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Department of Transport,
Tourism and Sport

Sustainable Mobility Policy Review

Background Paper 3
Climate Change Challenge

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Context and questions for consideration

This background paper is one of a number of papers that have been prepared by the Department of Transport, Tourism and Sport to inform a public consultation on Ireland's sustainable mobility policy. The review work arises from a commitment in the *Programme for a Partnership Government*[1] to review public transport policy "to ensure services are sustainable into the future and are meeting the needs of a modern economy". The public consultation is designed to give stakeholders, interested parties and the general public the opportunity to reflect on the information and analysis in the papers, to share their views, and to contribute to the development of a Sustainable Mobility Policy Statement.

Sustainable Mobility can be described as linking people and places in a sustainable way by supporting:

- comfortable and affordable journeys to and from work, home, school, college, shops and leisure;
- travelling by cleaner and greener transport; and
- a shift away from the private car to greater use of active travel (walking and cycling) and public transport (e.g. bus, rail, tram).

All elements of sustainable mobility (public transport, cycling, walking) are being considered in the policy review. Each background paper includes a number of questions to generate ideas about the extent to which the present approach to sustainable mobility is working well, the areas which are not, and future priorities.

This background paper brings together readily available data and statistics on the transport emissions in Ireland. This paper also outlines the current climate change challenges facing Ireland and the steps that are being taken to reduce emissions in line with climate action policies. Participants in the public consultation are not confined to answering the suggested questions and are invited to offer any other contribution they wish to make. It is recommended that submissions are confined to circa 2,500 words or less.

3.1 Which sustainable mobility emissions mitigation measures, not currently employed in Ireland, should be considered for implementation?

3.2 Are there any measures identified as "potential measures" in Table 7.1 (page 57) that you would like to see implemented?

3.3 Are there any emissions reduction measures, currently employed, that should be amended or fully discontinued?

3.4 How should mitigation measures be prioritised (e.g. on basis of: least cost, carbon abatement potential, disruptive effects, co-benefit potential etc.)?

1 Structure of the paper

Section 2: **Climate change** focuses on the global climate change challenge and climate action at the national, European and global level. The Section also describes Ireland's emission reduction targets and projections, as well as the relative potential contribution of different sectors towards reaching emission targets. Finally, an outline of the national policy approach to tackling climate change is provided.

Section 3: **Emissions in the transport sector** describes the dramatic changes in transport trends and emissions since 1990 and discusses the sources of transport emissions along with potential causative factors.

Section 4: **Challenges facing the transport sector** describes the main obstacles facing the transport sector in addressing climate change and reducing emissions, namely: Ireland's increasing travel demand; dispersed settlement patterns; dependence on new technologies; and the need for widespread behavioural change.

Section 5: **Current measures that reduce transport emissions** outlines the policy interventions and incentives that have been implemented to reduce emissions from the transport sector, namely: continued investment in the sustainable mobility network to increase capacity and promote modal shift; implementation of EU regulations; redesigning tax regimes; incentives to encourage alternative fuel and technologies; and the introduction of a Biofuel Obligation Scheme.

Section 6: **Avoid-Shift-Improve Emissions** examines potential ways to: avoid emissions through reducing the frequency and distance of trips; to reduce emissions by shifting towards more environmentally friendly modes of transport, such as walking, cycling or using public transport; and to improve emissions through promoting efficient fuel and vehicle technologies.

Section 7: **Concluding points** includes a summary table to map the Avoid-Shift-Improve mitigation measures currently employed in the transport sector and identifies potential new mitigation measures.

2 Climate change

2.1 Introduction

This Section focuses on the global climate change challenge and climate action at the global, European and national level. Ireland's national emission reduction targets and projections to 2020/2030 are also described, as well as the overall national policy approach to tackling climate change.

2.2 The climate change challenge

It is widely recognised that climate change is one of the greatest global challenges. Evidence for warming of the climate system is unequivocal and it is extremely likely that human activity has been the dominant cause for the increase in global average temperatures by almost 1˚C since pre-industrial times[2]. The projections indicate that continued emissions of greenhouse gases (GHG) will cause further warming and changes to the climate system. The impacts of climate change are diverse and wide ranging. In Ireland, predicted impacts include sea level rise; more intense storms and rainfall; increased likelihood and magnitude of river and coastal flooding; water shortages in summer; increased risk of new pests and diseases; adverse impacts on water quality; and changes in distribution and time of lifecycle events of plant and animal species on land and in the oceans[3]. International, European and national measures and targets have been introduced with the aim of improving adaptation to the adverse impacts of climate change, fostering climate resilience and supporting low GHG emissions developments.

2.3 Global response to climate change

At an international level, Ireland is a party to both the *United Nations Framework Convention on Climate Change* (UNFCCC)[4] and the *Kyoto Protocol*[5], which together provide a legal framework for addressing climate change. In December 2015 Ireland was, as part of the European Union (EU), a signatory to the *Paris Agreement*[6], which aims to restrict global temperature rise to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C.

2.4 EU response to climate change

A key European objective is to reduce GHG emissions by 80-95% by 2050 compared to 1990 levels[7]. While maintaining a focus on this long-term goal, the EU has also established intermediate targets out to 2050. In March 2007, the European Council adopted an objective to reduce GHG emissions by 20% by 2020 compared to 1990 levels through a combination of the Emissions Trading Scheme (ETS) and individual Member State targets for non-ETS emissions established through the 2009 Effort Sharing Decision (ESD)[8] (Box 1). Under the *Climate Policy Framework for 2020 to 2030*[9], the EU agreed ambitious commitments to further reduce GHG by at least 40% by 2030 as compared with 1990; emission reductions are to be delivered collectively by the EU with reductions in the ETS and non-ETS sectors amounting to 43% and 30% by 2030 compared to 2005 respectively[10].

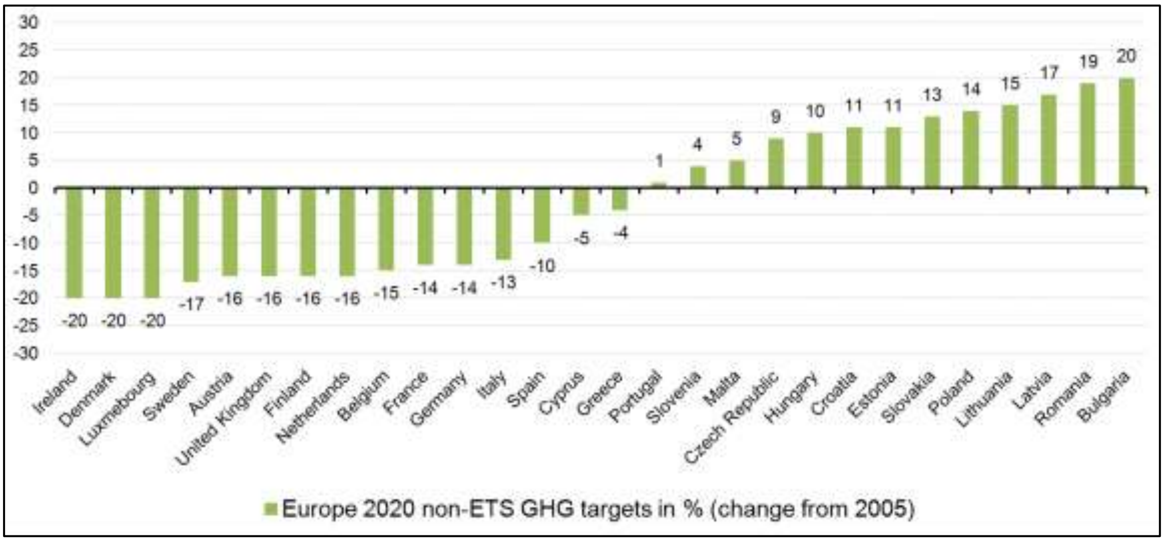
Box 1. ETS and ESD explained

The EU Emissions Trading System (ETS) is a carbon market that limits emissions from more than 11,000 heavy energy-using installations (such as power stations & industrial plants) and airlines operating between EU countries as well as Iceland, Liechtenstein and Norway. The trading system is a cornerstone of the European Union's policy to combat climate change cost-effectively.

The ETS was established in 2005 under *Directive 2003/87/EC*[11]. It is based on a 'Cap and Trade' principle whereby the cap ensures carbon dioxide (CO_2) is a product and valued at a price which is determined by the supply and demand in the market. Installations that are part of ETS are allocated a defined number of emission allowances. One emission allowance equals one tonne of CO_2. Annually, each installation must surrender sufficient allowances to cover all their emissions. If a company reduces their emissions they are permitted to sell their excess allowances on the market. Alternatively, where emissions are exceeded additional allowances must be purchased.

The Effort Sharing Decision (ESD) set binding individual Member State annual targets for non-ETS emissions (primarily emissions associated with heating in buildings, transport, waste and agriculture). The ESD targets are expressed as percentage changes from 2005 levels and were calculated based on the relative wealth of Member States' (measured by gross domestic product (GDP) per capita). Less wealthy countries are allowed emission increases in these sectors because their relatively higher economic growth is likely to be accompanied by higher emissions. Nevertheless their targets represent a limit on their emissions compared with projected business as usual growth rates.

By 2020, the national targets should collectively deliver a reduction of around 10% in total EU emissions from the sectors covered compared with 2005 levels. Together with a 21% cut in emissions covered by the EU ETS, this should accomplish the overall emission reduction goal of the climate and energy package, namely a 20% cut below 1990 levels by 2020.



Source: European Commission's Directorate-General for Climate Action

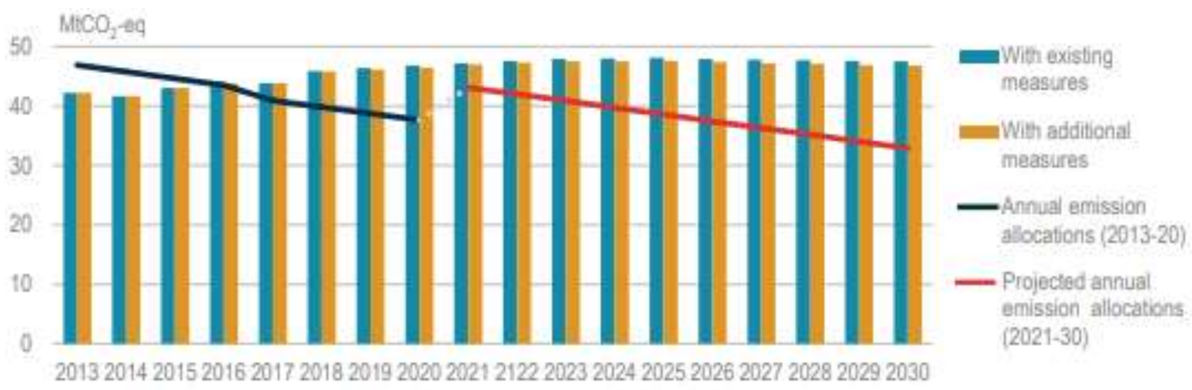
2.5 National response to climate change

Ireland has a legally binding non-ETS emissions reduction target for each year between 2013 and 2030; by 2020 Ireland's non-ETS emissions should be 20% below their level in 2005. The 20% reduction target is the most demanding 2020 reduction target allocated to EU Member States under the ESD, shared only with Denmark and Luxembourg; it can be compared to an EU average reduction target of 10%. In May 2018, the European Commission published allocations of individual targets for EU Member States for the non-ETS sector out to 2030[12]; Ireland must reduce non-ETS emissions by 30% by 2030 relative to 2005 levels. Again, this target is higher than the EU average reduction target of 23%.

According to the latest Environmental Protection Agency (EPA) projections, Ireland's non-ETS emissions in 2020 could be in the range of 5-6% below 2005 levels[13]; it is expected that Ireland will exceed all annual binding limits from 2016 to 2020 with a predicted 'gap to target' of 9-10 MtCO_2eq (Figure 2.1). The legislative framework governing the ESD emissions reductions targets includes a number of flexibility mechanisms including provisions to bank any excess allowances to future years and to trade allowances between Member States[14]. Ireland expects to make use of both of these mechanisms in meeting its compliance requirements in the short term; although it is noted that reliance on such flexibilities is not be a sustainable approach in the longer term. Shortfalls in reaching the 2020 and subsequent annual targets will result in costs as well as placing Ireland on a more arduous trajectory to the 2030 target and beyond. The majority of Member States are expected to overachieve on their non ETS emissions reduction obligations; as such, it is predicted that a surplus of emission credits will be available for purchase to Member States requiring compliance (*c.* 1,500Mt CO_2)[15].

Figure 2.1: Emissions projection under EPA scenarios

(with existing policy measures and with additional policy measures) (bars) and legally binding annual emission ceilings under ESD to 2020 (black line) and projected annual emission allocation (red line).



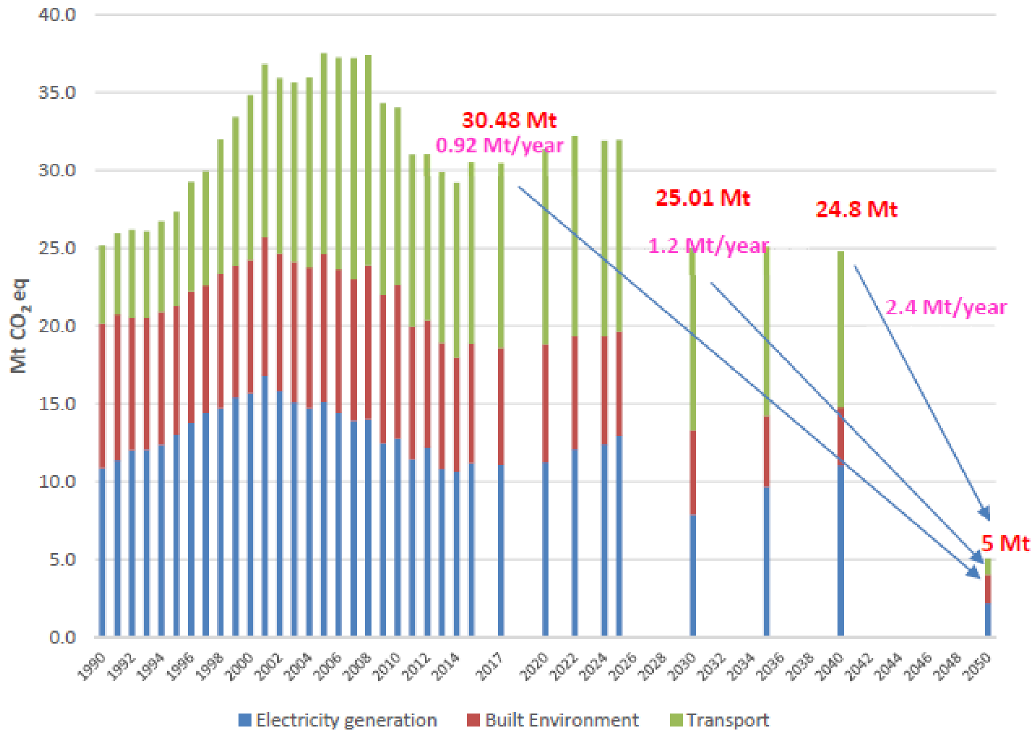
Source: International Energy Agency[16]

Policies and measures beyond those already in place will be necessary to ensure Ireland is on the correct pathway to reach the more onerous 2030 targets and to ultimately decarbonise the economy by 2050. Ireland's emissions will need to be reduced each year by approximately

$0.92MtCO_{2eq}$ to achieve the objective of at least an 80% reduction by 2050, relative to 1990 levels (Figure 2.2).

It is important to recognise that Ireland's likely shortfall reaching the 20% reduction target by 2020 reflects both reduced investment capacity over the period of the economic downturn, as well as the burdensome nature of the target itself, which can be argued was distorted by the period of rapid economic upturn during the Celtic Tiger and was not consistent with what was achievable on a cost-effective basis. It is clear that meeting the current and future GHG emissions targets represents a significant challenge for Ireland.

Figure 2.2: Estimated annual emission reductions required to achieve an 80% reduction relative to 2005 levels by 2050.



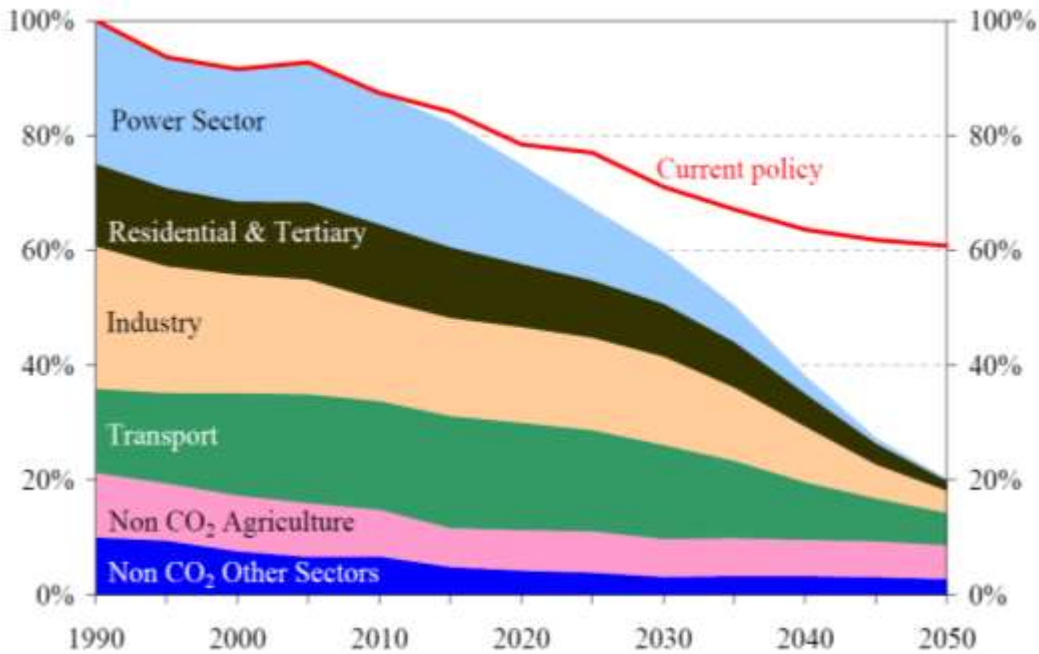
Source: EPA

2.6 Emission reduction potential of individual sectors

The European Commission's *2050 Low-Carbon Economy Roadmap*[17] determined that all sectors must contribute towards the EU 2050 target of an 80% reduction in GHG emissions but the relative contribution of individual sectors will be limited according to their technological and economic potential. The *Roadmap* concluded that clear differences exist between sectors in relation to their capacities to reduce emissions. Figure 2.3 illustrates the projected relative rates of contribution from individual sectors towards the 80% emission reduction target from the baseline year in 1990 until 2050.

Figure 2.3: Projected emission reduction capacities of non-ETS sectors between 1990 and 2050

100% equates to 1990 baseline emission levels; 20% represents the EU 2050 80% emission reduction target



Source: *2050 Low-Carbon Economy Roadmap*

The power generation sector has the biggest potential for reducing emissions, with a projected near complete elimination of CO_2 emissions by 2050 due to a steady decrease in emissions from 2005 onwards. It is assumed that electricity will increasingly be generated from renewable sources, low-emission alternatives, or fossil fuel power from stations equipped with carbon capture and storage facilities.

The emission reduction capacity in the building sector is also very substantial; with a projection of nearly 90% emission reduction from the house and office building sector by 2050. Emission savings are expected through developing passive housing technology in new builds and retrofitting the existing housing stock to improve energy efficiencies. In addition, it is expected that the trend of substituting fossil fuels with renewable electricity for heating, cooling and cooking will continue.

Industry emissions are expected to exhibit a gradual increase in emission reduction potential up to 2030 as technologies develop and become more energy efficient. Post 2035, carbon capture and storage technology is anticipated to impact greatly on the emission reduction capacity in the sector, particularly in industries with limited scope to further enhance emission reduction through energy efficient means (e.g. the cement and steel manufacturing industries). It is estimated that energy intensive industries could cut emissions by more than 80% by 2050.

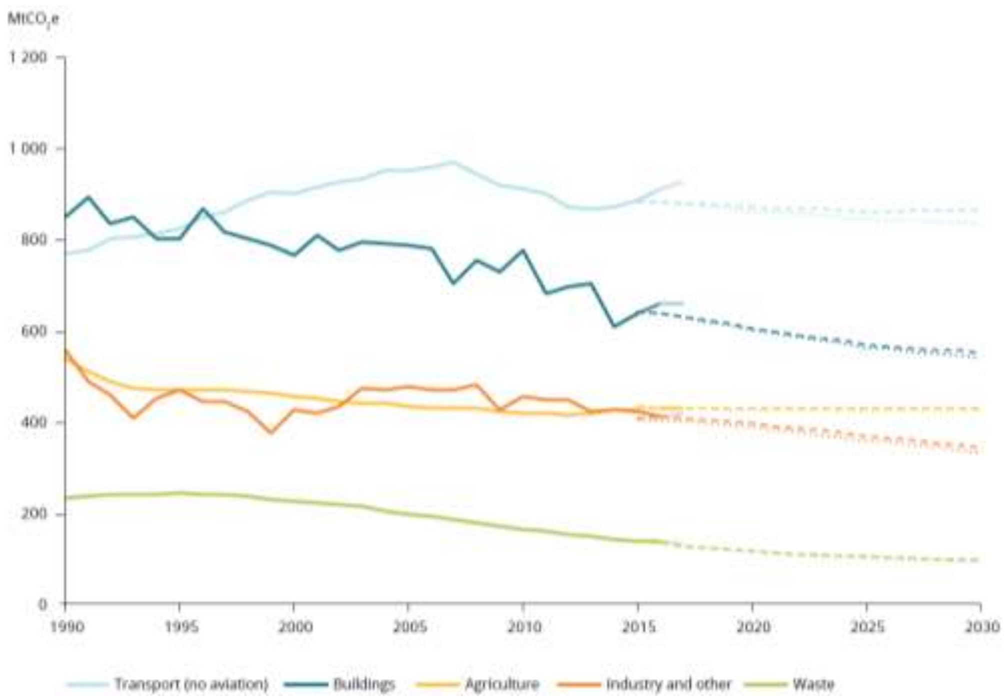
It is recognised that agriculture has a limited capacity to reduce emissions as global food demand grows, but reductions are possible. Emission savings can be made in the areas of fertilisers, manure and livestock management. Additionally, agriculture can play an important role in storing carbon in plants, forests and soils systems. Agriculture can also produce energy from biomass that can displace fossil fuels.

The *Roadmap* acknowledges that the transport sector in Europe has the capacity to reduce emissions to *c*. 60% below 1990 levels by 2050; the majority of the emission savings in the sector are not anticipated until post 2035 as technologies develop, mainly as vehicle electrification becomes more advanced and established. In the shorter term, emission savings are expected through improving efficiencies in the combustion engine and the incremental increase in biofuel use. Estimates by the European Environment Agency (EEA)[18] suggest that transport emissions will remain relatively stable over 2015-2030 (Figure 2.4). It is also recognised that emission savings generally costs considerably more in transport than in other sectors which may somewhat account for the relative lack of progress in decarbonising transport globally; however, as a consequence transport makes up an ever-increasing share of overall emissions. There is also the argument that new transport infrastructure takes time to develop and build, therefore investment in the short-term is required to achieve GHG savings in the longer term to coincide with when savings become more expensive in other sectors.

The consensus emerging from Europe is that the power generation sector has the greatest potential to contribute to emission reductions in the near future, with building and industry efficiencies also playing a considerable role. Post 2030, due to advancing technologies, the relative contributions of the transport and industry will increase. Contributions from the agricultural sector are more restricted.

Figure 2.4: EU GHG emission trends and projections under the ESD based on national inventories and forecasts.

