commercial Sector$_{heat}$, 1.8 kt CO_2 Residential Sector$_{heat}$, 11.6 kt CO_2 Residential Sector$_{electricity}$

Note: Only Gas PP is shown in this Sankey, since the values are very small for other generation technologies.

Renewable use case Option 2 shows the addition of 50MW solar power with capacity factor of 70 MW/km² and 40% usability of total surface. Out of the 50 MW Solar rooftop 25 MW are south facing, 12.5 MW each east and west, which we base on a detailed data driven analysis of PV model orientation for the town. The results show that the total CO_2 footprint is reduced by 15.8 kt CO_2 which is equal to a 18% reduction versus the baseline. The CO_2 intensity from electricity is reduced to 195g/kWh from 375g/kWh.

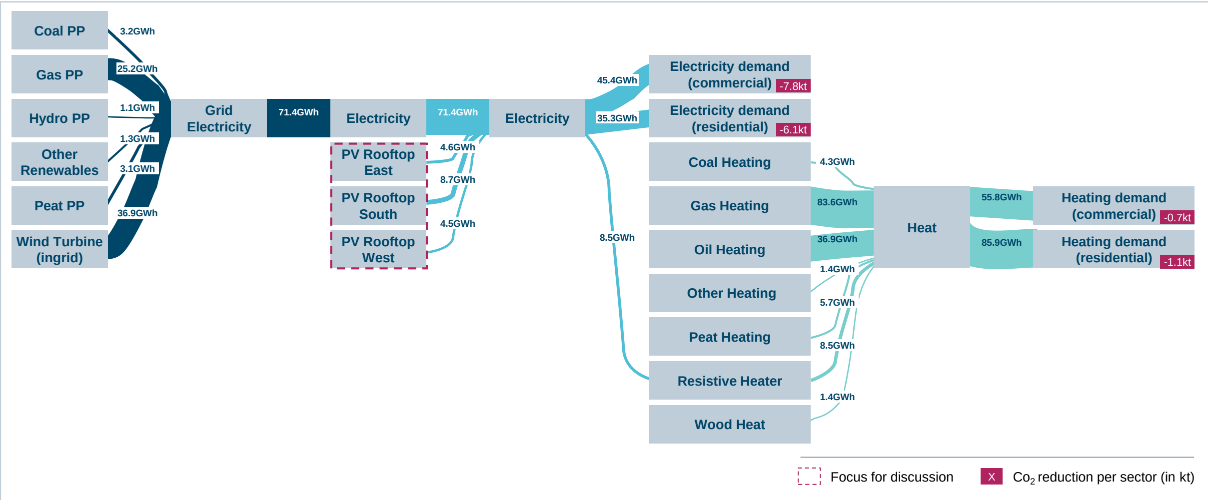


Figure 31: Option 2: Considering rooftop PV

By sector, the emission reductions are 7.8 kt CO_2 Commercial Sector$_{electricity}$, 0.7 kt CO_2 Commercial Sector$_{heat}$, 6.1 kt CO_2 Residential Sector$_{heat}$, 7.8 kt CO_2 Residential Sector$_{electricity}$.

Across all renewable use cases, up to 29.3 kt of CO_2 per year can be reduced. A large contribution is achievable by mounting PV rooftop on housing types in Portlaoise or by installing an onshore wind farm close to the town. An indicative estimation has shown, that to do so ~500,000 PV modules need to be installed.

Solar farms:

Besides building up PV on rooftop in Portlaoise, a solar farm that is ground mounted may evolve as other technological option to decarbonize the town. However, it needs to be considered that network connection cost may make this option from a financial point of view less attractive in direct comparison to the rooftop option. In the light of emerging energy communities within Europe and available usable area the idea of a community concept has been supported by the SEAI. A local solar farm contributes to the Sustainable Energy Community (SEC) by using renewable energy and enables consumer empowerment by e.g., providing a yield to the community in case of excess energy production.

