A2MAC1
Hyundai Ioniq 5 Project 45 2021
Magnet 1 Assembly

AC loop
A2MAC1
Hyundai Ioniq 5 Project 45-2021 EV/Hybrid Thermal System Schematic
EV/Hybrid thermal system schematic
Hyundai Ioniq 5 Project 45 2021

A2MAC1
Hyundai Ioniq 5 Project 45 2021
Motor/generator 1
A2MAC1

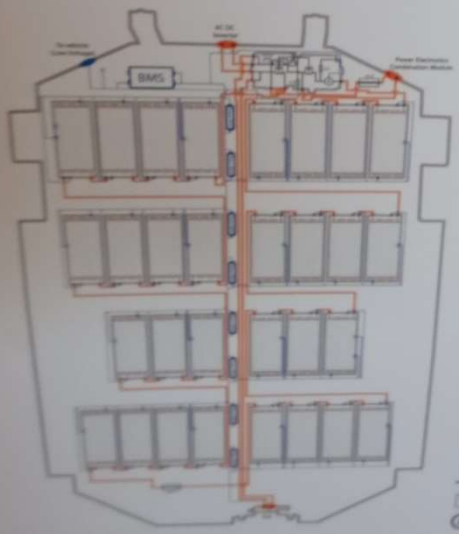
A2MAC1
Hyundai Ioniq 5 Project 45 2021
2nd AC DC inverter

A2MAC1

Hyundai Ioniq 5 Project 45 2021

High voltage battery Electric schematic

Hyundai Ioniq 5 Project 45-2021
72.6kWh High Voltage Battery Electric Schematic



High Level Specification:

- 30 modules of 12 Cells (1.93 kWh)
- 12 Cells/module
- 360 total cells (180S 2P)

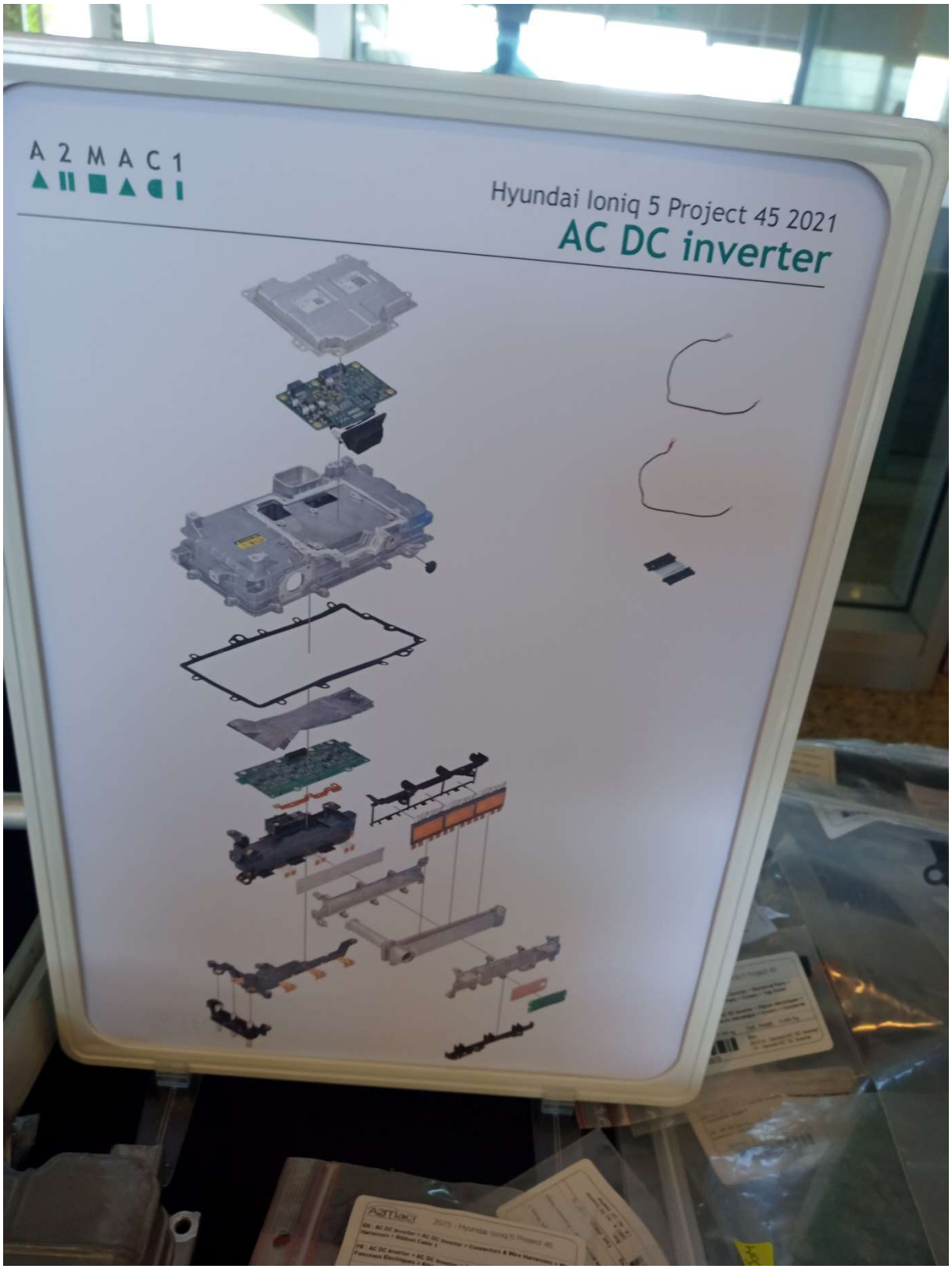
Module Details:

Key :

- Positive Terminal
- Negative Terminal
- BMS Harness
- Temperature Sensor
- Current Sensor

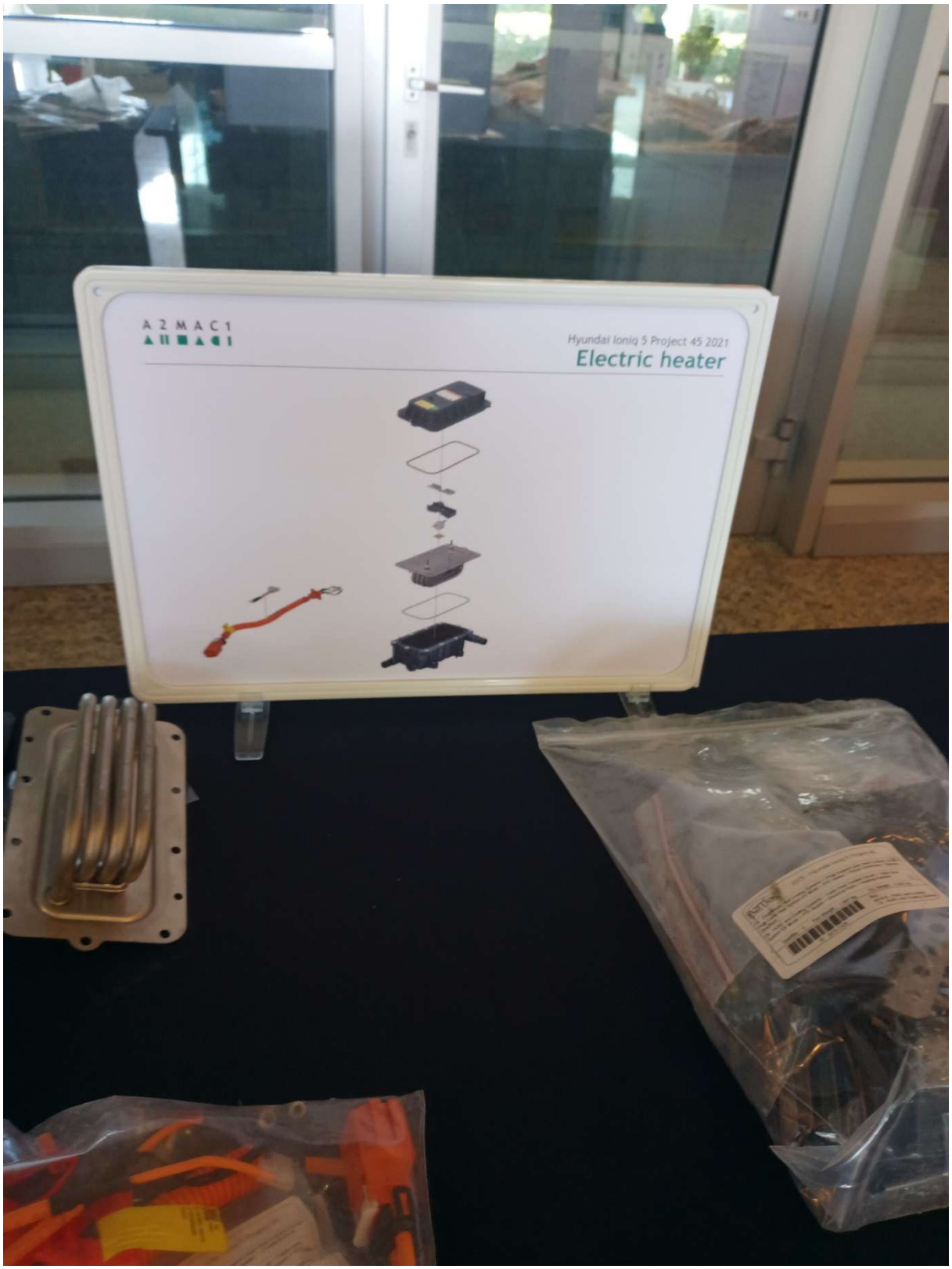
A2MAC1
Hyundai Ioniq 5 Project 45 2021
Solar charge unti

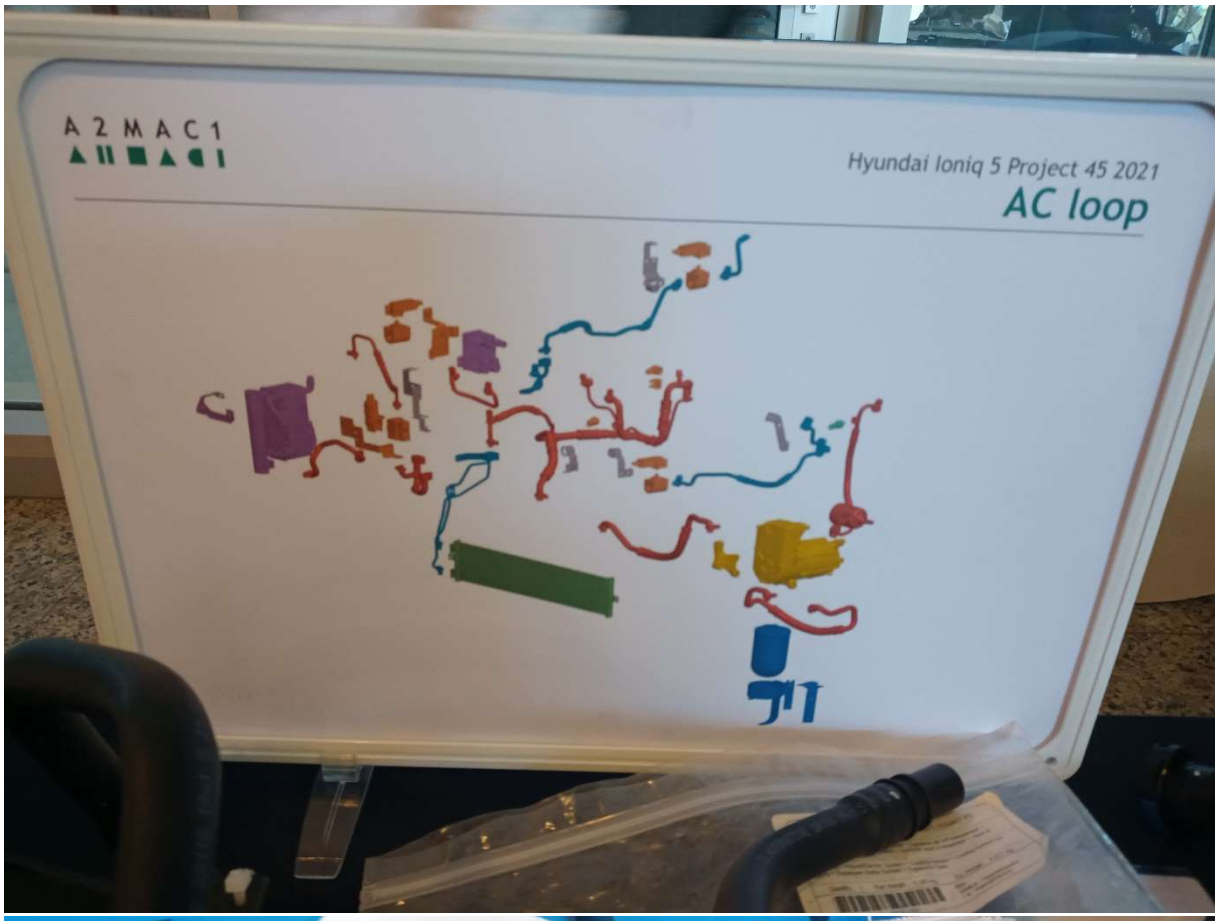
A2MAC1
Hyundai Ioniq 5 Project 45 2021
Electric heater


A2MAC1
Hyundai Ioniq 5 Project 45 2021
AC DC inverter

Hyundai Ioniq 5 Project 45 2021
Stator 1
tosbos
A2MAC1
Motor/generator 1 rotor magnet
Hyundai Ioniq 5 Project 45 2021
Row #1&3=
Magnet 1
Magnet 2
Row #2&4=
Magnet 1
Magnet 2

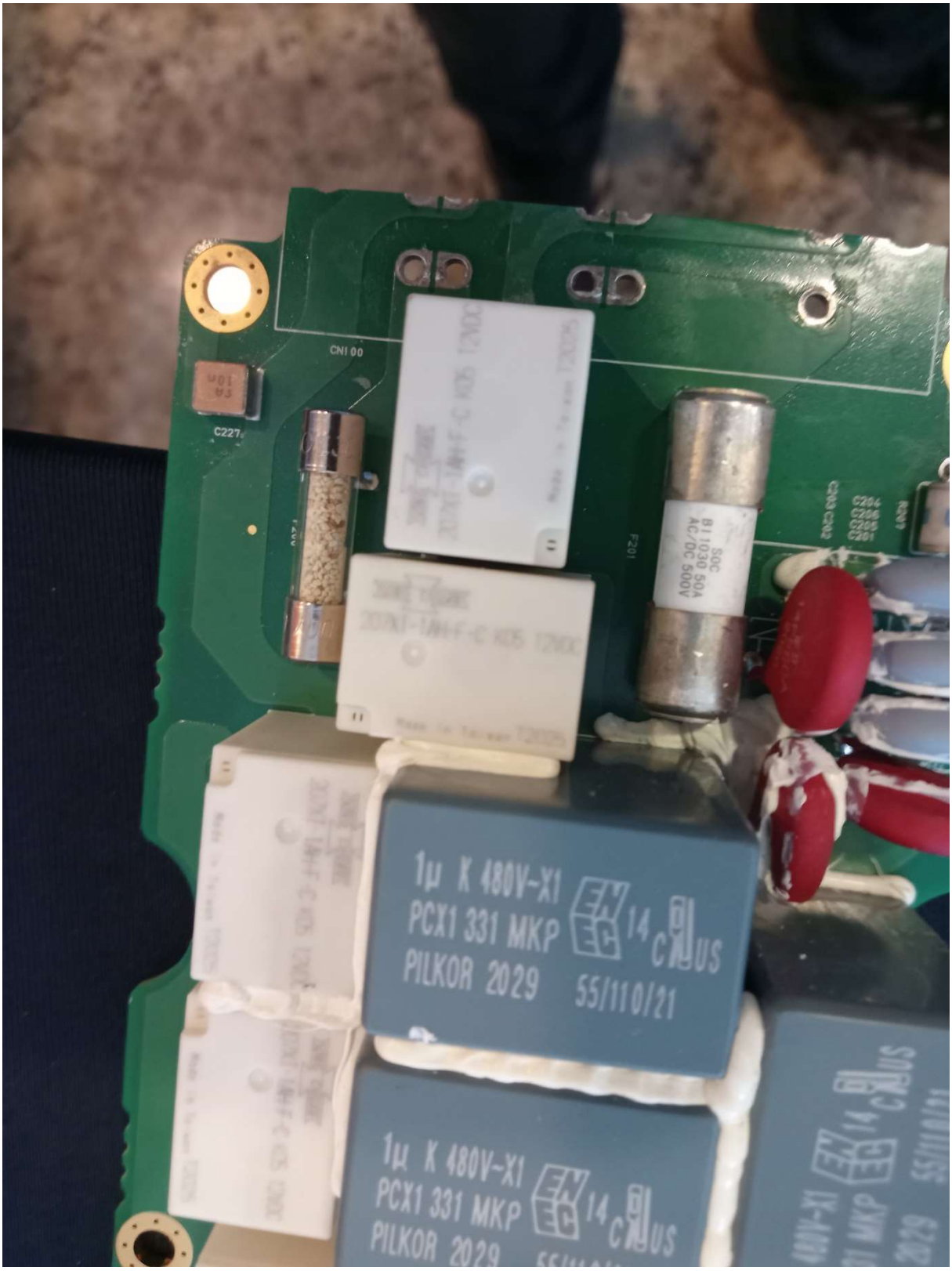
A2MACI
HV components & cabling systems schematic
Hyundai Ioniq 5 Project 45 2021
2021 Hyundai Ioniq 5 Project 45 HV Components & Cabling Systems Schematic


A2MAC1
Hyundai Ioniq 5 Project 45 2021
Electric heater


A2MAC1
Hyundai Ioniq 5 Project 45 2021
AC loop

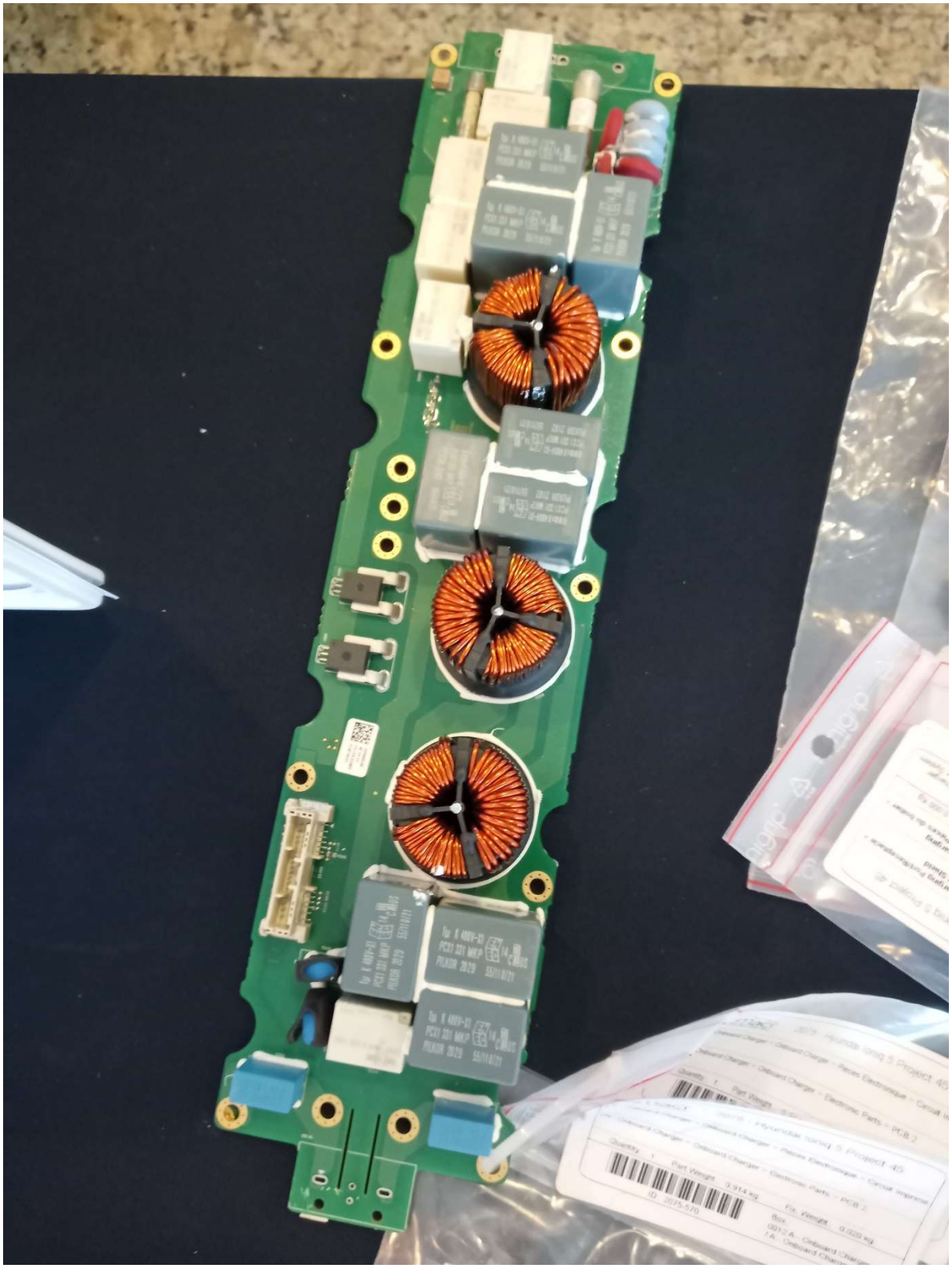
aamaci
2015 - Hyundai Ioniq 5 Project 45
R - On-Board Charger - External Components - Exterior Charging Cable - Recep
Receptacle - Prise de boîtier - Boîtier inférieur (Prise)
D - Onboard Charger - External Components - External Charging Cable -
Mechanical Parts - Housing Parts - Housing Bottom (Plug)
Quantity 1 Part Weight 0.060 kg Pcs. Weight 0.120 kg
Sys. 10 - 0 - 2 - Onboard Charger
10 - 0 - Onboard Charger System
ID 2015-145