Note solid lines represent historic GHG emissions (1990-2016); dashed lines represent projections 'with existing measures'; dotted lines represent projections 'with additional measures'



Source: EEA[18]

2.7 Climate change policies

At a national level, the main climate change policy drivers include the *National Policy Position on Climate Action and Low Carbon Development*[19] as well as the *Climate Action and Low Carbon Development Act 2015*[20]. The *National Policy Position* established the central objective of achieving a transition to a low carbon and climate-resilient economy by 2050 through a long-term vision that CO_2 emissions will be reduced by at least 80% by 2050, compared to 1990 levels, across the electricity generation, built environment and transport sectors, while carbon neutrality will be achieved in the agriculture and land-use sectors. The *Climate Action and Low Carbon Development Act 2015* provided the statutory basis for this national transition objective, including the development of a *National Mitigation Plan*[21] and *National Adaptation Framework*[22].

The *National Mitigation Plan (NMP)*, which was approved by Government in June 2017, sets a national pathway towards a transition to a competitive, low carbon, climate resilient and environmentally sustainable economy by 2050 through the reduction of non-ETS GHG emissions across the transport, agriculture, energy, and built environment sectors. The transport contribution to the *NMP* highlights a wide-ranging number of mitigation measures aimed at reducing sectoral emissions, focusing primarily on promoting behavioural change and modal shift; investing in public transport to increase capacity; and encouraging a transition towards alternatively fuelled vehicles.

The *NMP* initiated the process of developing medium to long term mitigation choices for the years to come. The *Climate Action Plan to Tackle Climate Breakdown*[23], published in June 2019, is the follow-on plan to the *NMP*; it maps out a whole-of-Government approach to climate action and a potential pathway to meet Ireland's 2030 emissions commitments. The *Plan* clearly recognises that Ireland must significantly step up its commitments to tackle climate disruption and sets out strong governance arrangements to ensure that climate action is a key consideration in all State projects. The *Plan* calls for the establishment of sectoral carbon budgets and greater accountability of responsible sectoral Ministers to the Oireachtas.

Also under the *Climate Action and Low Carbon Development Act*, a *National Adaptation Framework* was prepared and published in January 2018 outlining a strategy to reduce the vulnerability of Ireland to the negative effects of climate change while also availing of all positive impacts. Under the *Framework*, there is a legislative requirement for the Minister for Transport, Tourism and Sport to publish a statutory sectoral adaptation plan. In advance of this obligation, *Developing Resilience to Climate Change in the Irish Transport Sector*[24] was published in November 2017 under the non-statutory *National Climate Change Adaptation Framework*[25]. This adaptation plan outlined climate research and analysis on the likely impacts of climate change in the transport sector, including: more frequent storm events; rising sea levels; and increased incidents of flooding, and proposes actions to develop greater climate resilience.

In recognition of an over reliance on oil and the need to transition to alternative fuels and technologies to decarbonise transport by 2050, a *National Policy Framework on Alternative Fuels Infrastructure for Transport*[26] was published in May 2017. This *Framework* will ensure that the availability of refuelling or recharging stations is not a major obstacle to alternative fuel/technology market penetration. It will also provide a supportive, enabling environment for suppliers and consumers and provide increased confidence and reassurance in Ireland's commitment to this emerging market. A cornerstone of the *Framework* is an ambition that by 2030, all new cars and vans sold in Ireland will be zero-emissions capable.

In order to consolidate the existing patchwork of legislation and reporting obligations across energy, climate and other related policy areas, the EU introduced a requirement that all Member States must develop integrated National Energy and Climate Plans (NECPs) for the period 2021 to 2030 and every subsequent ten year period. The measures outlined within the individual NECPs must collectively ensure that the EU's 2030 targets for GHG emission reductions, renewable energy, energy efficiency and electricity interconnection are met. Ireland submitted its first draft NECP[27] in December 2018 and must submit a finalised plan by 31st December 2019.

Table 2.1: Ireland's climate policy framework strategies and targets, 2014-2030

	Climate Policy Framework	Target/Objective
2014	- *National Policy Position on Climate Action and Low Carbon Development*	- Reduction of at least 80% by 2050 (compared to 1990 level) in energy-related emissions and carbon neutrality in agriculture and land-use sectors.
2015	- *Climate Action and Low Carbon Development Act 2015*	- Statutory basis for the national transition objective laid out in the national policy position.
	- *Ireland's Transition to a Low Carbon Energy Future 2015-2030*	- Complete energy policy update, which sets out a framework to guide policy until 2030.
2017	- *National Mitigation Plan*	- Closes the gap to 2020 target and prepares for the 2030 target.
	- Annual transition statements	- Contains an overview of climate change policies and the annual sectoral mitigation transition statement.
2018	- *National Adaptation Framework*	- Provides sectoral adaptation plans to reduce the vulnerability of the negative effects of climate change.
	- *Project Ireland 2040*: including *National Planning Framework* and *National Development Plan*	- Seeks to achieve the ten strategic outcomes of the *National Planning Framework*.
	- Draft National Energy & Climate Plan (NECP)	- Member State requirement to establish a 10-year NECP for the period from 2021 to 2030 in order to meet the EU's new energy and climate targets for 2030.
2019	- *Climate Action Plan to Tackle Climate Breakdown*	- Provides a potential pathway to meet Ireland's 2030 emissions commitments
	- Final NECP	- Finalised plan to be submitted to the EU by 31st December 2019
2020	- EU ESD	- 20% of emissions reduction in non-ETS sector compared to 2005.
2030	- EU Effort Sharing Regulation	- 30% of emissions reductions in non-ETS sector compared to 2005.

2.7.1 Policy synergies and conflicts

Pursuing a low carbon vision not only helps achieve national climate change commitments but also delivers additional potential co-benefits, including: improved energy security, economic opportunities and significant benefits in the areas of health, lifestyle, travel costs, local environment and air quality. Due to the wide cross-cutting nature of climate change, it is also possible that complementary or antagonistic policies exist or may arise. Tackling climate change has tangible positive synergies with spatial and land use planning; this is recognised in *Project Ireland 2040* under the *National Planning Framework*[28] and *National Development Plan: 2018-2027*[29]. Other important complementary policies include *Smarter Travel*[30] and *Ireland's Transition to a Low Carbon Energy Future 2015-2030*[31].

Similarly, policies aimed at climate change action can strongly reinforce improving air quality objectives; reducing levels of dangerous pollutants through limiting emission sources addresses both environmental concerns. Given the disproportionate influence of traffic pollutants on ambient air quality in urban areas, it can be argued that a reduction of these harmful emissions is equally as important as mitigating CO_2 emissions. To help address air quality concerns the forthcoming *National Clean Air Strategy*[32] will provide the policy framework necessary promote integrated measures across Government to reduce air pollution and promote cleaner air.

3 Emissions in the transport sector

3.1 Introduction

This Section outlines the dramatic changes in transport use and emissions over the last two decades along with the main drivers of this change. An overview of the private car, freight and public transport sectors is presented together with their associated emissions.

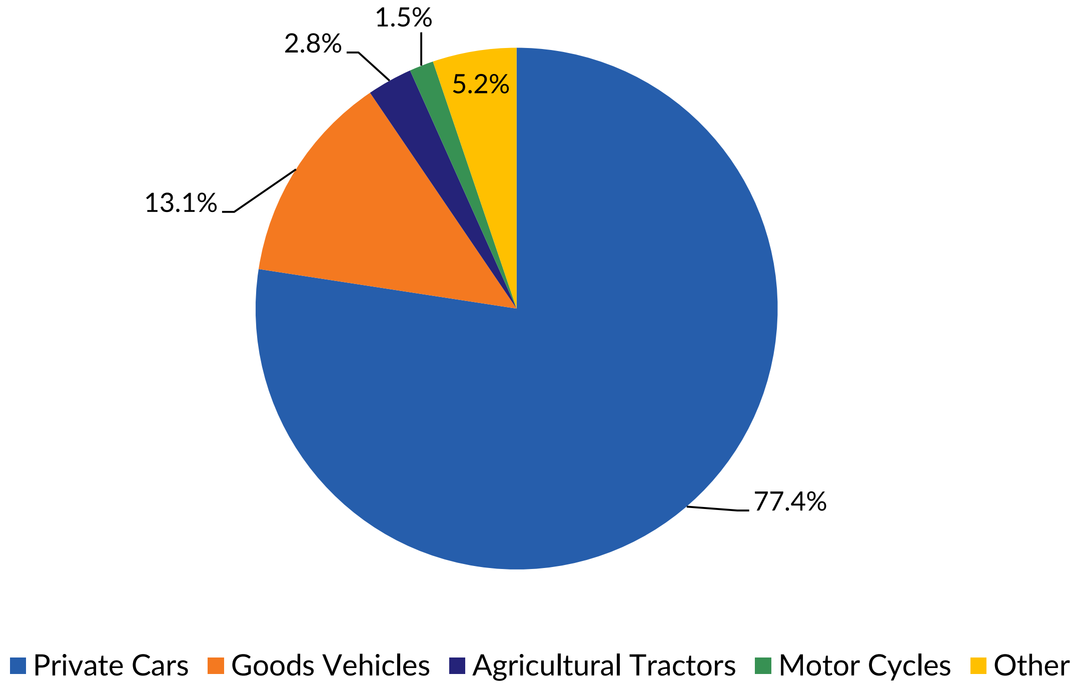
3.2 Emissions in the Irish transport sector

At the end of 2018, there were over 2.71 million licensed (taxed) vehicles on Irish roads. Private cars accounted for the majority of these vehicles (over 77%); goods vehicles accounted for 13% of the national fleet with agricultural vehicles and motorcycles collectively representing a further 4.3% (Figure 3.1)[33]. It is not surprising therefore that the primary source of land transport emissions were from the private car sector (*c.* 52%), followed by the goods sector which accounted for 27.1% of emissions (18.5% from heavy duty vehicles (HDVs) and 8.4% from light duty vehicles (LDVs)) in 2017. Public transport (jointly buses, taxis and rail) emissions accounted for approximately 4.5% of emissions.

In 2017, the transport sector was the second largest contributor of non-ETS emissions, accounting for over 27% of emissions. Agriculture was the highest emitting sector contributing over 46%. Emissions in the agriculture sector are projected to increase over the period 2018-2030 by 1-4% depending on the level of policy intervention; projected emissions in the transport sector, over the same time period, vary from a 1% decrease in emissions to an 11% increase depending on the degree of policy intervention[13].

These transport emissions do not include international aviation or maritime travel emissions; international maritime transport emissions are being tackled as part of a global approach led by the International Maritime Organisation (IMO)[34] while emissions from airlines within the European Economic Area are accounted for under the ETS scheme, with international emissions the focus of an International Civil Aviation Organisation (ICAO) agreement[35]. Maritime transport emits *c.*1000 million tonnes of CO_2 annually and is responsible for approximately 2.5% of global GHG emissions; direct emissions from aviation account for nearly 3% of the EU's total GHG emissions and more than 2% of global emissions. Emissions referred to hereafter in this paper relate solely to land transport emissions.

Figure 3.1: Vehicles under licence in Ireland, 2018



Source: Bulletin of Vehicle and Driver Statistics

3.2.1 Drivers of transport emissions

Numerous studies have been carried out to examine the causal relationships between emissions and economic growth, employment and population levels. One extensive study, that reviewed data from 58 countries across Europe, Asia, America and Africa between 1990 and 2012, demonstrated that economic growth, CO_2 emissions and energy consumption are positively statistically correlated[36]. Analogous relationships have been shown in Ireland with strong evidence that emissions are increasing in line with economic and employment growth, particularly in the *Energy Industries*, *Agriculture* and *Transport* sectors[37].

Ireland is currently experiencing increasing population growth and a period of economic recovery. The 2016 Census[38] registered a growing national population of over 4.76 million, the greatest recorded census population since 1851; while the labour force exceeded 2.3 million people in 2016 - an increase of 3.2% over 2011 levels. The need for travel and the movement of goods and services grows broadly in line with growing populations and economies. Future increases in the national economy and population will likely create further growth in travel demand. Figure 3.2 illustrates the complex and interactive relationship between the main drivers of increased travel demand and corresponding transport emissions.

Figure 3.2: Interactive relationship between main drivers of transport emissions

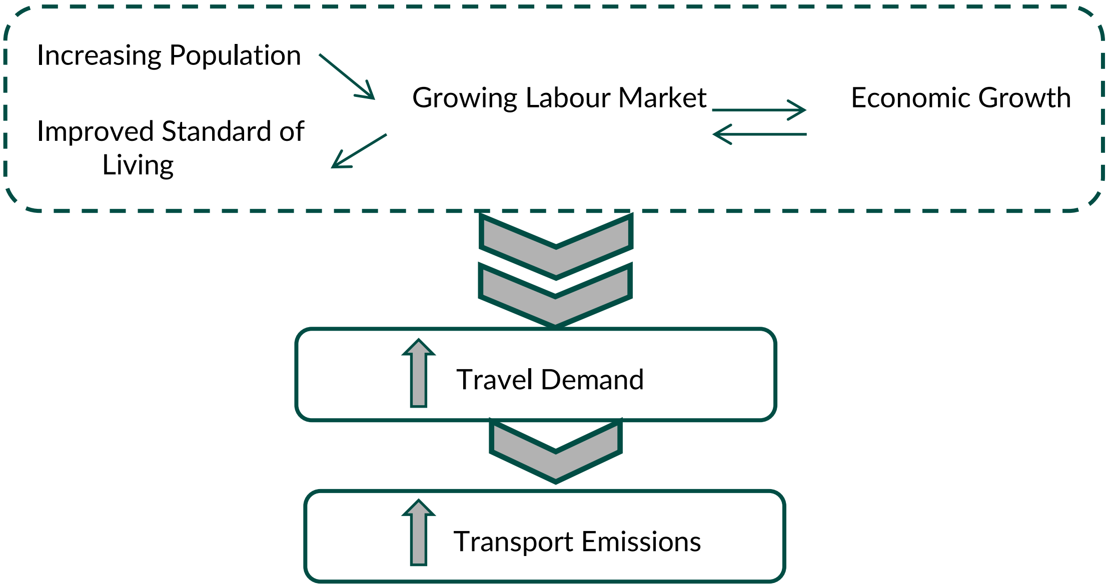
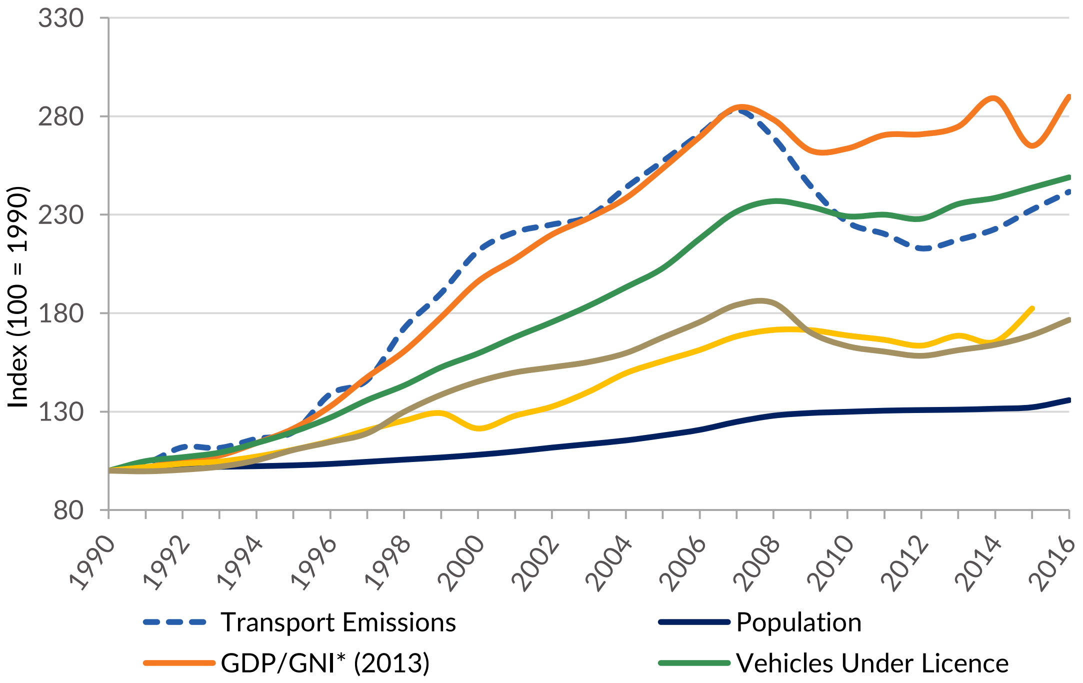


Figure 3.3 shows the strong correlation between transport emissions and general economic activity (gross domestic product (GDP) and total employment) between 1990 and 2016; emissions increased by 131% from *c.* 5 million tonnes of CO_2 in 1990 to 11.9 million tonnes in 2017, peaking in 2007 at 14.3 million tonnes. This period coincided with a marked rise in both economic output and car ownership levels with car ownership increasing by approximately 150% between 1990 and 2017 (from *c.* 800,000 to over 2 million cars). The growth of the economy between 1990 and 2007 was associated with significant growth in total employment and increased inward migration. This led to an increase in transport demand with more people and goods requiring greater movement.

The decrease in emissions over the years 2008 to 2012, which resulted in a reduction of *c.* 3.5 Mt CO_{2eq}, coincided with the significant economic downturn and consolidated by improvements in the energy efficiency of the national car fleet, further underpinned by changes to vehicle registration tax and motor tax introduced in mid-2008. In addition, the Biofuels Obligation Scheme was introduced in 2010, displacing a proportion of fossil fuel with a biofuel alternate. Interestingly, the largest fall in transport emissions was within the HDV sector, specifically in construction, with 1.6 Mt or 46% of the overall reduction. This coincided with a large decrease in employment in the *Building and Construction* occupational group (over 100,000 individuals between 2006 and 2011). There was a much smaller reduction in CO_2 emissions from the private car sector over this period (0.27 Mt or 7.7% of the total reduction), partly due to a rise in total annual vehicle kilometres for private cars of 10.7% between 2011 and 2015. Between 2013 and 2016, CO_2 emissions rose again, increasing by just less than 1 Mt.

Figure 3.3: Trends in economic and transport indicators in Ireland, 1990-2016



Source: CSO

Table 3.1 shows emissions from the various land transport sectors between 2012 and 2016, the period when transport emissions began to increase again following a decline during the economic recession. The data shows that private car emissions have increased moderately over this period (3%) but that the main sector that experienced growth in emissions was 'fuel tourism' (68% increase). Fuel tourism is the practice of purchasing fuel in one jurisdiction for use in another (e.g. purchasing fuel in the Republic of Ireland for use in the UK). The price differential of fuel purchased north and south of the border is driven by a number of variable factors including exchange rates and tax differentials. The HDV sector displayed the second largest increase in emissions over the time period 2012-2016 with 16% growth recorded. Conversely, both emissions from the public passenger (buses and coaches) and rail sectors fell by 10 and 21% respectively; collectively, over this period land transport emissions rose by 9%.

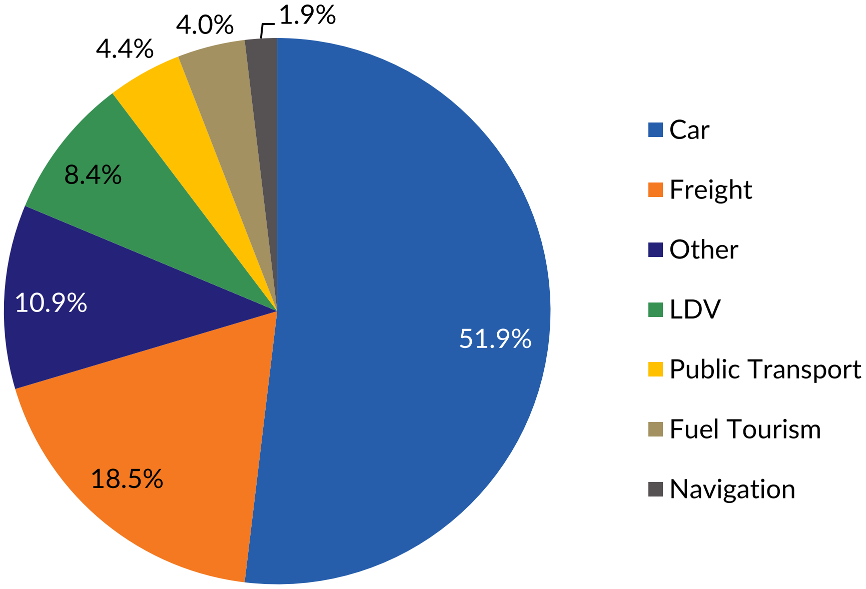
Table 3.1: Land transport CO_2 emissions, 2012-2016 (data excludes emissions from navigation, aviation and unspecified emissions i.e. emergency vehicles, diggers, lawnmowers etc.)

Sector (CO_2 kt)	2012	2013	2014	2015	2016	% Growth 2012 –2016
Fuel Tourism	680	624	869	1,396	1,142	68
HDV	1,881	1,726	1,838	1,851	2,189	16
LDV	927	958	972	971	958	3
Private car	6,006	6,130	6,283	6,273	6,199	3
Public Passenger	439	418	399	391	395	-10
Rail	142	137	126	129	112	-21
Total CO_2 (kt)	10,075	9,993	10,486	11,011	10,994	9

Source: Sustainable Energy Authority of Ireland (SEAI)

Figure 3.4 illustrates the breakdown of total transport emissions per mode in 2017; private car use dominated, accounting for over half of total transport emissions (51.9%); the freight sector was the second largest contributor (18.5% from HDVs and 8.4% from LDVs); collectively public transport (buses, taxis, rail) accounted for a little over 4.4% of emissions. In 2017, it is estimated that fuel tourism was responsible for around 4% of all transport emissions.

Figure 3.4: Transport CO_2 emissions per mode, 2017

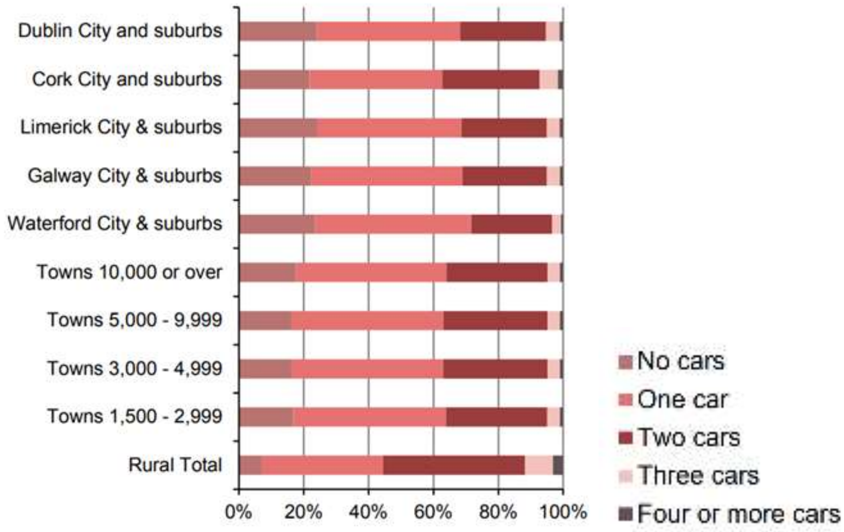


Data adapted from EPA and SEAI estimates

3.3 Private cars sector in Ireland

There are over two million private cars in Ireland accounting for 74% of all journeys taken; this figure rises to 81% for those journeys classified as originating in thinly populated areas. The total annual vehicle kilometre driven by car has increased by over 7% between 2011 and 2016. According to Census 2016 figures[39] car ownership among households is continuing an upward trend with nearly 77% of households in urban areas owning at least one car compared with 91% of households in rural areas (Figure 3.5). Rural households are also more likely to have two cars or more: 54.5% of car owning households in rural areas compared to 33% in urban areas. Ireland's dependence on the car is more pronounced outside Dublin where 76% of all journeys taken are by car compared to 54% of all journeys in Dublin; in addition, drivers in the Greater Dublin Area (GDA) on average make shorter trips than other parts of the country (17,304 kilometres compared to 19,206 kilometres in 2015).

