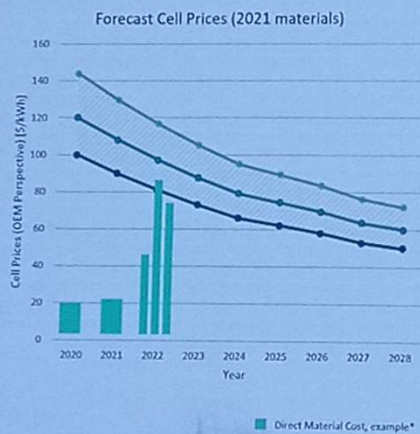




2022 EV Trends: Increased risk in Battery costs

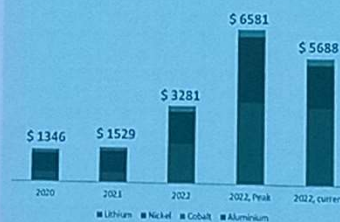
2022 is the first year, battery cell costs are increasing substantially due to raw material cost fluctuations



Dramatic battery raw material price increase in 2022

Nickel: +300% (peak)
Cobalt: +250% (peak)
Lithium Carbonate: +600% (peak)
Lithium Hydroxide: +800% (peak)

Tesla Model Y Battery Cell Materials



Tesla NCA	Weight per Car [kg]
Lithium	7.69 kg
Nickel	58.52 kg
Cobalt	3.27 kg
Aluminum (Oxygen)	

* Without processing, tax

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Hyundai IONIQ 5 RWD: Powertrain Overview

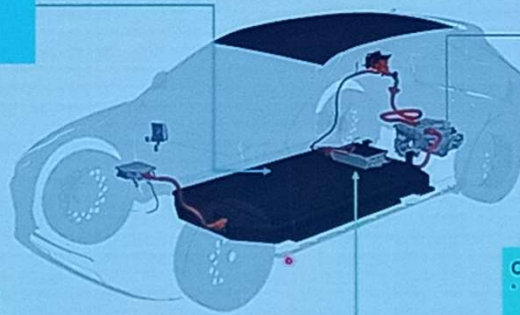
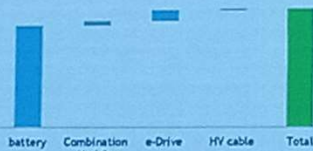
HV-BATTERY

- 72.6 kWh (specification, measured to be 77.3 kWh) / 653 V
- Pouch Cells by SK Innovation
- 450 kg / 474 l
- 171 Wh/kg, 163 Wh/l



Detailed bottom-up cost analysis on component level

Cost Analysis IONIQ 5 Powertrain, 2022, 150k, Korea



E-AXLE

- Ratings: 160kW, 350 N.m (Peak Motor torque)
- Weight and Volume: 90.68 kg / 99 ltr (bounding box volume)
- KPIs: 1.76 kW/kg; 1.61 kW/l
- 3-in-1 System (high level of integration in the e-axle)
- Inverter and Motor partially realize the HV boosting Function

COMBINATION MODULE: OBC + DC/DC

- Combined module, integrates both DC/DC and OBC
- 11.92 kg, 47l (very large and bulky solution)
- 11 kW, 1 phase OBC
- 1.4 kW DC/DC
- Good level of integration between modules, relatively compact

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Hyundai Motors: Electric Global Modular Platform



800V

First 800V system in volume production



125kW - 560kW

Modular e-axle design for the platform



- Genesis
- Kia
- IONIQ



Fast Charging in 18 min

One of the fastest charging time among EVs



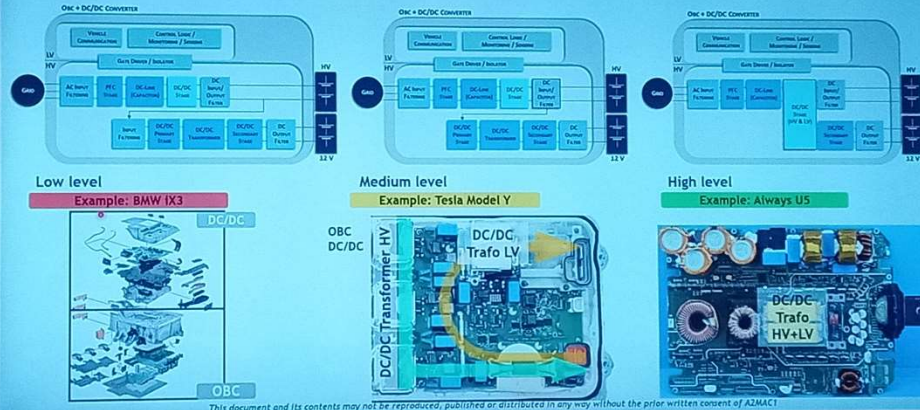
SiC Technology

Key to make a more efficient and achieve higher range

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System integration: HV Architecture

