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QUANTIFYING TRANSPORT ENERGY EFFICIENCY SAVINGS

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ABSTRACT

The importance of quantifying energy savings and improvement in energy efficiency for each sector of the economy is now widely recognized in order to demonstrate progress towards targets and compliance with legal obligations. The focus of this paper is specifically on evaluating energy efficiency in transport using the ODEX methodology.

More detailed data has recently become available on transport energy trends and the underlying factors that allow the authors improve the calculation of Ireland's transport ODEX. Through data mining of administrative databases mileage, volume, age, engine type and size data are available at a disaggregated level for each mode of road transport.

In particular this paper examines private car energy efficiency, quantifying the change arising from improved data. There was an overall slight improvement (0.71 percentage points) in the Irish private car ODEX when both proposed changes of using MJ/km as the unit consumption measure and modeling the stock by vintage were applied.

The overall effect of the revised transport ODEX calculation does not show a significant increase in energy savings associated with the value of the ODEX indicator (0.82%). However the purpose was to improve the methodology of how the ODEX was being calculated, not necessarily increasing the savings.

Keywords: Energy Efficiency, ODEX, Private cars, Transport energy

1 INTRODUCTION

Energy efficiency is defined as a ratio between an output of performance, service, goods or energy to an energy input. It can also be described as the achievement of the same results with less energy or achieving an improved result with the same energy. Broadly speaking energy efficiency in transport relates to moving people or goods more effectively i.e. the same amount of people or goods with less energy or a greater number of people or goods without an increase in energy consumption. This can be achieved through a number of approaches such as: technical energy efficiency improvement for example where the specific energy consumption of the vehicle stock is improved, behavioral improvements such as eco-driving and car sharing or through other measures such as modal shift, logistics management or changing speed limits to name but a few. The approaches used to measure

energy efficiency in transport will give further insight into what is considered energy efficiency in transport however it is not trivial to quantify all transport energy efficiency savings. Some improvement such as behavior changes are extremely difficult to quantify, thus transport behavioral energy efficiency improvements are not addressed in this paper.

The importance of quantifying energy savings and improvement in energy efficiency for each sector of the economy is now widely recognized in order to demonstrate progress towards targets and compliance with legal obligations. Energy efficiency is currently the subject of significant policy activity in both Ireland and Europe. European Union Directive 2006/32/EC on energy end use efficiency and the energy services directive (ESD) sets an indicative target for Member States to achieve a 1% per annum energy efficiency improvement resulting in a cumulative target of a 9% improvement in energy efficiency by 2016. There is also a target of a 20% improvement in energy efficiency of the whole economy by 2020 at both an Irish government and EU level. Energy efficiency is also seen as an enabler of renewable energy and the most cost effective method of reducing carbon emissions from energy use.

The focus of this paper is specifically on evaluating energy efficiency in transport using the ODEX methodology. The ODYSSEE (**O**nline **D**atabase **Y**early a**SS**essments of **E**nergy **E**fficiency) project was set up in 1993 with the objective of developing indicators of energy efficiency for Europe. The collection and improvement of data relating to energy usage drivers, energy efficiency and CO_2-related indicators were later added as objectives. Within the EU ODYSSEE project, a number of sectoral indices and an overall economy wide energy efficiency index called ODEX (**OD**YSSEE energy efficiency ind**EX**) indicators have been developed [1]. These indices aggregate trends in unit consumption by sub-sector or end-use into a single index per sector based on the weight of each sub-sector/end use in the total energy consumption of the sector. ODEX indicators provide an alternative to the usual energy intensities only related to energy efficiency and exclude changes in energy use due to other effects such as climate fluctuations, changes in economic structure of industry and lifestyle changes for example.

1.1. Overview of Irish transport energy and modal split

The analysis in this paper covers the period 1995 to 2008. Transport energy use increased by 110% (excluding fuel tourism[1]) in this 13 year period. The modal split of this transport energy use is presented in Figure 1. The by public passenger services (including taxis) recorded the largest growth over the period of 248%, closely followed by the road freight category which increased by 212% and air transport energy increased by 142%. Private cars, which consume the largest amount transport energy, increased their consumption by 85% and rail consumption increased by 33%.

[1] Fuel tourism is defined as fuel purchased within the State by motorists and hauliers but consumed outside the State.