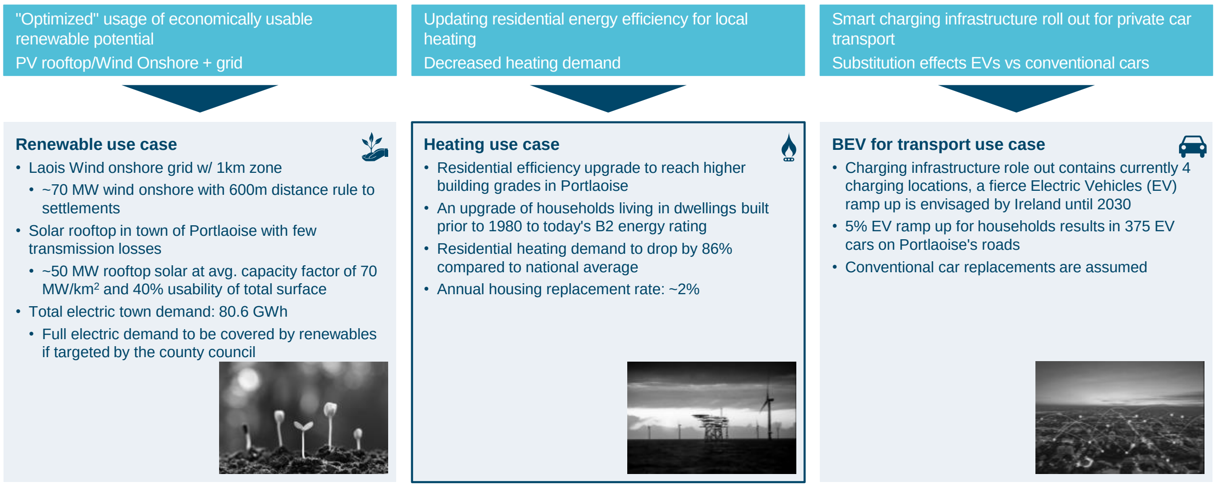
Implementation area assessment for solar PV (rooftop and farms):

For an overall installed PV capacity of 50 MW, the total required area for 500,000 PV modules is 830,000 m², as a standard PV module is equal to 1.64 m² and a general PV usability factor is ~40%. At present, Portlaoise has ~7,500 residential homes (average roof space 50 m² on one side of roof). This means that 375,000m² of the required 830,000 m² can be met in the residential area. Portlaoise town also has a few large commercial spaces that can be used for PV installation e.g., Hospital: 8,880m², Prison: 51,170 m², Laois Shopping Centre: 23,700 m², HSE buildings: 10,360m², Schools: 22,970m². Assuming half of this space is available, one can consider additional 180,595m² of potential space for PV installation. Cumulatively, residential, and large commercial spaces would contribute to ~555,600 m² PV. For the remaining ~280,000 m² space needed, multiple options can be explored: sports field (Laois GAA –98,500 m² grass, Portlaoise FC: 38,500 m² grass, Portlaoise GAA: 15,200 m² grass, Portlaoise Rugby Club: 79,400m² grass), Community Facilities (Parish Church and Parish Centre, Portlaoise Leisure Centre, Knockmay Community Building, Portlaoise Family Resource Centre, LOETB Community Education Service Portlaoise, Portlaoise Enterprise Centre). If the 830,000m² surface area cannot be achieved by local buildings, a higher coverage of PV may be achieved by building up a smaller solar farm close to the town. One potential option is to consider the Kyletalesha Landfill (outside of boundary) where part of ~55 hectares (23 hectares of this consist of closed landfill cells) could be used for a solar farm.

Note: For this, an investment volume of ~ €55 Million for the PV rooftop and ~€23.5 Million for the wind turbines is required. Operational costs are not considered at this stage and a detailed business case calculation may be carried out in a further project with financial modelers and banks [30], [31].

Heating Use Case

The Heating Use Case illustrates the effectiveness of CO_2 savings in the residential sector when moving to B2 or higher energy ratings. While the Climate Action Plan indicates all social housing are required to retrofitting to B2 only, our Use Case illustrates the impact of a more aggressive approach to reduce the carbon footprint for heating. The baseline for energy ratings and housing structures has been deducted in Chapter 3 of this study, where all housing types have been categorized by age. The SEAI Building Energy Rating (BER) grades are taken for baseline computations, including some adjustment made from the town council.



The housing fleet can be categorized by age with the following percentages:

- Prior 1980: 28%
- 1981-1990: 8%
- 1991-2000: 17%
- 2001-2010: 44%
- 2011 or later: 3%

The above percentage shares show that most housing types have been built after the year 2000. In the Heating Use Case, the housing types build prior to 2000 are subject to upgrades implying that 3,984 houses will fall into B2 category after renovation. By making use of insulation and housing retrofit programs, the residential heating demand drops by ~70% compared to national Irish average. Furthermore, the Heating Use Case assumes an annual housing replacement rate of ~2% i.e., ~20% of aged houses will be replaced in the coming decade. This also addresses the likelihood of some buildings being classified as "protected structures" and not amenable to retrofits.

Although the heating demand reduction is to be interpreted as a pure energy efficiency effect with the same heating sources in household, the effect on the town decarbonization is impressive. Almost 16% of overall thermal energy demand versus the baseline footprint can be reduced, by actively addressing housing upgrades in the residential sector. **This results in annual CO_2 saving of 13.5kt CO_2, as shown in** Figure 32.