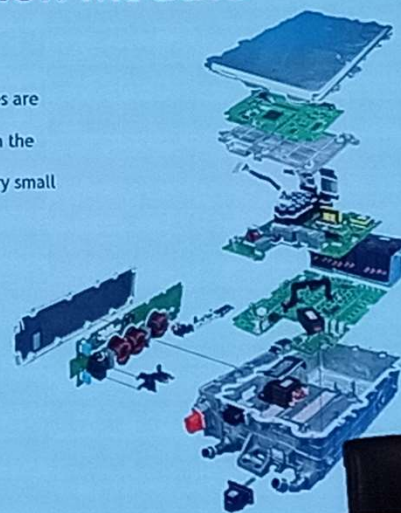
Different levels of integration have been studied.



Hyundai IONIQ 5: Combination Module

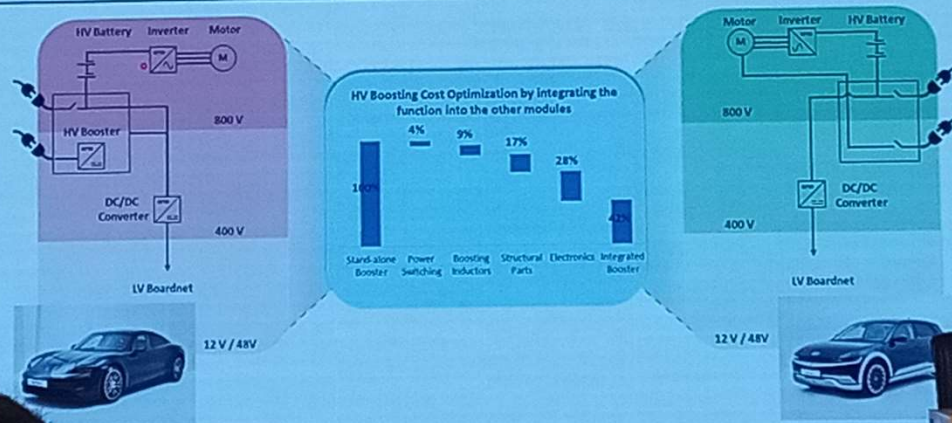
Functional Principle / Short Description

- 11 kW Onboard Charger (OBC) and 800 to 12 V DC DC Converter
- OBC and DC DC Converter parts share all PCBAs. The main shared functionalities are input/output filtering, control and cooling system.
- The OBC is bidirectional and can be used to operate 220 V devices via a plug on the vehicle.
- The DC DC Converter uses a small DC DC Transformer and is in general built very small

