Scenario Analysis: Establishing a cut-off date for the importation and registration of conventionally-fuelled vehicles in Malta

Draft

4th November 2019

Table of Contents

1. Introduction

In August 2018, PwC were commissioned, following a public tender[1] to review the current Malta National Electromobility Action Plan 2013 – 2020 (MNEAP) and update the Action Plan to 2030. In addition, the terms of reference also involved advising the government appointed e-Cars Committee by preparing a study for a cut-off date for the importation and registration of Internal Combustion Engine (ICE) vehicles in Malta.

Moreover, following discussions with the Ministry for the Environment, Sustainable Development and Climate Change (MESDC), the scope of the ICE cut-off date study was extended to include an estimation of the reduction in CO_2 emissions under the different cut-off date scenarios being considered.

Within this context, this report presents the results of the study carried out on the future of ICE vehicles in Malta, including the scenario analysis to support the proposal for an ICE cut-off date. It sets out the underlying principles and outcomes of the study, including an assessment of the key discussions held with relevant stakeholders, current market status, underlying assumptions underpinning the developed fleet model, an assessment of the results for the different scenarios tested as well as the expected changes in CO_2.

For ease of reference, this document is structured as follows:

i. *Chapter 2: Context analysis* – This chapter sets out the context within which the different ICE cut-off date scenarios are being assessed, outlining the overarching emission targets, national transport targets and trends in electromobility characterising the market.

ii. *Chapter 3*: *Consultation with relevant stakeholders* – This chapter provides an overview of the main discussions held with relevant stakeholders, mainly the MESDC, the Ministry for Finance (MFIN), Enemalta, and the Car Importers Association. This was carried out in order to understand the implications of having an ICE cut-off date on these different bodies and the planning time needed by these stakeholders to allow for a smooth transition to non-ICE vehicles.

iii. *Chapter 4: Fleet model - methodology and results* – This chapter sets out the methodology and assumptions underpinning the fleet model developed for assessing the baseline scenario and the different potential ICE cut-off dates. It also presents the results from the model and compares the expected outcomes in terms of fuel mix under the different scenarios.

iv. *Chapter 5: Estimating CO2 emissions* – This chapter outlines the approach for determining the CO2 emissions for each of the scenarios tested based on both vehicle category and fuel mix of the respective fleet. It also sets out the results in terms of the expected CO2 emissions under each scenario relative to the emission targets for Malta for 2030 and 2050 respectively.

v. *Chapter 6: Conclusion* – This final chapter provides an overview of the baseline and ICE cut-off date scenarios relative to the various factors that should be considered in determining an ICE cut-off policy for Malta. The results of this assessment have been compiled into a qualitative multi-criteria analysis.

[1] This work is being carried out as part of the PROMETEUS Project, which is being funded under the INTERREG Europe Programme

2. Context

2.1. Current state of affairs

2.1.1. Overarching environmental and energy targets in the EU

The 2015 Paris Agreement, signed by 197 countries and ratified by all EU Member States, has strengthened the global response to the threat of climate change and set the target of limiting temperature increases around the world to below 2°C higher than pre-industrial levels. In line with the agreement, the European Commission set a long-term strategic vision for a prosperous, modern, competitive and climate-neutral Europe by 2050. To achieve this, Member States are expected to reduce total greenhouse gas (GHG) emissions between 80% and 95% below 1990 levels by 2050.

Near-term emission goals mainly stem from the 2020 Climate and Energy package[2] enacted into EU Legislation in 2009, which sets out a number of binding targets for all EU Member States to be achieved by 2020 through the Europe 2020 strategy. The Europe 2020 strategy sets out three main targets on climate change and energy that are interrelated and mutually support one another, which were revised under the 2030 climate change and energy framework. These frameworks include targets to reduce emissions of greenhouse gas emissions, increase the share of renewable energy, and improve the EU's energy efficiency.

The GHG reduction target is split between EU emission trading system sectors (ETS), such as heavy-industry and energy generation, which account for roughly 45% of EU emissions, and non-ETS sectors, such as transport, agriculture, and waste, which account for the remaining 55% of EU emissions. Under the Effort Sharing Regulation (ESR) the emission reduction target for non-ETS sectors has been translated into individual binding targets for each member state.

Malta has agreed to a binding target for limiting increased GHG emissions by 2020, from 2005 levels under the effort-sharing decision, and a second target to reduce GHG emissions has been set to be achieved by 2030. The ESR targets for Malta for 2020 and 2030 are:

- Target of ESR emissions for Malta for 2020 = +5% over 2005 levels
- Target of ESR emissions for Malta for 2030 = -19% over 2005 levels

2.1.2. Fleet targets – ICE cut-off dates

As part of the effort to reduce emissions, several countries are taking action to phase out ICE vehicles. The majority of these incentives aim to increase the number of electric vehicles (EVs) on the road through the imposition of an ICE cut-off date, which indicates the date after which no new ICE vehicles can be imported and registered[3]. The ICE cut-off dates already communicated by other countries range from as early as 2025 in Norway, until 2040 for most major countries such as France, the U.K., and China, with even earlier cut-off dates being imposed in cert. The table below sets out the ICE cut-off dates of a number of countries and Appendix I sets out the cut-off dates imposed on different types of vehicles in various cities.

[2] European Commission 2020 Climate & Energy Package - https://ec.europa.eu/clima/policies/strategies/2020_en#tab-0-1 (accessed 2019)
[3] Survey of Global Activity to phase out Internal Combustion Engine Vehicles – Centre for Climate Protection (2018)

ICE cut-off date	Countries
2025	Norway
2030	Netherlands, Denmark, India, Ireland, Israel
2032	Scotland
2040	Taiwan, China, France, Britain, and potentially Germany

Source: Centre for Climate Protection (2018)
Table 1: ICE cut-off date for various countries

Locally, the drive towards low emission vehicles is defined within the Malta Transport Strategy (2016) that sets a goal of achieving zero-emission urban logistics by 2050. Furthermore, interim targets for fleet composition were also set for 2025 and 2030 respectively as set out in the table below.[4]

Date	% of non-ICE vehicles
2025	20%
2030	50%
2050	100%

Source: Malta National Transport Strategy (2016)
Table 2: Fleet target dates for Malta

Malta also has a commitment to introduce 5,000 electric vehicles (battery-electric and plug-in hybrid vehicles) by 2020.[5]

Within the context of these targets, Malta is in the process of establishing an ICE cut-off date for the importation and registration of “conventionally-fuelled” vehicles. In this respect, Malta has adopted the definition of conventionally-fuelled as set out in the EU white paper on transport (2011), which defines conventionally-fuelled vehicles as vehicles using non-hybrid, internal combustion engines.

Moreover, under the Directive 2014/94/EU on the deployment of alternative fuels infrastructure, Malta is required to provide appropriate compressed natural gas (CNG) refuelling infrastructure along its TEN-T Core network by 31st December 2020, and appropriate LNG refuelling infrastructure by 31st December 2025.

2.1.3. Emission targets for the road transport sector

Transport represents almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities. In 2016, road transport contributed nearly 21% of the EU's total emissions of CO_2, the main greenhouse gas. Because the transport sector has not seen the same momentum towards decarbonisation as other sectors, the Commission has adopted a low-emission mobility strategy. This facilitates the increasing movement of people and goods in a clean and efficient manner, primarily by moving towards zero-emission vehicles, alternative fuels and a more efficient transport system.

As at 2017, EU total GHG emissions were equal to 4,466 million tonnes of CO2 equivalent (MtCO2e), which correspond to a 22% reduction in emissions from 1990 levels[6]. In 2018, the EU presented its long-term vision for a climate-neutral future with the objective to keep the global temperature increase well below 2°C by 2050[7]. This vision is currently being implemented across the Union through the 2020 climate and energy package[8], and the 2030[9] climate and energy framework as explained above.

[4] National Transport Strategy 2050 – Transport Malta (2016)
[5] Malta Transport Master Plan 2025 – Transport Malta (2016)
[6] European Environment Agency – Total greenhouse gas emission trends and projections (2018)
[7] European Commission – A clean planet for all, a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (2018)
[8] European Commission 2020 Climate & Energy Package - https://ec.europa.eu/clima/policies/strategies/2020_en#tab-0-1 (accessed 2019)
[9] European Commission 2030 Climate & Energy Framework - https://ec.europa.eu/clima/policies/strategies/2030_en (accessed 2019)

The EU has also set fleet wide targets for new vehicles, which OEMs must abide to. By 2021, phased in from 2020, emissions from new passenger car fleets must be reduced to an average 95g CO_2/km, while emissions from new light duty vehicles are to be reduced to an average of 147g CO_2/km[10]. This follows significant CO_2 reductions already delivered by carmakers, as average new car emissions in 2015 were 119.6g CO_2/km compared to 186g CO_2/km in 1995. Reductions have also been achieved in pollutants such as nitrogen oxides (NOx) and particulate matter (PM), which are some of the main causes of health issues due to poor air quality.

As the continent's largest investor in R&D, the European automotive industry has firmly committed to continue to lower GHG emissions from ICEs through the development of more fuel-efficient technologies. More importantly, the industry has also committed towards developing more alternatively fuelled vehicle options[11].

To this end, on 17 April 2019, the European Parliament and the Council adopted Regulation (EU) 2019/631[12] set CO_2 emission performance standards for new passenger cars and for new light commercial vehicles in the EU for the period after 2020. As from 2025, car manufacturers will have to meet more stringent targets in terms of emissions of new cars and vans, with stricter targets applying from 2030. Manufacturers whose average emissions exceed the limits will have to pay an excess emissions premium. These targets have been defined as a percentage reduction for cars and vans:

- Cars: 15% reduction from 2025 onwards and 37.5% reduction from 2030 onwards;
- Vans: 15% reduction from 2025 onwards and 31% reduction from 2030 onwards;

While these regulations apply to the M1 and N1 category of vehicles, additional rules have also come into force for heavy duty vehicles under the M2, M3, N2 and N3 categories. Similarly, these set emission standards for lorries, buses and coaches for 2025 and 2030 aim to reduce the average emissions from road freight.

- Heavy-duty vehicles: 15% reduction from 2025 onwards and 30% from 2030 onwards.

These policy actions are expected to bring various benefits besides contributing to the EU's commitments under the Paris Agreement, including reducing fuel consumption, strengthening the competitiveness of the automotive industry and creating jobs.

2.2. Trends in the electromobility sector

2.2.1. Demand-side considerations

In their bid to reduce overall GHG emissions across the EU, most Member States have prioritised electric vehicles as the main alternative fuel in road transport[13]. Electric car deployment has been increasing swiftly over the past decade, with the global EV fleet surpassing 5 million in 2018, (of which BEVs amounted to c. 3.3 million) up by 2 million since 2017 [14]. China represented the largest market for EV registrations (c. 45%), followed by Europe (c. 24%) and the United States (c. 22%)[15]. In the EU, alternatively-powered vehicles made up c. 7.4% of the total new passenger cars in 2018, which include electrically-chargeable vehicles[16] (c. 2.0%), hybrid electric vehicles[17] (c. 3.8%)

[10] European Commission – Reducing Co2 emissions from passenger cars - https://ec.europa.eu/clima/policies/transport/vehicles/cars_en (accessed 2019)
[11] Regulation (EC) 443/2009 - setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles
[12] Official Journal of the European Union – Regulation (EU) 2019/631 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, repealing Regulations (EC) No 442/2009 and (EU) No 510/2011 (2019)
[13] European Commission, 'Member State fiches', (2019); Nearly all Member States with the exception of Italy, Hungary and the Czech Republic (which have identified natural gas as their prioritization) have prioritised the promotion of electromobility in their NPFs.
[14] International Energy Agency – Global EV Outlook 2019 (2019)
[15] ibid.
[16] Includes battery electric vehicles, fuel-cell electric vehicles, extended-range and plug-in hybrid electric vehicles.
[17] Includes full-hybrid vehicles and mild-hybrid vehicles (48V).

and other non-electric alternative fuels[18] (c. 1.5%)[19]. Given total vehicle registrations in Europe in 2018 amounted to c. 15 million[20], at 2% of the fleet, total electrically chargeable vehicles amounted to c. 0.3 million in that year.

A Royal Bank of Canada (RBC) capital markets study sets out forecasts for annual demand of BEVs/PHEVs in Europe[21] with some of the key milestones set out in the table below:

Date	BEV	PHEV	Total
2019	0.3 million	0.4million	0.7 million
2020	0.5 million	0.7 million	1.2 million
2025	1.6 million	1.1 million	2.7 million
2030	3.1 million	1.6 million	4.7 million

Source: RBC Capital Markets – Electric Vehicle Forecast Through 2050 & Primer (2018)

Table 3: Projected annual BEV/PHEV demand for Europe

This study further shows that BEVs / PHEVs will make up 22% of new purchases by 2030, with 48% of sales having some level of electrification[22]. Central and Eastern Europe are forecasted to follow in line with the rest of Europe, albeit at a three- to five-year lag[23]. A report by PwC Autofacts – a global team of automotive industry specialists and professionals – further outlined the electrification of passenger vehicles as one of the major long-term trends transforming the automotive industry[24]. The International Energy Agency (IEA) have similarly projected EVs to make up almost half of all vehicles sold in Europe by 2030, under the EV30@30 scenario.

2.2.2. Supply-side considerations

In line with the regulatory developments to limit emissions from road transport discussed in Section 2, current production forecasts also anticipate ramp up in EV production across the EU. After several years of apprehensive growth, the ZLEVs model offerings and production numbers are expected to surge up to a combined offering of 333 different ZLEV models and more than 4 million light-duty vehicles (equivalent to roughly 20% of total EU production) by 2025[25].

The ability for the automotive industry to successfully achieve these supply projections are dependent on a number of factors, outlined in the figure below:

[18] Includes LPG (Autogas), Ethanol, Bio-Diesel and Natural gas (CNG, LNG).
[19] European Automobile Manufacturers Association (ACEA) – The Automobile Industry Pocket Guide (2019)
[20] https://www.best-selling-cars.com/europe/2018-full-year-europe-car-sales-per-eu-and-efta-country/
[21] Includes Western, Central and Eastern Europe
[22] Includes hybrids and 48V
[23] RBC Capital Markets – RBC Electric Vehicle Forecast Through 2050 & Primer (2018)
[24] PwC Autofacts – 'Five trends transforming the Automotive Industry' (2018)
[25] Transport and Environment – Electric Surge: Carmakers' electric car plans across Europe 2019-2025 (2019)

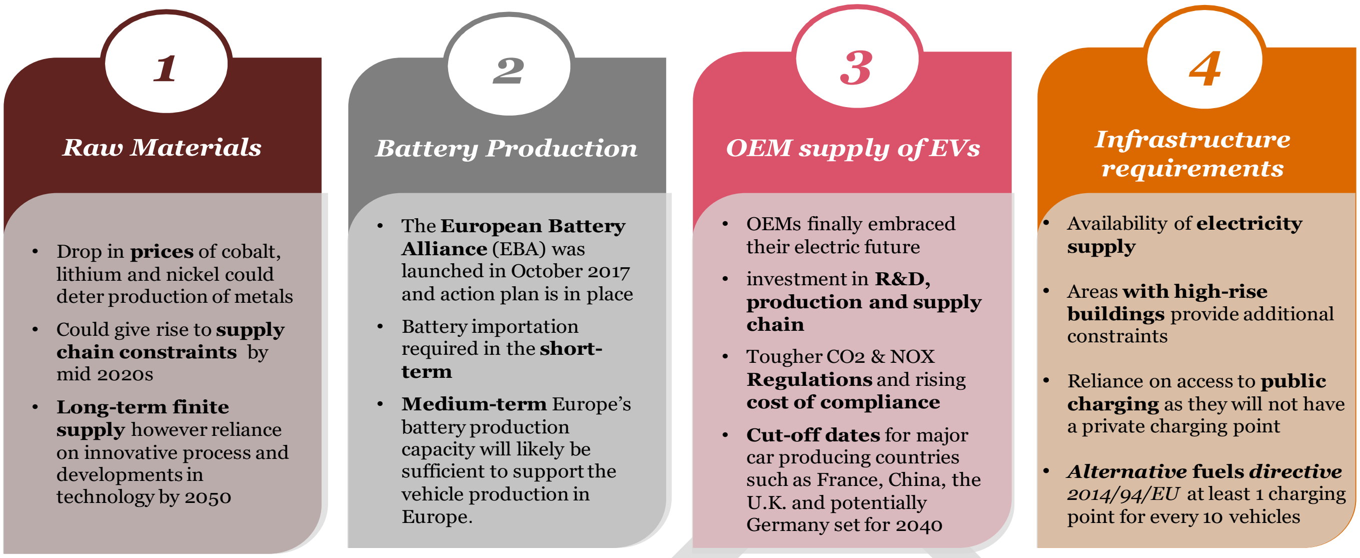


Figure 1 – Factors influencing the supply of electric vehicles

1. **OEM supply of EVs**: Considering the increasingly stringent regulatory drive to reduce emissions from road transport, as well as the forthcoming registration bans of diesel and petrol vehicles across European and other countries and cities as set out in Section 2.1.2 and Appendix I, OEMs have been pushed to embrace their electric future and increase their commitment towards the electrification of their fleet.

