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MODELLING MALTA'S ROAD TRANSPORT SYSTEM TO EVALUATE CARBON DIOXIDE EMISSIONS AND THE BIOFUEL POTENTIAL: A TOOL FOR POLICY-MAKING

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ABSTRACT: The Maltese road transport sector accounts for a significant part of Malta's annual CO_2 emissions. Like all EU member states, Malta has a number of obligations emanating from the 2020 Climate and Energy Package, including a target of 10% renewable energy (RE) share in transport [1] as well as a ceiling of +5% GHG emissions by 2020 (reference 2005) for sectors covered by the effort sharing decision (ESD) [2]. In order to assess which policy measures are best suited to enable Malta to meet these targets a model was devised which projects future fuel demand to determine the amount of CO_2 released as well as the quantity of biofuel necessary to meet the RE target. The aim of this study was to analyse the parameters which determine fuel consumption by road transport in Malta with particular focus on private road transport, and integrate these in a model to project the fuel energy consumption and associated CO_2 released by this sector in 2020. The study then superimposes the effect of biofuel blending on the net CO_2 inventory for passenger cars and concludes that even if the average passenger transport demand keeps growing at a rate of 1.97% per year (average for 2005-2011), the net CO_2 emissions by this sector would still fall below their 2011 levels under all six scenarios.

Keywords: Transport, Carbon Dioxide, Malta

1 BACKGROUND

Studies to project the fuel consumption by a particular vehicle fleet often do so by projecting the annual average mileage per vehicle, the vehicle fleet growth, and the vehicle efficiency distribution, which is continuously changing as new, more efficient vehicles replace older stock. The fuel consumption is then translated into CO_2 emissions using the appropriate carbon emission factors (CEF) for the fuel types in use. This approach was for instance used by Huo *et al* [3] to project the Chinese motor vehicle growth and corresponding oil demand. Such projections have underlying assumptions such as a drop in the average mileage of each car as the fleet grows, which do not necessarily apply to Malta. Furthermore, the vehicle fleet growth projections tend to be based on models such as that described by Dargay *et al* [4] which uses an S-Type function to correlate the number of vehicles per 1000 people and the GDP per capita. This may be suitable to assess the long-term general trend but was found unsuitable to use for the short term between 2013 and 2020.

This study assesses various data sets to determine which parameters would affect the vehicle fleet growth, efficiency and mileage between 2013 and 2020 in Malta. Since the scope of this study was to develop a policy tool, the model focuses on passenger cars (UNECE category M1) which during 2011 used 62% of fuel energy consumed by road transport. This is the largest and most dynamic sector (within road transport) and should therefore continue to be the focus of future policy measures.

2 VEHICLE FLEET SIZE

Since projecting Malta's fleet size using an S-Type function to correlate vehicle ownership and GDP proved futile, other parameters were assessed. Figure 1 shows the annual GDP growth [5] and the number of newly registered vehicles between 1971 and 2012. The number of scrapped vehicles between 2006 and 2012 is also indicated [6]. Pre-2006 scrappage data is omitted as it was deemed unreliable. In fact the National Statistics Office (NSO) performed a re-assessment of vehicle stock data in 2005. The chart indicates that for the period 1971-1989, new vehicle registrations followed annual GDP trends but with a delay of a few years. This could be attributed to the fact that the purchase of a new car when Malta's per capita GDP was still under $5,500 was an investment which required sustained growth over a number of years rather than one particularly 'good' year. On the other hand, the number of new car registrations per year from 1990 onwards never fell below the 30 units per 1000 population, not even when Malta had negative economic growth. (The exception of 1993/1994 most likely reflects invalid data. NSO data shows vehicle stock increases for 1993 and 1994 of 43,051 and 22,885 vehicles while new registrations for the same years were 9,635 and 10,638.) This shows that at higher per capita GDP levels (>$6,000 in Yr2000 in real US$) other parameters became the predominant factors affecting the number of new registrations. Similarly, the number of scrapped vehicles during the period 2006 to 2012 did not follow trends in GDP. These observations are important as GDP has historically been closely coupled with passenger transport demand (although a progressive decoupling has been observed at EU level from 2009 onwards [7]). The model assumes that nowadays changes in car fleet size are independent of GDP and indirectly to transport demand.

