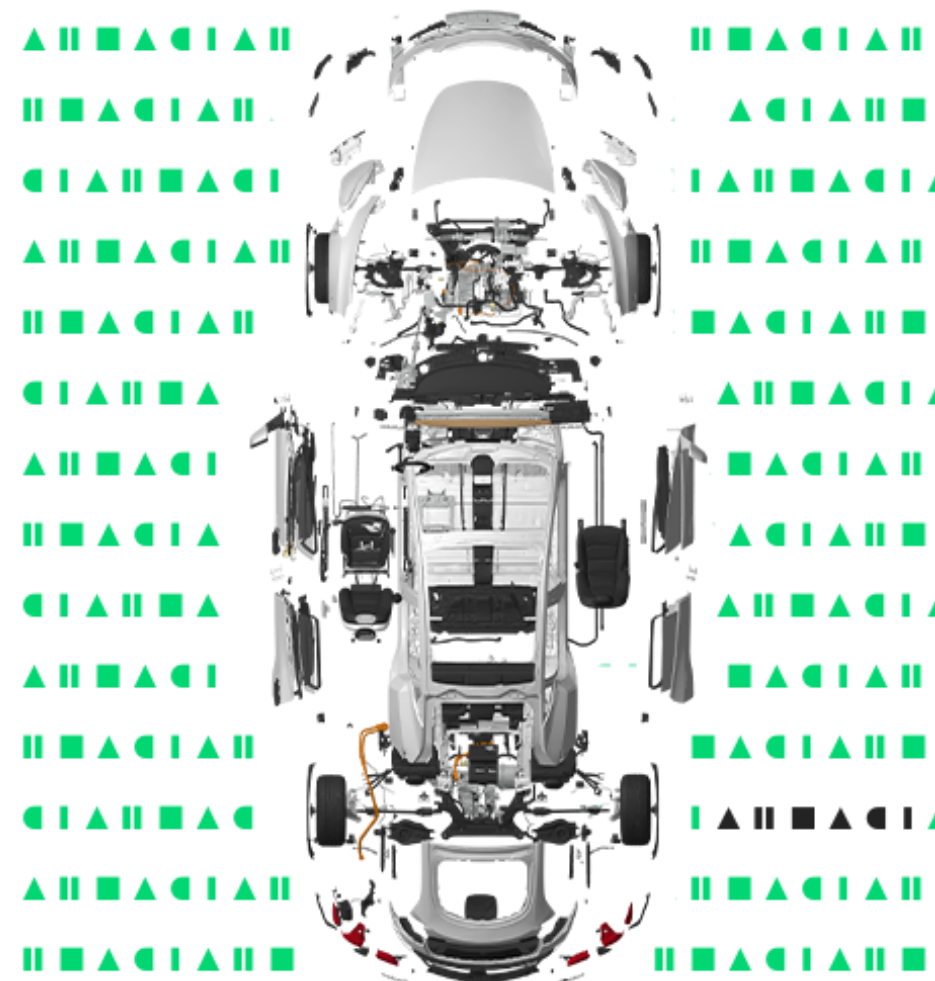


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# Sustainability Insights Battery Packs

ARPA-E

Miranda Jarvis  
Florian Waimer



# A2MAC1 is the leading insights provider for automotive OEMs / Suppliers



## Insights

Technology Insights  
Performance Insights  
Market Insights

## Platform

Benchmarking Software-as-a-Service



Benchmarking support delivered to all major OEMs and over 200 of their suppliers



A highly effective benchmarking methodology with standardized & repeatable processes



**25**

Years



**600+**

Staff worldwide



**1500+**

Analyzed vehicles



**650+**

OEM and Supplier customers



**Global**

Footprint with 17 locations



**40Million**

Images and digital twins in our database



**100+**

New vehicles per years



**>650k**

Users worldwide

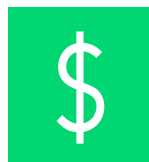
# A2MAC1 covers the entire range of battery technologies