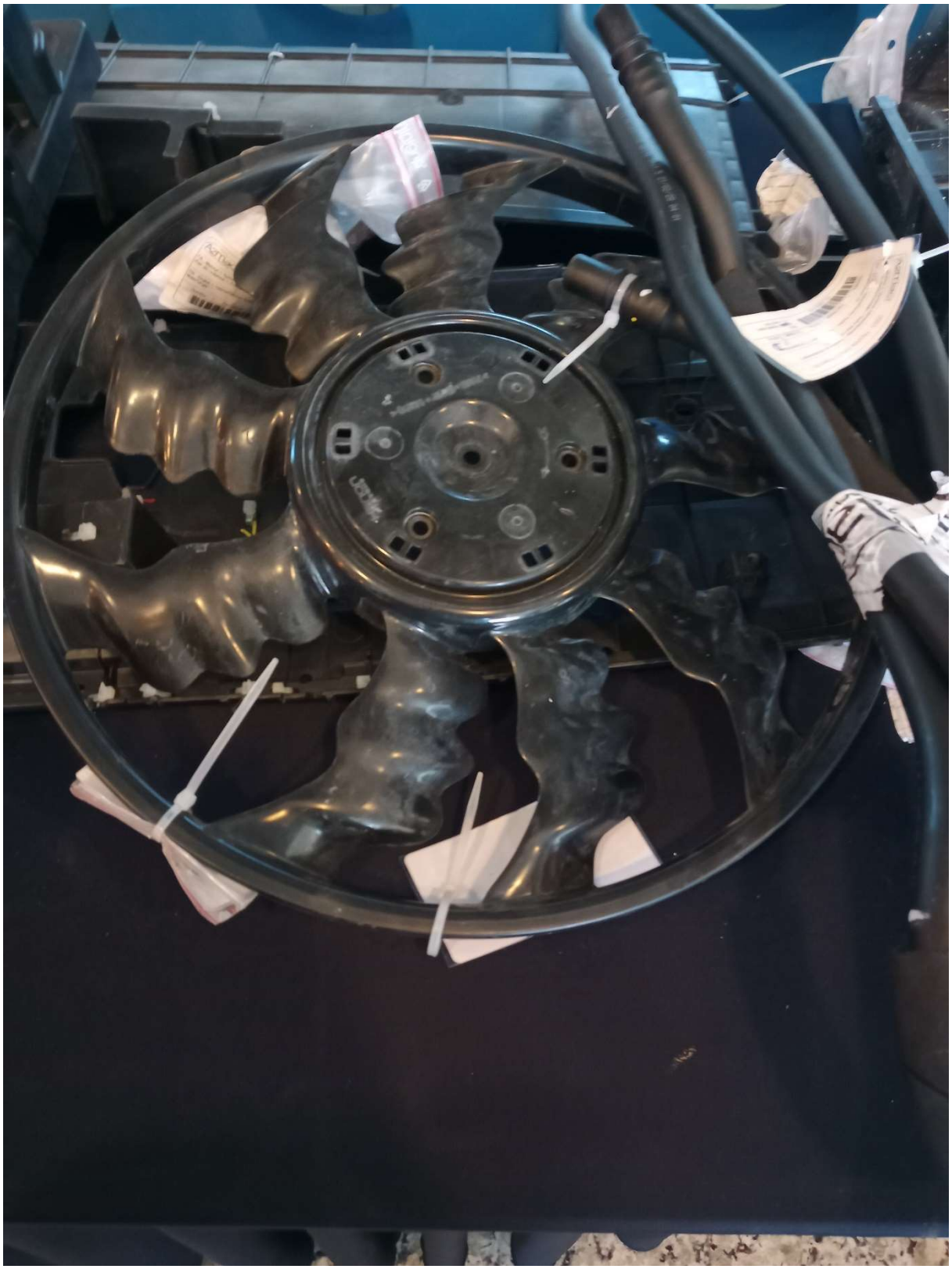
165
6075


CN100
C227
F201
SOC
B1 1030 50A
AC/DC 500V
1µ K 480V-X1
PCX1 331 MKP
PILKOR 2029
55/110/21
1µ K 480V-X1
PCX1 331 MKP
PILKOR 2029

Nr 4
NOZ
ZON

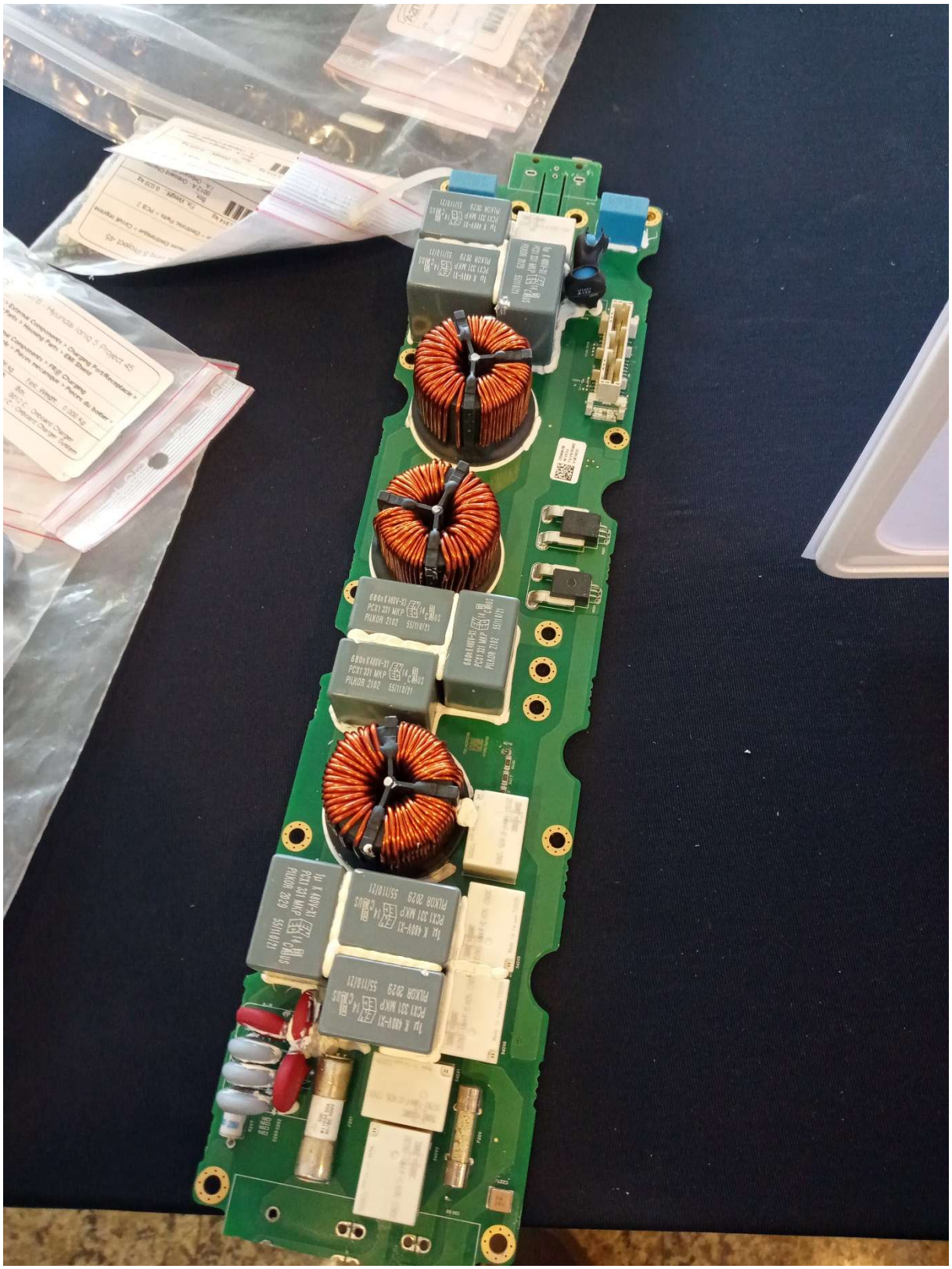
ATTACH
2015 - Hyundai Ioniq 5 (Page) (0)
(0) - Charger Cable - Charge Cable - Charging Cable - Charger
(1) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
Connection Cable - Charging Station Cable - Charge
(2) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(3) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(4) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(5) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(6) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(7) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(8) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(9) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
(10) - Charger Charge - Charge Connection - Charge Charging Cable - Charger
Connection Cable - Charging Station Cable - Charge
Page 1 of 1 (0



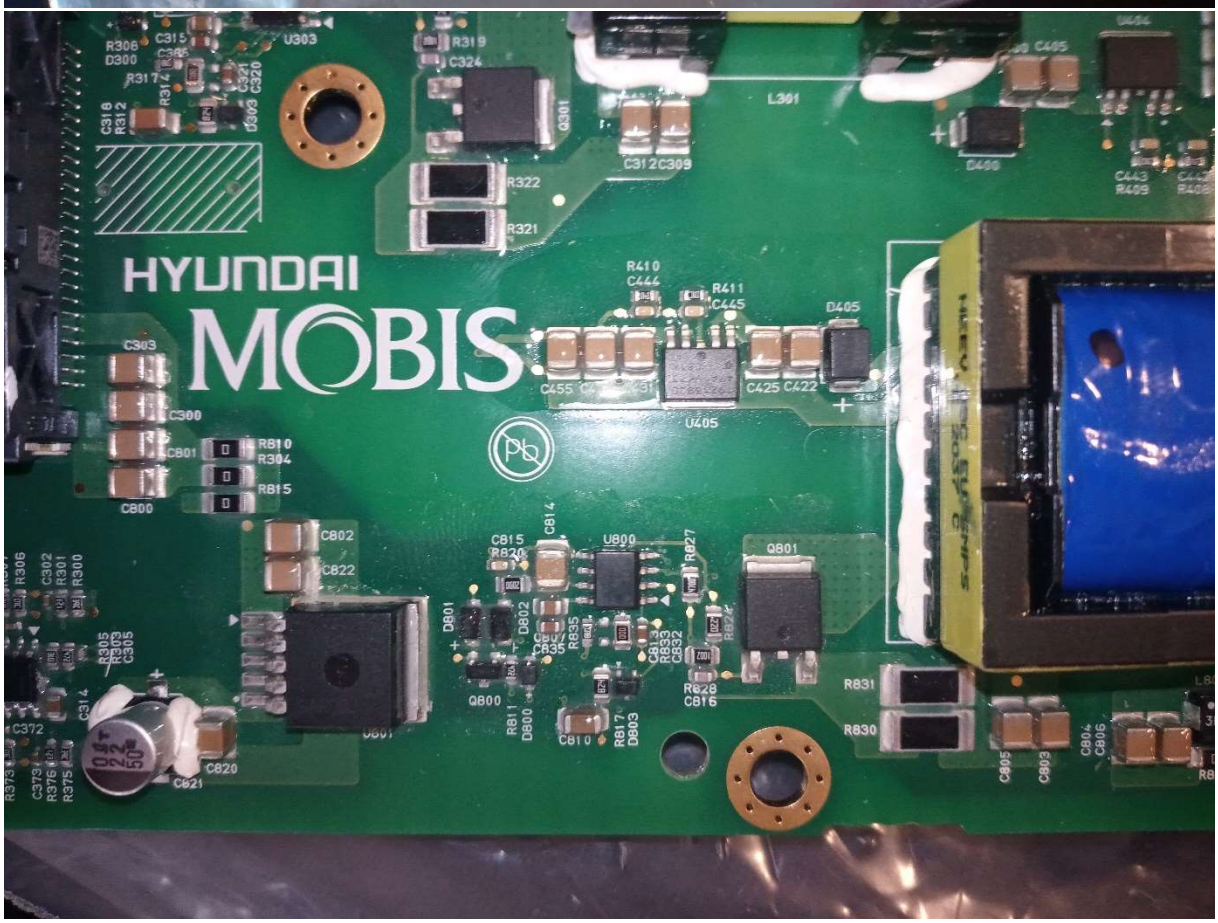


A2Maci
FR : Second AC DC Inverter > Second AC DC Inverter > Electronic Parts > PCB 1
Quantity : 1
Part Weight : 0.121 kg
Fast Weight : 0.009 kg
ID : 2075-549
Box :
0010 A - Second AC DC Inverter / A - Second AC DC Inverter
Bolt
A2Maci
EN : Second AC DC Inverter > Second AC DC Inver...
Relays > Relay 1
FR : Second AC DC Inverter > Second AC DC Inverter > Pièces électriques > Relais > Relais 1
Quantity : 1
Part Weight : 0.395 kg
Fast Weight : 0.006 kg
ID : 2075-787
Box :
0010 A - Second AC DC Inverter / A - Second AC DC Inverter

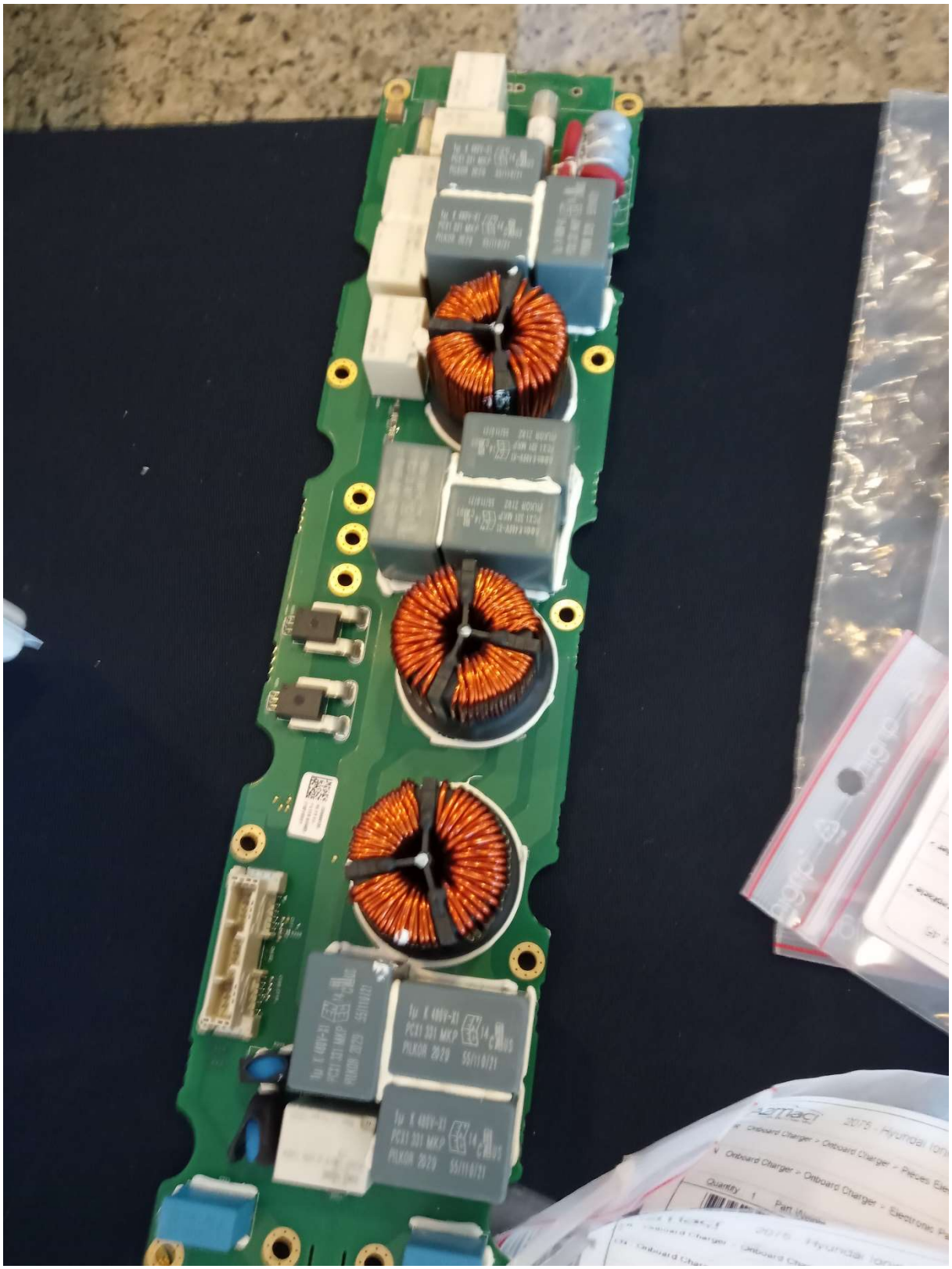
Quantity 1 Part Weight 0.121 kg
ID : 2075-549
Box
AC DC Inverter > Second AC
ay 1
nd AC DC Inverter > Pièces électriques



Quantity 1
Part Weight 0.130 kg
Fix Weight 0.028 kg
ID 2075-567


HYUNDAI
MOBIS

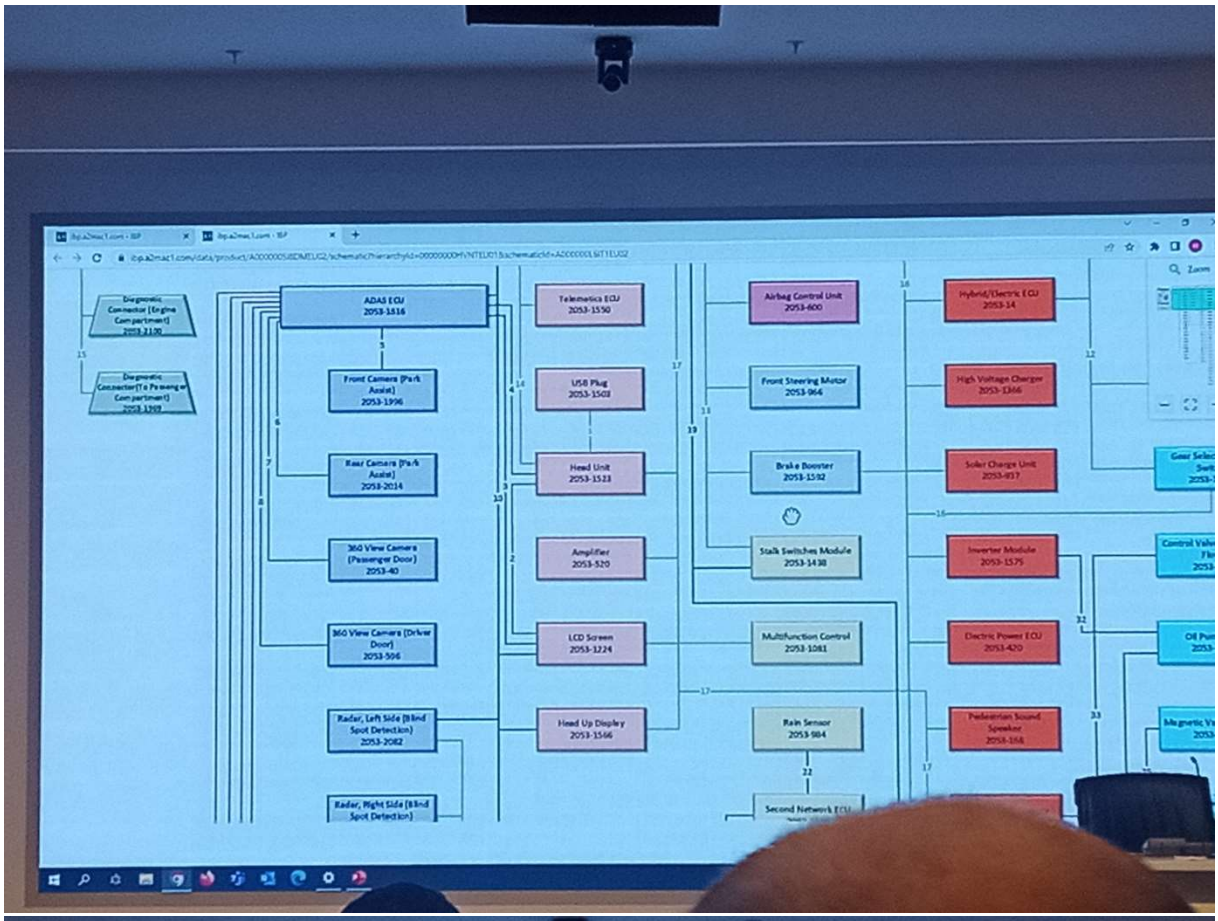
AZMACI
2015 - Hyundai Ioniq 5 Project 45
AZMACI

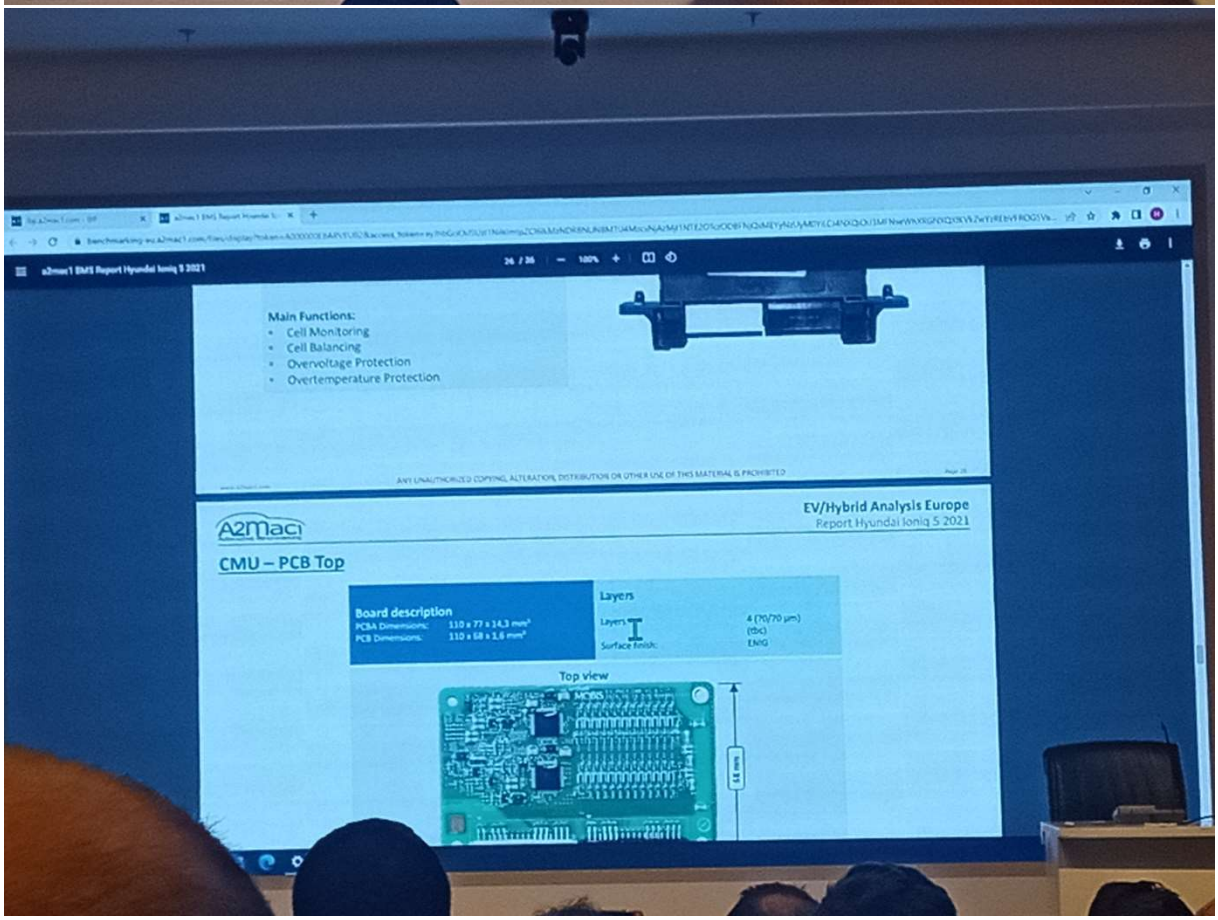

1µ X 400V-X1
PCX1 331 MKP
PULKOR 2020
55/110/21
Quantity 1
Part Number

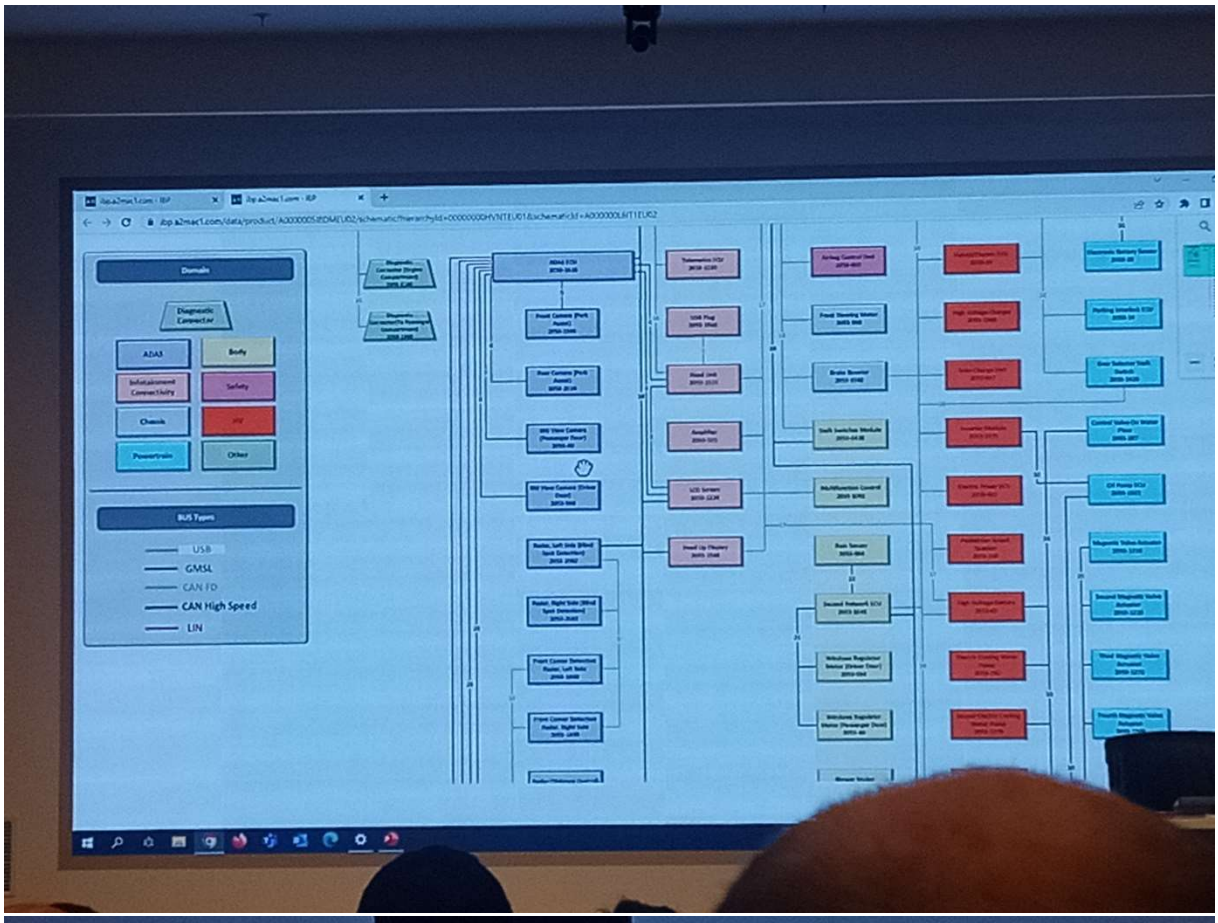
A2Mac1
2075 - Hyundai Ioniq 5 Project 45
EN : Second AC DC Inverter > Second AC DC Inverter > Electronic Parts > PCB 2
FR : Second AC DC Inverter > Second AC DC Inverter > Pièces électroniques > PCB 2
Quantity : 1
Part Weight : 0.001 kg
Fast Weight : 0.009 kg
ID : 2075-553
Box :
0010 A - Second AC DC Inverter
/ A - Second AC DC Inverter
ID : 2075-748
Part Weight : 0.044 kg
Fast Weight
Box :
0010 A - Second AC L
/ A - Second AC DC Inven
ID : 2075-595
ID : 2075-540
ID : 2075-777

