Electric surge:

Carmakers' electric car plans across Europe 2019-2025

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Abbreviations

EV Electric Vehicle. *In this report, this stands for vehicles propelled by an electric motor: battery electric vehicles, fuel cell electric vehicles and plug-in hybrid electric vehicles*

BEV Battery Electric Vehicle

FCEV Fuel Cell Electric Vehicle

ZEV Zero-Emissions Vehicle: BEV and FCEV

PHEV Plug-in Hybrid Electric Vehicle

ZLEV Zero and Low Emission Vehicles (EU legal definition)

HEV Mild and Full Hybrids

ICE Internal Combustion Engine

LIB Lithium-ion batteries

OEM Original Equipment Manufacturer, carmaker

Summary

Electric cars are about to go mainstream in Europe, and 2020/2021 is likely to be a tipping point for the market. Until recently, the EV market was limited to a niche of early adopters but tomorrow's landscape will be very different as EVs enter a new phase and near the mass market. This report shows where the future electric cars and batteries will be produced in Europe, and analyses the expected production trends, and whether or not these are enough to meet the EU demand up until 2025.

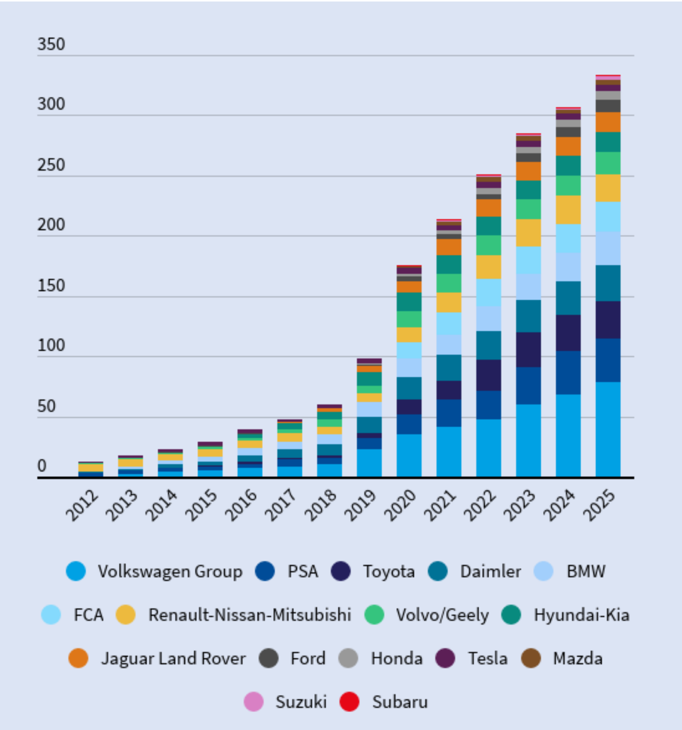

Figure 1: Total number of available EV models on the market in Europe

The current production forecasts show that most carmakers are ready to embrace electrification and are leaving behind the 'technology neutrality' approach, focusing on scaling up electric car volumes instead. After several years of timid growth, the number of EV models produced across the EU (and available on the market as a result) is about to surge to new heights: from about 60 battery electric (BEV), plug-in hybrid (PHEV) and fuel cell (FCEV) models available at the end of 2018, up to a combined of 176 models in 2020, 214 models in 2021 and 333 models expected in 2025. This is no coincidence since 2020/21 is the year when the mandatory EU CO2 target of 95g/km is kicking in.

Based on the light vehicle production forecast data acquired by T&E and in-house analysis, the production of electric vehicles in Europe is expected to multiply six-fold between 2019 and 2025, reaching more than 4 million cars and vans, or more than a fifth of the EU car production volumes. T&E modelling shows that if carmakers stick to their plans, this will be more than enough to comply with the EU Car CO2 standards for 2025 recently agreed, or a minimum of 15% in 2025.

As technology progresses, an increasing number of these will be battery electric vehicles (BEVs), or around 60% of total EU EV production in 2025 (up from close to half in 2018). In comparison, the forecasted production plans for other alternative powertrains such as fuel cell cars and natural gas (CNG) are negligible: only 9,000 FCEV are forecasted to be produced by 2025, and 1% or less of CNG and LPG vehicles of the EU total production.

While the production forecast is more solid up to 2021 (and necessary given the mandatory CO2 targets), beyond that the exact volumes and locations for vehicle production are difficult to predict with certainty as there is always an inherent uncertainty in estimating future manufacturing subject to unexpected economic and geopolitical changes (e.g. Brexit). However, the currently available information (IHS Markit forecast) nonetheless shows a positive picture of ICE production being progressively replaced with EV manufacturing EU-wide. While a lot of it will be located in Western Europe – e.g. Germany, France Spain and Italy[1] – Slovakia is forecasted to have the highest per capita EV production by 2025, with the Czech Republic and Hungary also having significant production per capita. This shows the industrial opportunities will exist across Europe, predominantly in western countries but also in Central and Eastern Europe. Together, the

[1] Also in the UK, but due to Brexit there is huge uncertainty as to whether the production plans will be delivered

Volkswagen Group, PSA, Renault-Nissan and Daimler are expected to make up two-thirds of EV production in Europe by 2025.

The supply of EU-manufactured batteries is also expected to be sufficient after 2023, provided the current plans are delivered. Currently, at least 16 large-scale lithium-ion battery cell manufacturing facilities exist or are likely to come online across Europe. The confirmed plans alone will deliver up to 131 GWh of battery production capacity in 2023 (growing to 274 GWh in 2028). The 2023 demand needed to electrify vehicles (cars, vans, buses and trucks) and for stationary storage batteries is estimated by T&E at around 130 GWh, or within the planned capacity provided it comes online on schedule. Based on existing data, we estimate that this scale of battery manufacturing will bring around 120,000 jobs in 2023 and 250,000 jobs in 2028 from direct and indirect employment in the battery value chain.

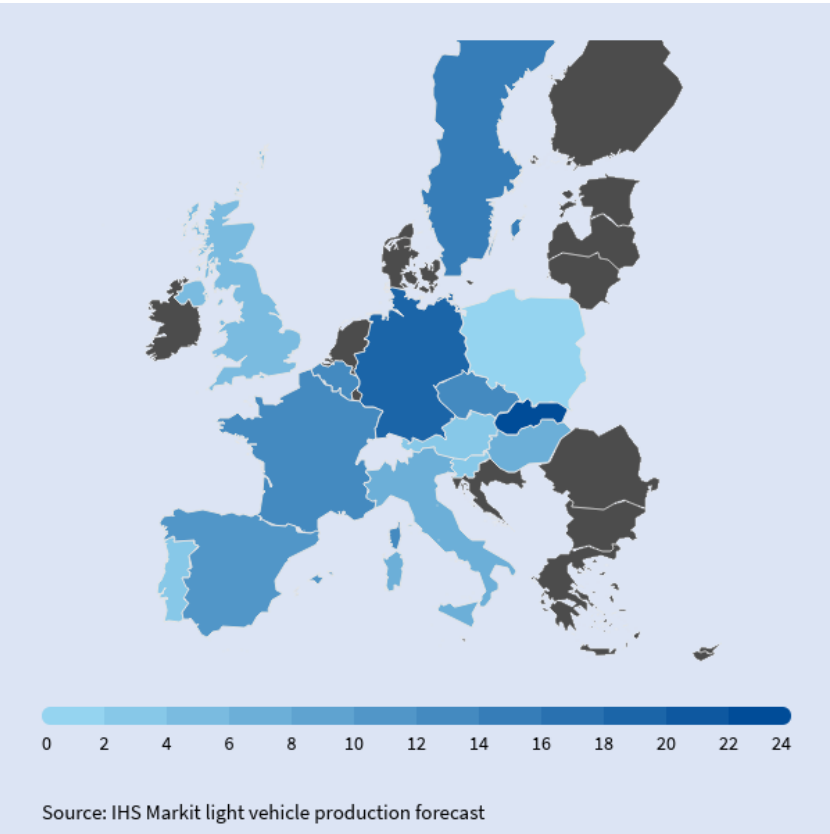

Figure 2: EU EV production per 1,000 inhabitants in 2025

But whilst carmakers' current plans suggest a bright future for electric cars, there is no guarantee these will be delivered on the road beyond 2021. Changes in policy in Europe or abroad, a lack of fiscal reform or adequate charging infrastructure, or simply a change of direction in a handful of key companies could all slow down or derail the transition to electromobility. Given the enormous amount of money committed to the transition – jointly EU carmakers plan to spend around EUR 145 billion on electric cars - success in this field is now a top industrial priority for Europe.

Success in this area will require the swift reform of national vehicle and corporate fleet taxation. New taxes should be designed smartly so they drive the uptake of those electric vehicles that deliver the highest environmental benefit, whilst also ensuring equity and stimulating carmakers to overachieve on their EU targets. Simultaneously the EU should spearhead an electric recharging masterplan to ensure interoperable recharging infrastructure is rolled out across the EU, notably at home, in the workplace, in urban areas and on all of Europe's key roads.

The incoming Commission has a key role to play in making the transition to electromobility a success. It should recognize electromobility as a top industrial priority and mobilise key instruments such as funding tools, research and development as well as new regulations for infrastructure and batteries to drive the market forward. An EU-wide phase-out of newly sold conventional engine cars by 2035 at the latest would help send a strong signal across the industry and ensure a timely and focused preparation of manufacturing and supply chain industries for the transition.

1. Introduction

Transport is Europe's largest source of carbon emissions contributing 27% to the EU's total CO2 emissions, with cars representing 44% of these, according to the European Environment Agency (EEA)[i]. Transport is the only major sector in which emissions have grown since 1990[ii], driving an increase in the EU's overall emissions in 2017[iii] (latest year available).

The 2015 global Paris Agreement aims to limit the temperature rise to below 2°C and to pursue efforts to go further to 1.5°C. If the EU is to achieve the Paris climate goals, transport emissions must be reduced to zero. To achieve that, the Commission has proposed a net zero 2050 scenario, estimating that all new car sales will have to be zero emission by the mid-2030s. At least 24 EU countries support the 2050 carbon neutrality goal – the high level agreement is expected in autumn 2019[iv].

Drastically speeding up emission reductions from light duty vehicles is of vital importance and is required urgently. In order to achieve the necessary reduction in emissions, Europe, and indeed the world, cannot rely on incremental improvements to conventional vehicles. Instead, a transformation is needed in the way that personal mobility is delivered, notably a shift to zero emission electric vehicles.

Despite a strong growth in 2018 (see Figure 3), the European electric vehicle (EV) market only reached a 2.5% market share in 2018 - 2.0% for the EU alone -, with the top markets being Norway (49%) Sweden (8%), Netherlands (6.7%), Finland (4.7%) and Portugal (3.4%).[v]

Passenger cars have been dominated by internal combustion engines (ICEs) for the last 100 years, but as this report shows, we are on the verge of a transformational shift to EVs. The current technological changes, EV sales and production commitments are mainly driven by regulation and climate targets. T&E previously estimated to meet 2020/21 CO2 targets EU carmakers needed to sell 5/7% plug-in vehicles[vi]. However, SUV sales are rising strongly and diesel sales falling so this number is likely to be closer to 10%.[2] Until then carmakers do not need to sell EVs and have been suppressing EV sales and limiting the number of available models.[vii]

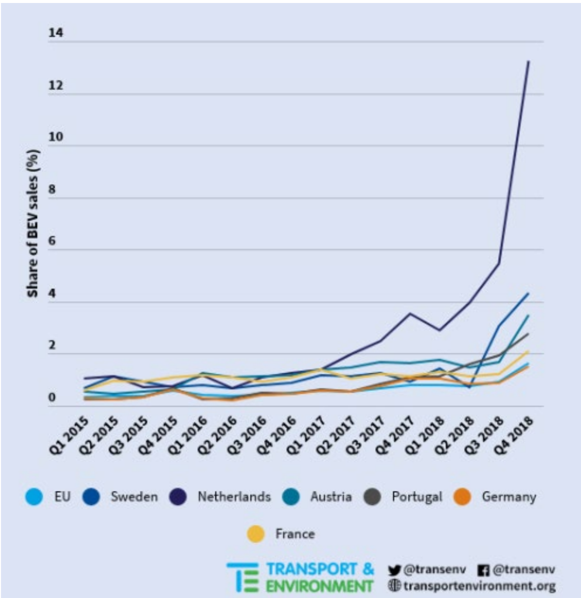

Figure 3: Quarterly EV market share in the EU and 6 countries emissions per sector

The EU has recently agreed the CO2 emissions reduction targets for new passenger cars for 2025 and 2030. The 2025/30 standards will require carmakers to reduce CO2 emissions from all new cars by 15% in 2025 and 37.5% in 2030 (15% and 31% for vans), compared to 2021 levels. Alongside, the regulation incentivises carmakers to sell 15% of zero and low emission vehicles (ZLEV)[3] from 2025, and 35% from 2030 onwards – offering a reduction of up to 5% on their overall CO2 targets if they overshoot these sales benchmarks. As plug-in hybrid cars are counted less than 1, in reality higher shares of electric car sales are required to hit the benchmarks.

This report analyses the production of EV passenger cars and batteries in Europe in the short and medium term, and whether it will be enough for the CO2 goals. First, Chapter 2 presents an analysis of what we can

[2] T&E will publish its updated analysis of the 2020/21 standards after the summer

[3] Defined as cars emitting less than 50 g CO2/km, which on today's technology includes battery electric, hydrogen fuel cell, plug-in hybrid and range-extender models

expect from the car market in the EU in terms of number of EV models, the respective split per technology, detailing carmaker strategies, as well as a comprehensive overview of where the future European EV production will be located. Next, Chapter 3 focuses on batteries and compares the total demand for automotive lithium-ion batteries driven by the EU EV production with the total expected European battery production capacity. Finally, Chapter 4 analyses the expected outcome from the 2025/2030 CO2 emission standards and whether or not the EU EV production will be enough.

This paper does not aim to predict the future; rather it aims to give some insights on what can be expected from the EU vehicle market in the medium-term future based on the carmakers' production plans known to date. The purpose of this report is to analyse the impact of current industrial plans and CO2 regulations on the European market - it should not be considered as a market forecast.

2. Carmakers' EV plans across Europe: 2019 to 2025

2.1. Forecast data on EV production

This report is based on the T&E analysis of the IHS Markit[4] light vehicle production database and forecast, acquired by Transport & Environment in February 2019, and coupled with in-house T&E research on major model and production announcements since (see Annex for more information). The IHS forecast is based on detailed regional economic, industrial and sales analysis and distinguishes between short-term and long-term projections. There is an inherent uncertainty in forecasting future production volumes and locations 5 years ahead, which can be subject to updates and adjustments – this analysis therefore shows what is possible and currently in the pipeline, rather than a definitive prediction.

