EVS37

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P3 Charging Index - Asia

Comparison of the fast-charging capability of various battery electric vehicles

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II. Charging diagrams of P3 field tests

III. Vehicle consumption evaluation

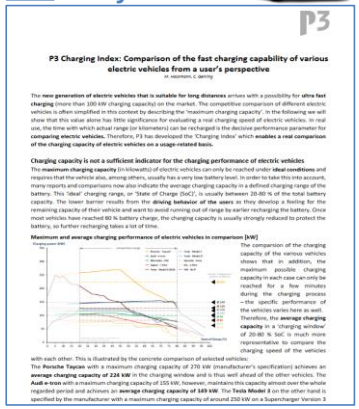
IV. Deep dive into the P3 Charging Index for the Asian market

V. Learnings and outlook by considering the P3 Charging Index

Content

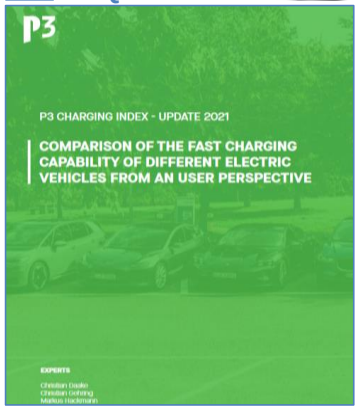
Since 2019, P3 has published four reports for the European and US markets on the long-distance suitability of all-electric vehicles.

1 Porsche Taycan


P3 Charging Index: Comparison of the fast charging capability of various electric vehicles from a user's perspective

P3 Charging Index
Europe - Issue 01
12 / 2019

1 Mercedes EQS



P3 Charging Index
Europe - Issue 02
04 / 2021

1 KIA EV6

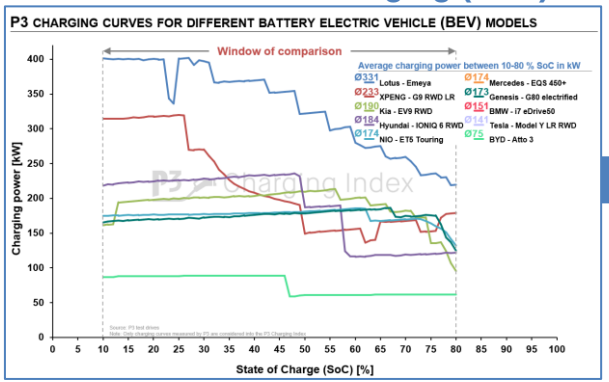
P3 Charging Index
Europe - Issue 03
07 / 2022

1 Lucid Air GT

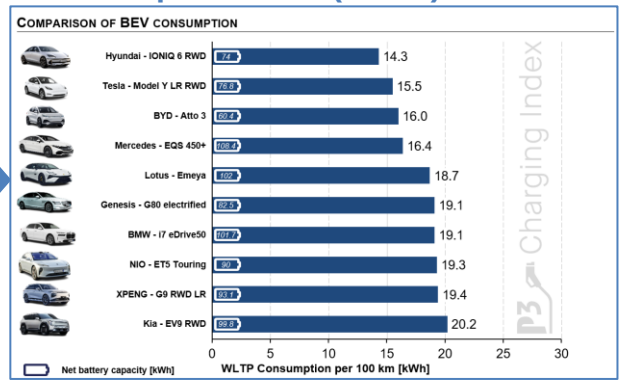
P3 Charging Index
United States - Issue 01
06 / 2023

The P3CI - Asia target value of 1.0 shows the ability of EVs to recharge to 300 km of range within 20 minutes starting from 10% SoC.

Delivered amount of energy in 20 minutes of charging (kWh)



Divided by consumption per 100 km (WLTP)



Recharged range within 20 minutes

P3 Charging Index = Recharged range within 20 minutes / 300 km

The **target value of 1.0** corresponds to a range of 300 km recharged within 20 minutes

The P3 Charging Index was introduced in 2019, where the target of OEMs was to gain 300 km recharged range within 20 minutes, which equates to a P3 Charging Index of 1.0. Since then, electric mobility has evolved rapidly, with an increasing number of vehicles being able to charge up more range within this amount of time, which results in values greater than 1.0.

The P3CI - Asia lists ten all-electric vehicles which are compared in one class, composed of EVs both from Asian and global OEMs.