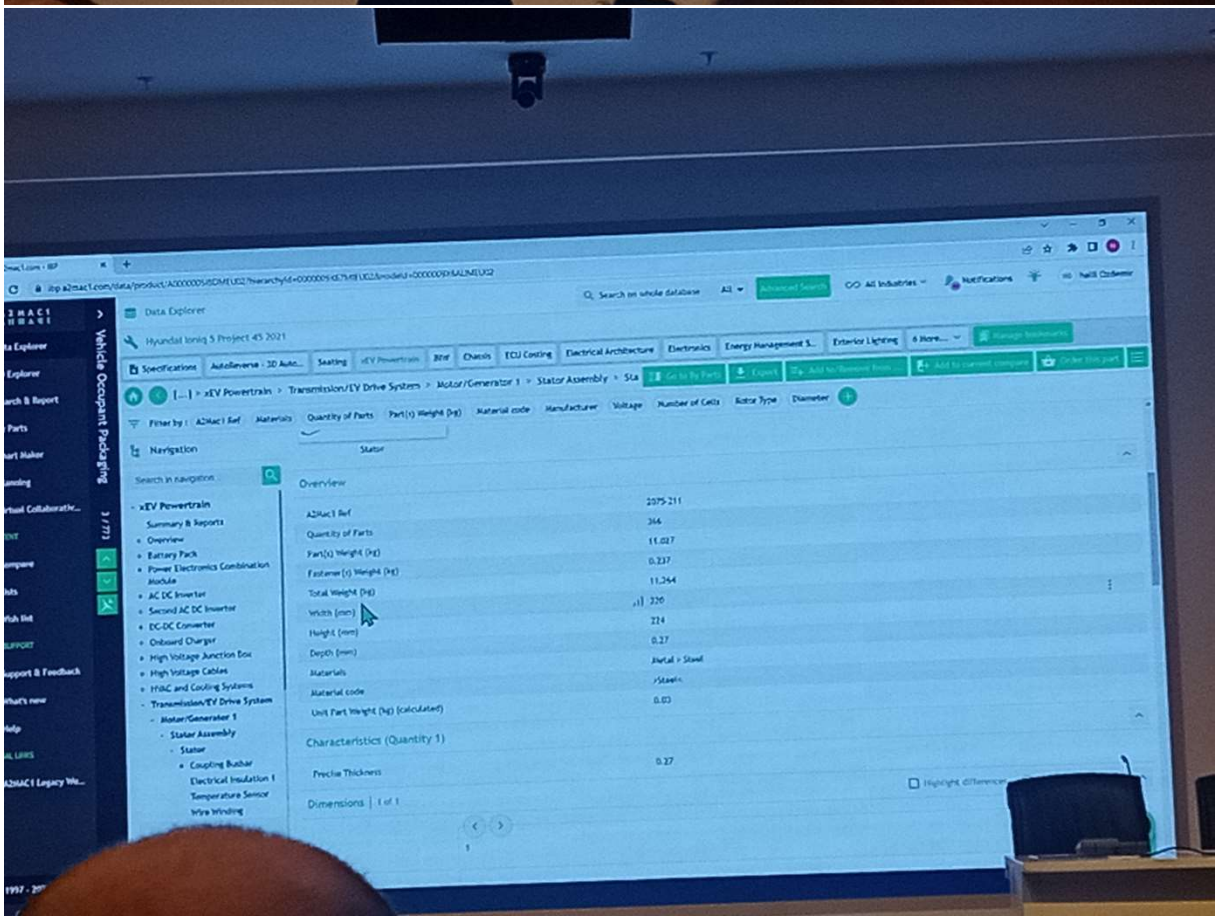
A2mac1
2075 - Hyundai Ioniq 5 Projet 45
FR - Onboard Charger > Onboard Charger > Pieces Electronique > Circuit Imprime
1
EN - Onboard Charger > Onboard Charger > Electronic Parts > PCB 1
Quantity : 1
Part Weight : 0.130 kg
ID : 2075-567
Fix Weight : 0.008 kg
Box :
0012 A - Onboard Charger
/ A - Onboard Charger System

minigrip
minigrip


ADAS ECU
2053-1816
Telematics ECU
2053-1550
Airbag Control Unit
2053-600
Hybrid/Electric ECU
2053-14
Front Camera (Park Assist)
2053-1996
USB Plug
2053-1503
Front Steering Motor
2053-964
High Voltage Charger
2053-1366
Rear Camera (Park Assist)
2053-2014
Head Unit
2053-1523
Brake Booster
2053-1592
Solar Charge Unit
2053-857
360 View Camera (Passenger Door)
2053-40
Amplifier
2053-520
Stalk Switches Module
2053-1438
Inverter Module
2053-1575
360 View Camera (Driver Door)
2053-506
LCD Screen
2053-1224
Multifunction Control
2053-1081
Electric Power ECU
2053-420
Radar, Left Side (Blind Spot Detection)
2053-2082
Head Up Display
2053-1566
Rain Sensor
2053-984
Pedestrian Sound Speaker
2053-168
Radar, Right Side (Blind Spot Detection)
Second Network ECU


a2mac1 BMS Report Hyundai Ioniq 5 2021
Main Functions:
Cell Monitoring
Cell Balancing
Overvoltage Protection
Overtemperature Protection
ANY UNAUTHORIZED COPYING, ALTERATION, DISTRIBUTION OR OTHER USE OF THIS MATERIAL IS PROHIBITED
A2mac1
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
CMU – PCB Top
Board description
PCBA Dimensions: 110 x 77 x 14,3 mm²
PCB Dimensions: 110 x 68 x 1,6 mm²
Layers
Layers 4 (70/70 µm)
Surface finish: (tbc)
ENIG
Top view
14,3 mm


Domain
Diagnostic Connector
ADAS
Body
Infotainment Connectivity
Safety
Chassis
HV
Powertrain
Other
BUS Types
USB
GMSL
CAN FD
CAN High Speed
LIN


Data Explorer
Hyundai Ioniq 5 Project 45 2021
Specifications
Autoliverse - 3D Auto...
Seating
xEV Powertrain
BIW
Chassis
ECU Coding
Electrical Architecture
Electronics
Energy Management S...
Exterior Lighting
Filter by :
A2MaC1 Ref
Materials
Quantity of Parts
Part(s) Weight (kg)
Material code
Manufacturer
Voltage
Number of Cells
Rotor Type
Diameter
Navigation
Overview
xEV Powertrain
Summary & Reports
Overview
Battery Pack
Power Electronics Combination Module
AC DC Inverter
Second AC DC Inverter
DC-DC Converter
Onboard Charger
High Voltage Junction Box
High Voltage Cables
HVAC and Cooling Systems
Transmission/EV Drive System
Motor/Generator 1
Stator Assembly
Stator
Coupling Busbar
Electrical Insulation 1
Temperature Sensor
Wire Winding
A2MaC1 Ref
2075-211
Quantity of Parts
366
Part(s) Weight (kg)
11.027
Fastener(s) Weight (kg)
0.237
Total Weight (kg)
11.264
Width (mm)
320
Height (mm)
224
Depth (mm)
0.27
Materials
Metal > Steel
Material code
/Steel<
Unit Part Weight (kg) (calculated)
0.03
Characteristics (Quantity 1)
Precise Thickness
0.27
Dimensions | 1 of 1
Vehicle Occupant Packaging

ADAS system architectures

Evolution towards centralized system with dedicated ECUs for a tradeoff between upgradeability and performance

Centralized ADAS system

Concept: Processing done by powerful central domain controller, no or very few pre-processing of sensor data inside modules
Seen in: Tesla, Xpeng P7, Ford Mach-E

Advantages: Easy implementation of functionalities via software updates. Sensor fusion easily implementable

Drawbacks: High performance necessitates performant cooling.
Usage of coaxial cables for video data transmission

Partial centralization

Concept: One subsystem (e.g. park assist, DMS, surround view) has a dedicated ECU where sensor data is processed before it arrives in the ADAS ECU
Seen in: Ford Mach-E DMS, BMW IX3 park assist, Xpeng P7 surround view
Advantages: Sensor-ECU off-the-shelf solutions can be easily implemented. Dedicated ECU enables faster data processing for the given task

Drawbacks: Usage of too many dedicated subsystems complicates the ADAS system and drives up the cost

Distributed ADAS system

Concept: Processing of sensor data is performed on the sensor modules; ECUs only consolidate the pre-processed data

Seen in: BMW IX3, Genesis GV80

Advantages: Small, cost-efficient ECUs. No coaxial cables in ADAS wireharness
→ Best choice for cost-efficient, low-autonomy vehicles

Drawbacks: High cost of modules
Upgrades of performance
because raw sensor data

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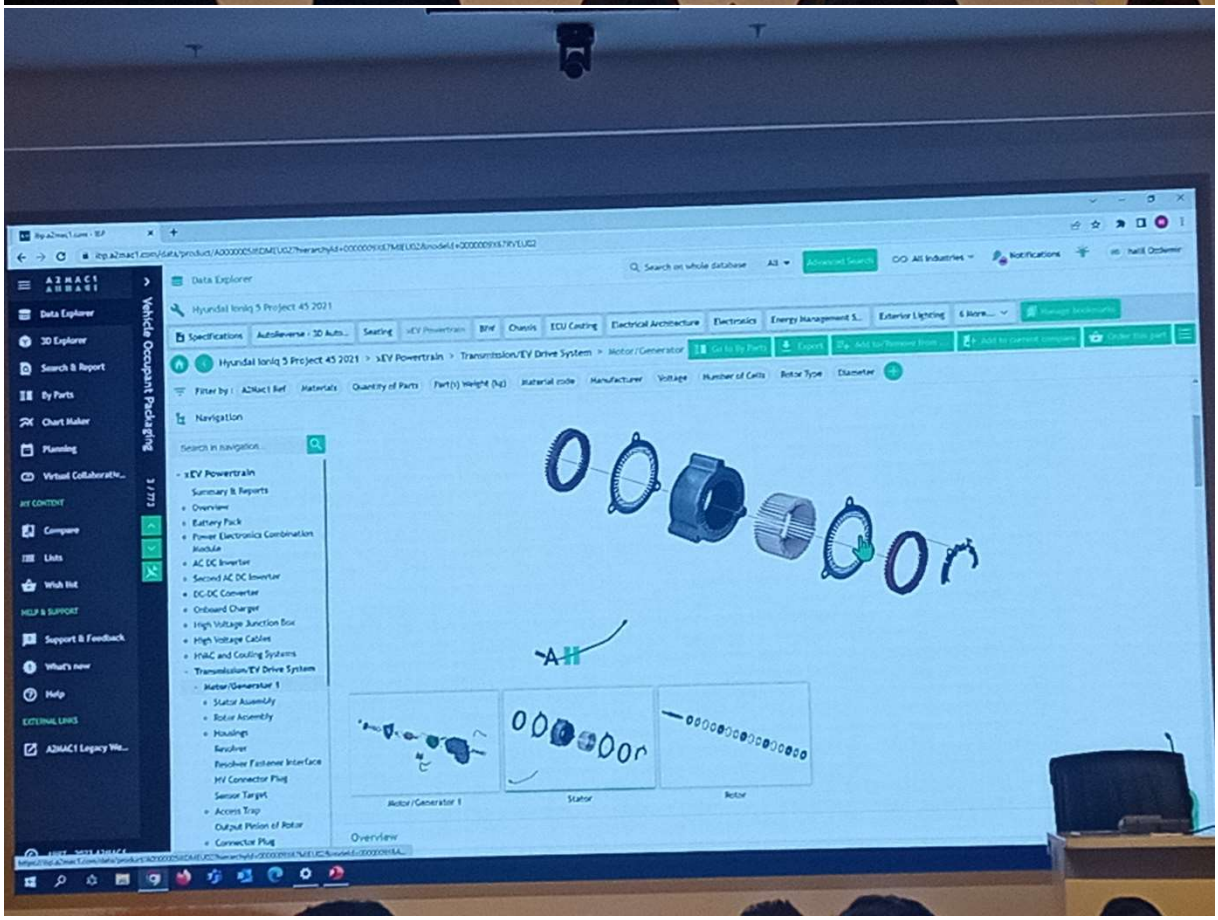
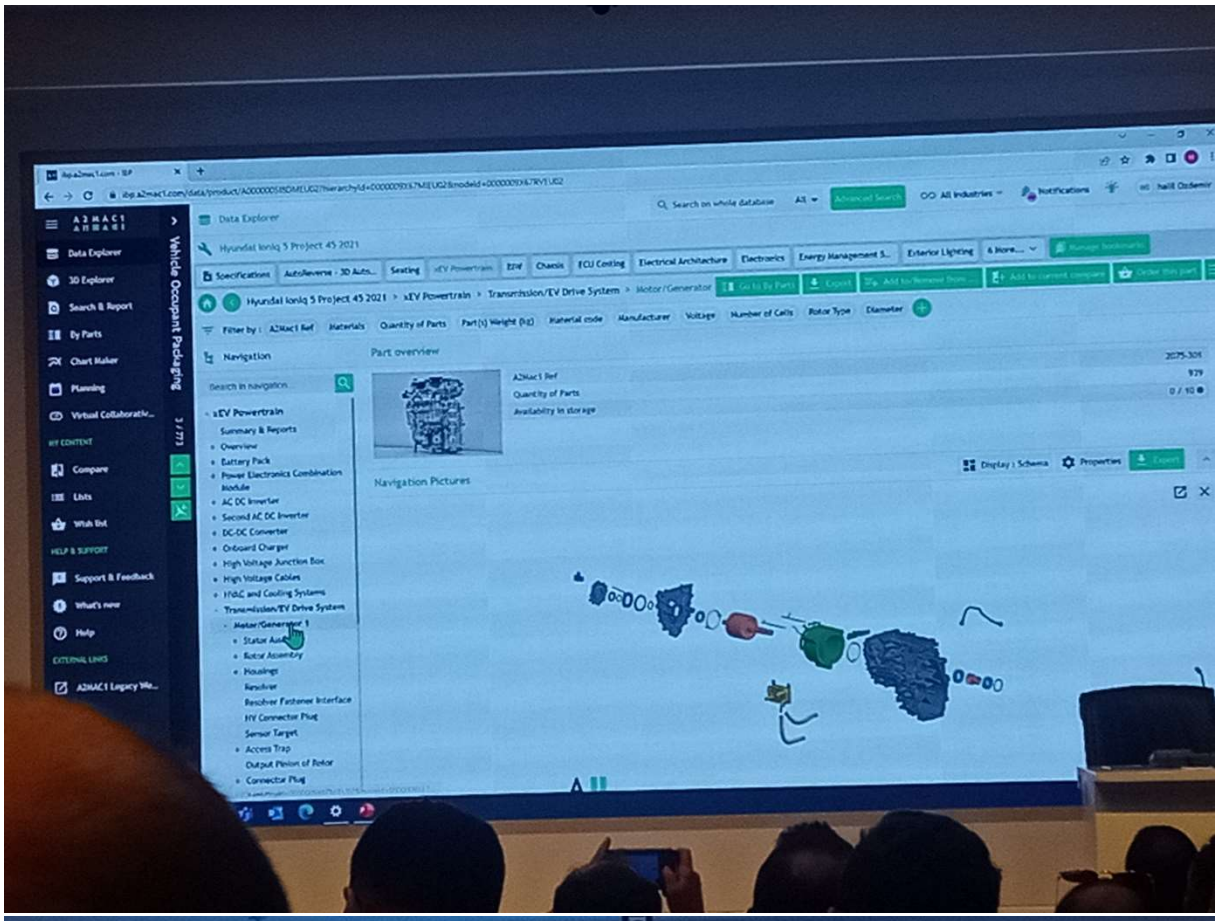
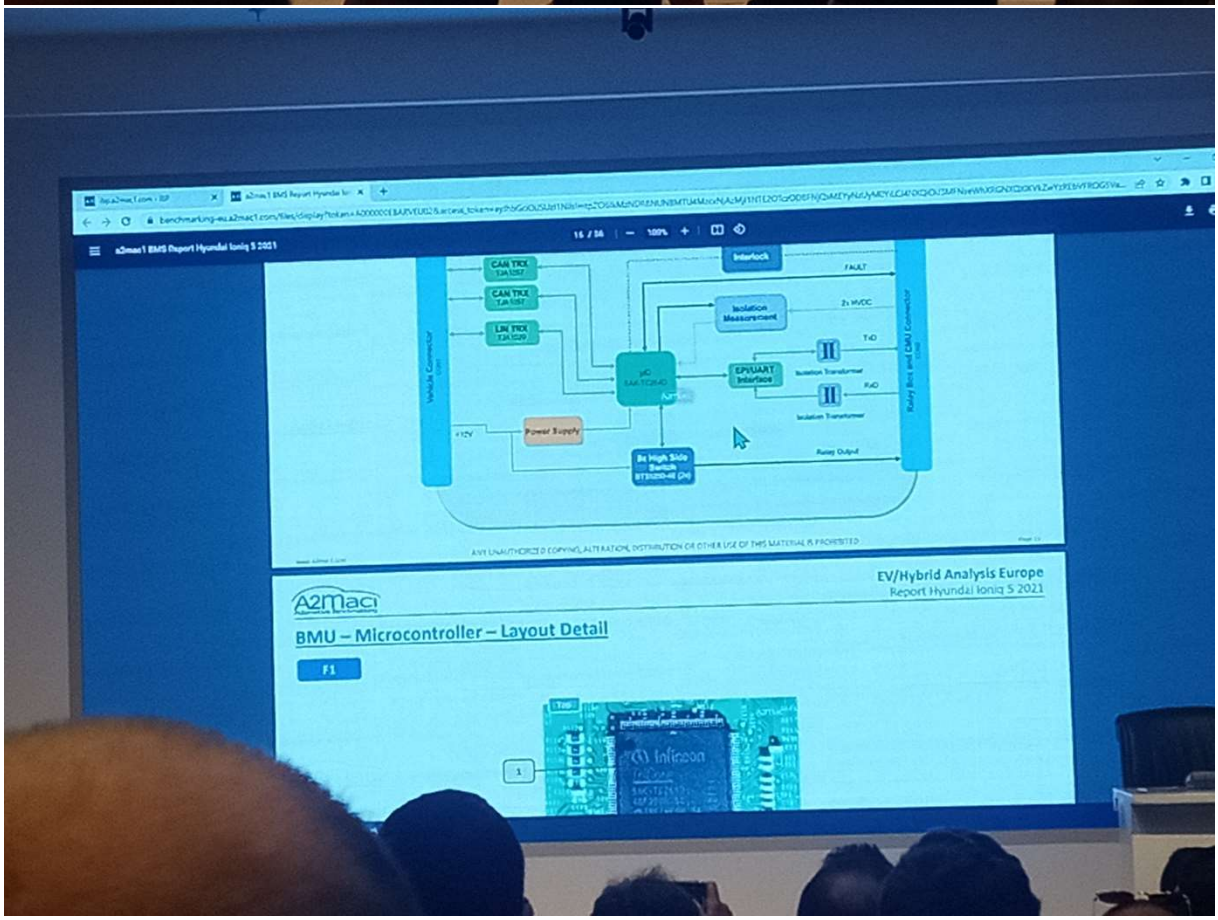
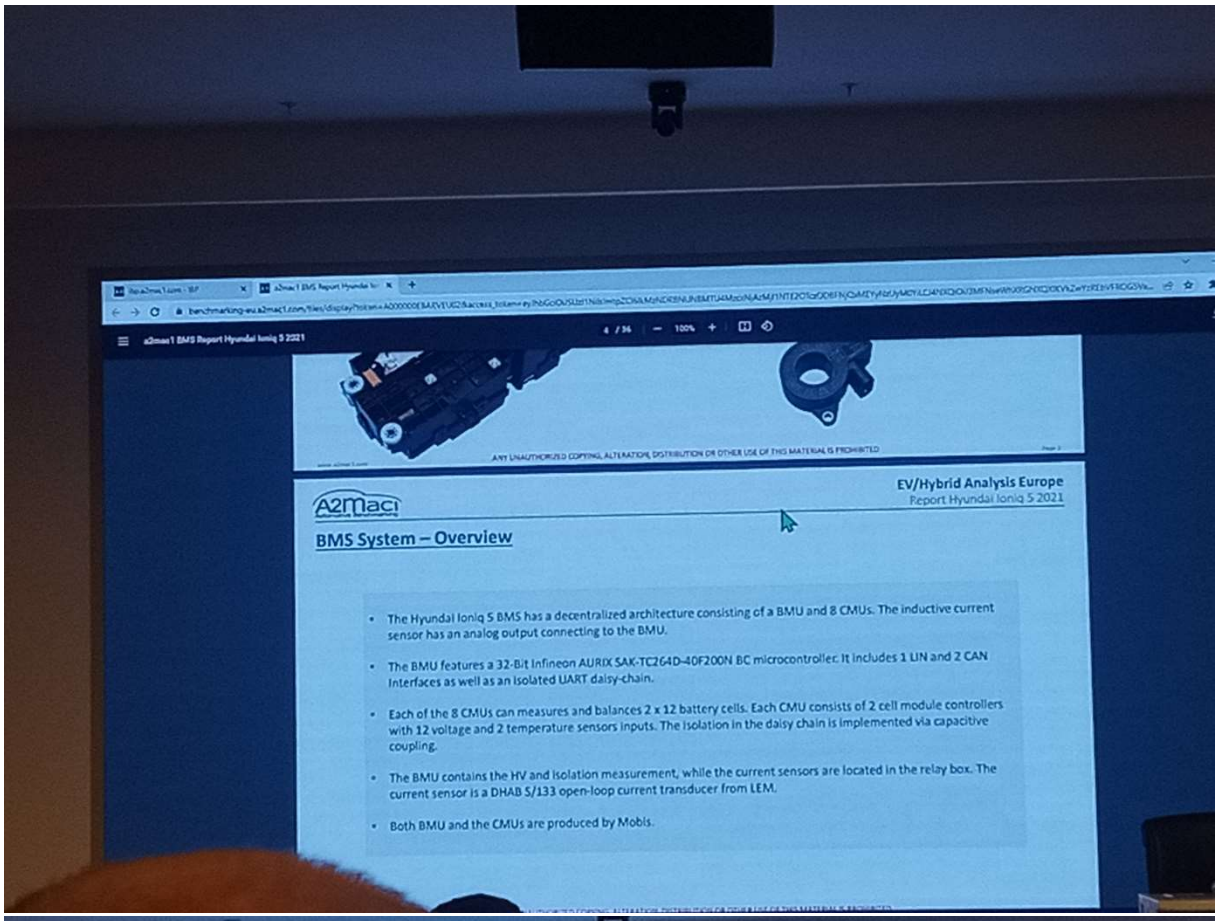