The IHS Markit database contains light vehicle production plans[5] with complete model portfolio for all carmakers. For each model, production location[6] and many vehicle characteristics are included including propulsion technology, fuel type, lithium-ion battery capacity when relevant, vehicle segment, etc. All global carmakers are included, not just the major OEMs. The dataset also includes production volume forecast from 2019 to 2025[7], which T&E analysed to understand the future EU vehicle production landscape.

The dataset focuses on vehicle production and thus does not include information on vehicle sales which would account for imports and exports from different markets. The scope is the European Union (EU), sometimes designated as Europe[8].

IHS production forecasted values are based on OEM announcements until early 2019 and therefore might not reflect all of the latest adjustments or changes. However, in the sub-Section '*2.2 EV models coming to the market up to 2025*', latest announcements and production plans have been taken into account to be an exhaustive and up to date account of the number of EV models coming the market in the next years.

[4] IHS Markit global leader in information and industry intelligence. This remains the property of Transport & Environment, and any copy of the data contained in this report is not allowed.
[5] Based on United States' EPA convention; a single common standard is applied. Light vehicles have a Gross Vehicle Weight below 6 tons and combine the passenger car and small truck vehicle types. Micro cars and three wheelers are excluded.
[6] Vehicles can be produced in Europe with part of the vehicle being imported from outside the EU (e.g. the powertrain or the battery).
[7] In terms of industrial plans the 2030 timeframe is too distant to assess production plans as it is not within the timeframe of current product developments and would thus be highly speculative.
[8] In practice the following countries marked as European in the database were excluded: Russia, Kazakhstan, Uzbekistan, Ukraine, Serbia, Belarus and Turkey. Unless specified otherwise, Europe or EU is used to designate the EU region.

2.2. EV models coming to the market up to 2025

The number of BEV models available on the market has stayed consistently low in the past as carmakers saw them as compliance cars until recently, producing the minimum needed to hit CO2 targets. Today, less than 40 battery electric car and van models are available on the market, and the supply of most of these vehicles is being surpressed as shown previously by T&E[viii] –notably though very long waiting times, launch delays, dismissive dealerships or unavailibility in some regions or countries.

This section shows how, in the run-up to the 2020/2021 CO2 emissions standards, Europe will see a surge in the number of new light duty EV models coming to market every year (both cars and vans). Only major carmakers are included, so this analysis is on the conservative side, and is based on plans on which OEMs are yet to deliver. For more details on the methodology please refer to the Annex.

Battery Electric Vehicle (BEV) models

The number of new BEV models expected to be come to market in the next years surges from 6 new BEV models in 2017 (and 5 in 2018), to 19 new BEV models in 2019, 33 in 2020, 22 in 2021, 30 in 2022 and 33 in 2023 (see Figure 4 below). The year 2019 is a transitional year, and as of 2020 the offer will jump considerably to around 30 models annually. This is a consequence of the entry into force of the car CO2 emission standards in 2020, and illustrates that the European EV market is compliance-driven.

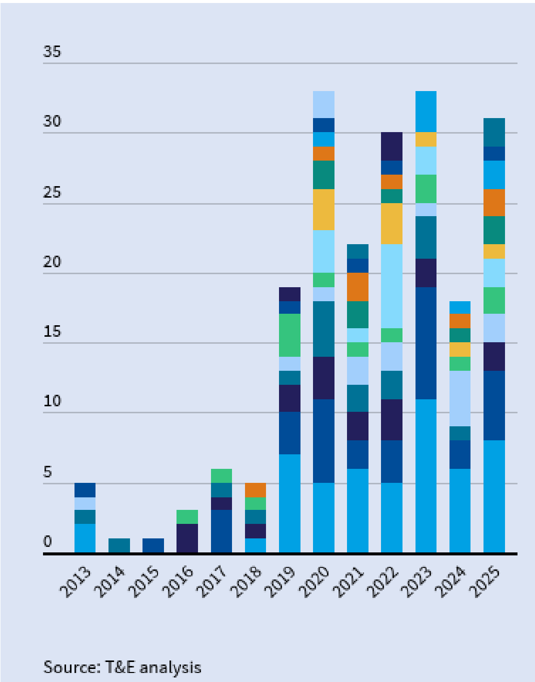

Figure 4: Number of new BEV models coming to the market in Europe

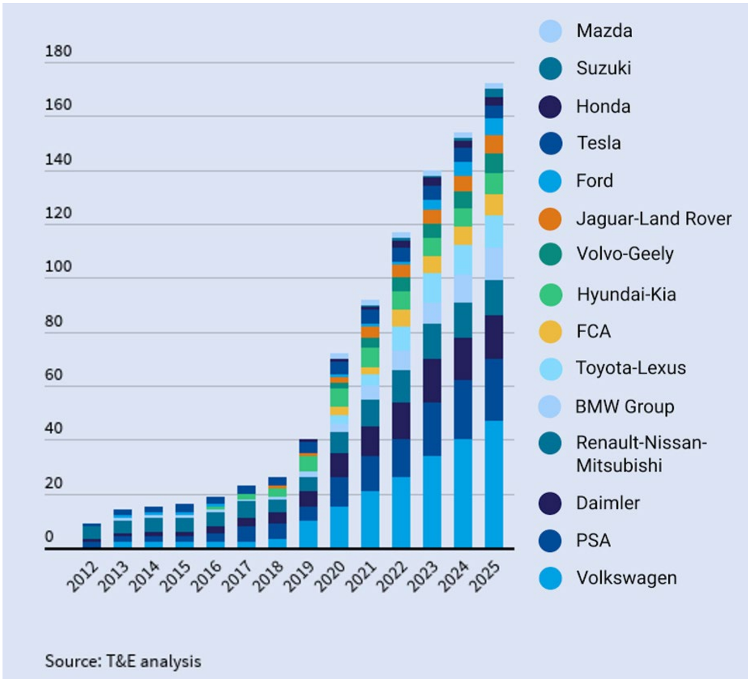

Figure 5: Number of BEV models on the market in Europe

The total number of BEV models on the market in the EU will surpass 100 in 2022 and reach 172 in 2025 (see Figure 5). The market leader is the Volkswagen Group (Volkswagen, Audi, SEAT, Porsche and Skoda) with close to 50 different BEV models in 2025. PSA and its sub-brands Peugeot, Citroen, Opel and DS are in second position with 23 BEV models in 2025. Next are Daimler (16), Renault-Nissan Alliance (13), and BMW and Toyota both at 12 models in 2025. We expect more announcements and new models to come in the mid-2020s given the recent introduction of the new and more stringent post-2020 CO2 emission standards.

Plug-in Hybrid Electric Vehicle (PHEV) models

The future availability of PHEV models follows a similar pathway as for the BEV models: low number of available models prior to 2019 and a strong growth afterwards. From Figure 6 below, it is obvious that PHEVs are mainly used by carmakers for compliance with CO2 standards, as the number of new models to the market peaks in 2020 when the 95g/km standard kicks-in - to almost 50 models which is twice the number of new models expected on the market in the other years.

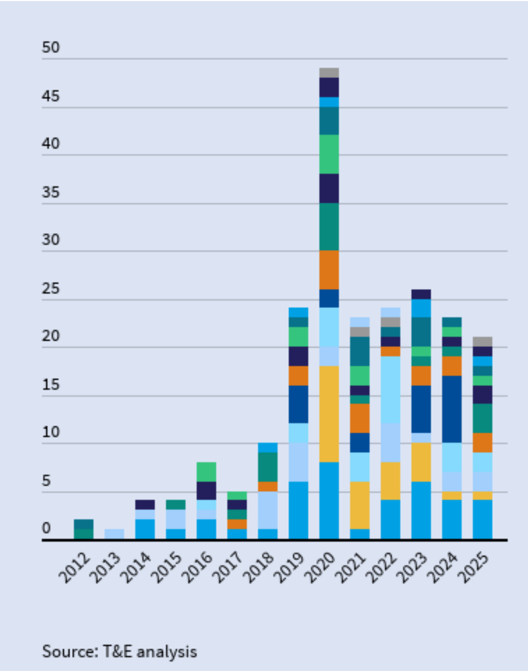

Figure 6: Number of new PHEV models coming to the market in Europe

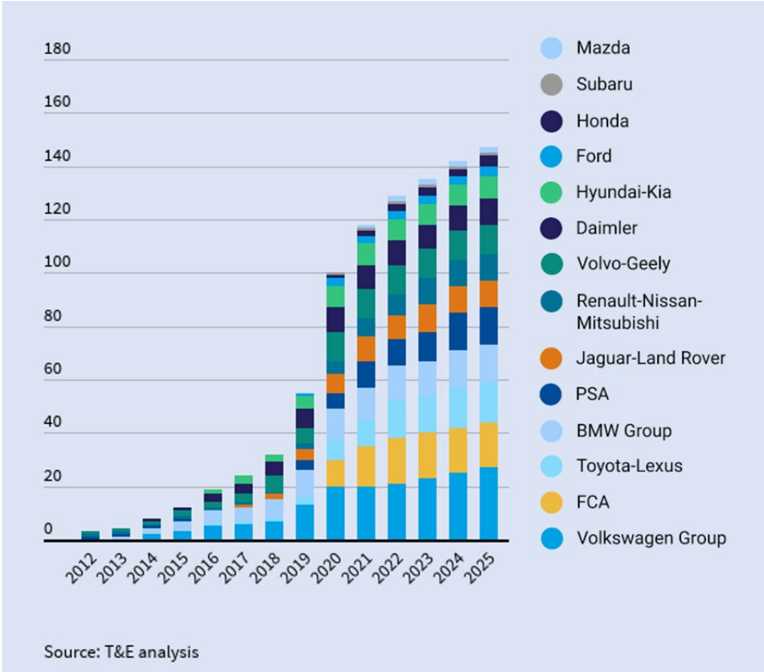

Figure 7: Number of PHEV models on the market in Europe

The total number of PHEV models expected to come to market rises sharply from 2019 to 2020 from 55 to 100 (see Figure 7). Compared to the trend for the BEV models, the number of PHEV models available grows more slowly after 2020. The top PHEV manufacturers are the Volkswagen Group with 27 models available in 2025 and the Fiat-Chrysler Group (FCA) with 17 models, followed by Toyota (15), BMW (14) and PSA (14).

Fuel Cell Electric Vehicle (FCEV) models

The increase in the number of new FCEV models coming to market is an order of magnitude lower than for other EVs. Only 14 FCEV models are expected in 2025, up from two models available today (Toyota Mirai and Hyundai Nexo). The Volkswagen Group, Toyota and Daimler are expected to have four models each on the market in 2025 (Figure 8 and 9).

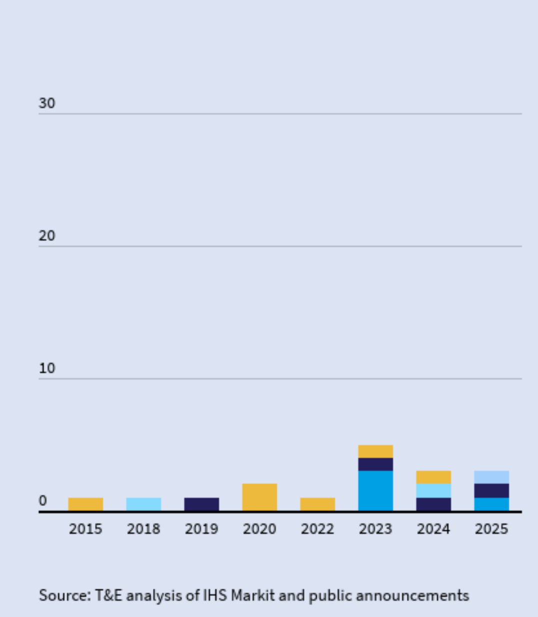

Figure 8: Number of new FCEV models coming to the market in Europe

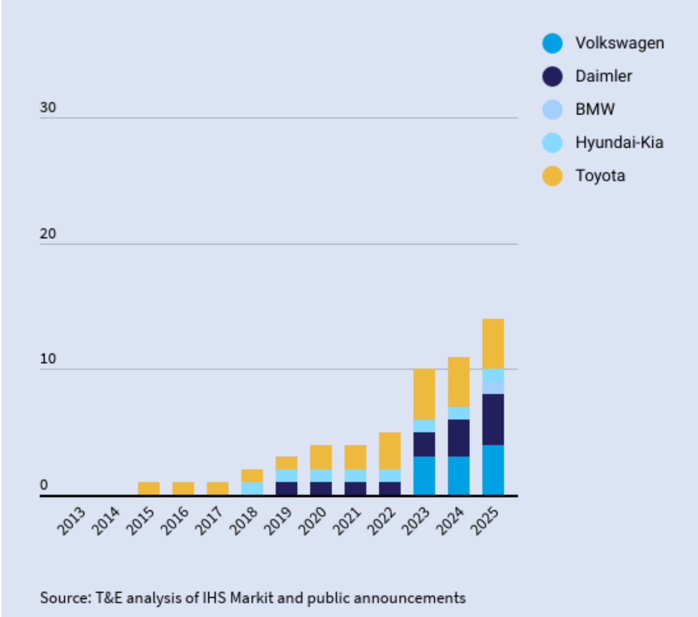

Figure 9: Number of available FCEV models on the market in Europe

Based on these findings, it can be concluded that the maturity of the FCEV technology is at least 10 years behind the BEV technology. It is too early to say whether the FCEV technology will be able to create its own space on the market after the uptake of BEVs and PHEVs. It is likely however that the number of models available would stay low in the foreseeable future and serve niche applications for vehicles with high utilisation rates and high mileage.

All Electric Vehicle models

Combined BEV, PHEV and FCEV account for all electric vehicle models manufactured and would add up to 333 models on the market in 2025 (see Figure 10). About 4% of those models would be FCEVs, with a majority, or 53%, being BEVs, up from 41% of the EV models available today.

A comparison of Figure 5 and 7 shows that even though the general trend for BEVs and PHEVs is similar, the growth rate and the number of available PHEV available seems to flatten as we approach 2025. The growth of BEV on the other hand, continues to follow a strong linear upward trend. Based on these trends, T&E predicts that the gap between the number of PHEV and BEV models available will continue to grow. Indeed, PHEV are largely seen as a transitional technology and are a result of carmakers' compliance strategy.