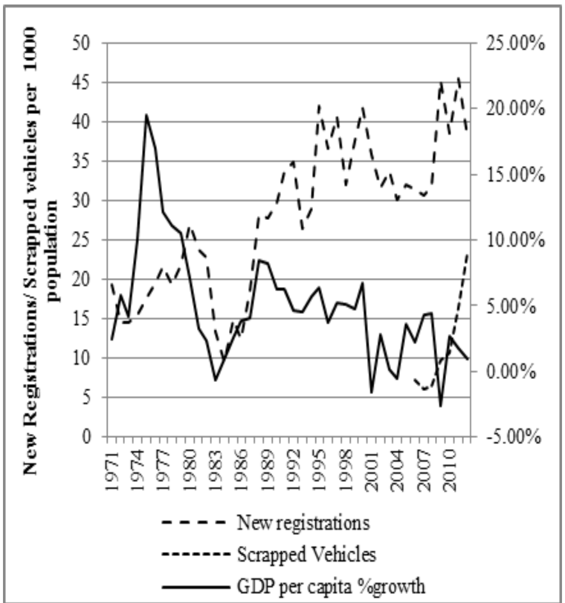

Figure 1 New vehicle registrations/ scrapped vehicles per 1000 population time series; Data from NSO Library.

Figure 2 displays the vehicle registration data for the period 2001-2011 (disaggregate data for newly registered new and used vehicles is not available for years 2001-2003) . It is evident that a steep rise in the number of newly registered vehicles occurred during 2009 and this was sustained for the following years. Simultaneously a rise in scrapped vehicles occurred during the same year and rose sharply beyond 2010. This trend was a result of a combination of measures including the revision of the vehicle registration system, the removal of VAT on second hand cars imported directly by consumers from other EU member states, and a scrappage scheme introduced in 2010. Since the UK is a major source of imported used cars, the effect of these measures was compounded by a favourable GBP/EUR exchange rate which, as can be seen in Figure 3 touched the parity rate in January 2009, further encouraging second hand car imports. All this shows that the vehicle fleet size and composition is very sensitive to measures which are largely independent of Malta's economic growth and transport demand.

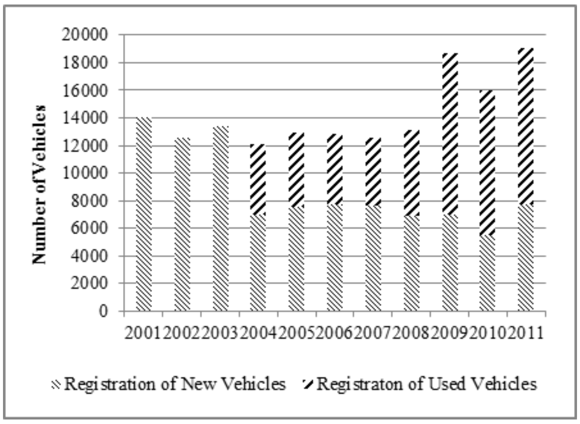

Figure 2 Newly registered vehicles time series

Although transport demand is not the major driver for new car purchases, it was necessary to examine the effect of additional vehicle stock on overall fuel consumption due to the reverse mechanism that more cars lead to more driving, decreasing alternative modes of transport such as walking, cycling, and public transport. A demographic assessment sheds light on Malta's current particular situation. As of 31st December 2009, there were an estimated 332,358 persons aged 18 years and over in Malta and so eligible for a driving license, with only 66.4% (or 220,749) of these in possession of a driving license. This means that by 2009, Malta already had 1.35 licensed vehicles per license holder. Even if everyone aged 18 years and over possessed a driving licence, there would already be 10 vehicles for every 11 drivers. Projecting these figures to 2020, assuming an increase of 60,399 in vehicle stock (based on constant annual growth as for average over the period 2001-2011), and using NSO's projected population aged 18 years and over (353,400 persons), there would be 1.05 vehicles per person aged 18+ and 1.59 vehicles per licence holder. This could indicate that much of the projected additional stock is effectively excess stock in the sense that a license holder can own more than one vehicle but clearly cannot drive them simultaneously.

The picture is even clearer if only passenger cars are taken into account. By the year 2007, the number of private cars had already exceeded the number of license holders and the gap would be even wider if the 13,440 licensed motorcycles were included. There is also no sign that the number of license holders shall increase in the short term. This has remained stable during the past decade. Furthermore, Malta's demographic report for 2010 published by NSO projects a contracting population within age group 18 to 70 years.

