Charging Index

Comparison of the fast-charging capability of electric vehicles

Report 12/24

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01 Management Summary

Porsche is back at the top of the P3 Charging Index with the updated 2024 Taycan, winning it for the second time since 2019. With nearly 400 kilometers of real-world range added in just 20 minutes, the Taycan leads the pack at fast-charging stations. It boasts the highest measured peak charging power at 325kW and achieves the highest average charging power of 282kW between 10% and 80% state of charge (SoC).

The Hyundai IONIQ 6 leads the P3 Charging Index in the mid-size category. The aerodynamically styled Korean sedan charges 346km in 20 minutes at a fast charger, ranking second overall behind the Porsche Taycan. Like the IONIQ 5 and IONIQ 9, which will be launched in 2024, the car is based on Hyundai Motor Group's 800V E-GMP (Electric Global Modular Platform).

The NIO ET5 and Xpeng G9 are also the first two vehicles from China to appear in the top 10 of the P3 Charging Index. The two newcomers from Asia use different technologies: the NIO ET5 has a real range of 294 kilometers with its 400V on-board network. In addition to the fast charge function, the NIO's battery can be automatically swapped for a 90% fully charged battery within five minutes at NIO's own battery swapping stations, which would mean a real range of 362 kilometers - a unique selling point in the P3 Charging Index.

The Xpeng G9, on the other hand, has an 800V electrical system and, like the Porsche Taycan, can be charged with more than 300kW of peak power.

Comparing the 2024 results with the winning vehicle of the first P3 Charging Index from 2019 (the first-generation Porsche Taycan) highlights the remarkable progress made over the past five years. The first-generation Taycan had a peak charging power of 270kW (2024: +55kW) and could recharge 216km of real-world range in 20 minutes. Today, that figure has increased by approximately 77%, reaching 383km of real-world range in the same amount of time.

In this edition of the P3 Charging Index, Porsche exhibits the highest charging power of all the vehicles compared, which also represents the second-highest charging power ever recorded by P3. Only the winner of the P3CI Asia, the Lotus Emeya, has already been able to be charged with more than 400kW by P3 as part of measurements for the P3 Charging Index Asia, ↗ which again underlines the ambitions of Chinese car manufacturers.[1] According to initial announcements, the Zeekr 007 - another vehicle from China - will charge its 75kWh LFP battery from 10 to 80% SoC in less than 10.5 minutes with more than 400kW.

However, German manufacturers have also announced massive further developments and will be able to use 800V technology in the coming years with the New Class (BMW), the MMA platform (Mercedes-Benz) and the PPE platform (Volkswagen Group), not only increasing charging performance but also significantly improving the overall energy efficiency of the vehicles.

Electric mobility is constantly evolving, and this is an incentive to continuously improve vehicles so that "charging like refueling" is not an illusion.

[1]At the time of publication of the P3CI 2024, no Ecotest consumption value was available for the Lotus. Therefore, this vehicle cannot be calculated and included on a comparable basis.

02 Motivation and Introduction

When it comes to the long-distance capability of electric vehicles, negative headlines often dominate, fueling personal discussions and debates on social media. This makes it challenging to engage in an objective and fact-based examination of the topic. Statements such as ***“It takes hours to charge an electric car”*** or ***“Electric mobility is only suitable for the city and short distances, long journeys are not possible as I like to drive 800 kilometers”*** have become common prejudices. Such statements create uncertainty among potential users and interested buyers, who often decide against purchasing an electric vehicle. This is largely because questions about charging behavior and long-distance suitability are not adequately explained or fully addressed.

As an independent management consultancy for electric mobility, P3 is dedicated to delivering clear and comprehensive insights on the subject. The P3 Charging Index 2024 investigates and analyses the long-distance suitability and charging behavior of modern electric vehicles in order to assess how good the charging performance of current electric vehicles really is. The aim is to answer the central question in a factual and data-driven manner:

“How many kilometers of real range can an electric car charge in 20 minutes at a fast-charging station?”

P3 is now publishing the sixth edition of the P3 Charging Index ↗ in December 2024. The following reports have been published since 2019:

READ ↗ P3 Charging Index 2019 with focus on Europa
READ ↗ P3 Charging Index 2021 with focus on Europa
READ ↗ P3 Charging Index 2022 with focus on Europa
READ ↗ P3 Charging Index US 2023 with focus on North America
READ ↗ P3 Charging Index Asia 2024 with focus on Asia

03 Methodology of the P3 CI

In competitive comparisons of different electric vehicles, the parameters of maximum charging power in kilowatts [kW] and time for fast charging from 10% to 80% SoC are often presented in a simplified form. However, from the user's point of view, these two parameters are only of limited importance for the everyday fast-charging capability of electric vehicles.

The P3 Charging Index was developed by the P3 Group in 2019 to make the real charging speed of electric vehicles comparable and easy to understand.

Key parameter for the user is the time needed to recharge the real range in kilometers. The P3 Charging Index uses this to compare the long-range capability of different electric vehicles. Using the vehicles' consumption and charging curves, the number of kilometers recharged in 10 and 20 minutes of charging time can be displayed, allowing a concrete comparison of the vehicles' fast-charging performance.

At the end of 2019, P3 recognized that there was no concrete comparison of fast charging behavior and developed the P3 Charging Index (P3CI), an independent standardization that enables a usage-based and realistic comparison of the fast-charging performance of electric vehicles. It considers the charging window between 10% and 80% state of charge (SoC), as this is when vehicles charge the fastest.

The ideal value of the P3 Charging Index is 1.0, which corresponds to an effective range of 300km in 20 minutes:

$$\text{P3 Charging Index} = \frac{\text{Real recharged range [km] in 20 minutes}}{\text{300km}}$$

! The P3 Charging Index only considers vehicles equipped with the European charging standard CCS2. A distinction is made between the luxury and mid-range categories. In order to ensure uniformity, practicality and comparability of the results, P3 refers to the consumption values of the ADAC Ecotest. All information on data collection and the vehicles considered can be found in Chapter 9.

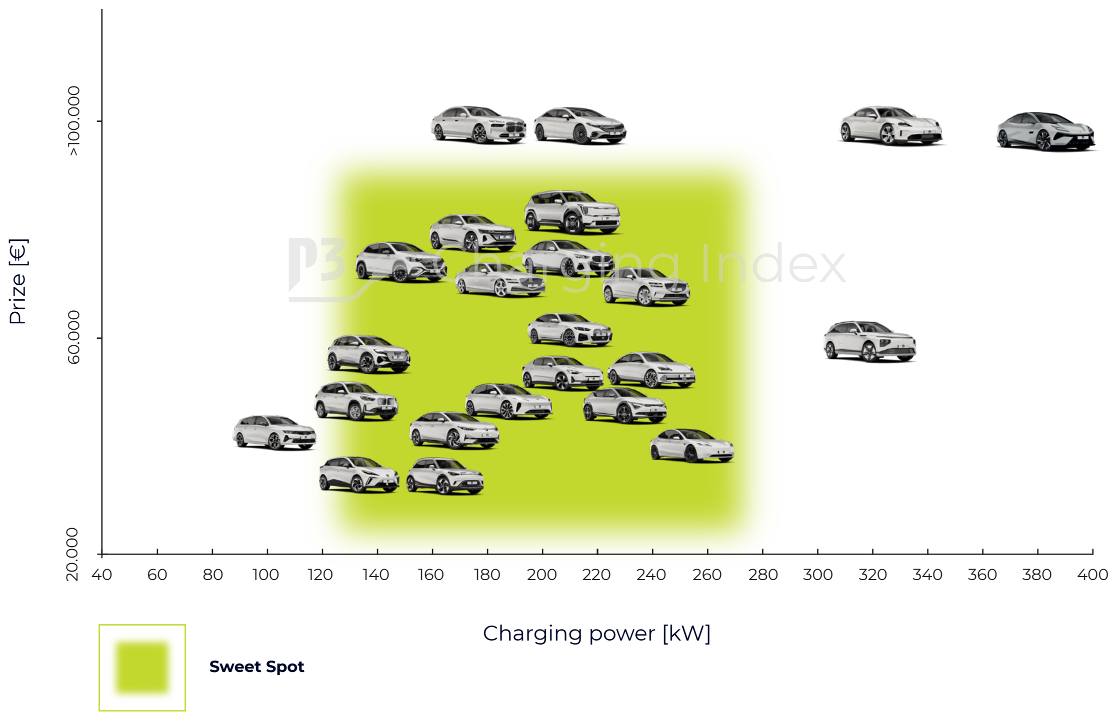
04 Comparison of charging power

The sweet spot of charging power is currently between 150 and 220kW, but up to 400kW is possible.