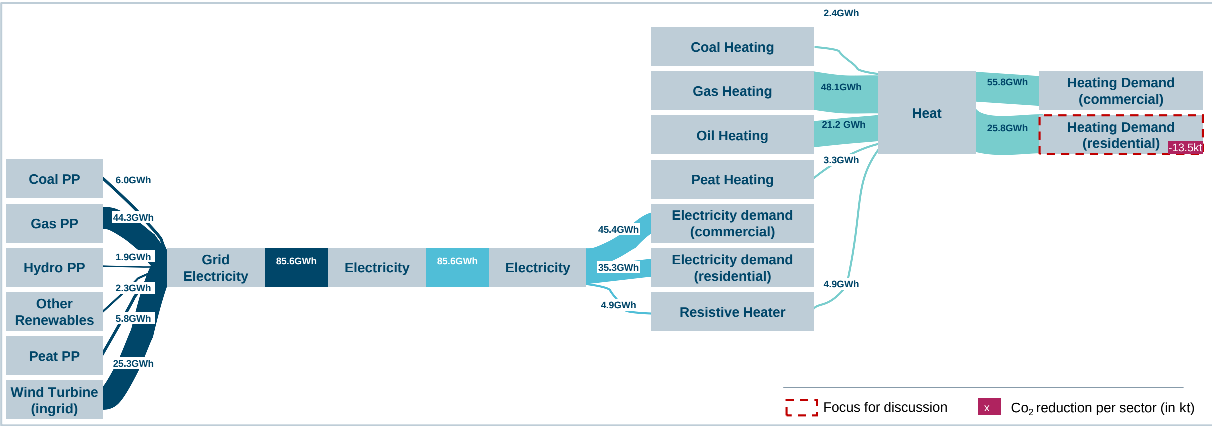


Figure 32: Heating Use Case impact

While most of the supplied demand is still satisfied by conventional heating sources in the thermal sector, the electricity usage for the heating sector is also halved. As the CO_2 grid electricity is at 375 g CO_2/kWh, the decarbonization effect through electricity means is rather small compared to the conventional fuel reductions in the heating sector. An energy rating upgrade for 3,984 households requires ~€72 Million for insulation or retrofitting in general. As the replacement rate is triggering a rather lower adoption in the residential sector (2% p.a.), politicians and stakeholders may find it useful to consider the time to construction in non-subsidized scenarios / investment in educational programs as an important decision variable in the political process.

The scenario has shown that upgrade of insulations for buildings to high energy ratings (e.g., B2) leads to a ~16% emission reduction within Portlaoise. An envisaged target of 30% emission reduction within the heating scenario would thus require additional effort besides better insulation. Such efforts should target a rethinking of local energy usage that policy makers may actively address. Long term evidence for persisting behavioural changes in the heating sector remain however unclear as long as the percentage of achievable energy savings compared to the aggregated household income is low. A technical replacement of heating sources in buildings additionally creates direct leverage to increase emissions savings, e.g., by replacing gas or oil-fired heating systems with heat pumps. However protected housing structures and facades are likely to fall under rigid legal restrictions, requiring regulatory and thus legal change. One further challenge to consider is the so-called landlord tenant problem that arises if residents renting their dwelling have a weak legal position to make landlords change the heating system. If a 30% thermal demand reduction through efficiency gains is targeted, an even higher percentage of all households need improved insulation and a shift to other residential heating technologies. However, current replacement rates show that this aggressive reduction strategy will not be achievable within the next 10 years.

Biogas plant as source of heating

An alternative heating use case would build on the use of a biogas plant with ~80% gas grid infeed in the local grid for heating purposes. This would affect the carbon footprint of the gas sector. However, a biomethane upgrade is technically needed to match gas quality for the grid. **Due to commercial sensitivity and an active ongoing bidding process for a local biogas plant, this report does not consider this option in the simulation**.

District Energy Opportunity

Another option explored as part of the study was District Energy. District Energy refers to both District Heating (DH) and district cooling systems. The fundamental idea of District Heating is to use local fuel or heat resources that would otherwise be wasted to satisfy local customer heat demands by using a heat distribution network of pipes as a local marketplace. Thus, District Heating provides a substitution of ordinary primary energy supply for various societal heat demands, while achieving lower environmental impact. For a competitive District Heating system, these three elements are obligatory:

a) suitable low-cost heat source,
b) the heat demand/market,
c) the pipes as a connection between source and demands.

Heat source: Traditional excess heat resources are combined heat and power (CHP) plants, Waste-to-Energy (WtE) plants, and industrial processes. During recent decades, some renewable heat from geothermal wells, solar collectors, and biomass fuels have been introduced into the global district heating systems.