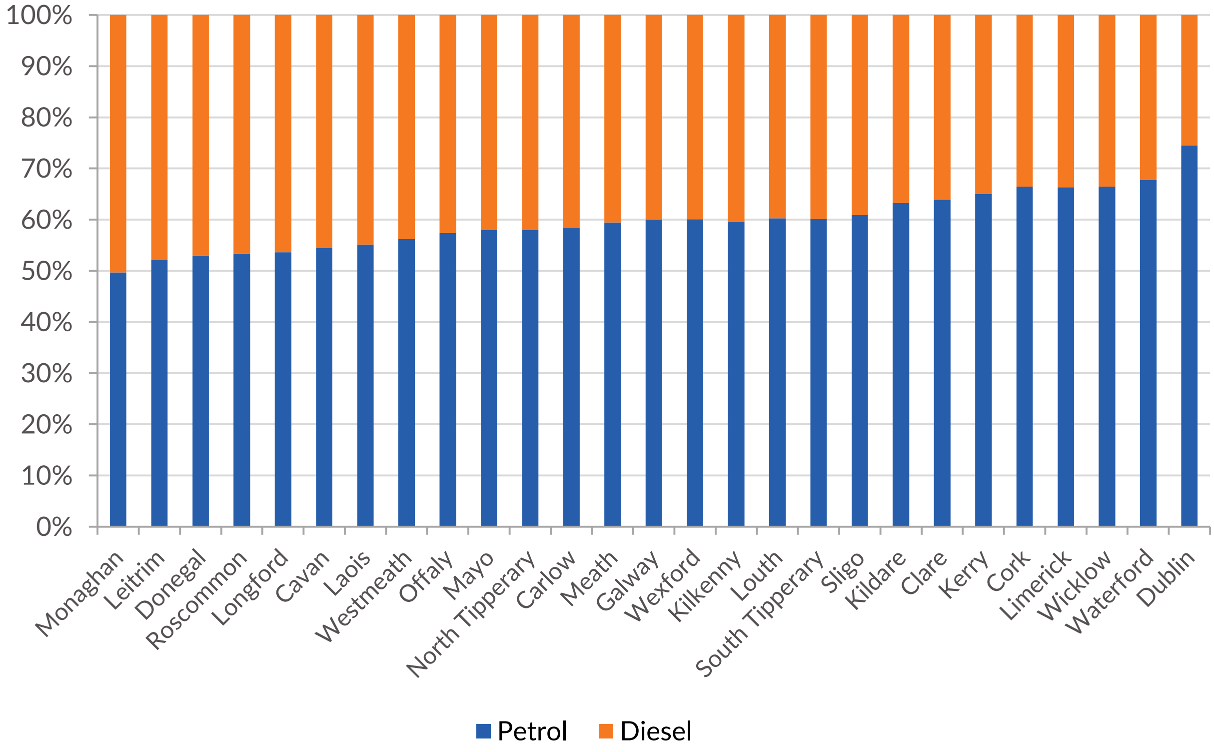
Figure 3.5: Car ownership by households by area type, 2016



Source: CSO

In 2017, petrol accounted for 46.6% of all private cars - a decrease of 4.4% from 2016 figures. In corollary, the proportion of the national car fleet fuelled by diesel increased by 4% to 51.8%. The dominance of diesel in the national fleet is continuing, in 2017 diesel accounted for over 65% of all new private cars sold; however, in 2018 diesel sales had fallen accounting for 54% of new car sales[40]. Figure 3.6 shows the significant proportion of diesel cars in rural counties in particular, most likely reflecting the fact that diesel cars are more economical to run over longer distances.

Figure 3.6: Private vehicles under current licence by fuel type in each licensing authority area

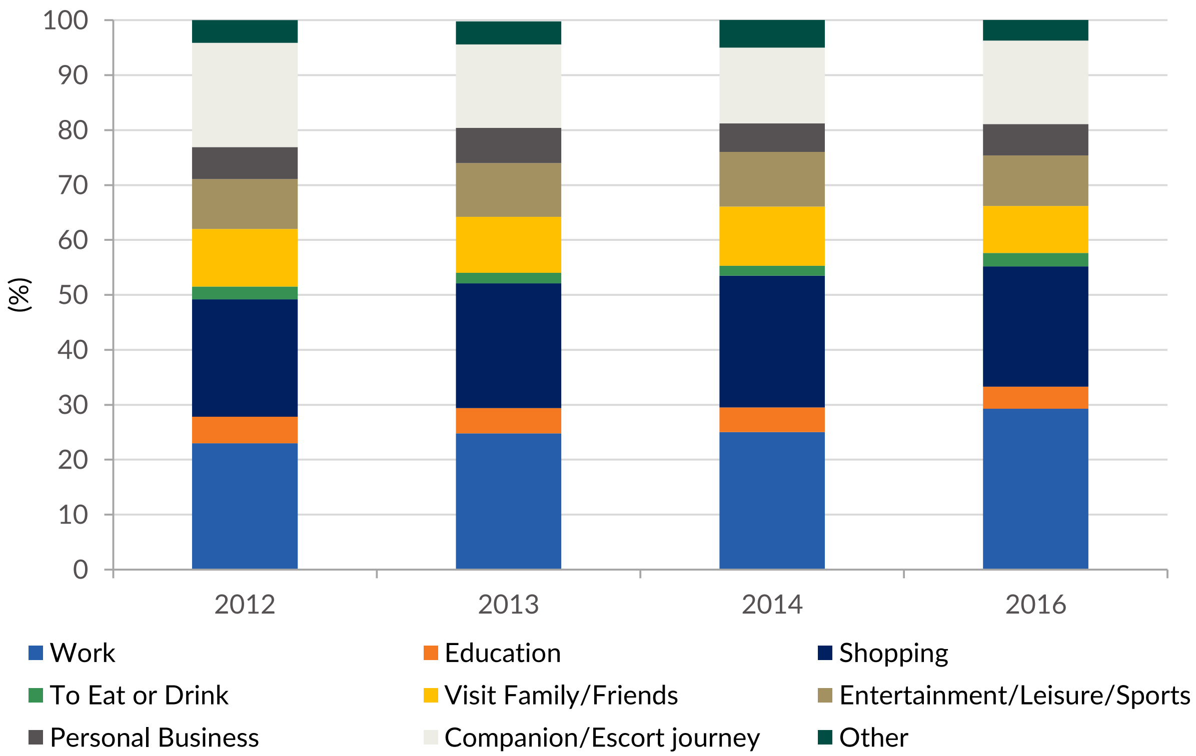


Source: Derived from CSO data 2016

*City & Councils

According to the National Travel Survey[41] journeys to work accounted for the largest share of all trips being made in 2016 at 29%; a 4% increase on 2014 figures (Figure 3.7). Shopping trips were the second largest category of journey types at 22% although it is important to note that education trips are currently under represented in the survey as respondents must be 18 years old or over. Also of note is the 5% increase in journeys of eight kilometres or more that were for the purpose of work between 2014 and 2016, illustrating a growth in commuting distances. Collectively shopping and commuter trips account for more than half of all car journeys; the predictable nature of these journeys may lend themselves to more sustainable alternatives such as active travel, car-pooling or public transport options.

Figure 3.7: Journeys by main purpose, 2012-2016

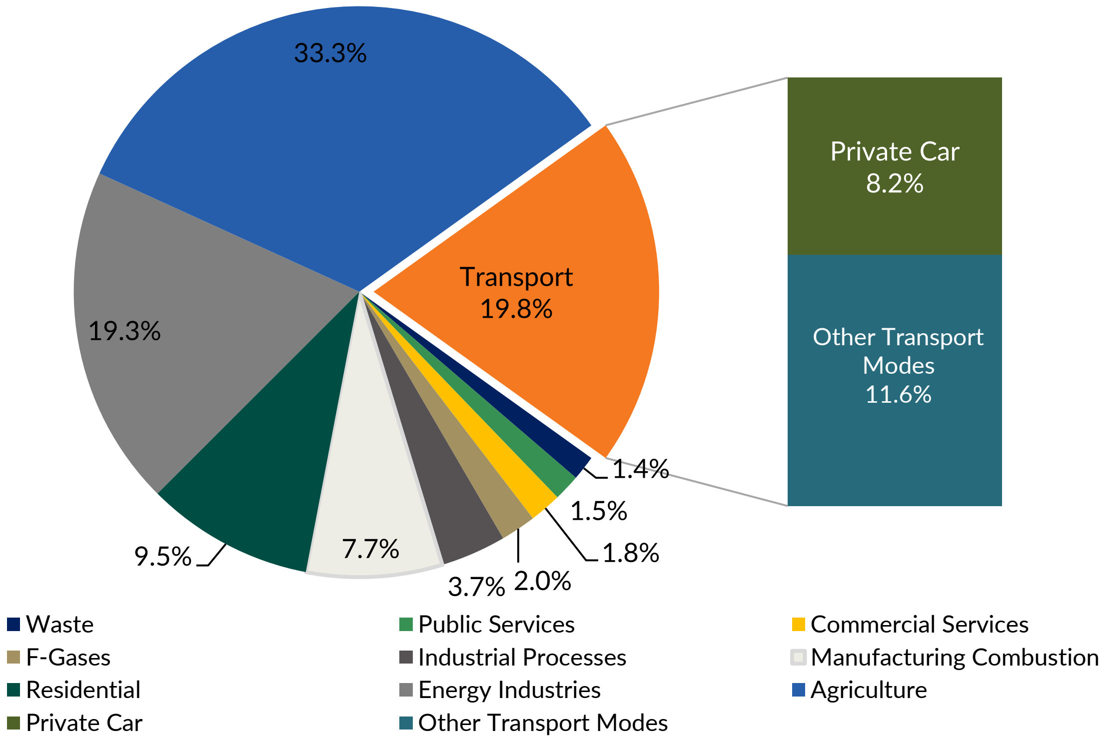


Source: CSO National Travel Survey 2016

3.3.1 Emissions profile

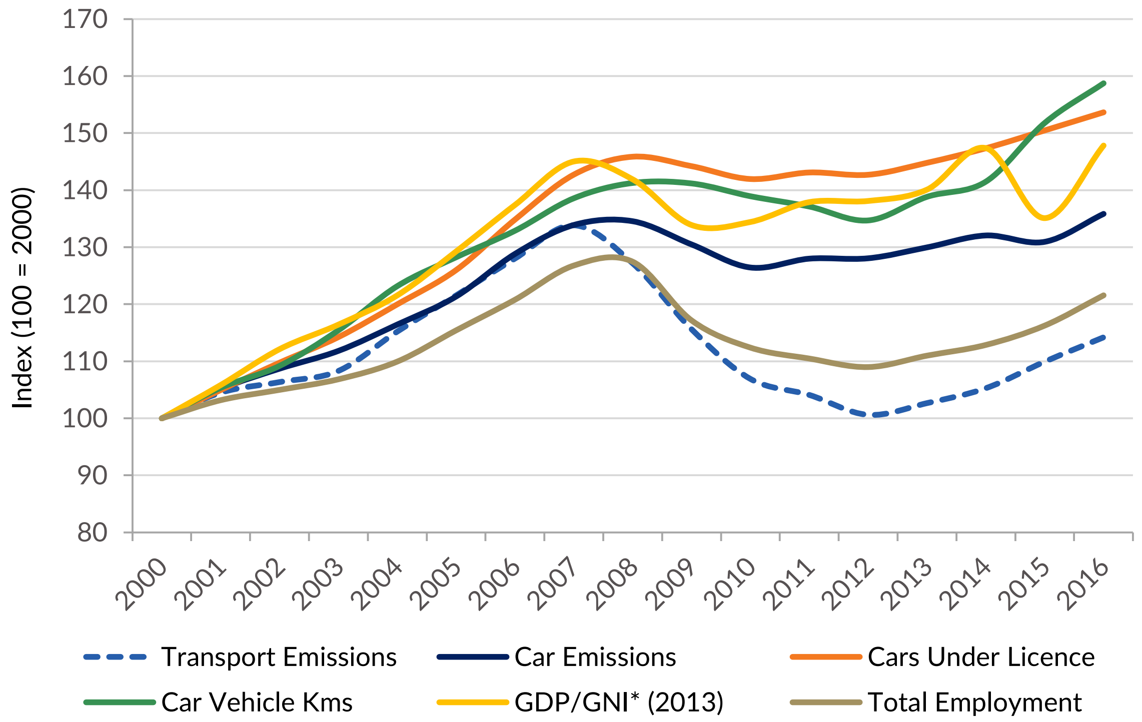
It is estimated that in 2017, the private car accounted for just under 52% of transport CO_2 emissions in Ireland and 8.2% of national non-ETS emissions (Figure 3.8). Economic growth, as measured by GDP, as well as vehicle kilometres has historically been a key driver for CO_2 emissions from private cars as Figure 3.9 illustrates; however, it is worth noting that since 2015 a divergence between car emissions and vehicle kilometres has been recorded, potentially due to increasing improvements in vehicle efficiencies.

Figure 3.8: Breakdown of non-ETS emissions per sector highlighting the contribution of the private car sector



Source: SEAI [42] and EPA[43]

Figure 3.9: Private car CO_2 emissions, 2000-2016



Source: CSO

Based on SEAI CO_2 emission data, it is estimated that the Greater Dublin Area (GDA) accounted for only a little over one third of the estimated private car emissions in 2017 (Table 3.2). While this analysis is very rudimentary, it does indicate that a strong focus on solutions that can address the needs of rural drivers is required if Ireland is going to successfully reduce national private car fleet emissions.

Table 3.2: Analysis of GDA versus non-GDA car emissions

County	Licenced Cars	Average Annual (km)	CO_2 Emissions (tonnes)**	% of CO2 Emissions
GDA*	839,542	16,187	2,310,292	36.6%
Non-GDA	1,239,803	19,028	4,010,452	63.4%

Source: Derived from CSO Transport Omnibus 2017 data

*Includes counties Dublin, Kildare, Meath, Wicklow plus Louth (Appendix 1)

**Based on average CO_2 emissions of 170g/km

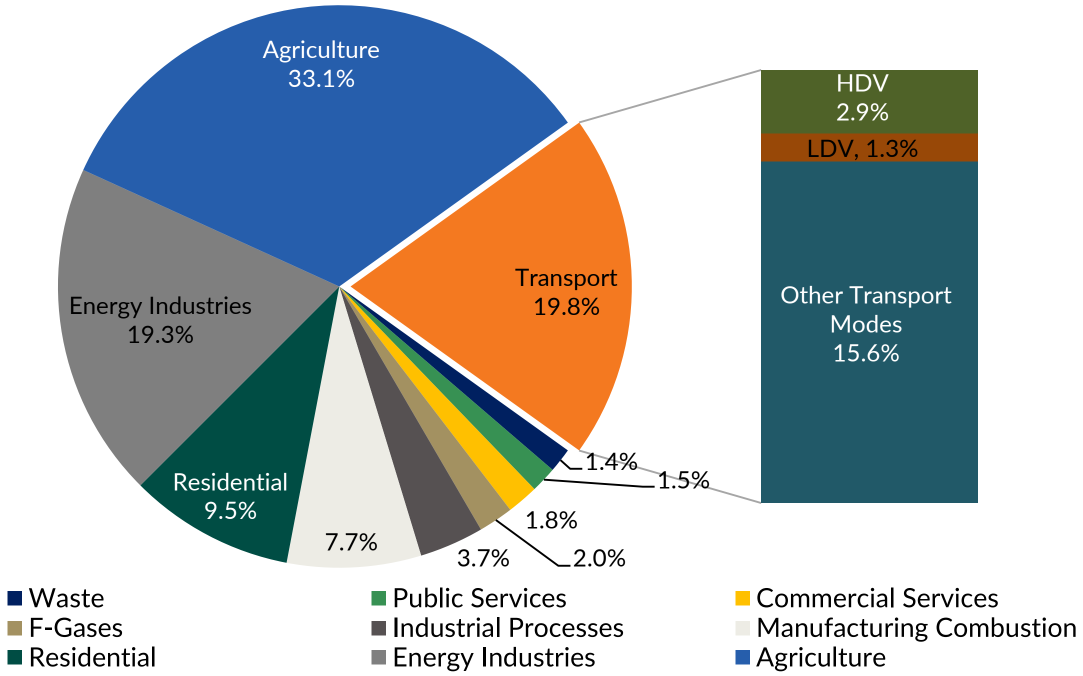
3.4 Light and heavy-duty vehicle sector in Ireland

At the end of December 2018, 355,273 goods vehicles were licenced in the State[33]. Approximately 89% of these were Light Duty Vehicle (LDV) and the remaining 11% were Heavy Duty Vehicles (HDVs). In recent years there has been a steady annual decrease in additional new goods vehicles being licenced with 28,051 new vehicles added to the fleet in 2016; 24,101 in 2017 and 13,014 in 2018; in contrast the number of second hand imports has risen. The levels of road freight activity are beginning to increase again following a sharp decline in 2007, rising from 9.7 billion tonnes-km in 2014 to 11.75 billion tonnes-km in 2017 (approximately 21% increase). In 2018, diesel accounted for 99.8% of the total fuel type for goods vehicles.

3.4.1 Emissions profile

It is estimated that in 2017 HDVs accounted for over 18% of total transport emissions and LDVs accounted for 8.4%, this represented approximately 2.9% and 1.3% of national non-ETS emissions respectively (Figure 3.10).

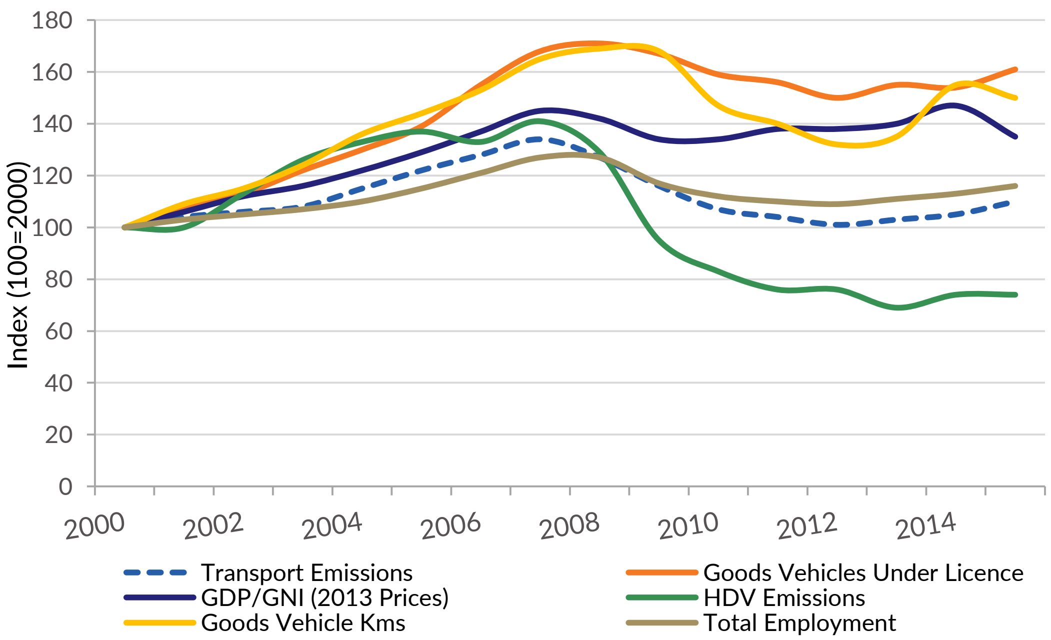
Figure 3.10: Breakdown of non-ETS emissions per sector highlighting the contribution of the freight sector, 2017



Source: SEAI and EPA

Figures reported by SEAI suggest that, in 2017, energy consumption increased by 1.6% and 4.8% in HDVs and LDVs respectively. Historically there has been a strong relationship between economic growth and emissions relating to the freight sector (Figure 3.11). Freight sector emissions experienced both the strongest increase and decline over the period 1990 to 2007 and from 2007 to 2015 respectively. The fall in transport emissions post 2007 was considerably sharper than the contraction of the economy itself and was driven primarily by a decrease in HDVs road freight and construction sectors which fell by 46%.

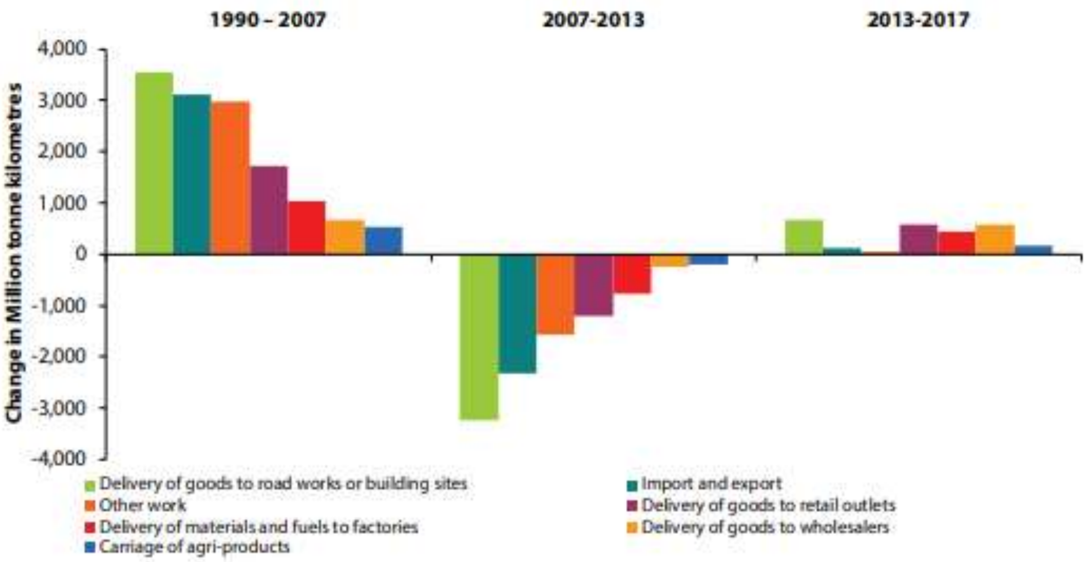
Figure 3.11: Road freight CO_2 emission, 2000-2016



Source: Derived from CSO and SEAI[40]

Figure 3.12 highlights the categories which contributed most significantly, in absolute terms, to changes in freight activity. The *Delivery of goods to road works or building sites* category experienced the largest absolute (3,545 Mtkm) and second largest percentage (521%) increase between 1990 and 2007; and subsequently both the largest absolute (3,261 Mtkm) and percentage (77%) decrease between 2007 and 2013. This category also increased by 51% from a low base between 2013 and 2017. The correlation between freight emissions and the construction industry represents a considerable challenge for policy makers balancing the need to support construction activities for housing and enterprise without significantly increasing associated transport emissions.