   OEMs are obliged to achieve fleet-wide average emission targets of 95g CO_2 p/km by 2021 and achieve further reductions of 15% and 37.5% for passenger vehicles by 2025 and 2030 respectively, relative to 2021 emission levels. The flexible design of the regulation allows carmakers several different options to take in order to achieve the target, which range from increasing their share of EVs (as a % of total vehicle sales) to shifting sales to lower CO_2 ICE variants and limiting the sales of the highest emitting ICEVs (such as sports cars and SUVs). However, it remains inevitable for OEMs to continue to avoid the electrification of their fleet, should they aim to avoid the hefty penalty fines that would be imposed on them for failing to meet the targets. Indeed, some brands, such as Volvo[26] and Land-Rover Jaguar[27] are even pledging to end the production of new models solely powered by ICE as of 2020. A summary table of OEM electrification strategies is included in Appendix III.

   In addition, specific regulation targeting emissions from road transport, several Member States and individual city jurisdictions have also announced plans to ban or limit to registration of petrol and diesel vehicles, with dates ranging from the earliest in Norway by 2025 to 2040 in major European countries such as France and the U.K., as well as China.

   Government regulations and policies such as the above are therefore acting as direct stimuli for OEMs to increase their R&D in the production and supply of electric vehicles, innovating across the EV value chain and focusing on scaling up EV car volumes. This is evidenced in the approaches taken by several OEMs to standardise production[28] allowing for the mass production of EVs.

   The supply of EVs by OEMs is also however dependent on battery production, the availability of supply of raw materials and country charging network infrastructure as explained below.

2. **Battery Production**: The need for efficient and capable batteries is growing rapidly and at an increasingly fast pace, with battery technology being employed for transport, power generation and

[26] Volvo Press Release July 2017 - https://www.media.volvocars.com/global/en-gb/media/pressreleases/210058/volvo-cars-to-go-all-electric
[27] Jaguar Land Rover – Going Electric - https://www.jaguarlandrover.com/2017/going-electric
[28] For example, the VW Group's MEB toolkit and investment in adjusting vehicle designs to allow for the mass production and compatibility of vehicle components across the production line.

industry. Similarly, the sole power-train of an electrically-chargeable vehicle is the lithium-ion battery-pack, which stores an electrical charge used to drive the electric motor of the vehicle. Therefore, in the shift from conventionally-fuelled vehicle to EVs, the availability of batteries plays a major role in potential for OEMs to scale up production.

The ever-increasing demand for EVs has boosted the global lithium-ion battery production from about 20 GwH in 2010 to 120 GwH in 2017[29], with more than half of these sales covering battery capacity for road transport. The global manufacturing capacity is currently around 150 GwH per year and is largely dominated by Chinese production facilities as factories in Europe host c. 3% of global production capacity[30]. However, this situation is expected to shift due to initiatives such as the European Battery Alliance (EBA), which was launched by the European Commission in 2017 to address this growing industrial challenge and reduce the dependence on non-EU entities for a market that is expected to grow to €250 billion by 2025[31]. The EBA has therefore outlined a number of key objectives that it will target in order to develop a sustainable battery cell manufacturing value chain in the EU, which include[32]:

a. Securing access to raw materials used in the production process, in a sustainable manner and fair cost;

b. incentivise the creation of European sources of raw materials through synthetic methods;

c. make the EU a leader in battery technology, with the smallest environmental footprint possible;

d. support new markets and initiatives for battery technology, that will support a growing sector while still serving to offer new sustainable solutions for power, transportation and industry and reduce the EU's overall GHG emissions;

e. develop and strengthen workforces in all areas of the value-chain, in order to grow Europe's R&I capacity;

f. standardise installation and manufacturing procedures and rules, to maximise safety for European citizens; and

g. harmonise charging infrastructure and allow for vehicle-to-grid solutions.

Furthermore, the EBA has set a target of 200 GWh per year of battery manufacturing capacity to be available in the EU by 2025[33], amounting to share of global cell manufacturing of between 7% to 25%[34]. Bloomberg NEF expects European lithium-ion battery manufacturers to reach this target by 2023 with 198 GWh per year overtaking North American production, which is only expected to increase to around 130 GWh per year by the same date[35]. A list of the current battery manufacturing plants and announced expansions are listed in Appendix IV.

While China is still expected to maintain the lion's share of lithium-ion battery production throughout the forecasting period, the growth of a European battery-production value chain would contribute positively in safeguarding adequate supply of batteries of European OEMs, in order not to hamper production.

---

[29] European Commission – Lithium-ion batteries for mobility and stationary storage applications; Scenarios for costs and market growth
[30] ibid.
[31] European Battery Alliance – About us - https://www.eba250.com/about-eba250/ (a November 2019)
[32] European Battery Alliance – Priority actions - https://www.eba250.com/actions-projects/priority-actions/ (a November 2019)
[33] Energypost.eu – The European battery alliance is moving up a gear (2019)
[34] European Commission – Lithium-ion batteries for mobility and stationary storage applications; Scenarios for costs and market growth (2018)
[35] Greentech media – Europe set to race past US in battery manufacturing (2019)

3. **Raw Materials**: As the production and uptake of EVs and EV technology continues to progress, so does the demand for raw materials used in production of essential EV components such as the battery-pack. Similar to the scale at which OEMs can expand their production of EVs is intrinsic to the supply of batteries, so too are the supply of batteries constrained by the availability of the raw materials used in their production. The rapid growth in battery demand over the past few years has seen the emergence of a new supply chain, in which the mining, battery manufacturing and automotive industries have become increasingly interwoven[36].

   There are currently multiple types of battery chemistries used to power EVs, further explained in Appendix V, each having specific properties related to stability and safety, lifetime and energy density (i.e. how much charge can be stored into each cell)[37]. However, irrespective of the different types, there are three main raw materials which play a major role in the batter production process and these include lithium, nickel and cobalt.

   Analysis carried out by McKinsey has shown that assuming global battery production of 940 GWh, the market for cobalt will remain tight indicating a shift away from cobalt-intensive batteries. However, similarly a shift towards more nickel-intensive batteries will also prove to be a challenge for the currently projected supply capacity development, indicating that the scarcity issue could be shifting from one commodity to the other[38].

   Wood Mackenzie have similarly shown that these supply constraints may be exacerbated in the short-term, due to falling commodity prices which have led to a decrease in investment from mining projects in new companies. While the price of raw materials falling can be considered a positive in terms of falling battery costs, it represents a double-edged sword as mining and refining operations generally take a number of years to yield the required output which could result in constraints by the mid-2020s[39]. Contrarily, other sources have also argued that critical metals and other rare earth materials used in the production of batteries will be sufficient to supply the expected uptake in EVs over the coming decades[40].

4. **Charging infrastructure**: Some of the resistance currently affecting the demand and uptake of electric vehicles mainly stems from the lack of availability of EV charging infrastructure, especially relative to the wide availability and quick refuelling times gas stations offer for conventionally fuelled vehicles. While this has mainly been addressed with increases in EV range, and plug-in hybrid offerings, it remains a reality hindering uptake in rural/suburban settings who generally have longer commutes and less infrastructure support in their areas[41].

   Policy approaches to promoting the deployment of EVs and attempting to kick-start demand, generally provide an impetus for automakers to provide an initial roll out of publicly accessible charging infrastructure[42]. This is further backed up through legislation such as the Alternative Fuels Directive[43] and the Energy Performance Building Directive[44], which include minimum measures to attempt to increase "EV readiness" through the deployment of EV charging points in new or refurbished buildings and parking lots, and across cities and highway networks.

   Considering the influence the availability charging infrastructure has on the demand for EVs, the rate of deployment of charging infrastructure may also determine the supply of EVs. Investment in and announcements of an increase in EV charging can be considered a catalyst for OEMs to increase supply and investment in EVs, due to higher expectations of EV demand.

[36] McKinsey – Metal mining constraints on the electric mobility horizon (2018)
[37] ibid.
[38] ibid.
[39] Wood Mackenzie – Global battery Raw Materials Long-Term Outlook
[40] Transport and Environment – Electric vehicles life cycle analysis and raw material availability (2017)
[41] Automotive news - Misconceptions about EVs hindering demand (a November 2019)
[42] International energy agency – Global EV Outlook (2019)
[43] Directive 2014/94/EU on the deployment of alternative fuels infrastructure
[44] Directive 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

2.2.3. Factors affecting price convergence

Over the past few years, consumer demand for motor vehicles has slowly started to shift away from ICE vehicles and in favour of EVs. In Europe, the share of consumers that have reported considering an EV as their next purchase has risen to between 40% to 60%[45]. Despite this, EVs and PHEVs only made up c. 2% of sales in 2018 in the EU[46]. One of the main hurdles faced by consumers in purchasing such vehicles was found to be the EV's upfront cost, which explains this gap between consideration and registrations[47].

Research shows, that price convergence could be assessed either from a total cost of ownership[48] (TCO) point of view or from an upfront cost perspective. Given that the upfront cost of a vehicle was stated to be one of the main barriers to mass demand and given its social implications, we have identified four main market drivers, which affect price convergence from a macro-level perspective in terms of the upfront cost of the vehicle. These are set out in the figure below:

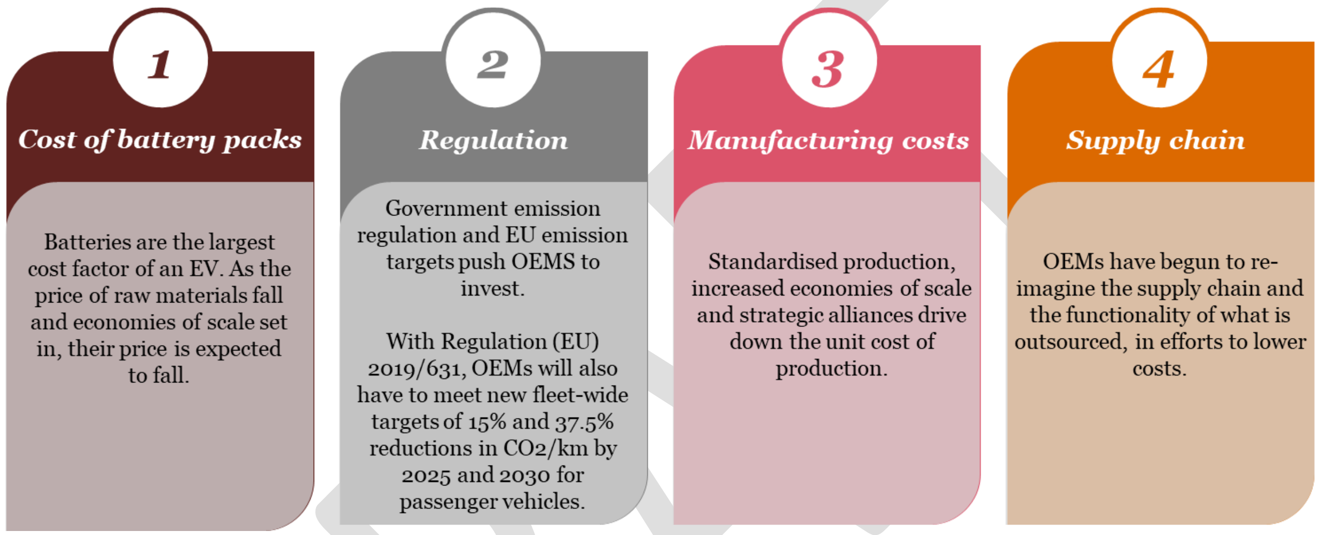


Figure 2: Four key factors affecting upfront price convergence between ICE and electric vehicle

1. **Battery-pack**: The cost of the battery remains the largest single factor in determining the cost of a BEV, due to the costs of obtaining the battery cell material components (such as lithium and cobalt) and a lack of large battery manufacturing plants in Europe. The cost of lithium-ion batteries has declined significantly over the past 10 years, falling from c. $1,200 per kWh[49] in 2010 to a range of $190 - $210 per kWh today[50]. At these levels, the battery-pack results in a premium of between $9.5k to $10.5k[51] for a BEV relative to a similarly sized ICE counterpart. It is expected that through economies of scale from increased global production, and technological advancements the price of battery-packs will continue to fall significantly over the next decade. Estimates by RBC Capital Markets and Bloomberg NEF project a drop of battery costs to c. $100 per kWh by 2025 and c. $70 per kWh by 2030[52], which would result in cost savings of up to $7k (assuming a small to mid-size passenger BEV with a 50-kWh battery-pack). With respect to the forecasted changes in the battery price, Appendix II sets out the expected change in the price gap between an ICE vehicle and an electric vehicle in 2025 and 2030, relative to the 2019 scenario.

---

45 McKinsey – Electrifying insights: How automakers can drive electrified vehicle sales and profitability (2017)
46 European Automobile Manufacturers Association (ACEA) – The Automobile Industry Pocket Guide (2019)
47 McKinsey – Electrifying insights: How automakers can drive electrified vehicle sales and profitability (2017)
48 Apart from the upfront cost of the vehicle, this includes all the expenses spent on fuel, insurance, maintenance, repairs, service, interest on loan payments as well as the losses incurred due to depreciation of the car at the end of the same period.
49 BloombergNEF – A behind the scenes take on lithium-ion battery prices
50 McKinsey – Making electric vehicles profitable (2019)
51 ibid.
52 RBC Capital Markets – Electric Vehicle Forecast Through 2050 & Primer, 2018,' A behind the scenes take on Lithium-ion battery prices', March 2019

2. **Government Regulations**: Ever-tightening government emission regulations have acted as a direct incentive for OEMs, not only in the EU but also globally, to invest further in the electrification and efficiency of their fleets in turn impacting the overall price of electrified vehicles.