The majority of electric vehicles on the market today offer maximum charging capacities between 150 and 220kW, limited by the prevalence of 400V vehicle architecture. Vehicles based on an 800V platform can achieve charging capacities in excess of 300kW, as demonstrated by the Porsche Taycan and Xpeng G9. At the top end is currently the Lotus Emeya, which can charge up to 402kW[2] and sets new standards with charging currents of up to 600A. P3 anticipates further increases in performance in the future due to expected developments in charge current and battery technology.

FIGURE 1:

Focus area for charging capacities of all price classes (approximation)



[2]At the time of publication of the P3CI 2024, no Ecotest consumption value was available for the Lotus. Therefore, this vehicle cannot be calculated and included on a comparable basis.

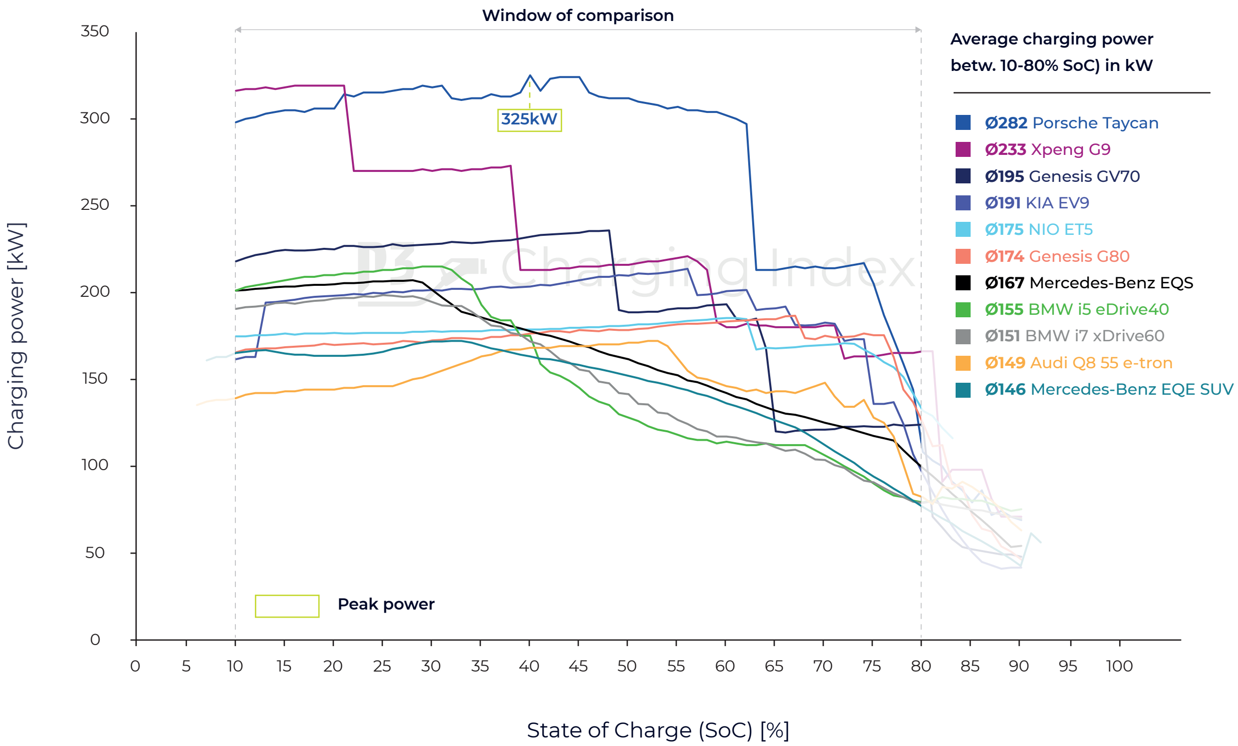
Achieving the maximum possible charging capacity depends on various factors.

The maximum charging performance of electric vehicles is only achieved under ideal conditions, i.e. when the vehicle has a low state of charge (SoC) and the battery is at the optimum temperature for fast charging, which can be achieved, for example, by preconditioning. The aim is to ensure that the vehicle's high-voltage battery is tempered so that it is within the optimum temperature window at the start of charging. This prepares the battery for the maximum possible charge. In some vehicles, if available, this is done via the vehicle's navigation system when the charging stop is scheduled (e.g. Porsche Taycan); in others, battery preconditioning can also be started manually (e.g. BMW). How important a preconditioned battery can be, especially in cold weather, was highlighted by P3 in the publication, "Charging in cold temperatures". ↗

It is also necessary for the charging station to be able to provide the maximum possible charging power for the vehicle. In particular, the increasingly common plug combination of two CCS outputs per charging station means that the charging station always operates with static power sharing (e.g. continuous distribution of the maximum 400kW charging power of 200kW each to two charging point plugs). Alternatively, the power is reduced as soon as the second charging point is used (dynamic power sharing). At present, only a few operators use charging points with only one charging plug of up to 400kW, which ensures that high charging power can be delivered continuously and without restriction.

FIGURE 2 :

Comparison of charging performance for P3CI luxury class vehicles



RESET | Porsche Taycan | Xpeng G9 | Genesis GV70 | KIA EV9 | NIO ET5

Genesis G80 | Mercedes Benz EQS | BMW i5 eDrive40 | BMW i7 xDrive60 | Audi Q8 55 e-tron | Mercedes Benz EQE

Interactive graphics (desktop only)

For a better comparison of the charging curves, please use the show/hide function by clicking on the desired vehicle button.

The Porsche Taycan, Xpeng G9 and Genesis GV70 vehicles have an 800V electrical system and, as can be seen in Figure 2, achieve the highest charging performance compared to all other vehicles. The reason for this is that they are charged with a higher voltage. The vehicles with a 400V architecture, such as the NIO ET5 and the BMW and Mercedes-Benz vehicles, are limited by their lower battery voltage and a maximum possible charge current of 500A at around 200kW.

The comparison of different vehicles shows that the charging curves are very individual and that the maximum charging power is only reached for a certain period of time during the charging process, with the vehicle-specific performance varying greatly. This is particularly evident in the charging curve of the Xpeng G9, which quickly loses a lot of power and therefore also shows a large difference between maximum (319kW) and average charging power (233kW) between 10% and 80% SoC.

- **Porsche Taycan:** With the model to be launched in 2024, the charging power is increased by 50kW compared to the first generation from 2020 and the fast-charging window is now significantly extended. With a peak of 325kW, the Porsche Taycan achieves the highest charging power of all vehicles and maintains its peak plateau with more than 300kW up to over 60% SoC. This is reflected in the average charge between 10% and 80% at 282kW, which is also a good ratio of peak to average charge. The average charge power is the highest average of all the vehicles, meaning that the Porsche is the clear leader in charge performance and the new “Performance Battery Plus” can be charged from 10% to 80% in 18 minutes.

- **NIO ET5:** The electric estate car from China has a 400V architecture and charges almost constantly at around 180kW. This results in an average of 175kW over the entire SoC range, which is significantly higher than other 400V vehicles. The NIO ET5 is also unique in that it is the only vehicle in the comparison to have a battery swapping system. This allows the empty high-voltage battery to be swapped automatically for a 90% charged high-voltage battery in about five minutes at battery swapping stations, giving a real range of 362 kilometers.[3] There are currently 58 NIO Power Swap Stations in operation in Europe.[4]