Figure 3.12: Absolute change in road freight activity by mode of work done, 1990-2017



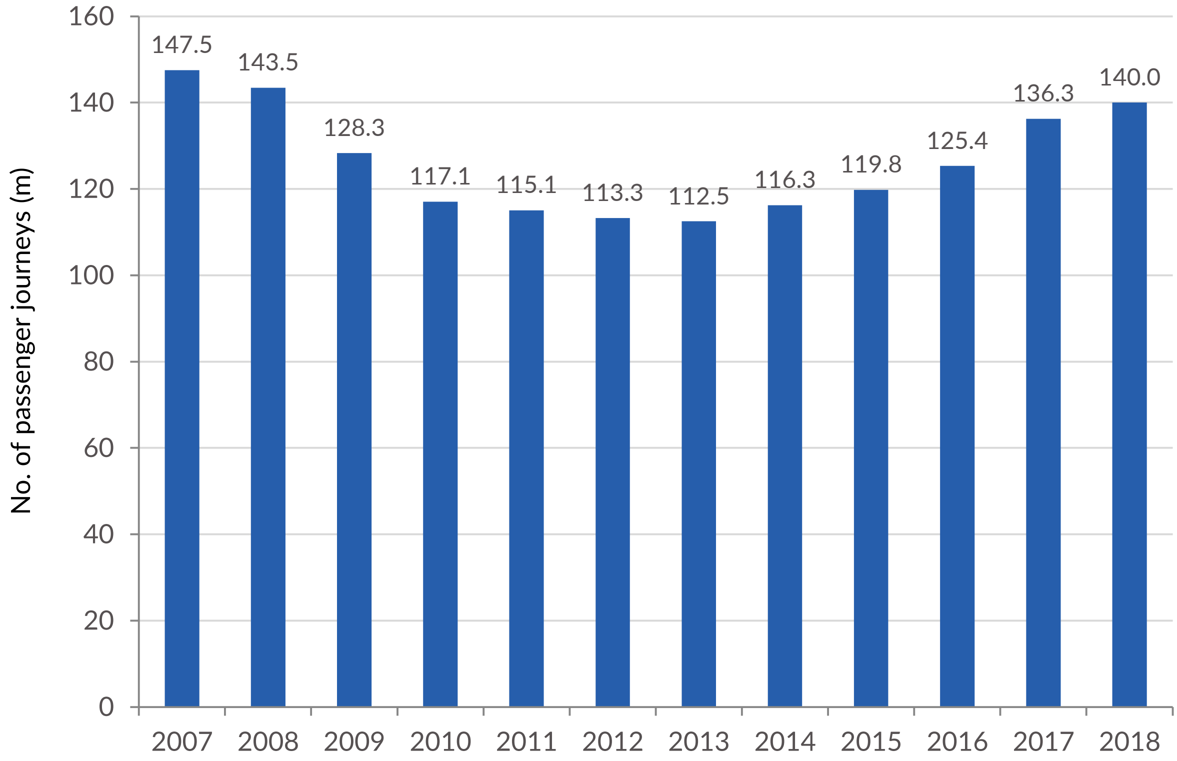
Source: SEAI

3.5 Public transport sector in Ireland

The total number of passengers travelling on subsidised Public Service Obligation (PSO) public transport services has grown each year since 2012. In 2018, the number of passengers using these services increased to over 268 million, a 28% increase on 2012 figures[44]. According to the National Travel Survey 2016, travelling by public transport accounted for 5.5% of all journeys taken nationwide in 2016.

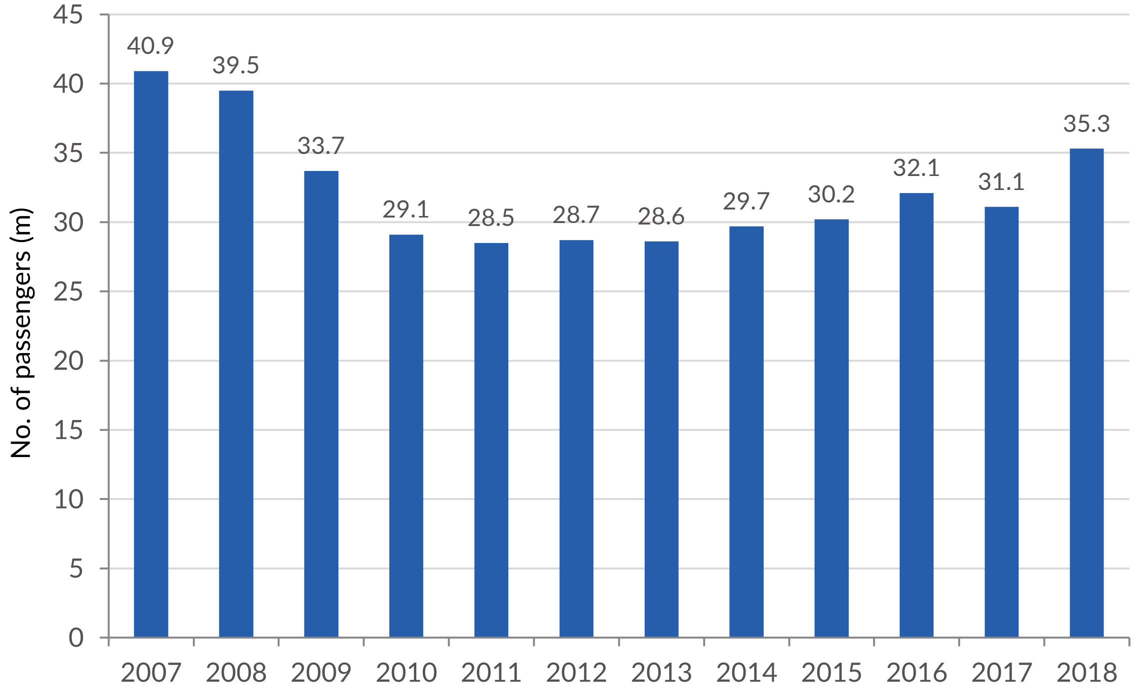
Bus services form the backbone of the Irish public transport system. The number of bus passenger journeys (on Dublin Bus and Bus Éireann PSO services) have followed the established transport demand trend; declining after 2007 followed by renewed growth in recent years (Figure 3.13 and Figure 3.14). Data available for PSO services also shows annual increases in passenger numbers for both Dublin Bus (140 million) and Bus Éireann (to 35 million) in 2018.

Figure 3.13: Dublin Bus passenger journeys, 2007-2018



Source: NTA Bus and Rail Statistics

Figure 3.14: Bus Éireann passenger journeys, 2007-2018

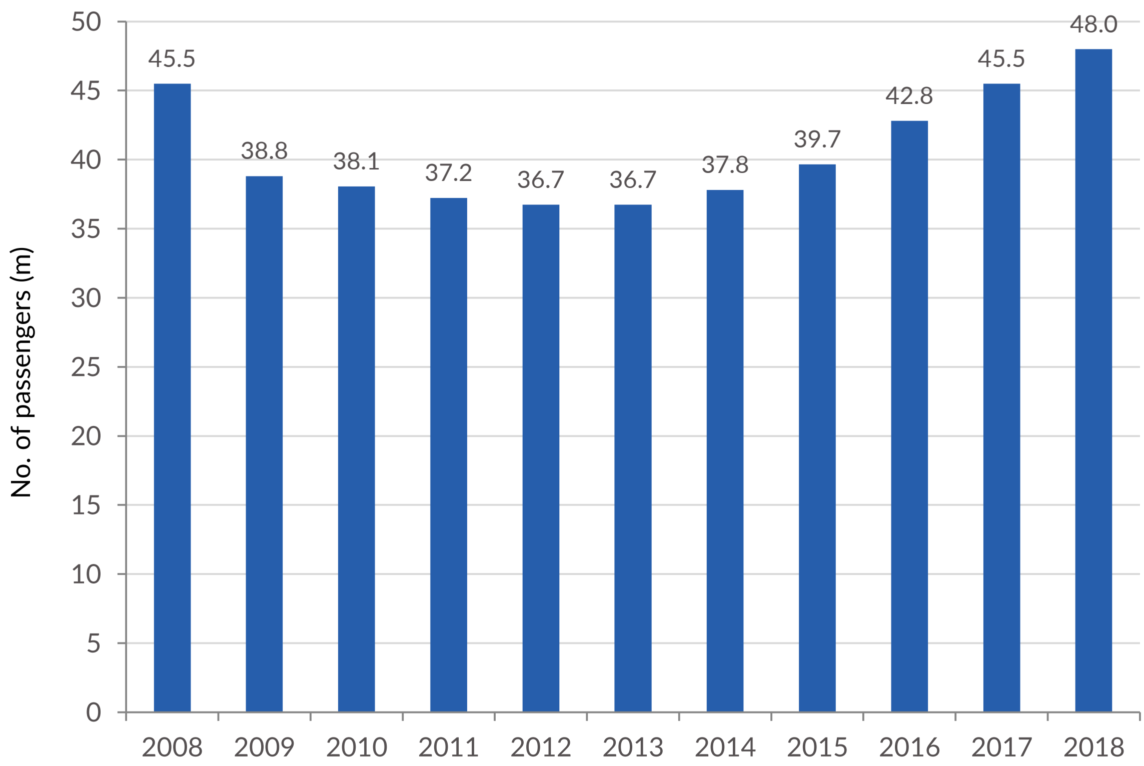


Source: NTA Bus and Rail Statistics

The total number of heavy rail passengers fell from 44.7 million in 2008 to 36.7 million in 2013. Recent years have however seen a renewed growth in rail passengers (Figure 3.15). Data for 2018 indicate heavy rail usage has increased above pre-recession levels transporting 48 million passengers; the greatest increase was seen on DART services. The introduction of new services, such as those through the Phoenix Park Tunnel has also helped passenger numbers continue to expand.

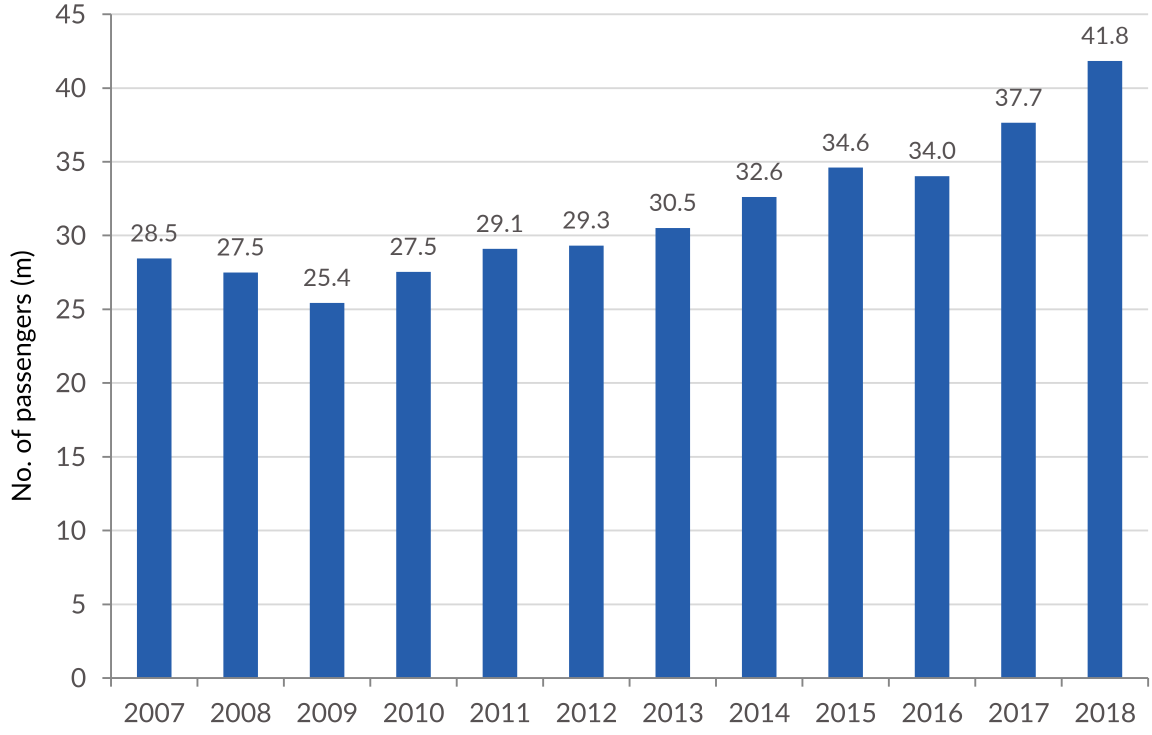
Since 2009, the Luas has experienced consistent growth in the number of passengers using the service until 2016 where numbers fell by 1.4%, or 500,000 passengers in comparison to 2015 (Figure 3.16); this dip was attributed to 12 days of industrial dispute when the tram service was not operating. Numbers on Luas returned to growth in 2018 to 41.8 million.

Figure 3.15: Heavy rail passenger journeys, 2008-2018



Source: CSO and NTA Rail Statistics Bulletin

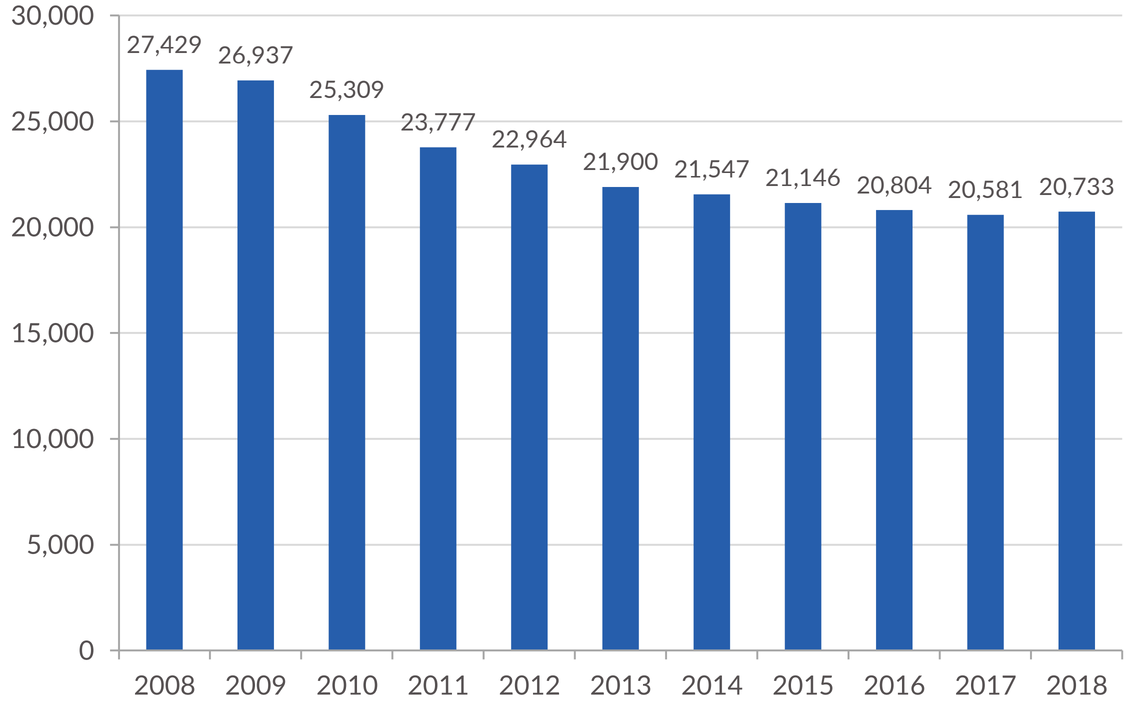
Figure 3.16: Light rail passenger numbers, 2007-2018



Source: NTA Bus and Rail Statistics Bulletin

Small Public Service Vehicles (SPSVs) (taxis, hackneys and limousines) are also considered part of the public transport sector. Figure 3.17 illustrates trends in SPSV use in Ireland where the total number of SPSVs in the Irish fleet has declined by 32% from the peak of 2008 (27,429) to 2018 (20,733). About half of these licenses are based within Dublin.

Figure 3.17: Valid SPSV vehicle licenses, 2008-2018

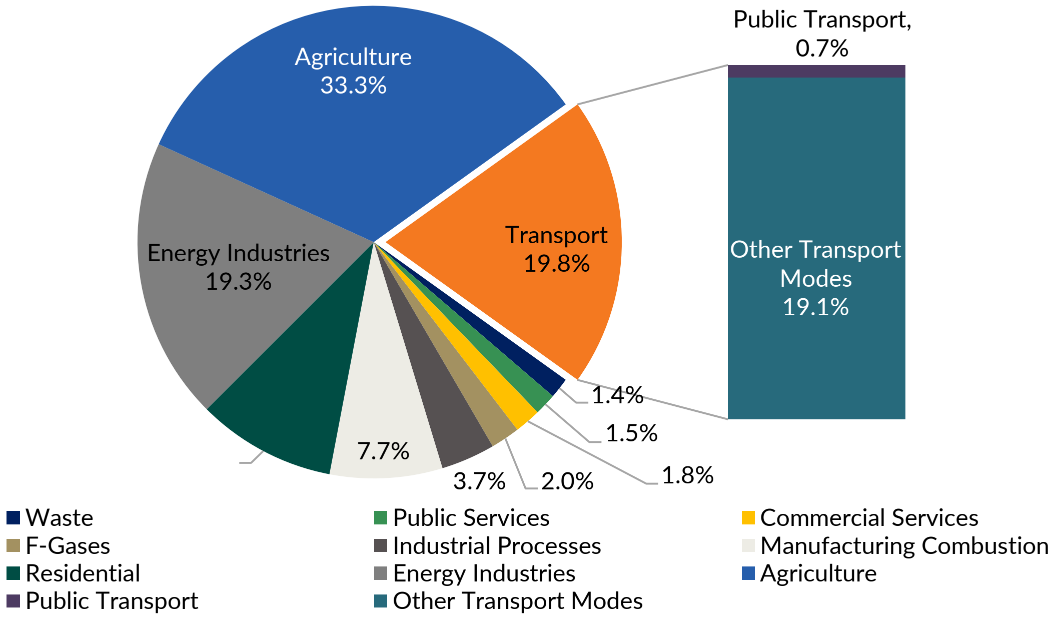


Source: NTA statistics

3.5.1 Emissions profile

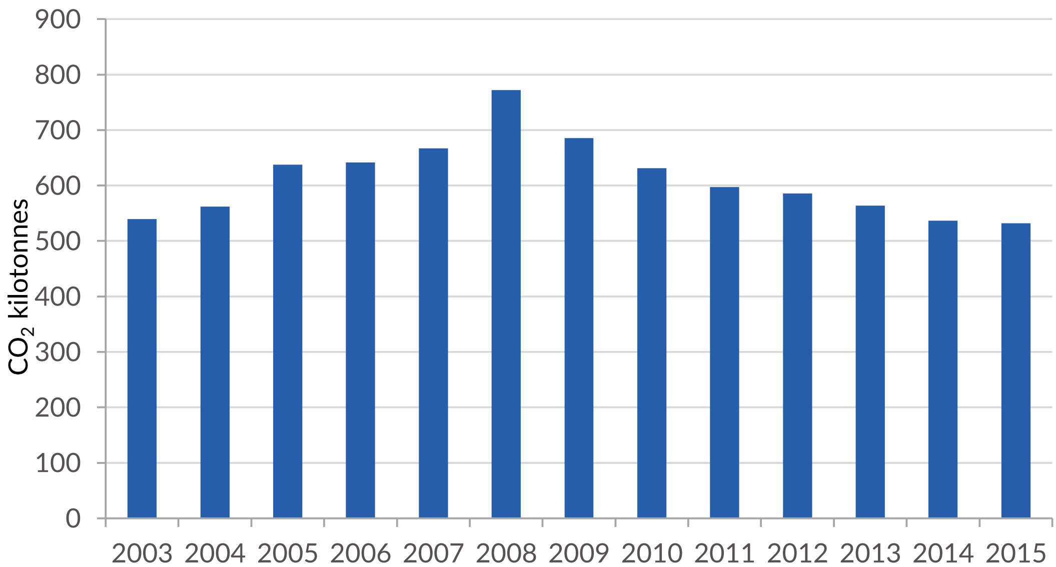
Public transport emissions only accounted for an estimated 4.4% of total land transport emissions in 2017, representing less than 1% of the national non-ETS emissions (Figure 3.18). The majority of these emissions arose in the *Public Passenger* category (3.4%) which includes bus, coach and SPSV journeys. The rail sector accounts for the remaining 1%. Emissions from public transport follow the familiar trend (Figure 3.19), peaking in 2008 at over 770 kilotonnes of CO_2 followed by a steady decrease until 2015. In 2015, it was estimated that CO_2 emissions from the SPSV sector amounted to 112 kilotonnes based on an assumption of an average annual vehicle kilometres of 38,000. This equates to 28% of total public passenger emissions.

Figure 3.18: Breakdown of non-ETS emissions per sector highlighting the contribution of the public transport sector, 2017



Source: SEAI and EPA

Figure 3.19: Estimated CO_2 emissions (kilotonnes) from the public transport sector, 2003-2015



Source: Data extrapolated from SEAI figures

4 Challenges facing the transport sector

This Section outlines the main challenges in addressing climate change and reducing emissions that are specific to the transport sector.

4.1 Increasing travel demand

Transport demand is derived and largely dependent on the level of activity within the economy. Ireland's climate commitments are set against a welcome return to economic growth, which coupled with a dispersed demographic and raising population, will add significantly to transport demand pressures. The transport system is expected to respond to this additional need whilst remaining cost competitive for businesses as well as addressing the related congestion, climate mitigation and air quality concerns. As such, developing cost-effective mitigation measures for the transport sector is challenging.

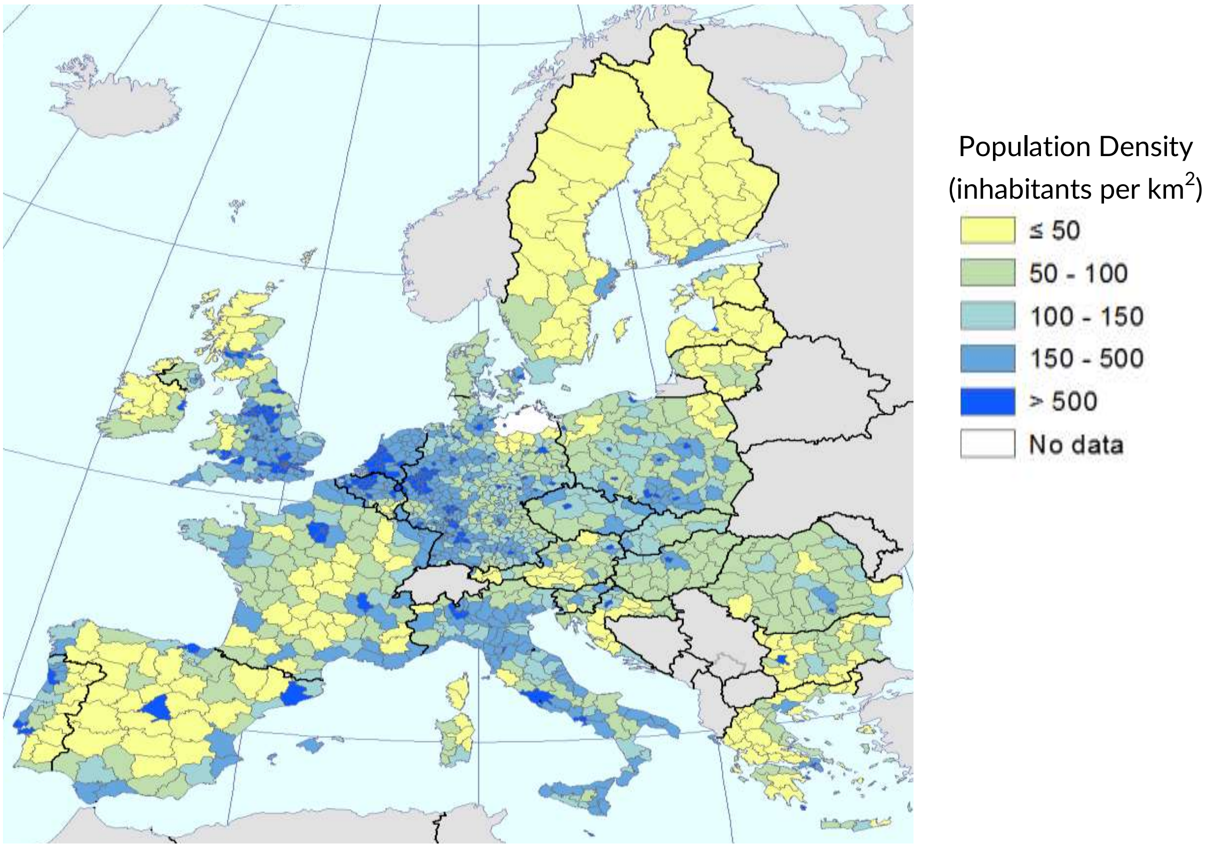
4.2 Settlement patterns and land use planning

Settlement patterns play a fundamental role in influencing how people travel, both the distances undertaken and the modal choice. The provision of sustainable mobility options is only realistic when development patterns locate populations close to employment centres and complementary services such as education, retail and leisure. Walking and cycling, in particular, become increasingly viable as transport options when the distance between such services is reduced.