Mercedes-Benz – EQS 450+ (108.4 kWh)

Lotus – Emeya (102 kWh)

BMW – i7 eDrive50 (101.7 kWh)

KIA – EV9 RWD (99.8 kWh)

XPENG – G9 RWD LR (93.1 kWh)

NIO – ET5 Touring (90 kWh)

Genesis – G80 electrified (82.5 kWh)

Tesla – Model Y LR RWD (76.8 kWh)

Hyundai – IONIQ 6 RWD (74 kWh)

BYD – Atto 3 (60.4 kWh)

1) Battery capacities are net in kWh
2) The order of vehicles is based on the battery capacity in kWh in decreasing order
3) Sources (Pictures / Consumption): EV Manufacturer
4) Flags show domestic market of the manufacturer for P3CI - Asia

Content

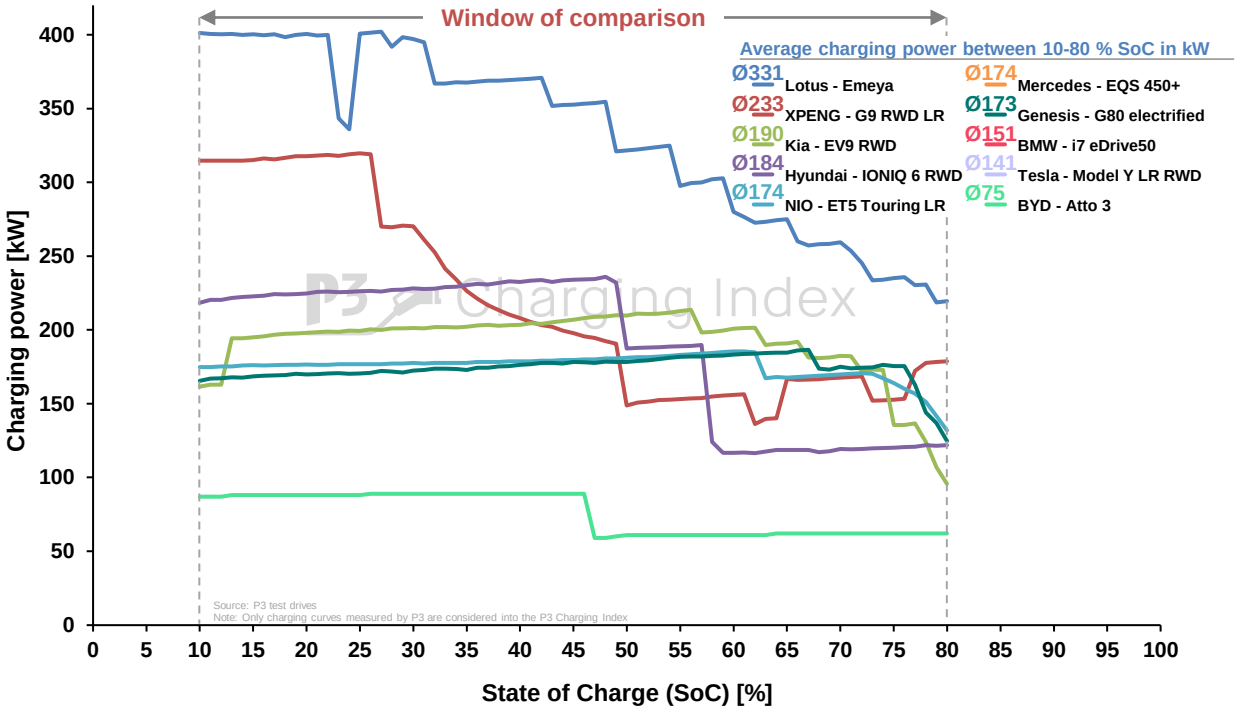
Charging curves were measured at public EVSEs with CCS1 / CCS2 and up to 400 kW. Tesla EVs were measured at Tesla Supercharger V3.