   Since 2015, a target of 130g CO_2 per km has applied for the EU fleet-wide average emission of new passenger cars, and from 2021 this will fall to 95g of CO_2 per km[53] for new passenger cars. According to provisional data from the European Environment Agency (EEA), the average emission levels of new cars registered in 2018 in the EU and Iceland were 120.4 g CO_2/km[54], and has been on the increase due to a decline in diesel sales and a surge in SUV sales. This gap between the target and actual level is further exacerbated, in that from September 2018, the EU has moved away from the New European Driving Cycle (NEDC) test to assess emissions and fuel economy in passenger cars and has developed a new stricter testing mechanism, known as the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) complimented by new regulations for Real Driving Emissions (RDE). Compliance plans for OEMs to meet these targets will comprise of four principal options[55]:

   a. Investing further in technology to reduce the emissions from conventionally fuelled vehicles, such as the electrification of fleets through mild-hybrid[56] (48V) and full-hybrid[57] solutions;

   b. increasing the sales of zero-to-low emission vehicles (ZLEV) as a share of their total annual vehicle registrations;

   c. re-designing vehicle offerings and marketing strategies in order to incentivise customers to opt for smaller and less polluting vehicles; and/or

   d. making use of the pooling mechanism allowed under Regulation (EC) No 443/2009, such as the fleet pooling agreement reached between Tesla and Fiat Chrysler Automobiles (FCA) which cost hundreds of millions of euros[58]

   All the options listed above lend to a trend of increasing investment in EV technology and production capabilities, which in turn results in falling costs for consumers. This trend is further expected to continue in light of the requirements emanating from regulation 2019/631[59] explained earlier.

3. **Manufacturing Costs**: Research by McKinsey has shown that EVs are currently costing OEMs c. $12,000 more to produce than a comparable ICE vehicle for the small- to midsize-car segment[60]. While most of these costs are related to the cost of the battery-pack as mentioned earlier, a significant premium emanates from the production process of the rest of the vehicle. The same report has also shown, that through the pursual of design simplifications, strategic decontenting and the development of a dedicated EV production platform, OEMs can achieve production cost savings of c.$5,700 to $7,100.

   The Volkswagen (VW) Group MEB platform is an example of a move to standardise production of new battery electric vehicles and increase economies of scale. The $7 billion investment is expected to enable the VW group to manufacture vehicles across the group's fleet offering, from urban city cars to large

[53] Regulation EC No. 443/2009 of the European Parliament and of the council of 23 April 2009 ' setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles
[54] European Environment Agency – Monitoring of CO2 emissions from passenger cars under Regulation (EC) No 443/2009 (2019)
[55] Transport & Environment – Mission Possible: How carmakers can reach their 2021 CO2 targets and avoid fines
[56] Mild Hybrid / 48V: Makes use of largely the same architecture of an ICE vehicle, however utilises a 48V battery instead of the traditional 12V battery standard in modern vehicles. This allows for a number of vehicle functions (start/stop, water pumps, air conditioning, infotainment) to be run solely through the extra battery capacity, reducing overall fuel consumption.
[57] Hybrid: Allow for higher efficiency than mild-hybrid vehicles as the battery helps to power the propulsion of the vehicle, rather than just assisting in the tertiary functions of the vehicle. Full-hybrids can operate very similarly to a pure BEV at low speeds, with minimal energy requirements.
Example: Toyota Prius
[58] Financial Times – Fiat Chrysler pools fleet with Tesla to avoid EU emission fines - https://www.ft.com/content/7a3c8d9a-57bb-11e9-a3db-1fe89bedc16e
[59] Official Journal of the European Union – Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, repealing Regulations (EC) No 442/2009 and (EU) No 510/2011 (2019)
[60] McKinsey – Making electric vehicles profitable (2019)

minivans using many of the same parts, that will enable it to make a profit on the sale of electric vehicles. On the other hand, companies such as BMW, Jaguar Land-Rover and the PSA Groupe have opted for a more flexible platform solution, in which factories can be easily adapted to adjust for demand without losing efficiency[61].

Moreover, the VW group has also announced its willingness to share its MEB platform and toolkit with the industry in order to drive down its unit costs of development and have so far reached an agreement in principal with the Ford Motor Company[62]. Similar strategic alliances and agreements in the automotive industry can further help to promote technological advancement and allow for product and platform sharing, serving to hasten the price convergence of electric vehicles and traditional ICE vehicles.

4. **Supply Chain**: Today's automotive supply and value chains are well established; however, these are being upended by the introduction of EVs. This is due to the inherent design of BEVs, which do not require many of the traditional parts associated with motor vehicles (fuel systems, transmissions, exhaust) as they are replaced with other new parts (battery-packs and electric motors).

   RBC Capital Markets forecast that due to the introduction of regulation on CO_2 and NOx[63], there is an increasing cost to make ICE-specific parts more compliant, which in isolation is positive for suppliers. However, due to lower overall volumes of ICE products and increasing competition from new entrants, it is forecasted that there will be further pressure on supplier margins. This will result in overall lower production costs for manufactures. Manufacturing costs can further be driven down as OEMs take the opportunity to re-imagine and streamline the supply chain and the functionality of what can be outsourced and what can be insourced.

Within this context and with all these factors at play, several sources indicate a range within which price convergence is expected to be achieved, mainly resulting from the anticipated fall in the battery price, amongst the other variables mentioned above. A comparative analysis of publicly available sources indicates that price convergence of EV and ICE vehicles ranges from dates as early as 2022 if one looks at TCO as the point of convergence and 2024 – 2030 in the case of the upfront cost of a vehicle. The table below sets out the different sources considered and expected price convergence dates based on both upfront cost and TCO:

Upfront Cost	
Source	**Price Convergence Date**
RBC Capital Market (2018)	2025 – 2030 (battery cost/efficiency)
The Oxford institute for energy studies (2018)	2028 (petrol) 2024 (diesel)
McKinsey & Company (2019)	2025-2030 (battery cost / efficiency)
Clean Technica (2019)	2022-2025 for VW cars
BloombergNEF (2019)	2024-2030 (battery cost/ efficiency)
European federation for Transport and Environment (2019)	2024 – 2030 (battery cost / efficiency)
Carscoops – Morgan Stanley (2019)	2024 (battery costs / higher cost to produce ICE)

[61] Automotive News – EV architecture divides automakers (2019)
[62] Volkswagen Newsroom – Ford and Volkswagen expand their global collaboration to advance autonomous driving, electrification and better serve customers (2019)
[63] Commission Regulation EU No. 459/2012 amending regulation EC No. 715/2007 of the European Parliament and of the Council and Commission Regulation EC No. 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6), Regulation EC No. 443/2009 of the European Parliament and of the council of 23 April 2009 ' setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles

Total cost of ownership	
Deloitte (2019)	2022 (includes government incentives)
The Sunday Times (2018)	Mid 2020s
UBS (2017)	2023 (including government incentives)

Table 4: Comparative analysis of expected price convergence dates

3. Consultations with Stakeholders

3.1. Discussions with relevant stakeholders

Between December 2018 and April 2019, a number of consultations were carried out in order to understand the impact and implications of an ICE cut-off date policy on relevant stakeholders, government finances, the national electricity grid and the environment.

- *Discussions with Minister for Environment, Sustainable Development and Climate Change (MESDC):* As previously stated, the Effort Sharing Regulation set a binding target for Malta to achieve a reduction of 19% in non-ETS sector emissions compared to 2005 levels, by 2030. The 2005 direct emissions from road transport in Malta was equal to c. 415.02 kT CO_2 equivalent, as reported in the National Inventory Report (NIR) for Malta 2019[64]. As of 2017, Malta's reported level of ESR emissions were c. 34% higher than 2005 levels at 557.73 kT CO_2, this implies that CO2 emissions would need to fall by 66% to achieve the 2030 target. MESDC would naturally opt for the earliest ICE cut-off date in order to mitigate CO2 emissions from road transport.
- *Discussions with Ministry for Finance:* In 2018, Government revenue from motor vehicle registration taxes, annual circulation license fees and excise duties on petroleum products was estimated to amount to c. €263 million[65], around 9% of total government revenue[66]. Any policy decision to restrict the importation and registration of ICE vehicles would therefore have a direct impact on government finances, and so it should consider the need to undertake a separate exercise involving a thorough review of the present fiscal regime arising from car registrations and fuel tax. In this respect, the Ministry estimated that they would require between 2-3 years to plan and formulate a new fiscal regime taking into account the considerations of an ICE cut-off date and potential update to the National Transport Policy. Moreover, it was pointed out that due deliberation should be given to the social dimension of such a policy, as car use impacts all segments of society making price convergence an important consideration in deciding on a cut-off date timeframe.
- *Discussions with car importers*: With cut-off dates in the major car producing countries such as France, China, the U.K. and potentially Germany being set in 2040, raised their concerns regarding the availability of electric vehicles to satisfy the potential demand going forward, should an earlier cut-off date be set for Malta. This is because OEMs are likely to plan production and ramp up supply in line with demand in major global markets and for which Malta plays a relatively insignificant role. Nevertheless, given the stricter regulations binding OEMs to produce vehicles with lower emissions and the heavy fines applicable if targets aren't met, are factors that will largely impact the supply of electric vehicles across Europe despite the cut-off dates being imposed at national levels. The meeting with the car importers also highlighted the implications that an early cut-off date could have on the labour force, as there will be a greater requirement for professionals trained to handle EVs during repair works and maintenance, and the appropriate equipment and replacement parts.

- *Discussions with Enemalta*: A consultation was carried out with Enemalta to assess the impact of a cut-off date on the national electricity grid, due to the increased demand for electricity as EVs make up a larger portion of the fleet mix going forward. From our discussions, Enemalta estimate that additional generation capacity would need to be deployed to address any peak load demands when charging BEVs. In this respect, Enemalta stated that they would require around 7 years to introduce additional capacity in line with the projected increases in demand.

---

64 Malta Resources Authority – Malta's National Inventory of Greenhouse Gas Emissions and Removals (2019) refer 2005 CRF Table 1s1A3.b (Co2 from Road Transport)
65 Ministry for Finance – Financial Estimates for 2019 (October 2018)
66 Ministry for Finance – Economic Survey (2018)

4. Fleet model - methodology and results

4.1. ICE cut-off date scenarios considered for the purposes of the model

Following research carried out on both the demand and supply side of the market, and post discussion held with relevant stakeholders, we set out potential timeframes within which an ICE cut-off date for Malta could be considered.

With a growing market economy and an increasing population, together with a national electricity grid infrastructure that has minimal excess capacity, senior representatives from Enemalta stated that around 6/7 years would be required from the announcement of an ICE cut-off date to upgrade the current electricity generation capacity. This would imply that the earliest feasible cut-off date would be in 2026/ 2027 in order to ensure the availability of electric supply to meet a growing demand for electric vehicles, given the likelihood that excess capacity will be consumed by increased economic activity. This period will also allow MFIN to plan and formulate a new fiscal regime given the need for around 2 – 3 years for this to be carried out.

Moreover, considering the analysis carried out on price convergence in section 2.2.3 above, various sources indicate that price convergence on the upfront cost of an ICE and electric vehicle is likely to take place between 2024 – 2030 mainly driven by the expected drop in the battery price and need for OEMs to meet stricter regulations.

Within this context, the developed model looks into a number of scenarios to test the impact of different ICE cut-off dates on the both the fuel mix of the national fleet and CO2 emissions. The scenarios tested are:

- *Scenario 1a: 2026 ICE cut-off date pre-price convergence* – this scenario assumes a 2026 ICE cut-off date taking place pre-price convergence, implying that car owners will hang on for longer to their ICE vehicles thereby slowing down scrappages and purchases in initial years till price convergence is reached. In this scenario price convergence is assumed to be reached at the later date of 2030.

- *Scenario 1b: 2026 ICE cut-off date post price convergence* – this scenario assumes a 2026 ICE cut-off date taking place post price convergence thereby once the ICE cut-off date kicks in, all new vehicle registrations would be BEVs / PHEVs. This scenario assumes that price convergence would be reached in the earlier years between 2024 – 2026.

- *Scenario 2a: 2028 ICE cut-off date pre-price convergence* – this scenario assumes a 2028 ICE cut-off date taking place pre-price convergence. This implies that car owners will hang on for longer to their ICE vehicles thereby slowing down scrappages and purchases in initial years till price convergence is reached. In this scenario price convergence is assumed to be reached at the later date of 2030.

- *Scenario 2b: 2028 ICE cut-off date post price convergence* – this scenario assumes a 2028 ICE cut-off date taking place post price convergence thereby once the ICE cut-off date kicks in, all new vehicle registrations would be BEVs / PHEVs. This scenario assumes that price convergence would be reached in the earlier years between 2024 – 2026.

- *Scenario 3: 2030 ICE cut-off date* – this scenario assumes a 2030 ICE cut-off date, whereby given the timeframes within which price convergence is expected to be achieved, at this date it being assumed that upfront cost price convergence would have been reached.

- *Scenario 4: 2032 ICE cut-off date* – this scenario takes assumes a 2032 ICE cut-off date that is post-price convergence and closer to the 2040 cut-off date being imposed by larger countries.

- *Scenario 5: 2034 ICE cut-off date* – Similarly, this scenario takes assumes a 2034 ICE cut-off date that is post-price convergence and closer to the 2040 cut-off date being imposed by larger countries.

4.2. Fleet model overview

Based on the potential ICE cut-off dates being considered for Malta, the developed demand model aims to forecast the fleet mix under the baseline scenario, i.e. no cut-off date and for the potential ICE cut-off dates discussed in section 4.1 above.

The objective of the model is to assess the conventional and alternative fuel fleet mix over the forecasting period 2019-2050, in relation to the national fleet targets set out in the Malta National Transport Strategy, whereby 50% of the national vehicle fleet is to consist of non-conventionally fuelled vehicles by 2030, and 100% by 2050. Moreover, the model was extended to estimate the corresponding CO_2 emissions from road transport for the different scenarios being considered.

To arrive at the fleet mix under the different scenarios, forecasts of the national vehicle fleet over the 32-year period 2019-2050 were prepared for each of the scenarios based on the underlying drivers influencing vehicle demand locally and respective ICE cut-off policy. Such forecasts also include projections for annual scrappages throughout the projected period, in order to derive the annual vehicle purchases and new vehicle registrations. The forecasted fleet under each scenario was then split by fuel type, specifying the uptake of petrol, diesel, hybrid, pure electric (BEVs), plug-in hybrids (PHEVs) and natural gas vehicles. Projected fuel mix trends for Malta were based on the year-on year changes in projected fuel mix for Western Europe[67] and international technological developments.

It should be noted at the outset that the underlying model provides a basis for all scenarios tested by primarily outlining the baseline scenario and corresponding fleet mix. Then, for each of the considered ICE cut-off dates, the corresponding fleet mix was determined and applied to the baseline accordingly, together with additional assumptions as deemed appropriate.

4.3. Overarching Assumptions

Several overarching assumptions were taken in building the fleet demand model, particularly in relation to policy, market supply, the fleet and price convergence. These are set out hereunder:

Policy assumptions:

(i) *Unchanged modal shift policy* - In projecting the total demand for vehicles in Malta, it was assumed that there will be no change in policy relating to modal shift other than existing measures. This implies that any policies or measures introduced to reduce the dependence on private passenger vehicles, and increase the usage of public transport, cycling and walking going forward have not be taken into consideration in forecasting the national fleet. On this basis, the current fleet mix was held fixed and was maintained going forward for each of the scenarios.

(ii) *Unchanged congestion reduction policy measures* - Similarly, no new congestion reduction policy measures where considered in projecting the vehicle fleet. Hence, the fleet was forecasted on the assumption that current policy in relation to congestion reduction will continue to apply across the forecasting period.