Heat demand: For District Heating to be economically feasible, there needs to be a sufficient heat demand within a given area. This is because the denser the heat demand, the shorter the pipelines required, which means lower investment costs, and lower operational costs through lower losses and lower pumping requirements. In countries like Ireland, where there is higher risk attached to investments in DH due to lack of knowledge and experience, it is better to initiate DH projects in areas with highest heat densities available. The highest heat densities will be found in dense urban areas, particularly those with high-rise residential developments. Certain building types, known as 'anchor loads', such as hospitals, nursing homes, and hotels are ideal for optimal DH operation as they have long hours of space heating demand and large hot water demands. Additionally, if the anchor load is a public sector tenant, it can offer security in terms of connection and payment reliability. In case of Portlaoise, **lack of high rise residential, limits DH potential to fewer Public buildings which impacts the overall financial feasibility of DH.**

Piped Network: District heating requires network planning for longer periods (e.g., 50 years), usually resulting in high up-front capital expenditures. Due to the high capital costs, DH systems will have longer paybacks compared to other well-established heating systems, but the network has a much longer lifetime. Operations and maintenance cost are to be added to the analysis over the entire lifetime. It is difficult to compare DH to other solutions under the same short-term economic analysis when the benefits accrue over a much longer investment period.

In many ways, an investment in DH should be considered in the same way as other long-term infrastructure investment, such as motorways or electricity transmission assets. **Usually, most regions without favorable source and demand conditions (e.g., a local waste heating source, concentrated demand) are hesitant to engage in building up local heat networks due to high upfront costs.**

Established expertise of district heating has paved the way for introduction and deployment of district cooling systems, mainly for covering space cooling demands in buildings. However, this district cooling development has been more recent compared to the development of district heating. District cooling systems are therefore neither as common nor as extensive as district heating systems [32, 33]. **Hence, District Energy (heating and cooling) were not further investigated as part of the study.**

Transportation Use Case

Figure 33 gives an overview of the Battery-operated electric vehicle Transportation Use Case.

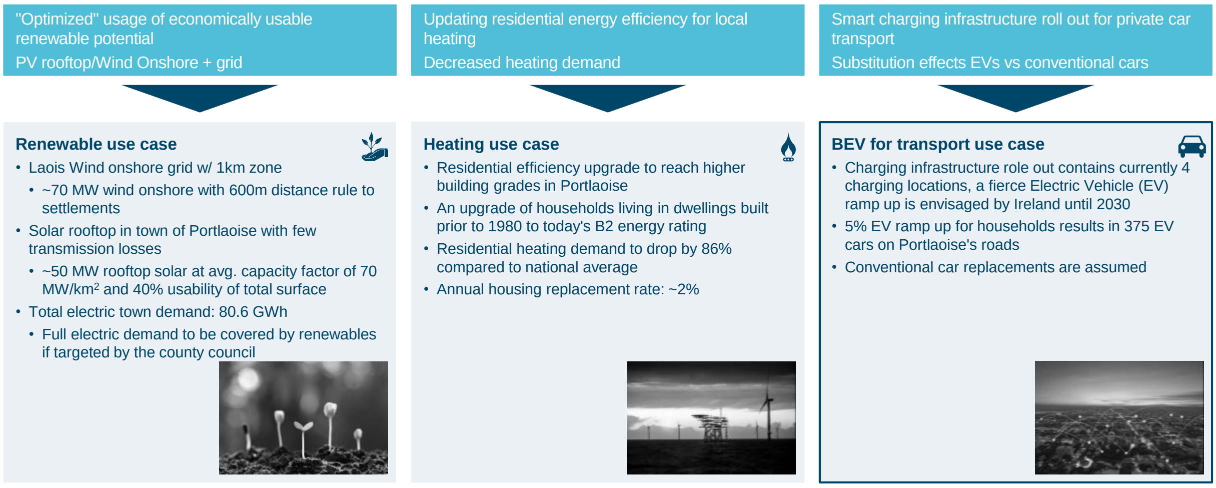


Figure 33: Focus on Transportation Use Case

The Transportation use case builds on the existing infrastructure for charging points in the town of Portlaoise. At present, 4 public charging locations are installed. Locations and the technical characteristics can be checked by using the open charge map website. The Battery-operated Electric Vehicle (BEV) for the transport use case assumes a ramp up of electric vehicles and illustrates decarbonization effects at town level in the passenger sector. The use case itself falls into the Irish national BEV strategy, targeting all newly registered cars to be fully electric by 2030. This is also stated in the target of 950,000 EVs on Irish roads by 2030. This is an aggressive target considering the existing charging infrastructure, investment required and present penetration of BEV in Europe (6% of vehicles owned are BEV in Europe in 2020, which includes Nordics where rates are substantially higher). The Use Case thus considers a more conservative ramp-up to, 5% of conventional cars getting replaced by electric vehicles and charged from the national grid electricity, with an hourly carbon footprint of 375 g CO_2/kWh. A more aggressive case of ramp-up to 20% replacement is also assessed.

