LOW CARBON PATHWAYS FOR LIGHT GOODS VEHICLES IN IRELAND

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Abstract

Transport is the most significant energy consuming sector in Ireland, accounting for 40% of final energy demand in 2013. Focusing on the different transport modes, the two greatest contributors were private cars and road freight, accounting for 51% and 25% of transport energy use respectively (when fuel tourism and unspecified fuel use in transport are excluded [1]. There is a significant level of analysis on private car energy use in the literature, with very little published analysis on freight transport, which is largely limited to heavy goods vehicles (HGVs) [2].

This paper has a specific focus on energy and related CO$_2$ emissions associated with light goods vehicles (LGVs) in Ireland, addressing the knowledge gap in freight transport energy use. It takes advantage of recently available data on the LGV stock profile, and efficiency performance following the implementation of European policy limiting light-commercial vehicle specific emissions in EU No. 510/2011. The paper focuses on low carbon pathways to 2050 but also explores short term targets regarding improvements in the fuel economy of new LGVs. The European Parliament and the Council of the European Union reached an agreement regarding a regulatory proposal that all light-commercial vehicles should achieve maximum specific emissions levels of 178gCO$_2$/km by 2017 and 147 gCO$_2$/km by 2020 [3]. The former has already been achieved and Ireland is currently on target to meet the latter.

The paper develops low carbon pathways for LGV transport in Ireland for the period to 2050 using a multi-model approach together with LGV scenario analysis. The analysis is carried out using i) the Irish TIMES energy systems model and ii) an LGV stock model for Ireland. The Irish TIMES model [4] is an integrated energy systems model that generates least cost energy system pathways for Ireland to meet future energy needs to 2050 subject to policy constraints (in this case, CO$_2$ emissions reductions). The LGV stock model is a stock model of Ireland’s LGV stock for the period 2013 – 2050 and simulates the impact of changes in the LGV stock on energy and related CO$_2$ emissions.

This paper develops scenarios, and uses both models to explore the technology improvements and renewable vehicle penetration for LGVs that will be required to achieve ambitious long term emissions reduction targets, i.e. to achieve 80% - 95% CO$_2$ emissions reductions (relative to 1990 levels) by 2050.

Introduction

Transport in is the most energy intensive sector in Ireland with on-road transport accounting for a 67.5% share of the energy demand in the transport sector; 43% from private cars, 21% from road freight, and 3.5% from public transport [1]. The transport sector is currently heavily dependent on fossil fuel, primarily gasoline and diesel, with a mere consumption of liquid biofuels of 102 ktoe in 2013 (2.4% of total transport demand) [5] which began to emerge in the transport sector from 2005 onwards following the introduction of the biofuels directive [6]. The biofuels obligation scheme was further introduced in 2010, obliging suppliers of mineral oil to ensure that at least 4.166% (by volume) of motor fuels sold on the market comes from renewable sources [7]. This was increased to 6.383% in 2013 with the aim of contributing
towards Ireland’s legally binding target of 10% of energy demand in transport to be provided through renewable sources by 2020 [7].

This focus on increasing renewable penetration has grown considerably in the last decade, strongly driven by the Copenhagen Accord which established a political consensus on limiting mean global temperature to 2°C. An Inter-Governmental Panel on Climate Change assessment report detailed the need for a global total reduction in greenhouse gas (GHG) emissions of 50% by 2050 relative to 1990 in order to limit global temperatures to this level [8]. Following this analysis, the European Commission advised that in meeting this target it is the responsibility of the countries which are members of the Organisation for Economic Co-operation and Development (OECD) to reduce GHG emissions to a level between 80% and 95% by 2050 relative to 1990 [9].

Ireland stands as an interesting case as it had the 4th lowest percentage of renewables in transport of all 28 EU member states and 5th lowest percentage of renewables in final energy consumption in 2013, excluding electricity and weightings, shown in Figure 1 [10]. This highlights both the potential and the need for renewable energy penetration in transport in Ireland to work towards decarbonisation of this sector. Ireland’s target is to achieve a 20% reduction of non-Emissions Trading Scheme (non-ETS) sector emissions by 2020. In 2013 transport accounted for 19% of non-ETS emissions with 11.07 Mt CO₂eq. There is significant potential to reduce non-ETS emissions through the decarbonisation of transport [11].