A main conclusion drawn from this assessment is that additions to the current vehicle stock should not trigger new transport demand within the passenger transport sector. Instead, new vehicles could be replacing older cars which however are not scrapped perhaps due to a relatively low circulation tax applicable on pre-2009 vehicles. In fact NSO statistics show that as at Dec 2011, 21% of licensed passenger cars were older than 20 years.

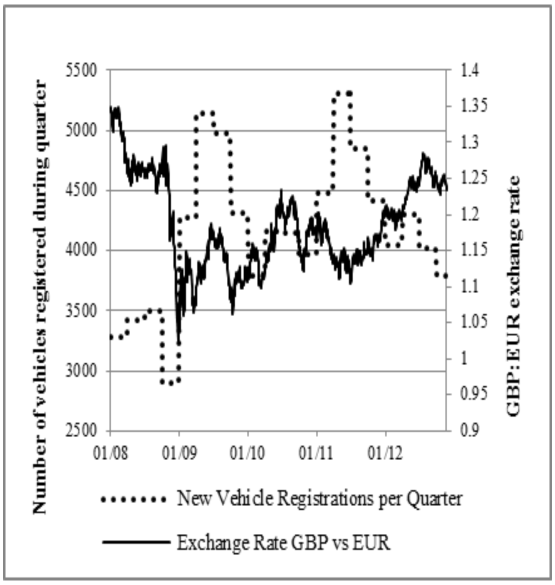

Figure 3 Compounded effect of exchange rate, vehicle registration tax and scrappage scheme on the number of registered vehicles. Vehicle data from NSO Library, exchange rates from European Central Bank website: http://www.ecb.europa.eu.

The model devised here assumes that overall transport demand (mileage) is split between all licenced cars with newer cars used more often, in line with the assessment performed in section 4.

3 FLEET EFFICIENCY PROFILE

The fleet fuel efficiency depends on the fleet composition which, in turn depends on the vehicle year of manufacture (VMY), engine size and type, driving conditions, and various other technical factors, which together determine each vehicles' consumption factor measured in gFuel/km. In order to estimate the consumption factor of pre-2010 vehicles a model described by EMEP/EEA emission inventory guidebook 2009 (updated May 2012) [8] was used. This model is mainly intended to estimate emissions for GHG inventory purposes, but can also be used to estimate the fuel consumed per km by each vehicle category corresponding to different EURO classes. Since vehicles in Malta were until recently not classified by EURO class, the VMY was used to categorise them. The EMEP/EEA guidelines propose three tiers with tier 3 being the most elaborate. Since the focus was on passenger cars, a tier 3 approach for diesel and petrol passenger cars was adopted. This however required as input the annual average speed for each car category. No local official figure was found and so reference was made to the data collected during the National Household Travel Survey held during 2010 by PriceWaterhouseCoopers on behalf of Transport Malta [9] . The dataset includes a list of trips with start and finish address, trip duration, and mode of transport performed by a sample of 6,666 participants. Using a sub-sample of these trips and a GoogleMaps® application which calculates the distance driven between two locations, an average speed of 21.43km/h was estimated. The resulting average consumption and emission factors for passenger cars are shown in Figure 4.

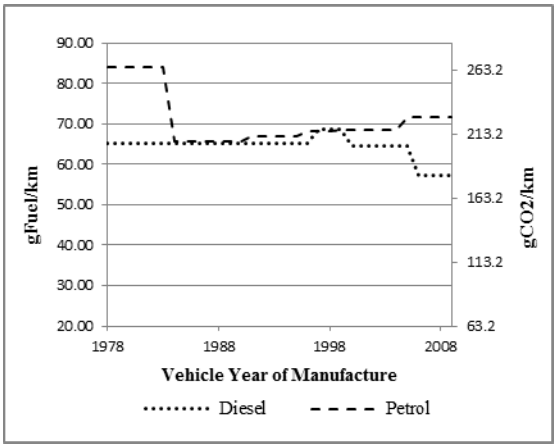

Figure 4 Modeled Average Consumption & Emission Factors for Passenger Cars by Year of Manufacture in Malta (based on EMEP/EEA emission inventory guidebook 2009.)

For post 2009 passenger cars the consumption factor was estimated by assuming a linear reduction in CO_2 emissions, from the average reported for new vehicles registered in Malta during 2010 (Petrol 124.24gCO_2/km, Diesel 128.38gCO_2/km) and the 2020 target of 95gCO_2/km determined by Regulation (EC) 443/2009 [10]. The model applies a loading factor to this trajectory to reflect the gap between consumption as measured on the New

European Driving Cycle (NEDC) and real life driving conditions in Malta. Based on tests measured by Allgemeiner Deutscher Automobil-Club and user data collected by spritmonitor.de [11], a conservative loading factor of 20% was selected for the baseline scenario. However, allowing this factor to be user- defined allows the modelling of scenarios which could result should other measures to promote the take up of cars with an average efficiency below the assumed EU trajectory are introduced.