1. Most charging curves were **measured at EVSEs with** a CCS1 or CCS2 connector and a **maximum charging power of up to 400 kW.**
2. These charging stations are mostly from manufacturers like **ABB, Alpitronic, BTCPower, Signet, Tritium, and Xcharge.**
3. Only the **Tesla EVs** were **measured at Supercharger V3 with NACS (US) or CCS2 connector (Europe).**
4. **Derivation of charging power** by measuring of communication (PLC) **between EV and EVSE** with an inductive coupler and *Vector CANoe.*
5. This ensures that **the charging station does not restrict the charging power**, as it is the **EV that determines the charging power.**
6. The **EVs were preconditioned** (if available) for the **best possible charging performance.**
7. Redundant **video recording of the EVSE screen.**

EV = Electric Vehicle
EVSE = Electric Vehicle Supply Equipment
CCS = Combined Charging Standard
NACS = North American Charging Standard
PLC = Power Line Communication

A comparison of the EVs from Asia shows that Lotus Emeya with over 400 kW and XPENG G9 with 320 kW are clearly on top.

P3 CHARGING CURVES FOR DIFFERENT BATTERY ELECTRIC VEHICLE (BEV) MODELS

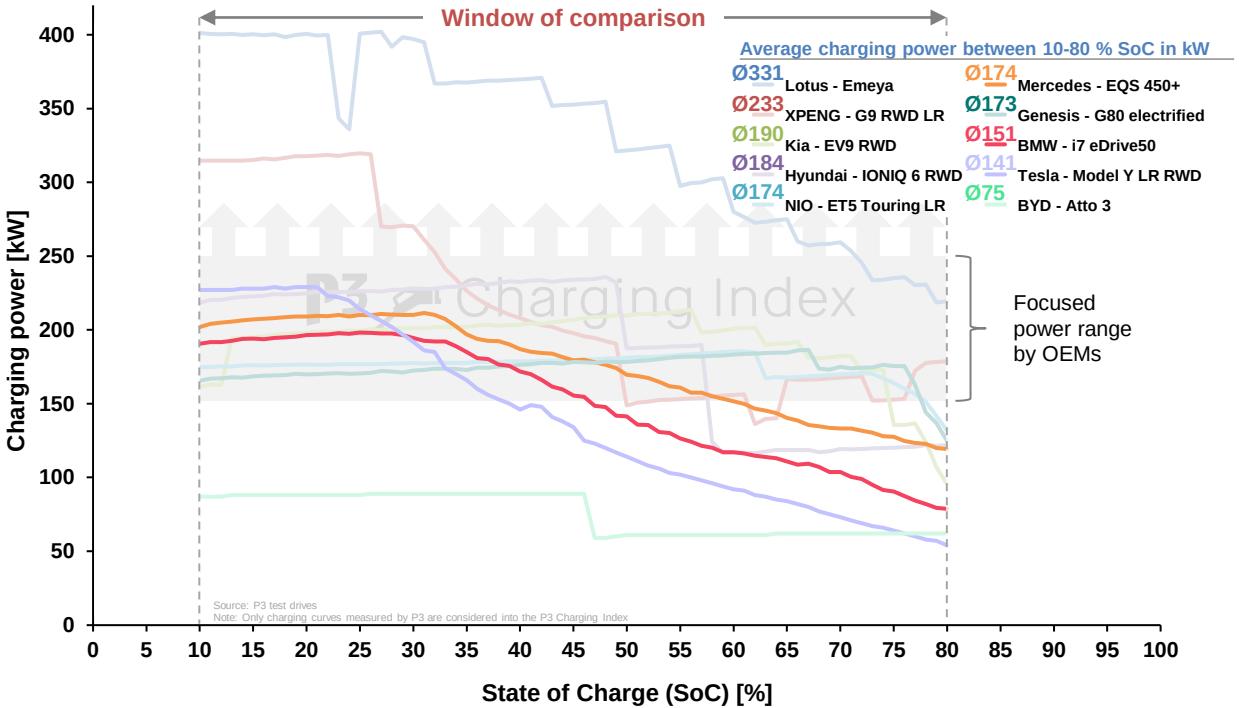


KEY FINDINGS

- The **Lotus Emeya** reaches **402 kW at peak** and the **average value of 331 kW** is significantly higher than all the max values of the other vehicles.
- This charging power is achieved by a **charging current of over 550 A**. However, the **first plateau** is affected by a **power dip** probably due to **increased temperature**, which causes power regulation.
- The **XPENG G9** also delivers **charging performance** with up to **320 kW at peak** and an **average of 233 kW.**
- The **Hyundai IONIQ 6** with the E-GMP platform charges with **over 235 kW** at its peak and its **average of 184 kW** is also remarkable.