Energy models have been used in creating low-carbon pathways in the transport sector [4], [12]. To date, the majority of transport models have focused on projections of private cars and HGVs - creating low-carbon pathways to decarbonise on-road transport in some cases - [2], [13], [14], [15]. In general, modelling transport demand is only possible with a sufficient level of data present. Focusing on Ireland, projections of HGVs and the private car fleet have been possible through the extensive data provided by the Central Statistics Office (CSO) and National Car Test (NCT), dating back to 1995 for HGVs through the freight survey carried out by the CSO, and dating back to 2000 for private cars when car testing became obligatory for all cars aged four year and older. Annual mandatory testing came into effect for LGVs in 2007, thus providing the data which is used here for a LGV stock model to be built.

The definition of LGVs and HGVs varies between countries; for the purpose of this paper, the authors define one LGV as a goods carrying vehicle with an unladen weight between 0 kg and 2032 kg. In Ireland LGVs consist mainly of vans (73% of LGVs in 2013), jeeps (14%), crew cabs (7%), pick-up trucks, estates, chassis cabs and open lorries (6%) and are fuelled nearly completely by diesel (99.75% of LGVs), as of 2013. Petrol LGVs are excluded from this analysis for this reason. This paper identifies potential transitions to decarbonise LGVs in Ireland through an increase in the level of biofuels and improvements in fuel economy.
Two scenarios are assessed: an 80% reduction in CO₂ emissions in all of Ireland by 2050 relative to 1990, and the same scenario with the added constraint of no imported biofuels. These scenarios are run by the Irish TIMES model – a least-cost optimisation energy systems model of Ireland – which indicates the least-cost pathway in freight (HGVs and LGVs combined) to contribute to this target. These results are then soft-linked with the LGV stock model to highlight technology roadmaps and policy measures which may be taken to reach these targets.

The paper is structured as follows: the methodology section introduces the models used, giving a specific focus to the LGV stock model, and introducing the scenarios used to heavily reduce the dependence on fossil fuels in the LGV sector. The results section identifies the feasibility of decarbonizing the LGV sector and presents the technology and policy roadmaps which may allow a contribution from the LGV sector in meeting the targets laid out by the scenarios used. Ireland’s potential level of biofuels by 2050 is also presented. The conclusion sector concludes and highlights areas of further work and limitations to the modelling techniques used.

Methodology

Two models are used and soft-linked in this analysis. The Irish TIMES model is a top-down policy evaluation model, while the LGV Stock Model works on a bottom-up basis. This section describes the methodologies behind each model and how they are used in projecting a low carbon pathway for LGVs.

Irish TIMES Model

The Irish TIMES model is a linear optimisation model with an objective function to minimise total system cost subject to imposed constraints for the Irish energy system. Mathematical equations describe the relationships and interaction between the technologies, drivers and commodities in the Irish TIMES model. The model simultaneously solves for the least cost solution subject to emission constraints; resource potentials, technology costs, technology activity and capability to meet individual energy service demands across all sectors. When deciding between technologies, it takes into account residual capacity (e.g. existing cars on the road), their fuel, operational, and maintenance costs and compares them with new technologies that require capital investment costs but generally have improved efficiencies and lower emissions. Generally the model is run in the absence of policy constraints and then re-run with a constraint (e.g. maximum permitted level of CO₂ emissions). The outputs include the costs, level of efficiency required, and fuel switching in each sector to achieve this constraint at least cost.

LGV Stock Model

A number of works have identified the importance in modelling LGV activity and energy use. In [16], survey data from the UK and France is used (while stating the implications related to the lack of data in this sector) to highlight the patterns in van activity and identify the opportunity for electric vehicles to reduce emissions. Similarly, [17] highlights a growth in van activity of 40% in the UK over the time period 2000 – 2010 and criticises the lack of knowledge of data in this area, while [18] comments on the issue with an overlap between LGVs being used for both commercial and private use, not always involving the physical transfer of goods. In general, freight projections are usually driven by tonne kilometres (tkm), as is the case in [2] and [19], however the main complication with modelling LGVs arises due to the lack of data detailing how many trips are carried out which involve the actual transfer of goods e.g., an electrician may use a van to drive to a household and provide a service without any physical transfer of goods. Due to this lack of data, vehicle kilometres (vkm) are projected in the LGV stock model, rather than tkm. All variables are disaggregated by seven unladen weight bands (which can be seen in Table 1) and are projected from 2013 onwards, which stands as the base year.
Variable Projection