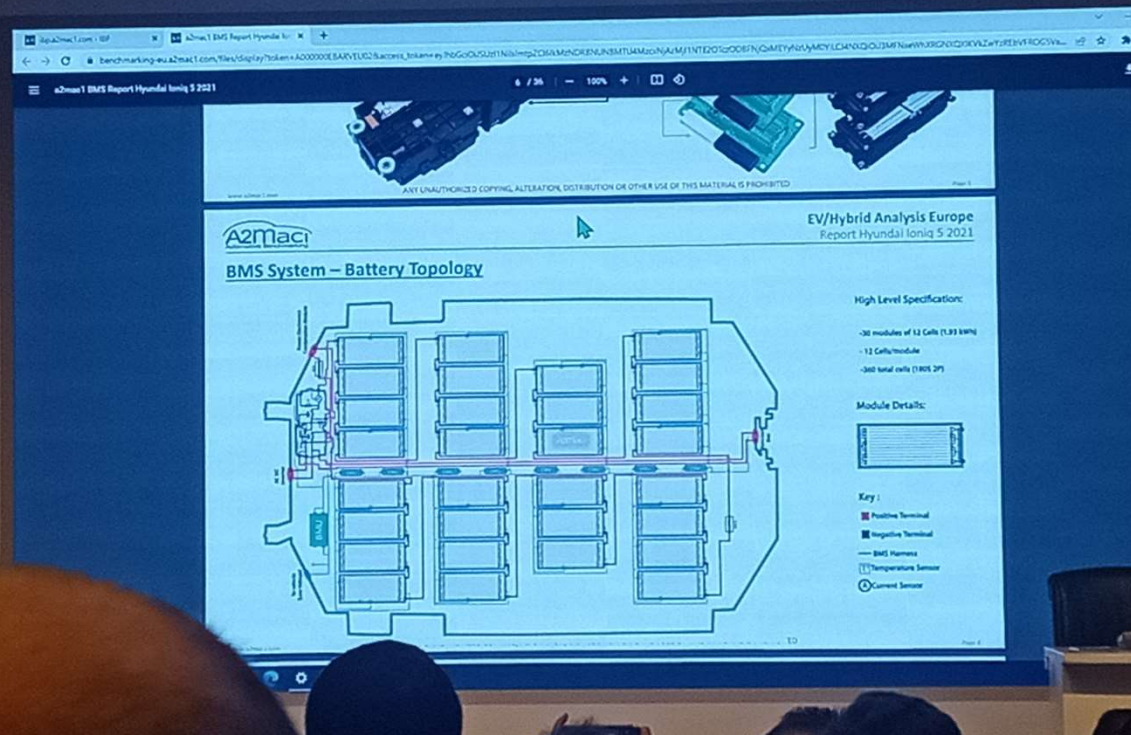


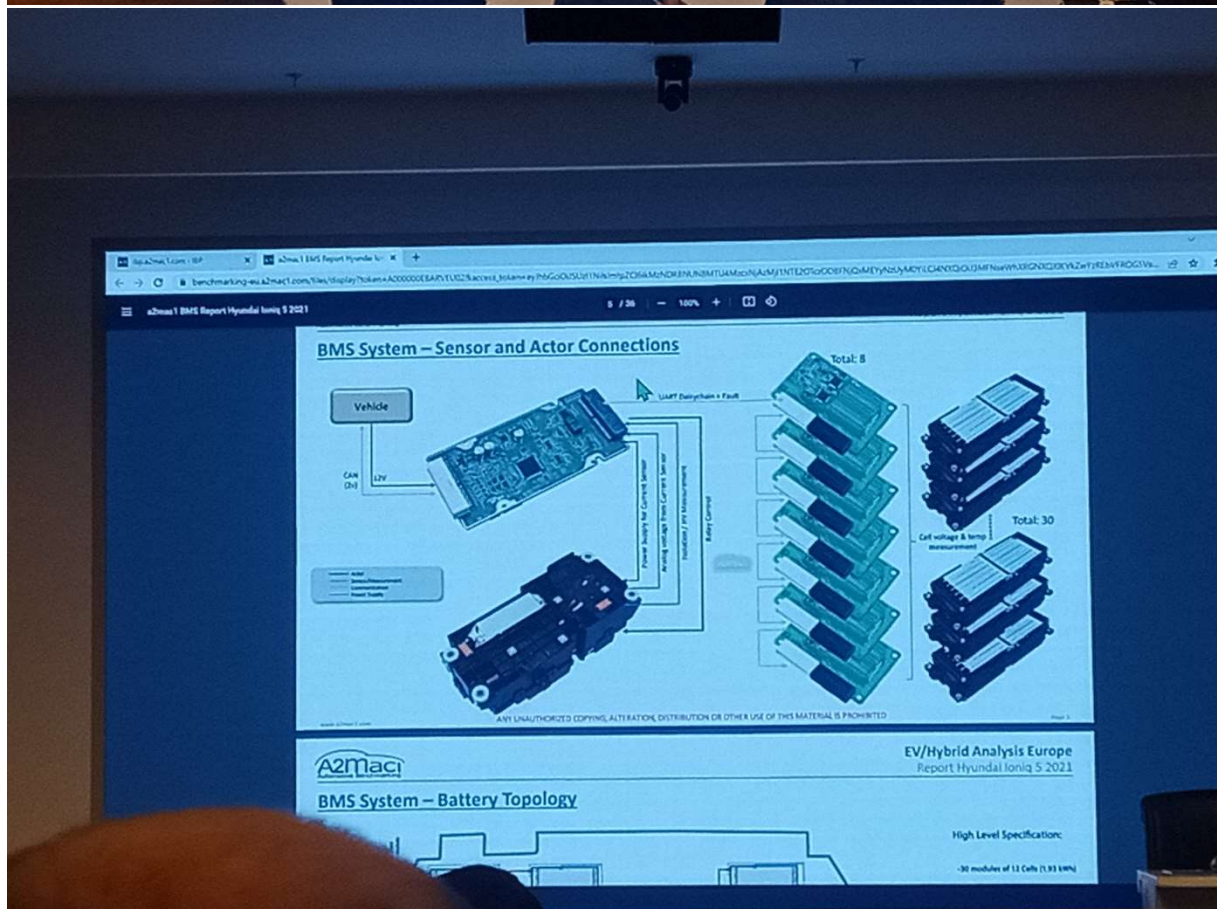