Data Explorer
Hyundai Ioniq 5 Project 45 2021
Hyundai Ioniq 5 Project 45 2021 › xEV Powertrain › Transmission/EV Drive System › Motor/Generator
Navigation
Part overview
Navigation Pictures
xEV Powertrain
Summary & Reports
Overview
Battery Pack
Power Electronics Combination Module
AC DC Inverter
Second AC DC Inverter
DC-DC Converter
Onboard Charger
High Voltage Junction Box
High Voltage Cables
HVAC and Cooling Systems
Transmission/EV Drive System
Motor/Generator 1
Stator Assembly
Rotor Assembly
Housings
Resolver
Resolver Fastener Interface
HV Connector Plug
Sensor Target
Access Trap
Output Pinion of Rotor
Connector Plug


a2mac1 BMS Report Hyundai Ioniq 5 2021
Interlock
FAULT
Isolation Measurement
2x HVDC
TXD
EPI/UART Interface
RXD
Isolation Transformer
Isolation Transformer
Power Supply
+12V
Relay Output
Vehicle Connector
Relay Box and DMU Connector
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMU – Microcontroller – Layout Detail
F1
Infineon


a2mac1 BMS Report Hyundai Ioniq 5 2021
4 / 36
100%
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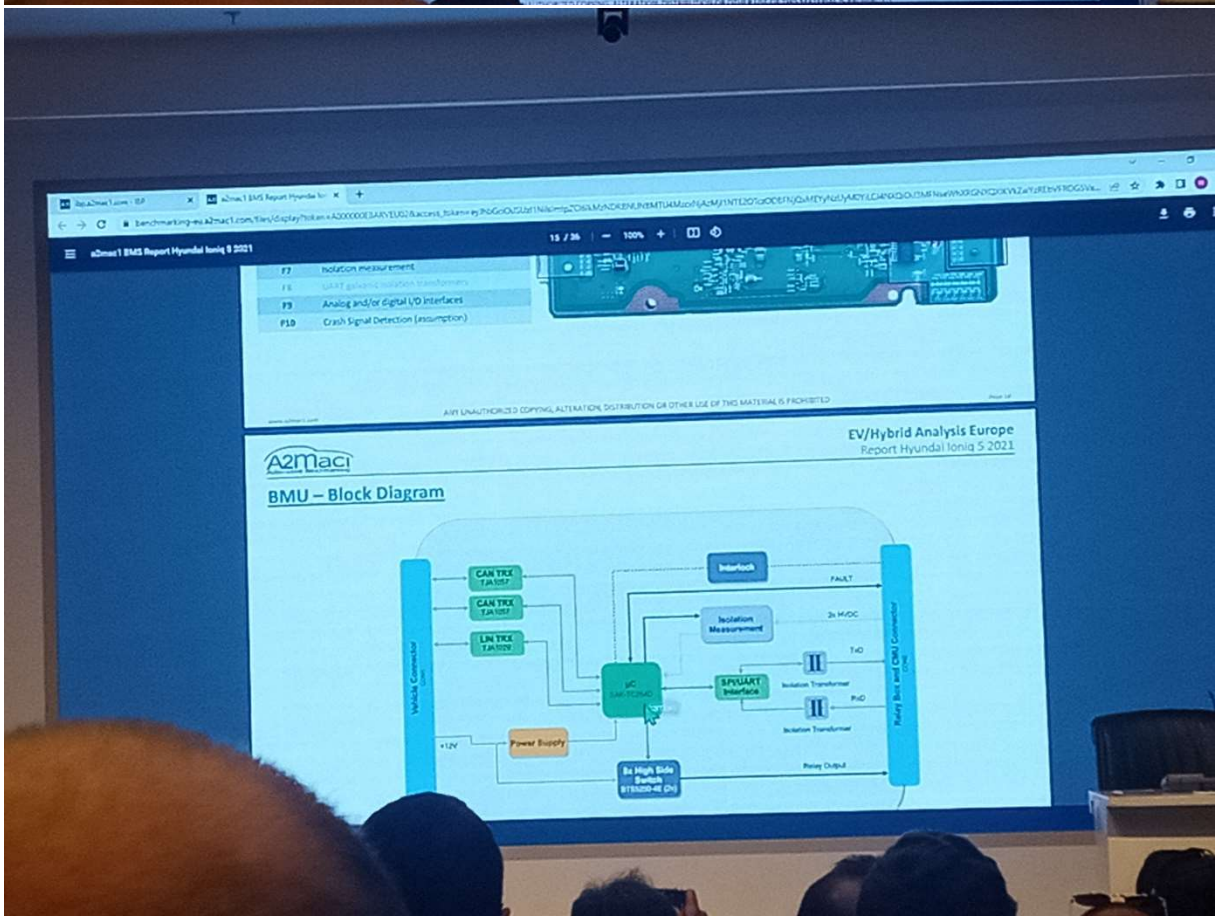
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMS System – Overview
The Hyundai Ioniq 5 BMS has a decentralized architecture consisting of a BMU and 8 CMUs. The inductive current sensor has an analog output connecting to the BMU.
The BMU features a 32-Bit Infineon AURIX SAK-TC264D-40F200N BC microcontroller. It includes 1 LIN and 2 CAN Interfaces as well as an isolated UART daisy-chain.
Each of the 8 CMUs can measures and balances 2 x 12 battery cells. Each CMU consists of 2 cell module controllers with 12 voltage and 2 temperature sensors inputs. The isolation in the daisy chain is implemented via capacitive coupling.
The BMU contains the HV and isolation measurement, while the current sensors are located in the relay box. The current sensor is a DHAB S/133 open-loop current transducer from LEM.
Both BMU and the CMUs are produced by Mobis.


a2mac1 BMS Report Hyundai Ioniq 5 2021
15 / 36
100%
F7 Isolation measurement
F9 Analog and/or digital I/O interfaces
F10 Crash Signal Detection (assumption)
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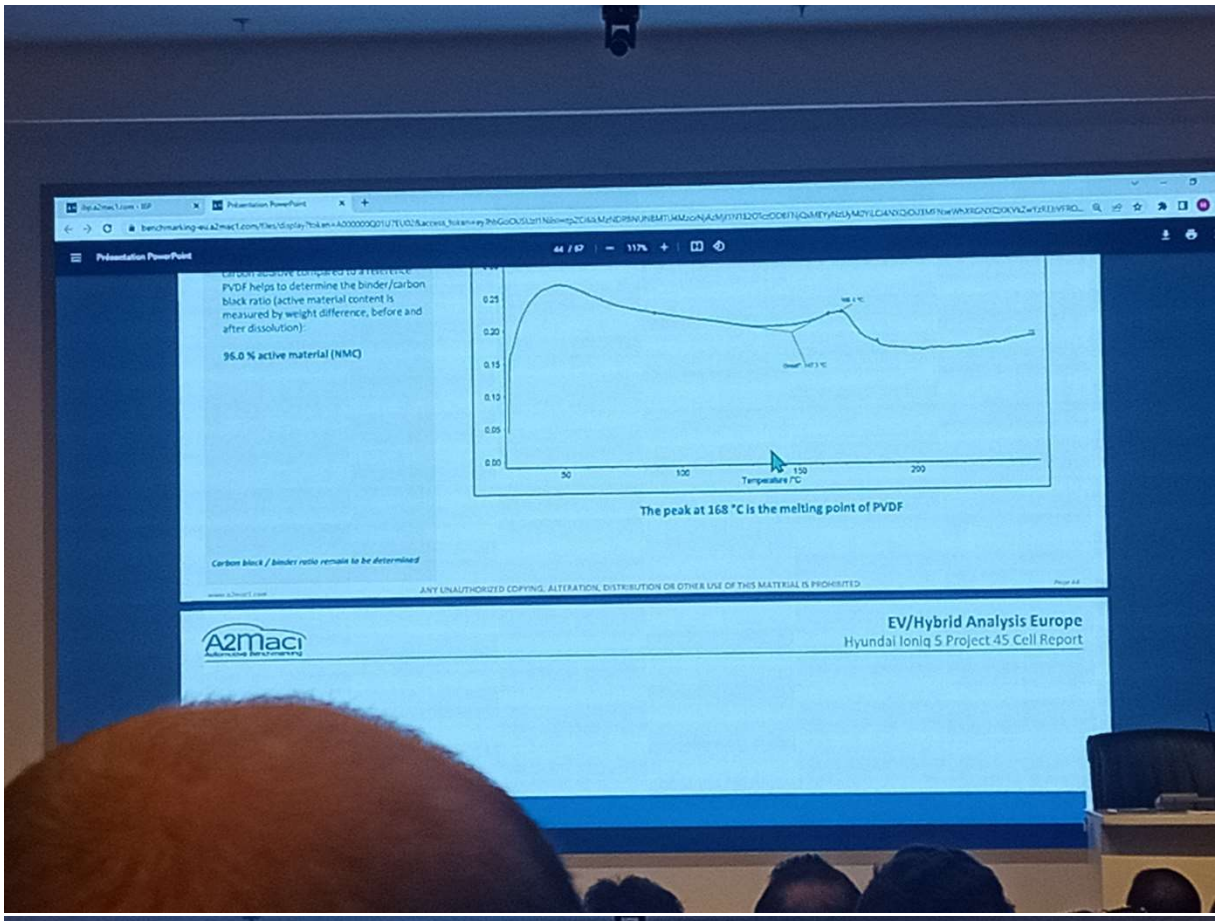
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMU – Block Diagram
Vehicle Connector
CAN TRX
CAN TRX
LIN TRX
Interlock
FAULT
Isolation Measurement
2x HVDC
TxD
SPI/UART Interface
Isolation Transformer
RxD
Isolation Transformer
Relay Box and CMU Connector
+12V
Power Supply
Relay Output


Presentation PowerPoint
PVDF helps to determine the binder/carbon black ratio (active material content is measured by weight difference, before and after dissolution):
96.0 % active material (NMC)
Temperature /°C
The peak at 168 °C is the melting point of PVDF
Carbon black / binder ratio remain to be determined
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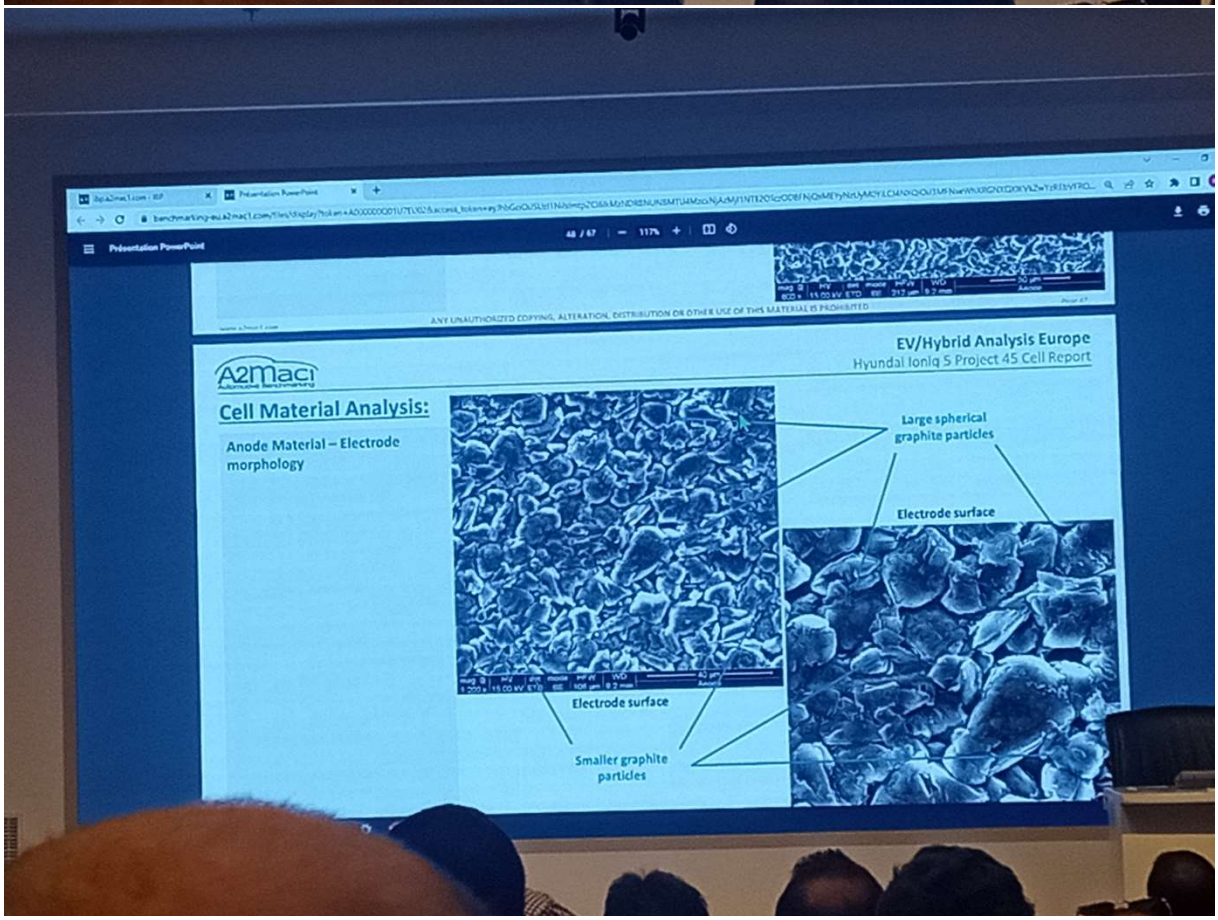
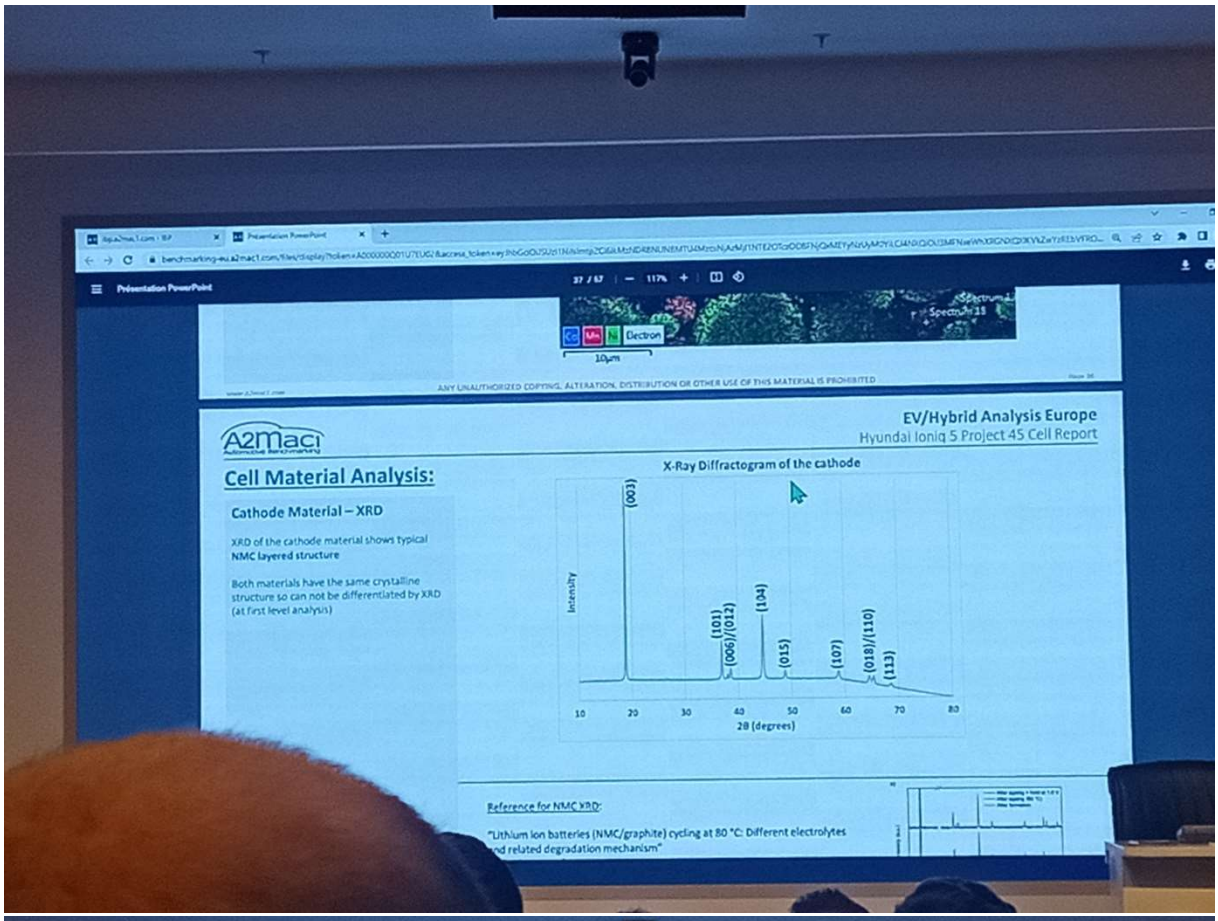
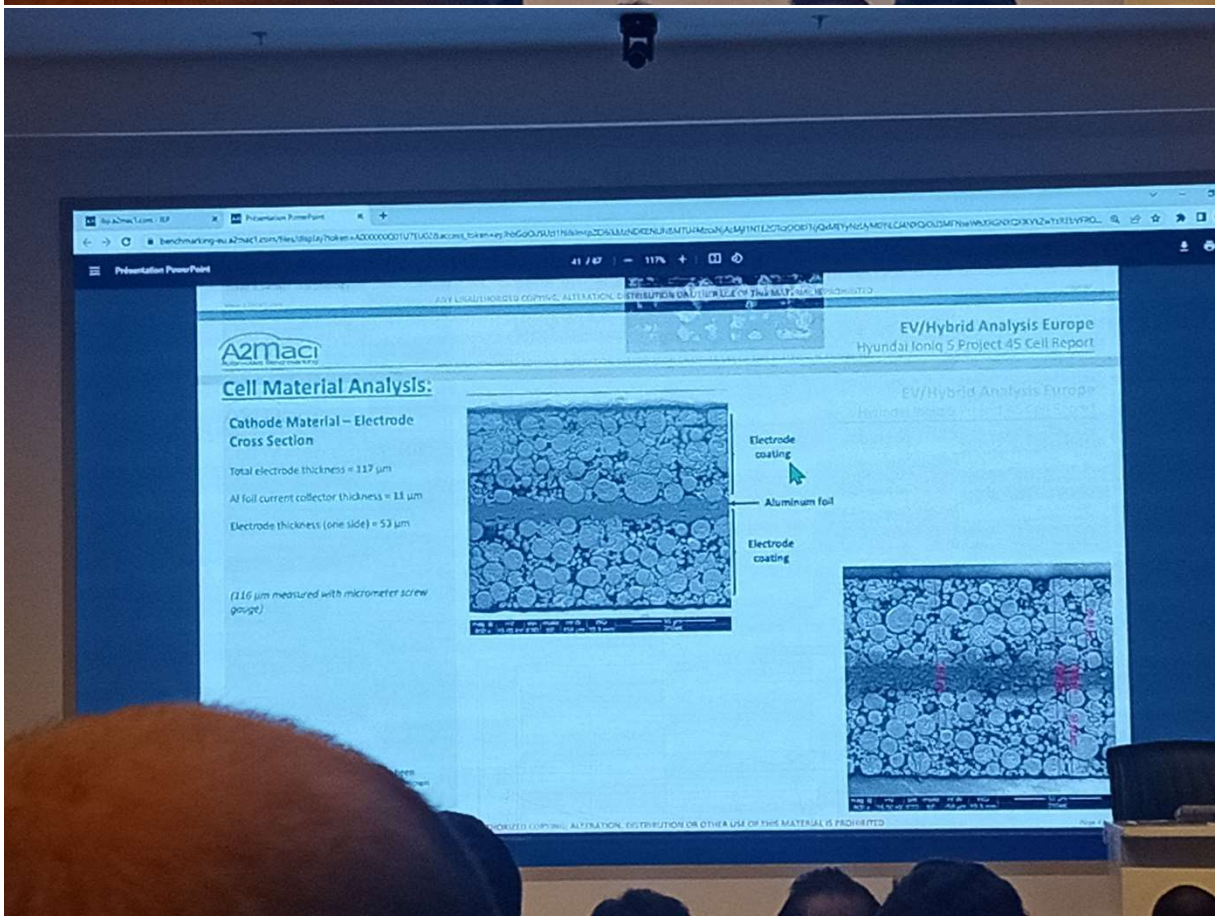
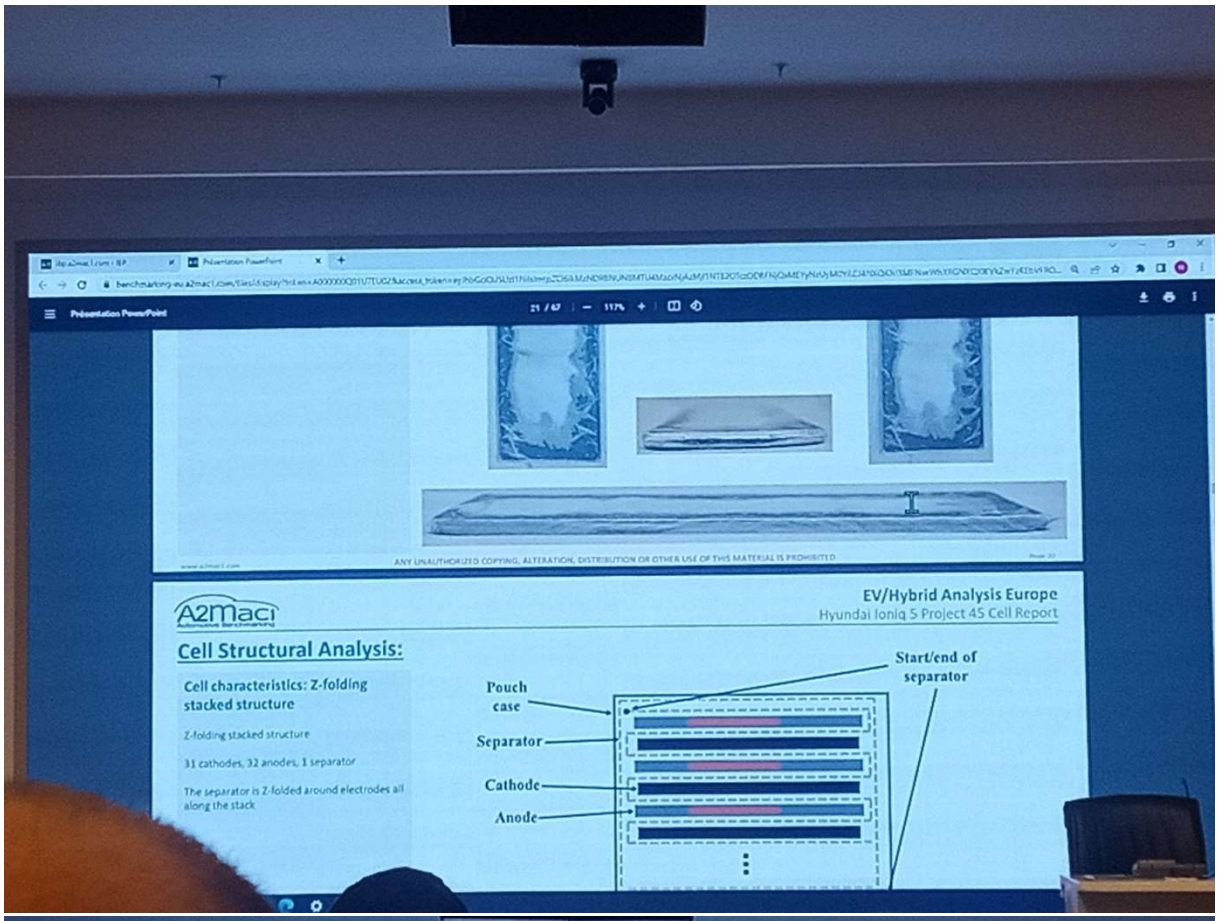
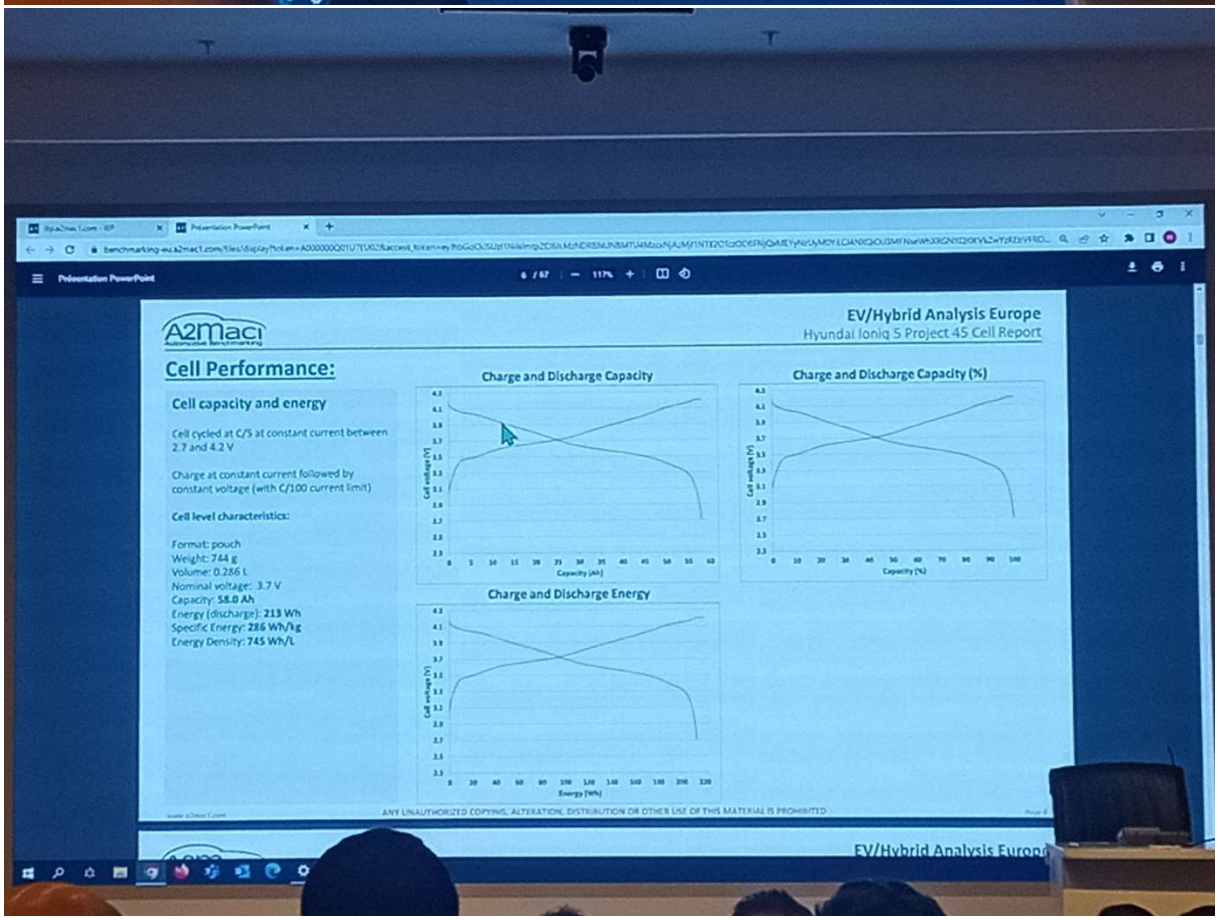
A2Maci
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report