Mileage

Vehicle kilometres are projected using data from the commercial vehicle road worthiness test (CVRT) which obliges all Irish LGVs to be tested annually. Gross national product (GNP) and fuel prices are used as drivers for vkm and are projected exogenously to 2050 by the Economic and Social Research Institute (ESRI) and the European Commission respectively [20],[21]. These projections are used in tandem with an income elasticity of demand (\(\gamma_I\)) and a fuel elasticity of demand (\(\gamma_{FP}\)). A mean long-run income elasticity of demand of 0.93 was chosen based on a review of traffic-related elasticities of demand using a combination of 150 published values from international studies [22]. A fuel elasticity of demand of 0.1 is chosen from the National Road Authority (NRA) [23], inferring that a change in fuel price will have a minute effect on total LGV energy demand. Equation 1 describes the projection of total vehicle kilometres for a year \(y\).

\[
V_{km}^y = V_{km}^{y-1} \times (1 + \Delta GNP^y \times \gamma_I^{Vkm}) \times (1 + \Delta FP^y \times \gamma_{FP}^{Vkm})
\]

The average mileage per vehicle per year is linearly projected based on the 13 years of available data from the Vehicle Registration Unit (VRU). A reduction of 0.63% in the mileage over this time period is used in the projection of vkm/year based on this historic data.

Specific Energy Consumption

At the time of this paper, there were limited amounts of data available regarding the specific energy consumption (SEC) of LGVs. The Sustainable Energy Authority of Ireland create estimates of the SEC of LGVs by linking the database of the makes and models of LGVs licensed in Ireland (accessed from the VRU) with the UK’s Vehicle Certification Agency’s database of official vehicle fuel consumption test results. However, fuel consumption has only been recorded in this database since 2011, which does not provide enough data to effectively carry out a back projection on SEC. To address this gap, a Finnish study dedicated to unit emissions of traffic is used to estimate the SEC of LGVs by unladen weight [24]. The study determines that the energy consumption and emissions are “to a certain extent linearly dependant on the mass of the vehicle”. The SEC of LGVs for all seven unladen weight bands is determined through linear interpolation and extrapolation using unladen weight \(m\) and the SEC from two goods carrying vehicles used in the study. This methodology is used for determining the SEC of vehicles in Ireland between 1988 and 2010. Table 1 shows the calculated SECs using Equation 2.

\[
SEC_x = SEC_a + \left(\frac{m_x - m_a}{m_b - m_a}\right) \times (SEC_b - SEC_a)
\]

<table>
<thead>
<tr>
<th>Unladen Weight Band (kg)/ Euro LGV Standard</th>
<th>0-610</th>
<th>611 - 813</th>
<th>814 - 1016</th>
<th>1017 - 1270</th>
<th>1271 - 1524</th>
<th>1525 - 1778</th>
<th>1779 - 2032</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 5 (&gt;2009)</td>
<td>2.87</td>
<td>3.08</td>
<td>3.19</td>
<td>3.31</td>
<td>3.44</td>
<td>3.57</td>
<td>3.70</td>
</tr>
<tr>
<td>Euro 4 (2007 - 2008)</td>
<td>2.82</td>
<td>3.05</td>
<td>3.17</td>
<td>3.30</td>
<td>3.45</td>
<td>3.6</td>
<td>3.74</td>
</tr>
<tr>
<td>Euro 2 (1997 - 2000)</td>
<td>2.69</td>
<td>2.98</td>
<td>3.13</td>
<td>3.29</td>
<td>3.48</td>
<td>3.66</td>
<td>3.84</td>
</tr>
<tr>
<td>&lt;1993</td>
<td>2.59</td>
<td>2.88</td>
<td>3.02</td>
<td>3.19</td>
<td>3.37</td>
<td>3.55</td>
<td>3.73</td>
</tr>
</tbody>
</table>
The deterioration of an LGV engine is of a factor of $1.003^v$, where $v$ is the vintage of the LGV, as assumed from [25]. This equates to a progressive reduction in the fuel economy of the vehicle in a year-on-year basis.