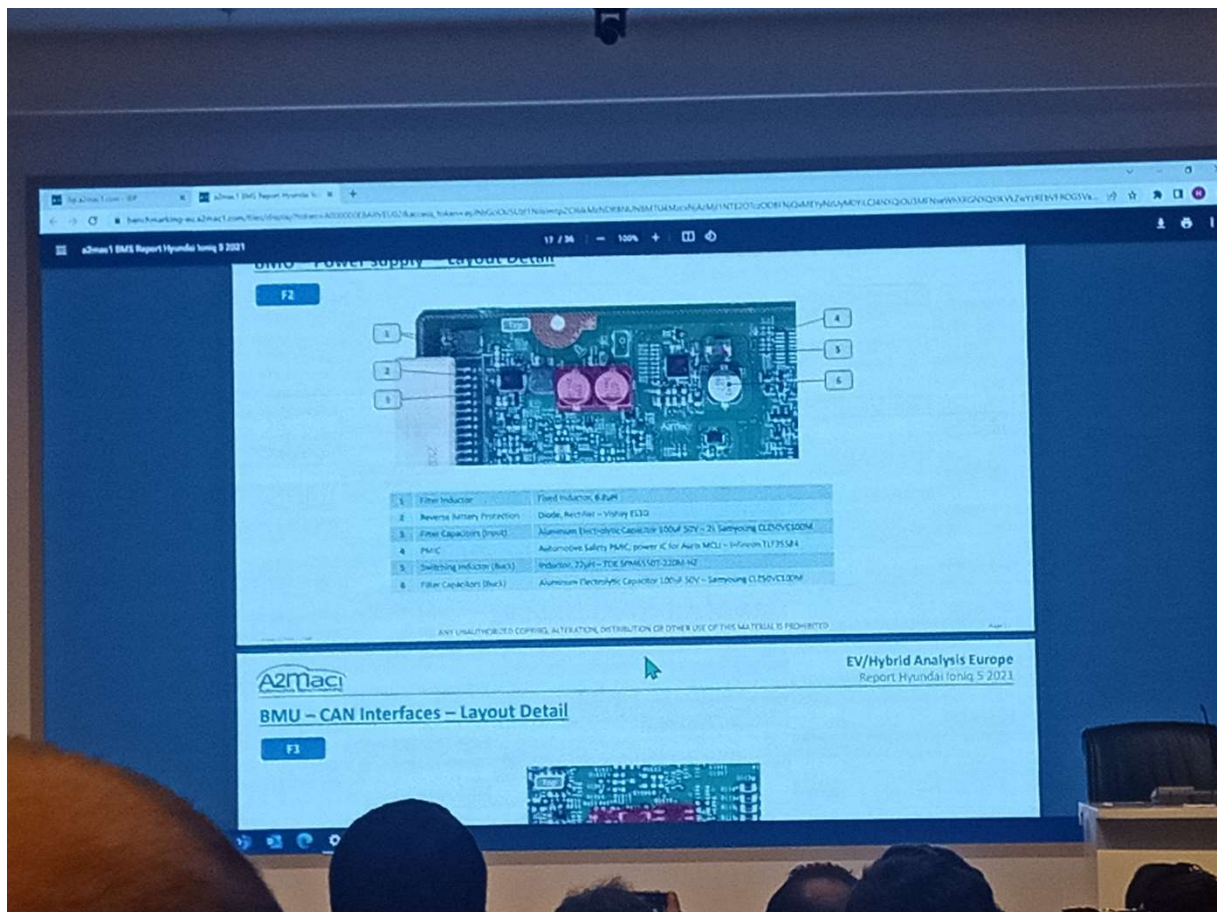
Power Electronics: Trend towards integration