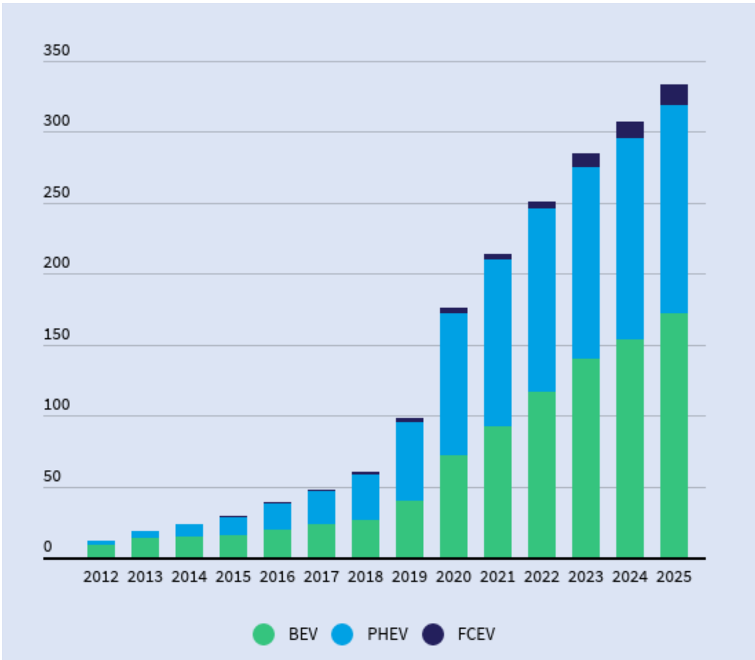

Figure 10: Total number of available EV models on the market in Europe

After 2025, as technology improves, battery costs reduce and regulations (CO_2 stanards and taxes) get more stringent, the EV market will focus more on BEVs. This confirms recent announcements from major carmakers, such as Volkswagen[ix] and Renault, which have all committed to direct electrification. Toyota is the last of the major carmakers to do so and has recently marked a strategic shift away from hybrids and fuel cell vehicles (June 2019)[9].

2.3. Shift in production volumes

2.3.1. Market evolution

As more and more EV models are produced and available on the market, the number of vehicles sold and produced in Europe will also grow. Carmakers will be selling these vehicles more actively. First, they will rely on them for compliance (see Section 3) in early 2020s, but after 2024 EVs are expected to reach market maturity as they reach price parity with conventional cars.[x] To date EU car makers are investing €145.8 billion in electric cars and batteries[10], and success of the EU transition to emobility has become a key industrial priority.

Nearly all EVs produced in the EU are expected to be sold in Europe, as EV exports are unlikely for several reasons:

- First, the European carmakers and other foreign carmakers selling in the EU will dedicate their production to the EU market to comply with CO_2 standards.
- Second, unlike conventional ICEs, EVs cannot be easily exported to countries that do not yet have the necessary charging infrastructure.
- Finally, as regards China (world's largest car market), carmakers have created joint-ventures with local carmakers to manufacture their EVs in China to be able to sell them without tariffs. Similarly, OEMS are producing close to the US market.

Although some EVs could be exported to other regions, their numbers are expected to be low for the reasons described above, and it is likely that more ICE would be produced for exports. Therefore, the share of EVs calculated here based on production figures is likely to be conservative compared to the overall vehicles sales share.

[9] Toyota will add BEV to its line-up and brings forward its target to sale 1 million ZEVs by 5-years (from 2030 to 2025). Forbes: https://www.forbes.com/sites/neilwinton/2019/06/12/toyota-concedes-defeat-on-battery-cars-but-will-hedge-with-hybrids-fuel-cells/#7067b42c3cd7

[10] As of April 2019: Volkswagen: $91 billion ($57 billion in batteries), Daimler: $42 billion ($30 billion in batteries), FCA: $10 billion, Renault: $10 billion, BMW: $6.5 billion, JLR: $2.34 billion, PSA: $0.77 billion, Volvo: $0.725 billion. Source : Reuters : https://graphics.reuters.com/AUTOS-INVESTMENT-ELECTRIC/010081ZB3HD/index.html

The number of EVs produced in Europe is expected to surge, from around three quarters of a million in 2019 to more than 4 million in 2025, see Figure 11. In market shares, this increases from 4% in 2019 up to 22% in 2025 with 13% BEVs and 9% PHEVs.

The planned production of PHEVs increases linearly from around 300,000 vehicles this year up to close to 1.8 million units in 2025. The expected production of BEV appears to grow slightly faster than PHEV, to almost 2.5 million units in 2025.

The split of planned EV production between BEVs and PHEVs slowly shifts from about half BEV and half PHEV in the early 2020s to around 60% BEVs and 40% PHEVs in 2025. We expect this trend to continue and BEV to make up an increasing share of total EV production.

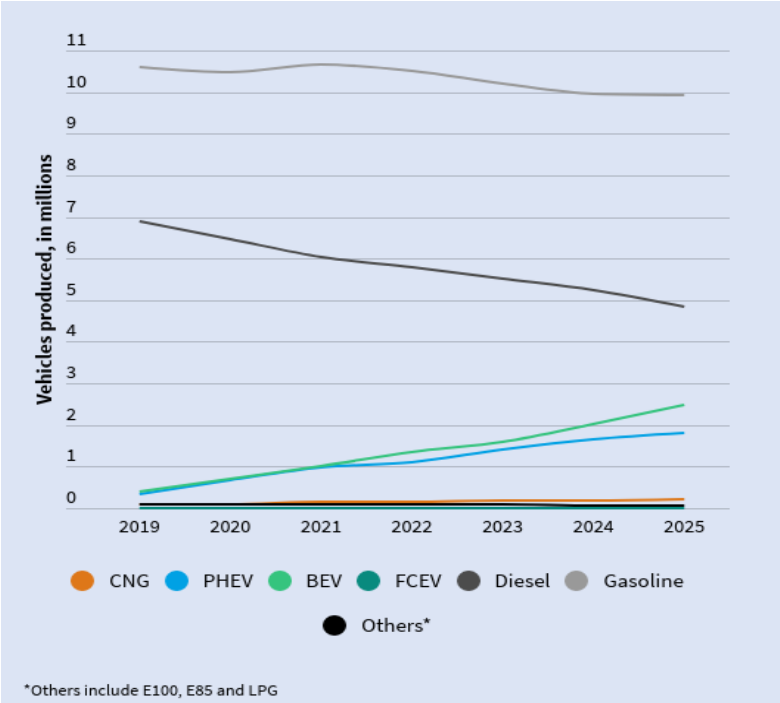

Figure 11: EU production of vehicles per type in 2025, in million units (Source: IHS Markit)

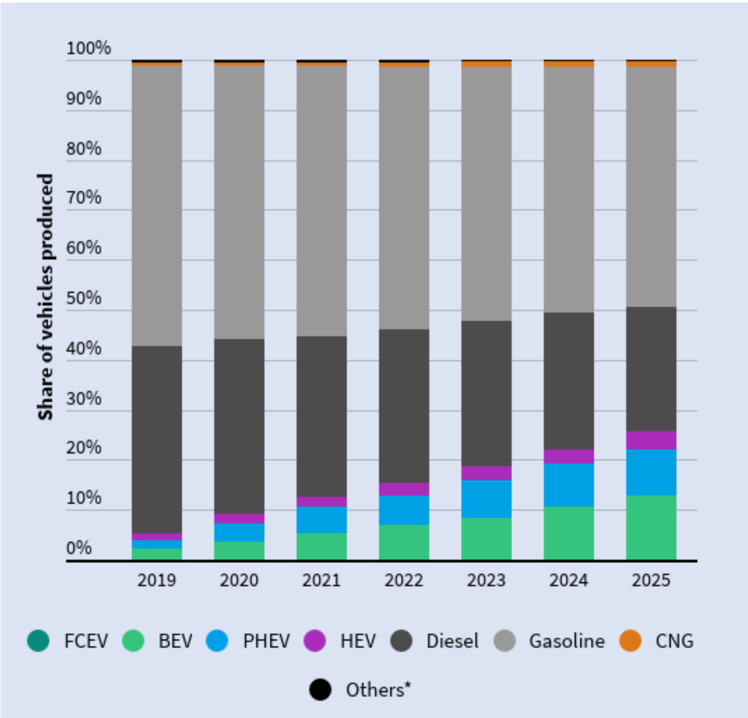

Figure 12: EU production of vehicles per type in 2025, in share of total production (Source: IHS Markit)

From Figure 12, it is clear that direct electrification is the preferred clean technology pathway carmakers are opting for. The uptake in production of CNG vehicles, FCEVs, and LPG is insignificant: CNG vehicle production reaches 200,000 units in 2025 (about 1% of total production) and FCEV production stays below 10,000 units (0.05%). The role of other alternative fuels or powertrains is nearly insignificant compared to what is expected for EVs in terms of new models (see Section 2.2) and share in total production (see next Section).

On the other hand, the share and total production volume of both gasoline and diesel cars are dropping. The decline in diesel is very pronounced, while the drop in gasoline sales is slower, or under one million units less (gasoline HEV is included here). Combined this amounts to a drop of about 2.7 million ICE vehicles produced, or a reduction of 15% compared to 2019. This drop is balanced out and absorbed by the increase in EV production which reaches similar 22% of total production in 2025.

Based on current forecast, the drop in ICE production would be offset by the increase in EV production with the additional 3.6 million EVs produced, leading to a **net increase in production of vehicles of 900,000 vehicles** in 2025 (+5% vs. 2019).

2.3.2. FCEV production

Many carmakers have recently made strategical commitments on electrification. E.g. Germany's three largest carmakers (Volkswagen, BMW and Daimler) have agreed on a common approach favouring battery electric mobility[xi], and even if they invest in a few FCEV models, they do not seem to consider the technology to be ready for the mass market in the next 10 years.

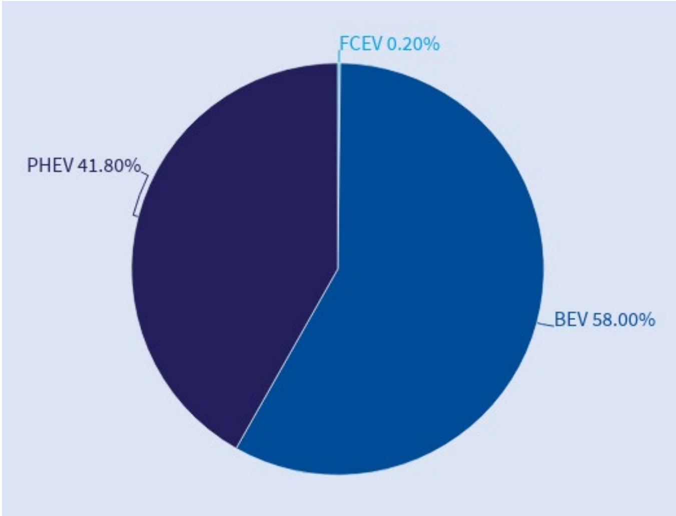

Figure 13 – Forecasted European production of EV per type in 2025 (Source: IHS Markit)

It is expected that only 9,000 FCEVs would be produced in Europe in 2025. This is 0.2% of total EV production within Europe (and less than 0.4% of all ZEVs). These vehicles are split between Volkswagen, Audi and Daimler.

Some Japanese and Korean OEMs in particular (e.g. Toyota, Honda and Hyundai) might still see a role for fuel cell hydrogen cars but according to the data obtained by T&E, they do not plan to have any manufacturing capacity for these vehicles in Europe. Thus, they would be importing these vehicles if they were to sell any.

2.3.3. CNG production

According to data acquired by T&E, vehicles running on compressed natural gas, CNG (or biomethane) will play a negligible role in the expected future production of vehicles in Europe.

About 200,000 CNG vehicles are expected to be produced in Europe in 2025, which is 1% of the total European vehicle production as shown in Figure 14. These vehicles would be produced mainly by Volkswagen Group (notably Volkswagen, Skoda and SEAT) and Fiat.

LPG vehicles (or Liquefied Petroleum Gas) decrease three-fold between the volumes produced in 2019 and those planned for 2025, or around 0.1% of the total production.

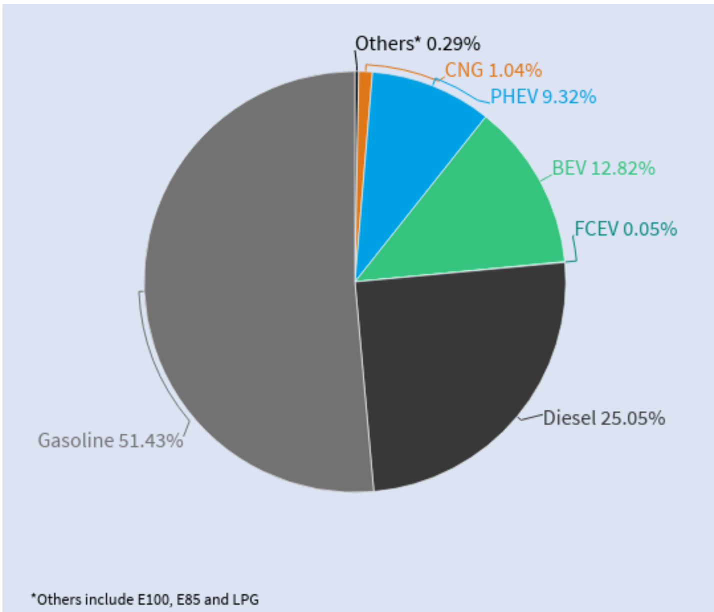

Figure 14: Forecasted European production of vehicles per type in 2025 (Source: IHS Markit)

2.3.4. Full Hybrids

Full hybrids (HEVs) are internal combustion engine vehicles that have a small battery for energy recuperation but no plug to recharge. These vehicles typically have a battery capacity from 0.7 kWh up to 4 kWh. Full hybrids are distinguished from mild hybrids[11], that are considered here as conventional ICE vehicles (typical batteries are from 0.1 kWh to 0.7 kWh).

Despite some misleading advertisement by Toyota[xii] claiming their hybrid vehicles are “self-charging”, these vehicles need to refuel with conventional petrol (or diesel) and are not zero or low emission, offering a CO2 reduction of around 24% -27%[12] compared to ICE based on official test results (NEDC).

As seen in Figure 12, the share of HEVs in the European vehicle production mix increases from around quarter of a million units in 2019 up to 650,000 in 2025 (from 1.3% to 3.4%). [13] Toyota is producing the vast majority of all HEVs in 2019 and is expected to account for over 40% of HEV EU production in 2025.

In short, FCEVs, CNG and hybrid vehicles will play a small role in the foreseeable future as carmakers are opting for direct electrification as the preferred technology pathway. This makes sense from the perspective of limited R&D budgets and the need to give signal to the supplier and supply chain industries to plan capital intensive investments, such as batteries.

2.4. Individual OEM production plans

The two previous sections have shown that carmakers appear to be committing to producing EVs in Europe. In this section, we will investigate the difference between some carmakers’ plans.