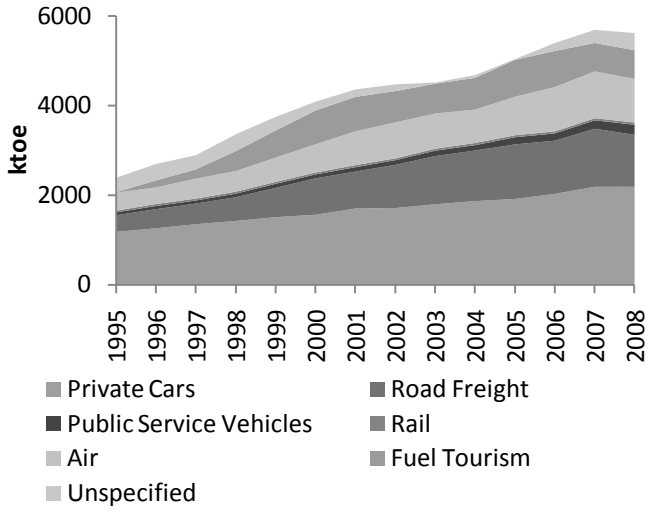


Figure 1 Transport energy use between 1995 and 2008 split by mode of transport

2 ODEX METHODOLOGY

This section provides an overview of the ODEX methodology. It reproduces explanations and equations from the ODYSSEE project documentation in order to assist in explaining the methodology [3]. If the energy consumption in any particular year can be defined by Equation (1) as:

$$UC_t \times A_t \qquad (1)$$

Where *UC* is the unit consumption and *A* it the activity level and *t* is the year being analysed.

Then energy efficiency can be calculated as the change in unit consumption (improvement) between two years as described in Equation (2).

$$\frac{UC_t}{UC_{t-1}} \times A_t \qquad (2)$$

Thus energy efficiency savings are what would have been consumed had if not been for the improvements in year *t*.

Energy consumption variation per sector can be monitored when the consumption is split into unit consumption (*UC*) by an activity variable (*A*).

Hence the formula:

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i A_{i,t} \times UC_{i,t-1}} \qquad (3)$$

Alternatively, the following formula could be used:

$$\frac{I_t}{I_{t-1}} = \frac{UC_{i,t}}{UC_{i,t-1}} \qquad (4)$$

Substituting for $UC_{i,t-1}$ in Equation (3), as defined by manipulating Equation (4):

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i A_{i,t} \times UC_{i,t} \times \frac{I_{t-1}}{I_t}} \qquad (5)$$

The denominator in Equation (5) can also be described as the energy consumption in year *t* multiplied by the ratio of the unit consumption index in year *t-1* to that of year *t*. If Equation (5) is inverted to give Equation (6) it can be seen that the index of the sector is the sum of the index of each subsector weighted by the energy share of each subsector.

$$\frac{I_{t-1}}{I_t} = \frac{\sum_i EC_{i,t} \times \frac{I_{t-1}}{I_t}}{\sum_i EC_{i,t}} \qquad (6)$$

Equation (6) can also be express as Equation (7) where the ratio of consumption between two years (I_{t-1}/I_t) can be expressed as the sum of the sub-sectoral index ratios $I_{i,t-1}/I_{i,t}$ weighted by the share of each sector in the total energy consumption.

$$\frac{I_{t-1}}{I_t} = \sum_i ec_{i,t} \times \frac{I_{i,t-1}}{I_{i,t}} \qquad (7)$$

From Equation (7) it can be concluded that unit consumptions at the most disaggregated levels (by sub-sector or end-use) can be expressed in different units into one index per sector based

on the weight of each sub-sector/end-use in the total energy consumption of the sector. Similarly, a global ODEX can be calculated from the aggregation of sectoral indicators. In the ODEX calculations a three year moving average of the final index is calculated in order to remove the impact of non efficiency affects such as business cycle variation.

As the ODEX is calculated as an index of energy efficiency, a decrease in the ODEX signifies an improvement in energy efficiency. An increase in the ODEX normally signifies deterioration in energy efficiency. However, where there is significant growth in activity in a sector or sub-sector there can also be growth in the ODEX and in this case an increasing ODEX does not correspond to deterioration in energy efficiency.

A technical ODEX is where the unit consumption used to calculate the ODEX is normalised to remove the influence of variables which are not explicitly accounted for in the ODEX calculations. The unit consumption can be influenced by a number of factors. Creating a technical ODEX is a way of normalising the effect of these influences. The technical ODEX is not a likely or actual outcome but a methodology for quantifying certain influences on the ODEX calculation.