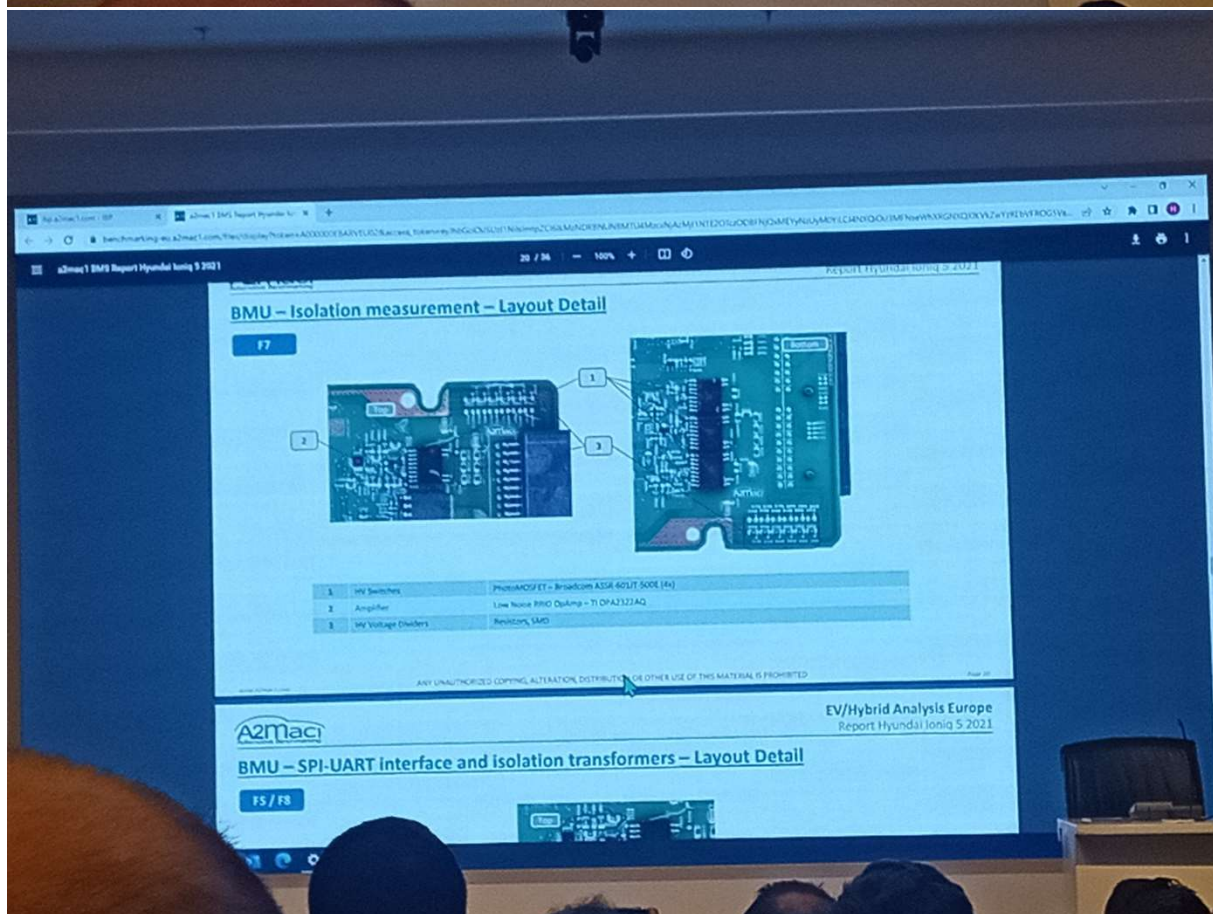
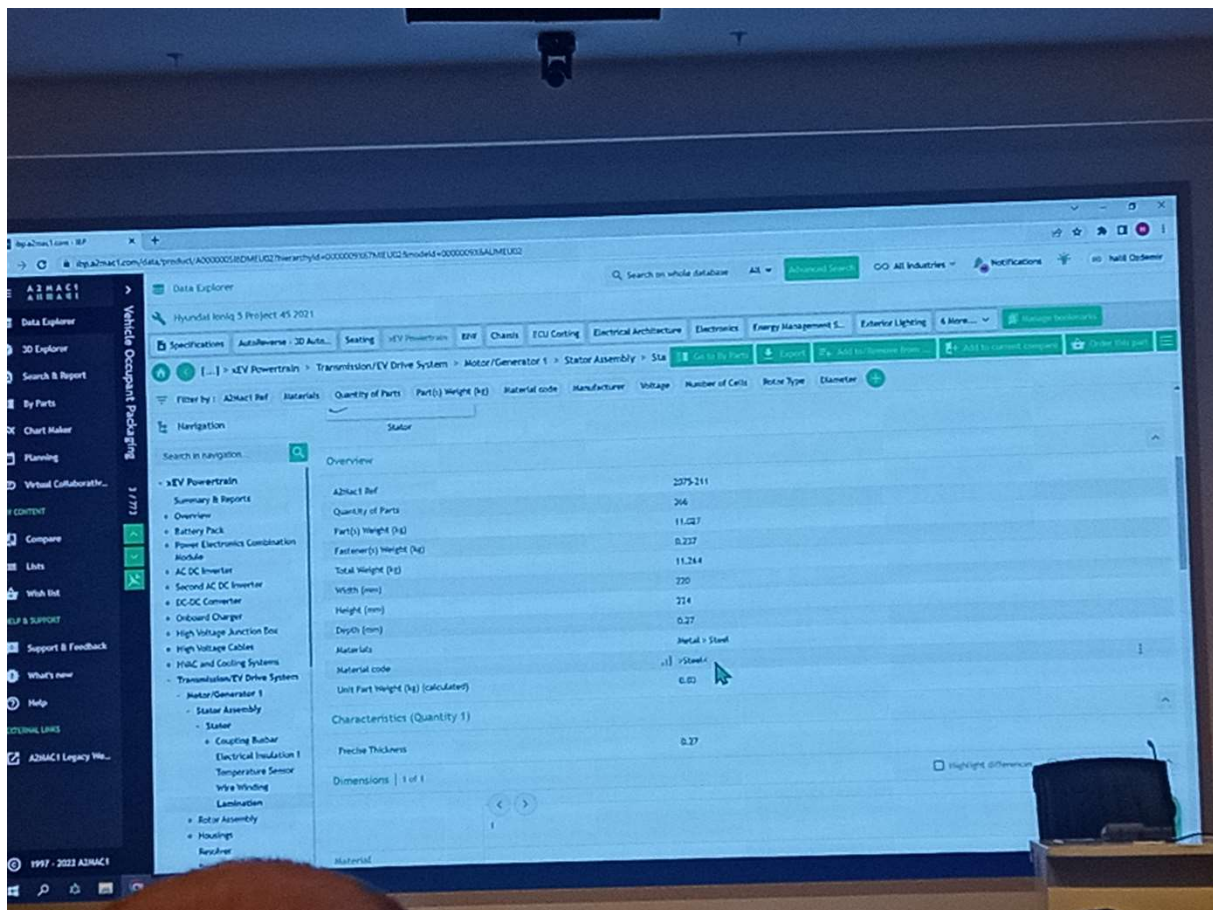
IONIQ 5 800V system with boost functionality integrated in eDrive for cost improvement