The Volkswagen Group is the undisputed leader in the expected production of BEV with close to 1 million BEVs produced in 2025[14], or more than a third of all the BEVs expected to be produced in Europe. The sub-brands of Audi, SEAT, Skoda and Volkswagen will all be producing BEVs using five new MEB platforms[15] developed by the group (4 in Germany and one in Czech Republic). PSA which will produce similar electric vehicle models under different brands (Peugeot, Citroen and Opel) is also expected to produce a high number of electric cars. Daimler (Mercedes and Mini) and Renault-Nissan also make up a significant share in the total BEV production of 11% and 10% respectively.

For PHEVs, the general trend is similar, although the Volkswagen Group is expected to produce much less PHEVs than BEVs and is in second place for PHEV production in 2025 with about 300,000 units. The first is PSA which is expected to be the largest PHEV manufacturer (about 350,000 units in 2025), while FCA sits in third position with 250,000 units.

For electric vehicles overall, the Volkswagen Group is in the first place with about 1.2 million EVs, followed by PSA with 700,000 units and both Daimler and Renault-Nissan with close to half a million units in 2025. Together, they make up two thirds of the planned EV EU production in 2025.

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[11] Mild hybrids are cars with a starter generator in place of the starter motor. They enable a car to idle for longer in stop-start traffic, but they can't provide electric-only drive.

[12] Based on 2017 EEA registration data comparing average CO2 emissions from ICEs (diesel and petrol) with the average CO2 emissions from Toyota’s full hybrids sold that year. When including Lexus alongside Toyota (which sells premium vehicles), the CO2 reduction from full hybrids is about 24%.

[13] Range extended electric vehicles are classified as PHEVs and hybrid CNG vehicles are classified as HEVs.

[14] Audi: about 300,000 BEVs; Volkswagen: 300,000; Porsche: 160,000; SEAT: 75,000 and Skoda: 50,000

[15] MEB standards for ‘Modularer E-Antriebs-Baukasten’ in German which translates into Modular E-drive construction kit.

While the forecast data acquired by T&E shows slight variations in carmakers' strategies, all *European* carmakers are expected to have very similar strategies and focus on EV to replace ICE production (see Figure 15). The total forecasted share of EVs varies between carmakers but stays between 19% and 23% for most of them (Volkswagen, PSA, Renault-Nissan, BMW, Ford, and Jaguar Land Rover). Daimler and FCA have a higher share with 26% and 27% respectively: Daimler's sub-brand Smart would be fully battery electric as of 2021 (Mercedes alone would produce 22% EV), and FCA focuses more on selling PHEV and thus will have to sell more of them to achieve the CO2 emission reductions compared to other carmakers. Finally, Volvo - which produces lower volumes than other European carmakers - is expected to shift more rapidly towards the production of electric models XC40 and XC60 and away from ICE. This will have a significant impact on Volvo's total mix as both models make up close to 60% of its car production.

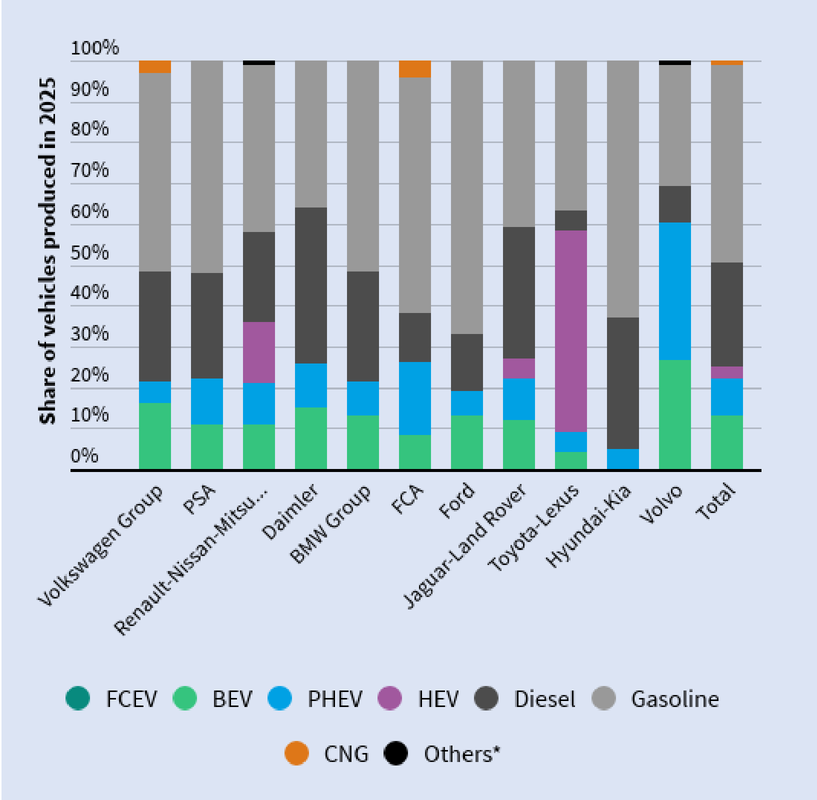

Figure 15: Split in planned European production of vehicles per OEM in 2025

Almost all European carmakers have an expected share of BEVs in the total EV production between 50% and 60%. Volkswagen Group stands out with a much higher share of BEVs at ¾ of the expected EVs produced. Both FCA and Volvo are favouring PHEVs with only 32% BEVs in the EV production mix for FCA and 45% for Volvo.

Finally, both Asian carmakers (Toyota and Hyundai-Kia) appear as outliers because their production mix in the EU is likely not to be representative of their sales mix as they also rely on imports. The number of imported and sold EVs from foreign carmakers is likely to vary and to be adjusted to what is required to comply with the CO2 standards. Nonetheless, Toyota is the only carmaker to focus on hybrids - it makes up around 50% of the carmaker's production volumes in Europe.[16]

2.5. Expected production per vehicle segment

In the next 5 years, the number of vehicles produced in each segment stays relatively constant with around 0.9 million vehicles in segment A, around 4.3 million in segment B, around 8.0 million in segment C, around 3.2 million in segment D and 2.4 million in segment E.

Each vehicle type has its specificities with regards to preferred segment. Both PHEVs and diesel ICE cars are virtually inexistent in small car segments (A & B), and this is not expected to change much in the next years,

[16] It should be noted that this forecast was carried out before Toyota has committed to binging forward its electrification plan and a more recent forecast would likely show a higher share of EV.

see Figure 16 below. This is different for gasoline ICE cars that focus much more on small and medium cars and are less present in larger car segments (though there is a risk this might change with the current decline in diesel sales). BEV production, however, appears to be evenly split between vehicle segments.

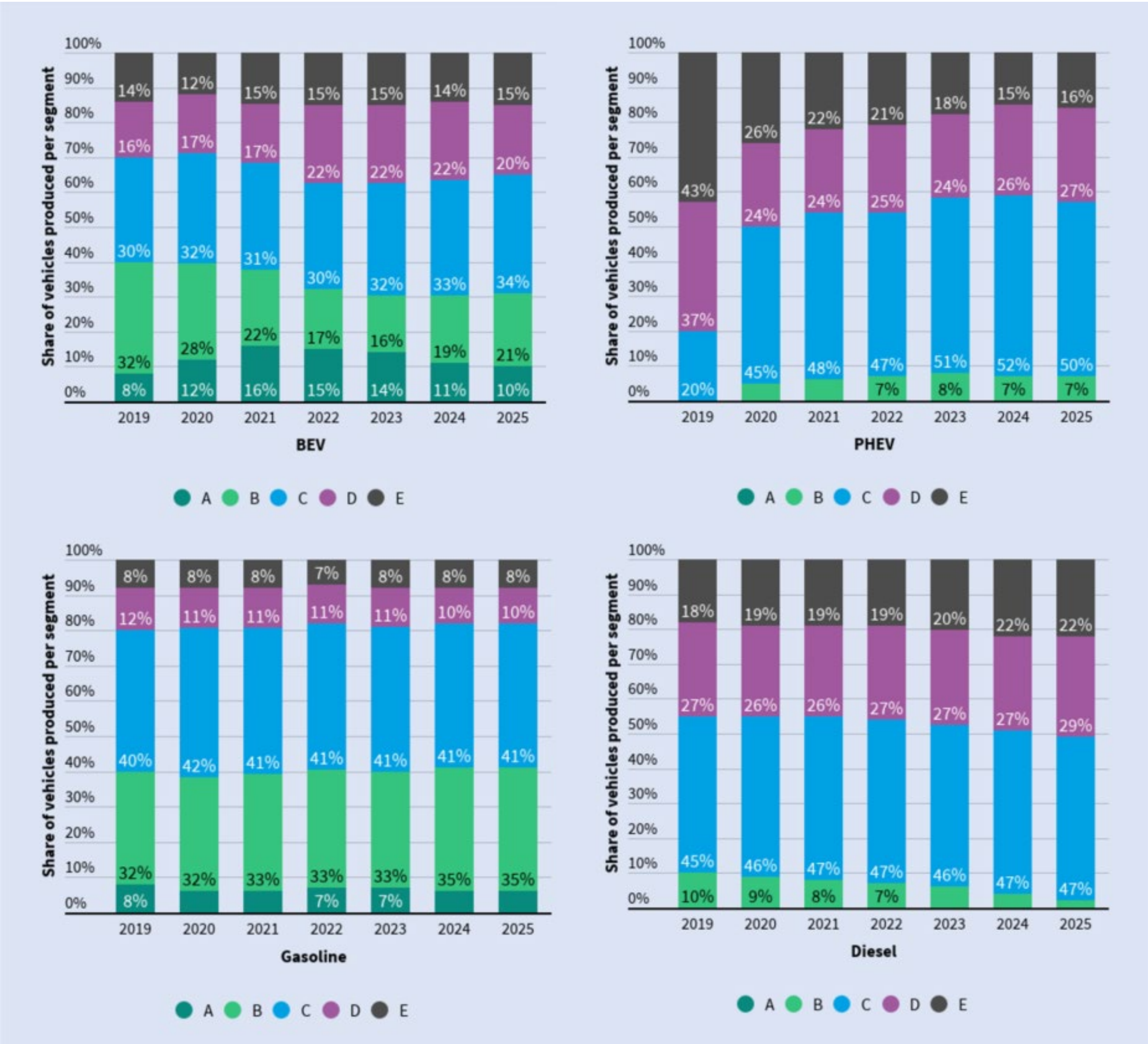

Figure 16: Production of vehicles per segment in the EU (Source: IHS Markit)

The number of small (A & B), medium (C) and large (D & E) BEVs produced in Europe is fairly equal and all increase proportionately between 2019 and 2025. On the other hand, PHEVs are much underrepresented in smaller (A & B) segments and overrepresented in larger ones (segment D and E), often premium vehicles. This is explained by the fact that a plug-in hybrid car can hardly be a small one as it needs to fit both powertrain systems: the combustion engine and the electric drivetrain with battery. Finally, gasoline vehicles are expected to remain more present in smaller segments that often drive less kilometers while diesel vehicles on the contrary are typically bigger cars and drive further.

In short – provided manufacturers realise their current production plans as expected – **BEVs will be available in equal proportion in small, medium and large vehicle segments and would therefore be able to fulfill various needs and requirements from different consumer groups and use cases**. Smaller vehicles will be best suited in urban areas with air pollution restrictions and limited available space. Larger

BEVs (alongside PHEVs) will be available for drivers that require high annual mileage thanks to more dense batteries combined with a network of fast charging allowing to replenish the batteries in about 15 minutes.

2.6. Location of EV production

Production of EVs is gradually replacing that of ICEs and this affects all major vehicle manufacturing countries in Europe. According to data acquired by T&E, together Germany, France, Spain, Italy and the UK[17] will produce about 85% of the EV in 2025 (out of the total EU production), whereas they will produce about two thirds of the conventional cars. These countries are the five biggest vehicle markets today and are expected to also be the largest EV markets in Europe in the future.

However, the overall number of vehicles produced only tells part of the story given the difference in the size of countries and their workforce across Europe. To understand how production will evolve over the years and how this is prone to affect the country's economy and employment we should also look at the evolution of the number of vehicles produced per capita, as shown in Figure 17 below[18].

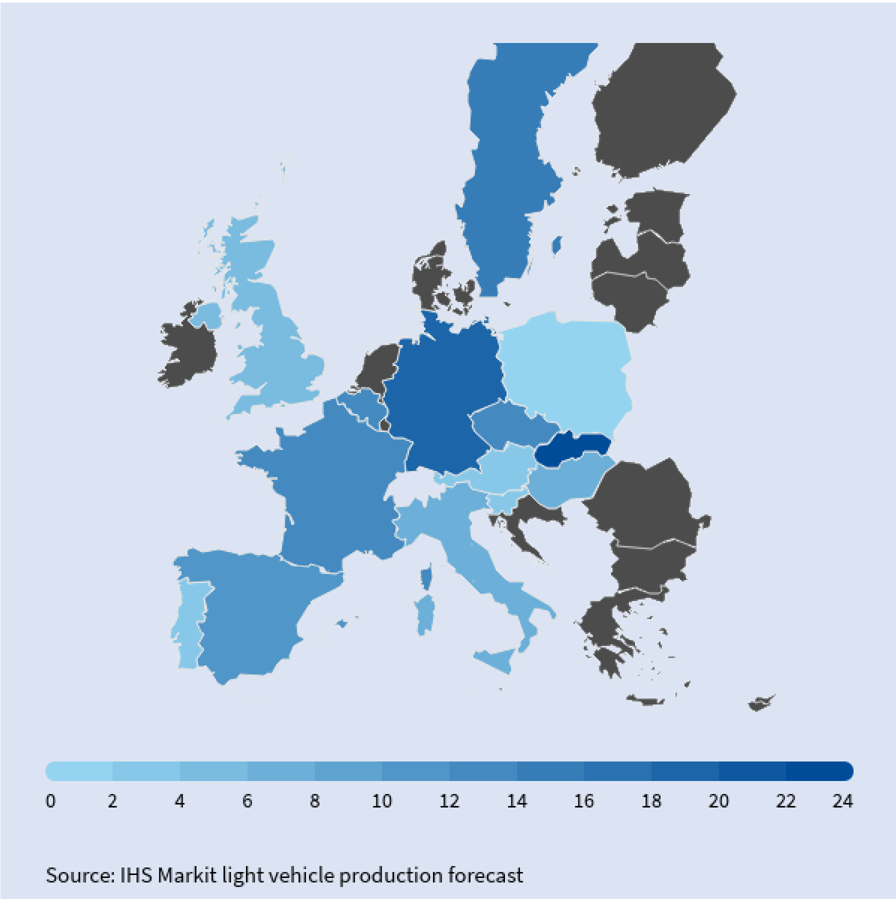

Figure 17: EU EV production per 1,000 inhabitants in 2025

As can be seen, Slovakia has by far the highest forecasted production of electric vehicles in Europe, or 25 EVs produced per thousand inhabitants in 2025. Germany and Sweden follow with 19 and 14 EVs produced per thousand inhabitants respectively, while Belgium, the Czech Republic and France all have around 12

[17] The UK figures cannot be predicted with certainty since the outcome of Brexit will determine whether or not the planned production will take place (unlikely in the no-deal scenario)

[18] Based on Eurostat population statistics, assumed constant over 2017-2025.