The majority of global EVs locates them in the transition between 150 kW and 250 kW, which represents the current focused power range.

P3 CHARGING CURVES FOR DIFFERENT BATTERY ELECTRIC VEHICLE (BEV) MODELS

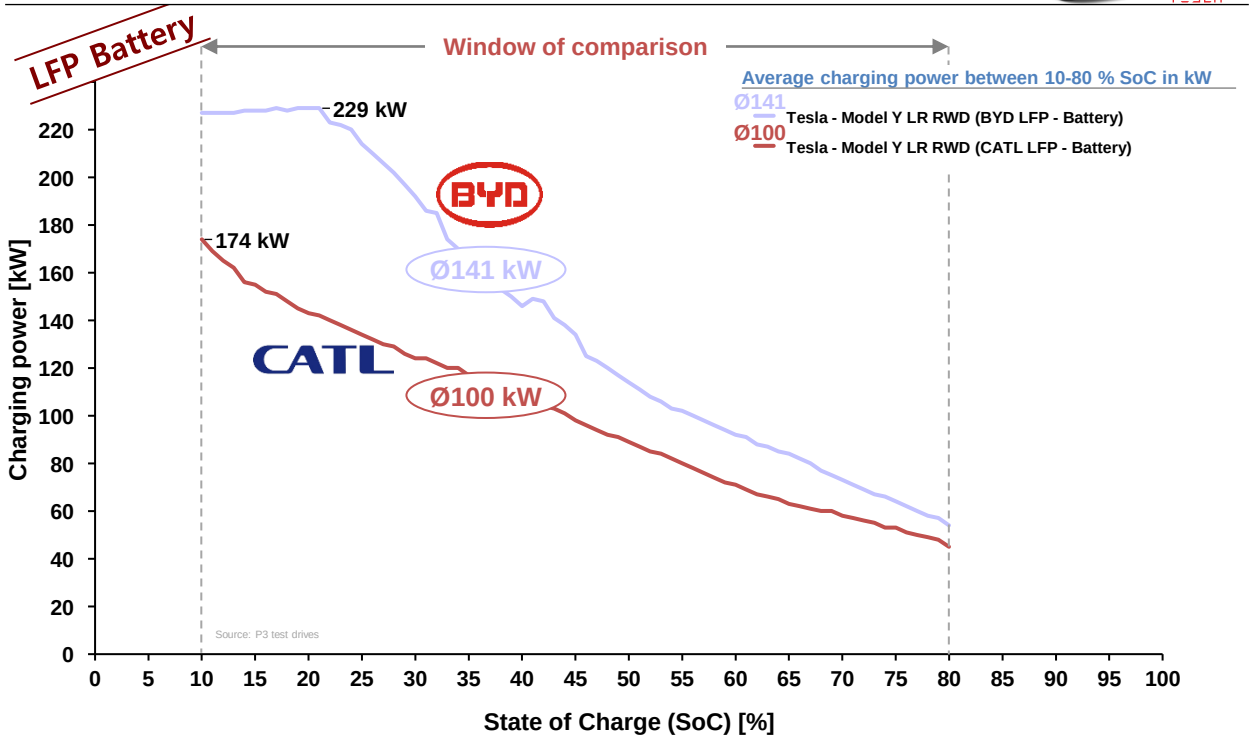


KEY FINDINGS

- The **charging power** for most EVs is currently in the range of **150 kW to 250 kW**. This can be achieved with a **400 V system architecture** at a charging **current of 500 A**, as well as with an **800 V system** and thus lower charging currents.
- For EVs with **800 V system** architecture (or their platforms), **charging currents** are **expected** to **increase in the medium term**, which will **push their charging capacity** into the **range from 250 kW to 350 kW.**
- However, this presents a challenge for vehicles with **400 V architecture**, as the required **charging currents exceed the current CCS standard of 500 A**.

Automobile manufacturers are innovating their EVs to incorporate new technologies while maintaining the same underlying platforms.