Stock

LGV stock is disaggregated and projected here by seven unladen weight bands, while total stock is calculated from the division of the projections of vkm and vkm/vehicle. Survival profiles for the various unladen weight bands of LGVs are built using the same methodology carried out as that of private cars in [26], determined here through the historic data on the number of LGVs by year of registration between 2002 and 2013. Survival profiles are based on year of registration rather than year of manufacture to account for the level of LGVs imported into Ireland. A simple year-on-year survival probability is calculated using this methodology.

$$Survival\ Rate_{v}^{UWB} = Average\left(\frac{Stock_{v}^{UWB} - Stock_{v-1}^{UWB}}{Stock_{v}^{UWB}}\right) \times (1 + Survival\ Rate_{v-1}^{UWB})$$ \hspace{1cm} (3)

Here the survival represents the probability of one LGV of vintage ‘$v$’ in an unladen weight band ‘$UWB$’ of surviving to a vintage ‘$v$’. The stock for every LGV disaggregated by unladen weight band and vintage for every year ‘$y$’ is calculated using the following equation:

$$Stock_{v,y}^{UWB} = Stock_{0,y-1}^{UWB} \times Survival\ Rate_{v}^{UWB}$$ \hspace{1cm} (4)

The level of sales are subsequently accounted for on a year-by-year basis that allows the level of stock required to satisfy the total demand of vkm to be reached.

Total emissions in the LGV sector are calculated through the product of the stock, mileage, and SEC of each disaggregated band, i.e. vintage and unladen weight, multiplied by an emissions factor. An emissions factor of 73.3 tCO$_2$/TJ for diesel and level of biofuel blending is taken from [1]. EN 590 explicitly states a maximum of 5% of biodiesel by volume is allowable in conventional ICEs, therefore an assumption of 5% unweighted biofuels blending is assumed by 2020 and held constant to 2050.

$$Total\ LGV\ Emission = Emissions\ Factor \times \left(\sum Stock_{v,UW}^{ULW} \times Mileage_{v,UW}^{ULW} \times SEC_{v,UW}^{ULW}\right)$$ \hspace{1cm} (5)

Low Carbon Scenarios

Irish TIMES Scenarios

Two scenarios are explored using the Irish TIMES model. The first stays in keeping with the recommendations laid down by the EU for OECD countries which achieves an 80% reduction in CO$_2$ emissions by 2050 relative to 1990 ($CO_2$-80 scenario), describing the level of effort required by the freight sector in order to achieve an overarching constraint. The second scenario carries out the same analysis as the $CO_2$-80 scenario with the added constraint of a restriction on the importing of any biofuels. The purpose of this scenario is to reduce any external dependence on imports of biomass in the future and to determine the next cheapest alternative to cover the energy demand of what would have been supplied by imported biofuel originally ($CO_2$-80 No Biolmp Scenario).

Low Carbon Scenarios

Three scenarios are analysed to quantify the emissions reductions associated with each individual variable. Initially a business as usual (BaU) scenario is developed which assumes no improvement in the energy efficiency of LGVs from now to 2050 with no switch over to renewable fuel vehicles. The BaU marks a baseline for all other scenarios as to what may happen in the absence of any policies.
The second scenario quantifies the potential emissions reduction from focusing on the efficiency improvements of LGVs, with no penetration of renewable vehicles. A focus is placed on three individual efficiency measures. The first limits the average specific emissions of all new LGVs to 147 gCO₂/km, as required by The European Parliament and the Council of the European Union in Regulation (EU) No. 510/2011 [3]. The second simulates the switch to more efficient vehicles following the simulation of a policy in 2021 which bases LGV tax on emissions, rather than unladen weight as is the case today. This simulation uses the same percentage change in the efficiency of the private car fleet for the five years following the change in taxation from engine size to specific emissions in 2008, which saw a drastic drop in the emissions of the new car fleet [27]. Finally, an improvement in the fuel economy of LGVs out to 2050 is assumed based on the Energy Technology Perspectives report released by the IEA which identifies a potential 47% improvement in the efficiency of light-duty vehicles, relative to a baseline gasoline vehicle [28].