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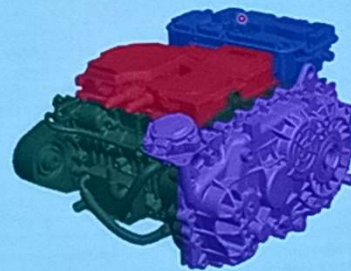




Hyundai IONIQ 5 : e-Axle Overview

Specifications & KPI

Phase	3- phase
Weight [kg]	90.68
Volume [Lit]	99
Peak power [kW]	160
Continuous power [kW]	88
Peak Torque [Nm]	350
Output Peak Torque	3720
Cooling	Oil Cooled
Rotor speed [RPM]	14600 (calculated)
Manufacturer GBX and Motor	Hyundai- Mobis
Manufacturer Inverter	Vitesco
Mechanical Production	South Korea
Assembly	South Korea
E-Axle total Cost [150k/a]	1672 \$



■ Inverter ■ Motor ■ GearBox ■ JunctionBox

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Hyundai IONIQ 5- Battery

Overview & KPI

General

- Hyundai Ioniq 5 with the new E-GMP architecture
- 800 Volt system

Mechanical Structure

- The cooling plate is directly attached to the enclosure frame from below, forming the bottom enclosure
- The battery is protected from below with GFRP based plate
- The cells are cooled from the bottom, directly cooled by the cooling plate