Energy efficiency savings using ODEX can be calculated from the following definition of the ODEX:

$$ODEX = \frac{E}{(E + ES)} \times 100 \qquad (8)$$

Where E is the total energy in year t and ES represents the energy savings in year t. With some manipulation of Equation (8) the energy saving (ES) can be calculated as:

$$ES = (\frac{100}{ODEX} - 1) \times E \qquad (9)$$

2.1 Transport ODEX

The transport ODEX is a weighted energy share of a number of sub-sectors or mode of transportation unit consumption indices. The intention of the transport ODEX is to evaluate the transport energy uses at the level of 8 modes or vehicle types, namely: cars, trucks, light vehicles, motorcycles, buses, domestic air transport, rail and water transport. For each mode the energy efficiency indicators are as follows:

- Cars: specific consumption in litres per 100 kilometre (l/100km)
- Trucks and light vehicles: unit consumption in tonne kilometre (ton-km)
- Air transport: unit consumption per passenger
- Rail, Water: unit consumption of energy in tonnes of oil equivalent[2] (toe) per passenger kilometre (toe/pkm)
- Motorcycles, Buses: unit consumption of energy per vehicle (toe/veh)

The existing Irish transport ODEX calculation by mode is limited by data availability and is currently calculated as follows:

- Private car specific consumption in litres per 100 kilometre (l/100km)
- Trucks and light vehicles: unit consumption in tonne kilometre (ton-km)
- Rail: unit consumption of energy per passenger kilometre (toe/pkm)
- Buses: unit consumption of energy per vehicle (toe/veh)

[2] This is a conventional standardised unit of energy and is defined on the basis of a tonne of oil having a net calorific value of 41686 KJ/kg.

- Aviation: unit consumption of energy per passenger (toe/pas)

As the ODEX methodology is primarily used for cross-country comparisons within the ODYSSEE project, aviation is not usually included, as per the ESD. The following modes of transport are not included in the existing ODEX calculations due to data gaps: taxis, motorcycles, water transport and the unspecified category which refers to off road vehicles such as cranes and diggers.

3 DATA AVAILABILITY

More detailed data has recently become available on transport energy trends and the underlying factors that allow the authors improve the calculation of Ireland's transport ODEX. Through data mining of administrative databases mileage, volume, age, engine type and size as well as emissions data is available at a disaggregated level for each mode of road transport including a category generally termed as unspecified which refers to off road vehicles such as cranes and diggers, plus unaccounted for energy due to modeling errors. This data allows for the creation of more energy efficiency specific unit consumption indices used in the ODEX calculation, as opposed to the initial unit consumption indices which were based on that data available when the indicators were first created.

It is proposed to change the unit consumption indices used in the ODEX calculations to the following:

- Private car specific consumption in mega-joules per kilometre (MJ/km)
- Trucks : unit consumption in tonne kilometre (ton-km)
- Light vehicles: unit consumption in vehicle kilometre (veh-km)
- Rail: unit consumption of energy per passenger kilometre (toe/pkm)
- Buses: unit consumption of energy per vehicle passenger kilometer (toe/pkm)
- Aviation: unit consumption of energy per passenger (toe/pas)

4 PRIVATE CARS

Improvements in the energy efficiency of private cars are driven by the agreement between car manufacturers and the European Union. Initially on a voluntary basis it was agreed to lower the average fuel consumption of all new private cars to 130g/km of CO_2 by 2012. In 2009 a mandatory target of 60% of all fleet vehicles to meet the 2012 target of 130g/km with all cars meeting this level by 2015 as part of EU regulation No. 443/2009. It is widely acknowledged that purchasing patterns have outweighed any improvements in energy efficiency in recent years [4].

The focus of this paper is to improve the contribution of private car transport energy efficiency to overall energy efficiency changes in the transport ODEX and quantifies the change arising from improved data. In 2008 private car transport accounted for 61% of road transport and 44% of all transport energy excluding fuel tourism.

As already mentioned more detailed data has recently become available on transport energy trends and the underlying factors of energy use in the transport sector. Since the year 2000 the private car stock can be disaggregated by fuel, by age and by engine size band by the Department of transport's vehicle registration unit (VRU). The specific fuel consumption in litres per 100 kilometres for new cars has been recorded by the VRU for all new cars due to legislative changes to the requirements of new car labels. The Energy Policy Statistical Support Unit (EPSSU) of the Sustainable Energy Authority of Ireland (SEAI) link the data for fuel consumption of new cars from the VRU with the UK Vehicle Certification

Agency (VCA) in order to find the data on the specific emissions in grams per kilometre of carbon dioxide of all new cars between 2000 and 2007. The VRU has started to record new car specific emissions since 2008, when a tax change was introduced to taxes[3] of all cars, purchased from 2008 onward, to be based on emissions as opposed to engine size bands.