Ireland also has a relatively low population density with 70 persons per square kilometre compared to 117.7 for the EU-28 (Figure 4.1)[45]. Such settlement patterns give rise to dispersed journeys for which public transport provision is not always feasible. The net result is a higher dependence on private car use and longer journeys compared with more densely populated urban settlements.

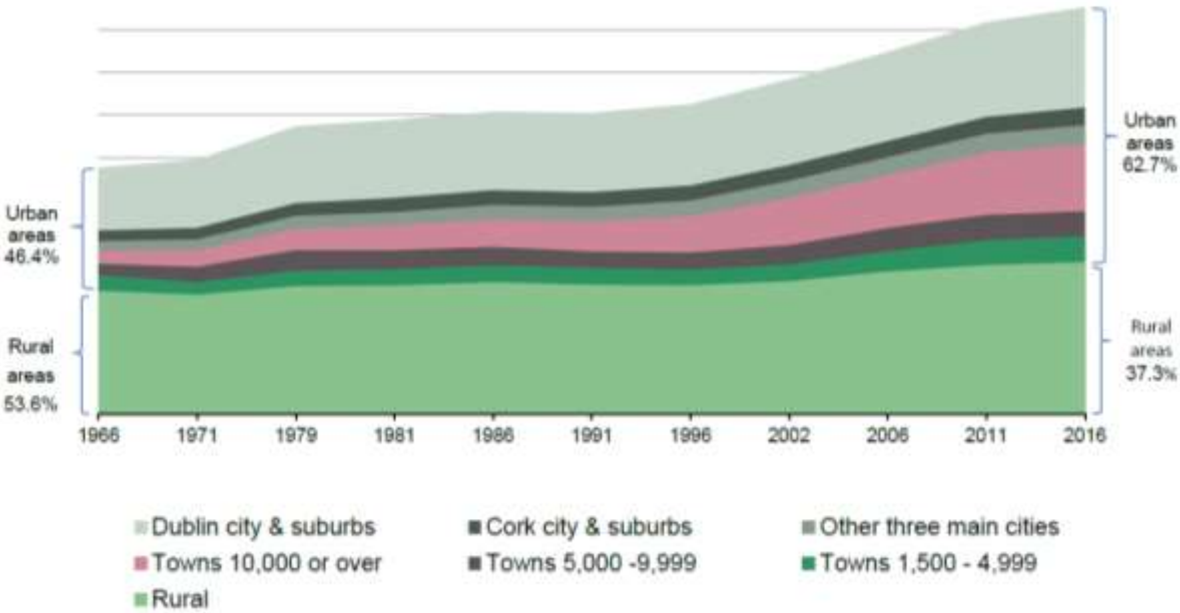
Land use and transport planning are inherently linked and mutually reinforcing. Instances where this linkage has not been optimally recognised have contributed to legacies of dispersed suburbanisation and one-off housing, associated with increased travel demand. Dispersed settlement patterns pose substantial challenges in terms of the provision of effective public transport services or suitable active travel networks leading to a greater dependence on private car use. As illustrated in Figure 4.2, Ireland has seen an urbanisation trend over the last 50 years, but the greatest absolute increase in the population has been in the large towns instead of cities or suburb centres. In 1966, 1 in 10 people in urban areas lived in large towns, compared with more than 1 in 4 in 2016. Likewise, in 1966 Dublin city accounted for over half the urban population of the country with 51% of urban dwellers living there; in April 2016 this had fallen to 39%.

Figure 4.1: Population density (persons per square km), 2015



Source: Eurostat[46]

Figure 4.2: Urbanisation trend in Ireland, 1966-2016



Source: CSO Census 2016

The *National Planning Framework* (NPF) provides guidance to ensure that the climate implications of spatial choices are fully considered and aligned with the national objective to transition to a low carbon economy. Implementation of the *NPF* will support more efficient patterns of development thus reducing travel demand; meaningful public and active transport networks can be provided and greater levels of modal shift can be promoted.

4.3 Dependence on technology and wide-spread behavioural change

Technology will undoubtedly offer one of the most cost-effective and feasible pathways to achieving emission reductions in the transport sector. Ireland does not have a vehicle manufacturing industry and as such is wholly dependent on the speed and direction of technology developments from elsewhere to realise emissions savings in the national vehicle fleet. EU regulations on vehicles emissions have been very beneficial in reducing Irish emissions. Data reported in the *NMP* estimates that technological efficiency improvements in vehicles will save over 12,000ktCO_{2eq} between 2017 and 2030.

Alongside technological developments, behavioural change amongst motorists will be critical in reducing emissions in the transport sector. Many mitigation measures are dependent on modal shift or a change in the fuel and/or technology currently employed to meet travel demands. It is critical to develop a better understanding of the important role that behavioural economics and psychology play in decision making to facilitate a greater uptake of energy efficient or sustainable mobility options. Normalising new technologies and addressing consumer concerns will be required to accelerate the mitigating impact that alternative fuels and technologies can potentially have.

4.4 Energy security

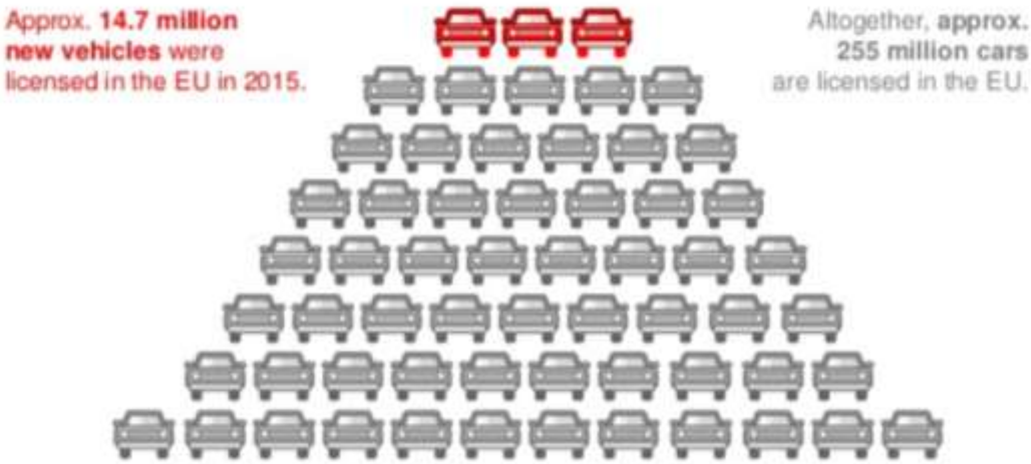
The use of fossil fuels is firmly embedded in the driving culture of Ireland. Diesel is the dominant fuel, accounting for 58% of all energy use in transport. From an energy security perspective the very high dependence on oil is not desirable and greater diversification of fuels is required[47]. Such diversification could be achieved by increasing indigenous renewable electricity, biofuel and biogas production.

4.5 Vehicle turnover rates

Vehicles are long-lasting assets with slow replacement rates; the average age of an Irish car in 2017 was 8.62 years for original vehicles and 9.02 years for imported vehicles. Only *c.*5% of the EU vehicle fleet is replaced annually[48] (Box 2). The increasing durability of vehicles negates rapid fleet replacement, consequently the emission reduction benefits of new vehicle and improving vehicle emission standards will likely take over a decade to be fully achieved. Measures to modernise the legacy fleet will therefore be needed and must work in tandem with mitigation measures aimed at new vehicles in order to successfully decarbonise the entire transport sector.

Box 2: Legacy Fleet

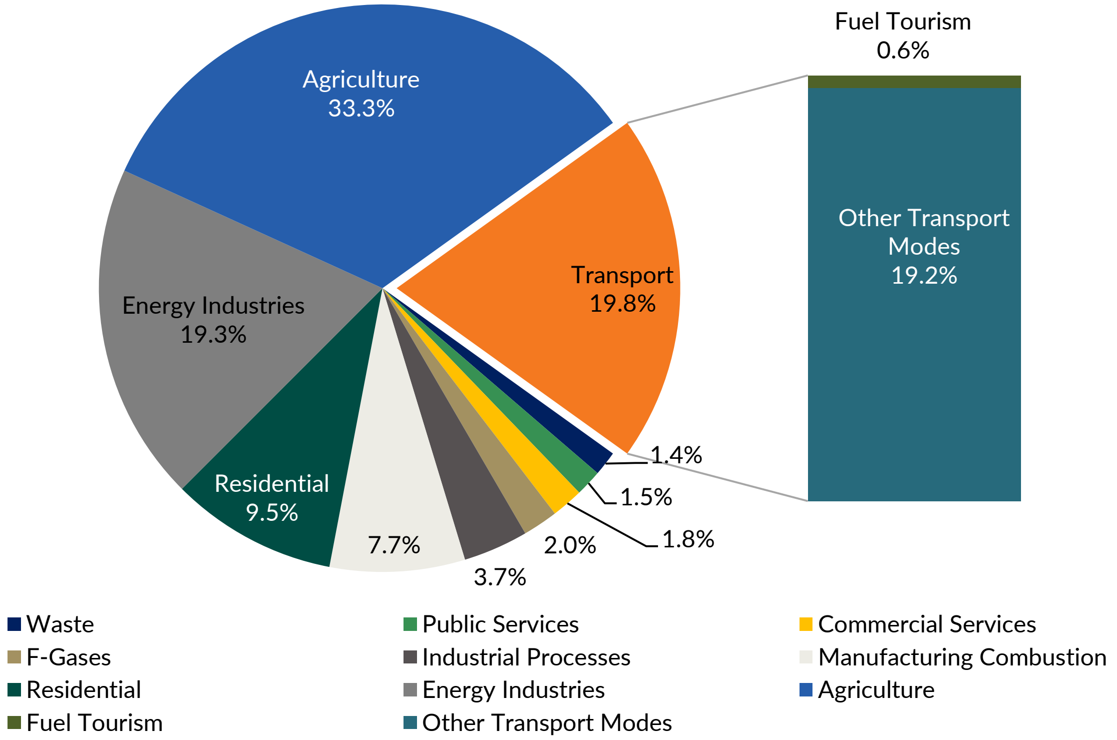
There were approximately 255 million cars licensed in the EU in 2015; only c.5% (14.7 million) of this fleet was new. The majority of vehicles form the 'legacy' fleet. Mitigation measures aimed at limiting emissions from older vehicles, through for instance scrappage programmes, retrofits or upgrades, should be considered for reducing emissions in the short to medium term.



4.6 Fuel tourism

The growth in Irish transport emissions since 1990 has, in part, been due to the changed pattern in fuel tourism. Fuel tourism is the practice of purchasing fuel in one jurisdiction for use in another. In 2017, it was estimated that fuel tourism accounted for 4% of transport emissions, representing nearly 0.6% of national non-ETS emissions (Figure 4.3). Estimates suggest that between 2017 and 2030, the elimination of fuel tourism could lead to a reduction of up to 13,000 ktCO_2eq. In examining the feasibility of fuel price equalisation across the border in order to reduce, if not to eliminate fuel tourism, it is clear that the role of exchange rate movements and the potential impact of Brexit add considerable complexity. It is important to note that an approach involving a price equalisation model secured through taxation would increase fuel cost to consumers nationally.

Figure 4.3: Breakdown of non-ETS emissions per sector highlighting the contribution of fuel tourism, 2017



Source: SEAI and EPA

5 Current measures that reduce transport emissions

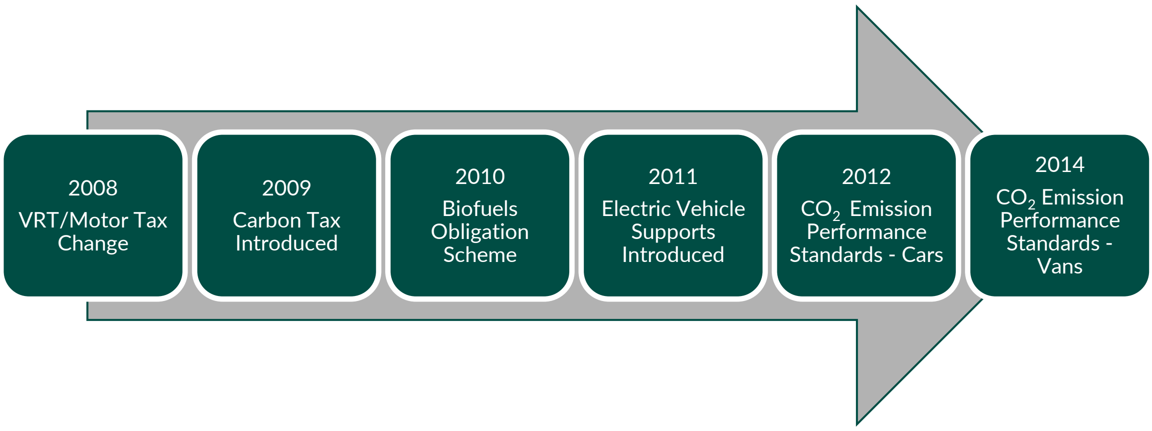
This Section focuses on the policy interventions and incentives that have been successfully implemented to date to reduce emissions from the Irish transport sector.

5.1 Introduction

The *European Strategy for Low-Emission Mobility*[49] states that in order to meet the EU's commitments under the *Paris Agreement*, decarbonisation of European transport sectors must be accelerated and should be firmly on the path towards zero-emissions by mid-century. Moving to a low carbon society represents a significant challenge for Ireland's expanding transport sector where the use of fossil fuels and individual travel patterns are firmly established. Decoupling growing transport demand and subsequent emissions from economic growth and activity remains a major issue; projections indicate that without additional policy intervention transport emissions are likely to rise by 11% over the period 2018-2030. This is largely driven by a projected rise in population and employment resulting in increased travel demand and a greater number of trips.

Decarbonising transport will require a significant step-change in how people travel, do business and the types of fuels and technologies they employ. Pursuing a low carbon vision for transport will not only contribute to achieving Ireland's climate change commitments but can also deliver benefits, such as, improved energy security, economic opportunities from renewable and indigenous fuels, and co-benefits in the areas of health, lifestyle, travel costs, local environment and air quality. A number of successful measures have already been introduced to reduce transport emissions (Figure 5.1).

Figure 5.1: Timeline of key transport mitigation measures



5.2 Investment in sustainable mobility and promoting modal shift

Private car use is the leading mode choice in Ireland with 74% of all journeys being taken by car. Where feasible, promotion of meaningful alternatives to the car is essential; therefore, in 2018 alone nearly €400 million was invested in sustainable mobility infrastructure with close to an additional €300 million for its operation. Under *Project Ireland 2040*, €8.6 billion will be invested in sustainable mobility infrastructure for the period 2018-2027. In 2018, sustainable mobility (public transport, walking or cycling) accounted for over almost 70% of all journeys into Dublin at peak morning times, this figure has increased dramatically from 59% of journeys in 2010[50]. Census results indicate that cycling to work has shown the largest percentage increase (42.8% over five years).

In the short term, projects such as *Luas Cross City* and the *10-minute-DART* are helping cater for some of the increasing demand on the transport network. In the medium- and longer-term the completion of the *City Centre Re-signalling Programme*, the new *National Train Control Centre*, the *DART Expansion Programme*, the *MetroLink* and *BusConnects* will all greatly enhance the capacity of the public transport system and will provide viable alternatives to private car use.

Modal shift away from private cars is also being encouraged through a variety of mechanisms, including:

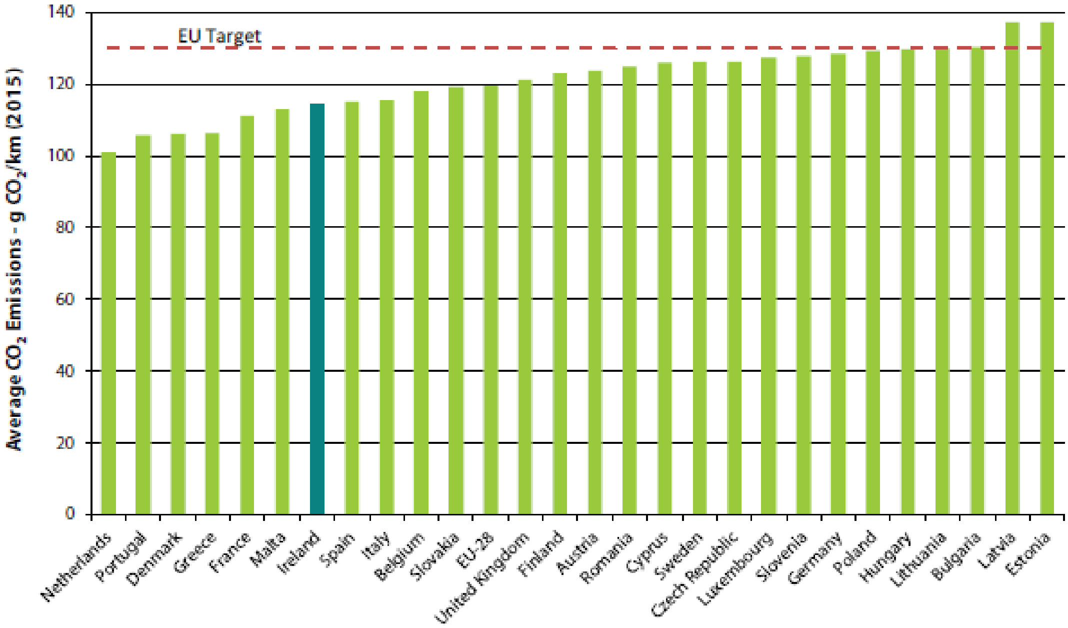
- tax incentives such as the *Cycle to Work* and *Taxsaver* Schemes to promote active and public transport commuting;
- the *Green Schools Travel Programme* which seeks to increase the number of students walking, cycling, scooting, using public transport or carpooling to school. According to 2016 CSO figures, the car remains the main means of travel for primary school students with 327,039 children (6 out of 10) being driven to school in 2016; and
- *Cycle Right*, a national cycle training standard which was launched in 2017 and aims to develop sustainable travel habits early in life.

5.3 Implementing EU regulations

EU legislation sets mandatory emission reduction targets for all new passenger cars registered in the EU; this measure has greatly increased the availability of lower emission vehicles in the Irish market. The legislation is the cornerstone of the EU's strategy to improve vehicle fuel economy and has driven car manufacturers to develop innovative energy efficient technologies. The regulation requires that the fleet average emissions from new cars registered in the EU will be less than 95g CO_2/km by 2021, representing a CO_2 reduction of 42% compared with the 2007 new passenger car fleet average of 164g CO_2/km. Similar targets have been set for new light commercial vehicle fleets with a requirement that new vans registered in the EU will not emit more than an average of 147g CO_2/km by 2021 (19% less than the 2012 average). The successful implementation of these regulations in the short term is fundamental in moving the transport sector towards decarbonisation. In the medium to longer term, the EU has also set regulations that will ensure that by 2025 and 2030 the average emissions from new cars will be 15% and 37.5% lower respectively compared to 2021 levels; similarly emissions from new vans will be 31% lower by 2030 than 2021 levels.

New cars entering the fleet are now approximately 25% more energy efficient than they were in 2007. Emissions from new cars sold in Ireland fell from 164g CO_2/km in 2007 to *c.* 112g CO_2/km by 2016. Figure 5.2 shows the average CO_2 emissions from new cars across the EU in 2015; Ireland is ahead of both the EU target of 130g CO_2/km and the average emissions from new car sales in many other EU Member States (EU28 average in 2016 was 118.1g CO_2/km).

Figure 5.2: Average CO_2 emissions of new passenger cars by Member State, 2015



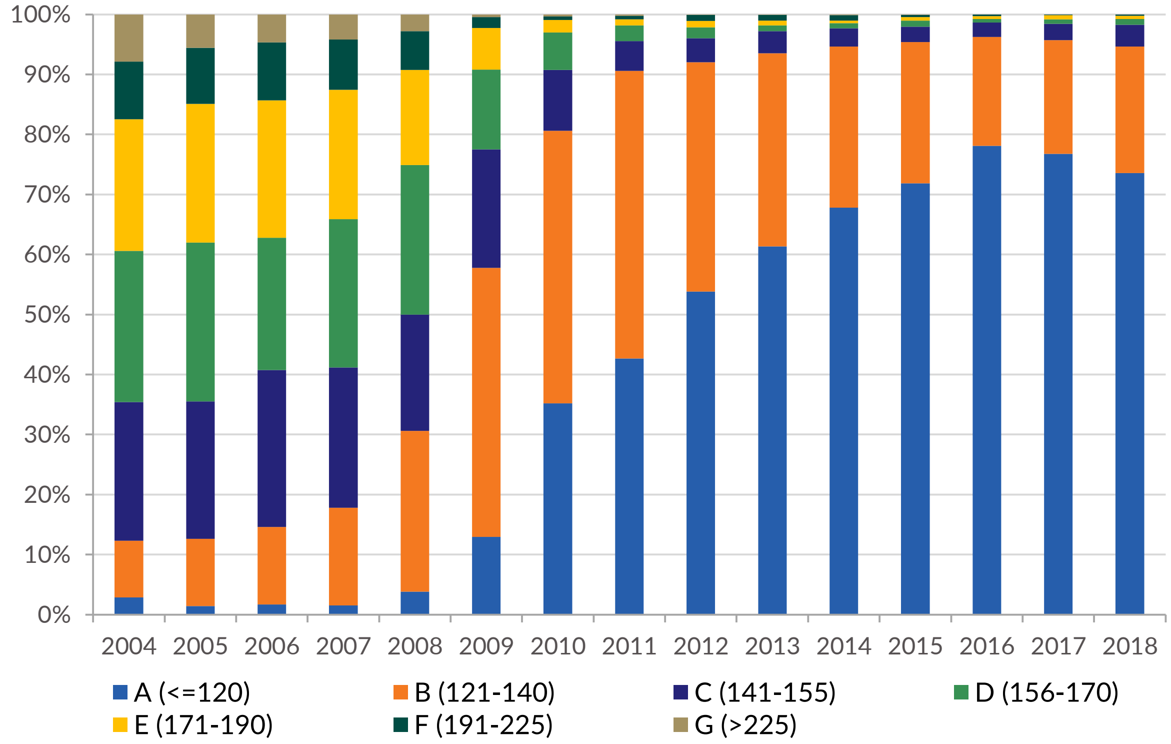
Source: EEA[51]

In addition, new EU regulations will come into force from 2020 onwards that will permit the setting of maximum new HDV fleet emission averages and thereafter progressive emission reduction standards. In essence, fleet average CO_2 emissions from HDVs will be obliged to be 15% lower by 2025 and by 30% lower by 2030 compared to a reference period of July 2019 to June 2020.

5.4 Rebalancing vehicle registration tax (VRT) and motor tax

The vehicle registration and motor taxation systems in Ireland were changed in July 2008 to be based upon CO_2 emissions rather than engine size[52]. The tax changes had an immediate effect in changing buyer behaviour, encouraging the take up of low CO_2 emitting vehicles. Initially, vehicles were categorised into seven graduating bands, A to G, with those choosing to purchase lower-emission vehicles paying less in VRT and motor tax. Since January 2013, a revised banding structure was introduced, splitting the lowest CO_2 Band 'A' (1 - 120g/km) into four new bands and Band 'B' (121 - 140g/km) into two new bands. A zero emissions band for electric vehicles was also introduced for motor tax purposes only. There has been a marked change in the proportion of new cars purchased within the lower emission band as shown in Figure 5.3; new private cars sold in the 'A' emission band rose from 1.5% in 2007 to 77% in 2017. Cars with CO_2 emissions of 140 g/km or higher now comprise just 4% of new car purchases.

Figure 5.3: Share of new private cars in each emissions band, 2004-2018



Source: *Transport Trends*[53]

Rebalancing the motor tax and VRT regimes has ensured that technological improvements are impacting more rapidly on the composition of the national car fleet compared to an alternative taxation system based on engine size. The net effect has been to accelerate the reduction of carbon emissions through significant fuel and energy savings over the lifetime of each vehicle. The rebalancing has proved a very effective means of influencing purchasing decisions; however, the impact of the measure was somewhat curtailed initially due to the marked decrease in new car sales during the recession.