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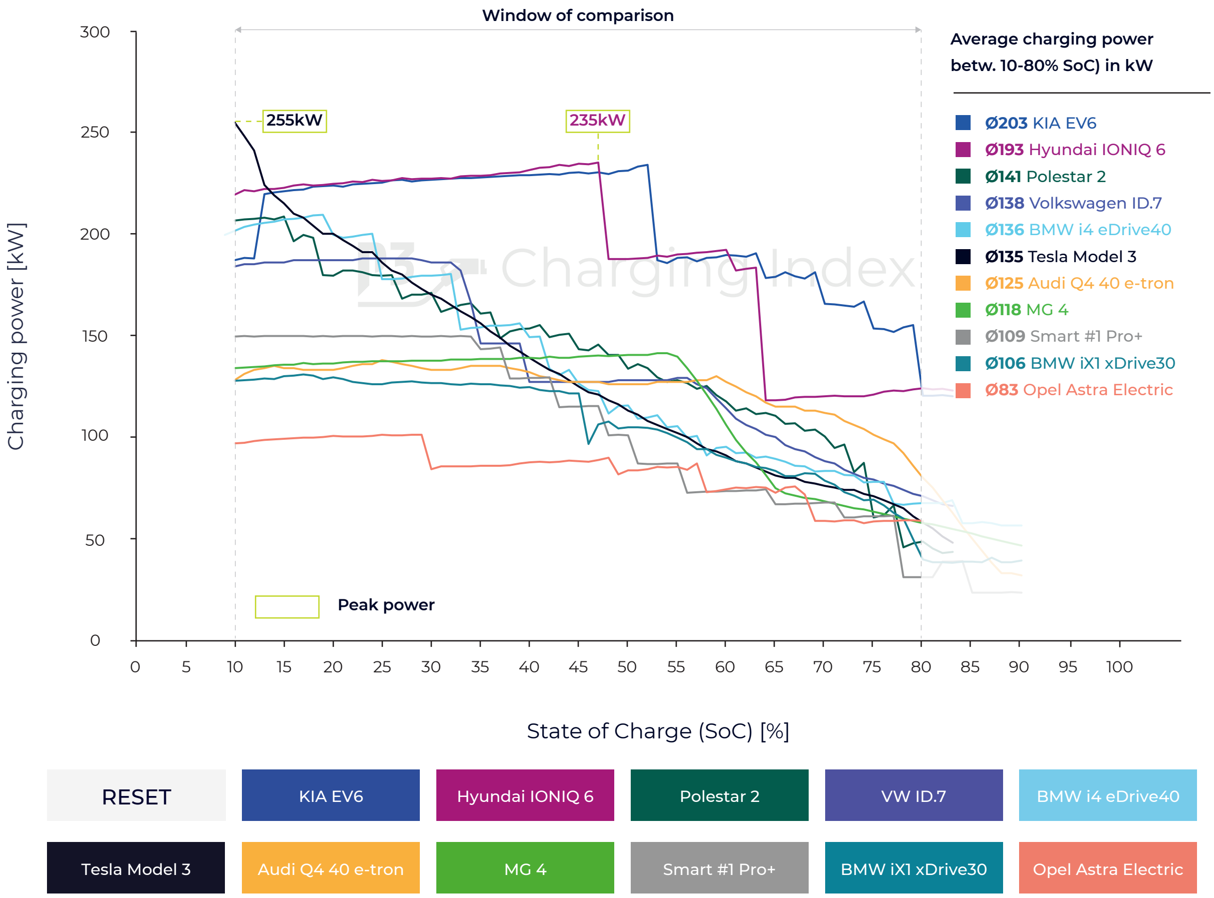
[3]Assuming a battery of the same size with 10% SoC is replaced by one with 90% SoC
[4]Compare NIO.com [04.12.2024]

- **Mercedes-Benz EQS:** The Mercedes-Benz EQS is based on a 400V architecture, but with its large 107.8kWh battery it can deliver a peak power of around 210kW and an average power of 167kW in the measured SoC window (10-80%).

- **BMW i5:** The all-electric BMW i5 eDrive40 has an 81kWh battery and, like the Mercedes, is based on a 400V architecture. At its peak, the i5 achieves a maximum charging power of 215kW and is charged on average with 155kW from 10% to 80% SoC; the BMW i7 and BMW i4, which are equipped with different battery sizes, can also achieve similar values. The BMW iX xDrive50, which has been available on the market since 2021 (see P3 Charging Index 2022), is also at a similar level to the i5 and i7.

FIGURE 3:

Comparison of charging performance for P3CI premium class vehicles



Interactive graphics (desktop only)

For a better comparison of the charging curves, please use the show/hide function by clicking on the desired vehicle button.

The 800V vehicles also dominate the premium class segment, as shown in Figure 4. The KIA EV6 and Hyundai IONIQ 6 are characterized by consistently high charging performance over a wide SoC window. The Tesla Model 3, on the other hand, lags significantly behind with an impressive but very short peak charge, which is why it is in the middle of the pack in terms of average charge.

- **Tesla Model 3:** Even after the major facelift in 2023, the Tesla Model 3 still has an impressive peak charge power of 255kW. However, this peak is only achieved at Tesla's own Superchargers, which are the only charging stations capable of delivering more than 600A to the vehicle. The CCS standard is currently set at a maximum of 500A, which is why other charging station manufacturers have not yet released this power.

- **Hyundai IONIQ 6:** The Hyundai IONIQ 6 is based on the Hyundai Group's 800V E-GMP platform, which also underpins the IONIQ 5 and the recently launched IONIQ 9, KIA EV6 and EV9 and Genesis GV60 models. The vehicles feature a high charging capacity over a long SoC window, which is reflected in a peak charging capacity of over 230kW and an average charging capacity of almost 200kW.

- **Volkswagen ID.7 Pro:** Although the Volkswagen ID.7 Pro achieves a significantly lower peak charging power than the Tesla Model 3, it can keep the maximum charging power of 190kW stable up to around 30% SoC, while the Tesla Model 3 only charges at around 160kW at this point. After that, the charging power of the Volkswagen is gradually reduced, resulting in an average charging power of 141kW. With the introduction of the VW ID.7 Pro S, which was not yet available at the time of the test, the battery capacity and presumably also the charging power were additionally optimized.

The charging performance of electric vehicles will once again increase significantly in the coming years.

In Germany, manufacturers such as BMW, Mercedes-Benz and Volkswagen will rely on innovative and new platforms in the future to make charging procedure faster and more efficient. According to initial announcements, these efforts are expected to be accompanied by the following key metrics:

BMW will increase charging speed by up to 30% compared to the current generation with the overdue switch to an 800V architecture, with the New Class available from 2026. According to initial information from the Munich based company, it should be possible to recharge a range of 300 kilometers within ten minutes.[5]

Mercedes-Benz is pursuing a similar approach with the MMA platform. The all-electric CLA is to be equipped with an 800V architecture and achieve a maximum charging capacity of over 320kW.[6]

With the new Porsche Macan and the Audi Q6 e-tron, the Volkswagen Group has for the first-time launched vehicles based on the newly developed PPE (Premium Platform Electric) platform. This flexible platform will continue to evolve over the coming years, enabling the brands to integrate the latest technologies in high-voltage systems, powertrain, and chassis. Porsche also recently announced the launch of an all-electric Porsche Cayenne, which is expected to significantly exceed the current 270kW charging performance of the Porsche Macan. The electric Porsche Cayenne is expected to offer even higher and more stable charging performance.[7] However, it is likely to be at least another one to two years before the next generation of electric cars from the German premium manufacturers are ready for series production and available.

[5]Compare Press.bmwgroup.com [Last access 28.11.2024]
[6]Compare Electrive.net [Last access 28.11.2024]
[7]Compare Newsroom.porsche.com [Last access 28.11.2024]

The new electric car manufacturers from China are already setting new standards in terms of charging speed, as the following announcements show. Vehicles such as the Zeekr 007 with the Golden Brick Gen2 battery are expected to achieve exceptional C-rates of up to 5.5C with a charging power of more than 400kW, which corresponds to a charging time of 10.5 minutes for 10-80%. A C-rate of 1C means that a battery can be fully charged or discharged within one hour. This would make the LFP battery from China probably the fastest rechargeable battery in the world at the moment.[8] With its Qilin battery, CATL has developed a technology that can recharge almost 300 kilometers in ten minutes, according to a statement from CATL.[9] The Lotus Emeya, equipped with the CATL Qilin battery, already highlighted China's progress in the P3 Charging Index Asia in May 2024: the sedan was charged by P3 experts at a public CCS charging station in Germany with a maximum of 402kW. The average value between 10% and 80% was 331kW, outperforming the Porsche Taycan by almost 50kW. This charging performance was achieved by charging the vehicle at up to 600A using the 800V architecture.[10]

The current maximum charging power for electric vehicles is based on max. 920V (CharIN) and max. 500A (CCS standard). For higher charging currents, the standard would have to be adapted, which is currently being worked on.