Presentation PowerPoint
ANY UNAUTHORIZED COPYING, ALTERATION, DISTRIBUTION OR OTHER USE OF THIS MATERIAL IS PROHIBITED
A2Maci
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report
Cell Material Analysis:
Anode Material – Electrode morphology
Large spherical graphite particles
Electrode surface
Electrode surface
Smaller graphite particles


Présentation PowerPoint
37 / 67
Electron
10µm
ANY UNAUTHORIZED COPYING, ALTERATION, DISTRIBUTION OR OTHER USE OF THIS MATERIAL IS PROHIBITED
A2Mac1
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report
Cell Material Analysis:
Cathode Material – XRD
XRD of the cathode material shows typical NMC layered structure
Both materials have the same crystalline structure so can not be differentiated by XRD (at first level analysis)
X-Ray Diffractogram of the cathode
Intensity
(003)
(101)
(006)/(012)
(104)
(015)
(107)
(018)/(110)
(113)
10
20
30
40
50
60
70
80
2θ (degrees)
Reference for NMC XRD:
"Lithium ion batteries (NMC/graphite) cycling at 80 °C: Different electrolytes
nd related degradation mechanism"


Présentation PowerPoint
41 / 67
A2Mac1
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report
Cell Material Analysis:
Cathode Material – Electrode Cross Section
Total electrode thickness = 117 µm
Al foil current collector thickness = 11 µm
Electrode thickness (one side) = 53 µm
(116 µm measured with micrometer screw gauge)
Electrode coating
Aluminum foil
Electrode coating


Présentation PowerPoint
ANY UNAUTHORIZED COPYING, ALTERATION, DISTRIBUTION OR OTHER USE OF THIS MATERIAL IS PROHIBITED
A2Maci
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report
Cell Structural Analysis:
Cell characteristics: Z-folding stacked structure
Z-folding stacked structure
31 cathodes, 32 anodes, 1 separator
The separator is Z-folded around electrodes all along the stack
Pouch case
Separator
Cathode
Anode
Start/end of separator


Présentation PowerPoint
A2Maci
EV/Hybrid Analysis Europe
Hyundai Ioniq 5 Project 45 Cell Report
Cell Performance:
Cell capacity and energy
Cell cycled at C/5 at constant current between 2.7 and 4.2 V
Charge at constant current followed by constant voltage (with C/100 current limit)
Cell level characteristics:
Format: pouch
Weight: 744 g
Volume: 0.286 L
Nominal voltage: 3.7 V
Capacity: 58.0 Ah
Energy (discharge): 213 Wh
Specific Energy: 286 Wh/kg
Energy Density: 745 Wh/L
Charge and Discharge Capacity
Charge and Discharge Capacity (%)
Charge and Discharge Energy
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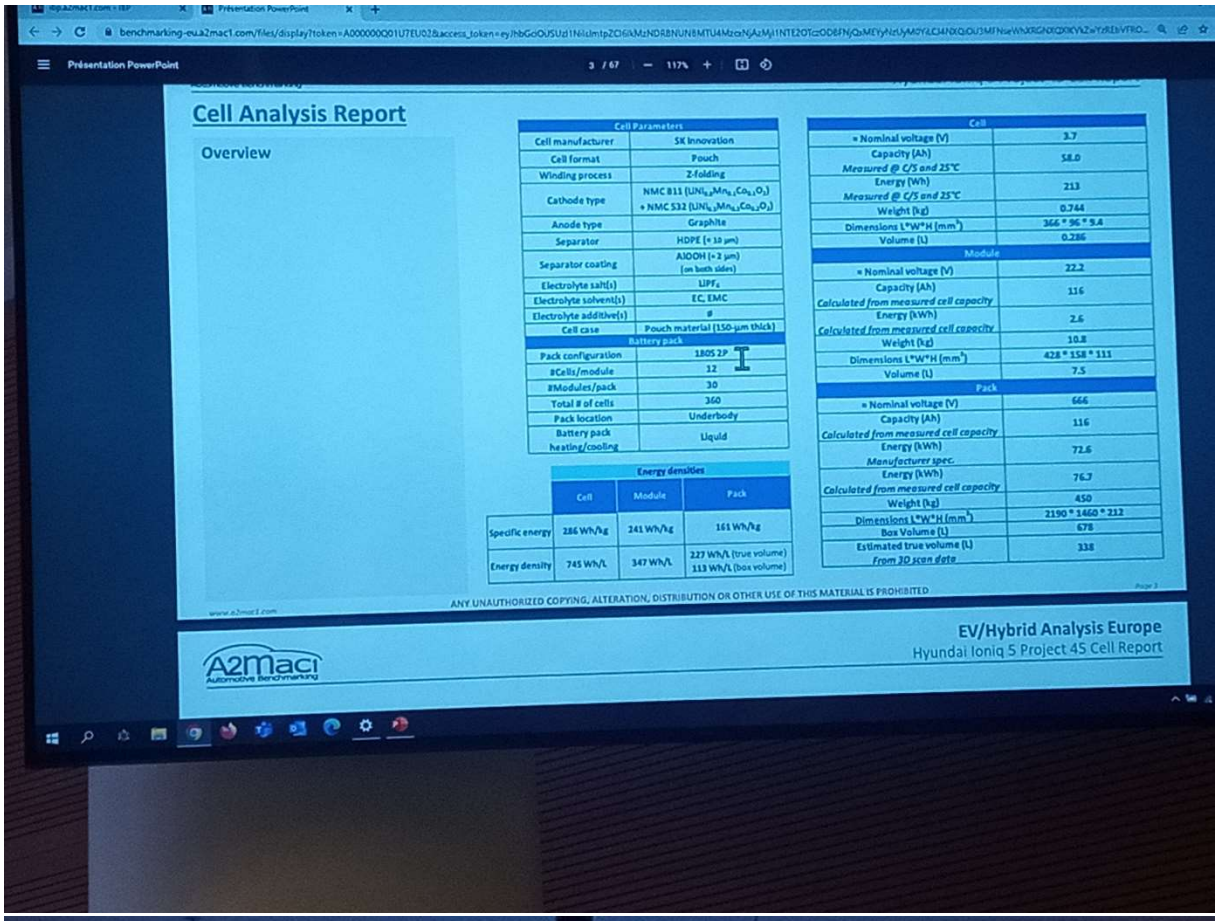

Cell Analysis Report

Overview

Cell Parameters	
Cell manufacturer	SK Innovation
Cell format	Pouch
Winding process	Z-folding
Cathode type	NMC 811 ($LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$) + NMC 532 ($LiNi_{0.5}Mn_{0.3}Co_{0.2}O_2$)
Anode type	Graphite
Separator	HDPE (~10 µm)
Separator coating	AlOOH (~2 µm) (on both sides)
Electrolyte salt(s)	$LiPF_6$
Electrolyte solvent(s)	EC, EMC
Electrolyte additive(s)	ø
Cell case	Pouch material (150-µm thick)
Battery pack	
Pack configuration	180S 2P
#Cells/module	12
#Modules/pack	30
Total # of cells	360
Pack location	Underbody
Battery pack heating/cooling	Liquid

Energy densities	Cell	Module	Pack
Specific energy	286 Wh/kg	241 Wh/kg	161 Wh/kg
Energy density	745 Wh/L	347 Wh/L	227 Wh/L (true volume) 113 Wh/L (box volume)

Cell	
≈ Nominal voltage (V)	3.7
Capacity (Ah) *Measured @ C/5 and 25°C*	58.0
Energy (Wh) *Measured @ C/5 and 25°C*	213
Weight (kg)	0.744
Dimensions L*W*H (mm^3)	366 * 96 * 9.4
Volume (L)	0.286
Module	
≈ Nominal voltage (V)	22.2
Capacity (Ah) *Calculated from measured cell capacity*	116
Energy (kWh) *Calculated from measured cell capacity*	2.6
Weight (kg)	10.8
Dimensions L*W*H (mm^3)	428 * 158 * 111
Volume (L)	7.5
Pack	
≈ Nominal voltage (V)	666
Capacity (Ah) *Calculated from measured cell capacity*	116
Energy (kWh) *Manufacturer spec.*	72.6
Energy (kWh) *Calculated from measured cell capacity*	76.7
Weight (kg)	450
Dimensions L*W*H (mm^3)	2190 * 1460 * 212
Box Volume (L)	678
Estimated true volume (L) *From 3D scan data*	338

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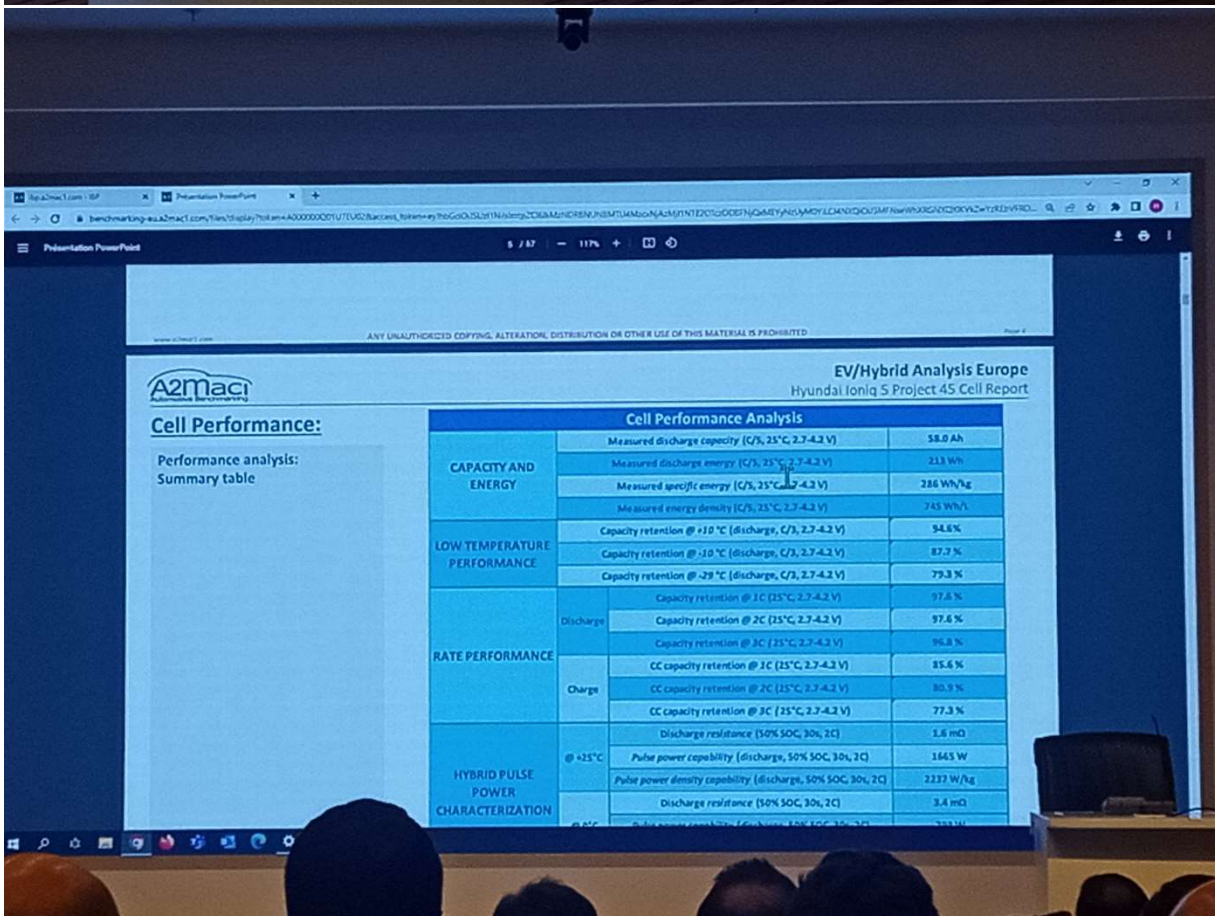

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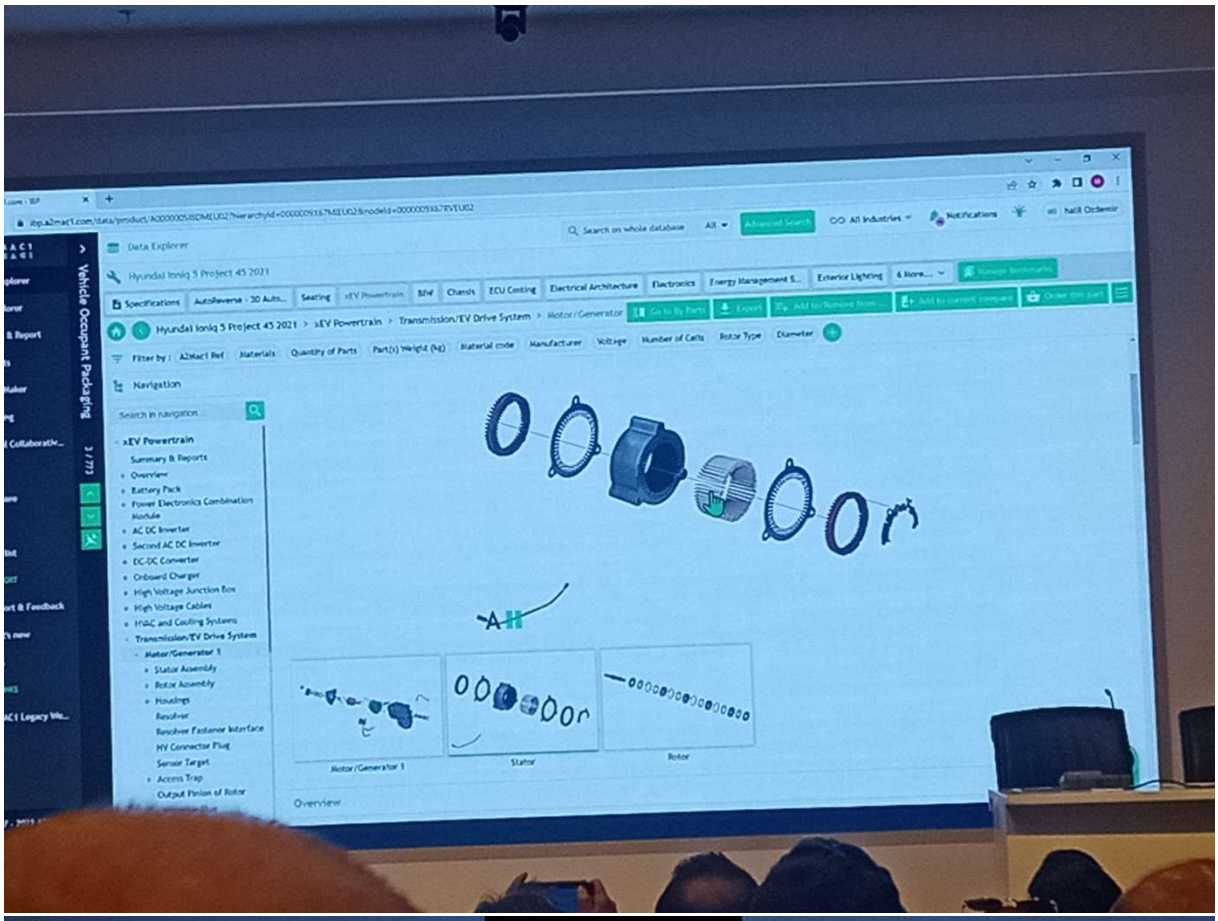
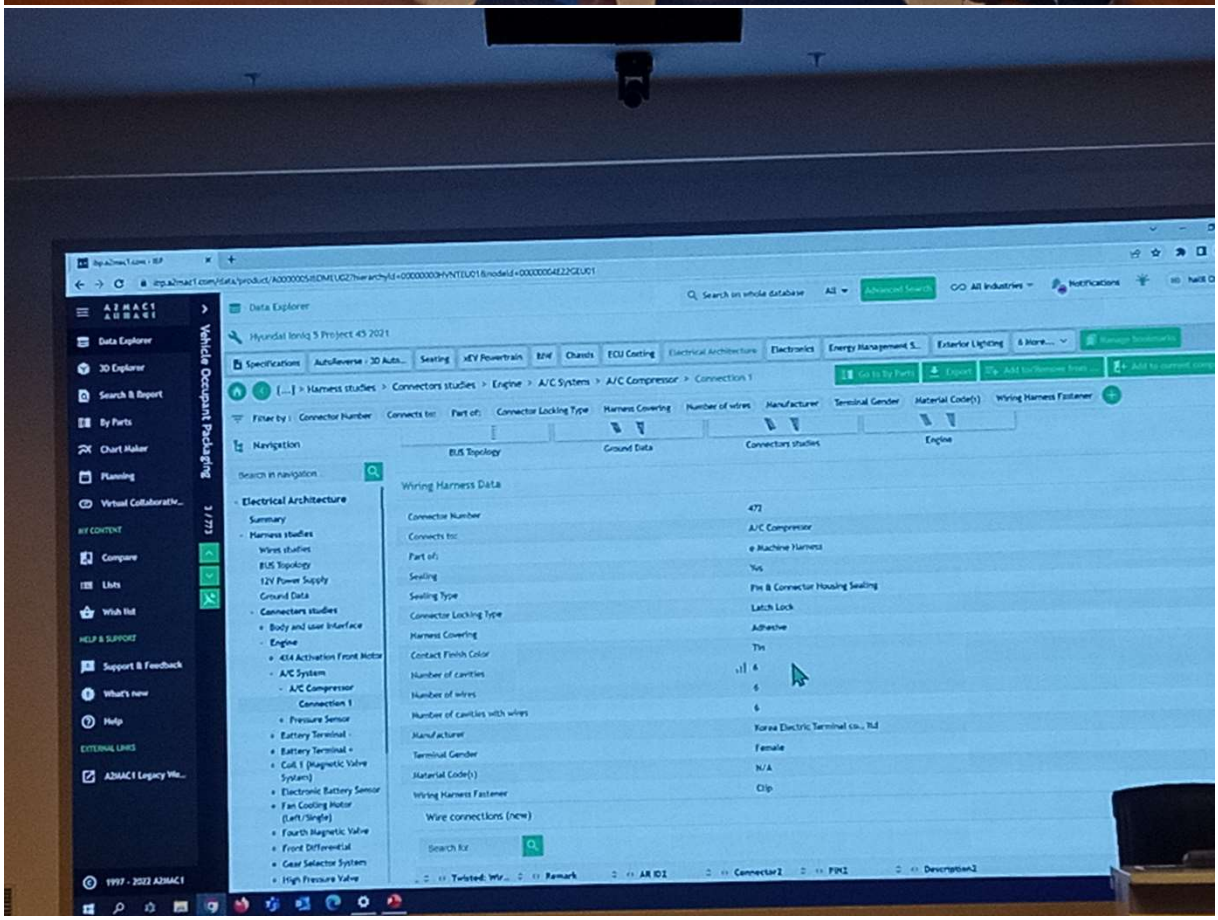
Cell Performance:

Performance analysis:
Summary table

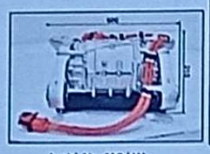
Cell Performance Analysis			
CAPACITY AND ENERGY		Measured discharge capacity (C/5, 25°C, 2.7-4.2 V)	58.0 Ah
		Measured discharge energy (C/5, 25°C, 2.7-4.2 V)	213 Wh
		Measured specific energy (C/5, 25°C, 2.7-4.2 V)	286 Wh/kg
		Measured energy density (C/5, 25°C, 2.7-4.2 V)	745 Wh/L
LOW TEMPERATURE PERFORMANCE		Capacity retention @ +10 °C (discharge, C/3, 2.7-4.2 V)	94.6%
		Capacity retention @ -10 °C (discharge, C/3, 2.7-4.2 V)	87.7 %
		Capacity retention @ -29 °C (discharge, C/3, 2.7-4.2 V)	79.3 %
RATE PERFORMANCE	Discharge	Capacity retention @ 1C (25°C, 2.7-4.2 V)	97.8 %
		Capacity retention @ 2C (25°C, 2.7-4.2 V)	97.6 %
		Capacity retention @ 3C (25°C, 2.7-4.2 V)	96.8 %
	Charge	CC capacity retention @ 1C (25°C, 2.7-4.2 V)	85.6 %
		CC capacity retention @ 2C (25°C, 2.7-4.2 V)	80.9 %
		CC capacity retention @ 3C (25°C, 2.7-4.2 V)	77.3 %
HYBRID PULSE POWER CHARACTERIZATION	@ +25°C	Discharge resistance (50% SOC, 30s, 2C)	1.6 mΩ
		Pulse power capability (discharge, 50% SOC, 30s, 2C)	1665 W
		Pulse power density capability (discharge, 50% SOC, 30s, 2C)	2237 W/kg
	@ 0°C	Discharge resistance (50% SOC, 30s, 2C)	3.4 mΩ


Data Explorer
Hyundai Ioniq 5 Project 45 2021
Hyundai Ioniq 5 Project 45 2021 > xEV Powertrain > Transmission/EV Drive System > Motor/Generator
Navigation
xEV Powertrain
Transmission/EV Drive System
Motor/Generator 1
Stator Assembly
Rotor Assembly
Housings
Resolver
Resolver Fastener Interface
HV Connector Plug
Sensor Target
Access Trap
Output Pinion of Rotor
Motor/Generator 1
Stator
Rotor
Overview

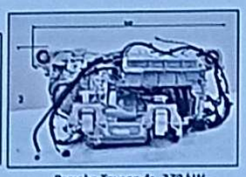

Data Explorer
Hyundai Ioniq 5 Project 45 2021
(...) > Harness studies > Connectors studies > Engine > A/C System > A/C Compressor > Connection 1
Navigation
Electrical Architecture
Harness studies
Connectors studies
Engine
A/C System
A/C Compressor
Connection 1
Wiring Harness Data
Connector Number 472
Connects to: A/C Compressor
Part of: e Machine Harness
Sealing Yes
Sealing Type Pin & Connector Housing Sealing
Connector Locking Type Latch Lock
Harness Covering Adhesive
Contact Finish Color Tin
Number of cavities 6
Number of wires 6
Number of cavities with wires 6
Manufacturer Korea Electric Terminal Co., Ltd
Terminal Gender Female
Material Code(s) N/A
Wiring Harness Fastener Clip
Wire connections (new)

2022 EV Trends: Quantum leap in power density of eDrive

Disruptive Technological innovations, such as the first motor in market with continuous hairpins, enable a jump in KPIs.



Lucid Air, 410 kW



Porsche Taycan 4s, 270 kW

Main 2022 e-Drive Trends

- High integration of E-drive modules result in smaller volume and provide more space for occupant package.
- SiC provides better performance than IGBT but at a higher cost
- RC-IGBT (reverse current IGBT) is the best available alternative. This technology has been seen in BMW ad Ford EVs

Case study: 2022 Lucid Air

- Outstanding performance of Lucid Air E-Motor versus main competitors thanks to:
  - High integration degree between motor and gearbox
  - Innovative continuous hairpin winding (wave winding) to maximize the power output
  - Higher e-drive input voltage (>900V) for higher rotation speed without loosing torque
  - SiC technology makes the inverter unit compacter and more efficient

FACT: Lucid E-drive has 2.3x the volumetric power d[illegible] 8x gravimetric power density than the Tesla model [illegible] e-drive!

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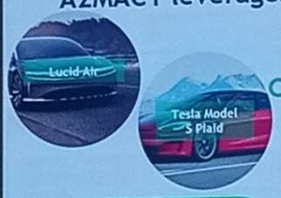
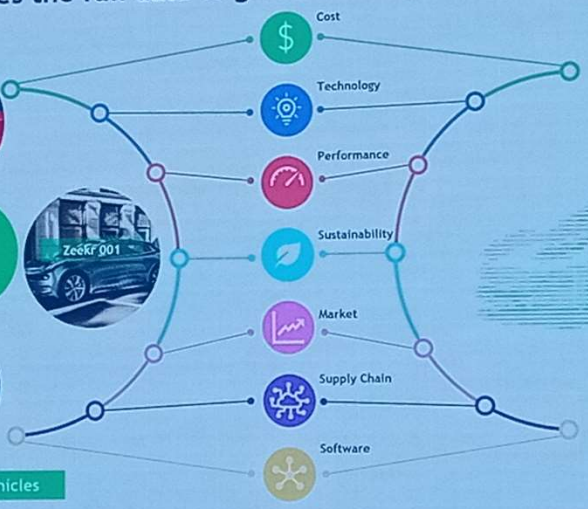
A2MAC1 leverages the full data to generate Insights & Improvement ideas



360° Vehicle Insights on all relevant Competitive Vehicles & Platforms, high-innovative vehicles as well as cost-challengers

+1500 further vehicles



These 360° Vehicle Insights are then benchmarked vs. your vehicle [illegible] based [illegible]

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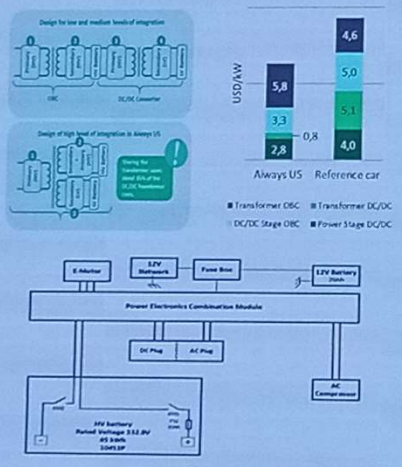
2022 EV Trends: Next level of integration in Power Electronics

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 e-motor assembly.
- With this special design, BYD also minimizes effort for HV cable cost, w cable in powertrain

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Holistic view is key to be cost competitive…

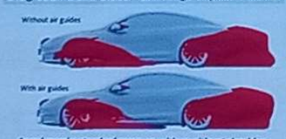
Aerodynamic improvements seen on the Model S plaid serve as performance optimization as well as cost reduction measures

Tesla Model S Plaid : front bumper air guides
PP+PE MD10, 0.57kg total, injection molding, glued and ultra-sonic welding on bumper

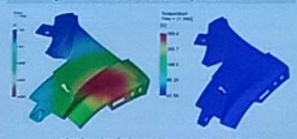
Tesla Model S Sales Volume
Note : 2021 based on Models S and X combined

PERFORMANCE IMPACT
Drag Coefficient: 0.003 Est. range impact*: 1.5km

COST IMPACT (right & left guides)
Mfg Cost : 3.85€ Assembly cost : 3.42€



Aerodynamics standard pressure, with vs without airguides
Assumptions : standard body high, (*) 1 Cd point decrease = 0.5km range increase



Injection simulation to determine Should Cost*
Assumptions: 1000 unit/batch, 10 & 15 shifts/week, etc.
EXW Price, Product/Process engineering costs not included

Parameter	Value	Unit
Cost for Aero improvement guides:	8.9	$
Battery Cost: 2021	15.0	$
Battery Capacity:	100	kWh
Cost / Wh	0.15	$/Wh
Energy Consumption (WLTP, researched)	170	Wh/km
Battery Cost /km of range	0.15	$/km
Range Gain	1.7	km
Energy used for 1.5km	289	Wh
Battery Cost for 298 Wh or 1.5km Range	43.5	
Savings per Vehicle	**34.6**	

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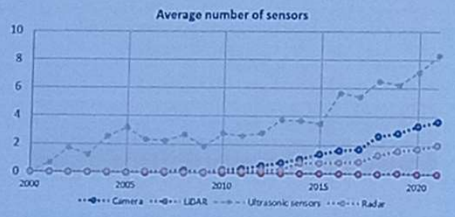
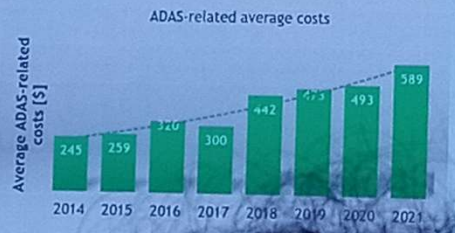
2022 EV Trends: Further cost jump to achieve Level 3 ADAS

Cost increase for ADAS functions gets further acceleration due to number of sensors & wide-scale market launch of LiDAR





Main 2022 ADAS trends

- Cameras are continuously developing in ADAS sensor suites
- Further increase in cameras and their applications is expected in the upcoming years
- Solid-state LiDARs are a new category of high-end sensor modules introduced in vehicles produced in 2022.
- High-class vehicles such as Lucid Air or Mercedes EQS use laser scanners for advances towards autonomy levels 3 and 4.

Case study: 2022 Lucid Air

- Large cost share of ECUs due to powerful centralized ADAS processor and redundancy measures to ensure desired performance
- Lucid Air ADAS system is verifying the prediction that the ADAS system cost share gains importance with every step towards full vehicle autonomy
- Large quantity of cameras and introduction vehicles with LiDAR pave t sophisticated, advanced driver assistance functions

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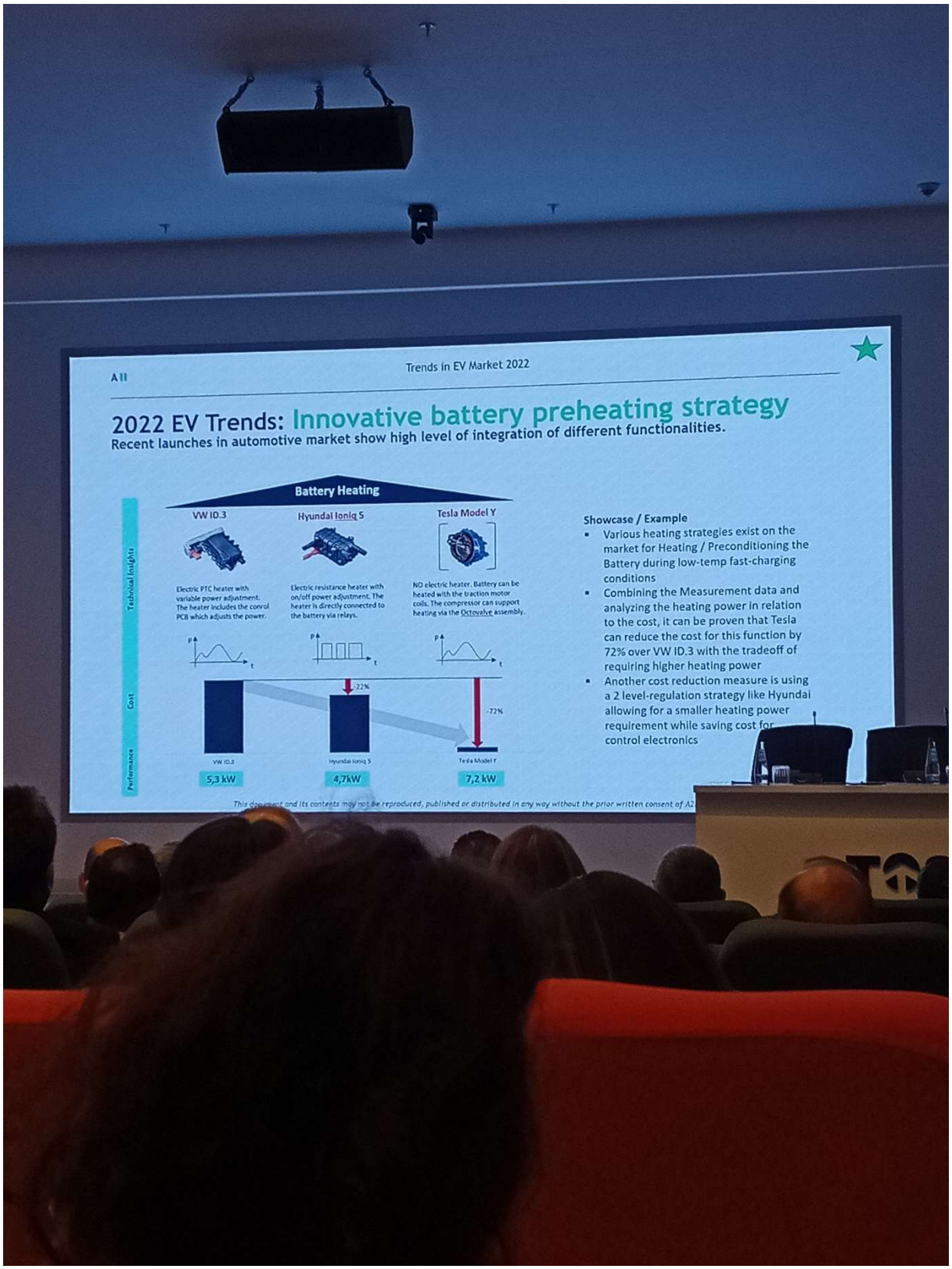
A II
Trends in EV Market 2022
2022 EV Trends: Innovative battery preheating strategy
Recent launches in automotive market show high level of integration of different functionalities.
Battery Heating
VW ID.3
Hyundai Ioniq 5
Tesla Model Y
Technical Insights
Electric PTC heater with variable power adjustment. The heater includes the conrol PCB which adjusts the power.
Electric resistance heater with on/off power adjustment. The heater is directly connected to the battery via relays.
NO electric heater. Battery can be heated with the traction motor coils. The compressor can support heating via the Octovalve assembly.
Cost
-22%
-72%
Performance
VW ID.3
Hyundai Ioniq 5
Tesla Model Y
5,3 kW
4,7kW
7,2 kW
Showcase / Example
Various heating strategies exist on the market for Heating / Preconditioning the Battery during low-temp fast-charging conditions
Combining the Measurement data and analyzing the heating power in relation to the cost, it can be proven that Tesla can reduce the cost for this function by 72% over VW ID.3 with the tradeoff of requiring higher heating power
Another cost reduction measure is using a 2 level-regulation strategy like Hyundai allowing for a smaller heating power requirement while saving cost for control electronics
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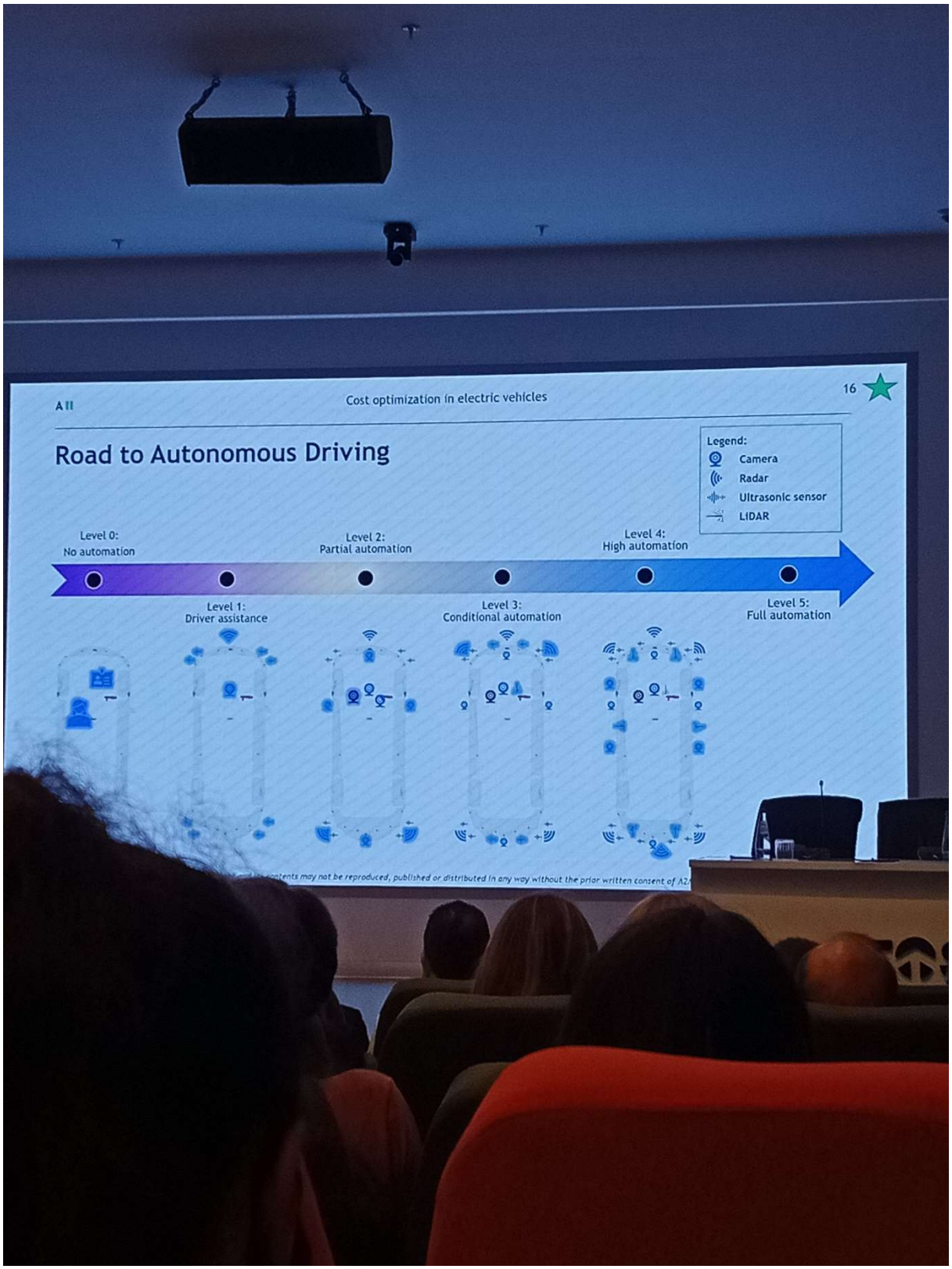
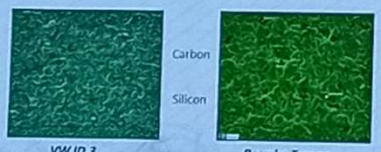

A II
Cost optimization in electric vehicles
16
Road to Autonomous Driving
Legend:
Camera
Radar
Ultrasonic sensor
LIDAR
Level 0:
No automation
Level 1:
Driver assistance
Level 2:
Partial automation
Level 3:
Conditional automation
Level 4:
High automation
Level 5:
Full automation

2022 EV Trends: Move towards alternative Cell chemistries

Market is moving away from conventional NMC cell chemistry to more application-tailored chemistries

BYD Han LFP Blade Battery



VW ID.3 *Porsche Taycan*

BEV Cell chemistry

- Till date OEMs are driven by maximizing the range of vehicles by maximizing energy density and specific energy
- Range of 400-500km can be achieved easily, other parameters can be optimized

High performance / fast charging

- Anode chemistry must be adapted
- New solutions will be available next year
- Possible solutions:
  - Graphene instead of Graphite
  - Silicon anodes with adjusted electrolytes
  - Solid electrolytes

LFP Batteries

- Used in stationary applications and commercial vehicles (mainly in China)
- Latest developments lead to similar battery specific energy, whilst reducing cost and dependence on Nickel and Cobalt
- Tesla implements LFP cells to reduce cost of entry level vehicles in the Chinese market