5.5 Carbon Tax

Carbon pricing has the potential to reduce fossil fuel consumption and increase improved energy efficient practices. A carbon tax was introduced in Budget 2010, at a level of €15 per tonne of CO_2 emitted[54]. This tax applies to both petrol and diesel, representing an increase of €0.042 and €0.049 per litre respectively. In Budget 2012, this level was increased to €20 per tonne of CO_2 emitted[55] resulting in price increase relative to the baseline of €0.014 per litre for petrol and €0.016 per litre of diesel. Budget 2020 introduced a further increase on the rate of carbon tax from €20 per tonne to €26[56]. The impact of carbon tax on fuel efficiency is difficult to singularly assess; however, research suggests that fuel prices play an important role in reducing long-term fuel demand and consequently emissions.

Under the *Climate Action Plan*, a commitment to implement a carbon tax rate of at least €80 per tonne by 2030, accompanied by a trajectory of increases over successive annual Budgets was made. While decisions on the timing of the introduction of new carbon tax rates will be taken in a budgetary context, this commitment is a strong signal for timely investments in low-carbon alternatives, where possible. Furthermore, the *Public Spending Code*[57] is being reviewed to ensure that the shadow price of carbon is appropriate and suitably reflects the long-term nature of climate change-related costs.

5.6 Promoting new technologies and fuels

Public and active transport are not always viable travel options, particularly in rural areas; a transition to alternatively fuelled vehicles will be required to affect a substantial national reduction in transport emissions. Ireland's *National Policy Framework* on *Alternative Fuels Infrastructure for Transport in Ireland: 2017-2030* sets an ambitious target that from 2030 all new cars and vans sold in Ireland will be zero emission (or zero emission capable) and that other technologies will be fuelling larger vehicles, so that by 2050 the nation's car fleet along with much of the public transport buses and rail lines will be low/near zero emissions. The use of alternative fuels in Ireland's PSO bus fleet is investigated in another background paper published as part of the Department's policy review. In the interim, Ireland is seeking greater diversification of fuels in the freight sector to include a mix of natural gas, biogas, electricity, renewable diesel and biofuels. The *Framework* includes a range of measures aimed at supporting the uptake of low emission vehicles and addresses infrastructure requirements to ensure an appropriate national refuelling network, including a sufficient number of electric vehicle (EV) charging points and natural gas refuelling stations. It is expected that the implementation of similar Frameworks across Europe will reassure car manufacturers and investors of the EU's long-term commitment to the adoption of vehicles powered by alternative fuels.

5.7 Incentivising electric vehicles (EVs)

Based on current information, the full electrification of the national car fleet represents a feasible option in Ireland, where supporting grid infrastructure is developed. While there are no certainties in predicting future technologies, there are strong indications from car manufacturers and energy market analysts that mass market adoption is probable for EVs[58]. Advances in battery technology, increasing competition in the market and falling vehicle costs would suggest that electrification will be the predominant low carbon choice for private car, taxis and commercial vans in the short to medium term. As such, under the *Climate Action Plan* a target of having 840,000 EV passenger cars and 95,000 EV vans on Irish roads by 2030 has been established.

In 2009, EVs were identified as an important element in efforts to achieve both energy efficiency and renewable energy targets as part of the EU *Climate Change-Energy Package*[59]. Supporting this finding, a commitment was made in the *Programme for a Partnership Government* for Ireland to become a leader in the take-up of EVs. A dedicated *Low Emission Vehicle Taskforce*[60] was established to consider the range of measures and options available to Government to accelerate this uptake. Phase 1 of the *Taskforce* focused solely on EVs under three work streams: Market Growth Stimuli and Visibility; Infrastructure, Energy Regulation and Pricing; and Planning Legislation, Building Regulations and Public Leadership. Preliminary recommendations from the *Taskforce* were considered in the 2018 and 2019 budgetary process and a suite of continued and new EV supports were announced as part of both Budgets (Box 3). The *Taskforce* published a progress report in September 2018[61].

Due in part to the suite of generous incentives available and up to 80% saving in transport costs when compared to a new fossil fuelled car[62], the EV uptake rate is beginning to improve. As of the end of May 2019, there were over 11,400 EVs registered in Ireland: 6,892 full battery electric vehicles (BEVs) (6,563 private cars) and 4,526 (4,449 private cars) plug-in hybrids (PHEVs). Sales of EVs across the EU have also displayed an upwards trend since 2008 and BEV sales increased by 51% in 2017 compared with 2016, while the sale of PHEVs increased by 35% in the same period[63]. BEVs still represent a small fraction of total European new car sales (0.6 %) and the EU acknowledges that full electrification will be a slow process; estimating that at least 80% of the new car fleet in 2030 will still contain an internal combustion engine (ICE).

Box 3: Current incentives to accelerate EV ownership in Ireland

- In April 2011, SEAI launched a grant scheme offering up to €5,000 for a new Battery Electric Vehicle (BEV) or a Plug-in Hybrid Electric Vehicle (PHEV) purchased and registered in Ireland. This scheme is continuing in 2019.
- EVs also qualify for VRT relief: BEVs are eligible for up to €5,000 relief until the end of 2021, while PHEVs and conventional hybrids are eligible for up to €2,500 and €1,500 respectively until the end of 2019.
- A nationwide rollout of EV charging points was undertaken with approximately 1,100 public, standard and fast charge points across the island of Ireland, including almost 80 fast chargers. In 2019, it was announced that a further €20m will be invested in upgrading and expanding the charging network. In October 2019, ESB announced the introduction of pricing on a phased basis for the public electric vehicle charging network.
- Domestic chargers were provided free of charge for over the first 2,000 successful applicants. In Budget 2018, a new grant of up to €600 towards the installation of home charger points for buyers of new and second-hand EVs was introduced.
- BEVs qualify for the lowest tax band of motor tax at €120 per annum, while a PHEV is typically taxed at c. €170 per annum.
- In Budget 2018, a new Benefit in Kind (BIK) 0% rate was introduced to incentivise EVs without mileage conditions. In addition, rules to ensure that there is no BIK liability associated with recharging EVs in workplaces were announced. Budget 2019 capped the BIK to the first €50,000 of the value of the EV.
- EVs and the associated charging infrastructure also qualify under the Accelerated Capital Allowance Scheme.
- In February 2018, a new grant scheme to stimulate EV take-up in the Small Public Service Vehicle (SPSV -Taxi /Hackney/Limousine) sector was launched. A grant of up to €7,000 is available towards the purchase of BEVs and up to €3,500 for PHEVs.
- 2018 also saw the launch of an EV Toll Incentive Scheme. Under this Scheme, BEVs and PHEVs qualify for 50% and 25% toll reductions respectively up to a maximum €500 annual threshold for private vehicles and €1,000 for commercial vehicles.

There are a range of factors internationally accepted as barriers to the transition to EV technology including limited vehicle choice, range anxiety and low consumer awareness. The initial slower than anticipated transition towards electrification was not an Irish-specific issue, nor did it represent a lack of ambition or support by the Irish Government to the transition away from fossil fuelled vehicles. It is expected that with increasing range performances, technology advancements, greater affordability and improved consumer choice, large-scale change will be triggered in EV purchasing patterns (Box 4). Furthermore, studies have shown that the desire to purchase an EV is strongly correlated to greater consumer knowledge[64], while people with more experience driving an EV show more favourable attitudes towards e-mobility[65]. As such, it is likely that the normalisation of EVs will be compounding, progressively increasing the number of EVs in the fleet.

5.8 Incentivising natural gas and biogas

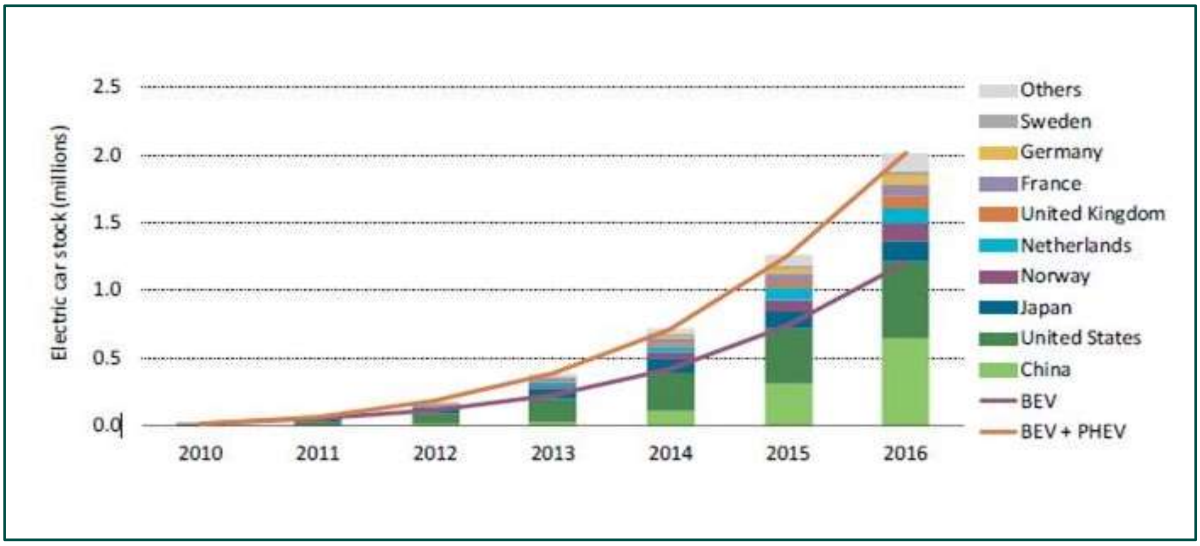
The full electrification of the Irish car fleet may be feasible but it is unlikely in the short to medium term that electrification will be viable in the freight sector. Instead a range of alternative fuels or combinations of fuels and technologies will be more likely, including: renewable biogas, biofuels, hydrogen, compressed natural gas (CNG), liquid natural gas (LNG) and hybrids. In order to support development of alternative fuels for the freight sector, a number of incentives have been employed. In the 2015 Budget[66], the excise rate for natural gas (NG) and biogas was set at the current EU minimum rate of €2.60 per GJ for a period of eight years. Following on from a commitment in the *NMP*, the accelerated capital allowance scheme was broadened in Budget 2019 to include vehicles and refuelling equipment powered by NG[67]. These measures incentivise the adoption of NG as a transport fuel by putting it in a competitive position relative to diesel. Importantly, the uptake of NG is seen as providing a pathway for the future use of renewable biogas in the transport sector (Box 5). The EU Commission has reported that Ireland has one of the highest biogas production potentials per capita within the entire EU (13 TWh/annum forecast)[68]. Nevertheless, limited availability of right-hand drive vehicles, the cost of transitioning large fleets, a limited refuelling network and cautious consumer confidence in new technologies may severely limit the uptake of alternative vehicles.

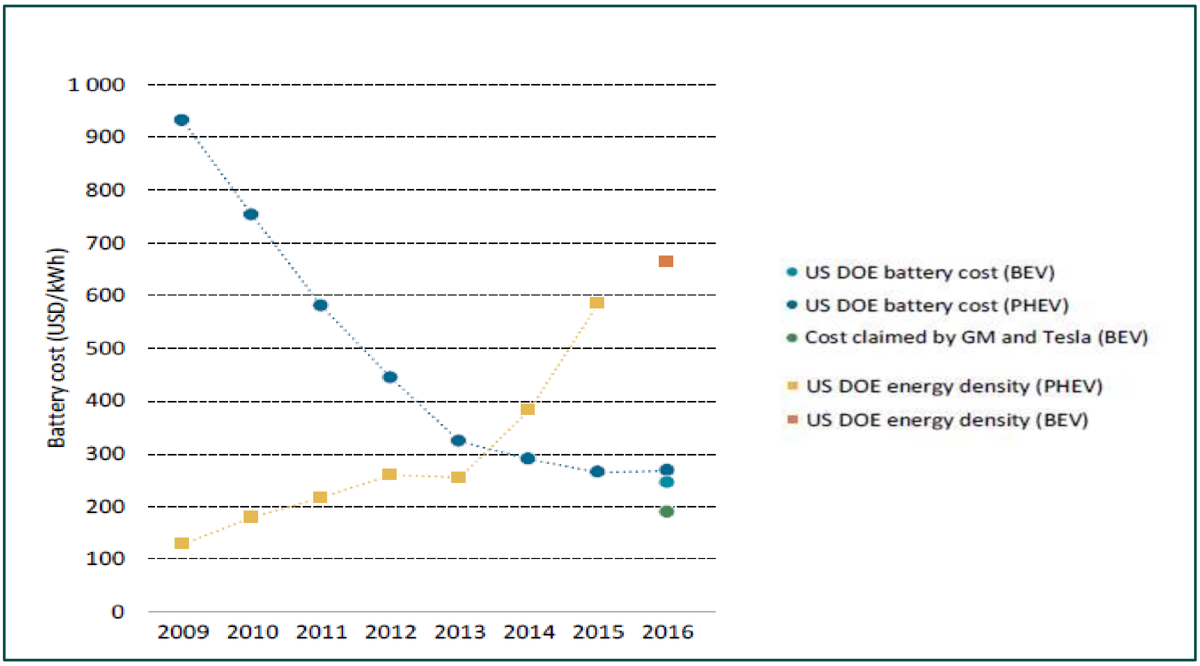
Box 4: Global outlook on electric vehicles

The number of EVs has been growing consistently since 2010 and surpassed the 3 million-vehicle threshold in 2017. To date, BEV uptake has remained steadily ahead of PHEVs. In 2017, China was by far the largest electric car market, accounting for half of EVs sold in the world. Norway is considered to have had the most successful deployment of EVs in terms of **global market share** (39%). It is followed by Iceland (12%) and Sweden (6%). Germany and Japan also saw significant growth, as EV sales more than doubled in 2017 from levels of the previous year.

Recent developments in battery costs and performance:

Over the past decade, developments in technology have greatly improved EV affordability and battery performances; battery unit costs have steadily decreased alongside improving battery capacity levels. Production volume has been identified as a key factor in battery pack cost reduction; an increase of battery pack size from 60 kWh to 100 kWh increases an average electric vehicle in range from 200 km to 320 km while also leading to a 17% reduction in cost per kWh at the pack level.



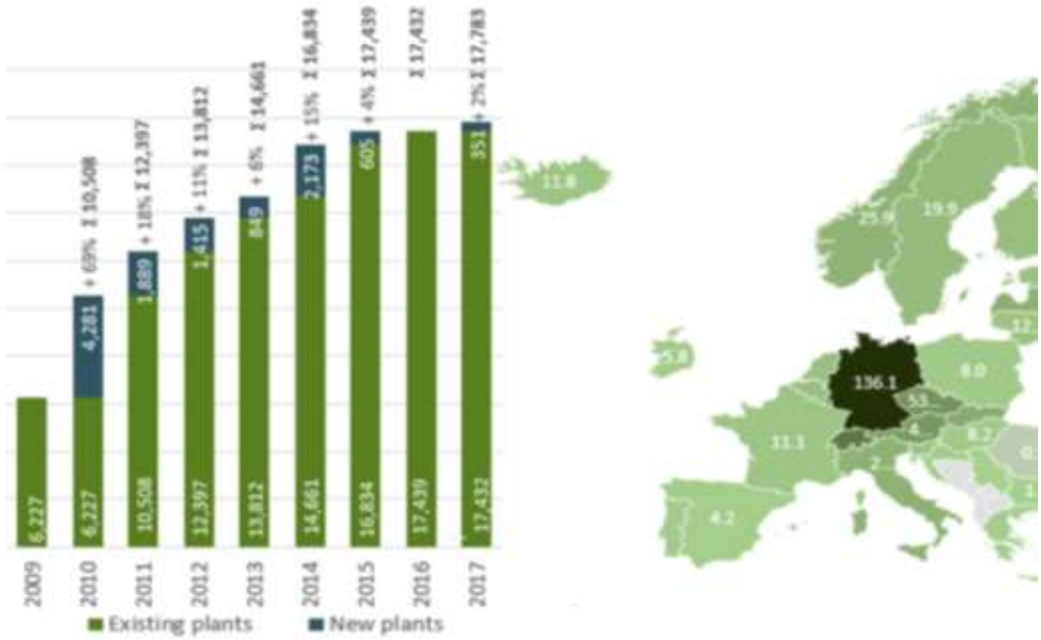


Source: IEA (2018)[69]

Box 5: Biogas

Biogas, or biomethane, which can be substituted for compressed natural gas (CNG), is likely to play a role in decarbonising the national fleet, particularly in fuelling HDVs. Biogas is produced through a fermentation process called anaerobic digestion from biomass: a mixture of agricultural residues and waste products such as animal slurry and grass silage. The gas produced is low-emission (almost CO_2 neutral) and can be upgraded to natural gas quality and injected into the national grid or used to fuel large vehicles such as HDVs.

Biogas production on a European level is a mature industry; with just under 18,000 biogas plants and 540 biomethane plants in operation across EU-28 at end-2017. Germany is the largest growth market in biogas production (2016), followed by France and Sweden. Sweden represents the greatest use of biomethane in transport; with renewable gas representing 91% of the vehicle gas mix in 2018, fuelling over 55, 000 vehicles. Approximately 31 biogas plants are in operation in Ireland, including 3 agricultural, 14 sewage plant facilities, 7 industrial landfills and 7 waste/industrial waste biogas plants (2014).



Left Figure: Development of the number of biogas plants in Europe (2017).
Right Figure: Number of biogas plants per 1 million capita in EU countries (2017).

5.9 Biofuel obligation scheme

Under the Renewable Energy Directive (RED)[70] mandatory national targets for all Member States were established for the use of energy from renewable sources. 16% of Ireland's gross final consumption of energy must come from renewable sources by 2020; the share of energy from renewable sources for transport (RES-T) must be at least 10%. Post 2020, under the recast RED more stringent targets exist; Ireland must oblige fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 from renewable sources. A sub-target for advanced biofuels of 3.5% in 2030 will also apply. Advanced biofuels are second-or-third generation biofuels which are produced from more sustainable feedstocks (wastes, residues and non-food crops) which have high greenhouse gas reduction and low or zero indirect land use change impact.

To assist in meeting the RED requirements, Ireland introduced a *Biofuels Obligation Scheme*[71] to ensure that a proportion of the transport fuel used in the State consists of environmentally sustainable biofuels. Broadly the approach is that the bio-and fossil-fuels are blended together and made available to consumers at the pump. The existing scheme places an obligation on suppliers of road transport fuels to ensure that a proportion of the fuels they place on the market here are produced from renewable sources. The biofuels obligation rate has increased over time from a share of 4.166% in 2010 to 11.111% (by volume) in 2019. A further increase to over 12% is proposed to come into effect from 1 January 2020.

Under the BOS, a weighting system is applied whereby biofuels produced from wastes and residues qualify for two biofuel obligation certificates per litre. The weighted share of biofuels in transport energy in 2017 was 7.4% which is almost three quarters of the way towards meeting the 2020 target of 10%[72]; however, it is projected that Ireland will not reach the national target for the share of 16% of gross final consumption of energy to come from renewable sources by 2020. According to the SEAI[73], an overall renewable energy share of just over 13% by 2020 is likely. The avoided CO_2 emissions associated with biofuels usage in transport are calculated on the basis of an assumed 100% displacement of emissions from conventional fuels. In 2017 alone, this biofuel measure reduced CO_2 emissions by 457 kilotonnes; this equates to an overall saving of 3.4 % in GHG emissions from the road transport sector as a consequence of achieving a biofuel penetration rate of 4.8 % by volume[74]. Greater emission reductions are likely in 2018 due to the introduction of a greater biofuel obligation rate, blending more biofuel into the traditional fuel mix and displacing additional fossil fuels and associated CO_2 emissions.

5.10 Mitigation research

Developments within climate change mitigation are advancing at a fast pace; in recognition of this the Department of Transport, Tourism and Sport developed a climate change research platform to co-fund academic research into areas where there is a dearth of Irish specific information. To date projects have been co-funded that consider potential mitigation measures in the freight sector and the role of behavioural change in promoting modal shift. Findings from these research projects will help inform further climate policy development.

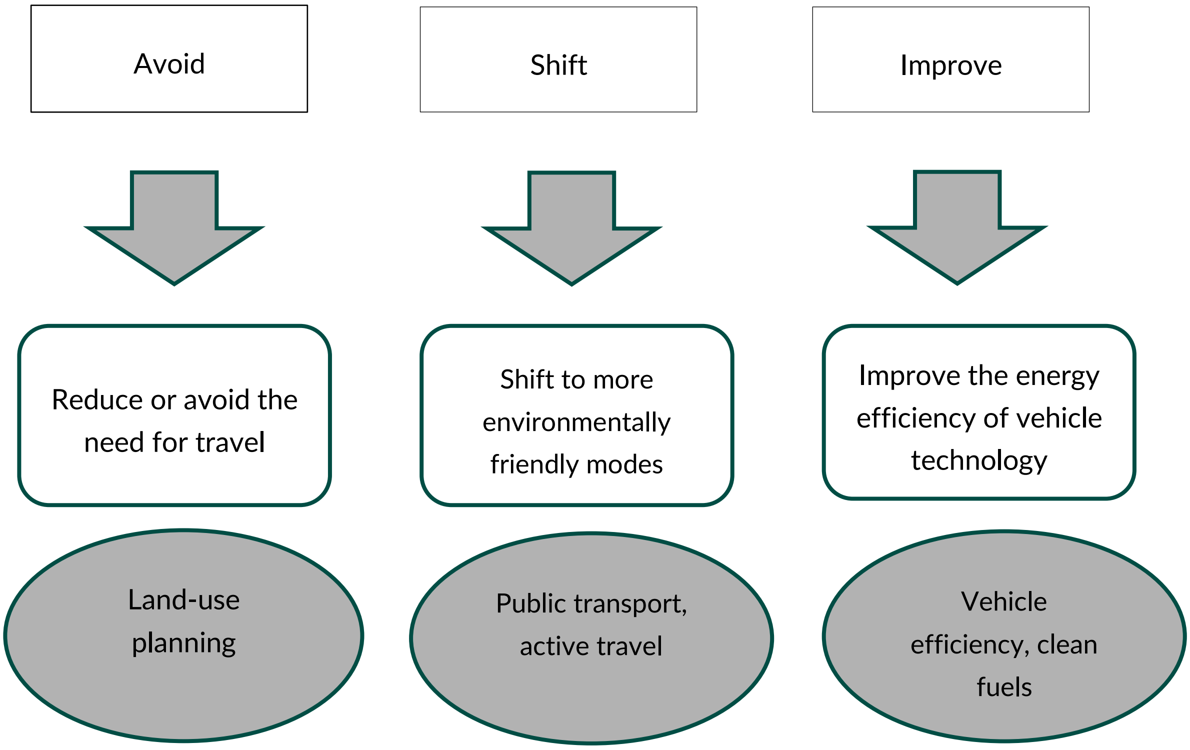
6 Avoid-Shift-Improve Emissions

The following Section examines measures that would help to avoid, shift and improve emissions within the transport sector.

6.1 Avoid-Shift-Improve Principle

The Avoid-Shift-Improve Principle is an established methodology of examining potential alternative mobility solutions. This technique looks at how to **avoid** emissions through reducing the frequency and distance of trips; how to reduce emissions by **shift**ing towards more environmentally friendly modes of transport, such as walking, cycling or using public transport; and how to **improve** emissions through promoting efficient fuel and vehicle technologies. Figure 6.1 provides an overview of the Avoid-Shift-Improve Principle.