EVs produced per thousand inhabitants. Hungary, Italy, Slovenia, Austria and Portugal are expected to have between 2 and 6 EVs produced for per thousand inhabitants.

Figure 18 below shows which carmakers are expected to produce EVs in which country in 2025.[19] While locations might be subject to change given the timeframe, it is nonetheless interesting to analyse what they are currently forecasted to be. Four countries - Germany, France, Spain and the UK[20] - are expected to have at least four different carmakers producing significant volumes of EVs in 2025 (more than 10,000 units). Two countries (the Czech Republic and Slovakia) have three different carmakers planning to produce EVs at large scale, which is significant for their economies. Planned production of EVs within each OEM is also expected to be spread widely among countries.

In terms of OEMs, the Volkswagen Group's EV production is the most widespread as it is expected to be found in seven different EU countries in 2025. The PSA Group is expected to produce EVs in six different EU countries, Daimler in four countries and both Renault-Nissan and Jaguar Land Rover in three countries.

[19] Only carmakers with expected production of more than 10,000 units were represented. Together, these lower volume production only account for 2% of the total EV production, therefore this exclusion is reasonable.
[20] The UK is the biggest uncertainty in the current analysis due to Brexit and lack of data on how this will impact car manufacturing

Figure 18: Member states' electric car production in the EU in 2025

For more details on member states' production plan, please visit an **interactive map** online.

Figures 19 and 20 below show the evolution of EV production between 2019 and 2025 per member state. The grey (ICE) and blue (EV) bars depict the variations (either growth or reduction) in vehicle production for conventional and electric cars. Combined the changes in the production of each vehicle type make up the overall evolution of the vehicle production market, which is captured with the green dots (right axis). While Figure 19 gives numbers per capita which are more representative of the importance of vehicle manufacturing in that country, Figure 20 shows absolute figures which are useful to understand the total contribution to the EU's market and economy.

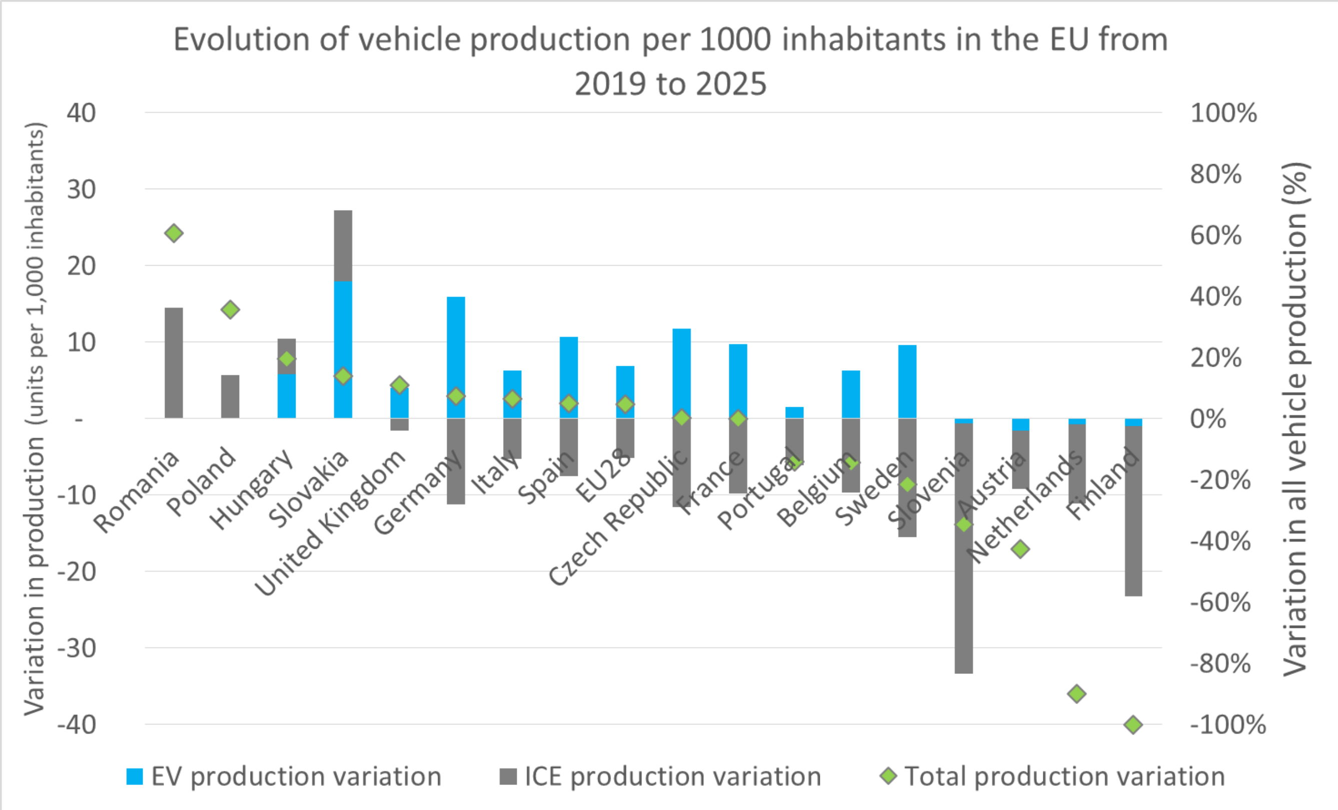

Figure 19: Evolution of vehicle production per 1,000 inhabitants from 2019 to 2025 (Source: IHS Markit)

We note that although large parts of production of EVs will be located in the main EV demand markets, Central and Eastern European countries will nonetheless have strong production of various vehicle powertrains in the coming years. Romania and Poland will see strong increase in the production of ICE vehicles (61% and 35% respectively) between 2019 and 2025, while Hungary and Slovakia both expect the increase in production of ICE and EVs leading to a combined growth of 20% and 14% respectively. The UK, Germany, Italy and Spain also show a net increase in vehicle production numbers (ranging between 5% and 11%), with EV production more than compensating for the decrease in ICE production. In France and the Czech Republic EV production is expected to balance out the losses in ICE production.

The countries that are expected to suffer from net losses in vehicles production are Portugal, Belgium, Sweden, Slovenia, Austria, the Netherlands and Finland since the reduction in ICE production is not balanced by the uptake of EV production (based on the production plans announced to date). Only in Belgium and Sweden does the production of EVs increases but is not sufficient to keep the total production from decreasing. In Finland there is no expected EV production in 2025.

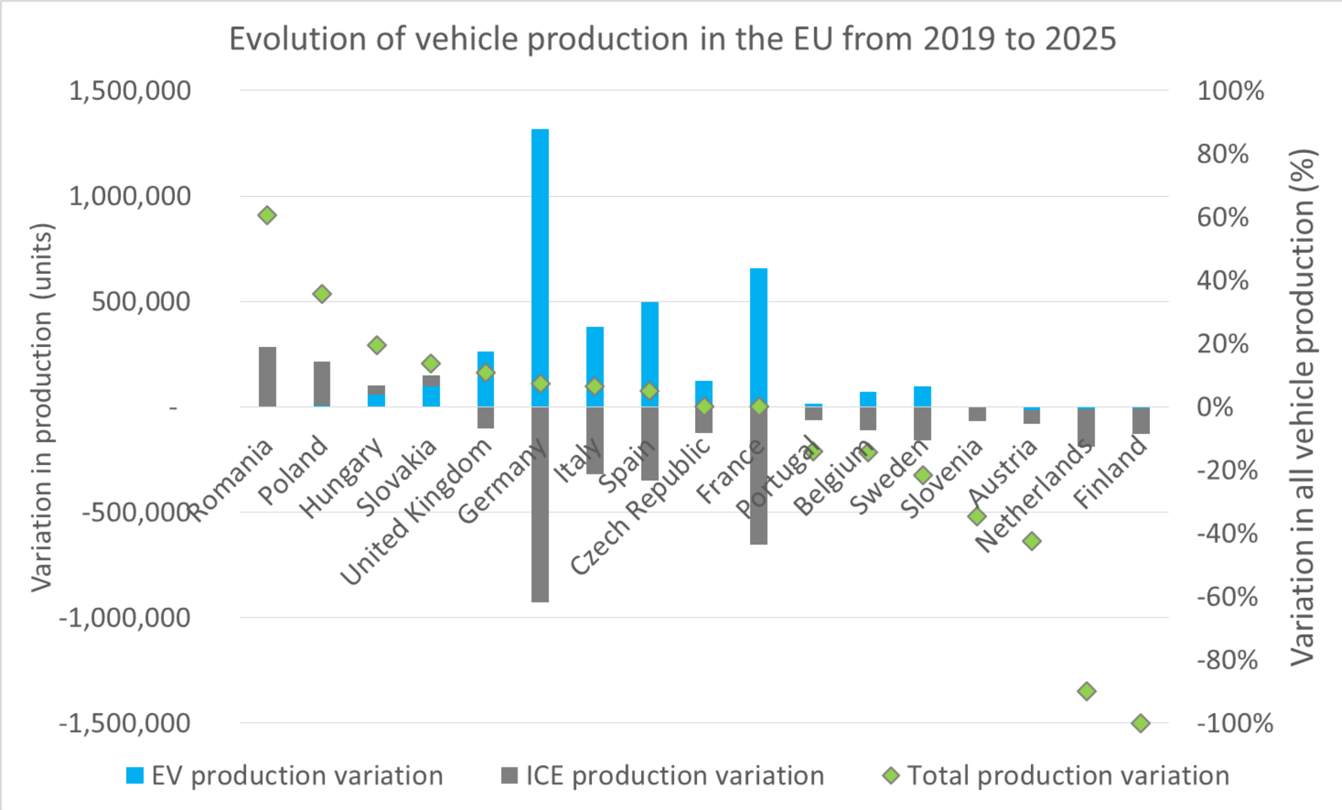

Figure 20: Evolution of vehicle production from 2019 to 2025 (Source: IHS Markit)

EU-wide, the increasing EV production ensures the overall growth of the EU vehicles production market with a 5% growth rate in 2025 compared to 2019, which translates into a net increase of 900,000 units (not represented here). As the sales of ICEs will continue deceasing as carmakers need to meet more and more stringent CO2 targets, countries (and manufacturers) who fail to plan timely new EV production will be the most impacted from the shift away from fossil-fueled vehicles.

The social or job aspects of the transition from manufacturing ICE vehicles to EVs are not assessed in this report but will be considered by T&E at a later stage.

3. Battery production in the EU

To manufacture millions of EVs, European carmakers (and other carmakers producing EVs in the EU) will need millions of kWh's of traction batteries – the lithium-ion battery (LIB) technology used today. Carmakers are currently securing their supply of batteries from various battery manufacturers and concerns are being raised as to whether the supply will be sufficient. In this section we analyse whether the planned LIB production capacity within the EU will be sufficient to cover the expected uptake of EV production in Europe as calculated in Section 2.

3.1. Lithium-ion battery demand for EU EV production

Based on the IHS dataset, T&E has calculated that the total lithium-ion battery demand from EV (and hybrid) production volumes within the EU is expected to reach 112 GWh in 2023 and 176 GWh in 2025 according to the forecasted battery sizes provided by carmakers (explained below).

As shown in Figure 21, most of this demand will come from BEVs with 91 GWh in 2023 and 148 GWh in 2025 (or 82% to 84% of the total battery demand). PHEVs have much smaller batteries and thus only add 17 GWh to the total demand in 2023 and 23 GWh in 2025 (or 15% to 13% respectively). The remaining part of the demand comes from the expected production of mild and full hybrids, which add about 3 GWh in 2023 and 6 GWh in 2025 (or around 3% of total demand).

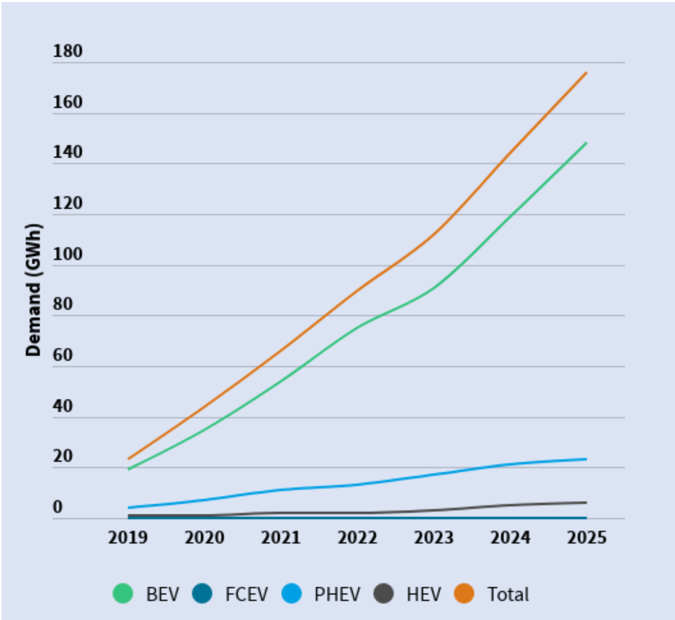

Figure 21: Lithium-ion battery demand from forecasted EV production in the EU (Source: IHS Markit)

Average battery size

The average battery size of the vehicles (BEV, PHEV and full HEV) has a direct impact on the LIB battery demand needed. According to the IHS data acquired by T&E, the average battery capacity of electrified vehicles increases between 2019 and 2025 (see Figure 22 below). [21] This trend is a result of consumer demand for longer ranges, technological improvements in batteries - mainly the increase in energy density of batteries (which allows to carry more battery capacity with the same mass) - and decreasing battery costs.

[21] The average is weighted based on expected production volumes i.e. total expected demand (in GWh) divided by total expected number of vehicles.