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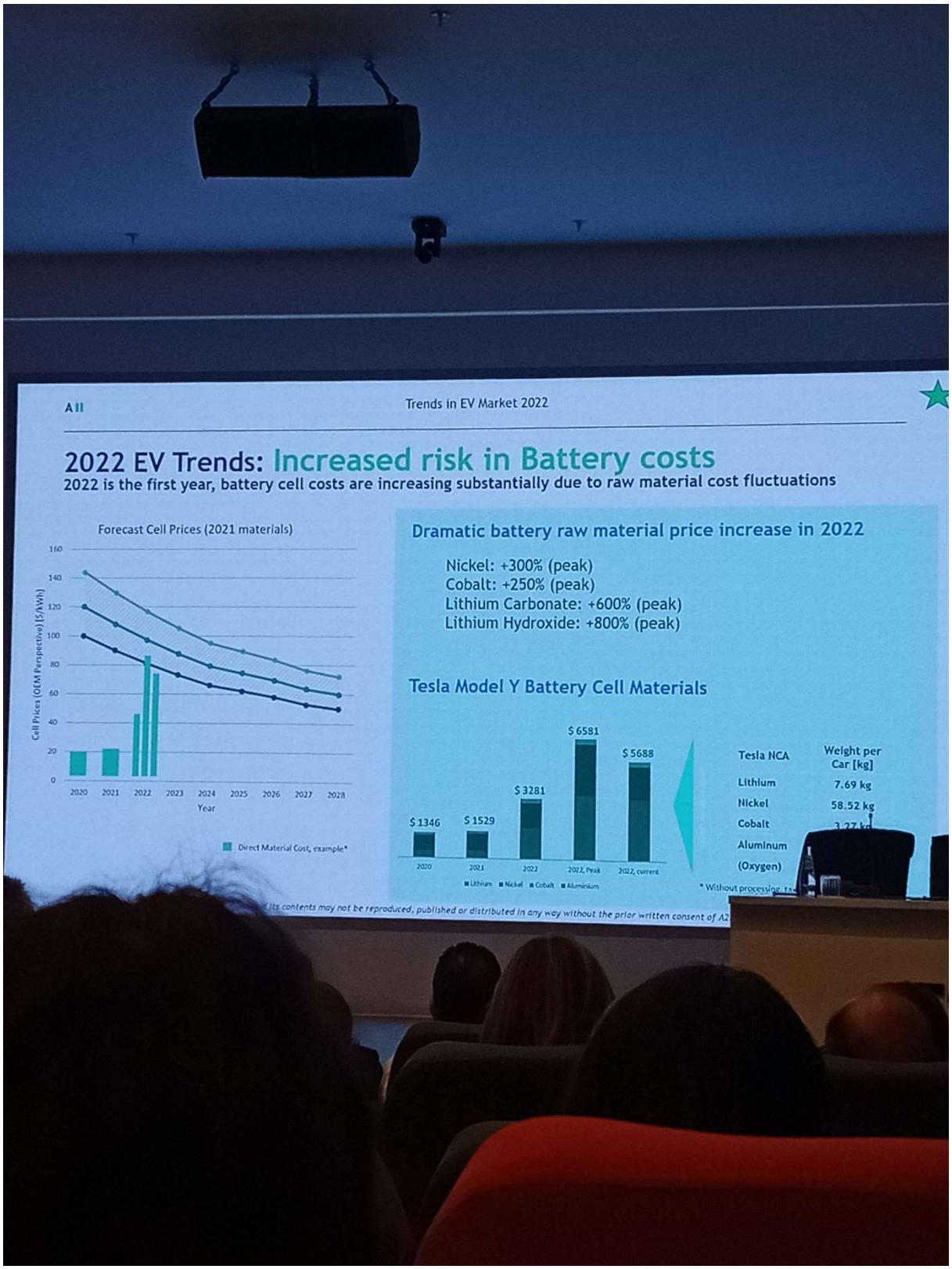
A II
Trends in EV Market 2022
2022 EV Trends: Increased risk in Battery costs
2022 is the first year, battery cell costs are increasing substantially due to raw material cost fluctuations
Forecast Cell Prices (2021 materials)
Cell Prices (OEM Perspective) [$/kWh]
160
140
120
100
80
60
40
20
0
2020
2021
2022
2023
2024
2025
2026
2027
2028
Year
Direct Material Cost, example*
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
$ 1346
$ 1529
$ 3281
$ 6581
$ 5688
2020
2021
2022
2022, Peak
2022, current
Lithium
Nickel
Cobalt
Aluminium
Tesla NCA
Weight per Car [kg]
Lithium
7.69 kg
Nickel
58.52 kg
Cobalt
Aluminum
(Oxygen)
* Without processing, tra
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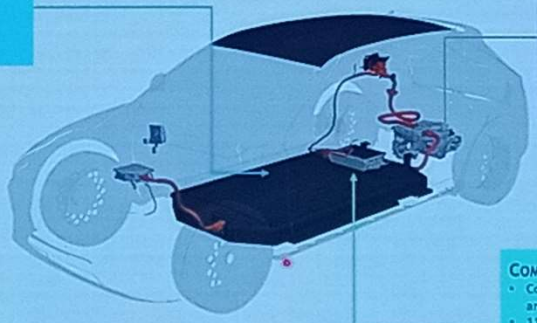
Hyundai IONIQ 5 RWD: Powertrain Overview

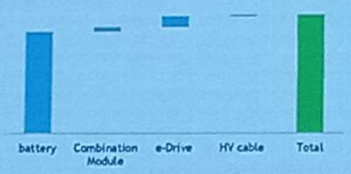
HV-Battery
- 72.6 kWh (specification, measured to be 77.3kWh) / 653 V
- Pouch Cells by SK Innovation
- 450 kg / 474 l
- 171 Wh/kg, 163 Wh/l

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



Detailed bottom-up cost analysis on component level

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



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 be
modules, relatively compac

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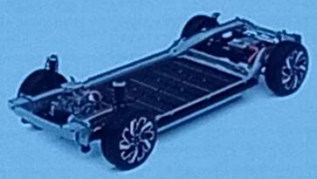
Hyundai Motors: Electric Global Modular Platform

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 efficien
and achieve higher ran

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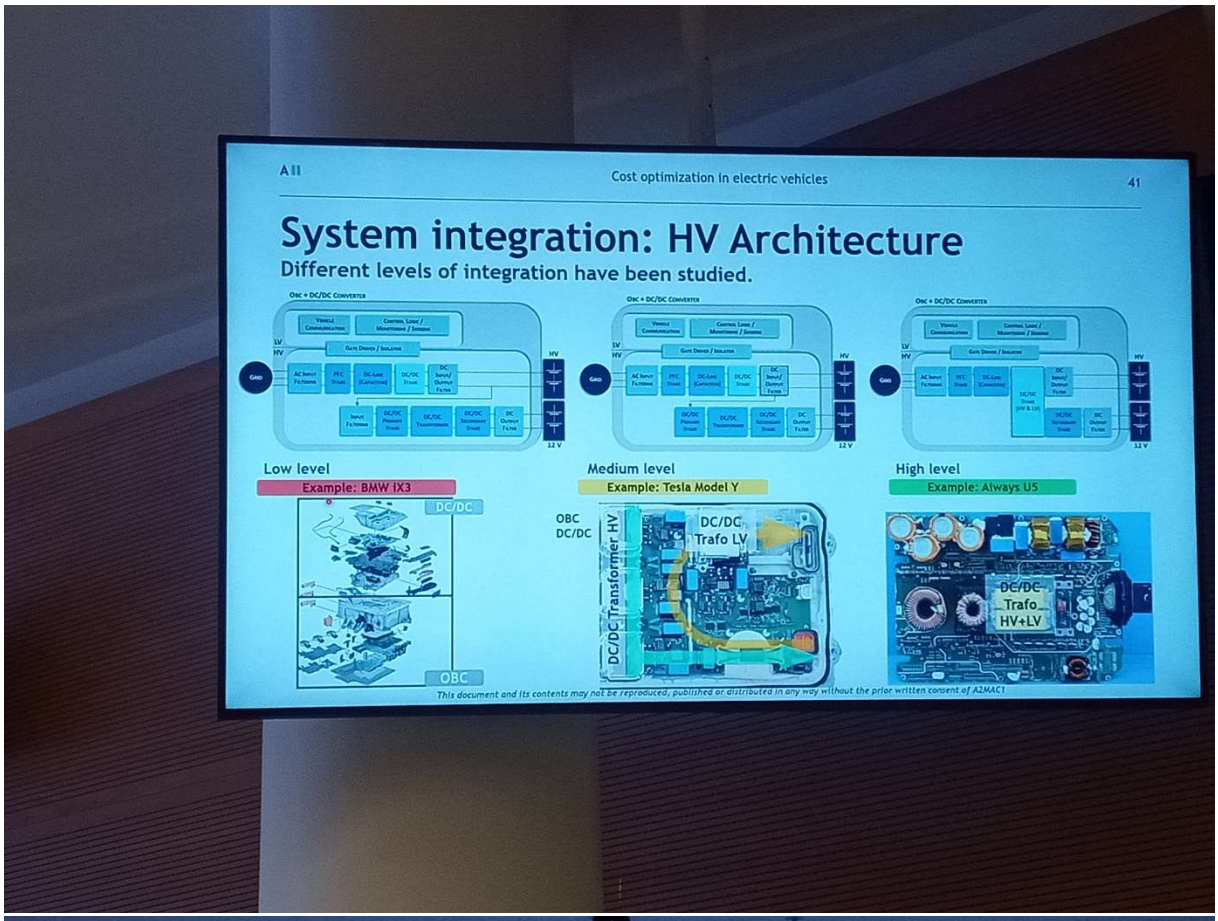
A II
Cost optimization in electric vehicles
41
System integration: HV Architecture
Different levels of integration have been studied.
Low level
Example: BMW iX3
DC/DC
OBC
Medium level
Example: Tesla Model Y
OBC
DC/DC
DC/DC Transformer HV
DC/DC
Trafo LV
High level
Example: Always U5
DC/DC
Trafo
HV+LV
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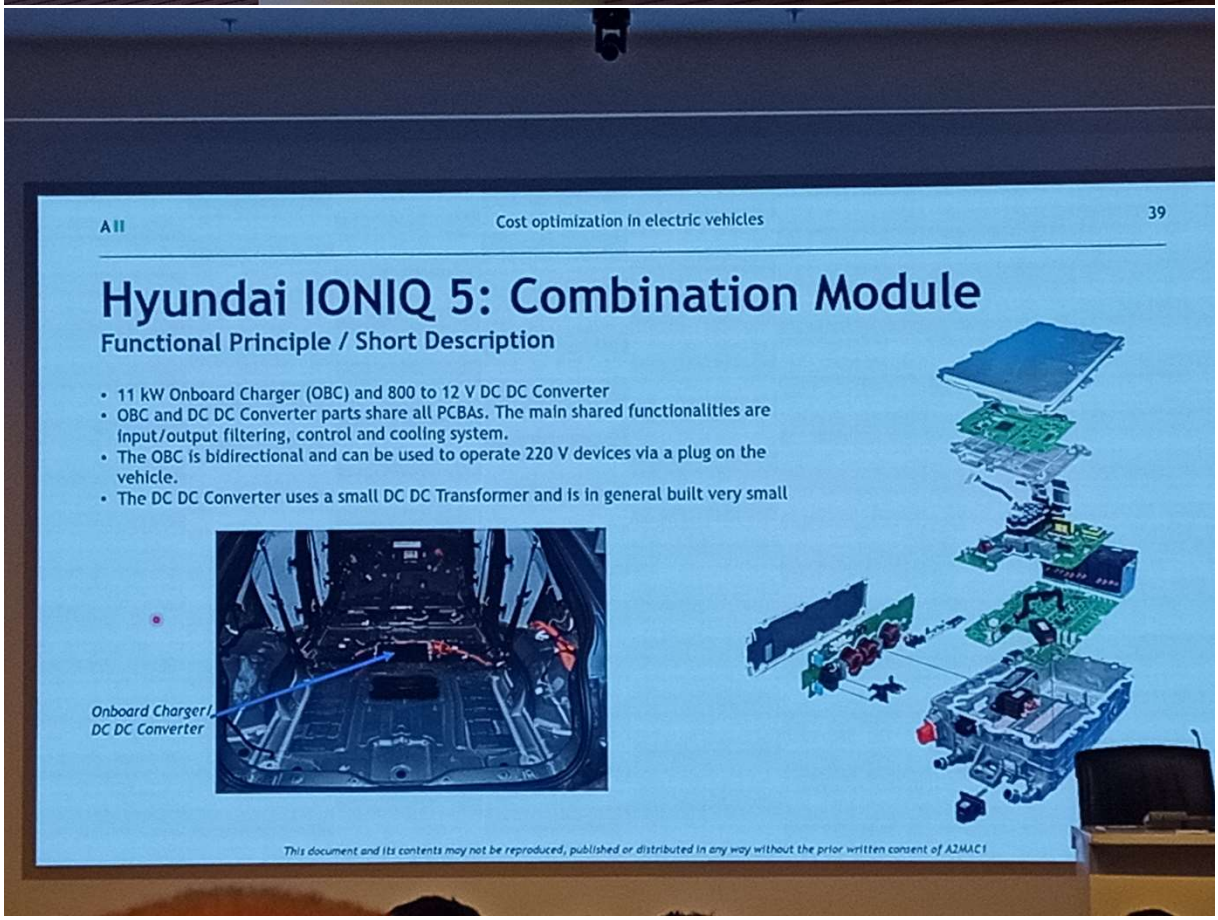
A II
Cost optimization in electric vehicles
39
Hyundai IONIQ 5: Combination Module
Functional Principle / Short Description
• 11 kW Onboard Charger (OBC) and 800 to 12 V DC DC Converter
• OBC and DC DC Converter parts share all PCBAs. The main shared functionalities are input/output filtering, control 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
Onboard Charger/
DC DC Converter
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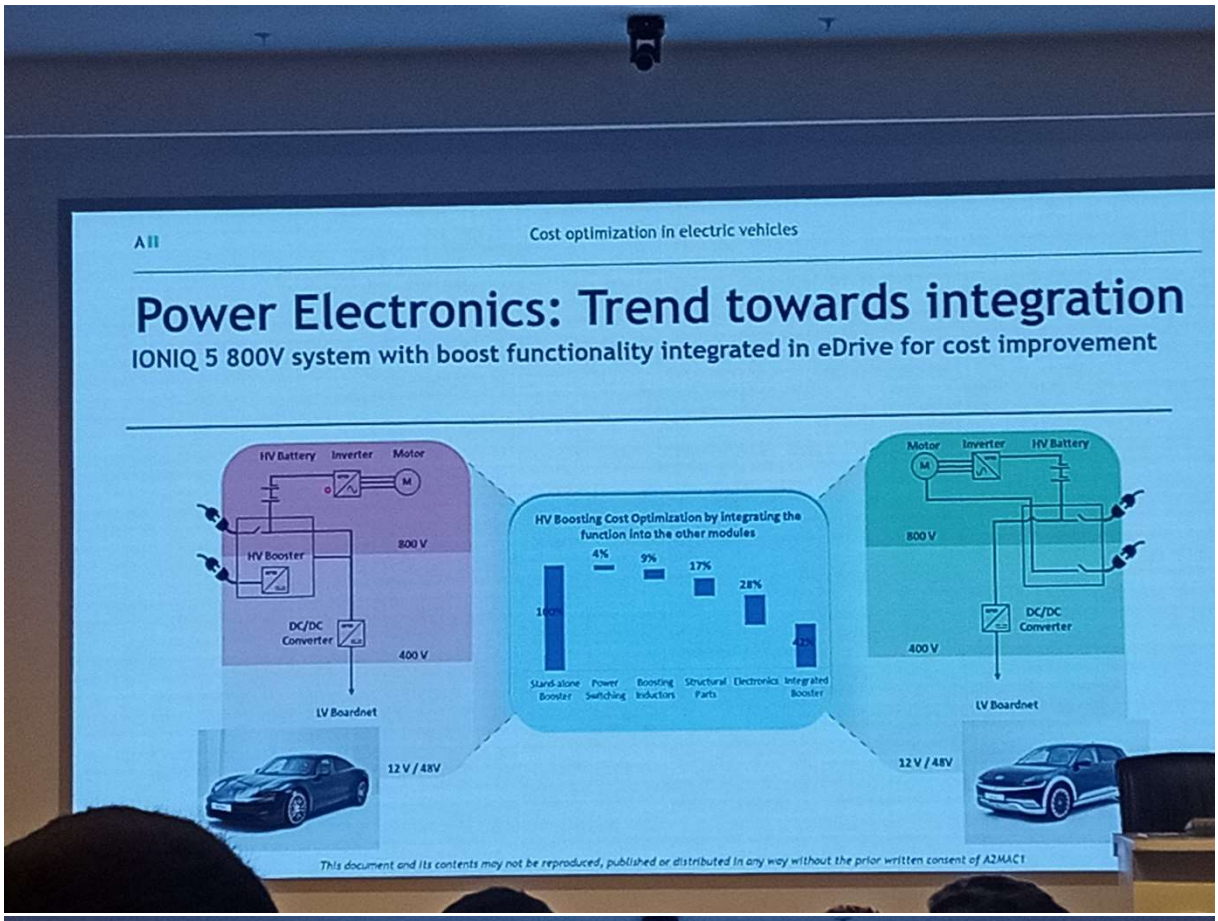
A II
Cost optimization in electric vehicles
Power Electronics: Trend towards integration
IONIQ 5 800V system with boost functionality integrated in eDrive for cost improvement
HV Battery
Inverter
Motor
HV Booster
800 V
DC/DC Converter
400 V
LV Boardnet
12 V / 48V
HV Boosting Cost Optimization by integrating the function into the other modules
100%
4%
9%
17%
28%
42%
Stand-alone Booster
Power Switching
Boosting Inductors
Structural Parts
Electronics
Integrated Booster
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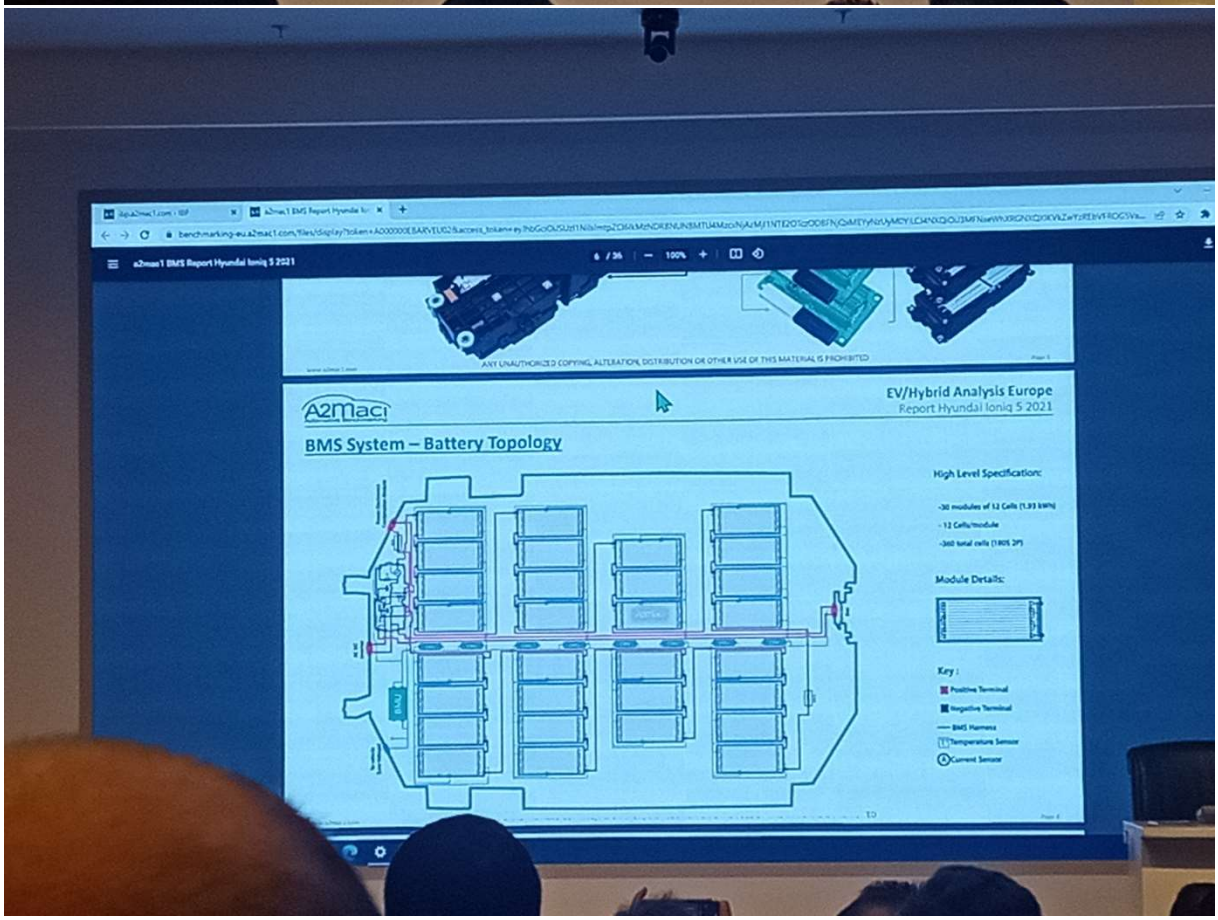
a2mac1 BMS Report Hyundai Ioniq 5 2021
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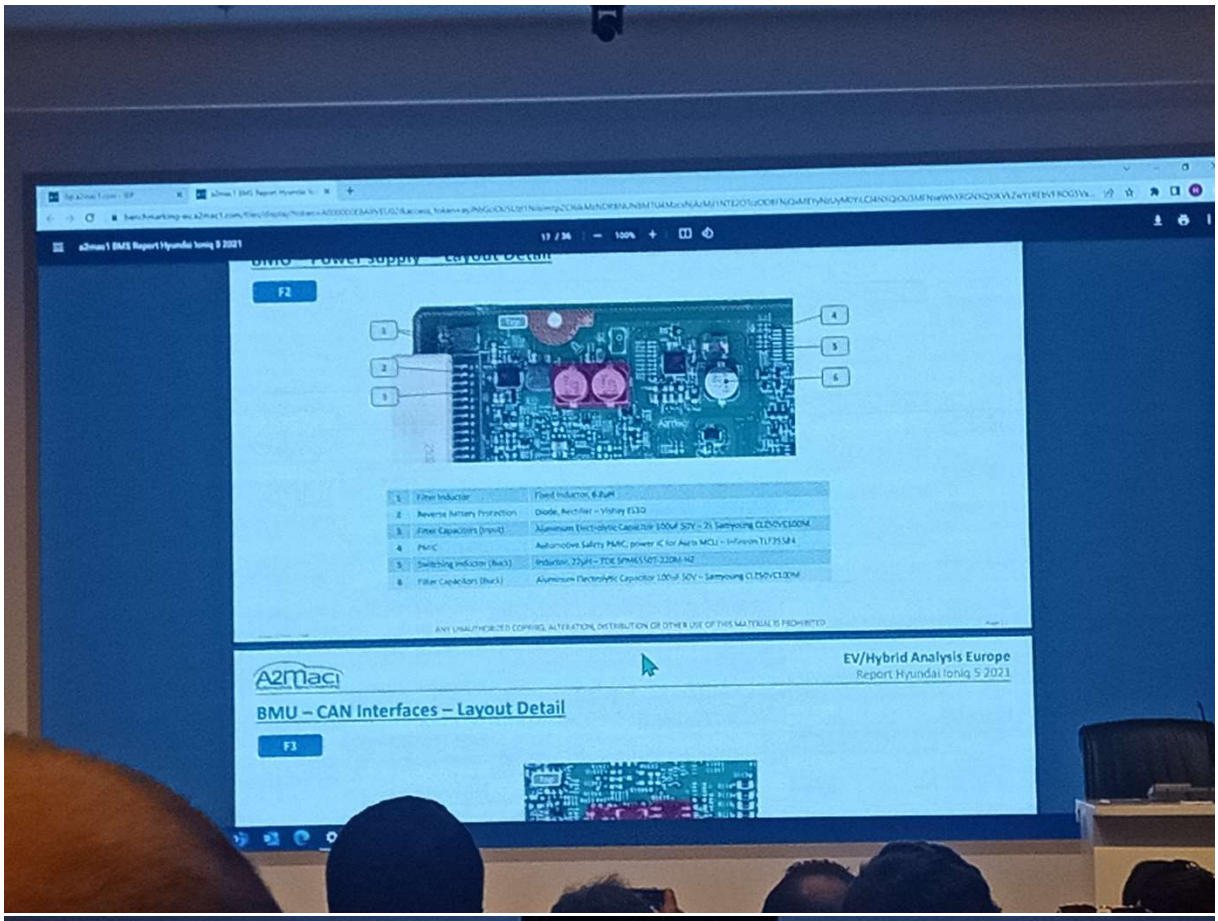
A2mac1
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMS System – Battery Topology
High Level Specification:
Module Details:
Key :
Positive Terminal
Negative Terminal
BMS Harness
Temperature Sensor
Current Sensor