Battery Cells & Modules

- Pouch Cells by SK Innovation
- Configuration of 180S 2P on pack level

Battery Management System

- 1 master and 8 slaves, located inside the battery
- 1 Relay Box at the back of the vehicle

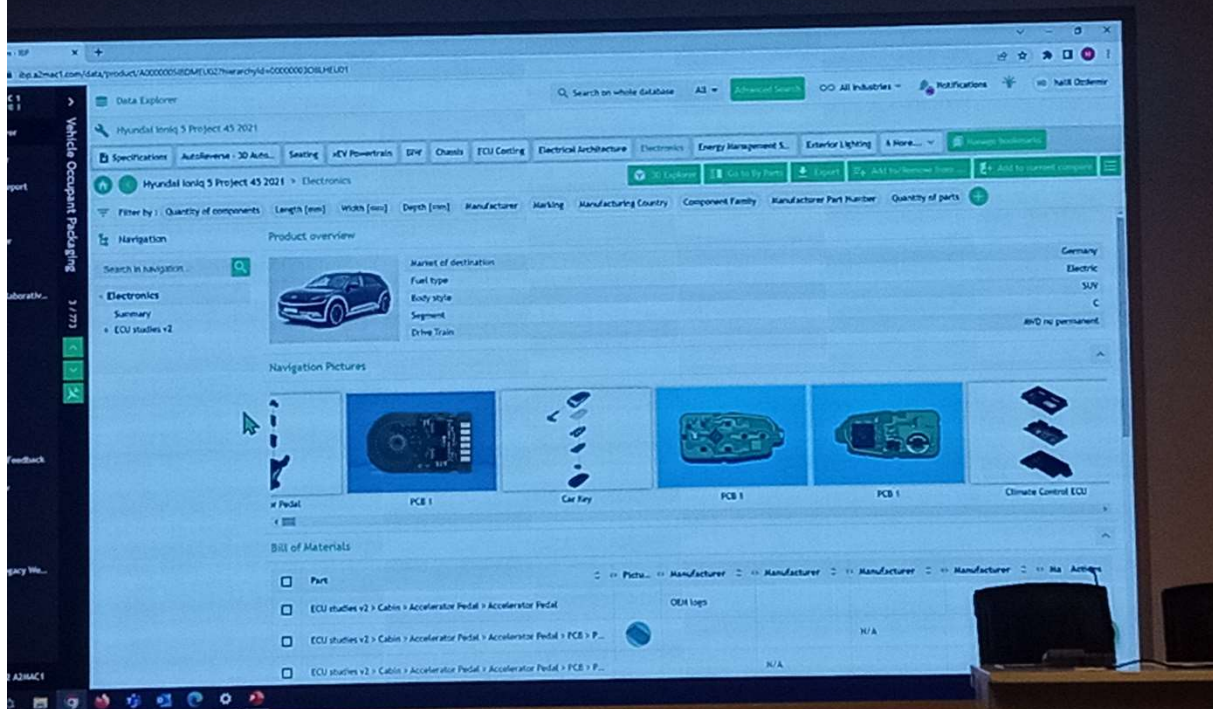
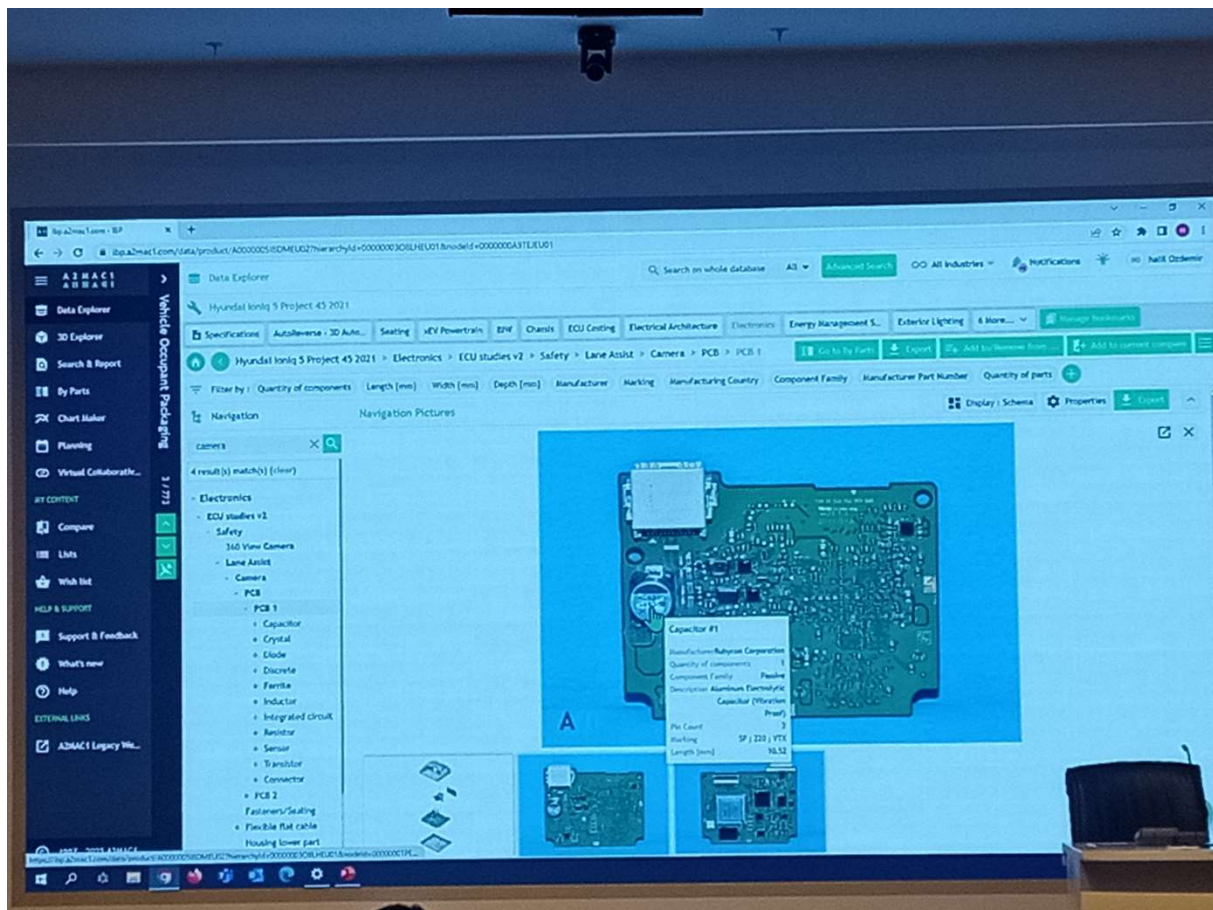
Interconnections