CASE STUDY OF TESLA MODEL Y LFP BATTERY EVOLUTION



KEY FINDINGS

- The current battery technology allows OEMs to **innovate their** vehicles, **without** the **customer initially noticing any major changes.**
- **Tesla** for example has upgraded the **Model Y** from a **CATL battery to BYD battery**, increasing the **average charging power** from **100 kW to 141 kW** between 10-80 % SoC.
- The **main difference for the average charging power** is based on a plateau that is **maintained** by the **BYD battery** up to almost **25% SoC.**
- For the **CATL battery instead**, **no plateau is visible**, but the **charging curve** is **decreasing linear.**

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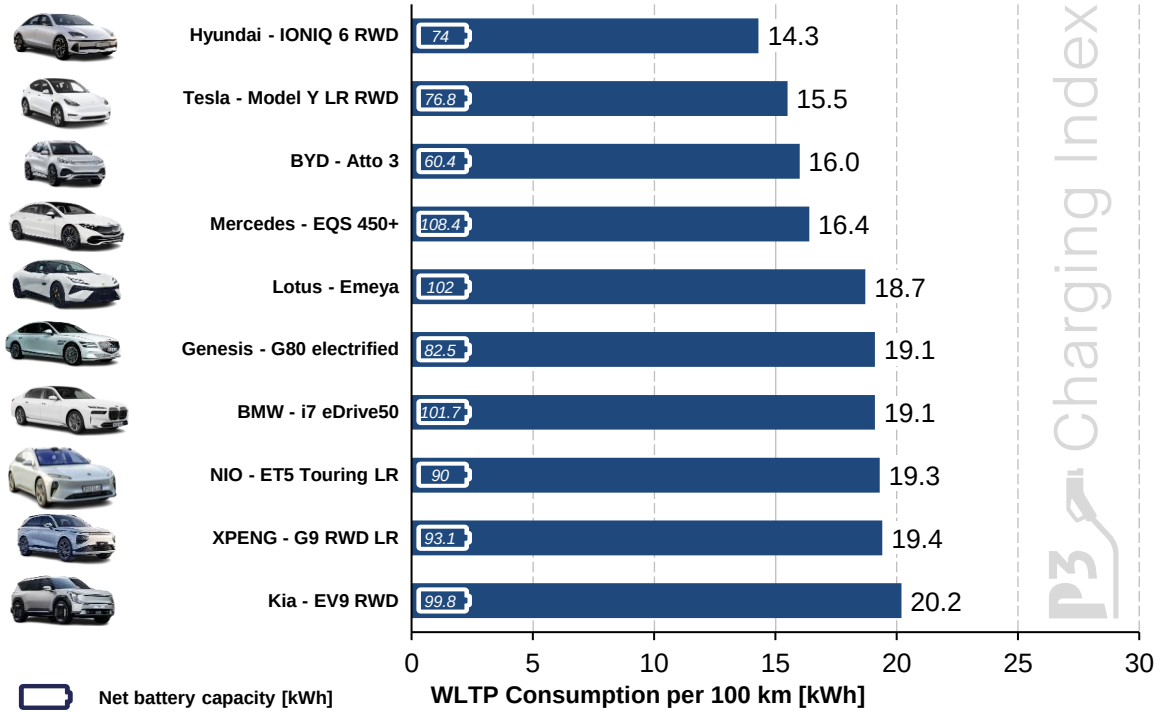
The Hyundai IONIQ 6 has the lowest consumption, that outperforms the other vehicles considered, but also has a small and light battery.

Comparison of BEV consumption



Key Findings

- The **Hyundai IONIQ 6** (14.3 kWh/100 km) and **Mercedes EQS 450+** (16.4 kWh/100 km) maintain a low consumption by **following a very aerodynamic design philosophy.**
- Due to the **Tesla Model Y´s less aerodynamic** SUV form factor, this reduces its overall consumption because of a **highly efficient ePowertrain** (15.5 kWh/100 km).
- With its even **larger 102 kWh battery**, **highly efficient ePowertrain** and sleek **aerodynamic design**, the **Lotus Emeya** achieves an overall consumption of outstanding **18.7 kWh/100 km**.
- The **BMW i7** is also remarkably below **20 kWh/100 km**, despite its similar **sized battery as the Lotus**.