4. MILEAGE

Official mileage data is elusive. The analysis of unofficial aggregate data collected by vehicle roadworthiness test stations and processed by NSO, indicates that the average annual mileage performed by older cars was lower than that for newer cars. A relationship between the average odometer reading and vehicle age for petrol and diesel passenger cars was obtained and this was integrated into the model. In this manner the overall annual mileage (which reflects the total transport demand by passenger cars) is not distributed equally between all cars but follows according to the equations:

For petrol: $y = -134.87x^2+9325.7x$ $\quad R^2=0.954$
For diesel: $y = -177.91x^2+11337x$ $\quad R^2=0.952$

Where y =Average odometer reading for vehicles of age x years.

5. TRANSPORT DEMAND

The model requires a fourth parameter: the overall mileage which represents the expected passenger transport demand. The conclusions drawn earlier (in sections 2 and 3) permit this parameter to be defined independently of parameters which determine the vehicle fleet stock turnover, fleet efficiency profile and distribution of mileage amongst the fleet.

The fleet size depends on parameters which set the number of newly registered vehicles and the number of vehicles withdrawn from circulations (scrapped, exported or garaged). The fleet efficiency profile depends on the specific loading factor applied to the average emission factor of new vehicles placed on the market during a particular year as well as the vintage year of the vehicles removed from circulation. The resulting fleet composition would in turn determine the mileage profile as the average mileage performed by each vehicle category would also depend on its age.

The overall mileage is allowed to change independently and is often pegged to the real growth in passenger transport demand (in terms of vehicle-km). Applying the model for the period 2005-2011 and adjusting for the discrepancy between estimated consumption and statistical fuel consumption, it was estimated that the average annual growth in total vehicle-km (transport demand) for petrol passenger cars was 1.97%. This growth rate was assumed for the baseline scenario.

6. VALIDATION

The unavailability of historical mileage data makes it difficult to validate the model against statistics. However it was possible to apply the model for the period 2005-2011 for petrol vehicles (cars, minibuses, motorcycles) and compare with fuel statistics, as petrol is almost completely consumed by road transport vehicles. The discrepancy between the year-on-year growth predicted by the model and the statistical growth varied between 0.47% (2005-2006) and 2.14% (2006-2007). This means that predicted changes in the fuel demand of the order of these figures may not be reliable. Notwithstanding these limitations, the model should still indicate trends in fuel demand subject to the chosen parameters. Due to the various data quality issues the model is expected to have more of comparative function to explore different scenarios. It lays down a methodology which can be further developed once more detailed fleet composition and mileage data becomes available.

7. MODEL OUTPUT

The model computes the projected consumption by passenger cars for each year between 2012 and 2020 using:-

$$\sum_{k=1}^{\text{max. age}} G(N_k M_k C_k)$$

G= scaling factor representing annual growth in overall mileage(spread evenly amongst all cars)
N_k= Number of cars with average age k
M_k= Average mileage performed by cars of age k
C_k= Average Consumption factor for cars with age k
Max. age = highest age of cars on the road.

Seven different scenarios were assessed using the developed model varying parameters to simulate measures which promote: (A) a large fleet turnover, (B) a reduced number of newly licenced cars coupled with a high scrappage rate, (C) low fleet turnover, (D) a 2.50% annual growth in vehicle-km (rather than 1.97%), (A-1) increased share of newly licenced new cars, (A-2) 15%

loading on type-approval emission factors, (A-3) 25% loading on type-approval emission factors.

The results are shown in Figure 5 (for petrol passenger cars) and Figure 6 (for diesel passenger cars). As expected, a slight increase in the annual transport demand (vehicle-km) growth rate will have a significant impact on the fuel consumption (and associated CO_2) emissions, but the fuel demand would flatten towards 2020 as a result of a more efficient fleet. Scenario A-2 (for petrol) and A-1 (for diesel) give best results in terms of CO_2 emission reductions. The former projects a net reduction of 5.56% in fuel/CO_2 with respect to 2011 as a result of a lower loading on the type approval consumption factors.