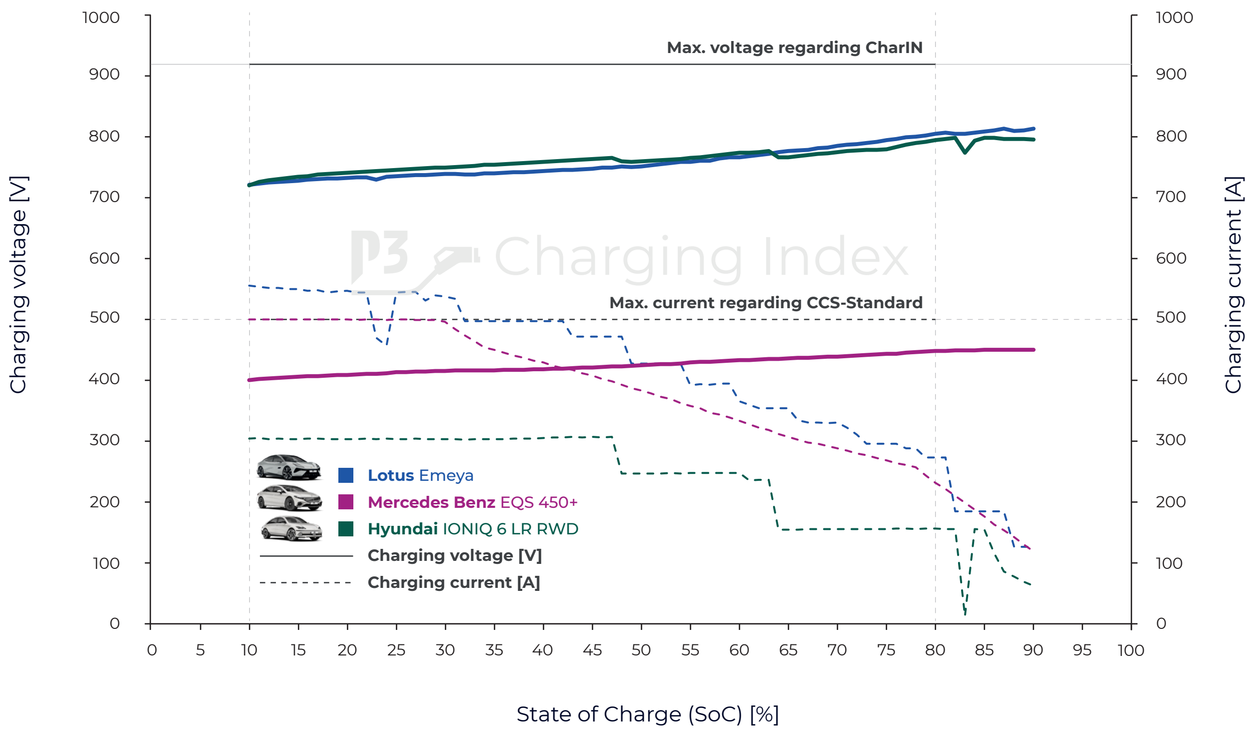
The current limits for CCS charging are defined by CharIN with a maximum voltage of 920V as the upper limit for HPC charging stations and the CCS standard with a maximum current of 500A. In order to achieve the maximum theoretical charging capacity of 460kW, both values must be fully utilized. However, this is hardly possible as the charging voltage starts well below 920V (720V to 730V for the Emeya) and rises as the SoC increases. This leads to differences of 48V (EQS) to 84V (Emeya) in the measurements taken from 10% SoC to 80% SoC. The charging currents, on the other hand, decrease significantly during the charging process.

[8] Compare Sina Finance [Last access 28.11.2024]
[9] Compare CATL www.youtube.com [Last access 28.11.2024]
[10] Compare P3-Group.com [Last access 28.11.2024]

This is due to the increase in SoC and temperature, so although the charge voltage increases, the charge current decreases in the same way. In order to achieve even higher charging capacities at the beginning, charging currents up to the 600A mark are increasingly being targeted, which the Lotus Emeya also uses to achieve >400kW peak charging capacity.

FIGURE 4 :

P3 current/voltage curves for various battery electric vehicle models (BEV)



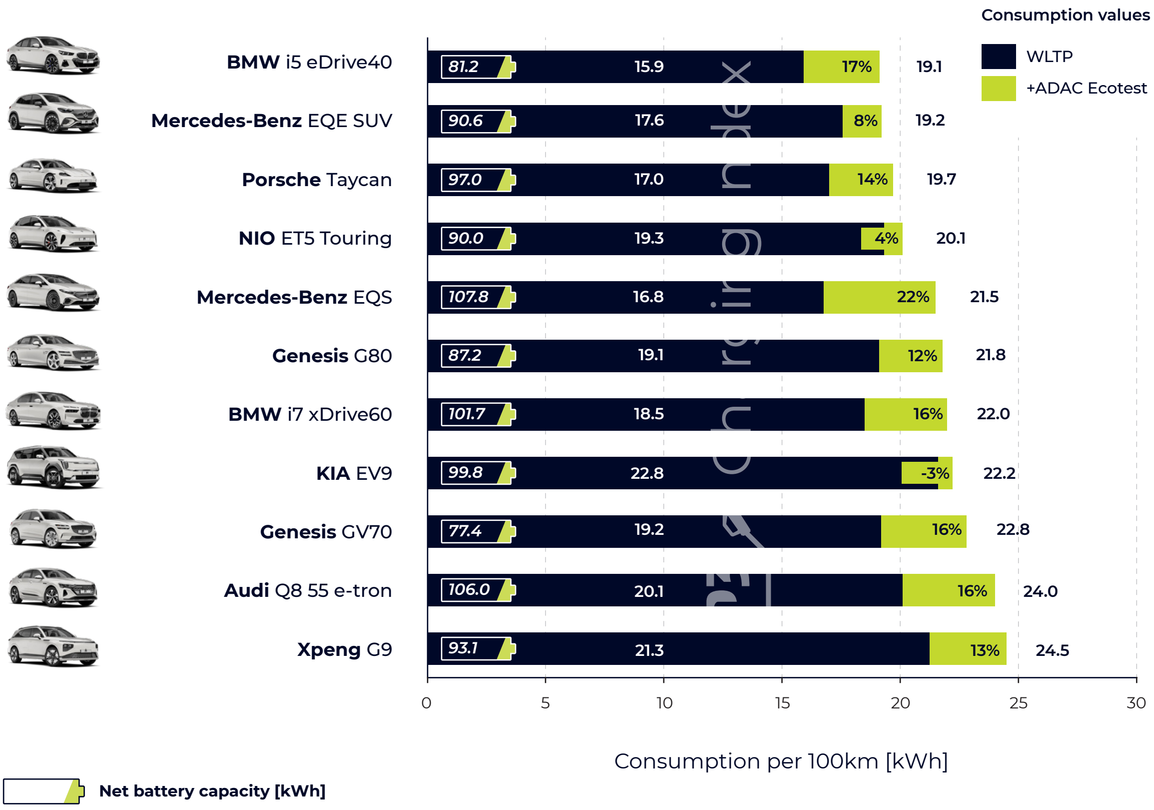
05 Comparison of the energy consumption

In order to include the most realistic consumption figures possible for the individual electric vehicles in the calculation of the P3 Charging Index, the consumption values determined by the ADAC Ecotest were used. In the graph shown, these are compared with the WLTP consumption data and are shown together with the relative differences. The ADAC electric cycle (part of the ADAC Ecotest) is run through in one go and repeated until an SoC <50% is reached or the cycle has been run six times. The vehicle is then fully charged using a type II charging plug (22kW or maximum possible AC charging power) and the required electrical energy is determined. The energy measurement also takes into account the charging losses that occur during normal charging (AC charging). [11]

[11]Compare ADAC.de [Last access 03.12.2024]

FIGURE 5 :

Comparison of fuel consumption and battery size of vehicles in the P3CI luxury class category