Figure 6.1: Avoid-Shift-Improve Principle



It is important to acknowledge that as the ultimate goal is to transition the transport sector towards full decarbonisation by 2050 it is not possible to use the above Principle to envisage all the potential mitigation measures that could be employed to achieve this objective; the rate of scientific and technical advancements is dynamic and in the coming years new and perhaps more cost-effective solutions to the transport emission challenge may yet emerge. This does not mean that Ireland should adopt a 'wait and see' approach, it is recognised that early action to limit GHG emissions will spread the burden of emissions reductions over a longer timeframe and potentially reduce the overall cost of reductions. Achieving as much of our climate change targets as possible through capital investment is desirable given the economic benefits of doing so and the lack of any economic return from paying compliance penalties. Nevertheless, there is a need to ensure that action taken in the short term does not lock Ireland into excessively expensive reduction pathways or lead to redundant assets in defunct/unsuitable technologies in the medium to long term.

Using the "Avoid-Shift-Improve" Principle, it is possible to map out existing transport decarbonisation policies and identify areas where future opportunities exist. The Principle, where relevant, was applied to three broad thematic areas: Mobility; Behavioural Change; and Vehicles – as collectively these themes cover the spatial, human and technological aspects of the transport sector.

6.2 Mobility

Reconciling the mobility needs of Irish citizens with the requirement to reduce national emissions is challenging. Transport is not an end in itself; it is a means for accessing employment, and an array of other services and amenities that contribute to healthy and fulfilling lives. Reducing the dependence on private cars and promoting the use of multi-occupancy vehicles and public/active travel modes is fundamental to achieving transport emission reductions. Following are several 'mobility' related measures that can help secure this objective.

6.2.1 Mobility measures to avoid emissions

Effective spatial planning and reducing long-distance commutes

Ireland is experiencing population growth with an increasing tendency towards dispersed, low-density developments. The largest increases in population over the past twenty years have been in Fingal, Cork (outside Cork City Council area), Kildare, Meath, Laois and Galway County (outside Galway City Council area) accounting for approximately 45% of the additional population growth since 1996[75]. These extensive catchments and dispersed land-use development patterns have resulted in greater car dependency, longer commutes, a high demand for road infrastructure and difficulties in supplying adequate sustainable mobility provision. Transport policies aimed at reducing travel demand and travel distances can only be delivered if there are effective spatial policies in place.

Spatial planning and the delivery of transport infrastructure and services are highly interdependent. The *National Planning Framework* plays a critical role in supporting the development of an integrated and efficient transport system by providing the national level policy blueprint for spatial development and sustainable settlement patterns. The *Framework* allows for growth in such a way that supports a transition to a low carbon and climate resilient economy. The location of schools, jobs, shops, and local services relative to the location of residential developments are critical determinants of the need to travel, the distances to be travelled and the modes of transport chosen. The provision of sustainable mobility alternatives can only be effective if matched with complementary development patterns which support and facilitate their use. This should improve the 'liveability' of urban places and encourage the use of public transport, walking and cycling.

Future investment in new public facilities must take account of the need for access without reliance on the car. Sustainable mobility use and modal shift can be strongly encouraged through efficient planning. In the Greater Dublin Area, the National Transport Authority published the

Transport Strategy for the Greater Dublin Area 2016-2035[76] to ensure that spatial planning and transport planning are appropriately aligned. While it is not currently a statutory requirement for other cities to develop a similar transport strategy the NTA has assisted several local authorities across Ireland in preparing plans to strengthen the levels of integration between spatial planning and transport planning across the country. The *National Planning Framework* includes a commitment to extend the NTA's statutory remit for transport planning in the GDA to the other cities.

Demand management practices

A number of cities and countries have introduced various suites of demand management measures to limit traffic and encourage alternative transport modes, especially in urban areas due primarily to congestion and air quality concerns. These measures include: parking policies; low emission zones; tolling; and teleworking practices.

- By reducing the public parking supply by a small percentage every year in urban centres, more space would be available to facilitate services and infrastructure for pedestrians, cyclists, and public transportation. Changes to parking supply in urban centres would have to be considered in tandem with policies on 'out-of-town' parking.

- Low Emission Zones are areas where entry of the most polluting vehicles is strictly regulated. Generally, the more polluting vehicles have to pay a higher tariff to enter a low emission zone but complete bans on certain vehicles are also common place.

- Technological developments mean that operating tolling systems has become increasingly streamlined and no longer requires physical tollbooths. Tolling may be a factor in reducing a number of unnecessary trips due to the added expense; but active avoidance of toll roads can also divert traffic and may add to localised congestion issues.

- Teleworking or e-working allows for work to be carried out independently of location and as such has the potential to reduce the number of commuter trips. Teleworking can reduce overheads, increase productivity, improve the retention of staff and their work-life balances, give people with a disability better access to employment and reduce trips and associated emissions.

- Staggered working or school opening hours may also have the potential to lessen congestion, which reduces idling emissions. Lighter traffic may also encourage a higher uptake in active travel such as cycling and walking.

- Private car journeys can be emission-efficient when transporting multiple passengers and driven in a proficient manner. As such, carpooling initiatives may have a role to play on certain routes not serviced by public transport such as commutes to rural or poorly serviced industrial estates. Sharing vehicles provides individuals with the flexibility of car travel without establishing complete dependence car use for all journeys.

6.2.2 Mobility measures to shift emissions

Cross border movements

The SEAI estimates that fuel tourism accounts for an estimated 4% of Irish transport energy demand and, if fully eliminated, could reduce Ireland's GHG emissions levels by up to 13,000 ktCO_2eq between 2017 and 2030. A prospective measure to help avoid fuel tourism is transitioning towards price equalisation between petrol and diesel. Currently the rate of excise applied to diesel is 23% less than on petrol. The potential exists to close this differential over time which would take into account air quality externalities and contribute towards reducing the level of fuel tourism by limiting the cost differential across the border. It is also important to note, that while measures that limit fuel tourism in Ireland would positively impact the national emission inventory, they would not necessarily yield emission savings; instead the emissions would simply shift and be accounted for in the UK's national inventory instead.

Park and Ride facilities

Given Ireland's distribution of population and employment centres there is significant commuter movement of people from the hinterlands into the metropolitan and city centre areas daily. Park and Ride facilities increase the effective catchment area for many to public transport or active travel links, resulting in an improved modal shift away from the private car. Park and Ride facilities have the ability to: reduce road traffic congestion; improve mobility within the city centres; and relieve pressure on city centre parking stock[77]. In order to achieve such benefits the Park and Ride facilities must be user-friendly and cost competitive relative to alternative travel choices. The perceived convenience, suitability and adequate availability of parking spaces to potential customers is essential; likewise, a lower cost of using Park and Ride facilities compared to continued use of private cars and city parking is central.

There is limited international evaluation on the benefits of Park and Ride facilities. A New Zealand study[78] demonstrated that increasing Park and Ride provisions produced high returns relative to most other types of investment schemes that encourage modal shift to public transport in major urban areas, with estimated benefit-cost ratios in the range of 2 to 4.

Ireland has invested in nationwide Park and Ride facilities at rail, light rail and coach stations. The *Transport Strategy for the Greater Dublin Area (GDA) 2016-2035* includes the planned development of a network of strategic rail-based Park and Ride facilities where rail services intersect with the national road network. The *BusConnects* initiative states that the complete redesign of the bus network will be accompanied by a network of bus-based Park and Ride sites at strategic locations. Action 89 of the *Climate Action Plan* commits to the establishment of a Park and Ride Development Office within the NTA and the development of a 5-year strategy and implementation plan with specific timelines.

6.3 Behavioural change

Behavioural change amongst motorists will be critical in reducing emissions in the transport sector. Many of the proposed measures to limit emissions require significant changes in how people travel and the technology/fuel they use. As such, it is essential that the role of behavioural economics and psychology in decision making is understood to better facilitate a greater uptake of energy efficient and sustainable mobility options. Normalising new technologies and addressing consumer concerns will be required to accelerate decarbonising the transport sector.

6.3.1 Behavioural change measures to avoid emissions

Eco-driving

It is well understood that fuel economy directly influences the CO_2 emissions from vehicles. Thus, reducing the overall fuel consumption of vehicles will directly improve tailpipe CO_2 emissions. Modified driving techniques can have a marked effect on reducing fuel consumption. Findings suggest that educational eco-driving campaigns have the potential to significantly reduce emissions (*c.* 5-10%) over sustained periods of time. By driving smoothly, choosing appropriate speeds, and minimising hard acceleration and braking, vehicle fuel consumption can be markedly reduced. A study carried out by the University of California[79] estimated that a typical freight truck uses excess fuel due to speeding (33%), hard acceleration (25%), idling (20%), hard turning (16%) and hard braking (6%).

All State public transport operators carry out eco-driving as part of their driver training programmes. For instance, Iarnród Éireann employ an *Eco-Driving System* which advises drivers when to "coast" rather than "power" based on known topography, load, and timetabling. They estimate that eco-driving can potentially save up to 5% on fuel use. In Bus Éireann, over 280 vehicles have been fitted with a telematics system which provides the driver with a continuous on-board driving style improvement system. The telematics system also provides valuable information on individual vehicle performance and route fuel consumption rates.

Significant fuel savings can be achieved through employing efficient driving styles and simple vehicle maintenance, such as:

- *Reducing Driving Speeds*: Energy use increases at higher speeds, a reduction in speed limits could potentially avoid emissions. While there is a lack of official and robust data on this issue, various sources suggest that moving from 100km/h to 120km/h increases fuel consumption by up to 20%[80]. Any reduction in national speed limits would need to be considered in the context of the design speed for existing infrastructure and the potential implications of traffic transfer on to alternative roads.

- *Avoiding Aggressive Driving:* Fuel consumption increases with acceleration; maintaining steady speeds is the optimal driving style for limiting tailpipe emissions. Aggressive starts and hard braking should be replaced with slow and smooth acceleration and deceleration. Selection of the correct gear is also important to avoid unnecessary fuel use.

- *Avoiding Idling: S*tudies have shown that vehicles idling in traffic (stopped at traffic lights or in traffic jams) produce high levels of emissions and can account for up to 10% of total fuel consumption. Reviewing and modifying traffic management systems to improve traffic flow would yield fuel and emission savings.

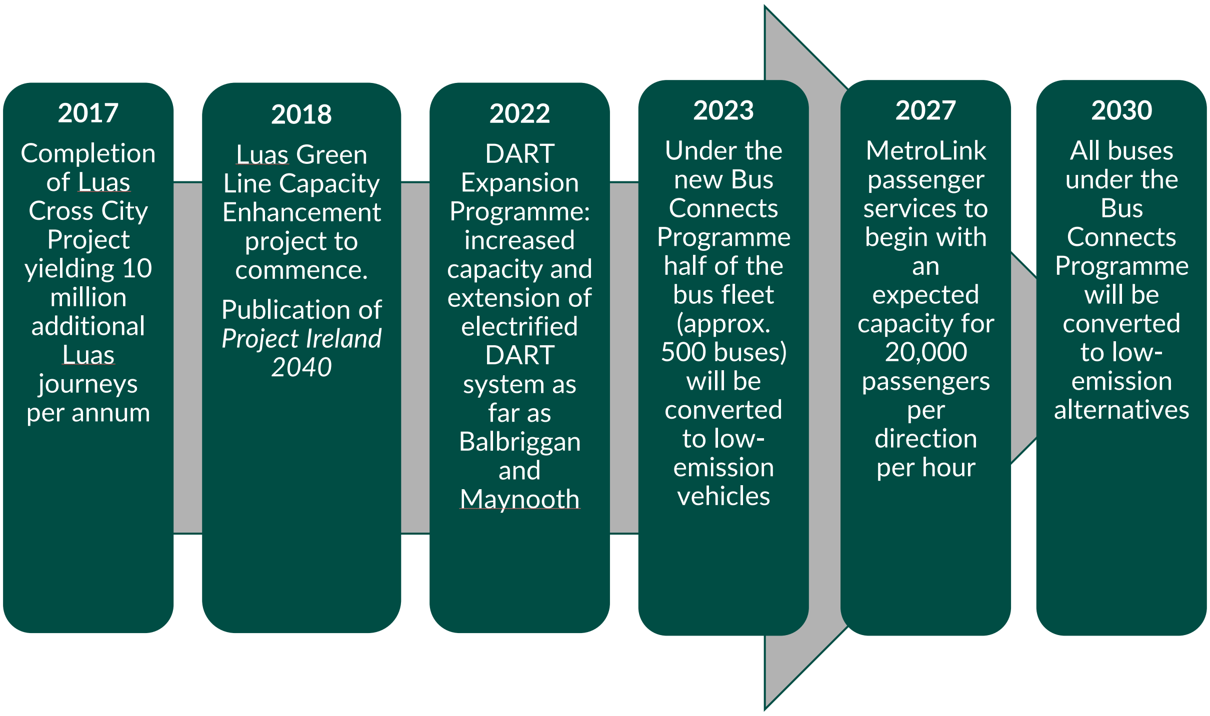
- *Maintaining Vehicles:* Properly serviced vehicles should perform more efficiently and use fuel more effectively. As carrying unnecessary weight impacts fuel use; excess weight should be limited, roof racks and boxes should be removed when not needed. Properly inflated tyres reduce rolling resistance; fuel consumption can be reduced by up to 5% by increasing the tyre inflation pressures from 2 to 3 bar[81]. Furthermore, use of air conditioning can increase fuel consumption as much as 10% in city driving in some car models. At low speeds, opened windows are more efficient for cooling vehicles, however opened windows alter the aerodynamic design of the vehicle therefore in some models at high speeds using A/C may be more efficient than the wind resistance from open windows and sunroofs.

6.3.2 *Behavioural change measures to shift emissions*

Shifting emissions requires the provision of meaningful alternatives to higher emitting options. As such, substantial investment into sustainable mobility measures is continuing, allowing for the greater provision of services and increased capacity on the network. Investment also continues into integrated ticketing, journey planners, on-board Wi-Fi and real time passenger information which help to make public transport an attractive travel mode. Modal shift in Dublin has increased dramatically from 59% of journeys in 2010 being made through sustainable means to 70% in 2018. According to the *Canal Cordon Report* both cycling and walking in Dublin have grown in popularity, increasing from 10,349 to 12,227 cycling trips and 19,711 to 23,858 walking trips between 2014 and 2018 respectively. Figure 6.2 outlines some of the key public transport mitigation measures out to 2030.

In contrast, some existing policies may potentially inhibit behavioural change towards low emitting alternatives, such as certain fuel subsidies. Presently, a rebate is offered to qualifying businesses once the price of diesel goes above a certain threshold in order to maintain competiveness. Businesses can also claim back VAT on diesel purchases. These subsidies can act as a disincentive to pursue more energy efficiency opportunities.

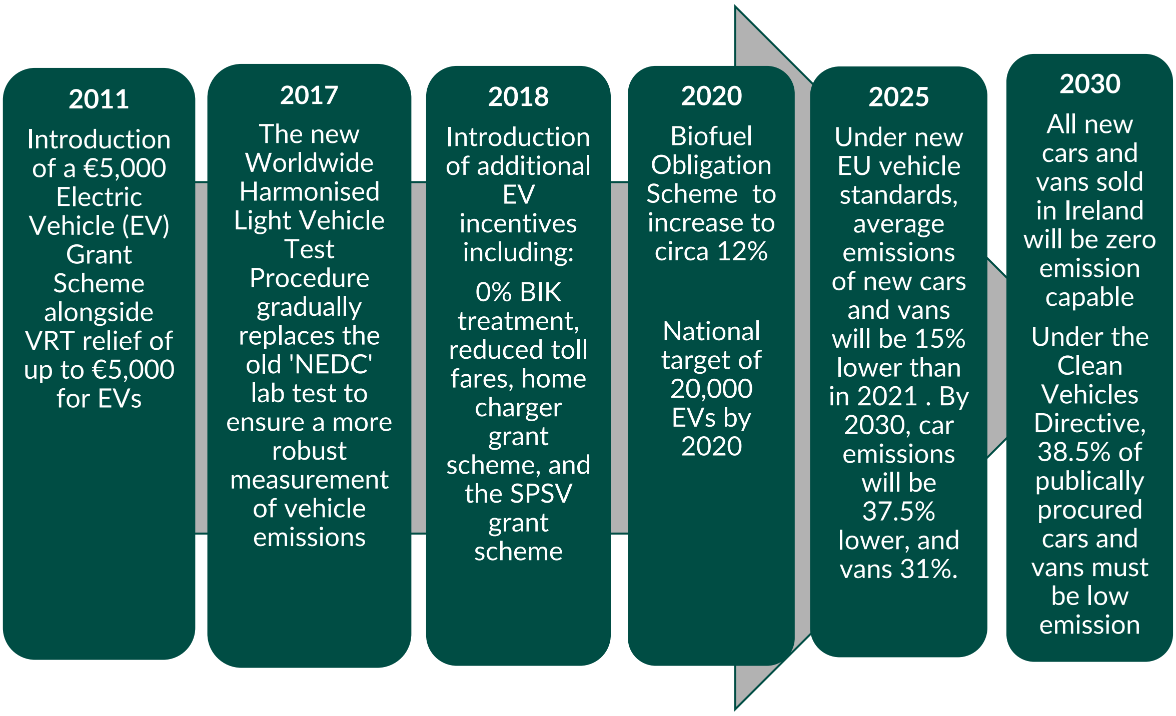
Figure 6.2: Timeline of key public transport mitigation measures



6.4 Vehicles

Changes in powertrain technologies, enhanced aerodynamics, marked weight reductions and transitioning to non-conventional fuels are techniques of improving vehicle efficiency and reducing tailpipe emissions. Figure 6.3 summaries the timeline for some of these core vehicular mitigation measures.

Figure 6.3: Timeline for key vehicular mitigation measures



6.4.1 Vehicular measures to shift emissions

Alternative fuels and technologies

In recognition that it is not always possible to provide substitute modes of transport to the private car, particularly in rural areas, the Government has developed incentives to encourage the transition away from conventional fossil fuels towards lower CO_2 emitting alternatives. A *Low Emission Vehicle (LEV) Taskforce* was established in December 2016 to consider the full suite of potential measures available to Government to expedite the deployment of low carbon technologies. Initially the *Taskforce* focused on developing measures to promote greater EV uptake rates; their preliminary recommendations were reflected in additional EV incentive measures announced in Budgets 2018 and 2019. Measures currently in place to encourage the transition to EVs include a purchase grant and VRT relief of up to €10,000 per car; a grant to support the installation of home charger points; a toll incentive regime; an additional purchase grant for the Taxi/Hackney/Limousine sector; and free public charging facilities. For businesses, there are also accelerated capital allowance (ACA) schemes in place as well as a 0% Benefit in Kind rate without mileage conditions on the first €50,000 of the value of the vehicle.

In the freight sector, the shift away from fossil fuels to lower emitting alternatives will be supported through Phase 2 of the *LEV Taskforce's* work programme which will consider measures to promote fuels such as natural gas, liquid petroleum gas and hydrogen. Currently, there is a

Government commitment to maintain duty levels of natural gas at the minimum level for a period of eight years and an ACA scheme to include natural gas refuelling infrastructure and vehicles. In addition, some manufacturers have begun exploring electrification as a means to transport road freight (e.g. E-Force, Tesla and Mitsubishi). Meanwhile, Sweden is trialling the world's first 'e-highway'. Several other in-road conductive solutions are also being considered internationally.

Rationalising freight

Ireland's road and rail networks play a vital role for economic activity by facilitating the movement of goods around the country. It is often seen as an immense challenge to limit emissions in the freight sector while still maintaining cost competitiveness within an international context. The easiest way to avoid emissions in this sector is to streamline operations and ensure that when movement of goods is required that the vehicle load and the journey route are optimised. Freight exchange platforms have an important role to play in this regard.

Unlike many other European countries, Ireland currently does not employ 'Freight Road User Charging'. Generally, this form of charging is considered aligned to the polluter pays principle. The schemes have the potential to deliver significant benefits, particularly through improving the efficiency of the HDV sector with less empty running; encouraging an increase in rail freight use, reducing some of the environmental impacts of HDVs; and providing additional revenue which can support improvements in the transport sector and finance the construction and maintenance of motorways. Critics of the system suggest it has minimal effect in freight traffic demand management as the freight operator passes the additional charges to the end user. A further alternative is the implementation of user-chargers whereby consumers/retailers are encouraged to purchase local products compared to goods with larger carbon footprints. This approach raises concerns regarding economic growth and limiting consumer choice.

Rail freight can represent a lower emitting viable alternative to road freight. Iarnród Éireann freight quantities are comparatively small and have declined starkly over recent decades. Long-run data from the CSO shows that the total tonnage of goods carried by rail decreased from 3.4 million tonnes in 1985 to 581,000 tonnes in 2016[82]. Rail freight has lower emissions than road, particularly over long distances with bulky loads. In addition, many European countries employ their inland waterways as alternatives to land freight. The absence of any significant competition from inland waterway or rail freight is atypical within the EU[83]. The limited number of high-volume bulk movements, Ireland's compact size and the low density of activity all negatively affect the economic viability of alternatives to road freight.

6.4.2 Vehicular measures to improve emissions

Car and light duty vehicle EU regulations

The successful implementation of EU regulations relating to improving car efficiencies remains fundamental to Ireland's short-term decarbonisation strategy. New cars entering the Irish fleet are now approximately 25% more energy efficient than they were in 2007. Due to the absence of vehicle manufacturing here, Ireland will remain strongly dependent on continued actions at an EU level to drive manufacturers to produce low emitting vehicles. EU CO_2 regulations for cars and vans continue to provide for progressive emission reductions at the fleet level and are on a decreasing trajectory up to 2030.

Heavy duty vehicle EU regulations

CO_2 emissions from HDVs rose by over 30% between 1990 and 2007 across Europe, mainly due to increasing road freight traffic, and are currently approximately 19% above 1990 levels[84]. Projections indicated that without significant policy action the emissions trajectory was set to continue to rise in the magnitude of 10% between 2010 and 2030; this trajectory may be even steeper in Ireland where a strong correlation between freight emissions and the construction industry during the last economic cycle was firmly established. It is clear that continuing the *status quo* in this sector will not achieve the objective of near complete decarbonisation by 2050. Recognising this, new EU regulations will come into force from 2020 onwards that will permit the setting of maximum new fleet emission averages and thereafter progressive emission reduction standards. CO_2 emissions for HDVs must be lower than those taken from a reference period of July 2019 to June 2020 by 15% by 2025 and by 30% by 2030. As of January 2019, HDV manufacturers must also calculate the CO_2 emissions and fuel consumption of all new vehicles (above 7.5 tonnes) produced for the EU market, using the new Vehicle Energy Consumption Calculation Tool (VECTO) (Box 6). The European Environment Agency will annually publish information on the performance of new HDVs for the EU market; collectively, the new emission regulations and data from VECTO should:

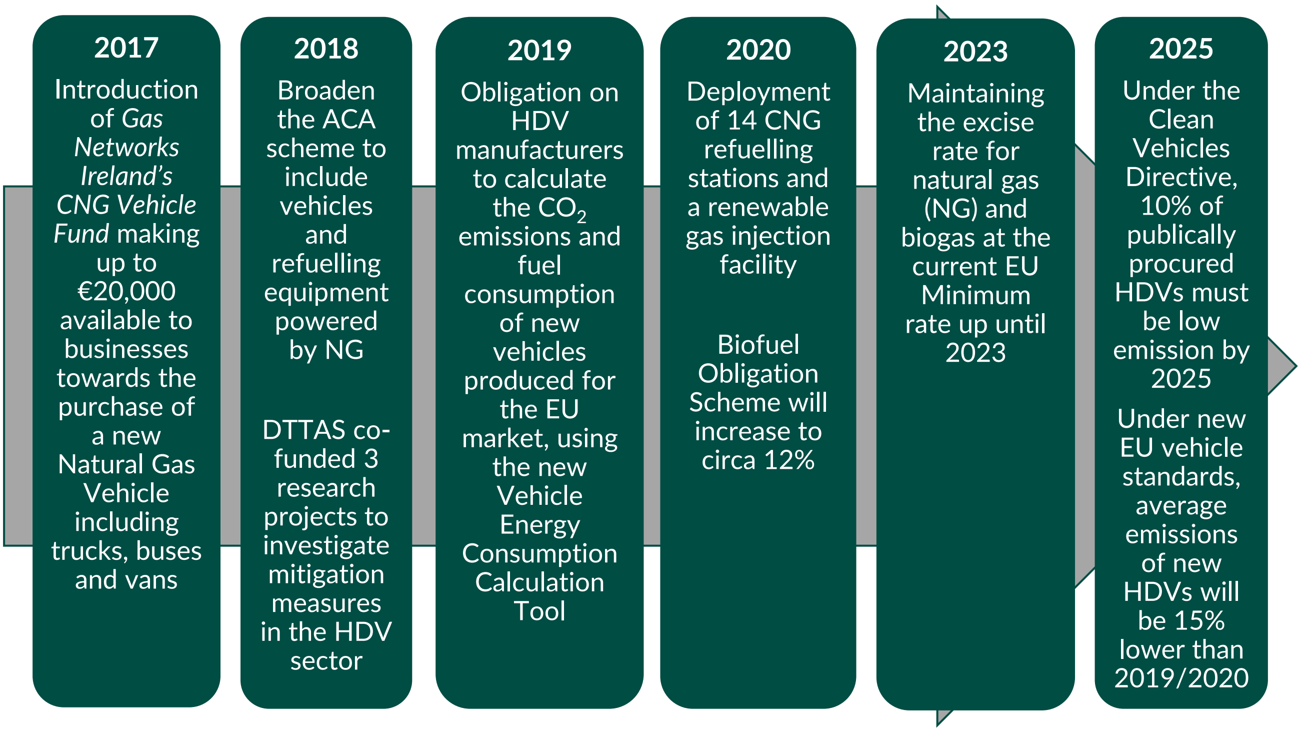
- Lead to improved fuel efficiencies and reduce transport operator fuel bills. Freight transport operators can experience fuel costs greater than a quarter of their operational costs and rank fuel efficiency as their top purchase criterion[85]. By publishing standardised information on fuel efficiencies consumers can compare vehicle types and make better purchasing decisions that will maximise fuel use and consequentially reduce emissions.