As car fleet and consumption values are crucial for this use case, a certain mix of fleet assumptions forms the basis of the simulation. As such, BEV are grouped into the following categories:

Category	avg. consumption (in kWh/100km)	battery capacity (in kWh)
Small town car	16.5	40
Medium sized car	20	60
Big luxury car	24	80

A substitution effect within conventional (diesel) cars is assumed, based on replacement assumption above.

As Figure 34 shows, shift to BEV does not impact the heating sector, electricity sector and the freight sector (no measures affecting the town's carbon footprint are assumed to materialize within the near future). The passenger transport sector is impacted by this transition. The dynamics of passenger transport that unfold, are closely connected to the question of charging infrastructure demand and driving profiles.

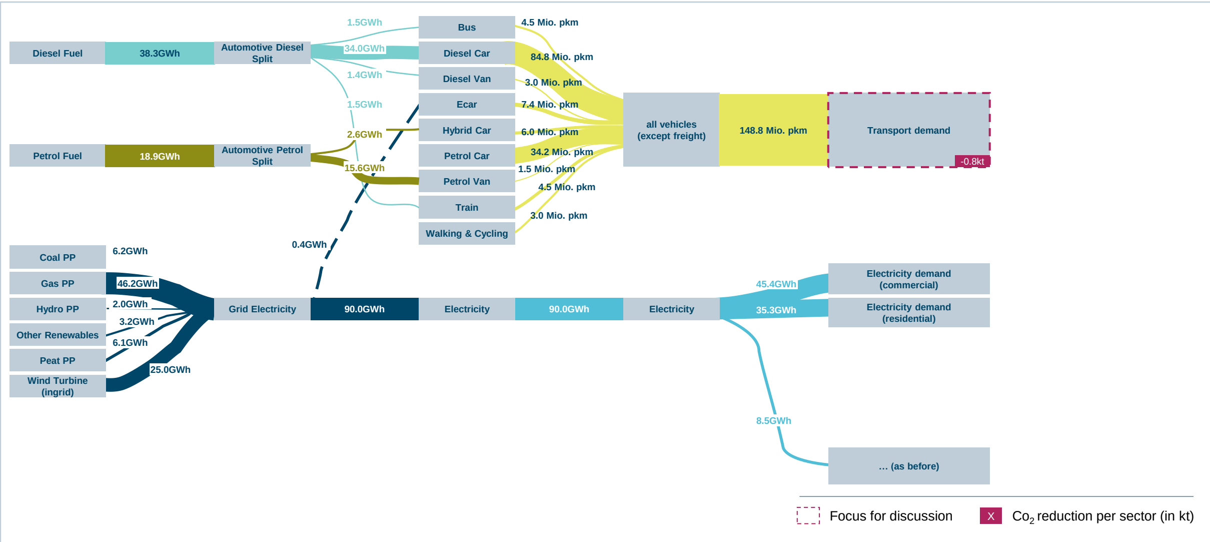


Figure 34: Transportation Use Case impact

With the Sankey diagram shown in Figure 34, we see how the electricity generation and passenger cars will now be connected through EVs, thus coupling the power sector with the transport sector. When increasing the share of BEV, the CO_2 footprint of personal kilometer decreases within the passenger sector. With 0% BEV, it is at 96.5 g CO_2/Pkm, at 5%, it is at 93.4 g/Pkm, at 20% it is at 84.1 g/Pkm. The total CO_2 footprint is lowered by ~ **0.8 kt per 5% BEV share**. We see that the impact on emission reductions is rather low if the CO_2 intensity of the grid electricity is based on the current national Irish energy mix. Thus, combining different scenarios mentioned in this report are needed to create higher leverage for decarbonization of Portlaoise.
It also needs to be stressed that a higher EV penetration requires complex region-system analysis. A faster rollout of EV requires an in-depth analysis of the charging infrastructure and types in the region. A geo-spatial charging infrastructure planning must be thoroughly analyzed by including multiple energy system relevant aspects. Among these aspects are the occurring load volumes induced by charging locations (e.g., superchargers) at substations within the grid, the consumer preferences for certain locations and the ability to shift load temporally by using vehicle to grid use cases. From a cost and regulatory perspective, grid reinforcements, charging infrastructure and BEV types need to be considered requiring an end-to-end simulation ranging from generation source to grid impact. Once BEV penetration reaches beyond 20%, it is recommended that an independent study is conducted to assess further CO_2 impact.

Conclusion

As all simulated scenarios in the register of opportunities demonstrate, partial decarbonization is achievable per sector and, in the case of e-mobility, in a cross-sector manner. Going forward, stakeholder interests, cost, technology preferences and incentive programs play significant roles in choosing the right decarbonization option for the town of Portlaoise. In terms of magnitude and overall CO_2 emission reduction, this report has shown that the available wind potential has meaningful benefits for the community. With a rather small number of turbines (~5) and in accordance with distance rules to settlements, 34% of emission can be reduced compared to the baseline through an investment of approximately €23.5 million for the turbines. Some funding programs such as the SEAI's "Better Energy Communities Program" [22, 23] or the Renewable Electricity Support Scheme could be leveraged for constructing an energy community that may even benefit financially from an in close proximity wind farm.