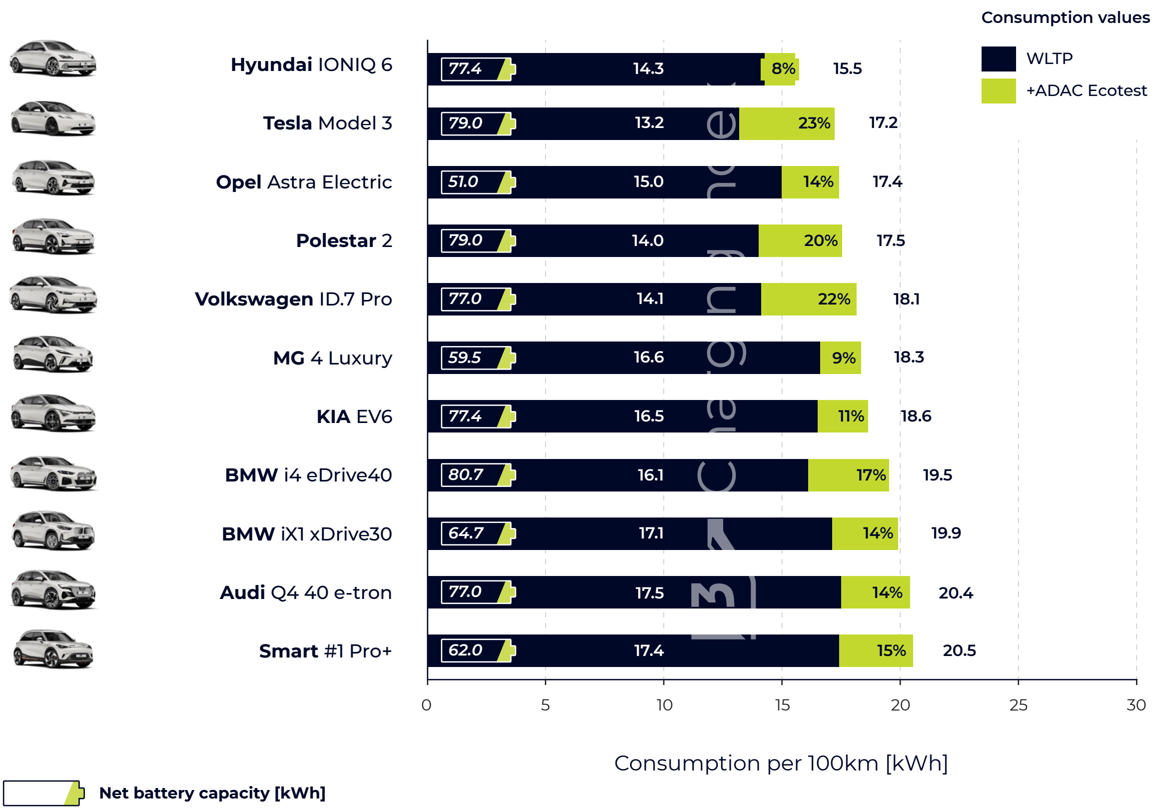


Compared to premium class vehicles, luxury-class vehicles generally have larger batteries, which range from 77.4kWh (Genesis GV70) to almost 108kWh in the Mercedes-Benz EQS in the vehicles analyzed. In addition to the weight of the battery, another factor for the energy consumption of an electric vehicle is the aerodynamics, which is described by the drag coefficient (cW value). Saloons in particular are characterized by very low drag coefficients, which has a positive effect on overall consumption. In comparison, most larger SUVs perform less well in terms of consumption, as they tend to consume more energy due to their higher wind resistance and often higher weight. One notable exception, however, is the Mercedes-Benz EQE SUV, whose consumption of 19.2kWh is only just behind that of the BMW i5 in the ADAC Ecotest.

Overall, the vehicles' fuel consumption varies widely, ranging from 19.1kWh per 100km in the BMW i5 eDrive40 to 24.5kWh per 100km in the Xpeng G9. In the i5 eDrive40, BMW has installed a particularly efficient powertrain. The business sedan has the lowest fuel consumption in the luxury class in both the WLTP and the ADAC Ecotest, with a difference of almost 20%. This is at the top end of the range and is only surpassed by the Mercedes-Benz EQS at 22%, while the majority of vehicles are below this with an average deviation of 12%.

FIGURE 6 :

Comparison of fuel consumption and battery size of vehicles in the P3CI premium class category



Premium class vehicles are generally equipped with smaller batteries than luxury class models, which can result in a lower battery weight and therefore lower consumption. The range here extends from at least 51kWh in the Opel Astra Electric Sports Tourer GS to just under 81kWh in the BMW i4 eDrive40. The Hyundai IONIQ 6 is particularly noteworthy, achieving an extremely low consumption of just 15.5kWh in the ADAC Ecotest. This means that the IONIQ 6 significantly undercuts the leader in the luxury class, the BMW i5, which has a consumption of 19.1kWh. In the overall ranking of all vehicles tested, the Hyundai IONIQ 6 is therefore the most fuel-efficient electric vehicle, which is mainly due to the aerodynamically optimized body of the saloon.

In fall 2024, VW and Mercedes achieved new record figures during real-world road testing.

In October 2024, Volkswagen was able to prove that low consumption values can be achieved in real-world operation with the ID.7 Pro S during a drive in Switzerland. The Wolfsburg saloon managed 794 kilometers on one battery charge in normal traffic flow on public roads. The specified WLTP value of 709 kilometers was thus once again significantly exceeded, which was achieved by average consumption at a particularly low level of just 10.3kWh/100km. Converted into diesel, the average consumption driven means only around 1.1 liters per 100km.[12]

Also in October 2024, Mercedes-Benz set a world record with a development vehicle of the new CLA, which is based on the new 800V MMA architecture for the first time: During a 24-hour test drive on the test track in Nardò in southern Italy, the near-production prototype covered a distance of exactly 3,717 kilometers within 24 hours in a real-world test.[13] According to the latest announcements from Mercedes-Benz, the top model of the vehicle will come with a battery with a usable energy content totaling 85kWh and is expected to achieve a consumption of 12kWh/100km.[14]

[12]Compare Volkswagen-newsroom.com [Last access 28.11.2024]
[13]Compare Group.mercedes-benz.com [Last access 28.11.2024]
[14]Compare Electrive.net [Last access 28.11.2024]

The consumption of electric vehicles will be significantly reduced again in the next generation of vehicles.

Trends are already emerging for the next generation of electric vehicles: BMW is emphasizing high efficiency when it comes to the “New Class”, which is set to be launched on the market in 2026 based on 800V architecture: the Generation 6 battery cell is expected to offer up to 30% more range, up to 30% faster charging and more than 20% higher energy density compared to the previous generation currently available on the market. This should increase overall vehicle efficiency by up to 25% through the sum of all measures.[15] With the PPE platform (first used in the Porsche Macan and Audi Q6), Volkswagen plans to further reduce fuel consumption and increase the range beyond the 600km mark.[16] The Chinese car manufacturer Xpeng, founded in 2014, published the data of the new P7+ in October 2024, which is based on an 800V architecture on the one hand, but is also supposed to achieve a very low consumption of just 11.6kWh thanks to a silicon carbide inverter, which in all likelihood does not represent WLTP consumption but the Chinese CLTC standard.[17]

[15]Compare Bmwgroup.com [Last access 28.11.2024]
[16]Compare Volkswagen-Group.com [Last access 28.11.2024]
[17]Compare Indsideevs.de [Last access 28.11.2024]

06 P3 Charging Index – Assessment of the long-distance suitability of electric vehicles

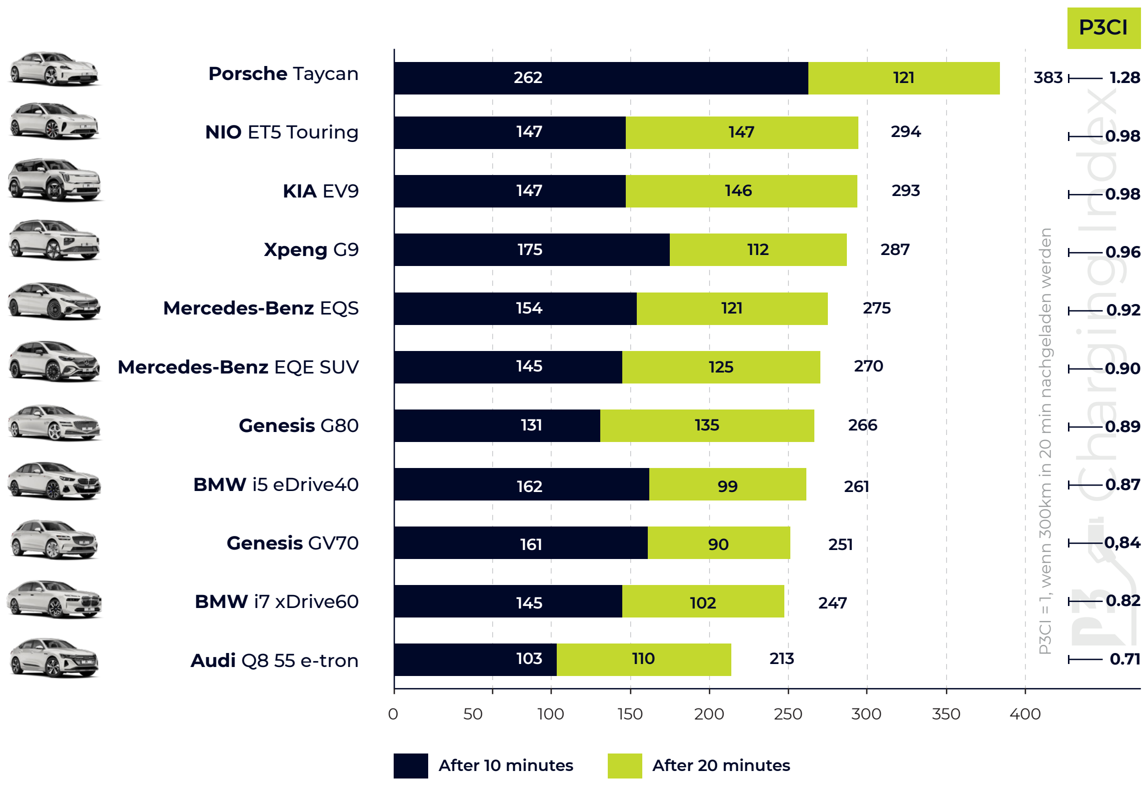
From the customer's perspective, neither the maximum charging capacity nor the consumption are individually decisive for long-distance suitability, because a typical, real charging process is essentially orientated towards one important question for the electric vehicle driver:

"How many kilometers of real range can an electric car charge in 20 minutes at a fast-charging station?"

P3 compares the charging power, consumption, and time in order to be able to compare the cars under real conditions:

FIGURE 7 :

Consideration of the real recharged range [km] in the P3 Charging Index - luxury class category



The Porsche Taycan is in first place in the luxury class of the P3 Charging Index and can recharge 262km of range in 10 minutes. In total, the saloon recharges 383km in 20 minutes. The Taycan thus impressively demonstrates the advantages that high charging performance in combination with low consumption can bring.

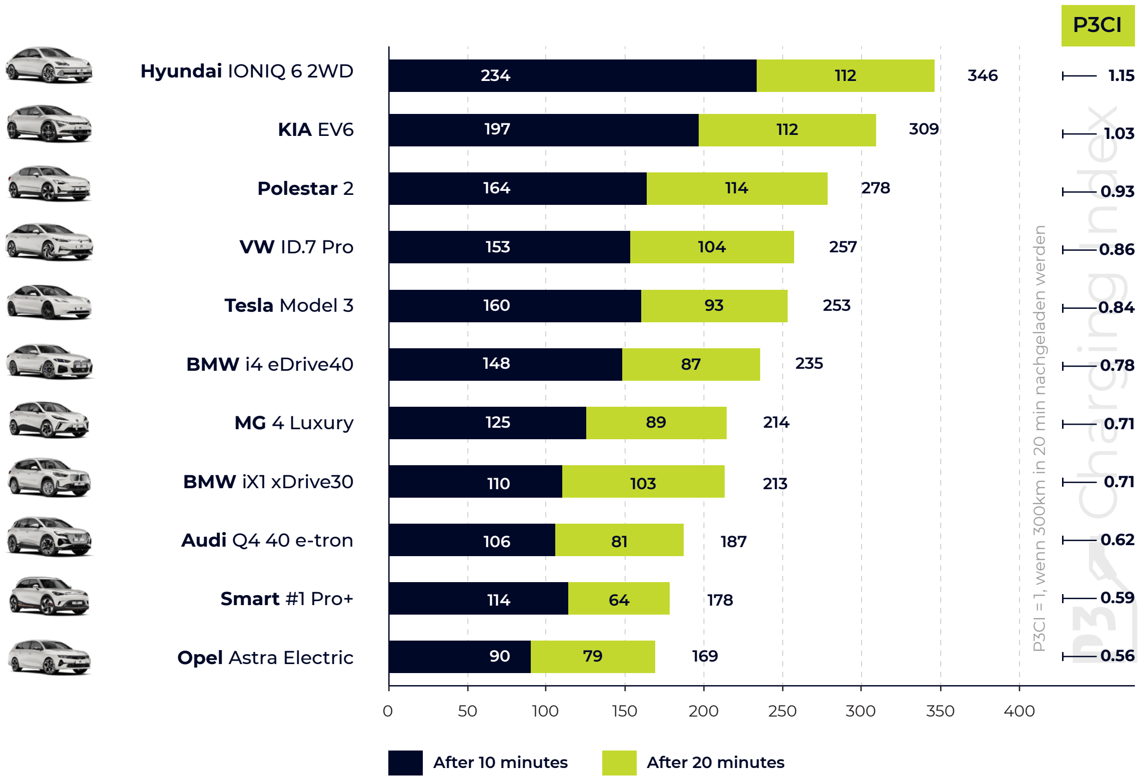
A Chinese car manufacturer secures 2nd place in the luxury class at the first attempt, despite the 400V architecture, which underlines the rapid development of the Chinese car manufacturer and shows how quickly it can catch up. The NIO ET5 Touring Long Range recharges 294 kilometers of range in 20 minutes and is also the only vehicle that can also be recharged using a battery swapping system. This allows the empty high-voltage battery to be swapped for a 90% charged battery fully automatically in around 5 minutes at battery swapping stations.

The KIA EV9 follows just behind the NIO ET5 and recharges 293 kilometers of range in 20 minutes, which is a remarkable result considering the dimensions (size and weight) of the vehicle.

The German vehicles with the 400V architecture come in behind the 800V vehicles. While they are still on a similar level to the 800V vehicles after ten minutes due to lower consumption and high charging performance, the comparatively weak charging performance becomes noticeable after approx. 40% SoC, which ultimately impacting the final result after 20 minutes.

FIGURE 8 :

Consideration of the real recharged range [km] in the P3 Charging Index – premium class category



The Hyundai IONIQ 6 is capable of recharging a range of 234km in just 10 minutes, with a total range of 346km achievable within 20 minutes, making it the winner of the premium class category of the P3 Charging Index. This demonstrates how a high charging capacity in conjunction with relatively low consumption can markedly extend the recharged range in 20 minutes.

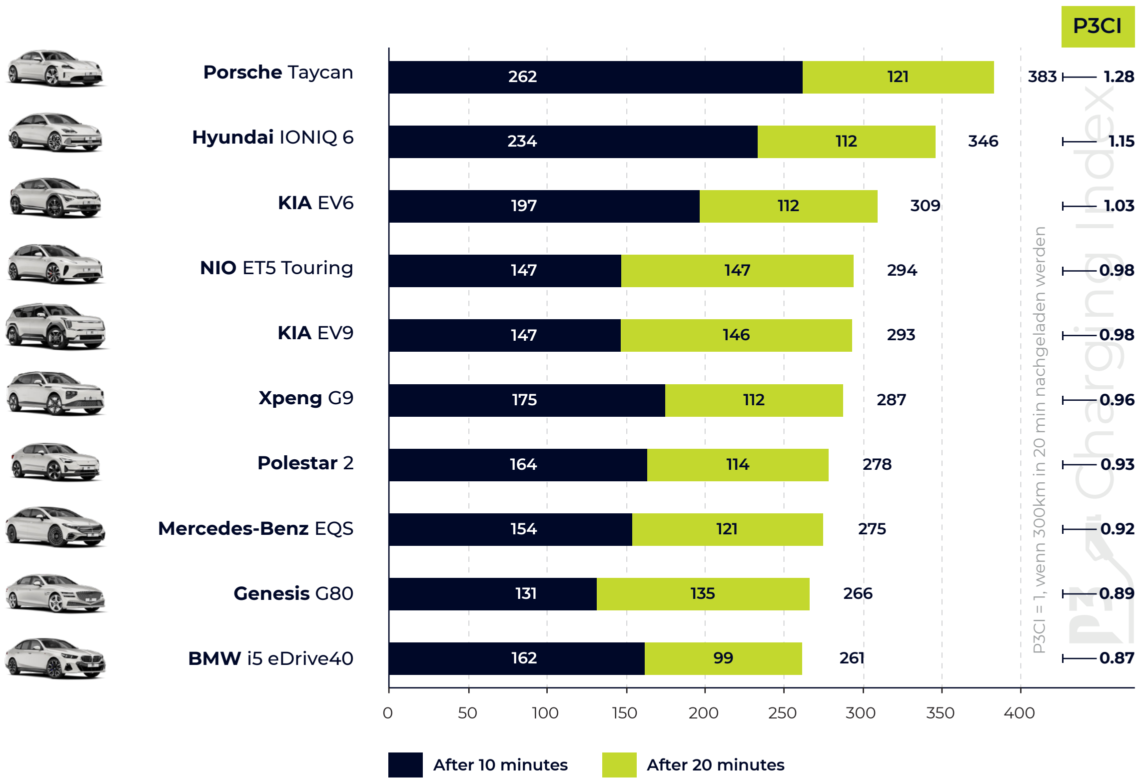
While the **KIA EV6** has a slightly faster charging time, its higher consumption rate makes a notable impact on the overall result. The KIA is capable of recharging a range of 309km in 20 minutes.