- Slaves are interconnected with short cables
- HV busbars for power connection

Nominal Battery Voltage [V]	666 (calculated)
Energy [kWh] (spec. by manuf.)	72.6
Energy [kWh] (A2mac1)	77.26 (based on cell report)
Energy density [Wh/l]	163
Specific energy [Wh/kg]	171
Weight [kg]	450 kg
Dimensions [mm ³]	1460 x 212 x 2190
Cooling	Liquid
Battery Assembly	Hyundai - Korea
Cell Supplier	SK Innovation
Country of Production	Korea

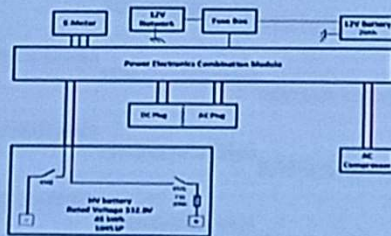
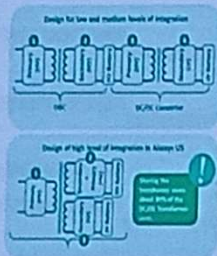


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2022 EV Trends: Next level of integration in Power Electronics

As technology matures, first OEMs are ready to launch fully-integrated Power Electronics concepts.



Integration of power electronics modules

- Even lowest degree of integration of power electronics modules (i.e., OBC and DCDC just share the housing) can lead to cost reduction.
- Higher degree of integration involves sharing of power path, power transformers and control functions.
- High degree of integration can improve the powertrain electrical architecture and therefore minimize HV cable cost.

Case study: BYD Dolphin Flagship

- BYD Dolphin is a good example of low cost, city car with relatively small battery capacity of 47kWh and cost of less than 15 k\$.
- BYD Dolphin integrates Inverter, OBC and DC/DC in one unit, which is mounted on top of motor assembly.
- With this special design, BYD also minimizes effort for HV cable cost, voltage drop and cable in powertrain