- Increase competition between vehicle manufacturers; accelerating innovation and the rate of deployment of low emission technology on the market. The HDV sector will need to maintain progress on technological improvements in order to preserve current market positions relevant to markets such as the United States, Canada, China and Japan where certification and fuel efficiency measures already exist. A *Transport and Environment* study[86] estimated that the introduction of HDV standards in the USA ensured the deployment of fuel saving technologies and brought about a 24% fuel efficiency gain from 2011 to 2017 with a new truck sold in 2017 being $8,200 more fuel efficient than a 2011 model.

- Support Governments in developing robust policy measures to limit emissions based on accurate baseline data.

Figure 6.4 outlines Irelands key mitigation measures over the next number of years in the HDV sector.

Figure 6.4: Timeline of key HDV mitigation measures



Box 6: Vehicle energy consumption calculation tool (VECTO) for heavy duty vehicles

HDVs account for approximately a quarter of European road transport emissions and c. 5% of total EU CO_2 emissions - a greater individual share than international aviation or shipping. European CO_2 emissions and fuel consumption standards for cars and vans have been successfully introduced; however, no system of measurement for CO_2 emissions from HDVs has been employed in the EU, despite well-established standards being in place in Japan, the USA and China for some years. To address this shortcoming, in 2010 the European Commission began developing a computer simulation tool called VECTO **(Vehicle Energy Consumption Calculation Tool)**, to model CO_2 emissions from heavy duty vehicles, accounting for specific variations in truck and trailer configurations, usage patterns, and different payloads. The simulator system uses key vehicle parameters, including weight, aerodynamics performance and engine efficiency to generate CO_2 emission values that will be made available to customers. VECTO will be used to provide baseline information on emissions from new HDVs and develop a registration and monitoring procedure; using this information the Commission will set progressive CO_2 emission reduction targets. It is expected that this will give customers transparent and reliable fuel consumption information which will lead to increased competition and innovation among manufacturers driving the market uptake of the cleanest vehicles. From 2019 truck manufacturers are required to certify the CO_2 emissions of all new trucks they sell in Europe from using the VECTO test procedure.

Vehicle registration, motor and carbon tax

The role and interrelationship of various elements of the tax system are key factors in decision making concerning vehicle purchasing and use. Nationally, the VRT and motor tax systems have been successfully employed to transition purchasing choices in favour of lower emitting passenger cars. Since rebalancing the tax systems, cars with CO_2 emissions of 140 g/km or higher now comprise just 4% of new car purchases. In order to complement the forthcoming stringent EU emission regulations, and to account for the increasing number of low emitting vehicles available in the market, the rebalancing mechanism must be reviewed and updated to encourage the uptake of low/zero carbon emitting vehicles in both car and HDV sectors (Action No. 83 in the *Climate Action Plan*).

The Government is also committed to using carbon tax as a core element in reducing GHG emissions over time. Carbon pricing has the potential to decrease consumption of fossil fuels and encourage energy efficiency improvements in a cost-effective manner, an approach advocated by the Climate Change Advisory Council[87]. Ireland has a national carbon tax, set at €20 per tonne of CO_2 emitted; Sweden, the country with the highest carbon tax (US$132), has developed tiered carbon taxes for different sectors, for instance industry and agriculture have lower carbon taxes due to concerns regarding international competitiveness[88]. It is acknowledged that an examination of the impact of the Irish carbon tax system is required (Action No. 8 in the *Climate Action Plan*) to ensure that sufficiently strong signals continue to drive changes in manufacturer and consumer behaviour.

Biofuel Obligation Scheme

Biofuels will be key in the future fuel mix. It is foreseen that biofuel use in the freight sector will be of growing importance in the medium term until more permanent solutions such as hydrogen, bio-gasification and full electrification develop. An extension to the Biofuel Obligation Scheme will be required if Ireland is to meet its 2020 target of at least 10% of the final consumption of energy in transport is from renewable sources.

Improving energy efficiency in the public transport fleet

According to the most recent EPA estimates, only *c.* 4.4% of Irish transport-derived carbon emissions come from the public transport fleet. Therefore, converting the public transport fleet to low-carbon alternatives would have a limited mitigation impact on national emission levels of CO_2; however, it would undoubtedly fulfil a strong leadership and demonstration role in normalising and promoting alternative fuel use in wider society. This could potentially encourage broader behavioural change; both in increasing modal shift towards more sustainable modes of transport and in fostering market acceptance and greater public awareness of low emission vehicles. Furthermore, transitioning vehicles away from diesel, particularly in urban areas, may offer significant co-benefits in relation to air quality.

The *Public Sector Energy Efficiency Strategy*[89] highlights the role that the public sector fleet can play in piloting, facilitating and accelerating market uptake of new technologies and alternative fuels. The efficiency of the public transport fleet is incrementally being improved through the replacement of older vehicles with more energy efficient models; currently only vehicles meeting the Euro VI emissions standard are purchased for the national bus and coach fleet with typical fuel savings of *c.* 6-8% between Euro VI vehicles and Euro V equivalents and even greater savings compared to older EURO standards. Under the *Project Ireland 2040* commitment, no more diesel-only buses will be purchased for the urban bus fleet post-July 2019; while under *BusConnects*, the bus fleet will transition to low emission technologies. The recently published *Climate Action Plan* also contains actions to accelerate the decarbonisation of the public bus fleet with the objective to only have low-emitting buses in the urban PSO bus fleet by 2035; this topic is discussed at length in *Background Paper 5: Greener Buses – Alternative fuel options for the urban bus fleet*.

It is also important to consider the potential contribution of electrified rail to the mitigation of greenhouse gas emissions. A full metropolitan area DART network for the Greater Dublin Area is planned, providing high-frequency electrified rail services to Drogheda, Celbridge/Hazelhatch, Maynooth and M3 Parkway, as well as new interchange stations with bus, Luas and Metro networks. This is the part of the national rail network that carries over 75% of total rail passengers each year. Iarnród Éireann has also secured up to €15m funding under the *Climate Action Fund* to design new hybrid power-packs for intercity railcars to reduce diesel use and greenhouse gas emissions. Following the proof of concept in one three car train, the hybrid power-packs could potentially be implemented across the wider fleet. These major rail projects will help supplement the range of viable low carbon alternatives to private passenger car travel and positively impact on our sectoral emissions profile.

Clean vehicle procurement

The European Commission recognised that public procurement can assist in the deployment of low-and-zero-emission vehicles and so has introduced a more rigorous *Clean Vehicles Directive*[90] to promote cleaner and energy-efficient public road transport vehicles. Importantly, under the Directive, Member States have been set minimum clean vehicle procurement targets and the scope has been broadened to include leased, rented or hire-purchased road transport vehicles. There are separate targets for LDVs and HDVs over two timeframes: from the date the Directive enters into force to end-2025 and from 2025 to 2030. In Ireland, 38.5% of the total number of LDVs (M1, M2 and N1 vehicles) must be 'clean' vehicles in both periods, while 10% of truck procurements and 45% of buses must be 'clean' by 2025 rising to 15% and 65% respectively by 2030. In addition, there are stringent sub-targets for zero-emissions buses. It is expected that these changes will result, in the longer term, in a wider deployment of clean and energy efficient vehicles.

6.5 Cost of mitigation measures

Central to the development of emission mitigation measures is robust economic evaluation to ensure that maximum emission savings can be achieved at least-cost to the State and its citizens. An established methodology is the Marginal Abatement Cost Curve (MACC) approach which estimates marginal costs per tonne of carbon abated for individual mitigation measures by comparing 'business-as-usual' economic activity with the 'low carbon' options. This technique allows for comparative analysis of 'low carbon' alternatives across a range of sectors.

The benefit of the MACC approach is the illustration of the impact of various mitigation measures relative to cost. Abatement costs for an array of measures was presented in the *NMP* with costs ranging from -€295 to €1,241. It is important to note that the most costly mitigation measure in the *Plan* (€1,241 per tonne of carbon abated) is attributed to the introduction of further incentives to promote the uptake of EVs. Meanwhile, on a societal basis the *Climate Action Plan* showed an expected average abatement cost over the period 2021 to 2030 for switching from fossil-fuelled passenger cars to electric vehicles on a total cost of ownership basis of approximately €116 cost per tonne (based on the lifetime total cost of ownership of electric vehicles). A summary of potential transport mitigation measures are outlined in Table 6.1. It is important to note that there are multiple scenarios possible in the design of certain measures so the estimates listed below are indicative of only one such scenario (please see Appendix 2 for additional information). This analysis indicates that the introduction of tax measures to alter purchasing patterns away from higher emitting vehicles is the most cost-effective mechanism of reducing emissions from the transport measures examined. The least cost-efficient approach is the introduction of additional incentives to encourage EV purchasing.

Table 6.1: Overview of marginal cost per tonne of carbon abated (€) as per MACC for potential transport mitigation measures, 2017-2030 from the *NMP*

Mitigation Measure	2017-2030 MAC (€/tCO_{2eq})
Motor Tax (Cars)	-88
Motor Tax (LDVs)	-74
Eco-Driving	29
Carbon tax	37
Biofuels	203
Fuel Tourism	241
Motorway Speed Limits	592
Electric Vehicle Supports	1,242

In addition to the mitigation potential of measures, a number of other considerations must be made, namely:

- **Timing:** Evaluating whether it is cost-effective to implement a measure now or, due to technological and market advancements, whether it is better to delay introduction to achieve improved value-for-money and affect a cheaper transition at a later date.
- **Data:** The potential impact of mitigation measures are evaluated based on future estimates of energy demand and supply, population growth, economic development, and technological advancements. The robustness of these forecasts must be scrutinised to ensure the projected models, costs, and likely impacts are as accurate as possible. It is therefore critical that the potential of mitigation measures is subject to updating and constant review.
- **Longevity:** Ensuring choices and investments made now do not lock Ireland into technologies or infrastructure that are only relevant in the short term and quickly become outdated and/or do not achieve the emission mitigation objective in the longer term.
- **Prioritisation:** Due to limited resources consideration should be given to whether mitigation measures should be prioritised for earlier implementation on a least cost basis across whole of Government regardless of the sector they arise from (meaning some sectors will carry more of the mitigation burden than others) or whether each sector

should contribute within their own capacity. Furthermore, the ability of key sectors to more strongly mitigate without negatively (or less negatively) impacting on the economics of their sector should be considered alongside the sequencing of introducing measures.

- **Ownership:** Mitigation measures do not have to be State supported; often individuals and business can make major impacts in terms of adopting low emission technologies and practices. For instance, a private car park operator may be interested in installing and operating EV charging facilities for the convenience of their customers, this adds to the overall EV charging network, which promotes EV uptake, while providing the business with a unique selling point. Such citizen and commercial engagement should be fostered and encouraged.

7 Concluding points

Ireland has challenging emission reduction targets out to 2020 and 2030. By 2020, Ireland's non-ETS emissions (primarily emissions associated with heating in buildings, transport, waste and agriculture) should be 20% below their level in 2005 and by 2030, Ireland must reduce non-ETS emissions by 30% relative to 2005 levels. Shortfalls in reaching the 2020 and subsequent annual targets will result in compliance costs as well as placing Ireland on a more arduous trajectory to the 2030 target and beyond.

Policies and measures beyond those already in place will be necessary to ensure Ireland is on the correct pathway to reach the 2030 targets and to ultimately decarbonise the economy by 2050. The transport sector accounts for 27% of all non-ETS emissions and so the sector has a significant role to play in helping Ireland reach these targets.

Both personal travel demand and the movement of goods is rising in line with a growing population and general economic growth; the challenge is further exacerbated by Ireland's dispersed settlement patterns. Addressing this challenge requires Ireland to deepen existing successful mitigation measures to ensure that trips become less carbon intensive, along with introducing new and innovative measures to improve efficiency, as well as better management and influencing of travel demand. This will involve a significant step-change in how we travel, do business and the types of fuels and technologies we use, requiring significant widespread behavioural change.

This paper examined the suite of mitigation measures already in place and the potential role of new measures to avoid, shift or improve emissions through:

- reducing the frequency and distance of trips;
- shifting towards more environmentally friendly modes of transport, such as walking, cycling or using public transport; and
- promoting efficient fuel and vehicle technologies.

Public feedback is being sought on the existing and potential measures contained in this paper, as well as any suggestions for new measures and polices that may assist setting the transport sector on the pathway to decarbonisation by 2050. Feedback is also sought on how these mitigation measures should be prioritised, for example on the basis of: a least cost approach, carbon abatement potential, disruptive effect, co-benefit potential etc.

Using the Avoid-Shift-Improve principle, the summary table overleaf maps the mitigation measures currently employed in the transport sector and identifies potential new mitigation measures.

Table 7.1: Avoid-Shift Improve Measures

		Instruments	Existing Measures	Potential Measures
AVOID	Private Car	Spatial planning Fuel subsidies/taxes Traffic management Road pricing	*NPF* Carbon tax College Gate and no car entry zones during peak times Tolls	Fuel subsidy/tax reform Road pricing Car sharing initiatives Teleworking
	Freight	User charges Traffic management Logistics planning	Tolls HDV cordon	User charges Logistics planning support
SHIFT	Private Car	Public transport investment Cycling/walking infrastructure Optimise PT system Low Emission Zones	BusConnects Smarter Travel Taxsaver Bike to Work Park & Ride sites	Parking policies New Park & Ride sites Low Emission Zones
	Freight	Rail freight		Rail freight promotion
IMPROVE	Private Car	Fuel economy standards Alternative fuel infrastructure & supports Ban on Internal Combustion Engine (ICE) cars Scrappage scheme Company car tax	VRT/motor tax EU regulations on CO_2 Biofuels Scheme EV incentives	Further EV incentives VRT/motor tax reform Scrappage scheme Ban/restrictions on ICE cars CO_2 company car tax
	Freight	Fuel economy standards Fuel subsidies Eco-driving	EU regulations on CO_2 Minimum excise relief for natural gas Biofuels scheme Eco-driving Research projects	VRT/motor tax reform Eco-driving supports Clean Vehicle Fund

Appendix 1: Greater Dublin Area

Source: NTA[75]

Appendix 2: Background note on mitigation measures

Measure	Description	Assumptions	Results	Uncertainties	Cost (2017-2030)
1. Biofuels	This measure involves increasing the biofuels obligation rate gradually to 10.3% in 2020 in order to achieve a higher level of penetration in the transport fleet. This represents the estimated maximum obligation rate which could be satisfied in 2020 given the technical constraints of the anticipated vehicle fleet and fuelling infrastructure.	Blending rate for biodiesel by volume increased to 6.5% and for bioethanol to 5% in 2020 which results in reaching 9.5% of RES-T target (assuming 100% of biodiesel is double-counting). It is assumed that the current biofuels 6% obligation rate adds 1.5cts to a litre of petrol and 3cts to a litre of diesel. Co-benefits not considered as uncertainty around air quality impacts.	High economic cost per tonne mainly due to the increased cost of purchasing fuel. Exchequer cost is negative overall due to the increase in excise duty (as biofuels are less energy dense).	There is generally large uncertainty concerning the price of biofuels. There is also uncertainty regarding the technical upper limits on blending with the current and future Irish vehicle stock and infrastructure.	Exchequer cost per tonne of **-€42**. Economic cost per tonne of **€203**.
2. Motor tax – Cars	In this measure the existing emissions car bands for motor tax are compressed by 20%.	The percentage share of cars in the motor tax bands remains the same so the tax take from motor tax is unchanged. The analysis uses the EPA COPERT vehicle stock	There is a high Exchequer cost due to loss of tax revenue from fuel sales. There is an economic benefit overall as a result of fuel savings to consumers.	There is a level of uncertainty around the future vehicle stock. There is also uncertainty regarding the response of consumers to the compression of the tax bands, in particular their	Exchequer cost per tonne of **€251**. Economic cost per tonne of **-€89**.

Measure	Description	Assumptions	Results	Uncertainties	Cost (2017-2030)
		forecast. It is assumed that the EU regulation CO_2 target for new cars of 95g/km is achieved in 2021 and remains constant thereafter.		willingness to adopt cleaner vehicles in response to the tax incentive.	
3. Motor tax – LDVs	For this measure the existing flat rate of motor tax for Light Duty Vehicles (LDVs) is changed to be based on emissions bands.	The same migration trend towards more efficient vehicles between 2017 and 2021 is assumed as to that for private cars (2009-2013). It is further assumed that levels settle in 2021 and remain the same along with new vehicle efficiency. The EPA COPERT vehicle stock forecast is used.	There is a high Exchequer cost due to loss of revenue from the fuel saved and motor tax receipts. Overall there is a low associated economic cost as a result of significant fuel savings to consumers.	There is a level of uncertainty around the future vehicle stock. There is also uncertainty regarding the response of consumers to the compression of the tax bands, in particular their willingness to adopt cleaner vehicles in response to the tax incentive.	Exchequer cost per tonne of **€282**. Economic cost per tonne of **€7**.
4. Electric vehicles	This measure sees a number of incentives introduced to drive growth in electric vehicle (EV) sales. The incentives included are free parking,	The incentives are removed once an EV penetration level of 70,000 is reached. Analysis assumes an annual growth rate of 87% in EV	There is a high overall cost to this measure due to the investment costs and loss of revenue from the fuel saved.	Co-benefits haven't been included such as noise and air pollution due to some methodological uncertainty.	Exchequer cost per tonne of **€1,039**. Economic cost per tonne of

Measure	Description	Assumptions	Results	Uncertainties	Cost (2017-2030)
	free tolls and the €5,000 grant and VRT relief.	sales between 2016 and 2020 and 30% thereafter. Emissions savings and costs are calculated on the basis of the 70,000 EVs stimulated. The EPA COPERT vehicle stock forecast is used. A 2ct premium on the daytime electricity rate is assumed to recover the costs of the charging infrastructure.		Determining the rates of sales growth in response to economic measures is difficult.	**€917**.
5. Eco-driving	This measure provides a grant of €10,000 to Heavy Duty Vehicle (HDV) and bus/coach operators for eco-driving training. A condition of the grant is that they need to have a telematics device installed to monitor driving behaviour.	It is assumed that 4% of HDV and bus/coach operators claim the grant each year. The telematics system is assumed to cost €300 with an additional annual subscription fee of €150. An annual fuel saving of 5% per operator is assumed for	There is a modest cost to the Exchequer due to the investment costs and loss of tax revenue from fuel sales. However, overall economic costs are low due to fuel savings arising to consumers from more efficient driving behaviour.	There is some uncertainty on the take-up of the scheme.	Exchequer cost per tonne of **€224**. Economic cost per tonne of **€23**.

Measure	Description	Assumptions	Results	Uncertainties	Cost (2017-2030)
		those participating in the scheme. The EPA COPERT vehicle stock forecast is used.			
6. Fuel tourism	This measure involves eliminating fuel tourism through closing the current petrol/diesel price differential with Northern Ireland.	It is assumed that the existing level of fuel tourism remains the same in the baseline. The current exchange rate and fuel price differential is applied. It is assumed that the fuel tax rate is increased to close the price differential.	There is a significant gain to the Exchequer overall as the loss of tax revenue from border fuel sales is offset by the increase in tax revenue from the higher fuel tax. Overall however there is a high economic cost associated with this measure due to the impact of the higher fuel cost on consumers.	There is a high level of uncertainty overall around fuel tourism as it can change from year to year depending on exchange rate movements and fuel tax levels.	Exchequer cost per tonne of **-€76**. Economic cost per tonne of **€194**.
7. Motorway speed limits	Under this measure the motorway speed limit is reduced from 120km/h to 110km/h for cars/LDVs and from 90km/h to 80km/h for HDVs. High speed is generally associated with greater	The analysis excludes those vehicles currently travelling below the new reduced speed limits. A number of assumptions are made on journey purpose split and the percentage of	Reduction of speed limits leads to Exchequer and economic costs due to increased transport time and a loss in fuel tax revenue. Savings from the reduction in air pollution is included	There is some evidence that a proportion of the motorway traffic will simply divert to other roads as a result of the measure.	Exchequer cost per tonne of **€209**. Economic cost per tonne of **€581**.

Measure	Description	Assumptions	Results	Uncertainties	Cost (2017-2030)
	CO_2 emissions per driven kilometre, so a reduction of speed on the motorway network will result in a CO_2 reduction.	motorway vehicle kilometres. It is assumed that the vehicle fleet becomes more efficient over time.	though avoided road accidents are not.		
Carbon tax	This measure consists of increasing the carbon tax on petrol and diesel from €20/tonne to €30/tonne.	It is assumed that the carbon tax tracks the EU carbon price once the two intersect. A fuel demand elasticity of -0.24 is assumed for petrol and diesel. Fuel demand is based on the national energy forecasts.	There is a significant Exchequer gain as a result of the additional tax revenue and a modest economic impact overall.	The results are sensitive to the assumptions regarding fuel demand elasticity and the forecast carbon price.	Exchequer cost per tonne of **-€917**. Economic cost per tonne of **€39**.

Acronyms

ACA	Accelerated Capital Allowance
BIK	Benefit in Kind
BEV	Battery Electric Vehicle
BOS	Biofuel Obligation Scheme
CO_2	Carbon Dioxide
CNG	Compressed Natural Gas
EEA	European Environment Agency
EPA	Environmental Protection Agency
ESD	Effort Sharing Decisions
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric Vehicle
GDA	Greater Dublin Area
GDP	Gross domestic product
GHG	Greenhouse Gas
HDV	Heavy Duty Vehicle
ICAO	International Civil Aviation Organisation
ICE	Internal Combustion Engine
IMO	International Maritime Organisation
LEV	Low Emission Vehicle
LDV	Light Duty Vehicle
LNG	Liquid Natural Gas
MACC	Marginal Abatement Cost Curve
NECP	National Energy and Climate Plan
NG	Natural Gas
NMP	National Mitigation Plan
NPF	National Planning Framework
PHEV	Plug-in Hybrid Electric Vehicle
PSO	Public Service Obligation
RED	Renewable Energy Directive
RES-T	Renewable energy share in transport
SEAI	Sustainable Energy Authority of Ireland
SPSV	Small Public Service Vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VECTO	Vehicle Energy Consumption Calculation Tool
VRT	Vehicle Registration Tax

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