Following the Highland facelift, the Tesla Model 3 still has the highest maximum charging capacity and lower consumption. However, the Polestar 2 and VW ID.7 remain ahead in a direct comparison. This is due to the fact that both the Polestar and the Volkswagen can recharge more energy in the same time thanks to a more stable charging curve. Overall, however, the three vehicles are at a very similar level.

The 800V vehicles from Korea clearly demonstrate superior performance compared to the 400V models. The Hyundai Motor Group models emerge as the clear winners after both 10 and 20 minutes of charging. Given the anticipated timeline for the introduction of electric vehicles from European manufacturers based on 800V in the premium class segment, which is not expected until the end of 2025 at the earliest, Asian manufacturers will retain their leading position in this segment for the time being.

FIGURE 9 :

Consideration of the real recharged range [km] in the P3 Charging Index - overall ranking



For the first time, the TOP 3 of the P3 Charging Index in the overall ranking all charge more than 300km real range in 20 minutes and thus have a P3CI greater than 1.0.

1st place
Porsche Taycan

With 383km in 20 minutes, the Porsche Taycan charges the most range at the HPC charging station, has the highest measured charging power with 325kW at the peak and the highest average charging power between 10% and 80% SoC with 282kW.

2nd place
Hyundai IONIQ 6

The Hyundai IONIQ 6 takes 2nd place in the overall ranking of the P3 Charging Index 2024 and charges a total of 346km in 20 minutes, which is due to both its excellent charging performance and low consumption.

3rd place
KIA EV6

The winner of the last European P3 Charging Index (2022), the KIA EV 6, slips from first place to third place in the overall ranking and can recharge 309km of new range in 20 minutes. This vehicle shows very clearly that the Hyundai Motor Group has developed a basis with the E-GMP platform that has been able to achieve remarkable charging performance for several years and will continue to do so in the future.

07 Excursus: Development of electric mobility

Five years after the publication of the first P3 Charging Index, the development of electric vehicles has come a long way:

P3 Charging Index 2019: The beginning of long-distance electric mobility.

In 2019, electric mobility was still at an early stage of technological development, particularly in terms of charging speed, range, and energy consumption. Nevertheless, the first vehicles with larger batteries and charging capacities of more than 100kW were launched. The Porsche Taycan set new standards with a peak charging power of up to 270kW and was able to maintain an average of 224kW in the charging range from 20 to 80% SoC. With this charging power, the Taycan was able to recharge approximately 216 kilometers of range in just 20 minutes. In comparison, the Tesla Model 3 achieved a maximum charge power of 250kW, with an average of only 128kW due to a constant reduction in charging power as the SoC increased. The energy consumption of the vehicles was typically between 22 and 28kWh/100km, which was considered efficient at the time. However, the target range of 300 kilometers after 20 minutes of charging remained an unattainable ideal. To make matters worse, a nationwide fast-charging infrastructure was still barely available, which severely limited the suitability of electric vehicles for everyday use on long journeys. The options in the event of an occupied or defective charging station in the vicinity were also very limited, so a charging station was often approached with a higher remaining SoC in order to have enough remaining range for an alternative charging station, just in case.

P3 Charging Index 2021: Significant progress in charging speed and efficiency.

In 2021, significant progress was already being made in the charging speed and efficiency of electric vehicles. The Mercedes EQS, equipped with a 400V system, achieved an average charging power of 164kW and was able to recharge up to 266km of range in just 20 minutes - a remarkable increase of 50km compared to the top models of 2019. Tesla was able to maintain its peak charging power of 250kW with the Model 3, while improving its average charging power and optimizing charging times in the 10-80% SoC range. Audi achieved a constant average charging power of 146kW with the e-tron 55 quattro, making it particularly suitable for long-distance driving, although consumption was expected to be in the higher range. Energy consumption has fallen to around 20-25kWh/100km for all vehicles, thanks to aerodynamic improvements and more advanced battery architectures.

P3 Charging Index 2022: Breakthrough in the premium class category.

Outstanding charging performance in the mid-size class was demonstrated in 2022. The KIA EV6, based on Hyundai's 800V E-GMP platform and equipped set new standards. With an average charging power of 203kW, the EV6 surpassed the ideal 300km range in just 20 minutes for the first time, achieving an impressive 309km (P3CI of 1.03). This was a significant improvement on the previous year's top models. The Hyundai IONIQ 5 and Audi e-tron GT also proved to be powerful vehicles with average charging capacities of 200kW and more, making long-distance journeys much easier. Energy consumption continued to fall, reaching 18 to 20kWh/100km in the premium class and 20 to 24kWh/100km in the luxury class, taking efficiency to a new level. These developments made electric vehicles increasingly attractive not only for premium customers but also for the volume market and have made a significant contribution to the market penetration of electric mobility in the past and today.

P3 Charging Index 2024: Top level charging speed and efficiency.

In 2024, electric mobility has advanced significantly in terms of technology, reaching new levels of charging speed and efficiency. The Porsche Taycan achieved a peak charging power of 325kW and was able to maintain an average charging power of 282kW in the charging range from 10 to 80% SoC. This allowed the vehicle to recharge up to 383km of range in just 20 minutes, a significant improvement over 2022. The Hyundai IONIQ 6 also made a strong statement in the premium class with an average charging performance of 193kW and a range of 346 kilometers in just 20 minutes. Consumption has been further reduced, with peak values of around 16-20kWh/100km for vehicles such as the VW ID.7. These advances not only make electric vehicles more suitable for everyday use, but also increasingly position them as an alternative for long-distance travel. The first vehicles from China are demonstrating their capabilities.

08 Conclusion and outlook

In this edition, the P3 Charging Index once again makes the real and practical charging performance of electric vehicles comparable, considering both the maximum and average charging performance of the vehicles, combining this with the overall efficiency and standardizing these key figures to a practical and realistic use case.

Electric mobility is suitable for long distances. The current generation of electric cars, such as the winning Hyundai and the almost twice as expensive Porsche, are proof of this. But the current success could be short-lived. Electric mobility has developed rapidly in recent years. Tesla has long been considered the unchallenged market leader, but the charging performance of the Tesla Model 3 has barely improved from 2019 (1st generation) to 2024 (Highland). The charging curve has been maintained since launch without any significant further development. Instead, European OEMs have continued to improve and will overtake Tesla in terms of charging performance by 2022. However, the focus should now be on keeping an eye on the Chinese OEMs and catching up. They are already setting the standard, and we can expect the bar to be raised even higher in the future with rapid development steps. European carmakers must act quickly and vigilantly, keeping an eye on the new manufacturers and, where necessary, forging strategic alliances to keep pace.

Despite all the new records, it is also important to develop electric mobility in a sustainable way, which was the subject of P3's recently published paper on the “State of Health” of batteries: the study shows that electric vehicle batteries have a long service life, even when used intensively. Even after driving more than 200,000 kilometers, most batteries retain more than 80% of their original capacity and can therefore be used well beyond the standard warranty period. Technological advances in cell chemistry and battery management systems continue to improve battery performance and durability. However, it is important to note that higher C-rates and faster charging lead to faster aging. The consequences of this for the batteries shown in the outlook, which are charged at extremely high charge capacities or C-rates, will become clearer in the future. Finally, the critical question is whether the battery system is designed for maximum performance or maximum life.

READ ↗ Battery aging in practice

From P3's point of view, it is not technically or economically expedient to keep increasing battery sizes. Rather, optimizing the factors of charging power, efficiency and options for vehicle and battery conditioning are the most important levers for the future optimal and user-friendly design of electric vehicles. The aim is to find the sweet spot between maximum and average charging power, battery capacity and consumption in order to provide end customers with a good mix of parameters with the vehicle. If a single parameter is prioritized over others, the others often fall significantly, which ultimately diminishes the customer experience. This can be illustrated using the example of a significantly oversized battery. This is heavier and has a negative impact on consumption. On the other hand, it also requires a significantly higher charging capacity to fully charge in a short time, which must be made possible by both the vehicle and the charging infrastructure.