The existing private car ODEX is calculated as an index of the specific unit consumption (litres/100km) of the car stock (SUC_{STOCK}), where SUC_{STOCK} is the weighted average of petrol and diesel SUC_{STOCK}.

$$SUC_{stock} = \frac{(SUC_{stock(t-1)} \times N_{stock(t-1)} + SUC_{NEWstock(t-1)} \times N_{NEWstock(t-1)}}{N_{stock(t)}} \quad (10)$$

Where SUC is the specific unit consumption in litres per 100 kilometres (l/100km), t is the year and N is the number of cars.

The petrol and diesel unit consumption indices are aggregated by using the share of the fuel type in the vehicle stock.

4.1 Volumetric Effect

There is a difference in the energy density of at litre of petrol and a litre of diesel. Petrol has an energy content of approximately 33 MJ/l whereas diesel has 37 MJ/l, that is diesel has approx 11% higher energy content which means that l/100km comparisons of the fuels do not reflect energy use. Diesel cars have lower l/100km values because there is more energy contained in a litre of diesel. The affect of the lower unit consumption value when specified in volumetric terms on the ODEX calculation is for the diesel stock specific consumption figure to improve the ODEX faster however it is more appropriate to compare energy improvements i.e. improvement in MJ/km values and in this case the diesel value is not falsely improving the ODEX.

[3] Vehicle registration tax (VRT) and annual motor tax (AMT).

Using Ireland as a test case, there is a 5.38% improvement in the private car unit consumption index when using MJ/km whereas the calculation of litres/100km gives an improvement of 6.08%. That is a difference of 0.67 percentage points.

4.2 Stock Model

The existing stock model used in the private car ODEX calculation is a crude estimate of the stock as it only splits the stock into new and existing cars.

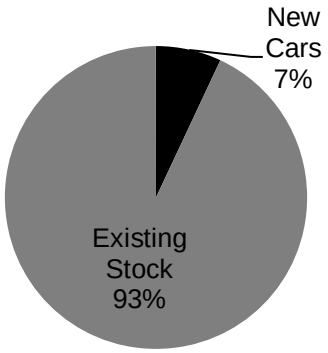


Figure 2 Stock profile for 2008 used in existing Irish ODEX calculation

The Irish private car ODEX improved by 1.2 percentage points when a stock model which reflected the vintage of the car stock was used. The new car specific unit consumption value on year of purchase remains the specific unit consumption value for cars purchased in that particular year as long as that vintage remains in the stock. The specific consumption was degraded (increased) by 0.3% per annum as suggested from empirical analysis on ageing of car engines elsewhere [4]. An on road factor of 20% was also used [2].

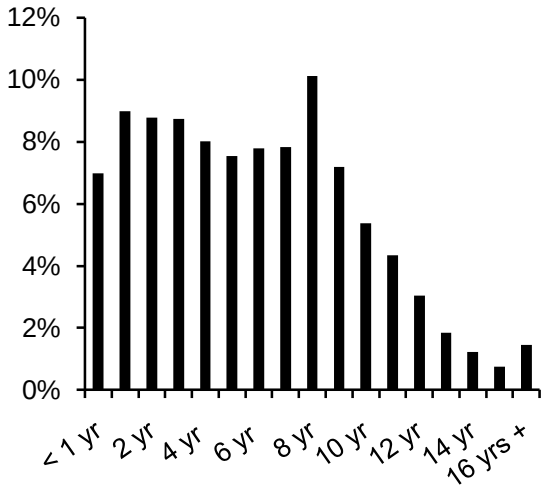


Figure 3 Proposed 2008 stock breakdown for ODEX calculation profiled by vintage

Figure 5 shows the results for the Irish private car ODEX at various stages of applying the changes proposed in this paper. There is a deterioration of 0.67 percentage points in the ODEX calculated between 1995-2008 when it is calculated using MJ/km rather than l/100km. However when the stock model is disaggregated by vintage, there is an improvement of 1.38 percentage points.