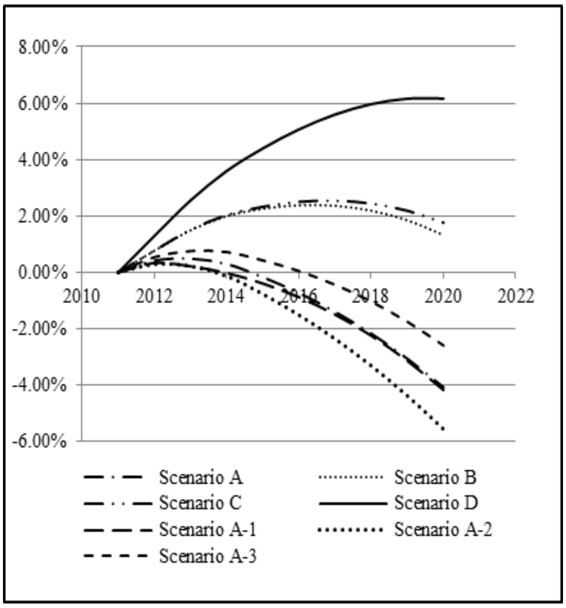

Figure 5 Projected percentage change (relative to 2011) in petrol consumption by passenger cars under various scenarios

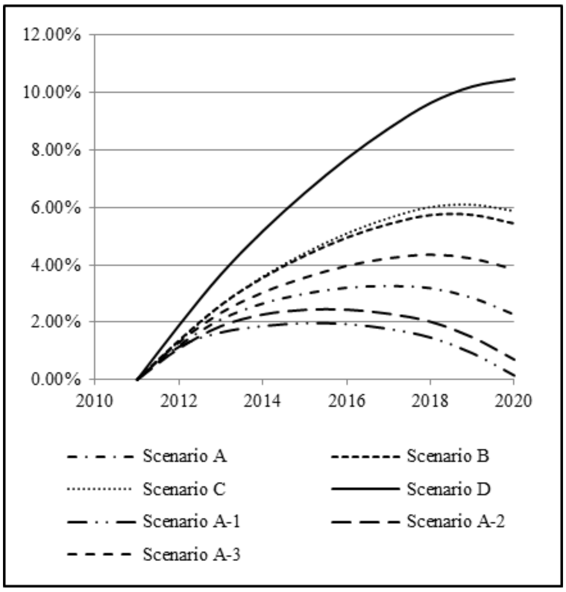

Figure 6 Projected Percentage Change (relative to 2011) in Diesel Consumption by Passenger Cars under Various Scenarios**.**

This represents a scenario were smaller, more efficient cars are incentivised so that the overall average CO_2 emission factor lies below the EU average for each year. The latter projects a marginal increase of 0.14% in diesel consumption with respect to 2011 levels due to a higher percentage of new cars being licenced every year ("used" to "new" ratio shifted from 79:21 to 40:60). This scenario is in line with measures which promote the purchase of new cars as against imported second had cars. Unfortunately the current registration tax regime effectively promotes imported second hand cars as it is partially levied on the book value of the vehicle which drops sharply as the car ages.

8 BIOFUEL POTENTIAL

The model projects CO_2 emissions by projecting fuel consumption. The effective CO_2 emissions depend on the carbon emission factor of the fuel being used and so shall depend on the types of fuel used to satisfy the demand. Malta's approach to meet its emission reduction targets under the Effort Sharing Decision and Renewable Energy Directive involve the blending of biofuel with mineral fuel gradually raising the blending ratio as 2020 approaches.

In order to estimate the effective CO_2 emissions (assuming that biofuels have zero emissions for the purpose of Malta's inventory) the projected trajectory needs to account for the biofuel substitution trajectory. The compounded effect for emissions due to passenger cars for Scenario C is shown in Figure 7 (petrol) and Figure 8 (diesel).

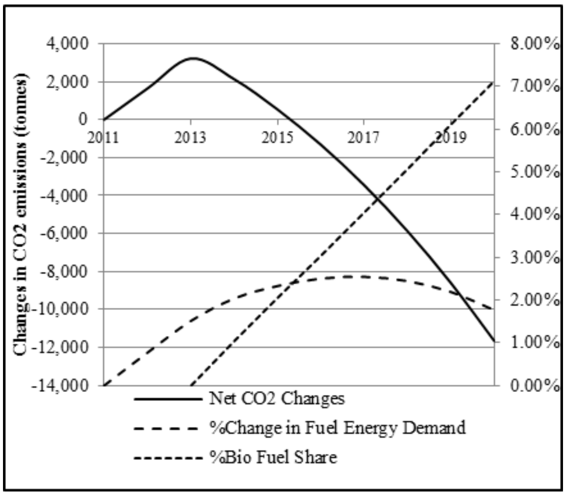

Figure 7 Projected CO_2 Changes (Petrol Passenger Cars) Scenario C with Bio-ETBE substitution.