In the long term, the success of electric mobility will largely depend on the combination of ultra-fast charging, high range, and reduced consumption. The technologies being developed by both European and Chinese manufacturers have the potential to complement each other and take electric mobility to a new level worldwide. While European manufacturers are aiming for ambitious targets in the coming years, China has already achieved them. This is both a challenge and an inspiration.

- **Charging with 800V will become the standard.** In the short to medium term, 800V technology is expected to become the standard for medium and luxury electric vehicles and charging times will be significantly reduced across all manufacturers. It is likely that other manufacturers will require charging currents more than 500A in order to achieve further increases in charging performance. Whether 800V technology will also find its way into the cost-sensitive compact class across the board cannot yet be predicted.

- **Moderate battery sizes save weight and costs.** In the near future, most electric vehicles will be launched with batteries between 80 and 100kWh net, according to current manufacturer announcements. This range represents a trade-off, as larger batteries offer greater range but also increase the weight and cost of the vehicle. The choice of battery capacity therefore remains a critical factor affecting both the efficiency and cost of vehicles.

- **Energy consumption has a major influence on range and operating costs.** The overall energy efficiency of the vehicle can be significantly improved by continuously reducing energy consumption. On the one hand, this can lower the running costs of the vehicle, and on the other hand, energy consumption has a significant impact on the range of the vehicle. This means that it is possible to achieve a high range with a moderate battery size, by balancing the parameters and identifying the sweet spot.

- **The fast-charging infrastructure is being expanded across the board.** On one hand, customer expectations are rising in terms of both the charging capacity of the vehicles and the charging infrastructure. On the other hand, charging point operators recognize an attractive business case and are increasingly focusing on HPC charging. In addition to the growing number of fast charging points in Europe, the average installed charging capacity is also steadily increasing. While the first generation of DC charging points could provide a maximum power of 50kW, charging parks with charging points in the 300-400kW range are increasingly being installed to meet the requirements of the current generation of vehicles. In addition to the expansion of the charging infrastructure for cars, an increasing number of CPOs are also announcing the construction of charging parks for electric trucks, which means that a P3 charging index for light and heavy commercial vehicles will become more realistic in the future.

09 Data collection for the P3 CI

As in previous editions of the P3CI, vehicles optimized for range (e.g. long range model rather than performance models)[18] are tested and compared to better assess their suitability for long-distance travel. Furthermore, only vehicles equipped with the European charging standard CCS (Combined Charging System - fast charging via Combo 2 plug) are considered. To ensure consistency, practicality and comparability of results, P3 refers to the ADAC Ecotest fuel consumption figures. The consumption data used are published on the ADAC website and are all based on the current Ecotest electric cycle, which will apply from 2021. The vehicles tested are mainly press vehicles from the manufacturers. The vehicle selection aims to represent as broad a cross-section of the market as possible. However, not all vehicles were available, meaning some electric vehicles are not included in the comparison test.

To ensure comparability of the data, all charging curves shown were recorded by P3 experts at charging points with a maximum charging capacity of 350kW or 400kW. The only exception was the Tesla Model 3, which was measured at a Tesla Supercharger V4. This is because the maximum charging power of Tesla models is only available at Tesla-owned Superchargers.

The P3 Charging Index 2024 compares 22 different all-electric vehicles, including, for the first time, vehicles from China, which are now also available in Europe. The vehicles compared are divided into two categories of eleven vehicles each, which are based on the gross list price of the model in question (German market):

- **Luxury class (> 62.500€)**
- **Premium class (≤ 62.500€)**

[18]The range derivative was not available in all cases or no ADAC Ecotest data was available

FIGURE 10 :

Overview of the tested vehicles (alphabetical order)

Luxury class (> 62.500€ GLP)			Premium class (≤ 62.500€ GLP)		
	**Audi** Q8 Sportback 55 e-tron	106.0		**Audi** Q4 40 e-tron	77.0
	**BMW** i5 eDrive40	8.2		**BMW** i4 eDrive40	80.7
	**BMW** i7 xDrive60	101.7		**BMW** iX1 xDrive30	64.7
	**Genesis** Electrified G80	87.2		**Hyundai** IONIQ 6 2WD	77.4
	**Genesis** Electrified GV70	77.4		**KIA** EV6 Long Range RWD	77.4
	**KIA** EV9 GT-Line AWD	99.8		**MG** 4 Luxury	59.5
	**Mercedes-Benz** EQE SUV 350+	90.6		**Opel** Astra Electric Sports Tourer GS	51.0
	**Mercedes-Benz** EQS 450+	107.8		**Polestar** 2 Long Range Single Motor	79.0
	**NIO** ET5 Touring Long Range	90.0		**Smart** #1 Pro+	62.0
	**Porsche** Taycan	97.0		**Tesla** Model 3 Max. Reichweite Hinterradantrieb	79.0
	**Xpeng** G9 Performance AWD	93.1		**Volkswagen** ID.7 Pro	77.0

Net battery capacity [kWh]

*To simplify the presentation in the graphs, not all models are shown with their full name as in Figure 10, but in some cases only the manufacturer and model are given.

Compact cars are not compared separately in this edition, as many new models are about to be launched or were not yet available for testing (e.g. Citroën ë-C3, Hyundai Inster, KIA EV3, Leapmotor T03, BYD Dolphin, Ford Puma GEN-E), in addition to those already on the market (e.g. MINI Cooper SE, Dacia Spring, Renault 5). In the next edition of the P3 Charging Index, this category will also be compared again, when sufficient vehicles are available.

In addition to 15 new vehicles (Audi Q4 e-tron 40, BMW i5, BMW i7, BMW iX1, Genesis G80, Genesis GV70, Hyundai IONIQ 6, KIA EV9, Mercedes-Benz EQE SUV, MG 4 Luxury, NIO ET5, Opel Astra, Smart #1, Volkswagen ID.7, Xpeng G9) that are included in the P3CI for the first time, there are also updates to vehicles from previous publications that have received a facelift. These have been re-evaluated in terms of charging performance, battery size and consumption (Audi Q8 e-tron, Polestar 2, Porsche Taycan, Tesla Model 3). The BMW i4, Mercedes-Benz EQS and KIA EV6 were included in previous editions.

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About P3

P3 Group GmbH is a leading, independent consulting and services company with an international focus. In addition to strategic management consulting, P3 offers innovative engineering solutions and software development for a variety of industries and customers worldwide.

Since its founding in Aachen in 1996, P3 has built up a global network consisting of 33 locations on 4 continents and employs over 1,800 highly skilled professionals in 27 subsidiaries.

The P3 Group has a particular focus on electric mobility. Since 2006, P3 has been supporting its partners along the entire value chain - from cell and battery production, powertrain concepts and charging infrastructures through to industrialization. This comprehensive expertise enables P3 to provide strategic advice and to develop and implement practical solutions for its customers through in-depth technological understanding.

In addition to consulting, P3 is active in the development of innovative technologies: These include investments in battery cell research, modular drive strategies, 48V on-board network architectures and customized software solutions that are shaping the e-mobility of tomorrow.

P3's customers include leading international car manufacturers, their suppliers, energy suppliers, charging infrastructure operators and public sector players. Through benchmarking and in-depth analyses, P3 supports these customers in mastering complex challenges and designing sustainable solutions.

P3 Group GmbH
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List of abbreviations

2WD	2 Wheel Drive
4WD	4 Wheel Drive
A	Ampere
AWD	All Wheel Drive
BEV	Battery Electric Vehicle
BLP	Gross list price
CCS	Combined Charging System
CPO	Charge Point Operator
cW	Flow resistance
E-GMP	Electric Global Modular Platform
FWD	Front Wheel Drive
h	Hours
HPC	High Power Charging
km	Kilometer
kW	Kilowatt
kWh	Kilowatt hours
LFP	Lithium iron phosphate
min	Minutes
MMA	Mercedes Modular Architecture
NMC	Nickel-manganese-cobalt
OEM	Original Equipment Manufacturer
P3CI	P3 Charging Index
PPE	Premium Platform Electric
RWD	Rear Wheel Drive
SoC	State of Charge
V	Volt

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