a2mac1 BMS Report Hyundai Ioniq 5 2021
17 / 36
F2
1
2
3
4
5
6
1 Filter Inductor Fixed Inductor, 8.2uH
2 Reverse Battery Protection Diode, Rectifier – Vishay ES1Q
3 Filter Capacitors (Input) Aluminum Electrolytic Capacitor 100uF 50V – 2) Samsung CL05V101M
4 PMIC Automotive Safety PMIC, power IC for Auto MCU – Infineon TLF35584
5 Switching Inductor (Buck) Inductor, 22µH – TDK SPM6530T-220M-HZ
6 Filter Capacitors (Buck) Aluminum Electrolytic Capacitor 100uF 50V – Samsung CL05V101M
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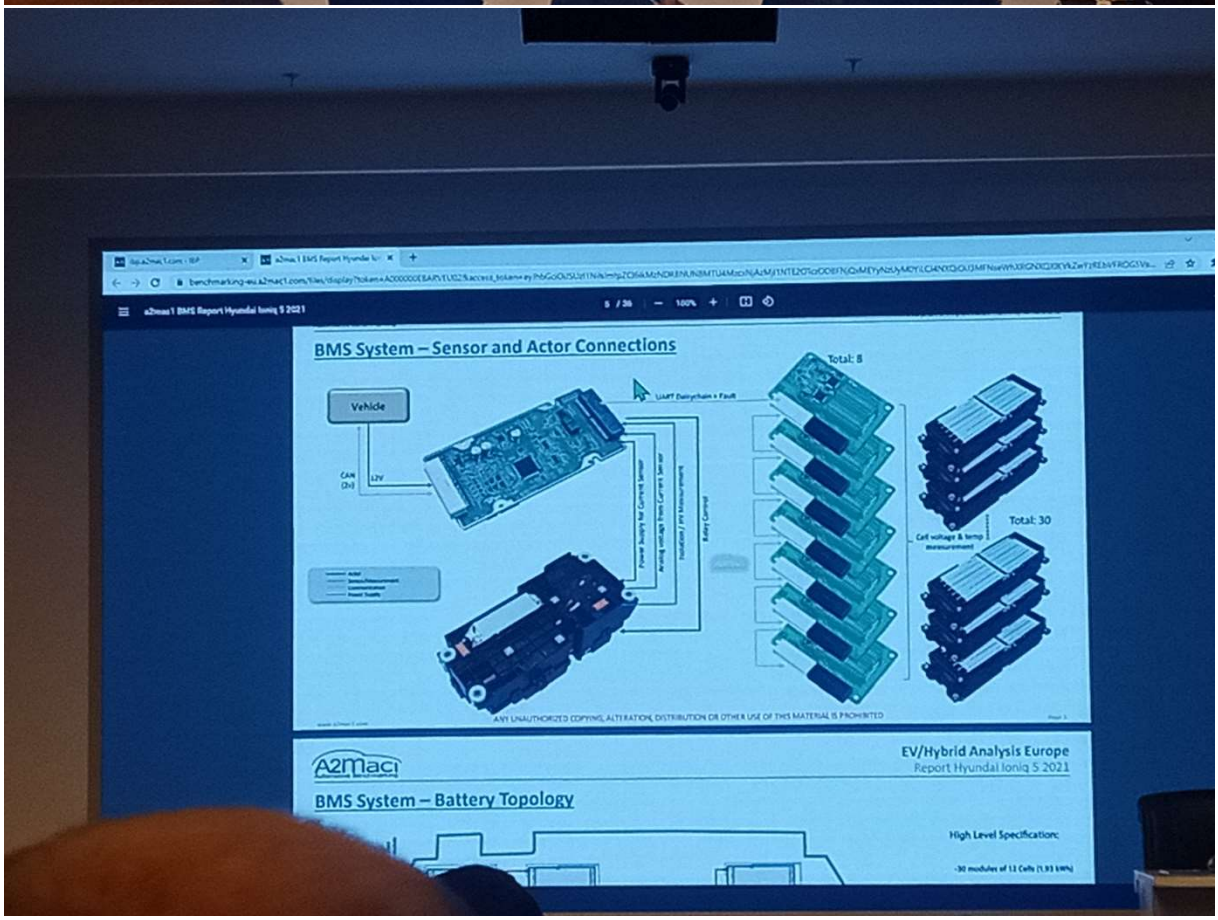
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMU – CAN Interfaces – Layout Detail
F3


a2mac1 BMS Report Hyundai Ioniq 5 2021
5 / 36
BMS System – Sensor and Actor Connections
Vehicle
CAN (2x)
12V
UART Daisychain + Fault
Total: 8
Total: 30
Cell voltage & temp measurement
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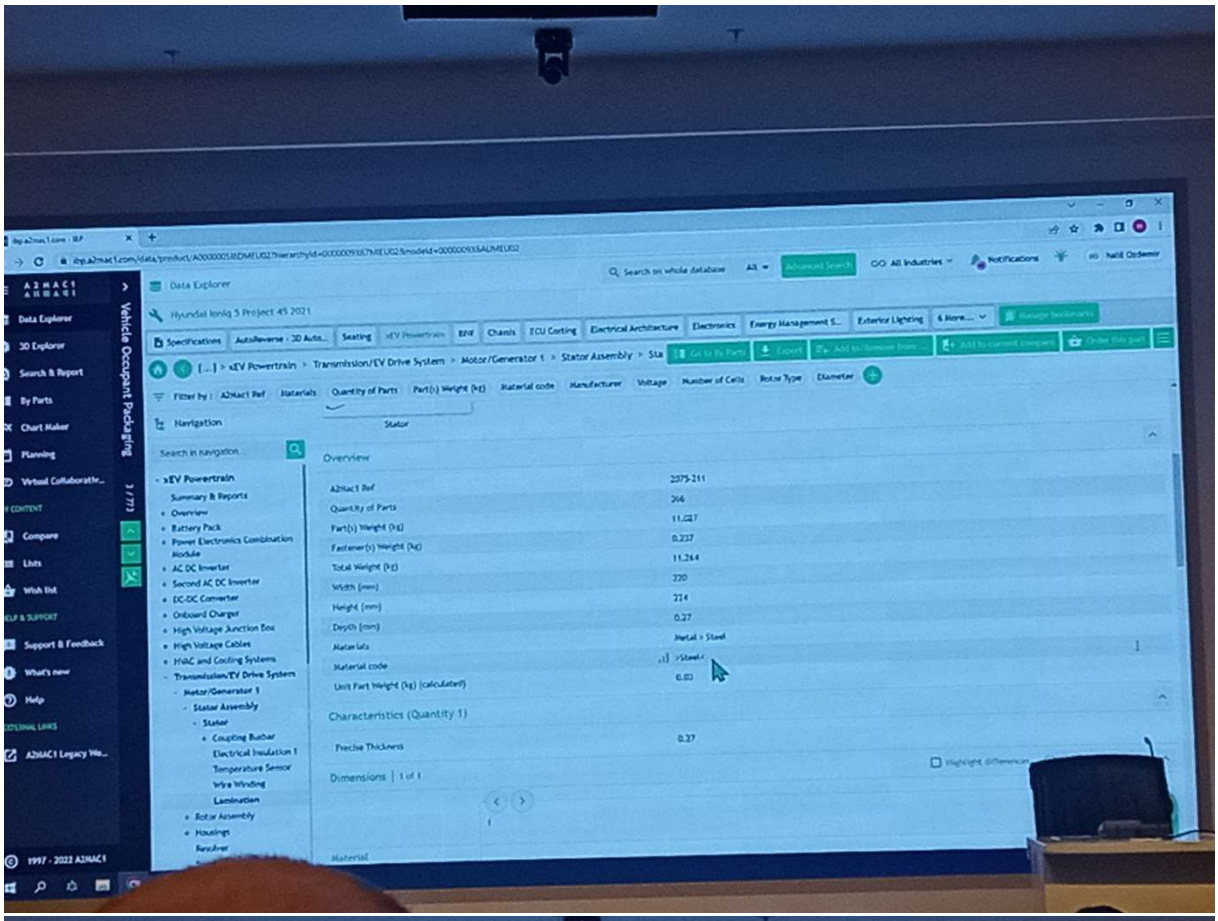
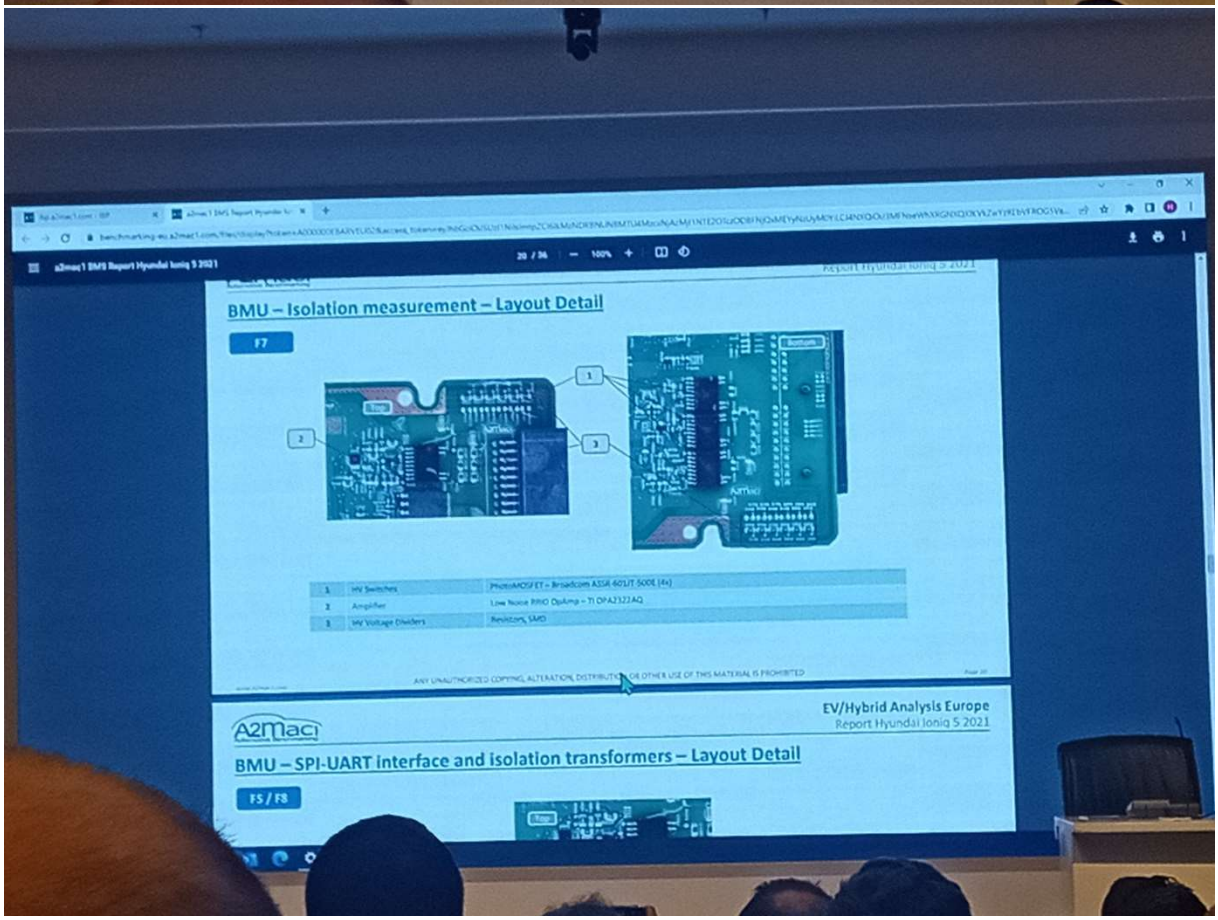
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMS System – Battery Topology
High Level Specification:

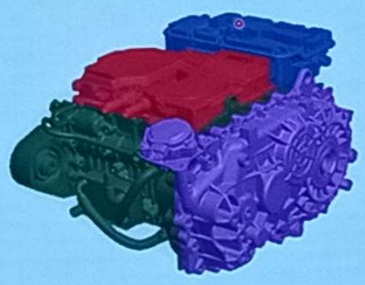

Data Explorer
Hyundai Ioniq 5 Project 45 2021
Specifications
Electrical Architecture
Electronics
Exterior Lighting
Vehicle Occupant Packaging
Navigation
Overview
Characteristics (Quantity 1)
Dimensions
Material


BMU – Isolation measurement – Layout Detail
F7
EV/Hybrid Analysis Europe
Report Hyundai Ioniq 5 2021
BMU – SPI-UART interface and isolation transformers – Layout Detail
F5 / F8

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 [mm³]	1460 x 212 x 2190
Cooling	Liquid
Battery Assembly	Hyundai - Korea
Cell Supplier	SK Innovation
Country of Production	Korea

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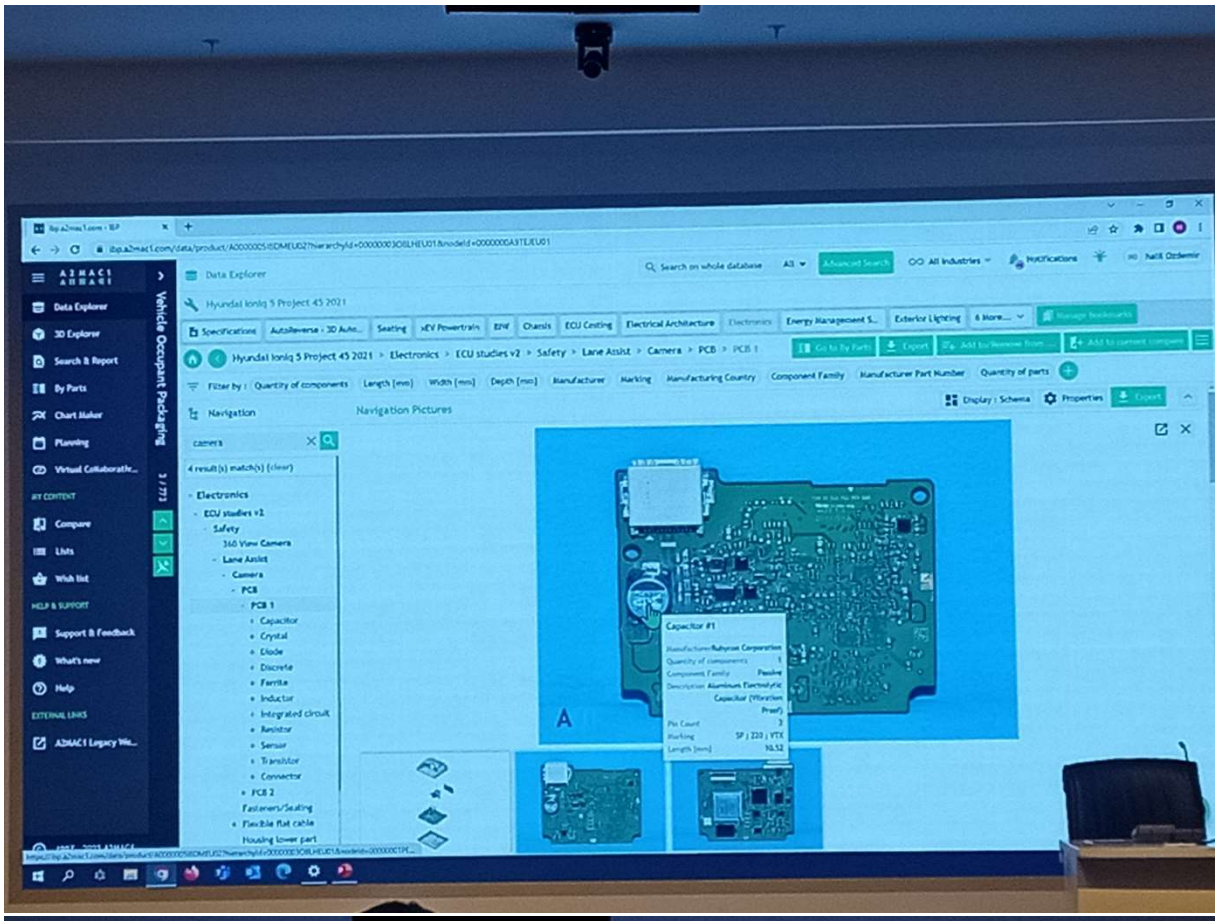
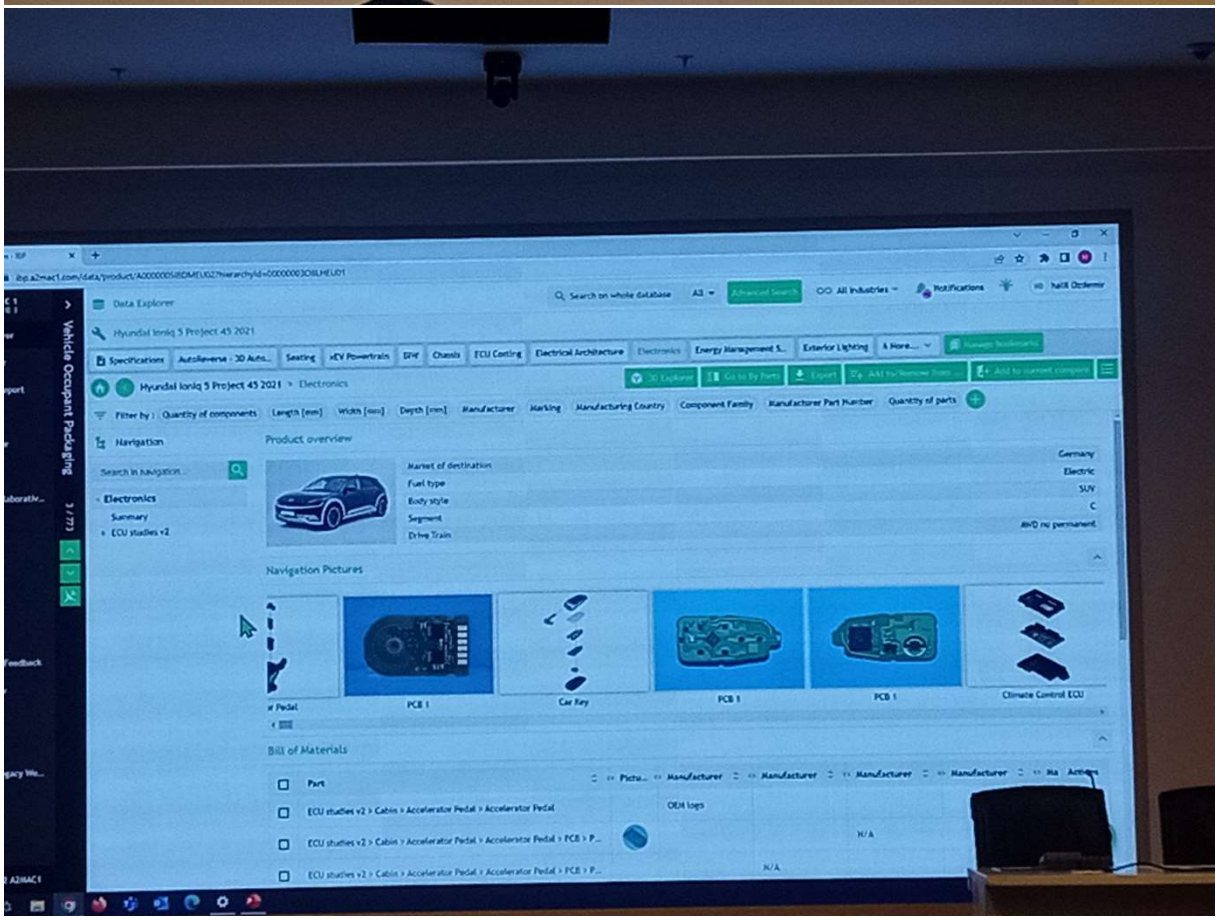
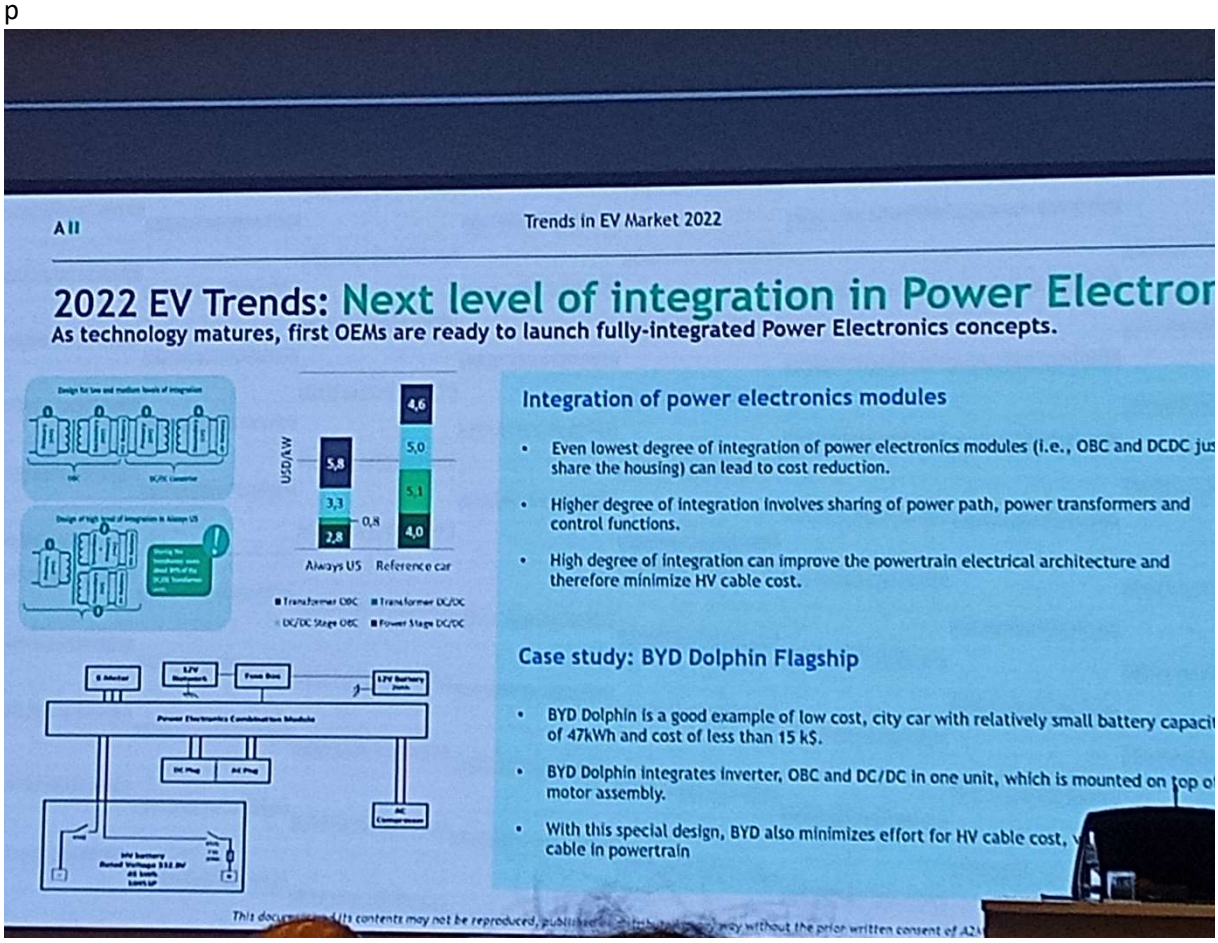

Data Explorer
Hyundai Ioniq 5 Project 45 2021
Hyundai Ioniq 5 Project 45 2021 > Electronics > ECU studies v2 > Safety > Lane Assist > Camera > PCB > PCB 1
Navigation
Navigation Pictures
Vehicle Occupant Packaging
Capacitor #1
A


Data Explorer
Hyundai Ioniq 5 Project 45 2021 > Electronics
Navigation
Product overview
Navigation Pictures
Bill of Materials
Vehicle Occupant Packaging

p


Trends in EV Market 2022
2022 EV Trends: Next level of integration in Power Electror
As technology matures, first OEMs are ready to launch fully-integrated Power Electronics concepts.
USD/kW
5,8
3,3
0,8
2,8
4,6
5,0
5,1
4,0
Always US
Reference car
Transformer OBC
Transformer DC/DC
DC/DC Stage OBC
Power Stage DC/DC
Integration of power electronics modules
Even lowest degree of integration of power electronics modules (i.e., OBC and DCDC jus 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 capaci 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 o motor assembly.
With this special design, BYD also minimizes effort for HV cable cost, cable in powertrain