Alternatively, residential rooftop PV installation may be more widely accepted by the local population. Rooftop decarbonization potential is also impressive - 50 MW of rooftop PV may achieve an 18% reduction in CO_2 emissions compared to the base case. From a consumer perspective this may be an interesting option, since the inclusion of a storage element in a residential system opens opportunities to sell back electricity.

The heating use case shows that by upgrading housing built prior to 2000 to B2 category (3,984 houses) using insulation and housing retrofit programs, ~16% of overall thermal energy demand can be reduced compared to the baseline footprint. This results in annual saving of 13.5kt CO_2.

The passenger transportation use case ranks lowest in terms of overall emission reduction effect given its overall 1% CO_2 potential contribution. However, since new mobility concepts are on the rise, policy makers and county councils may find this use case attractive. Particularly, as it indirectly helps to drive attitude and behavioral change, which has a positive effect on areas of decarbonization efforts.

6 ORGANIZATION IDENTIFICATION

Based on the Register of Opportunities discussed in Chapter 5, a list of potential vendors and partners (public, private and non-government) organizations were identified that can potentially support the town in its decarbonization efforts. While efforts were taken to highlight key organizations, the list is non-exhaustive and should be considered as a starting point for further exploring organizations depending on specific strategic initiatives adopted by the town. Finally, as decarbonization efforts are an emerging space, globally, we expect more collaboration opportunities in future.

Sr. No.	Category	Organization name	Brief description	Contact
1	Wind turbine manufacturer	Siemens Gamesa Renewable Energy	• Siemens Gamesa offers a range of onshore wind turbine technologies to cover all wind classes and site conditions.	Dublin, Ireland
2	Wind turbine manufacturer	MHI Vestas	• MHI Vestas is a JV between Vestas Wind Systems A/S and Mitsubishi Heavy Industries Ltd • MHI Vestas is a leading supplier of onshore and offshore wind solutions	Aarhus Denmark
3	Wind farm maintenance service providers	Lotus Energy Systems	• Lotus Energy Systems provides operations and maintenance, repair, overhaul, technical support, and staffing solutions for the wind industry	http://www.lotusenergysystems.com/
4	Wind farm maintenance service providers	Optinergy Limited	• Optinergy Limited provides operations and maintenance services for the wind industry in Europe	http://optinergy.ie/
5	Rooftop solar panel installation companies	Electric Ireland Ltd.	• Electric Ireland is a leading solution provider for solar rooftop deployment and residential batteries	https://electricireland.ie
6	Rooftop solar panel installation companies	Glenergy	• Glenergy is a supplier of heat pumps, hot water heat pumps, solar PV panels, Solar Thermal panels	Wicklow, Ireland http://glenergysolar.ie/
7	Rooftop solar panel installation companies	Solartricity	• Irish owned wholesale supplier of solar PV equipment. • Stock a range of solar PV panels, mountings, inverters, and ancillary components for next-day delivery throughout Ireland	Dublin, Ireland https://solartricity.ie/
8	Rooftop solar panel installation companies	Eco Horizon	• Installation of Panels from Solarwatt, a world leader in solar technology, offering high yield rates, efficiency, and mechanical strength	https://ecohorizon.ie/
9	Rooftop solar panel installation companies	Enerpower	• Enerpower are Ireland's leading Solar PV Installers with clients nationwide such as Lidl, BWG Foods, Tesco, Flahavans and Ardkeen Quality Food Stores.	Waterford, Ireland https://enerpower.ie