Supply-side assumptions:

(iii) *No vehicle supply constraints* – The model assumes an infinite supply of vehicles to satisfy the projected demand under each of the scenarios being considered. Hence projected demand in each of the scenarios is not constrained by the availability and ability to import EVs / PHEVs to Malta.

(iv) *Availability of resources and infrastructure* – Similarly, the model assumes that the necessary infrastructure and other-supply side resources, including labour and parts, will be available to meet the demand projected for each scenario.

(v) *Hybrid classification:* For the purpose of the model, the hybrid vehicle category was assumed to represent mild-hybrid vehicles (48V) and full-hybrid vehicles. Due to the fact that these vehicles still

[67] RBC Capital Markets – RBC Electric Vehicle Forecast Through 2050 & Primer (2018)

run on conventional fuel types (typically petrol) with electrification for efficiency, they were ICE vehicles and therefore excluded from demand projections post cut-off date.

Fleet / demand-related assumptions:

(vi) *All vehicle categories included* - The demand model forecasts the entire vehicle fleet, considering all vehicle categories, not solely light-duty passenger vehicles (M1) and light-duty commercial Vehicles (N1).

(vii) *Classification of ICE vehicles* - When running the model for different ICE cut-off date scenarios, it was assumed that the respective cut-off date will be imposed on the importation and registration of all 'conventionally fuelled vehicles[68]' defined as non-hybrid, ICE vehicles, irrespective of vehicle category. It was agreed with Transport Malta that this includes all petrol, diesel, LPG, CNG, LNG and hybrids that offer a range of less than 80km of electric battery autonomy (i.e. Mild and Full hybrids). The model therefore assumes a single ICE cut-off date for all vehicle categories in each of the scenarios tested as opposed to a phased ICE cut-off date for different vehicle categories.

(viii) *Fleet data* - The demand model is based on the latest fleet data obtained from Transport Malta as at Q4 2018. However, for the purpose of more granular data on the national fleet such as the year of manufacture, year of registration, fuel type and vehicle type, reference was made to Q2 2018 data and was extrapolated on the basis of the Q4 2018 data set.

(ix) *Demand for CNG and LNG* – In the case of CNG and LNG vehicle demand, it is assumed that this will commence 2021, and 2026 respectively, once the necessary refuelling infrastructure is set up, in accordance with the requirements set out in the Alternative Fuels Directive 2014/94/EU. Further information on the methodology used to arrive at demand for LNG and CNG vehicles is set out in Appendix VI.

(x) *Fuel mix projections* - The fuel mix projections for the Maltese fleet are based on the RBC Capital Markets Forecasts for Western Europe, applying the annual growth rates for each fuel type projected for Western Europe to the current fuel mix in Malta[69]

Price-related assumptions:

(xi) *Price convergence* – The model assumes that price convergence relates to the upfront cost of the vehicle as opposed to the TCO, particularly in light of social implications. Based on a comparative analysis of available research, it is evident that the upfront cost price convergence of EVs and their ICE equivalent can fall between 2024 and 2030[70]. The factors determining when the inflection point will occur are discussed earlier in section 2.2.3. Given this wide range of potential price equivalence dates, the 2026 and 2028 scenarios were further tested with two different sub-scenarios, to reflect the change in the fleet mix with a cut-off date taking place pre-price convergence and post-price convergence.

4.4. Forecasting annual fleet demand

To forecast the annual fleet up till 2050, the underlying demand drivers were determined by testing, through regression analysis, six different independent variables and fourteen combinations thereof, to understand which of these variables most accurately described the variation in the historical vehicle fleet over the period 2000-2018[71]. The variables tested included nominal GDP, real GDP, population, driving age population and GDP per capita,

From our testing exercise, real GDP and total population figures were found to be the most statistically significant variables relative to the others tested. Given that GDP and population are highly correlated with each other, GDP per capita was used to avoid the risk of multicollinearity. Consequently, the projected fleet was determined on the

[68] EU white paper on transport 2011.
[69] Based on NSO Q4 2018 fleet statistics; 99% petrol and diesel vehicles and limited penetration of EVs (c. 0.5%)
[70] Based on upfront cost; when considering Total cost of ownership price convergence can occur at a much earlier date c. 2022 - 2025
[71] 19 observations which represents the maximum number of observations given publically available data on the total national fleet

basis of real GDP per capita and the previous year's fleet i.e. lagged variable of the total motor vehicle fleet (MV_{t-1}) using the formula set out below:

$$\textbf{Motor Vehicle Fleet}_t = \textbf{Motor Vehicle Fleet}_{t-1} + \textbf{real GDP per capita}_t$$

It should be noted that the formula is based on a regression analysis derived from 19 historical observations. This formula was then applied to forecast the fleet up until 2050 based on independent projections for GDP and population to derive GDP per capita, determined as explained below.

4.4.1. Gross Domestic Product

Between 2000 and 2018, Malta's real GDP[72] grew by an average of 3.7% and superseded the EU-28 average real GDP growth of 1.47% over the same period. In particular, Malta's real GDP has increased significantly over the last five years, with a compounded annual growth rate (CAGR) of 7.4% over the period, whilst the CAGR for the EU over the same period was equal to 2.2%.

The International Monetary fund (IMF) Country report for Malta, issued in February 2019 (No.19/68), summarised the main reasons for the recent economic growth as a result of the following:

- a decline in imports, complimented by a strong increase in exports boosted economic growth;
- prudent fiscal policy helped in attaining the government's medium-term objectives three years ahead of schedule;
- Malta's economic growth translated into one of Europe's lowest unemployment rates in 2017, around half of the EU-28 average at 7.7%; and
- An increase in inward migration (which has put significant pressures on Maltese infrastructure, health and education systems, all of which face challenges).

Against this backdrop, Malta's GDP growth was projected to remain robust over the short-term and is expected to increase by 5.1%[73] in 2019 and 4.4%[74] in 2020 respectively. Projected EU-28 growth rates for the same period are being estimated at 1.9% in 2019 and 1.7% in 2020, based on the figures published in the European Economic Forecast (Autumn 2018). This indicates that Malta's economic growth rate is expected to be higher than the EU average in the short-term.

Over the period 2021 - 2030, Malta's real GDP growth rate is assumed to continue to outpace that of the EU at a declining rate, falling to the EU real GDP projected growth rate of 1.36%[75] by 2030. Post 2030, Malta's real GDP growth rate is expected to move in line with the EU average. Forecasts for the EU GDP growth rates are based on long-term GDP projections for 2030, 2040 and 2050 published by PwC[76] for five major European economies[77].

4.4.2. Population

Based on the latest figures published by the National Statistics Office (NSO), the total resident population stood at c. 493,600 at the end of 2018[78], representing an absolute increase of c. 102,000 individuals since the turn of the century. This population increase has largely taken place over the last five years, mainly due to a growing expatriate population brought about by strong local economic growth. In this respect, Malta's CAGR for population over the past five years stood at c. 2.9%, well above the EU average of c. 0.3% over the same period.

---

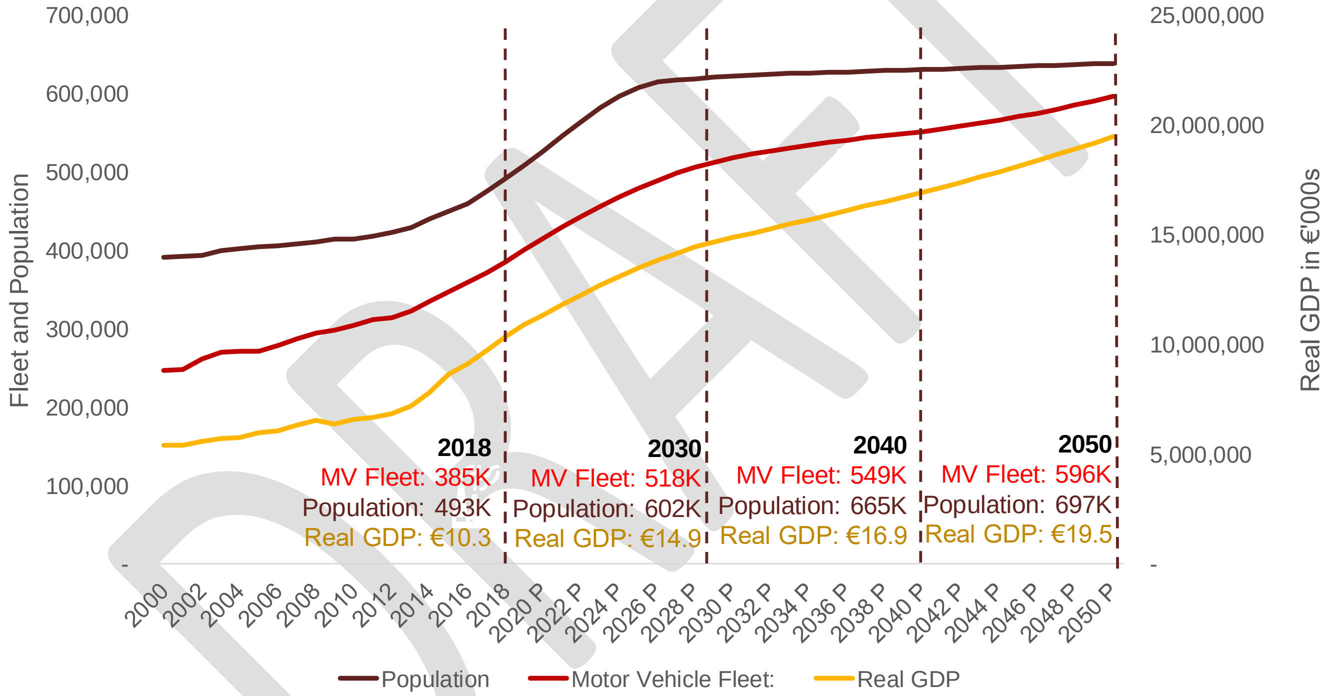
[72] Chain-linked volumes (2010), million euro were used to represent the Real GDP in Malta (downloaded March from Eurostat 2019) going back to 2000.
[73] IMF in the concluding statement of the 2019 Article IV Mission to Malta (2019)
[74] Autumn European Economic Forecast, November 2018
[75] PwC, The World in 2050 https://www.pwc.com/gx/en/issues/economy/the-world-in-2050.html
[76] Ibid.
[77] France, Germany, Italy, Netherlands, and Spain
[78] NSO – World Population Day (2018)

Over the 5-year period 2014-2018 the expatriate population increased at a CAGR of 22.5%, reaching c. 85,000 individuals at the end of 2018 (NSO, 2019), while the population of Maltese individuals increased at a CAGR of 0.4%[79] over the same period, largely in line with average European population growth rates.

The population projections published by Eurostat[80] were used to represent the Maltese population growth through 2050, which under a baseline projection results in a total population of c. 697,500 individuals growing at a CAGR of 1.1% over the projection period. This growth is forecasted to be largely driven by net migration to the island, while the Maltese population is expected to slightly plateau and then slowly decline due to an ageing population over the projection period.

4.4.3. Projecting the fleet

Based on these forecasts for GDP and population, the projected GDP per capita for Malta until 2050 was applied to the model equation '$Vehicle\ Fleet_t = Vehicle\ Fleet_{t-1} + Real\ GDP\ p/capita_t$', to arrive at the annual projected motor vehicle fleet up until 2050. The figure below sets out the annual fleet and corresponding GDP and population figures under the baseline scenario.



Source: Eurostat, NSO, PwC fleet demand model 2019-2050

Figure 3: Historical and projected GDP, population and fleet for Malta under the baseline scenario, Real GDP in € billions

From Figure 3 above, it can be observed that the total fleet as at 2030 is estimated to amount to c. 518,000 vehicles, based on a forecasted real GDP per capita of c. €24,700, up from the 385,300 vehicles in 2018 at a real GDP per capita of c. €21,000. By 2050, the total fleet under the baseline scenario is estimated to increase to c. 596,000 vehicles based on a forecasted real GDP per capita of c. €28,000.

Having forecasted the total fleet, the model then adjusts for vehicle scrappages and new purchases representing both vehicle replacement and increased vehicle demand forecasted year on year.

---

[79] NSO – Demographic Review & World Population Day (2007-2018), PwC Calculations
[80] Eurostat – Population projections on 1st January by age, sex and type of projection

4.5. Phasing out the existing fleet

4.5.1. Classic Vehicles

Vehicles with a year of manufacture over 30 years amounted to c. 19,500 as at the end of 2018. These vehicles were scrapped progressively over the period 2019-2034 down to c. 8,000 vehicles, which were retained throughout the remainder of the projected period to reflect the vintage vehicle stock in Malta. Moreover, 1% of the M1 vehicles that progressively aged to 30 years, were aggregated to the stock of classic vehicles throughout the projected period to account for increased additions to this vehicle category. As a result, classic vehicles are estimated to amount to c. 11,000 vehicles by 2050.

4.5.2. Vehicle Scrappages

A scrappage trend was determined based on NSO quarterly fleet statistics published, with the latest annual scrappages amounting to c. 8,000 vehicles for 2018. The scrappage trend was based on the 3-year average rate excluding the 2016 data point[81], which was equal to c. 2.2% of the total fleet. This scrappage rate was then applied to our total annual fleet projections throughout the forecasting period (2019-2050). As a result, scrappages over the projected period averaged c. 12,000 vehicles annually, representing a CAGR growth of c. 1.0%

4.6. Vehicle registrations

New annual vehicle registrations were determined based on the shortfall between the projected fleet stock at year-end and the next-year's projected fleet demand, after reducing scrappages. The table below sets out the determination of new vehicle registrations per annum based on the stock of vehicles and scrappages estimated for that particular year. As a result, annual vehicle registrations over the projected period averaged c. 18,500 vehicles over the projected period.

	2019	2020	2025	2030	2035	2040	2045	2050
Motor Vehicle Fleet, at beginning of the year	385,326	400,631	468,411	512,363	534,742	548,935	566,387	590,475
Scrappages, based on average useful life	(9,669)	(10,105)	(11,345)	(11,864)	(11,993)	(12,311)	(12,702)	(13,242)
MV Fleet Subtotal, after scrappages	**375,657**	**390,526**	**457,066**	**500,499**	**522,750**	**536,624**	**553,685**	**577,233**
New Registrations (i.e. shortfall between current vehicles in circulation and demand required for the following year) (i.e. purchases)	**24,974**	**24,975**	**22,409**	**17,441**	**15,251**	**15,174**	**17,037**	**18,973**
Motor Vehicle Fleet, at end of the year	**400,631**	**415,501**	**479,475**	**517,940**	**538,001**	**551,798**	**570,721**	**596,206**

Source: PwC Fleet Demand Model 2019-2050

Table 5: Determining new registrations of vehicles per annum

It should be noted that since fleet projections are based on the movement in projected real GDP per capita, vehicle purchases are therefore reflective of the cyclical changes in real GDP relative to expected population growth.

[81] The 2016 data point was excluded from our analysis after discussions with the NSO, in which the figure of c. 22,100 scrapped vehicles was determined to be an externality as it took into consideration retroactively scrapped vehicles from previous years.

4.7. Fleet Mix for the baseline scenario

The projected fleet was then split by fuel type, whereby the fuel mix of the new registrations was based on the RBC Capital Markets projections for Western Europe, (remove with a lag of five years) applied to Malta's current fuel mix as explained in the assumptions set out above in section 4.2 above.