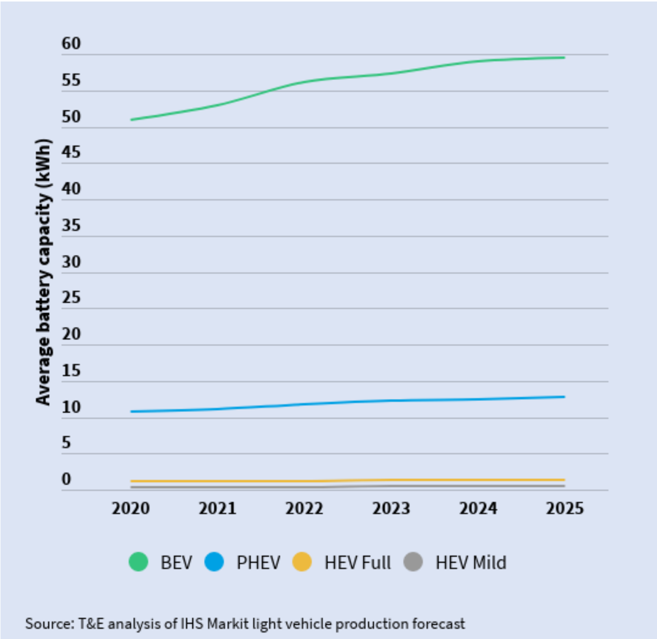

Figure 22: Lithium-ion battery demand from forecasted EV production in the EU

According to current forecasts, the average battery capacity of BEVs increases from about 50 kWh today up to 60 kWh in 2025 (+23%), the range of these vehicles thus also increases on average by more than 50 km. While the current LIB technology is likely to improve in the next 5 years (notably by newer chemistries requiring less cobalt and more nickel), a major break-through such as moving to solid state od Lithium-air batteries is not expected to penetrate the wider market until 2025.

For PHEV, the bigger the battery capacity, the bigger the electric range of the vehicle. Based on the current predictions the average PHEV battery capacity increases from 11.4 kWh to 12.7 kWh (+12%) (this might further increase if regulators push for longer-range PHEVs to decrease their CO2 emissions).

Full hybrids have a much smaller battery capacity as it is limited by the amount of energy the vehicle can recuperate when it decelerates. [22] The battery capacity increases from 1.1 kWh to 1.3 kWh between 2019 and 2025. Finally, the average battery capacity of mild hybrids increases from 0.4 kWh to 0.6 kWh, but this has limited effect.

3.2. EU planned production capacity of Li-ion batteries

The battery production is a strategic imperative for clean energy transition and the competitiveness of the European automotive sector according to the European Commission[xiii]. The European Battery Alliance[23], launched as part of this 'new industrial policy strategy' brings together actors from the whole battery value chain with the objective to build a strong and competitive European battery industry. This initiative was launched in October 2017 and tangible developments, such as creation of industrial consortia and large-scale investments are now emerging. This has already materialised into the plans for at least a dozen LIB cell manufacturing factories in Europe (see Figure 23 below), where the largest battery value lies. The European Battery Alliance has set a target of 200 GWh of annual battery production capacity to be available in the EU as of 2025.[xiv]

Based on the existing factory announcements[24], Benchmark Mineral Intelligence[xv] has estimated the future European battery manufacturing capacity to be at least 131 GWh in 2023 and 274 GWh in 2028. This is bound to increase further as some additional battery factories are confirmed (see further below list of five planned but not confirmed factories). To put this into perspective, the global capacity is expected to be 964.8 GWh

[22] A portion of the engine's power can also serve to charge the batteries but braking is the main source of energy recuperation.
[23] European Commission, European Battery Alliance *"The immediate objective is to create a competitive manufacturing value chain in Europe with sustainable battery cells at its core. To prevent a technological dependence on our competitors and capitalise on the job, growth and investment potential of batteries, Europe has to move fast in the global race. According to some forecasts, Europe could capture a battery market of up to €250 billion a year from 2025 onwards. Covering the EU demand alone requires at least 10 to 20 'gigafactories' (large-scale battery cell production facilities)."* European Commission: https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en
[24] Valid up until summer 2019, and subject to change or adjustment, especially on the capacity announced

in 2023 and 1,594 GWh in 2028. The share of European battery manufacturing capacity would therefore rise from 6.6% today, to 13.6% in 2023 and 17.2% in 2028.

Planned Li-ion battery factories in the EU

The European manufacturing capacity of up to 131 GWh in 2023 is estimated based on the announcements of the following battery manufacturing facilities[25] :

1. Northvolt in Skellefteå, **Sweden**: an initial line of 16 GWh (2021), increasing to 32 GWh in 2023
2. Northvolt in Salzgitter, **Germany**: cooperation with Volkswagen to start in March 2020 with 12 GWh, potential to increase to 30 GWh (not included in the estimated capacity) [xvi]
3. CATL in Erfurt, **Germany**: 14 GWh as of 2021, rising to 60 GWh from 2026 (and likely boosted further to 100 GWh)[xvii]
4. German partnership (BMZ & others), **Germany**: formerly known as TerraE consortium, aiming at two factories and capacity of 34 GWh by 2028
5. LG Chem in Wroclaw, **Poland**[26]: from 6 GWh today, to 70 GWh within 2-3 years[xviii]
6. Samsung SDI in Göd, **Hungary**: 2-3 GWh from 2016, under expansion to reach 15 GWh in 2020[xix]
7. Samsung SDI in Premstaetten, **Austria**: detail not know and not included in planned capacity[xx]
8. SK Innovation (SKI) 1 in Komárom, **Hungary**: production to start in early 2020, up to 7.5 GWh in 2022[xxi]
9. SK Innovation (SKI) 2 in Komárom, **Hungary**: completed by 2021, production capacity unknown[xxii]
10. AESC in Sunderland, the **UK**[27]: 2 GWh
11. Farasis, **Germany**: 6 GWh from 2022 up to 10 GWh[xxiii]

[25] Also called gigafactories as the output annual capacity is above 1 gigawatt-hour (GWh)

[26] Plus cathode manufacturing by Umicore and Johnson Matthey

[27] Chinese investment firm GSR Capital bought Nissan Motor Co's electric vehicle battery business - Automotive Energy Supply Corp (AESC) - including battery plants in Japan, the U.S. state of Tennessee and England.

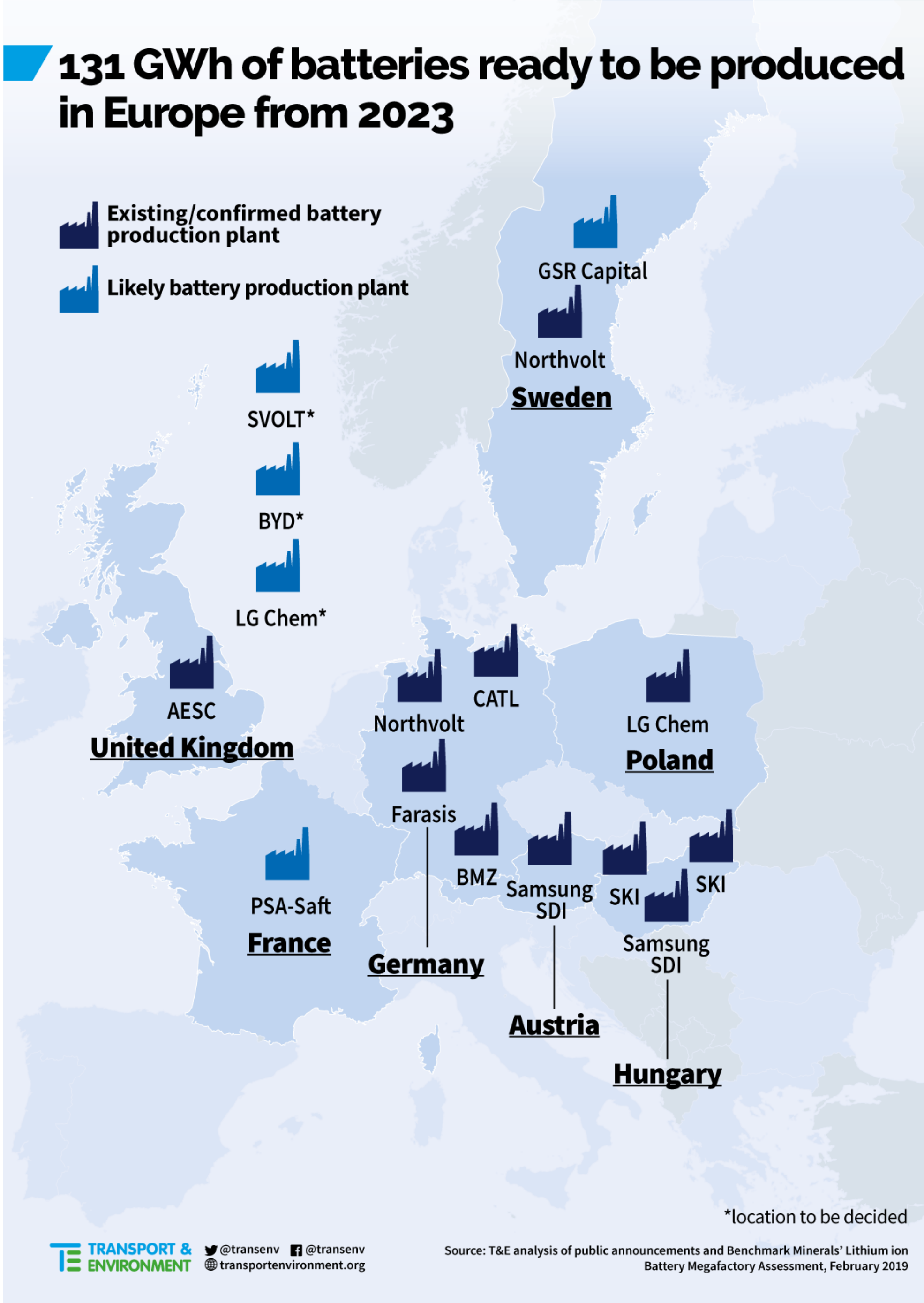

Figure 23: Lithium-ion battery manufacturing in the EU (Source: Benchmark Minerals' Lithium ion Battery Megafactory Assessment, February 2019)

Five more battery production plans are likely but have not been officially confirmed at the time of writing (thus not included in the planned production capacity estimates):

- SVOLT, Chinese Great Wall, location TBA, Europe with 20 GWh from 2022[xxiv]
- GSR Capital in Trollhättan, **Sweden**: not confirmed yet, but between 400,000 and 500,000 battery packs per year if goes through. Production at National Electric Vehicle Sweden (NEVS) facility[xxv].
- PSA-Saft consortium, in **France**: project under review by the EU Commission
- LG Chem, location TBA, Europe (second factory)
- BYD, location TBA, Europe[xxvi]

Planned EU battery supply vs EV demand

It is important to note that there will be other demands for li-ion batteries. For instance, similar lithium battery technology will be required for the growing demand from stationary storage applications to balance renewable generation or for distribution support at recharging sites or hubs at peak times (to avoid network reinforcements). However, as estimated by Bloomberg NEF, demand for lithium-ion batteries for stationary storage plays a minor role in comparison to transport needs, or less than 10% of the total global li-ion battery demand[xxvii]. Additionally, second life EV batteries will be used for stationary storage after their first life in an EV[28], and will reduce the amount of new batteries required in the future. A recent Element Energy report[xxviii] commissioned by T&E and industry partners shows that 2.25 GWh of 2nd life battery capacity will be available in Europe by 2030. Overall, it is expected that no more than 10% of the total new li-ion battery capacity in the EU will go to stationary storage applications (or 13 GWh).

Heavy duty vehicles will also electrify rapidly in the coming years (this is already the case for buses[xxix]), but T&E does not expect the demand for batteries from trucks and buses to be above 2 GWh each[29]. The majority of the EU battery cell supply is therefore expected to be available for electric cars. This can be further backed by the fact that large OEMs, notably BMW and Volkswagen, are among the main investors in the battery consortia such as Northvolt and CATL. High performing battery cells tend to be allocated first to high demanding (and valuable) applications such as vehicles, rather than less demanding applications such as grid services where the energy density of the battery is not a key characteristic.[xxx]

Together, the various applications for li-ion batteries in Europe are estimated to require slightly less than the 131 GWh that are currently expected to be produced within the EU, with the following rough break-out:

- Light-duty EV production (112 GWh)
- Stationary storage applications (13 GWh)
- Electric heavy duty vehicles (trucks and buses - 2 GWh each)

The applications account together for a total of 129 GWh, which means the supply and demand market for Li-ion batteries in Europe can be balanced if battery projects come online on schedule. The supply and demand trends are likely to continue to increase in line: the scale of production of batteries and the scale in EV production plans in the EU are of course interdependent with suppliers adjusting to the demand from manufacturers, as is the case with conventional technologies today.

There is expected to be no shortage of Li-Ion battery manufacturing capacity in the EU to accompany the European up-take of e-mobility as of 2023. However, until them carmakers will have to secure battery cell imports from outside Europe, notably Asia for the next few years.

[28] Typically a battery that has less than 80% state-of-health is considered at end of life and either recycled or has a second life either in the same application (re-use) or in a different application (re-purpose), usually grid applications.

[29] Assumptions: Average 300 kWh battery for trucks and buses, about 5,000 new e-buses produced in 2023 (close to 50% of the urban bus market) and 7,000 new electric trucks produced in 2023 (about 2% of the truck market).

3.3. Jobs in EU battery manufacturing

Production of Li-ion battery cells is a key industrial opportunity to prevent Europe from relying on foreign battery cell manufacturing which would negatively affect the competitiveness of European vehicle producers and expose EU industry to global supply shocks and fluctuations. Producing batteries within the Union also guarantees that more value is retained from the overall emobility value chain, and thus secures creation of new jobs.

According to the analysis by the Commission's Joint Research Center (JRC) [xxxi], the estimated number of direct jobs created in battery cell manufacturing is on average 140 jobs per GWh produced per year (ranges between 90 and 180). This analysis is based on estimates from 7 different battery production facilities (and takes account of high automation rates). With 131 GWh produced annually in 2023 and 274 GWh in 2030, this means there would be around 18,000 new jobs in battery cell manufacturing in 2023 (between 12,000 and 24,000) and 38,400 in 2028 (between 25,000 and 49,000).