The final scenario combines the improved efficiency scenario with the penetration of compressed natural gas (CNG) LGVs fuelled by bio-methane. To simulate this technology, we use data from the 6 gasoline and gas fuelled vans owned by Gas Networks Ireland (GNI). The purpose of this scenario is to assess the feasibility of the penetration rates of biofuels in freight in the TIMES CO₂-80 and TIMES CO₂-80 No Biolmp scenario.

The European Commission have proposed a maximum distance of 150 km between publicly accessible refuelling point to allow the circulation of CNG vehicles by the beginning of 2021 at the latest [29]. Due to the lack of any further planning post this operation, this scenario assumes no penetration of CNG LGVs prior to 2025.

Results
The results section is split into three parts. Firstly, a comparative overview of the results of the two scenarios in the Irish TIMES scenarios are presented (CO₂-80 and CO₂-80 No Biolmp). Secondly, policy roadmaps are presented based off the results of the Irish TIMES scenario results which may allow for the high level penetration of renewable vehicles in the freight sector. Both of these analyses suggest a high level penetration of biofuels in decarbonising the LGV sector. To account for this, the final section provides an analysis of the total quantity of Ireland’s available biofuel resource by 2050 which may be used to reduce any further dependence on imports of biofuel.

Irish TIMES Model
The transport sector experiences a drastic decarbonisation in the CO₂-80 scenario, with an 88% reduction in CO₂ emissions between 2010 and 2050 in all transport. In contributing to this emissions reduction, a range of renewable technologies are chosen by the model in the freight sector. Under the CO₂-80 scenario, there is a total of 318 ktoe of biogas and 240 ktoe of diesel in freight. In replicating this scenario in the LGV Stock model, all bio-gas is assumed to fuel LGVs and the remaining energy consumption is through diesel. This scenario is heavily dependent on exogenous sources of bio-energy for freight with imports of 3,555 ktoe compared to indigenous production of biofuel and biomass of 1,757 ktoe in 2050.

The CO₂-80 No Biolmp scenario sees a restriction on any biofuels or biomass imports in Ireland. This reduces the level of biofuels in freight by 40% relative to the CO₂-80 scenario and uses hydrogen fuel cell vehicles as result of the limit on biofuel and biomass imports, with no diesel being used as a fuel source in freight. An assumption is made in the latter scenario that close to all LGVs will be powered by biogas while HGVs use a combination of hydrogen fuel cells and bio-methane as a fuel source. The fuel mix of freight (HGVs and LGVs) with corresponding emissions intensity is shown in Figure 3.

In the Irish TIMES model, freight is aggregated into LGVs and HGVs. Therefore in recreating these scenarios in the LGV Stock Model, it is assumed that all the bio-gas in the CO₂-80 scenario fuels LGVs, along with some diesel while in the CO₂-80 NoBiolmp scenario all LGVs are fuelled by biomethane.
**LGV Stock Model**

The technology roadmaps from the Irish TIMES scenarios are tested in the LGV Stock Model to create policy roadmaps to 2050. The scenarios created allow for an insight into policy measures in Ireland which may contribute towards a low carbon LGV sector. Three scenarios are used for this purpose; BaU, Improved Efficiency, and Improved Efficiency with Renewable Vehicles.

The BaU is intended to provide a baseline of against which all other scenarios are compared. LGV stock experiences a 36% increase by 2050 relative to 2013 which satisfies the total energy services demand of 8,357 million vkm with an average of 25,925 km/LGV/annum. The SEC of new LGVs is held constant at the 2013 values with a weighted average of 2.16 MJ/km. This is lower than the current average SEC of the LGV fleet of 3.37 MJ/km allowing for an overall improvement in the fuel economy of LGVs. When linked with the growing stock out to 2050, there is a 0.26% increase in the total emissions by 2050 relative to the base year.

The Improved Efficiency scenario focuses on the effect of a number of individual policy measures towards the improvement of energy efficiency of new LGVs and the corresponding reduction in fleet emissions. Meeting the 147gCO\(_2\)/km target for new LGVs by 2020 as laid out by EU No. 510/2011 has only a slight reduction in emissions, 3% relative to the BaU scenario, due to the nature of the short time span – there are a small number of new LGVs entering the transport fleet between now and 2020 relative to the total LGV fleet to have a significant impact on the level of emissions in the short term, but this has a sufficient impact in the long-term due to the continuous introduction of new LGVs every year.