Baseline Scenario	2019	%	2020	%	2025	%	2030	%	2035	%	2040	%	2045	%	2050	%
Scrappages	(9,669)		(10,105)		(11,345)		(11,864)		(11,993)		(12,311)		(12,702)		(13,242)	
Registrations	24,974		24,975		22,409		17,441		15,251		15,174		17,037		18,973	
Cumulative Fleet																
Petrol	240,488	60.1%	248,444	59.8%	265,684	55.4%	260,058	50.2%	246,385	45.8%	226,057	41.0%	201,329	35.3%	175,481	29.4%
Diesel	154,772	38.9%	158,854	38.2%	169,316	35.3%	167,168	32.3%	158,685	29.5%	145,834	26.4%	129,976	22.8%	113,337	19.0%
ICE	**395,259**	**99.0%**	**407,298**	**98.0%**	**435,000**	**90.7%**	**427,226**	**82.5%**	**405,070**	**75.3%**	**371,891**	**67.4%**	**331,305**	**58.1%**	**288,818**	**48.4%**
Hybrid (48V/HEV)	2,520	0.3%	4,843	1.2%	31,889	6.7%	58,621	11.3%	74,989	13.9%	82,485	14.9%	83,072	14.6%	79,415	13.3%
Plug-in Hybrid	279	0.1%	413	0.1%	3,803	0.8%	9,687	1.9%	15,745	2.9%	20,804	3.8%	23,821	4.2%	25,544	4.3%
Pure Electric (BEV)	1,035	0.2%	1,343	0.3%	6,817	1.4%	19,838	3.8%	39,079	7.3%	73,368	13.3%	129,346	22.7%	199,353	33.4%
CNG	-	0.0%	-	0.0%	253	0.1%	740	0.1%	1,221	0.2%	1,209	0.2%	1,107	0.2%	964	0.2%
LNG	-	0.0%	-	0.0%	-	0.0%	13	0.0%	29	0.0%	36	0.0%	40	0.0%	44	0.0%
Other	1,539	0.4%	1,604	0.4%	1,713	0.4%	1,816	0.4%	1,868	0.3%	2,006	0.4%	2,031	0.4%	2,069	0.3%
Total	**400,631**	**100%**	**415,501**	**100%**	**479,475**	**100%**	**517,940**	**100%**	**538,001**	**100%**	**551,798**	**100%**	**570,721**	**100%**	**596,206**	**100%**

Source: PwC Analysis

Table 6: Fleet split by fuel mix incl. annual scrappages and registrations

This table gives a snapshot of the fleet mix every 5 years under the baseline scenario. The estimated figures indicate that over time ICE vehicles are expected to decline with electric vehicles increasing in proportion. This analysis further suggests that under a baseline scenario, independently of an ICE cut-off date policy, BEVs and PHEVs are expected to account for c. 5.7% of the total fleet in 2030 and c.37.7% by 2050.

The shift towards the electrification of the Western European fleet is seen as a progression, from the relatively quick and inexpensive fix presented by mild-hybrids (48V) that allow OEMs to leverage higher fuel economy out of their already existing platforms, all the way until BEV. In this respect, our projections take into account rapid near-term growth for mild- and full-hybrids as they bridge the gap for to switch to PHEV and BEV platforms, as their costs begin to converge with that of conventionally-fuelled vehicles. Over time therefore, we expect mild- and full-hybrid demand to begin to give way to EVs as the majority of the electric platforms in development and being planned are for the manufacture PHEVs and BEVs.

4.8. Fleet Mix for different ICE cut-off date scenarios

Taking the different ICE cut-off date scenarios tested by the model, when applying them to the baseline scenario and adjusting the fleet mix according to the respective ICE cut-off policy, the following mix between ICE and BEV / PHEV are expected by 2030:

Scenarios	50% target (non-ICE) achieved by when?	Years to achieve 50% non-ICE	Composition of fleet by 2030: % Petrol and Diesel	% ICE	% non ICE	non ICE % EV	non ICE % PHEV	No. of cars to be converted to achieve 2030 target (incl. hybrids)?
Baseline results								
	N/A	N/A	82%	94%	6%	4%	2%	229,000
2026 Cut-off date scenarios								
Pre-Price Convergence	2042 / 2043	24 - 25 years	76%	83%	17%	12%	5%	166,000
Post-Price Convergence	2041 / 2042	23 - 24 years	73%	79%	21%	14%	7%	151,000
2028 Cut-off date scenarios								
Pre-Price Convergence	2044 / 2045	26 - 27 years	78%	87%	13%	7%	3%	191,000
Post-Price Convergence	2044 / 2045	26 - 27 years	77%	86%	14%	10%	4%	186,000
2030	2046 / 2047	28 - 29 years	81%	92%	8%	6%	3%	216,000
2032	2048 / 2049	30 - 31 years	82%	94%	6%	4%	2%	229,000
2034	2049 / 2050	31 - 32 years	82%	94%	6%	4%	2%	229,000

Source: PwC Analysis

Table 7: Comparison of fleet mix at 2030 relative to fleet targets for the considered ICE cut-off dates

As previously explained, the 2026 and 2028 ICE cut-off date scenarios were further sub-divided into two separate cut-off dates, to reflect whether the policy decision would be taking place pre- or post-price convergence of ICEVs and EVs. For the pre-price convergence scenarios, a dampening factor was applied to slow down scrappages given the expectation that people are more likely to hang on to their ICE vehicles until the prices of EVs and ICEVs converge. In turn, this also leads to lower new registrations / purchases given that scrappages are moving at a slower pace. Based on a comparative analysis of publicly available research, the latest date for a price convergence projection was found to be towards 2030, and therefore pre- and post-price convergence scenarios for the remaining cut-off date scenarios tested, being 2030, 2032 and 2034, were not carried out as it was assumed all these scenarios will occur post price convergence.

Based on table 7 above, the following observations can be made:

- *Baseline Scenario*: under a baseline scenario assuming no shift in policy, the target to achieve a fleet mix of 50% non-ICE by 2030 will not be achieved. Moreover, results indicate that the 50% target will not be achieved throughout the whole forecasting period, with an EV penetration of c. 37.7% being estimated by 2050. In order to reach the target, policy would need to drive a further c. 229,000 vehicles to convert to BEV and PHEV by the end of 2030.

- *2026 Pre-Price Convergence ICE cut –off date scenario*: Taking a 2026 ICE cut-off date, under the assumption that price convergence would not yet have taken place, results show that the 50% target of non-ICE vehicles to be achieved by 2030 will again not be reached, with ICE vehicles still accounting for 83% of the fleet. Roughly 166,000 vehicles would still need to be converted to BEVs and PHEVs to achieve the target by 2030. Under this scenario, the 50% target is estimated to be achieved by 2042/2043 i.e. it would take c. 24 – 25 years to achieve.

- *2026 Post-Price Convergence ICE cut –off date scenario*: With a 2026 ICE cut-off date, under the assumption that price convergence between EVs and ICEVs would have already taken place, Malta will still fall short of its 50% target, as ICE vehicles would still account for 79% by 2030. Under this scenario, by 2030, there would still be a gap of c. 151,000 vehicles, which would need to be converted from ICE to EV by the stipulated date, in order to achieve the target. All things being equal, under this scenario, the 50% target is expected to be reached by c. 2041/2042.

- *2028 Pre-Price Convergence ICE cut –off date scenario*: The results of the 2028 pre-price convergence ICE cut-off date scenario indicates that ICE vehicles will still account for 87% of the fleet by 2030 with a gap of c. 191,000 that would still need to be converted to meet the 2030 fleet target. Under this scenario, 50% of the fleet will be made up of BEVs and PHEVs by 2044/2045.

- *2028 Post-Price Convergence ICE cut –off date scenario*: In a 2028 cut-off date scenario, under the assumption that price convergence between EVs and ICEVs would have already taken place, ICE vehicles will still account for 86% of the fleet by 2030. At this date, it is estimated that there will still be a gap of c. 186,000 vehicles that would need to be converted to meet the 2030 fleet target. Under this scenario, 50% of the fleet will be made up of BEVs and PHEVs by 2044/2045.

- *2030 ICE cut-off date scenario:* Under the 2030 ICE cut-off date scenario, Malta again falls short of its 2030 fleet target, with ICE vehicles still accounting for 92% of the fleet by this date and c.216,000 vehicles would still need to be converted to BEVs and PHEVs. Under this scenario, the 50% target is estimated to be achieved by 2046/2047.

- *2032 and 2034 ICE cut –off date scenario*: Under both the 2032 and 2034 ICE cut-off scenarios, the fuel mix projections are estimated to be the same as under a baseline scenario for 2030 as there would not have been any policy changes introduced before the 2030 target date. In this respect, ICE vehicles are estimated to make up 94% of the fleet by 2030, with a gap of c. 229,000 vehicles required to be converted in order to reach the target. Furthermore, under these policy scenarios 50% of the fleet will be made up of BEV and PHEVs by 2048/2049 and 2049/2050 respectively.

Based on the scenario analysis and corresponding model results, it can be concluded that the imposition of an ICE cut-off date policy for ICE vehicles is not enough in itself to achieve the target of having 50% non-ICE penetration in local roads by 2030. The introduction of complimentary policies may be required to aid in speeding up the transition of Malta's fleet to non-ICE.

With respect to results for 2050, the table below sets out the composition of the fleet by fuel type for each of the scenarios considered. It also indicates the number of ICE vehicles which remain on Malta's roads by 2050, implying that the 100% conversion of the fleet to non-ICE by this date is not expected to be achieved under any of the scenarios being considered. This further supports the need to compliment the cut-off policy with other measures.

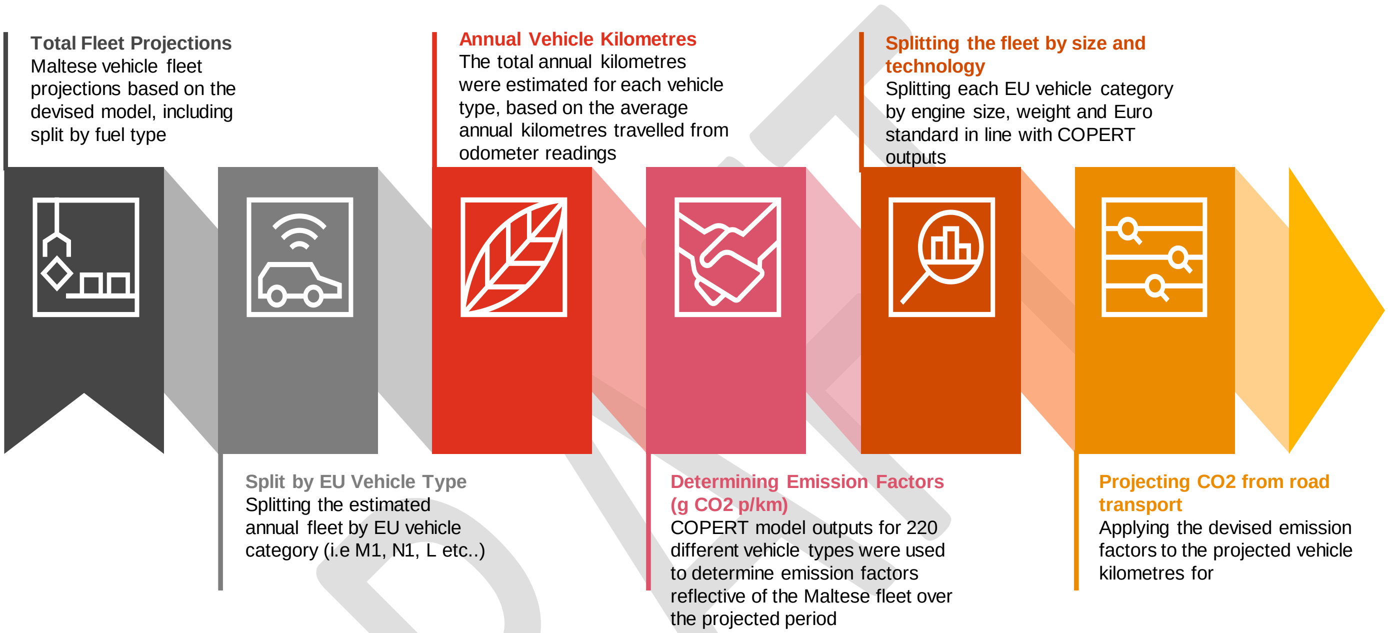
Scenarios	Composition of fleet by 2050					No. of ICE vehicles remaining (incl. hybrids)
	% Petrol and Diesel	% ICE	% non ICE	non ICE % EV	non ICE % PHEV	
Baseline results						
	48%	62%	38%	33%	4%	371,309
2026 Cut-off date scenarios						
Pre-Price Convergence	32%	36%	64%	54%	10%	211,728
Post-Price Convergence	30%	34%	66%	56%	11%	201,012
2028 Cut-off date scenarios						
Pre-Price Convergence	34%	39%	61%	52%	9%	232,558
Post-Price Convergence	34%	38%	62%	53%	9%	229,396
2030	36%	42%	58%	50%	8%	252,684
2032	38%	46%	54%	47%	7%	272,692
2034	40%	49%	51%	45%	6%	291,323

Source: PwC Analysis

Table 8:Comparison of fleet mix at 2050 and remaining number of ICE vehicles as at that date

5. Estimating CO2 emissions

Having determined the annual fleet mix over the projected period 2019-2050, the total CO_2 emissions expected to be generated from road transport also were estimated based on the assumed annual kilometres travelled and the weighted average CO_2 emission per kilometre (CO_2 g/km) for each fuel and vehicle type. The CO_2 emissions were estimated for the projected fleet under the baseline scenario and for each of the ICE cut-off date scenarios being considered.



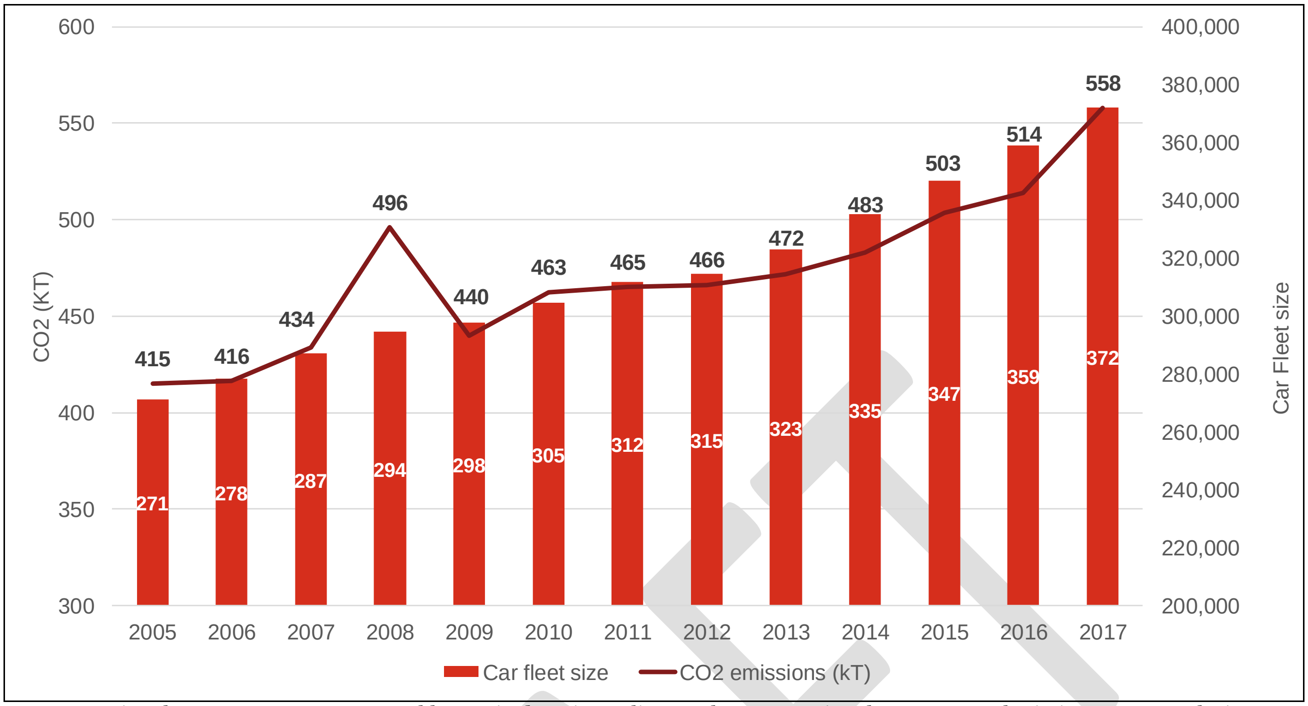
Source: PwC Analysis

Figure 4 – Overall approach to calculating CO_2 emissions from road transport

5.1. Historical CO_2 from road transport

As indicated in the figure below, between 2005 and 2017, Malta's CO_2 emissions from road transport grew by an average of c 2.5% from 415 kT of CO_2 in 2005 to 558 kT of CO_2 in 2017. The largest increase was registered over the last five years, as road transport emissions grew at a CAGR of c. 4.3%, in line with similar rapid growth in the motor vehicle fleet over the same period at c. 3.6%.