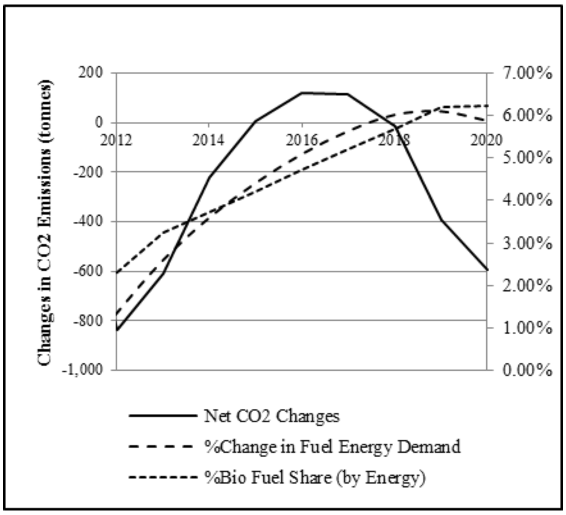

Figure 8 Projected CO_2 Changes (Diesel Passenger Cars) Scenario 'C' with Biodiesel Substitution.

The biofuel blending trajectory is selected in such a way that Malta would just meet its 10% RE target within the transport sector without exceeding the respective fuel EN standards. The chosen blending route reaches 6.74% (v/v) biodiesel share in diesel and 22% (v/v) bio-ETBE share in petrol by 2020, equivalent to a bio-share of 6.21% (e/e) and 7.11% (e/e) respectively. Bio-ETBE is being preferred over bio-ethanol as the latter would result in higher evaporative emissions during summer and this could comprise the air quality [12] [13] [14]. This has effectively restricted Malta's options to reach the 10% target, given that the use of electricity in the transport sector is negligible. In this regard Malta has included within the ILUC proposal (Indirect Land Use Change proposal) a clause to extend the applicability of the flexible mechanisms from the overall RE target to the transport RE target. However, the proposal may still have a long way to receive approval.

These results show that the effect of the selected biofuel blending trajectory more than offsets increases in CO_2 emissions due to additional fuel demand even under a scenario with low passenger car fleet turnover and a 1.97% annual growth in vehicle-km (Scenario C). This holds true as long as biofuels are considered as zero CO_2 emission fuels. In practice this is not the case, and post-2020 targets may be harder to meet if actual GHG savings figures are used along the same lines as in the EU Fuel Quality Directive.

An additional consideration is the added cost involved as a result of biofuel blending coupled with a higher fuel energy demand such as that projected under Scenario C. The biofuel substitution obligation would already cost circa 25 million euros (cumulative 2011-2020 at typical 2012 CIF Malta port biofuel prices), and the model projects an estimated additional one million euros should Scenario C prevail over Scenario A.

The results further highlight the point that keeping transport demand (for travel by passenger cars) in check is the key to achieve long term cuts in GHG emissions from within this sector and reduce the compliance costs associated with the RE directive.

9 CONCLUSIONS

The model specifically developed for the Maltese road transport scenario has been applied to the passenger car sector but can be expanded to cater for commercial vehicles. The quality of the projections can be improved by acquiring better estimates for average annual mileage and speed (possibly per vehicle category). Vehicle roadworthiness test stations are valuable sources of data, but the quality of the collected data needs to be significantly improved by incorporating data validation techniques during data capture. Today's technology also makes it possible to track a sample of vehicles to capture travel patterns, mileage and speed, essential parameters to improve projections.

Now that electricity generation, the major contributor towards Malta's GHG inventory, is expected to achieve significant cuts as a result of more efficient plants, investment in RES, fuel conversion from HFO to natural gas, and the Malta-Sicily interconnector, tackling transport-related emissions shall soon take the centre stage. The model could be of particular value to compare different policy options which affect any of the model parameters so as to determine which option is expected to yield best results (in terms of fuel energy cuts) and to what degree it needs to impinge on the relevant parameter to achieve the desired results.

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