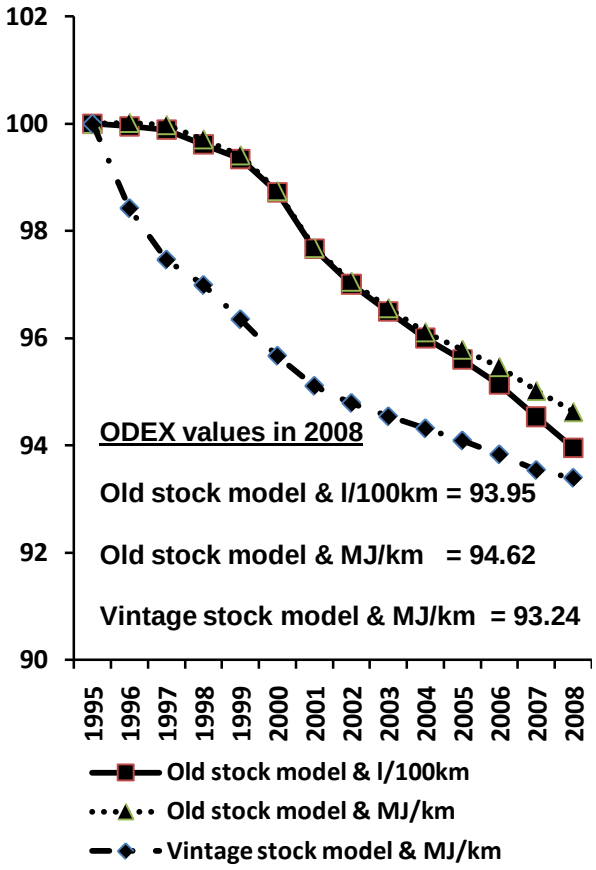


Figure 4 All calculated versions of the Irish private car ODEX

The ODEX indicators calculated in Figure 6 are not calculated as a three year moving average of the ODEX. As the calculations in this case are not being used for international comparisons it was deemed unnecessary and inappropriate in this case to apply the three year moving average.

4.3 Calculating energy efficiency savings for private cars

It is possible to quantify savings from the ODEX methodology as shown in Equation (9) the calculations of the private car ODEX discussed in this paper takes the influence of age degradation on specific consumption of 0.3% per annum and also includes an on-road factor of 20%. Factors which are not currently included in this ODEX calculation include an allowance for the influence of driving style and the impact of urban or rural driving.

Table 1: Quantified savings for private car energy efficiency improvements

	ODEX value in 2008	Savings (ktoe)
Old ODEX calculation	93.95	140
ODEX calculated using MJ/km	94.62	124
ODEX calculated using MJ/km & stock model split by vintage	93.24	158

4.4 Influences on the private car ODEX calculation

The effect of these purchasing patterns on the private car ODEX were examined to give insight into the influence of purchasing patterns on the overall energy efficiency of the car stock. The purchasing patterns of cars can be examined under different categories and this paper looks at two of these categories namely; fuel type and engine size.

4.4.1. Growth in car numbers and car ownership

In Ireland private cars have historically dominated in the road vehicle fleet. In 1995 private cars made up 78% of the road vehicle fleet. The number of private cars in the Irish fleet grew by 94% over the period 1995 to 2008 as show in Figure 6. Private cars had a share of 77% of all road vehicles in 2008.

Private car ownership in 2008 was at 435 cars per 1000 of the entire population or 548 cars per 1000 adults. The latter is still below the EU15 average of 592 by 7.4%, the UK average of 578 and slightly below the EU27 average in 2007 of 551 cars per 1000 of adults. Those indicators suggest there is still potential for growth in the private car fleet size.

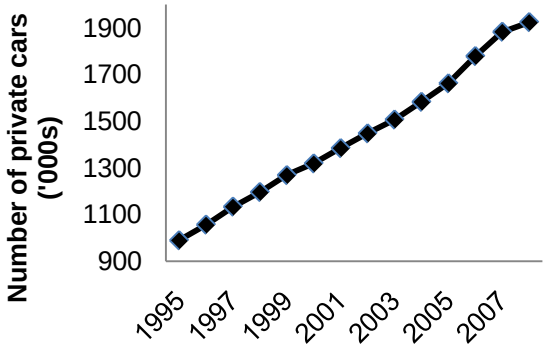


Figure 5 Growth in private car stock between 1995 and 2008

As the private car ODEX is calculated by unit consumption index, a variable influence by age of vehicles as opposed to the volume, the actual size of the stock is not an influencing factor but rather the vintage of the stock. Increasing new car sales will increase the improvement in the ODEX so the relative volume of new cars to the overall stock volume is important.