Under the 2030 ESR non-ETS emission targets, Malta is obliged to reduce its emissions from non-ETS sectors by 19% till 2030, relative to 2005-levels. Considering that the road transport sector is the largest contributor to the local non-ETS emissions, it would follow that a reduction in road transport emissions equivalent to the targets would at least be required. This would imply total CO_2 emissions equal to c. 336 kT of CO_2. On the other hand, CO_2 from road transport was c. 34% above benchmark levels as of 2017 and would require a minimum annual decrease of c. 3.8% in CO_2 emissions from road transport to achieve compliance with the target.



Source: National Inventory Report CRF Tables, United Nations Climate Change - National Inventory Submissions, PwC Analysis

Figure 5 – Historical CO2 from road transport and growth in MT motor vehicle fleet (2005-2017)

5.2. Split by EU vehicle category

In order to determine the CO_2 emissions being generated by the road transport sector in Malta, the annual total fleet projections over the forecasting period were further subdivided by EU vehicle category[82]. This split was based on the modal split of vehicles as at Q2 2018[83], which was kept constant and applied to the annual motor vehicle fleet projections from the devised model described in Section 4.

EU Vehicle Category	Number of Vehicles	Percentage of Fleet
M1 (Passenger Car)	296,086	78.1%
M2 (Passenger Van)	1,075	0.3%
M3 (Route Bus and Coaches)	805	0.2%
N1 (Light-Commercial Vehicle)	36,219	9.5%
N2 (Medium-duty Commercial Vehicle)	10,639	2.8%
N3 (Heavy-Duty Commercial Vehicle)	4,799	1.3%
L (Motorcycles and quadricycles)	27,278	7.2%
SP1 (Special Purpose Vehicles)	351	0.1%
T (Agricultural and Forestry)	2,086	0.5%

Source: NSO, News Release 125/2018 – Motor Vehicles Q2 2018

Table 9 – Modal split of the MT motor vehicle fleet by EU vehicle category as at Q2 2018

Each vehicle category was then split by fuel type, in order to derive the annual projections of the fleet by category and fuel type till 2050.

[82] Vehicle categories were based on the definitions provided by the European Commission - https://ec.europa.eu/growth/sectors/automotive/vehicle-categories_en

[83] Data provided by NSO with split of vehicles by EU category

5.3. Average annual kilometres

The average annual kilometres travelled for each vehicle category in Malta, was based on data provided by Transport Malta[84], which were as follows:

1. Passenger vehicles (M1) c. 8,000 kilometres;
2. Passenger vans (M2) c. 24,000 kilometres;
3. Coaches c.24,000 kilometres, and route buses c. 74,000 kilometres. For the purpose of our study, we took a weighted average of these figures based on the split of coaches and route buses in the Maltese M3 fleet as at the end of 2018[85]. This resulted in a weighted average figure of c. 50,000 kilometres for M3 vehicles;
4. Light-commercial vehicles (N1) c. 10,000 kilometres;
5. Medium-duty commercial vehicles (N2) c. 9,000 kilometres; and
6. Heavy-duty commercial vehicles (N3) c. 11,000 kilometres

For the purpose of our study, we also took the assumption that the annual kilometres of motorcycles (L-category) were equal to the annual kilometres of passenger vehicles (M1) at c. 8,000 kilometres. Special-purpose vehicles (SP1) and Agricultural vehicles (T) were assumed to travel similar distances to heavy duty vehicles.

These figures where then multiplied by the total stock of vehicles for their corresponding vehicle category, to determine the total annual vehicle kilometres expected to be travelled.

5.4. Determining emission factors (g CO_2 per kilometre)

For each of the fuel types tested in our devised vehicle fleet model, as well as for each EU vehicle category, a weighted average emission factor (g CO_2 p/km) was established. These were calculated on the basis described below:

- *Petrol, Diesel and Hybrid Vehicles*: The emission factors for conventionally fuelled-vehicles, and hybrid vehicles (both mild- and full-hybrid vehicles) were determined based on COPERT[86] model extracts, provided by the Energy and Water Agency (EWA). The model outputs provided annual energy consumption projections over the forecasting period for over 220 vehicle types, which were disaggregated as follows:
  - *Vehicle fuel type*: The main fuel-type driving the vehicle powertrain (ex. Petrol, Diesel or Hybrid)
  - *Vehicle type*: The type of vehicle being tested, whether it is a passenger vehicle, heavy-commercial vehicle or motorcycle
  - *Vehicle segment*: The engine capacity of the vehicle in question, to differentiate between a small passenger car running on a 0.8 to 1.4 litre engine and a larger passenger vehicle with an engine capacity larger than 2.0 litres. For heavier vehicles, weight was used to determine the vehicle segments to differentiate between a commercial-vehicle that has a carrying capacity of between 7.5t and 12t and those with a carrying capacity greater or less than.
  - *Emission standard*: The emission standard of the vehicle ranging from Pre-ECE emission standards to Euro 6 standards. This was based

[84] Data provided as of 2018, based on annual odometer readings
[85] NSO – Motor Vehicle News Release Q4 2018 - https://nso.gov.mt/en/News_Releases/View_by_Unit/Unit_B3/Environment_Energy_Transport_and_Agriculture_Statistics/Documents/2019/News2019_015.pdf
[86] COPERT is the EU standard vehicle emissions calculator that takes into consideration factors such as vehicle population, mileage, speed and other data such as ambient temperature to calculate emissions and energy consumption - https://www.emisia.com/utilities/copert/

A weighted average emission standard was determined for each vehicle category based on the projected vehicles split by type, segment and emission standard over the forecasting period. Vehicle types and segments were assumed to maintain the same split over the period 2019-2050, however the split of vehicles by emission standards was adjusted each year to consider older vehicles being scrapped and newer, less polluting vehicles entering the fleet. This equated to a c. 1% annual decrease in the specific vehicle emission factors. However, this decrease was slightly offset by a corresponding increase in the specific vehicle emissions per annum due to an anticipated increase in congestion leading to lower average vehicle speeds, and thus more CO_2 generated per kilometre travelled.

The emission factors were then converted from energy consumption (MJ/km) to total g CO_2 per km, using the following implied emission factors[87]:

- Petrol – 69.3 g CO_2 / MJ
- Diesel – 74.1 g CO_2 / MJ.

- *CNG:* In order to derive the emissions from CNG vehicles, the emissions from petrol and diesel cars were used as a proxy. Given that CNG vehicles have lower emissions than petrol vehicles (-18%), however have higher emissions than diesel vehicles (+6%) a weighted average of such adjusted emission factors was used to estimate emissions from CNG vehicles.
- *LNG:* Since LNG is best suited for heavy-duty vehicles, the CO_2 emission factor for such vehicles was based on that of diesel vehicles with a carrying capacity higher than 12t, adjusted (+16%) for the higher emissions associated with LNG.
- *BEVs:* BEVs do not make use of an ICE as a source of propulsion, and therefore do not directly produce any emissions during use. However, the electricity stored in the battery, which in turn is used to power the electric motor of the vehicle, can be generated from an energy source that produces emissions. Therefore, while there are no direct emissions resulting from BEVs, the increased demand for electricity may result in an increase in emissions from the energy generation sector. For the purposes of the study, the MESDC is interested in understanding the projections of the emissions from road transport in relation to the ESR emission target for 2030 i.e. to achieve a reduction in non-ETS sector emissions of 19% compared to 2005 levels. Since the emissions from the energy-generation sector do not fall under the ESR targets, we have assumed that emissions from pure electric vehicles will be equal to zero for the purpose of this exercise.
- *PHEVs:* Similarly, plug-in hybrid-electric vehicles are assumed to generate no emissions when the vehicle is running solely on the battery. Plug-in hybrid models currently offer ranges of 80km of battery autonomy, which more than covers the average daily distance travelled in Malta. Moreover, the majority of hybrid vehicles in Malta and available on the market are electric-petrol vehicles. However, for contingency purposes, we have assumed that plug-in hybrid vehicles still must rely on the ICE and therefore have modelled this into our emission calculations, taking an 80/20 split for the energy generation between the battery and ICE respectively. In this way, PHEVs in Malta were taken to produce 20% of the emissions of a similarly sized petrol passenger vehicle.

5.5. Projecting CO_2 from road transport

By applying the weighted average emission factors for each fuel and vehicle type (ex. M1 Petrol vehicle) to the total projected annual kilometres travelled for that vehicle category, the annual CO_2 emissions generated for that vehicle type could be estimated. The total CO_2 emissions by vehicle type were then aggregated in order to arrive at the total projected CO_2 emissions from road transport on an annual basis.

[87] Provided by the MRA, to bring in line with the implied emission factors used to determine the benchmark 2005 levels.

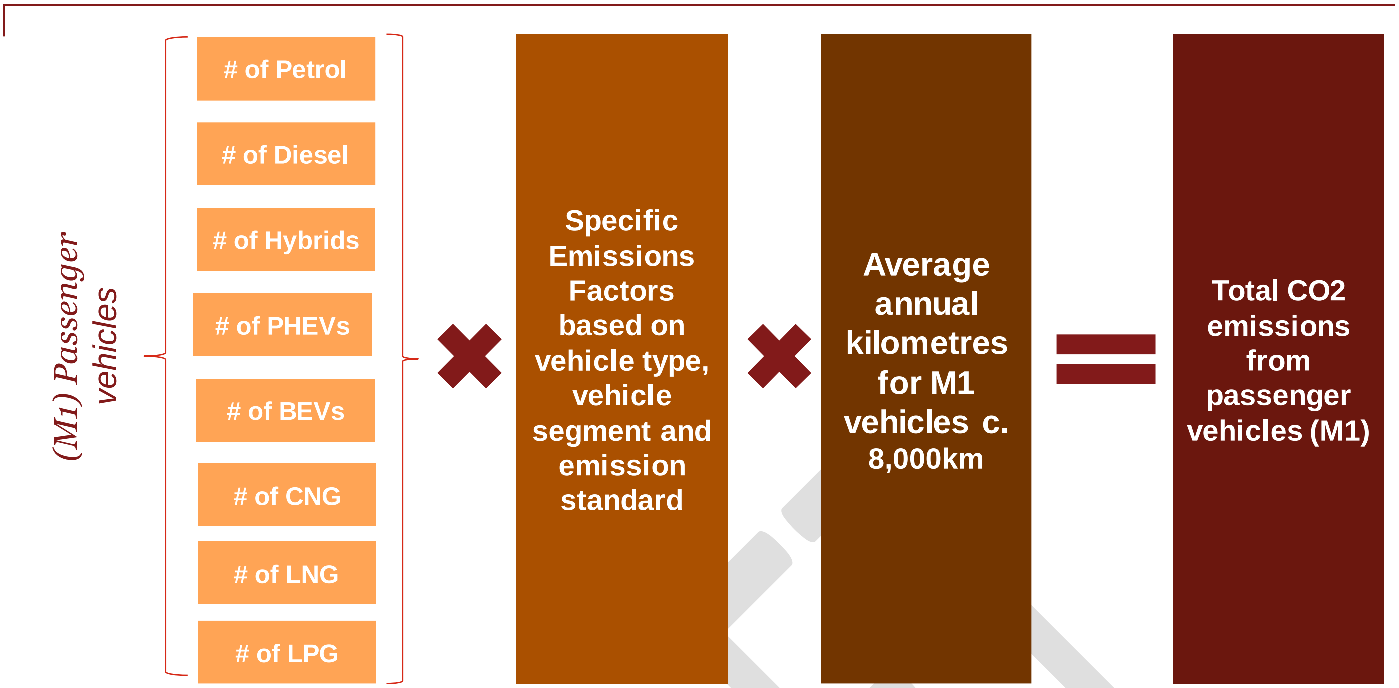


Figure 6: Methodology for determining CO2 emissions from road transport, example for M1 vehicles

5.6. Results

The table below sets out the results of the projected CO2 emissions from road transport relative to Malta's target for reducing CO2 emissions by 2030. The table also sets out CO2 emissions estimated for 2050 for each scenario assessed. In addition, the percentage of non-ICE vehicles as at these respective dates were computed for each of the scenarios, in line with the analysis carried out in Section 4.

	CO2 2005 ESR emissions from road transport (kT of CO2)	CO2 2030 ESR emissions from road transport (kT of CO2)	Difference from 2005 CO2 emissions from road transport (kT of CO2)	**Comparison to 2005 emission level from road transport %**	**% Non-ICE 2030 %**	**CO2 2050 emissions from road transport** (kT of CO2)	Difference from 2005 CO2 emissions from road transport (kT of CO2)	**Comparison to 2005 emission level from road transport %**	**% Non-ICE 2050 %**
Baseline results									
	415.02	**626.03**	**211.01**	50.8%	5.7%	**362.62**	**(52.40)**	-12.6%	37.7%
2026 Cut-off date scenarios									
Pre-Price Convergence	**415.02**	**564.57**	**149.55**	36.0%	17.4%	**238.75**	**(176.26)**	-42.5%	64.0%
Post-Price Convergence	**415.02**	**551.87**	**136.85**	33.0%	20.7%	**243.82**	**(171.19)**	-41.2%	66.3%
2028 Cut-off date scenarios									
Pre-Price Convergence	**415.02**	**591.25**	**176.23**	42.5%	13.0%	**268.20**	**(146.82)**	-35.4%	60.9%
Post-Price Convergence	**415.02**	**585.69**	**170.67**	41.1%	13.9%	**264.39**	**(150.63)**	-36.3%	61.5%
2030	**415.02**	**613.73**	**198.71**	47.9%	8.2%	**282.34**	**(132.68)**	-32.0%	57.6%
2032	**415.02**	**626.03**	**211.01**	50.8%	5.7%	**297.69**	**(117.33)**	-28.3%	54.3%
2034	**415.02**	**626.03**	**211.01**	50.8%	5.7%	**312.85**	**(102.16)**	-24.6%	51.1%

Source: PwC Demand Model 2019-2050

Table 10: CO2 emissions from road transport, percentage uptake of electric vehicles per scenario (2030 and 2050)

- *Baseline scenario* - Under a no-policy change i.e. no cut-off date, total CO_2 emissions from road transport (excluding indirect emissions related to energy generation from BEVs and PHEVs) are projected to increase to c. 626 kT of CO_2 by 2030, which translates to an increase of c. 50.8% compared to 2005 levels. Conversely, CO_2 emissions from road transport are projected to decrease to c. 362.6 kT CO_2 by 2050.