Using the change in fuel economy of new private cars in Ireland following a change in the taxation policy from engine size to specific emissions, a similar policy is simulated in LGVs. A change in the policy for taxation of LGVs from unladen weight to specific emissions resulted in a 13% reduction relative to the baseline following an improvement in fuel economy between 2021 and 2025.

Finally using the highest potential of fuel economy from engine and non-engine components identified by the IEA by 2050 contributes to a total reduction in emissions of 43% by 2050. This scenario highlights the total potential of reducing emissions by focusing solely on energy efficiency improvements of conventional ICE engines without considering the adoption of alternative or renewable fuel. Figure 3 summarises the potential emissions reduction from the fuel economy policy measures explored.
The final scenario considers the level of effort required to decarbonise LGVs according to the Irish TIMES scenarios through the penetration of CNGs. This decarbonisation is modelled using an initial introduction of CNG LGVs fuelled by bio-methane. The percentage level of sales of ICEs and CNGs is varied in the model to simulate the stock levels as laid out by the CO$_2$-80 and CO$_2$-80 No Biomp scenarios. Due to the current lack of infrastructure for CNGs, no renewable vehicle penetration in LGVs is assumed prior to 2025. To achieve an 85% penetration of bio-methane in freight by 2050, CNGs require an annual increase of 5% share of all LGV sales from 2026 onwards, with 100% of all LGV sales from 2045 onwards being CNGs. In an extreme scenario where a 99% CNG penetration rate is required, a much faster increase in CNG sales is necessary. This scenario requires a linear increase from 2026 to 2030 in the rate of CNG sales up to 100% and then held constant out to 2050.

The SEC of the CNG stock fuelled by bio-methane is taken at the average performance of four of the six petrol and gas vans, which had an unladen weight of approximately 1,500 kg, used by GNI. The same fuel efficiency improvement as diesel engine vans was assumed to 2050 with the same reduction in fuel economy per van per year applied. Compared to diesel LGVs, the petrol and gas vans had a higher rated SEC; the weighted average SEC in both the 85% and 99% CNG penetration scenario in the LGV stock model for bio-methane LGVs was 1.83 MJ/km compared to 1.45 MJ/km and 1.70 MJ/km respectively. The LGV Stock model assumes for all CNG LGVs to be fuelled entirely off bio-methane and results in zero tail pipe emissions for these vehicles. The calculated emissions from LGVs in 2013 was 1,161,111 tCO$_2$ while an 85% penetration has a corresponding 119,569 tCO$_2$ (89.7% reduction) and a 99% penetration has emissions of 5,209 tCO$_2$ (99.7% reduction).

Irish Bioenergy Supply

The total theoretical methane potential associated with agricultural slurries and manures was found to be 279 ktoe in 2050, the largest resource is in the form of slurry sourced from dairy cattle (58 ktoe), followed by slurry sourced from beef cattle (47 ktoe). Pig slurry, poultry manure, and sheep manure contribute 20 ktoe, 11 ktoe, and 14 ktoe respectively. These results assume that all of the slurry and manure generated can be collected, while in reality only a portion of cattle slurry and sheep manure can be collected, whereas almost all of the pig slurry and poultry manure can be collected owing to their large scale centralised production.
The OFMSW resource was found to be 62 ktoe, with 46 ktoe arising from commercial OFMSW (478,000 T collected), 14 ktoe from urban household OFMSW (286,000 T collected), and 2 ktoe from rural household OFMSW (33,000 T collected). The lower methane potential of rural household OFMSW is due to the 20% limitation on the amount of organic and garden waste that can be collected separately from rural households.

The energy potential associated with excess grass silage was found to be 1,154 ktoe, arising from a surplus of 3.38 MT dry matter of grass silage. Applying a silage yield of 11 TDM/ha/a [30] this is equivalent to silage production from 307,454 ha of land. In 2020 the projected land area under silage is 1,092,481 ha [31], of which 28% (307,454 ha) would be surplus to animal feed requirements, as such no additional land would be needed to provide the 1,154 ktoe of methane from surplus grass silage.

Table 2 outlines the theoretical resource of methane available from agricultural slurries and manures, OFMWS, and excess grass silage in 2050.