4.4.2. New car stock penetration rates/ renewal rates

The percentage of new cars in the fleet averaged around 11% over the period 1995 to 2007 (see Figure 7). In 1999 13% of all cars were new and in 2000 this increased to 17%. From the high of 2000 the new cars added in any particular year as a percentage of the overall fleet was decreasing year on year, with the exception of 2005 when new cars represented 10% of the private car fleet. There has been a significant improvement in the ODEX since 1999. Initially the improvement was fast, due to the number of new cars purchased in 2000 (17%), dubbed the millennium effect, the rate of improvement of the ODEX then slowed, however since 2006 the rate has picked up again, due to the increasing number of new diesel cars being purchased, over 20% of all new cars are diesel since 2003 and also due to the increase in the number of new cars purchased in 2005.

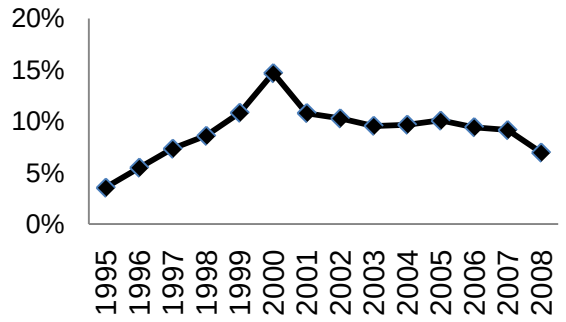


Figure 6 New cars as a percentage of the overall petrol and diesel stock

The overall correlation between the volumes of new cars as a percentage of the overall stock volume is -0.23 which is only a mild correlation that an increase in the percentage of new cars in the stock will result in an improvement of the ODEX. The constituents of the new car stock has more of an influence on the ODEX, that is why an examination of the purchasing patterns of new cars is required in order to examine the factors influencing the Irish private car ODEX.

4.5 Fuel type

Ireland is an interesting case for examining the share of cars by fuel type as detailed in Figure 8. In 1995 approximately 86% of all private cars in the vehicle stock were fuelled by petrol, in 2008 the share was 79.7%. When compared to other European countries it can be seen the Ireland had the highest share of petrol cars in Europe in 2007[4]. In 2008, 64% of new cars purchased were petrol cars.

As mentioned earlier when petrol and diesel unit consumption indices are combined a false improvement of the ODEX when calculated by using l/100km as the measure of the specific unit consumption. The influence of fuel switching in the Irish test case was 0.07 percentage points when the ODEX calculated by the combine petrol and diesel specific consumption in MJ/km index was compared to the aggregated sum of the individual fuels. This equated to 0.8 percentage points of the overall improvement.

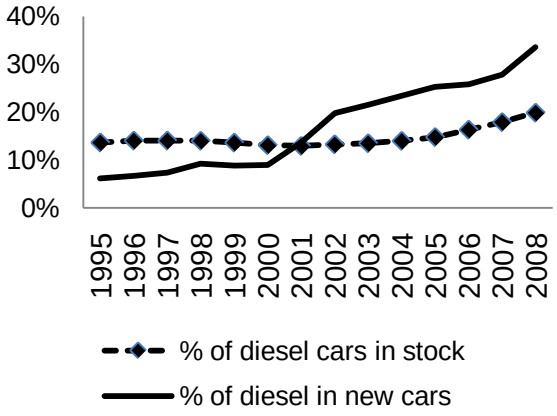


Figure 7 Diesel shares in both new cars and the car stock

The 2008 change of the vehicle registration tax (VRT) and the annual motor tax (AMT) to a system based on CO_2 emissions as opposed to engine size caused a significant step change in the shares of petrol and diesel cars in the purchase of new cars. This change will still take some time to filter into the stock as new vehicle numbers decreased dramatically coincidentally around the time of the introduction of the tax change. Most other European countries also experienced this drop in new vehicle numbers which can be attributed to the economic recession.

4.6 Engine size

The car engine size profile has changed dramatically in the 13 years between 1995 and 2008. Detailed data on fuel type and engine size band all licensed vehicles has been collected by the VRU since 2000. Using this data it is possible to estimate the average engine size of the stock. The estimates assume that the median value for each size range in 0.01litres below the maximum limit of the band. While this may not be the case for all engine-size bands, it facilitates comparison of

[4] According to statistics on the ACEA website. http://www.acea.be

the average engine size across a number of years.