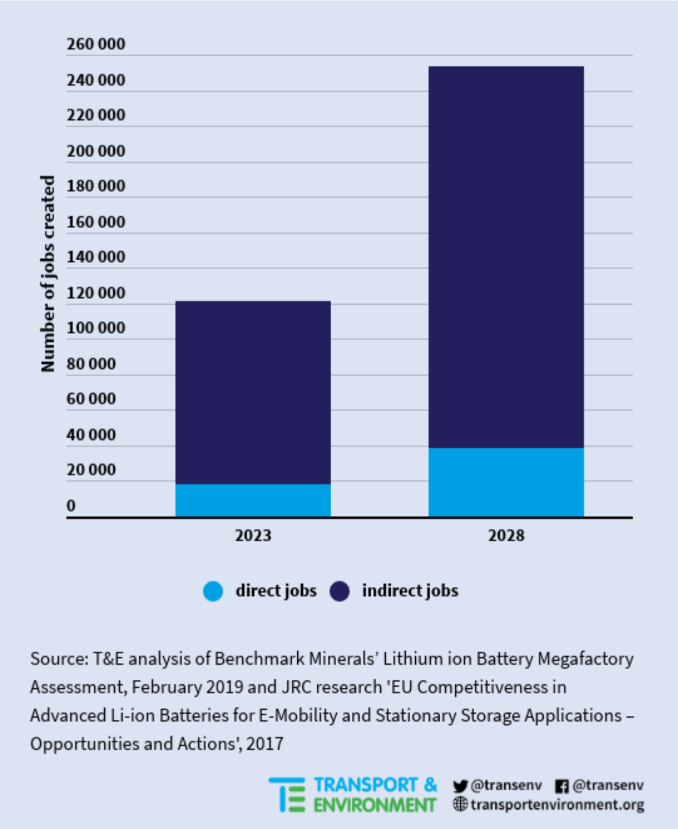

Figure 24: Job creation in the EU from lithium-ion battery manufacturing

On top of these high quality and future proof jobs from direct manufacturing, a significant number of indirect jobs are also created. According to Northvolt, their 32 GWh factory would create more than 20,000 indirect jobs. [xxxii] These jobs are expected to be created in the immediate vicinity of the cell producing plant and include suppliers, subcontractors, logistics, mechanical engineering, construction and automation companies.

Similarly, the JRC estimates the multiplication factor between the total number of jobs created along the complete value chain and the direct ones created in cell manufacturing to be in the range of 3.7 to 7.5. At European level, indirect jobs created from battery cell manufacturing would be between 68,000 and 138,000 (central estimate: 103,000) in 2023, and between 142,000 and 288,000 (central estimate: 215,000) in 2028.

We estimate that battery cell manufacturing has the potential to create about 120,000 future proof jobs in the EU from 2023, and 250,000 jobs from 2028.

According to the same JRC research, the specific investment costs for new li-ion battery cell manufacturing is currently around $150/kWh (134€/kWh) and will further decrease as manufacturing capacity scales up. Therefore, an investment totaling around €17 billion in 2023 and €37 billion in 2028 can be estimated to be necessary to ramp up the European battery cell production. This investment is also likely to bring new jobs in the ramp up of the factories, however, these jobs are hard to estimate and might not all be permanent.

Job creation in battery cell manufacturing is only part of the story and must be considered in a wide context of transitioning the vehicles production value chain from ICE to EVs. The social aspects of the transition are not assessed in this report but will be analysed by T&E at a later stage, in particular the overall impact on jobs. However, it should be noted that such a transition requires targeted political and economic support, in particular to ensure timely (re)training and skills programmes for the workforce.

4. EVs needed in 2025 & 2030 for CO2 compliance

As carmakers will need to comply with the EU CO2 emission reduction targets of -15% in 2025 and -37.5% in 2030, their vehicle offer will be very different in 6 years' time. In this section we analyse the expected EV demand from the 2025/2030 CO2 emission standards and model different scenarios for EV uptake. We calculate the potential share of EVs necessary in 2025 and 2030 to reach the required emissions reductions. To perform this analysis, a number of assumptions are required, including:

- Share of EVs in 2021 (the starting point for 2025/30 standards)
- Split in EV sales between BEV and PHEV in 2021, 2025 and 2030
- Average CO2 emissions of PHEVs in 2021, 2025 and 2030
- Average gap between NEDC CO2 emissions vs. WLTP CO2 emissions to correctly estimate the 2021 starting point
- Average improvement of the ICEs vehicles from 2021 to 2025, and from 2025 to 2030.

Carmakers are free to choose their compliance strategies, which means they could select different pathways for the mix of their new car sales and overall product portfolio. Five possible scenarios are modelled in this report, each representing a compliance strategy that some carmakers are likely to adopt. For more detail on the assumptions used in the different scenarios please refer to the Annex.

The five different scenarios that carmakers are likely to follow are:

- **Base scenario**: central scenario based on the central assumptions for each of the points mentioned above. This scenario is also used for the market as a whole.
- **High ICE improvement scenario**: carmakers EU-wide focus on improving the average fuel efficiency of their ICE cars fleet. This includes selling more (mild or full) hybrids and improving the average efficiency of the ICE vehicles.
- **Low ICE improvement scenario**: carmakers choose not to invest in the incremental efficiency gains of ICE engine and therefore the average CO2 emissions of ICE cars decreases at a much lower rate. In this scenario virtually all improvement comes from the increasing sales of mild hybrids. (High shares of both petrols and SUVs can be said to be partially represented in this scenario)
- **BEV scenario**: most carmakers focus on selling BEVs to comply with the CO2 emission standards. As a consequence, average emissions from PHEVs do not improve.
- **PHEV scenario**: more carmakers focus equally on PHEVs and BEVs (50/50 split) and make good progress on the reduction of the average emissions from PHEVs.

EV shares in different scenarios

In 2025, T&E modeling performed for this report shows that a carmaker in the Base scenario would have to sell at least 15% of EVs in 2025 (9% BEVs and 6% PHEVs), see Figure 25 below. Depending on the carmakers' ICE improvement strategy, this could vary between 12.5% and 17.9%. Where a carmaker makes good improvement on the average efficiency of the ICE vehicles, 12.5% of EVs would be sufficient to comply, while in the opposite situation where a carmaker makes low improvement on the efficiency of ICE - around 5% more EVs would be required, or 17.9%.

It should be noted that the assumption on ICE improvement is the central variable that influences the minimum share of EVs required. The past years' trend of increase in SUV sales (from 20% in 2014 to 33% in 2018[xxxiii]) and decline in diesel sales has impacted the average improvement of ICE fuel efficiency, which has flattened and even decreased (-0.2% per year between 2014 and 2017). The latest 2018 vehicle registration data from the EEA[xxxiv], which shows increasing car CO2 emissions for the second consecutive year, highlights that the SUV and diesel decline trends might exacerbate in the future, which is not fully modelled in this report but included in the low ICE improvement scenario.

Similar shares of EVs are required in BEV and PHEV scenarios. In the BEV scenario, to comply with the same CO2 reduction target less BEV sales (which have zero CO2 emissions rating) are required. However, PHEVs in this scenario have higher average emissions (compared to the Base scenario), so more PHEVs are required on the other hand. In the modelling, these two trends balance each other which explains why the total number of EVs is not affected. In the PHEV scenario, the opposite occurs: there are less BEVs but the PHEVs have lower CO2 emissions on average. Therefore, the main difference in the mix of new sales between the two scenarios, is that in the BEV scenario the share of BEVs is 3% points higher than in the PHEV scenario.

In 2030, the results follow a similar pattern (see Figure 26 below), and a carmaker that would follow the Base scenario would have to sell around 32% of EVs in 2030 (21% BEVs and 11% PHEVs), which varies between 29% and 36% depending on the degree of improvement of the ICE cars.

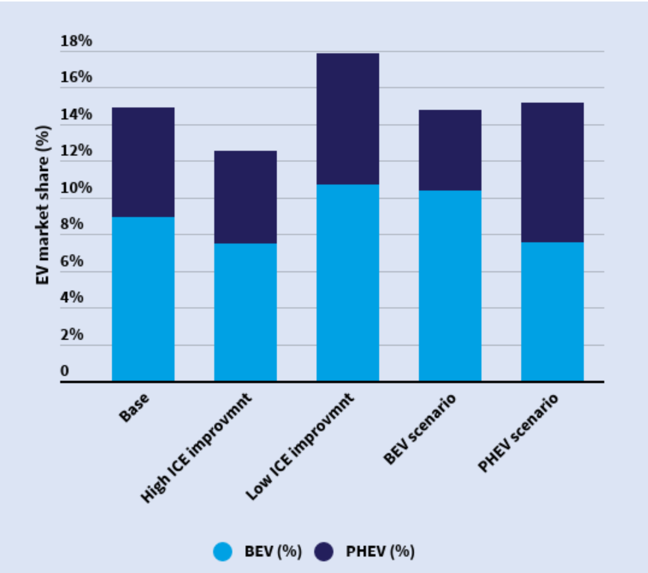

Figure 25: Expected minimum EV share in 2025 for CO2 compliance

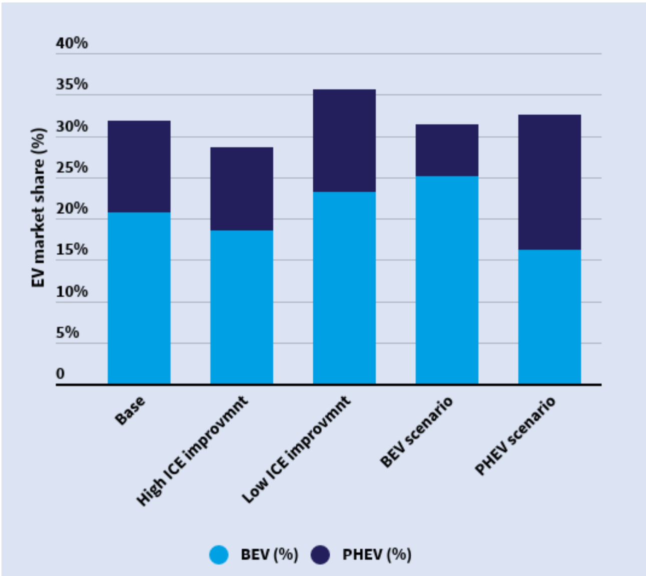

Figure 26: Expected minimum EV shares in 2030 for CO2 compliance

According to T&E Base scenario, the 2025/30 CO2 standards would require **at least 2.3 million EVs sold in the EU in 2025** (1.4 million BEVs and 0.9 million PHEVs) **and at least 5 million in 2030** (3.2 million BEVs and million PHEVs).

This analysis is conservative as regards the number of EVs as it is based on the minimum number of EVs required to meet the EU CO2 emission reduction targets. Some OEMs will likely overshoot the CO2 emission reduction target, notably those that focus solely on EVs (e.g. Tesla). They might either choose to sell extra EV credits to other manufacturers or benefit from EV sales bonuses – the latter is briefly discussed below.

More EVs are needed to benefit from regulatory flexibilities

Alongside the CO2 emissions reduction targets, the regulation incentivises carmakers to sell 15% of zero and low emission vehicles (ZLEV) from 2025, and 35% from 2030 onwards – offering a reduction of up to 5% on their overall CO2 targets if they overshoot these sales benchmarks. As plug-in hybrid cars are counted less than 1, in reality higher shares of electric car sales are required to hit the benchmarks.

In the scenarios presented above, the level of EV sales is not enough to reach or overshoot the ZLEV sales benchmark as the 15% of real-world EV sales translates into an equivalent ZLEV share of 12% in the Base scenario. As a consequence, if carmakers want to benefit from the ZLEV benchmark bonuses (or lower CO2 targets), they would have to rely exclusively on EVs to reach the CO2 reduction target (and thus make virtually no improvements on the average emissions of their new ICE fleet.

In the scenario where carmakers do not improve at all the ICE average emissions, the EV share would have to be at least 22% in 2025 to comply with the CO2 standards (13% BEVs and 9% PHEVs) - in this situation, a 2% CO2 bonus would be achieved. The benchmark thus rewards carmakers that choose to perform an immediate and rapid transition to EVs instead of relying on improved ICE and hybrids. In practice, the CO2 bonus would allow OEMs to increase the average emissions of their conventional cars if they sell 22% or more EVs in 2025.

2025 and 2030 target are well within reach

Based on the current productions forecast, the carmakers are expected to produce more EVs in the EU than what is necessary to comply with the minimum requirements of the EU CO2 emission reduction standards. Around 22% of the production of cars and vans in 2025 would be EVs if carmakers follow through on the current vehicle production forecast, which is higher than the average 15% EV sales share needed. It can be said that carmakers are already planning for sales beyond the regulatory compliance as they foresee a market driven demand for electric cars.

In addition, the upfront cost parity of EVs with their ICE equivalent is likely to me met in the mid-2020s, which would be a tipping point for the EV market and create a new wave in demand. According Bloomberg NEF[30], this price parity is expected to be reached in 2024, but this varies from one segment to another and depends on the driver use case. Carmakers that are able to secure the supply of batteries and scale up EV production fast would be able sell more EVs than the minimum required to answer the growing demand.

[30] BNEF expects the upfront cost parity to be reached in 2024 (and is getting closer every year): https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost

5. Conclusions and policy recommendations

5.1. Conclusions

The analysis presented in this report shows that:

1. A decade after their initial adoption, the **EU's 2020/21 CO2 standards are finally starting to drive investment in electric vehicles in Europe**. While not definitive, production forecasts available today show that carmakers are planning to produce over 4 million plug-in cars in 2025, of which around 60% are expected to be battery electric vehicles (BEV) and the rest plug-in hybrids (PHEVs);

2. The **planned numbers actually exceed the minimum EV volumes needed to comply with the future 2025 CO2 standards**, which T&E estimates to be 2.3 million EVs in 2025. This suggests that the European industry is eager to seize market share in the rapidly growing market for electric cars and to benefit as plug-in technology reaches cost parity with conventional cars by 2025. This ambition presents a great opportunity to accelerate the transition;

3. A third conclusion is that **car manufacturers are putting their money and production effort into the clean technology of their choice, and it is electrification**. Planned production of fuel cell vehicles in 2025 is negligible (9,000 units planned for 2025 vs 4 million EVs), and natural gas vehicles will remain a niche too, decreasing to 200k vehicles planned for 2025;

4. Most of the **EV manufacturing in Europe is expected to be located in Germany, France, Spain and Italy** (also the UK[31]), but parts of the future manufacturing are also expected to be located in central and eastern EU counties, notably **Slovakia**, Czech Republic and Hungary which rely on conventional car manufacturing today.

5. Whilst for the next few years Europe will have to import a part of the batteries required, in the medium-term Europe's battery production capacity will likely be sufficient to support the vehicle production in Europe. A dozen of the currently planned lithium-ion battery cell production factories will take a couple of years come online, but there is likely to be **enough battery supply by early/mid 2020s**. If production schedules are met, from 2023 these factories will account for a total of at least 131 GWh of annual battery production capacity, which is estimated to be around 15% more than the demand from electric cars and vans. Accounting for stationary storage (less than 10% of the total) and electric heavy-duty vehicles, the supply and demand of Li-ion batteries appears to be balanced and there should be no shortage of batteries in the medium-term future in the EU. The current shortage of battery supply is the consequence of late investments as manufacturers failed to anticipate the shift to EVs and to secure the supply on time. As a result, up to 2023 OEMs may have to rely on battery cell imports from Asia.