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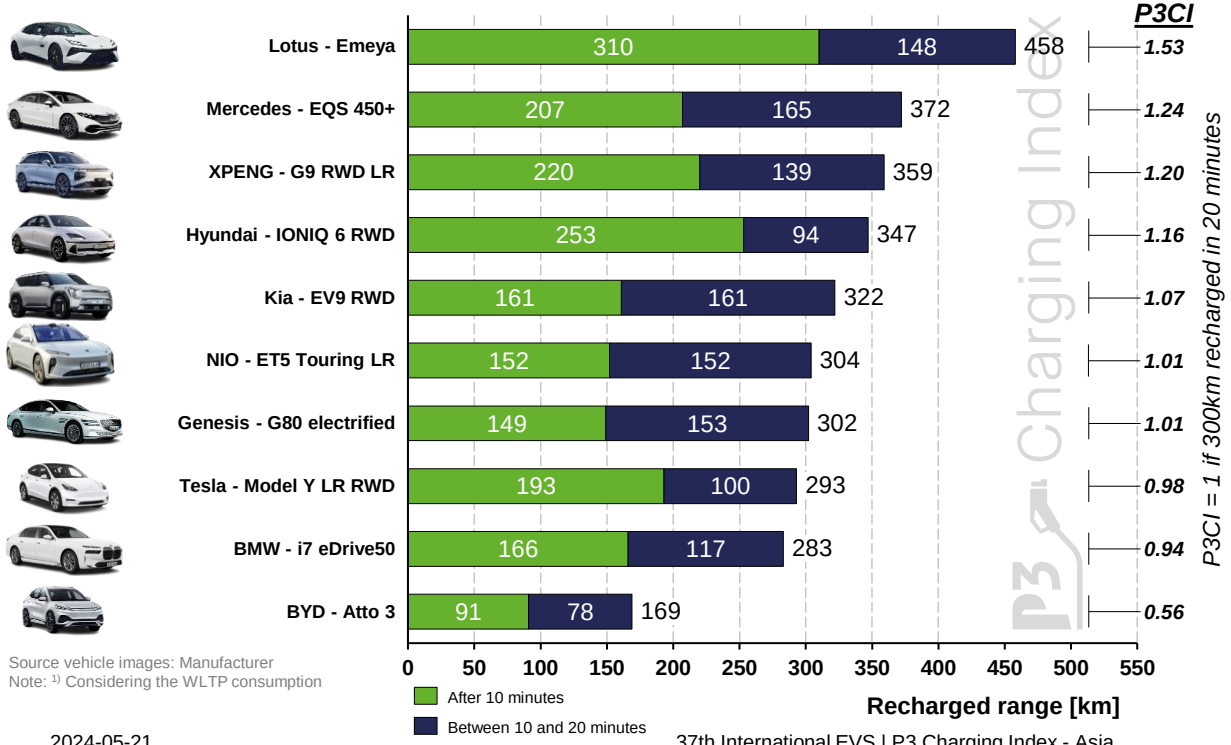
In total, seven EVs are above the P3CI of 1.0, with the Top 3 being significantly higher at almost 350 km plus.[1)]

Comparison of recharged range in km after 10 and 20 min of charging (start @10% SoC)



Source vehicle images: Manufacturer
Note: [1)] Considering the WLTP consumption

Key Findings

- Within **14 minutes**, the **Lotus Emeya charged up to 80% SoC**. **After 80%** SoC, the charging **power dropped**, **resulting in** only **148 km** recharged range between 10 and 20 minutes. Overall, the Lotus can charge **458 km** within 20 minutes to a **P3CI of 1.53**.
- The **IONIQ 6** has the **2nd highest** value for the **first 10 minutes** and **drops hard for the 2nd 10 minutes**, which is a result of its strategy of plateau charging, resulting in a **P3CI of 1.16**.
- The **KIA EV9** is one of the **most consistent** over the **20 minutes** with **161 km** on 1st and 2nd 10 minutes, resulting in a **P3CI of 1.07.** This results out of a **very consistent charging power** based on a **dip at the beginning** of **charging** and **the regular derating over time.**