**Table 1: Irish Bio-Methane Potential by 2050**

<table>
<thead>
<tr>
<th>Methane Resource (ktoe/a)</th>
<th>2050</th>
<th>Percentage Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Slurry</td>
<td>58.03</td>
<td>4%</td>
</tr>
<tr>
<td>Beef Slurry (Other Cattle)</td>
<td>48.64</td>
<td>3%</td>
</tr>
<tr>
<td>Cattle &gt;=2 Slurry</td>
<td>48.05</td>
<td>3%</td>
</tr>
<tr>
<td>Cattle 1-2 slurry</td>
<td>46.42</td>
<td>3%</td>
</tr>
<tr>
<td>Cattle &lt;1 Slurry</td>
<td>33.51</td>
<td>2%</td>
</tr>
<tr>
<td>Pig Slurry</td>
<td>19.62</td>
<td>1%</td>
</tr>
<tr>
<td>Chicken Manure</td>
<td>11.00</td>
<td>1%</td>
</tr>
<tr>
<td>Sheep Manure</td>
<td>13.62</td>
<td>1%</td>
</tr>
<tr>
<td>Grass Silage</td>
<td>1154.55</td>
<td>77%</td>
</tr>
<tr>
<td>Rural Household food and Garden Waste</td>
<td>2.22</td>
<td>0%</td>
</tr>
<tr>
<td>Urban Household food and Garden Waste</td>
<td>14.46</td>
<td>1%</td>
</tr>
<tr>
<td>Commercial Food Waste</td>
<td>45.68</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1495.8</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Conclusion**

A complete decarbonisation of the LGV sector in Ireland which would contribute towards an 80% reduction in CO₂ by 2050 relative to 1990 is technically feasible through the combination of efficiency improvements and the use of biofuels. An overall 43% reduction in CO₂ emissions relative to a BaU is possible through improvements in the fuel economy of LGVs. To help contribute to emissions reduction in the short term, a change in the policy of taxation for LGVs from unladen weight to specific emissions would improve the fuel economy of new LGVs by 23% if the same market response is mimicked in the LGV sector as the private car sector. This analysis assumes that no CNG LGV will be present in Ireland until 2025 due to the lack of infrastructure. To allow for an 85% - 99% penetration of CNG LGVs by 2050, between 70 and 80 refuelling stations would be required nationally. Given the availability of infrastructure for CNG vehicles by 2050, a penetration rate of 85% CNG LGVs by 2050 will contribute towards an 80% CO₂ emissions reduction by 2050, while a 99% penetration would be required if Ireland was to source all bio-fuels indigenously. This is achievable through linear increase in percentage share of CNG LGVs from 0% in 2025 to 100% in 2045 for an 85% penetration level and an increase from 0% in 2025 to 100% in 2030 for a 99% penetration. In terms of energy performance, ‘real world’ CNG LGVs operate less efficiently than the test values from diesel LGVs, however they have a zero specific emissions resulting in a zero carbon form of LGV. Replicating the Irish TIMES scenarios, there is the potential for between an 89.7% - 99.6% CO₂ emissions reduction by 2050 relative to 2013.
Our total theoretical bio-methane resource of 1,495 ktoe by 2050 would be enough to provide the energy requirement of both penetration levels of CNG LGVs if fuelled by bio-methane. The high penetration scenario would require 362.19 ktoe of bio-methane, this accounts for approximately 24% of the total theoretical bio-methane potential, and could be achieved by 72 facilities, treating 50,000T/a (wet weight) of grass silage. If construction of these plants were to commence in 2016, approximately 2 large anaerobic digestion plants would need to be built per annum. Therefore, while it could be possible to meet the bio-methane demand of LGVs in 2050, challenges still remain regarding the roll out and development of suitable anaerobic digestion facilities.

The methodology applied to the LGV stock model gives rise to a number of limitations which may lead to further work in this area. No rebound factor or on-road factor are taken into account in this analysis, which may account for the large difference in the fuel economy performance of the petrol and gas LGVs and test-value SEC of diesel fuelled LGVs. The model does not capture the switching from LGVs over to HGVs, and for this reason it would be desired to amalgamate this stock model with a HGV stock model to project all of the on-road freight sector together. Ideally the LGV stock model would be split between commercial and private vehicles detailing the total tonnage transferred and commodity transported along with vehicle kilometres. This would allow for more specific drivers to be associated with each commodity e.g., gross value added to the building sector to drive a projection of transported building goods.

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Bibliography