This report does not aim to predict the future – there is always an inherent uncertainty in estimating future manufacturing volumes and locations that can be subject to unexpected economic and geopolitical changes (e.g. Brexit). What it does show is that the EU car CO2 requirements are finally driving industry's investment in emobility. The current forecast data is a sign that a rapid expansion of EVs is possible, that OEMs are already planning for it, and that the current favourable locations to conventional manufacturing in Central and Eastern Europe can also benefit from new production opportunities.

[31] But uncertain due to Brexit

5.2. Recommendations

This analysis (backed by recent investment announcements) shows that Europe's car industry now has a real chance to leave behind a 20-year long history of unfulfilled promises on CO2 emissions. T&E has previously shown[xxxv] that carmakers delivered only about half of their commitments to EV sales as of 2018. They also notoriously failed to meet their own voluntary CO2 reduction goals in early 2000s resulting in the EU having to introduce mandatory targets in 2009. There are reasons to be more hopeful this time since, rather than aspirational goals only, current promises seem to be backed up by investments[xxxvi] into EV production - more than €145 billion by EU OEMs alone - and into securing the battery supply, notably by Volkswagen, BMW and others.

In fact, the data shows that the industry is gearing up to produce more electric vehicles than required by the EU's CO2 regulation, presumably in order to gain a global market share. This presents a unique opportunity to accelerate the EV transition beyond the minimum CO2 targets, which on their own are not enough to meet the carbon neutrality goal on time. To lock down carmaker commitments, the EU and national member states need to set ambitious and supportive measures to accompany the car industry transformation and ensure it is fast, fair and benefits all Europeans.

First, to give a strong long-term signal to the industry and ensure the huge investments in EV production are not in vain, the European Commission should propose an **EU-wide phase-out of internal combustion engine (ICE) light vehicles by 2035 at the latest**. This is not only necessary to comply with the Paris agreement and zero emission economy by 2050 (as the last ICE should be sold in early 2030s according to the EU Commission modelling), it is also an important industrial signal to give direction of travel and clarity for manufacturing and supply chain industries longer-term. After all, engineering choices in the next few years will determine production well into the 2030s.

Second, member states need to continue to **reform vehicle taxation in a way that accelerates the transition and reduces CO2 emissions,** so that taxes:

- Ensure that more EVs are sold than required by the EU CO2 regulation, in other words, that the potential for over-compliance is realised;
- Focus on high-mileage market segments such as corporate fleets and taxis to displace the maximum of fossil-driven kilometers. This can be done through employee-side measures (higher Benefit-in-Kind tax for ICE vehicles, lower for EV) and measures to reduce total cost of ownership (TCO) for employers via VAT/tax deductibility;
- Focus on the quality of EVs, e.g. their range, resource circularity and real-world CO2 reduction (including maximum CO2 requirements in the case of plug-in hybrids);
- Are socially equitable and promote affordable EVs to help consumers with lower purchase power. Incentives should not pay for luxury but for necessity, e.g. by price caps (that could depend on range);
- Are fiscally sustainable by balancing incentives for zero emission vehicles with increased taxes on polluting cars, preferably at the point of purchase to increase effectiveness and avoid adverse social impacts;
- Are phased down as battery prices decrease and the market matures; one way of doing this is to link incentives to market success.

Third, **charging infrastructure needs to be effectively deployed in line with the growing EV uptake at all levels**. While there is enough infrastructure for the early adopters today, much more needs to be done as electric cars go mainstream. Providing easy home and workplace charging is a top priority. So is a ubiquitous, interoperable and convenient coverage of public charging infrastructure along highways and suburban/urban roads, with a focus on areas not served by the market i.e. with lower utilization rates. Given the choice of EU carmakers to invest in electric cars, the review of the 2014 Alternative Fuels Infrastructure

Directive should follow the market and prioritise electric charging infrastructure for cars. It should also adopt the EU-wide “right to plug”, as well as channeling the EU Connecting Europe Facility and EU regional funds to provide seamless coverage.

Fourth, the **EU needs to put in place a comprehensive Green Industrial Agenda**, by setting and implementing coherent policies aimed at emobility leadership in all fields: transport, industry, research, innovation, etc. This needs to support the EU carmakers to transform the way they make cars and keep jobs in Europe. Notably, the EU should set an ambitious battery manufacturing framework – including environmental and social requirements and financial support – that would encourage the development of a sustainable and closed-loop battery production and recycling industry in Europe.

Finally, this report has shown that the uptake in EV production has the potential to replace the declining diesel manufacturing, notably in less wealthy regions heavily reliant on traditional manufacturing today. Earlier work shows that the additional spending from reduced oil imports – most of it spent in the service sector - more than offsets any job losses in the automotive industry. Still, some regions could be hit hard by the increasing automation in the automotive sector, of which electrification is one element. These should be able to benefit from a **diesel transition fund to help retrain, upskill and adjust workforce**. The German trade union IG Metall[xxxvii] has recently introduced an initiative whereby its employees would reduce working hours, but continue to receive the same salary and spend part of their time training and acquiring new skills. Industry, EU and national governments can all part-fund initiatives of this kind to prepare workers for the future.

Together, these measures are not only necessary to guarantee an effective, fast and socially just entry of electric vehicles into the mainstream market, but they will also ensure the EU car industry once and for all commits to electrification and delivers on its promises. This report shows it is possible; and a successful transition to emobility is also imperative to Europe’s economic and industrial future.

6. Annexes

6.1. EV model analysis: methodology and scope

In section 2., the analysis of production volumes and locations in sections 2.3, 2.4, 2.5 and 2.6 is based on the IHS Markit production database purchased by T&E in early 2019. No adjustements or updates have been made to the data, therefore the results presented only capture insights from the modelling of IHS Markit.

On the other hand, in section 2.2 concerning EV models coming to market in the EU, additional analysis is undertaken by T&E. The global HIS Markit vehicle production database was used as a starting point for the expected carmakers product plans and strategies which provided a skeleton for the analysis. Then, for each model, T&E experts translated production plans into expected availability on the European market based on knowledge of production plans, schedules, public announcements and uptaded information available.

For some models there can be a certain level of uncertainty for the availability of a model and/or for the year of availability. T&E experts have assessed global EV production data and public announcements made by the carmakers to carry out this analysis. Only models were the sales in Europe were deemed likely were taken into account (the model is ignored if there are no clear signals that the vehicle would be available in the EU). As a fall-back option when no market signals were available for the expected availability date in Europe (but sales were confirmed or very likely in Europe), the IHS Markit start of production date was used with a delay of two months to account for the lag between start of production and start of deliveries.

In the database some EVs are updated with only slight changes in the battery size or the engine/motor power. These vehicles were only counted once as this is not considered as a new product. On the other hand, when a model is entirely upgraded (i.e. new model generation, which happen after around 7 years), then it is counted as a new model on the market but not as an additional vehicle available on the market as it replaces the previous version of the model. This analysis includes both cars and vans.

The analysis of models expected on the market only cover the major carmakers, excluding small volume or niche manufacturers (e.g. Borgward, Bollore, e.GO), Chinese manfuacturers (BYD, Chery, etc..) or other foreign manufacturers with uncertain sales in Europe (Lucid Motor, Dyson, etc..), and sport/supercars cars (McLaren, Ferrari, Lamborgini). As a consequence, this analysis is conservative compared to the likely market growth in the next years.

6.2. EVs needed in 2025 & 2030 for CO2 compliance: Assumptions and methodology

Calculation of the EV share in 2025 and 2030 based on the minimum requirement from the CO2 standard

The Table 1 below details the main assumptions used in this model, they are briefly detailed in the text below.

Table 1: Scenario assumptions

Input overview	2021				2025			2030		
Scenarios	WLTP vs. NEDC gap	EV share (%)	BEV/PHEV split	PHEV average (g/km)	ICE improvement*	BEV/PHEV split	PHEV average (g/km)	ICE improvement*	BEV/PHEV split	PHEV average (g/km)
Base	20%	6%	55%	50	7.3%	60%	40	12.4%	65%	30
High_ICE_improvement	20%	6%	55%	50	**9.5%**	60%	40	**16.0%**	65%	30
Low_ICE_improvement	20%	6%	55%	50	**4.5%**	60%	40	**7.7%**	65%	30
BEV	20%	6%	**60%**	**55**	0.0%	**70%**	**50**	12.4%	**80%**	**45**
PHEV	20%	6%	**50%**	**45**	0.0%	**50%**	**35**	12.4%	**50%**	**25**

**ICE improvement: vs. 2021 ICE average*

2021- EV share (%): 6% (T&E estimates the EU market will be between 5% and 7% in 2021[32], report). Sensitivity analysis is performed on this assumption and increasing (respectively decreasing) the 2021 EV share by 1% leads to an increase (respectively decrease) of the 2025 EV share of +/-0.9%. However, lower share of EVs in 2021 means lower ICE average emission in 2021, which would in reality likely be balanced out by lower improvement on ICE in the following years. Therefore this assumptions was not considered key and is kept identical in all scenarios.

BEV/PHEV split: as the market matures, BEVs take up a larger proportion of the mix (it was 50%/50% in 2018). See Table 1 above for the assumptions in the different scenarios, base case assumptions are the following:

- 2021: 55 % BEV, 45% PHEVs
- 2025: 60%/40%
- 2030: 65%/35%

PHEV CO2 average (g/km, WLTP): as battery technology prices continue to fall and density increases, PHEVs are likely to see their range increase which gives lower type-approved CO2 emission values. The zero and low emissions vehicle (ZLEV) benchmark sets a threshold at 50gCO2/km to qualify as ZLEV (and thus earn ZLEV credits), and some national taxation systems also use this threshold. This creates an incentive for carmakers to makes PHEVs that emit less than 50g/km but doesn't incentivise them to go much lower. In 2017, the average emissions for PHEVs was around 54g/km (NEDC). See Table 1 above for the assumptions in the different scenario, base case assumption are the following:

- 2021: 50 g/km
- 2025: 45 g/km
- 2030: 40 g/km

WLTP vs. NEDC gap in 2021: 20% (as supported by car industry estimates & Get Real EU testing programme). This value is used to calculate the 2021 baseline in WLTP which will be higher than the 95gCO2/km in NEDC. In sensitivity analysis, smaller gaps are modeled (e.g. 15%, see T&E report) but the effect of this parameter is minimal. Possible gap inflation, makes the 2021 WLTP baseline higher, therefore the CO2 reduction is easier to achieve as it would be easier for carmakers to reduce their CO2 value (higher starting point) and this would lead to lower necessary EV shares to reach the same emission reduction. This is captured in the scenarios with high or low improvement for the ICE vehicles.

ICE improvement (vs. 2021):
Analysis is performed to calculate the most likely values and three scenarios are modeled (basecase, high improvement and low improvement) based on assumptions detailed below. The outcome of this analysis serves as inputs for the main modeling of EV shares.

To model the expected CO2 emission reduction from the average ICE, the following assumptions were used:

[32] Netherlands expects 12% BEV market share of new cars in 2021.

- **Share of mild and full hybrids** from 2019-2025 based on IHS Markit forecast. The share of mild hybrids increase from 4.5% in 2019 up to 54% in 2025, while the share of full hybrids increase from 1.3% in 2019 to 4.3% in 2025.
- **Full HEV CO2 emissions reduction vs. ICE average:** 27% in Base scenario (between 24% and 30%). 27% is the CO2 emission reduction when comparing Toyota full hybrids vs. the average for all ICE vehicles (diesel and gasoline) in 2017 based on EEA (Mainstream full HEV scenario). This value was 27% in 2016 and 31% in 2015 and 2014. When Lexus full hybrids are added to the comparison the gain drops to 24% as Lexus vehicles are premium vehicles and thus have higher emissions (Mainstream + Premium full hybrid scenario).
- **Mild HEV CO2 emission reduction vs. ICE average:** 13.4% in the Base scenario (between 10% and 15%). 13.4% is the average calculated based on several public announcements from carmakers and suppliers[33] while 10% and 15% is a realistic range.
- **Overall ICE annual improvement:** 0.65% annual CO2 emission reduction (between 0.2% and 1.1%). This annual improvement rate is applied to all vehicles, including mild and full hybrids and captures efficiency gains without assuming any difference between conventional ICEs and hybrids. During 2015-2017, the average annual efficiency improvement of conventional ICEs (diesel and petrol) was 0.2% while it was 1.1% over the period 2014-2017. We assume that the current trend in increase of SUV sales will continue over the next decade and this cancels most of the efficiency improvements (e.g. on light weighting). It is widely accepted among automotive industry experts that most of the CO2 emission reduction needed to comply with the post-2020 standards will come from electrification (hybridization and full electrification) since the potential for improvement of traditional ICEs reaches limits in terms of cost-effectiveness (when compared with hybridization strategy) and increase in sales of SUVs and decline in diesel sales is also bound to continue in the 2020s[34].

The results from this preparatory modelling, is a 7.3% emission reduction between 2021 and 2025 in the Base scenario, which is equivalent to a 1.9% reduction per annum. The high improvement scenario is based on a 9.5% reduction (2025 vs. 2021), or 2.5% p.a. and the low improvement scenario is a 4.5% reduction (2025 vs. 2021), or 1.1% p.a.

Between 2025 and 2030, this improvement rate will drop mainly because the potential to improve ICE vehicles will nearly flatten and market penetration hybrids will reach saturation. Furthermore, the upfront price of electric cars will be low than for ICE cars[35], making EVs sales the preferred compliance strategy. It was assumed that the annual improvement for ICEs between 2025 and 2030 is halved compared to the improvement between 2021 and 2025 (Base: 0.9%, High: 1.2% and Low: 0.6%). Combined with 2021-2025 improvement, we reach the following emission reduction between 2030 and 2021 for ICE: 12.4% in Base scenario, 16.0% in high and 7.7% in low.

The EU + EFTA new car market in 2025 and 2030 is estimated to stay at 2018 level: 15.5 million cars.

The share of EV required for compliance is calculated with the following formula:
Share EV_2025 (%) = (CO2_target_2025 – ICE_CO2avg_2025) / (PHEV_CO2avg_2025(1-SplitBEV/PHEV_2025) - ICE_CO2avg_2025)*

[33] Ricardo: 10-15% (NEDC) and 15-20% (WLTP), CLEPA (based on Continental data): 10-15%, Continental: 7-10% (NEDC), Renault (Continental system on diesel Scenic): 13% (NEDC), X-Engineer: 13-22% (NEDC) or 7-12%, Mahle: 12% (WLTP)
[34] For example Volkswagen Group aims at 50% SUV share in 2025 while the market average is 20% in 2014 and 33% in 2018. https://internationalfleetworld.com/volkswagen-aims-for-50-suv-sales-share-by-2025/
[35] BNEF expects the upfront cost parity to be reached in 2024 (and is getting closer every year): https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost

Endnotes

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