- *2026 and 2028 cut-off scenarios* - Under the 2026 and 2028 ICE cut-off date scenarios, total CO_2 emissions from road transport (excluding indirect emissions related to energy generation from BEVs and PHEVs) are projected to amount to c. 564.6 kT and c. 591.3 kT of CO_2 under the pre-price convergence sub-scenarios. On the other hand, under the post-price convergence sub-scenarios, total CO_2 emissions from road transport are expected equal c. 551.9 kT and 585.7 kT of CO_2 for the 2026 and 2028 ICE cut-off dates respectively. This implies that even under the earliest scenario (2026) and following price convergence, CO_2 emissions are still higher than 2005 levels by c. 33%. CO_2 emissions from road transport are then projected to fall to c. 238.8 kT and 268.2 kT by 2050 for the pre-price convergence 2026 and 2028 dates, while under the post-price convergence dates CO_2 emissions are projected to fall further to 243.8 kT and 264.4 kT respectively by 2050.

- *2030, 2032, 2034 cut-off scenarios* - Under a 2030 ICE cut-off date, CO_2 emissions are projected to reach c. 613.7 kT of CO2 by 2030 and fall to c. 282.3 kT of CO2 by 2050. The 2032 and 2034 follow the projections of the baseline model until 2032 and 2034 respectively. As a result, CO_2 emissions from road transport are forecasted to increase to 626.03 kT of CO_2 equivalent by 2030 for both scenarios, an increase of c. 50.8%% from 2005-levels. By 2050, CO_2 emissions from road transport are projected to fall to c. 297.7 kT and c. 312.9 kT of CO_2 under the 2032 and 2034 scenarios respectively.

Based on these results, it can be noted that through the imposition of an ICE cut-off date even as early as 2026, the CO2 target set for Malta for 2030 will still not be met and one may need to consider the introduction of additional complimentary policies to aid in meeting such target.

6. Conclusion

Based on the results of the fleet model and CO_2 emission calculations for each of the scenarios considered, it can be observed that both the fleet targets and road emission targets set for 2030 are unattainable in the absence of complimentary policy actions. Similarly, the results also indicate that Malta will fall short of its 2050 fleet target for 100% of the fleet to be non-ICE by this date, further supporting the need for complimentary policy.

Within this context, the table below sets out a multi-criteria analysis that takes into consideration both the results of the model as well as other qualitative factors that should be considered in determining an ICE cut-off date for Malta mainly stemming from the research and stakeholder discussions. The multi-criteria analysis provides an overarching framework to rank the various ICE cut-off dates tested. The criteria considered were mainly:

- Environmental impacts in terms of CO_2 emissions and impact on the national grid;
- Ability to contribute to National Transport Strategy fleet targets;
- Implications on the national tax regime;
- Supply-side considerations including availability of raw materials, battery production, supply of EVs / PHEVs by OEMs, and the necessary infrastructure; and
- Socio- economic implications including adequate timing for social acceptance and necessary training.

Cut-off date	Environmental impact and impact on the electricity grid		Fleet Target	Taxation Regime	Supply-side considerations				Socio-economic impacts			
	Contribution to ESR targets	Electricity Grid to support demand	Contribution to National Transport Strategy fleet targets	Adequate planning time to update tax regime	Supply of raw materials for battery production to meet demand	Adequate battery supply	Adequate vehicle supply	Availability of charging points	Social acceptance	Adequate time for educational campaigns	Adequate time to train labour force	Ability to charge vehicle
2026	X	✓✓✓✓✓	X	✓✓✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓	✓	✓✓	✓✓✓
2028	X X	✓✓✓✓✓	X X	✓✓✓✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓✓
2030	X X X	✓✓✓✓✓	X X X	✓✓✓✓✓	✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓	✓✓✓	✓✓✓✓	✓✓✓✓✓
2032	X X X X	✓✓✓✓✓	X X X X	✓✓✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓
2034	X X X X X	✓✓✓✓✓	X X X X X	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓

Table 11: Multi-criteria analysis of each cut-off date scenario

Source: PwC Fleet Model Analysis 2019-2050

The multi-criteria analysis indicates that the earlier the ICE cut-off date is announced, the more positive the environmental impact is expected to be, despite falling short of the ESR targets for Malta. On the contrary, there is likely to be a greater risk when it comes to the socio-economic dimension and supply-side of the market to address market needs. Hence, the challenge for the policy maker is to achieve a balance between these various criteria in arriving at the optimum ICE cut-off date, given the conflicting nature of these factors. Ultimately, it is evident that there is no clear-cut scenario in determining a single ICE cut-off date and any date that is chosen will always involve some sort of trade-off.

Appendices

Appendix I – ICE cut-off dates of different cities

Name	Country	Ban Commence	Ban Announce	Scope	Notes
Hamburg	Germany	May 2018	2018	Euro 5 Diesel Cars	While the bans have not yet come into effect in many cities, diesel vehicles below the Euro 6 standard are already forbidden to drive on a total track length of 2.2 kilometres in the metropolis on the Elbe since May 31, 2018.
Frankfurt	Germany	Feb 2019	Sep 2018	Euro 4 and 5 Diesel Cars	From February 2019 diesel cars made to Euro 4 standard and older will be prohibited from entering the city centre, the administrative court in Wiesbaden ruled in September. The air pollution control plan, to be updated by the state of Hesse, must also include a driving ban for diesel vehicles of the Euro 5 standard from September 2019.
Cologne	Germany	April 2019	Oct 2018	Older Diesel Cars	Old diesel vehicles are to be banned in certain areas of the cities.
Bonn	Germany	April 2019	Oct 2018	Older Diesel Cars	Old diesel vehicles are to be banned in certain areas of the cities. Impose ban on two roads.
Berlin	Germany	June 2019	Oct 2018	Euro 5 Diesel Cars	In October, the administrative court ruled that by the end of June 2019, cars and trucks with diesel engines that comply only with the Euro 5 or lower emission standard, should not be allowed to drive on at least eleven routes.
Darmstadt	Germany	June 2019	2018	Euro 5 Diesel Cars	This applies to two roads and affects vehicles of the Euro 5 class (and lower) and benzine engines of Euro 2 Class (and lower). Another element of the out-of-court settlement is the Green City Plan, which sees the increased support of public transport and cycling. If the NO2-pollution in Darmstadt doesn't fall in the second half of 2019, this plan will be further tightened.
Essen	Germany	July 2019	2018	Euro 5 Diesel Cars	As of July 2019, diesel-driven cars below the Euro 5 standard will have to stop in 18 of the city's 50 districts. In addition, the ban will be extended to Euro 5 diesel vehicles in September 2019. For the first time in Germany, a highway will be affected by the bans as well. Diesel vehicles will soon only be allowed to drive on the A40 to a limited extent – one of the most important traffic arteries of the Ruhr area.
Gelsenkirchen	Germany	July 2019	2018	Euro 5 Diesel Cars	The only street affected by the ban in Gelsenkirchen is one of the city's main traffic arteries: The Kurt-Schumacher-Strafe. From July 2019 onwards, only diesel vehicles of the Euro 6 standard will be allowed to operate there.

Mainz	Germany	September 2019	Oct 2018	Older Diesel Cars	A court ruled that Mainz, the state capital of Rhineland-Palatinate, must impose a driving ban on older diesel vehicles in September 2019 if nitrogen oxide and fine particulate matter pollution level are not brought down to agreed limits. The city can appeal against the ruling.
Stuttgart	Germany	2019	2018	Euro 4 Diesel Cars	The state of Baden-Wuerttemberg plans to ban older diesel cars with engines conforming to the Euro 4 emissions standard, which stems from 2005, in Stuttgart in 2019. A ban on diesel cars adhering to the Euro 5 emissions standard, which applied to vehicles made from 2009, is still before the court.
Aachen	Germany	N/A	2018	Diesel	A local administrative court in June said driving bans would be imposed unless values for nitrogen oxide pollution were met by the end of year.
Munich	Germany	N/A	Feb 2017	Diesel	In Munich, city authorities have not implemented a court ruling from February 2017, to ban some diesel vehicles on certain routes, despite facing fines for their failure to do so.
Dusseldorf	Germany	N/A	2016	Diesel	In Duesseldorf a court ordered, as early as 2016, that a driving ban for diesel vehicles should be seriously examined. Despite that, in August 2018 the district government of the city presented a new air pollution control plan without driving bans.
Helsinki	Finland	N/A	2018		Finland's capital has not proposed ban on diesel cars in the near future. Instead, it is banking on a 10-year plan to create a networked "mobility-on-demand" system that will integrate all forms of public and shared transport, from buses to driverless cars, to a point-to-point mini-bus service called Kutsuplus, to urban bike-shares, to ferries. Everything will be accessible through a single smartphone app. The idea is to make the system so good that almost no one will use private cars, because it will be cheaper and more convenient to use the city's integrated mobility system.
Oslo	Norway	2020	N/A	All private vehicles	Determined to go green, Oslo is slowly but surely ridding its city centre of motorists. Oslo has devised a series of highly dissuasive measures; it has eliminated 700 parking spots, re-zoned the city centre, turned streets into pedestrian walkways, and has raised the price of congestion tolls. It's not an outright ban as most people feared, however is seen more as a "Berlin Wall" against motorists.
					The first diesel ban occured in January 2017, with an inversion in play, with Oslo banning most diesel cars for the day. Traffic was down by 30 percent, and the city estimated that air pollution levels were lowered by a quarter - even though the diesel ban had many exceptions. Large diesel-powered trucks, diesel taxis, police and other official cars, and cars taking patients to hospital were exempt. six major throughways also remained open to diesel cars. City councillors realised

					that a broader ban on diesel engines could improve Oslo's air quality dramatically. In June 2017, Oslo's city council decided it would squeeze cars out of the city centre by banning parking spaced by 2019. It also committed to investing heavily in public transport, and prioritising bicycle traffic on 60 km (37 miles) of roads that currently prioritise car traffic.
Oxford	United Kingdom	2020/2035	2017	Gasoline and Diesel	All vehicles (initially during daytime hours on six streets, complete ban by 2035)
Rome	Italy	2024	2018	Diesel	Rome, one of Europe’s most traffic-clogged cities and home to thousands of ancient outdoor monuments threatened by pollution, plans to ban diesel cars from the centre by 2024, its mayor has said. Rome has no major industries, so nearly all the air pollution in the Italian capital is caused by motor vehicles. It has also tried to reduce pollution by allowing only cars whose number plates end in either off or even numbers to circulate on alternate days. Apart from health issues, pollution from combustion engines causes severe damage to Rome's many ancient outdoor monuments.
Athens	Greece	2025	2016	Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
British Columbia	Canada	2025/2040	2018	Gasoline and Diesel	All vehicles by 2040, 10% ZEVs by 2025
Madrid	Spain	2025	2016	Diesel	The Spanish capital is rich in gorgeous architecture, making it attractive to pedestrians. It already features many streets that ban cars other than emergency or delivery vehicles. But it's partly surrounded by mountains, which trap smoggy air over the city. Three-quarters of the smog comes from cars. Urban planners are redesigning 24 of the city centre’s busiest streets to free them of car traffic. The push is on to make almost the whole of central Madrid a pedestrian zone within the next five years. Even before then, parking fees for high-emission vehicles will be higher than for low-emission vehicles, like electric cars.
Mexico City	Mexico	2025	2016	Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Paris	France	2025	2016	Diesel	Gasoline or diesel engine cars will be banned from Paris starting in 2030. It has already banned diesel cars made before the year 2000, which produce more pollution than newer models.
Amsterdam	Netherlands	2030	2019	Gasoline and Diesel	
Auckland	New Zealand	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030

Barcelona	Spain	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Brussels	Belgium	2030	2018	Diesel	Low Emissions Zone (LEZ) Enforced or Planned in Belgium
Cape Town	South Africa	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Copenhagen	Denmark	2030	2017	Gasoline and Diesel	The goal is to make cycling into the centre easier, more convenient and cheaper than driving a car. The rate of car ownership in Copenhagen is among the lowest in Europe. About half the city's workers bike to work every day — even in winter. Copenhagen Mayor Frank Jensen said last October that he will soon propose legislation to ban new diesel cars from the city by the beginning of 2019. The rule won't apply to cars bought and registered by the end of 2018 and will leave out diesel vans and trucks.
Hainan	China	2030	2018	Gasoline and Diesel	
Heidelberg	Germany	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
London	United Kingdom	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Los Angeles	United States	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Milan	Italy	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Quito	Ecuador	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Seattle	United States	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030
Vancouver	Canada	2030	2017	Gasoline and Diesel	Signed the C40 Fossil-Fuel-Free Streets Declaration: Electric buses by 2025, ICE vehicles banned by 2030

Sources:

https://www.dw.com/en/move-is-on-to-ban-diesel-cars-from-cities/a-42747043

https://www.bloomberg.com/news/articles/2019-07-26/a-dead-end-for-fossil-fuel-in-europe-s-city-centers

https://en.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles

Appendix II – Movement in price gap between ICE and EVs in 2019, 2025 and 2030

Price gap between an ICE vehicle and electric vehicle in 2019 and forecasted for 2025 and 2030.