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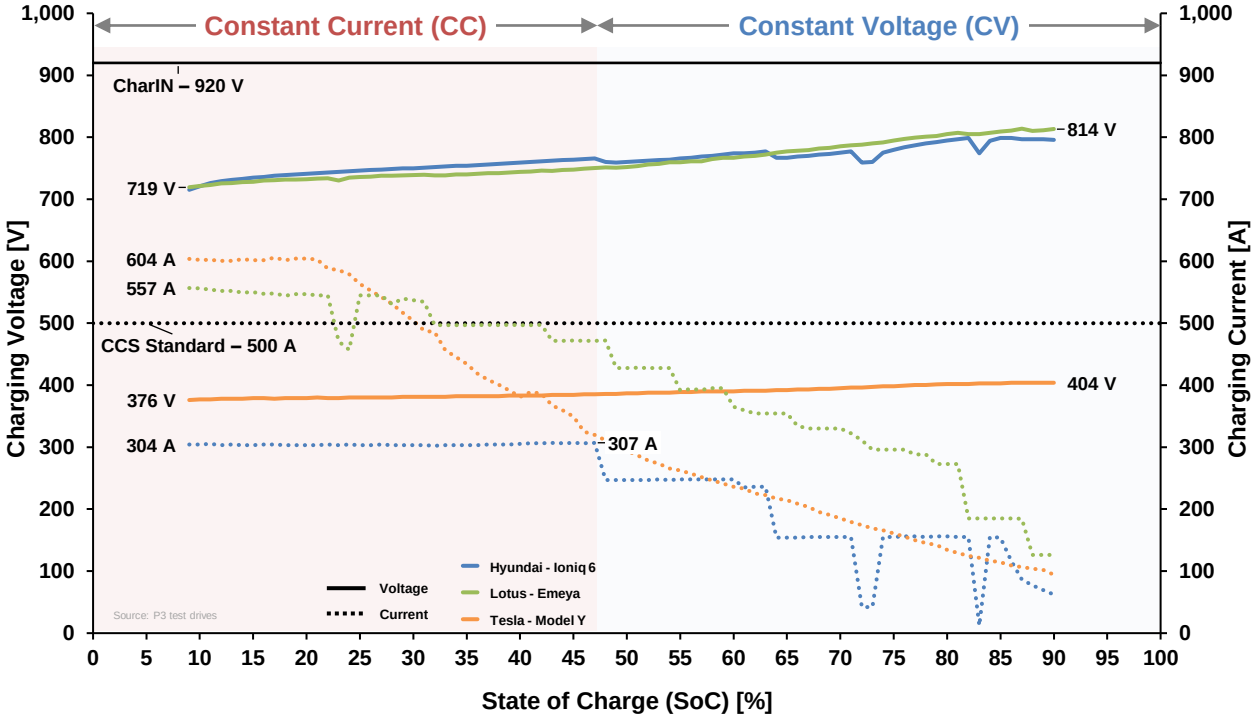
The max. charging power for EVs is based on max. 920 V (CharIN) and max. 500 A according to the CCS standard, resulting in 460 kW.

P3 CHARGING CURVES FOR DIFFERENT BATTERY ELECTRIC VEHICLE (BEV) MODELS



KEY FINDINGS

- The **current limits of CCS charging according to the standard** are defined by the CharIN **with max. 920 V** as the upper limit for HPC charging stations and the CCS standard with **max. 500 A**.
- Both **values must be fully utilized** to achieve the maximum **theoretical charging power of 460 kW**.
- The value of 460 kW is **not achieved as high charging currents are only possible up to 45%-50% SoC**, and the battery **voltage at these low SoC** values is still far from 920 V, often even well below 800 V.
- To further **increase the charging power**, either charging **voltage or current need to be increased**.

Management Summary

- The first EVs are able to charge up with **charging power greater 400 kW**, what **allows to recharge 300 km already in 10 minutes**, **even** if the overall **consumption is between that of the competitors.**
- The actual **focused power range by OEMs** to charge up their vehicles **is between 150 - 250 kW.**
- However, OEMs are **constantly evolving technology** and place them **into existing platforms**, to ensure updates like higher max. charging power, energy density, or **better charging performance**.
- Vehicles with **less average charging power** and **smaller batteries can compete with other EVs**, **by optimizing their overall consumption**.
- Compared to the **beginning of P3 Charging Index back in 2019**, several **vehicles are now able to recharge** a range of more than **300 km within 20 minutes**, which equates to a **P3 Charging Index of greater than 1.0.**
- The **maximum charging power of 460 kW** (920 V - CharIN and 500 A - CCS) is **not reached due to charging strategy limitations for battery systems**.
- To achieve higher charging power, EVs can get **charged with higher currents above the CCS standard range of 500 A for both, 400 V as well as 800 V system architecture.**

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