The estimated increase in the average engine size of the combined petrol and diesel stock over the period 2001-2008 was 5%, as shown in Figure 10. The effect of this increase is to increase the overall unit consumption of the stock by 0.75% per annum, thus offsetting the technical progress by 59%.

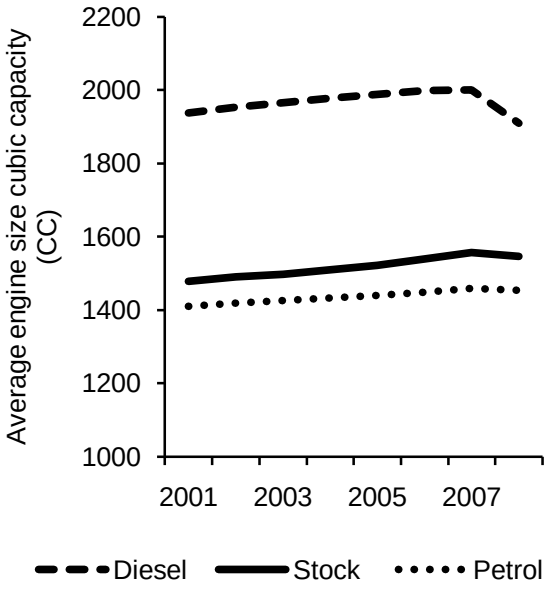


Figure 8 Average engine size of the separate and combined petrol and diesel stock

The change in the composition of the petrol stock by engine size band since 2000 is detailed in Figure 11. The largest engine size band for petrol cars is the 1.2 – 1.5 litre engine size band. The average engine size of petrol cars increased by 5% between the years 2000 to 2008. The largest growth was in the 1.7 to 1.9 litre engine sized cars, followed by the >2.1 litre engine cars. Since 2000 there was an increase in the share of vehicle >1.5 litre engine size and a decrease in the smaller engine sized cars.

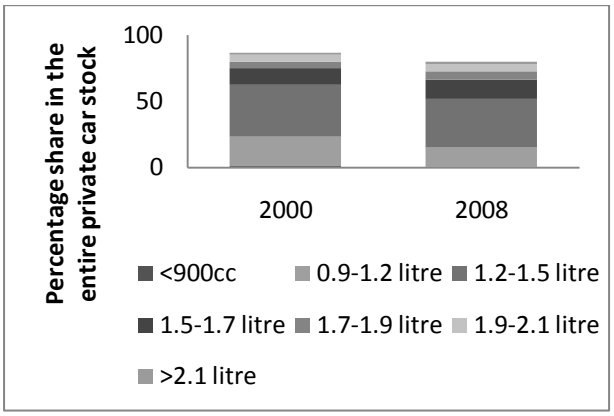


Figure 9 Change in petrol car stock composition by engine size

The change in the composition of the diesel stock by engine size band since 2000 is detailed in Figure 12. The largest growth in diesel cars between 2000 and 2008 was in the 1.2 to 1.5 litre engine size band. There are hardly any diesel cars in the less than 1.2 litre engine size band. The greater than 2.1 litre engine size band experience the second largest growth rate for diesel cars, followed by the 1.7 to 1.9 litre band. There was a reduction in the overall average engine size of diesel cars over the period 2000 to 2008 of 1%, however as diesel cars have historically had a larger engine size than petrol cars the overall average engine size of the stock increased.

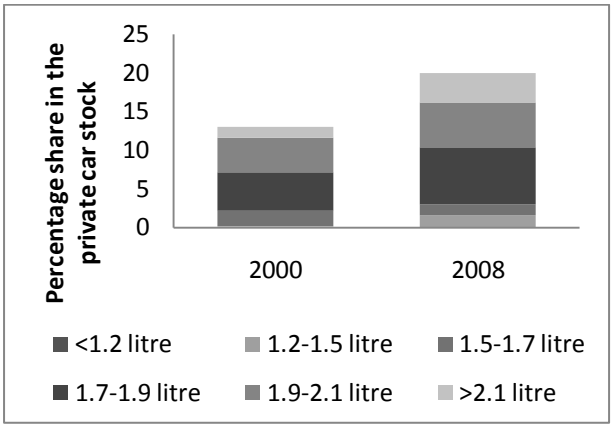


Figure 10 Change in diesel stock composition by engine size

As discussed when explaining the ODEX methodology a technical ODEX is where the unit consumption used to calculate the ODEX is normalised to remove the influence of

variables which are not explicitly accounted for in the ODEX calculations. Examining the ODEX in this method allows more obvious links to the effect of purchasing patterns on the ODEX. In order to investigate the influence of purchasing on the ODEX a technical ODEX was created to normalise for the increase in the average engine size in to quantify the affect of this increase on the ODEX.