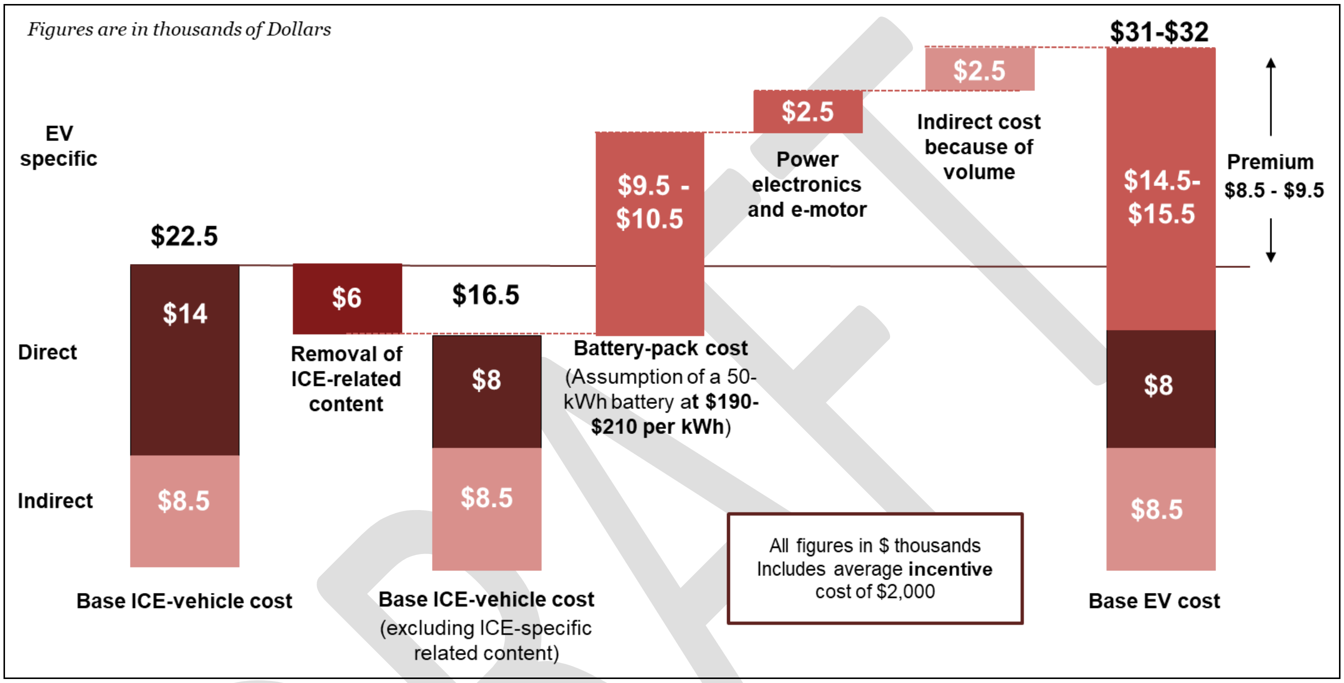


Figure 7:Price gap ICE vs electric vehicle 2019

Source: McKinsey (2019), based on a range of small to mid-size models, RBC Capital Markets (2018), PwC Analysis

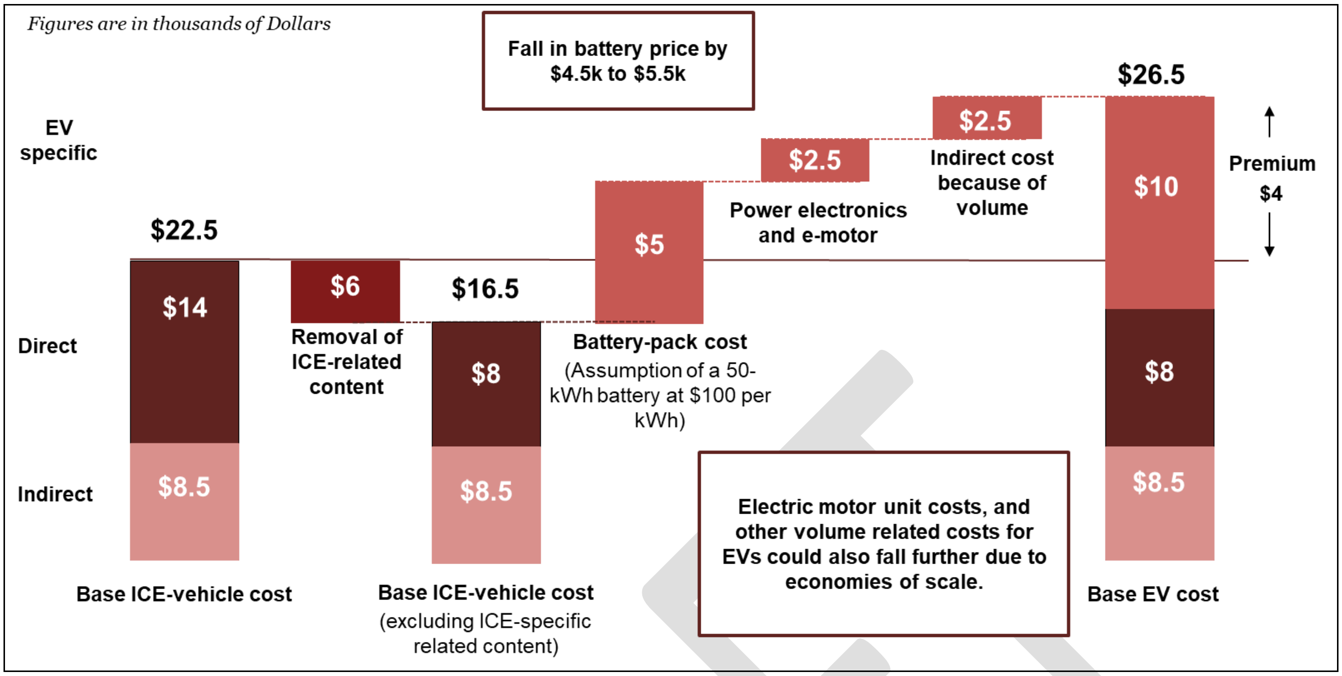


Figure 8: Price gap ICE vs electric vehicle 2025
Source: McKinsey (2019), based on a range of small to mid-size models, RBC Capital Markets (2018), PwC Analysis

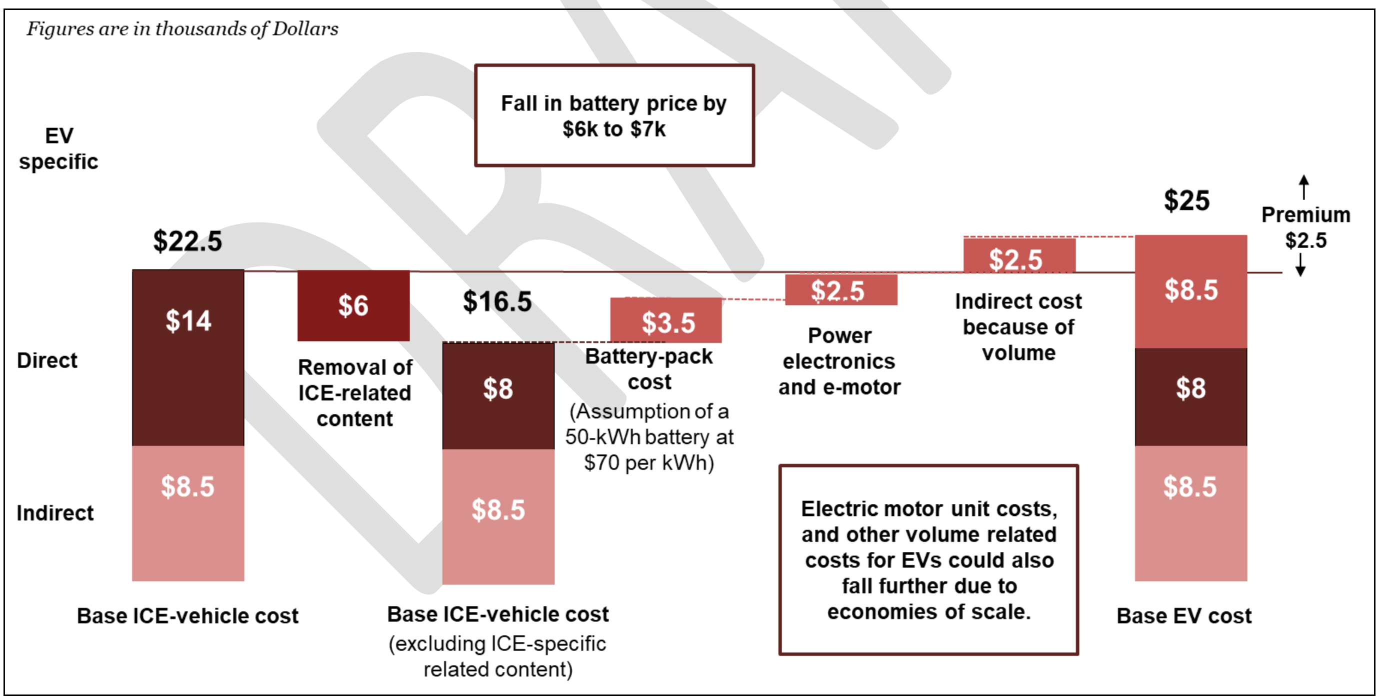


Figure 9: Price gap ICE vs electric vehicle 2030
Source: McKinsey (2019), based on a range of small to mid-size models, RBC Capital Markets (2018), PwC Analysis

Appendix III- OEM strategies and key targets

Manufacturer	Strategy and Key Targets
BMW Group	**25/25/25**: **25EV models** by **2025** which will make up to **25% of Total Sales**
Daimler	Total Electric fleet by **2025**. Plan to invest **€10bn** to electrify its fleet. To release **10 NEVs by 2022**
FCA	Electrified fleet by **2022.** Investing **€9bn** to develop electrified vehicles. Plans to eliminate diesel from EMEA by 2021
Ford	40 electric model including **16 BEV** models by **2022.** More dependent on hybrid technology in mid-term future.
General Motors	**1 million EV Sales** by **2026**. **20 BEV** models by **2023**.
Groupe Renault	EV will account for **10%** of Total Sales by **2022**. EVs will represent **20% of product range** by **2022**
Honda	Electrify European fleet by **2022**.
Hyundai-Kia	**23** EV Models by **2025**. plan to invest **$35 billion** in future mobility technology. Also has focused on Hydrogen-fuelled cars.
Mazda	"Sustainable Zoom-Zoom 2030" - All Vehicles will have some electrification by **2030**. **5%** of vehicles full-electrified by **2030**. Focus remains on ICE vehicles in medium-term.
PSA Groupe	Total Electric fleet by **2025**. Overall focus on PHEVs.
Tata motors	All models will have electrified option by **2020**. Plans to manufacture JLR 's electric vehicles within the UK
Tesla	Expanding production into China. Future to open new Gigafactory in **Europe** in **2021**
Toyota	Aims to sell over **5.5 million EVs** by **2030**. **10 BEVs** in China by **early 2020's.**
Volkswagen	Target of **3 million EVs** sold by **2025**. Investing **$84bn** through **2030**. Plans to offer 300 **electrified** versions of vehicles across all its brands.
Volvo	**50%** of group's sales to be fully electric by **2025**. **5 fully electric-vehicles** in next **3 years.**
China OEMs	Will be some of the biggest producers of EVs in the next few years. Manufacturers include: Geely, BYD & SAIC. All have aims to become leaders in EV industry
Commercial vehicles	Currently electrification of heavy-duty vehicles is not viable. Light commercial Vehicles and Busses are more likely to see price convergence in the near future. This is mostly because they operate in city and town centres and travel shorter distances. However, charging infrastructure remains a challenge

Appendix IV- Forecasted EU battery production capacity

Firm/Country	Production capacity	Launch date	Future target capacity	Target Year for capacity increase
LG Chem, Poland	10GWh	Operational	100~110GWH	2020
Samsung SDI, Hungary	2.5GWh	Operational	11GWH	2020
AESC, Sunderland	2GWh	Operational	N/A	N/A
Samsung SDI, Austria		Operational		
SK Innovation, Hungary	7.5GWh	2020	N/A	N/A
BMZ & Others, Germany	4GWh	2020	8GWh	N/A
Northvolt, Sweden	16GWh	2021	32GWH	2023
CATL, Germany	14GWh	2021	60GWH	2026
Farasis, Germany	6GWh	2022	10GWH	N/A
Northvolt, Germany	16GWh	2023/2024	24GWH	N/A

Sources:

LG Chem, Poland: http://en.thelec.kr/news/articleView.html?idxno=315
https://insideevs.com/news/341124/lg-chem-to-increase-battery-production-in-poland-to-70-gwh/

Samsung, Hungary: http://en.thelec.kr/news/articleView.html?idxno=58

http://www.fullertreacymoney.com/system/data/files/PDFs/2018/May/14th/RBC%20Capital%20Markets_RBC%20Electric%20Vehicle%20Forecast%20Through%202050%20%20Primer_11May2018.pdf

Northvolt, Germany: https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-and-northvolt-form-joint-venture-for-battery-production-5316

https://www.elektroniknet.de/international/northvolt-gigafactories-in-sweden-and-germany-166327.html

SK Innovation, Hungary:
http://www.fullertreacymoney.com/system/data/files/PDFs/2018/May/14th/RBC%20Capital%20Markets_RBC%20Electric%20Vehicle%20Forecast%20Through%202050%20%20Primer_11May2018.pdf

NorthvoltSweden: https://www.elektroniknet.de/international/northvolt-gigafactories-in-sweden-and-germany-166327.html
https://northvolt.com/production/

CATL, Germany: https://www.electrive.com/2019/02/04/catl-plans-up-100-gwh-battery-factory-in-germany/

Farasis, Germany: https://insideevs.com/news/348957/farasis-build-battery-plant-germany/

BMZ & Others: https://www.electrive.com/2018/11/20/battery-cell-production-in-germany-reforms/

AESC: Sunderland: https://www.envision-aesc.com/en/network.html

Samsung SDI, Austria: https://www.samsungsdibs.at/locations/

Appendix V – Overview of battery chemistries, relevant parameters and raw materials intensity

Cathode Material	**Chemistry**	**Description**	**Raw Material cost** **(USD/kWh)** **Low=better**	**Energy density** **(kWh/KG)** **High=better**	**Ni content** **(kg/kWh)**	**Co content** **(kg/kWh)**	**Li Content** **(kg/kWh)**
LCO	$LiCoO_2$	Low stability/safety Good Energy density Poor Lifetime	High	High	-	High	Med
NMC	NMC 111	Low stability/safety Very Good Energy density Good Lifetime	Med-high	Med	Med	Med	Med
NMC	NMC 622	Good stability/safety Very Good Energy density Good Lifetime	Med	High	High	Med	Med
NMC	NMC 811	Good stability/safety Very Good Energy Density Good Lifetime	Med	High	High	Low	Med
LMO	$LiMn_2O_4$	Very Good stability/safety Low Energy density Poor Lifetime	Low	Low	-	-	Med
LFP	$LiFePO_4$	Very good stability/safety medium Energy density Very Good Lifetime	Low	Med	-	-	Med
NCA	$LiNiCoALO_2$	Good stability/safety Excellent Energy density Poor Lifetime	Med	High	High	Med	Med

Source: https://www.mckinsey.com/industries/oil-and-gas/our-insights/metal-mining-constraints-on-the-electric-mobility-horizon

Appendix VI – Methodology to arrive at CNG and LNG vehicle demand

The projected take-up of CNG and LNG vehicles was determined on the basis of the current and projected EU take-up of Natural Gas vehicles (NGVs) as reported in Member State National Policy Frameworks (NPFs). The CNG take-ups of each Member State were calculated by considering the current and projected CNG vehicles in relation to the vehicle categories that could possible adopt CNG, which include passenger vehicles; route buses and light to medium commercial vehicles. On the other hand, the take-up of LNG was considered relative to each Member States' fleet of heavy-duty commercial vehicles with a gross weight rating (GWR) greater than 12 tonnes, for which LNG as a fuel is the most relevant.

The current and projected take-up rates for CNG and LNG for the EU-28 were calculated as presented below. A few countries were excluded from the analysis of CNG and LNG vehicles as they were determined to not be representative of the potential NGV demand in Malta.

	CNG				LNG		
	Current (%)	Projected (%)			Current (%)	Projected (%)	
Averages				**Averages**			
EU-28	0.2748%	0.5238%		EU-28	0.0269%	1.4009%	
EU-28 excl. Italy, Bulgaria	0.0864%	0.2999%		EU-28 excl. Italy, Slover	0.0267%	0.3943%	
Assumed uptake in Malta	N/A	0.0123%	2021		N/A	0.053%	2026
	N/A	0.0741%	2025		N/A	0.356%	2030
	N/A	0.2145%	2030		N/A	0.828%	2040
	N/A	0.2296%	2035		N/A	0.872%	2049

Source: PwC Analysis

The average European take-up rate, excluding Italy and Bulgaria for CNG, was applied to the Maltese fleet, with a time lag, to calculate the potential uptake of CNG vehicles in Malta. On the other hand, the uptake of LNG vehicles in Malta was adjusted slightly upwards from the average European take-up rate, excluding Italy and Slovenia for LNG. This was done by determining the minimum and maximum range of LNG uptake in EU Member States and stepping the demand in Malta up by one quartile from the average, while remaining below the maximum. The reason for this was to take into account the relatively large time lag between the current LNG uptake in the EU (2017) and the projected deployment of and L-CNG station in Malta (2026) and any potential advancements in LNG technology and model availability throughout this period.