Sr. No.	Category	Organization name	Brief description	Contact
10	Anaerobic digester installation / operating companies	Harp Renewables	• Harp Renewables is an Irish based company delivering Anaerobic Digestion Projects (AD) in the UK and Ireland with the capable assistance of the Technology provider Green Gas Technologies Ltd.	Meath, Ireland www.harprenewables.com
11		A-Consult	• Designs, manufactures, and installs precast concrete anaerobic digesters and storage tanks.	Retford, UK
12		Agrikomp UK	• Supplies anaerobic digester systems	Warwickshire, UK
13		Bord na Mona	• Bord na Mona is leading power generation, Home heating, waste collection service provider in the Ireland	Kildare, Ireland
14		Clearfleau Limited	• Supplies anaerobic digester systems	Berkshire, UK
15		Jones Celtic	• Supplies anaerobic digester systems	Dublin, Ireland
16		Kirk UK	• Supplies anaerobic digester systems	Clitheroe, UK
17	Gas network operator	Bord Gáis Energy Limited	• Supplies natural gas and electricity to customers across Ireland.	Gas network operator
18	Gas network operator	Ervia	• A multi utility company providing gas, water, and wastewater infra and services in Ireland and the UK.	Dublin, Ireland
19	Gas network operator	Gas Networks Ireland	• Gas Networks Ireland engages in the transportation of natural gas. It owns, operates, builds, and maintains a natural gas network	Cork, Ireland gasnetworks.ie/home/
21	Electric network charging point	ESB Ecars / CircleK	• Ireland. most Circle K stations with Charging facilities are hosting ESB Ecars chargers, some are owned by Circle K (such as Athlone services on the M6)	https://www.circlek.ie/ https://www.esb.ie/ecars
22	Electric network charging point	Ionity	• Ionity has a few charge points hubs in Ireland. These are exclusively CCS DC fast chargers.	Munich, Germany https://ionity.eu/en/
24	Sustainability solutions	Siemens Ireland Ltd.	• Siemens provides products and solutions in Smart Buildings, Energy Efficiency Solutions, Sustainability and Carbon Reduction, Energy as a Service Contracting, Grid Edge Solutions including Renewable Energy and Storage Solutions, eMobility (eVehicles), Infrastructure Based Digitalisation Solutions	Dublin, Ireland www.siemens.ie
25	Special Focus Group	Low Carbon Implementation Group	• Group focused on addressing implementation challenges and opportunities in Portlaoise and similar sized regional towns	Ireland
26	Innovation centre	The Cube	• A multi-point incubation hub for the development of a	Laois County, Ireland

Sr. No.	Category	Organization name	Brief description	Contact
			• Low Carbon Centre of Excellence, assisting in attracting and developing companies • with a low Carbon focus	
27	Transportation	National Transport Authority	• Supports provision of local public transport services commencing with 2 electric buses along 2 routes in Portlaoise	Dublin, Ireland https://www.nationaltransport.ie/
28	Government organization	Enterprise Ireland	• Supports sustainable economic growth, regional development, and growth of Irish enterprises in world markets	Dublin, Ireland https://www.enterprise-ireland.com/

Note: Relevant organizations were identified through public source information only. Siemens recommends additional Due Diligence before these organizations are approached / engaged for any decarbonization efforts.

In addition to the above organizations, **Sustainable Energy Communities (SEC)** provide a collaborative approach to managing the transition to a lower carbon footprint town [34]. Sustainable Energy Community (SEC) is a community that works together to develop a sustainable energy system. To do so, they aim to:

1. be energy-efficient
2. use renewable energy
3. consider smart energy solutions
4. An SEC can include a range of different energy users in the community such as homes, sports clubs, community centres, and businesses.
5. SEC connects sustainable energy & local economic development

At present, there are 28 registered SECs in Laois. Some of the benefits of setting up SECs include:

1. Achieve financial and energy savings
2. Enhance comfort and health from energy efficient buildings
3. Boost local employment
4. Support community development
5. Build capacity and access funding

By becoming an SEC, organizations will be able to access a range of supports from SEAI for energy projects. An integrated community approach makes it possible to deliver much more than is possible at an individual level.
SECs also contribute to national energy targets and reduce society's environmental impact. At a global level, low carbon and renewable energy sources support the need to address climate change by reducing our global emissions.

7 DATA SOURCES AND REFERENCES

[1] Town specific information: CSO Census 2016 extracted and provided by Dempsey Suzanne <sdempsey@laoiscoco.ie> and Laurence O'Reilly <L.OReilly@ors.ie>

[2] Electricity generation grid mix based on national grid mix: Energy in Ireland - report (SEAI 2019) , p. 32 Table 12 https://www.seai.ie/publications/Energy-in-Ireland-2019-.pdf

[3] Emission factors of Energy sources of electricity and heat generation: CO2 and CO2e Scope 1,2 (Annex I Covenant of Mayors (CoM Default Emission Factors -Version 2017) IPCC Standard.

[4] https://op.europa.eu/de/publication-detail/-/publication/278ae66b-809b-11e7-b5c6-01aa75ed71a1/language-en

[5] https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/electricity/ (latest retrieve on Oct 19th)

[6] https://www.seai.ie/publications/Energy-in-the-Residential-Sector-2018-Final.pdf

[7] https://www.seai.ie/publications/Energy-in-Ireland-2019-.pdf

[8] https://www.seai.ie/publications/Extensive-Survey-of-Commercial-Buildings-Stock-in-the-Republic-of-Ireland.pdf (latest retrieve on Oct 19th)