The growth in average engine size for petrol cars offset improvements in efficiency by 50% similarly the growth in the average engine size for diesel cars offset improvements in efficiency for diesel cars by 57% until 2007, however as the average engine size of diesel cars decreased in 2008 this contributed to an improvement in energy efficiency.

5 OVERALL ODEX CALCULATION

When the changes to the private car ODEX are incorporated into the existing overall transport ODEX calculation, there is a change in the 2008 transport ODEX value from 96.3 to 95.5, which is 0.8 percentage point improvement. In terms of energy savings, when calculated according to Equation (9) there was an improvement from 135ktoe to 163ktoe.

6 FURTHER WORK

The next step in the analysis of energy efficiency in the transport sector is to examine the road goods vehicles category. This category has been the fastest growing mode in the Irish transport sector[5]. When this category is further disaggregated by unladen weight it is clear that this growth in energy usage was not uniform across the mode, as highlighted by SEAI (Ireland 2009). Splitting this category by unladen weight will provide a more accurate estimate of energy efficiency improvements in this sector.

[5] Between 1990 and 2008.

The improvement in energy efficiency of the goods vehicle category was measures as energy per tonne-km. This is the most appropriate indicator of efficiency for the heavy duty vehicles but it is proposed to change the measure of energy efficiency for the light duty vehicles to energy per vehicle kilometre (veh-km). Vehicle kilometres are more appropriate than tonne-km for the less than 2 tonne unladen weight category as distance travelled reflects the energy demand driver for this category more appropriately than tonne kilometres [5].

Essentially by splitting the goods vehicles category another sub-category has been created. These sub-categories can be integrated into the transport ODEX calculation by two methods namely creating two more categories in the ODEX calculation or by combining the sub-categories to create a new goods vehicles sector energy efficiency index. The latter was the method chosen as it is useful to have an insight into both the individual light and heavy duty vehicle categories as well as overall goods vehicles. The method chosen also facilitates direct comparison between the old and new method for calculating energy efficiency in goods vehicles.

Similar to the overall ODEX calculation the goods vehicles sub-sectors namely light and heavy duty vehicles are combined by their energy shares in order to facilitate a single index representing the improvement in energy efficiency for the overall goods vehicles category.

7 CONCLUSION

The overall effect of the revised transport ODEX calculation does not show a significant increase in energy savings associated with the value of the ODEX indicator. This was not the purpose of the exercise. The purpose was to improve the methodology of how the ODEX was being calculated. The updated unit

consumption indices reflect more accurately the level of energy efficiency improvement as opposed to initial version of the indicators which were limited by the data availability.

In particular the paper improves the contribution of private car transport energy efficiency to overall energy efficiency changes in the transport ODEX and quantifies the change arising from improved data. If the vintage of the car stock is available then this data should also be used to further improve the accuracy of the ODEX calculation. The Irish private car ODEX improved by 1.38 percentage points when a stock model which reflected the vintage of the car stock was used.

The specific consumption values used for the calculation of the private car ODEX should be expressed in energy terms i.e. MJ/km not volumetric units (l/100km) as diesel cars have lower volumetric specific unit consumption values (i.e l/100km) than petrol cars. When the specific unit consumption of petrol and diesel are combined using the volumetric specific unit consumption (l/100km) effectively the lower diesel volumetric specific unit consumption inflates the improvement in the combined volumetric specific unit consumption.

The Irish private car ODEX deteriorated by 0.53 percentage points when the private car ODEX was calculated using MJ/km as opposed to litres/100km. However this change also future proofs the private car ODEX methodology to facilitate diversification of private car fuel types i.e. petrol and diesel and especially a shift to electric vehicles which will not have volumetric based specific car consumption.

Private car energy efficiency savings increased from 140 ktoe to 156 ktoe when the suggested changes in this paper were applied. Incorporating the improved private car ODEX into the overall transport ODEX there was an increase in savings from 134 ktoe to 163 ktoe.

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