[9] Table33: https://www.seai.ie/publications/Energy-in-Ireland-2018.pdf

[10] https://laois.ie/wp-content/uploads/Portlaoise-Local-Area-Plan.pdf

[11] https://www.laoistoday.ie/2020/07/27/no-floodlit-matches-in-mw-hire-omoore-park-as-e400000-green-stadium-initiative-to-commence/

[12] https://www.researchgate.net/publication/327320077_Evaluation_of_Energy_Consumption_in_German_Hospitals_Benchmarking_in_the_Public_Sector

[13] https://www.irishprisons.ie/wp-content/uploads/documents_pdf/IPS-Annual-Report-2019-Web.pdf

[14] https://www.seai.ie/business-and-public-sector/large-business/lien/

[15] https://www.seai.ie/grants/community-grants/

[16] https://www.teagasc.ie/media/website/rural-economy/farm-management/DairyFarmEnergyCoonsumption.pdf

[17] https://www.teagasc.ie/media/website/publications/2019/J-Upton-Energy-Feb-2019.pdf

[18] https://www.farmcarbontoolkit.org.uk/toolkit/energy-efficiency-advice-dairy-farmers#:~:text=Overview-,Research%20suggests%20energy%20use%20on%20dairy%20farms%20is%20associated%20with,energy%20savings%20of%20over%2060%25.

[19] http://www.delavalcorporate.com/globalassets/sustainability/energy-report/delaval_energyreport.pdf

[20] https://www.mdpi.com/1996-1073/13/5/1288/htm

[21] https://www.mdpi.com/2076-2615/10/3/390/pdf

[22] https://www.nationaltransport.ie/wp-content/uploads/2019/01/National_Household_Travel_Survey_2017_Report_-_December_2018.pdf (latest retrieve on Oct 19th)

[23] Global Modeling and Assimilation Office (GMAO) (2015)

a. MERRA-2 tavg1_2d_slv_Nx: 2d, 1-Hourly, Time-Averaged, Single-Level, Assimilation, Single-Level Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/VJAFPLI1CSIV.

b. MERRA-2 tavg1_2d_lnd_Nx: 2d, 1-Hourly, Time-Averaged, Single-Level, Assimilation, Land Surface Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC) 10.5067/RKPHT8KC1Y1T.

c. MERRA-2 tavg1_2d_flx_Nx: 2d, 1-Hourly, Time-Averaged, Single-Level, Assimilation, Surface Flux Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/7MCPBJ41Y0K6.

d. MERRA-2 tavg1_2d_rad_Nx: 2d, 1-Hourly, Time-averaged, Single-Level, Assimilation, Radiation Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/Q9QMY5PBNV1T.

e. MERRA-2 const_2d_asm_Nx: 2d, constants V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/ME5QX6Q5IGGU.

[24] OpenStreetMap (OSM) - OpenStreetMap und Mitwirkende: http://www.openstreetmap.org/; Cambridge: OpenStreetMap Foundation, 2004 (überarbeitet: 2019)

[25] http://windmonitor.iee.fraunhofer.de/windmonitor_de/3_Onshore/5_betriebsergebnisse/3_investitionskosten/

[26] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf

[27] Modeling Framework for Planning and Operation of Multi-Modal Energy Systems in the Case of Germany; C. Müller, A. Hoffrichter, L. Wyrwoll, C. Schmitt, M. Trageser, T. Kulms, D. Beulertz, M. Metzger, M. Duckheim, M. Huber, M. Küppers, D. Most, S. Paulus, H. J. Heger, A. Schnettler; Applied Energy, Volume 250, 15 September 2019, Pages 1132-1146.
[28] "Siemens' Position on Global Decarbonization and Climate Change", https://assets.new.siemens.com/siemens/assets/api/uuid:5eec5943-8791-4f36-b1bd-4191abd19694/version:1560784550/siemens-position-on-global-decarbonization-and-climate-change-v2.pdf
[29] http://windmonitor.iee.fraunhofer.de/windmonitor_de/3_Onshore/5_betriebsergebnisse/3_investitionskosten/ and https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf 2
[30] https://www.energie-experten.org/erneuerbare-energien/photovoltaik/solarmodule/groesse#:~:text=Sehr%20h%C3%A4ufig%20werden%20Photovoltaik%2DModule,%22%2D)%20Zellen%20%2D%20eingesetzt
[31] For PV: https://www.seai.ie/grants/home-energy-grants/
[32] Werner, S., 2017. International review of district heating and cooling. Energy 137, 617–631. https://doi.org/10.1016/j.energy.2017.04.045
[33] Werner, S., 2004. District Heating and Cooling, in Cleveland, C.J. (Ed.), Encyclopedia of Energy. Elsevier, New York, pp. 841–848. https://doi.org/10.1016/B0-12-176480-X/00214-X
[34] For Community groups: https://www.independent.ie/business/irish/shining-example-tipperary-county-council-harvest-solar-power-at-landfill-39708543.html