Sustainability



Technology



Cost



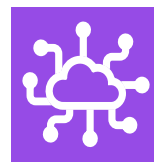
Performance



Market

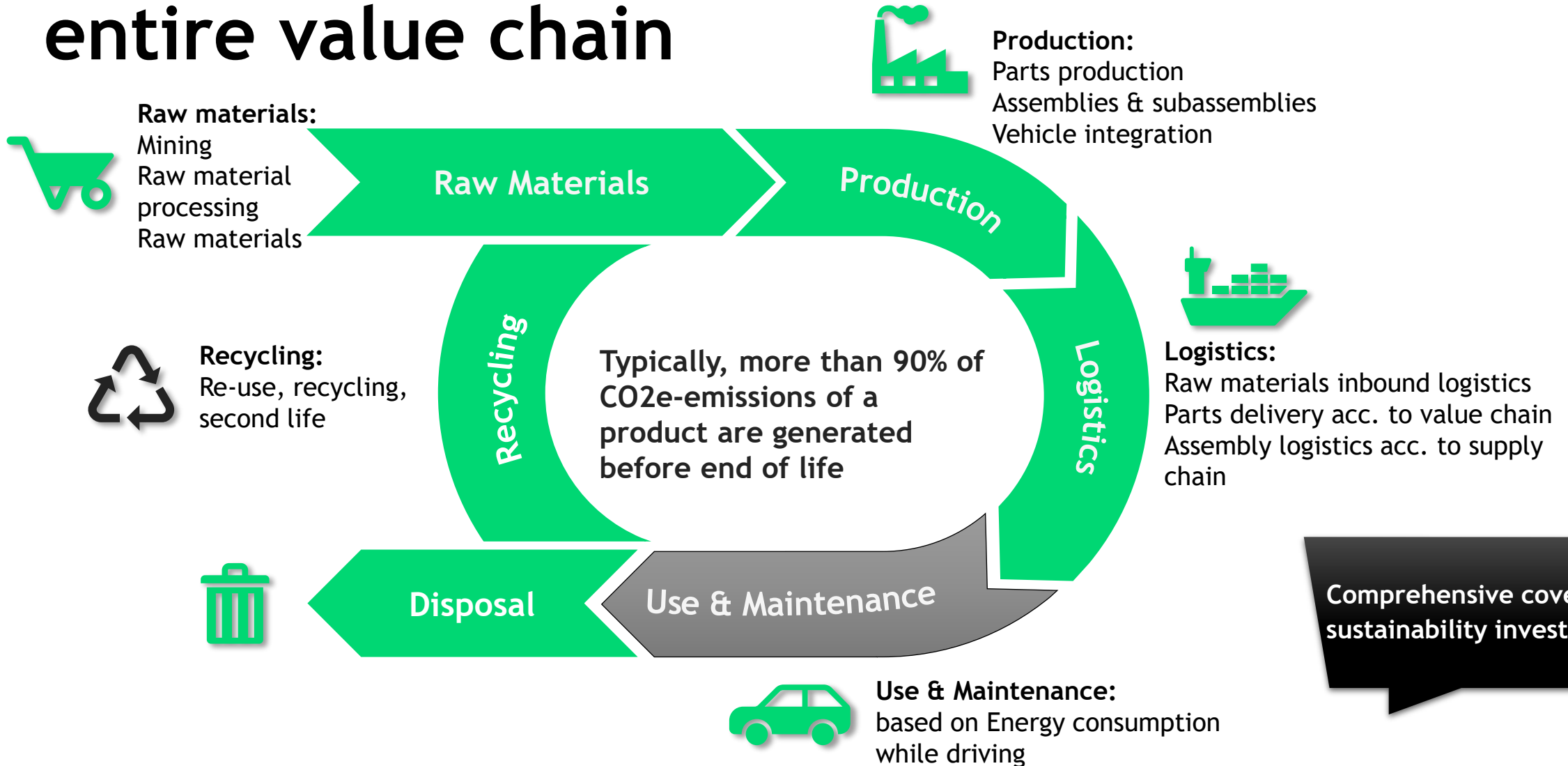


Sourcing

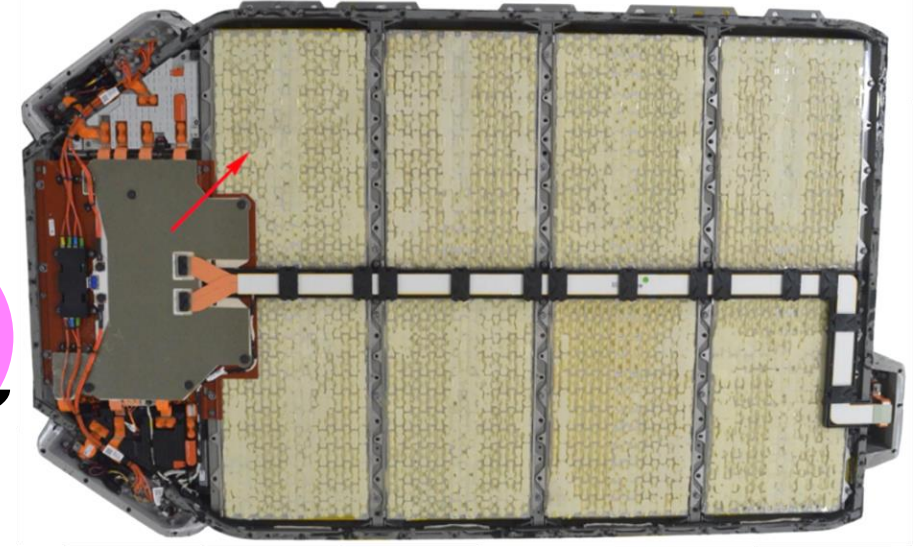
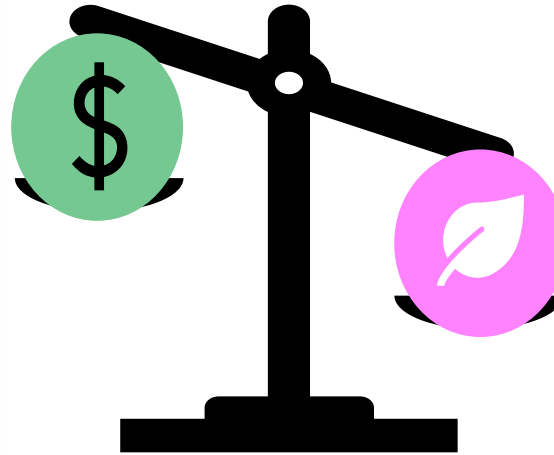
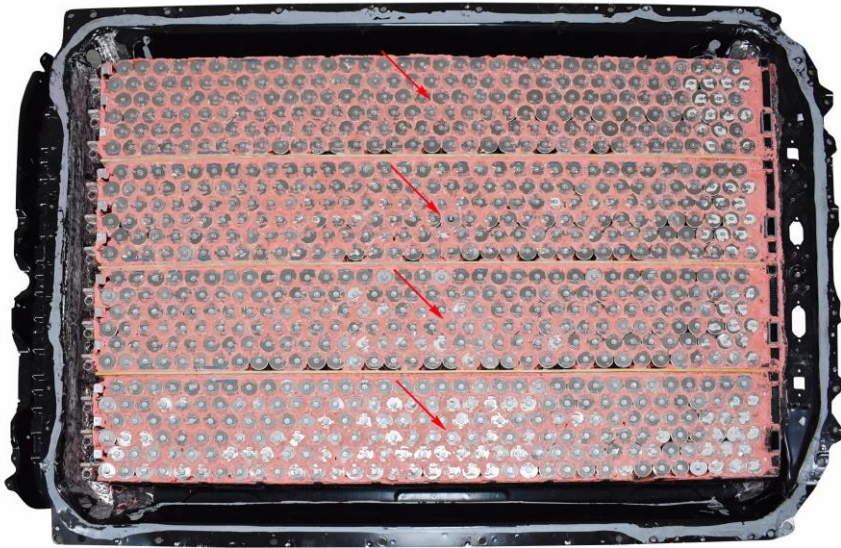


Software

# Our Sustainability investigations cover the entire value chain



# A2MAC1 is able to evaluate tradeoffs between Sustainability and Cost



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We provide in-depth bottom-up **cost evaluation on a full vehicle scale**, linking technical design choices to cost implications, through **state-of-the-art costing methods** and combined with **deep technical expertise**.

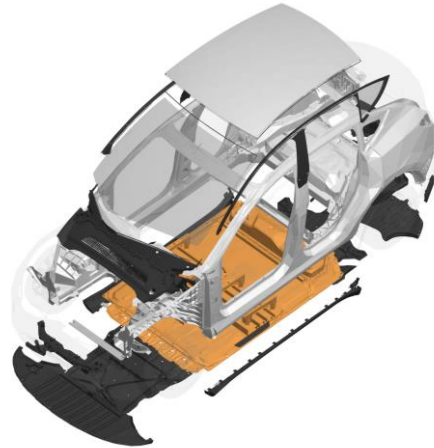
Cost and sustainability results are combined **to find the best solutions to balance economic and environmental interests**. We cover relevant technologies and manufacturing processes to effectively **evaluate commercial and sustainability levers**.

# Batteries to be compared

## High Integration Case

### Key Performance Indicators

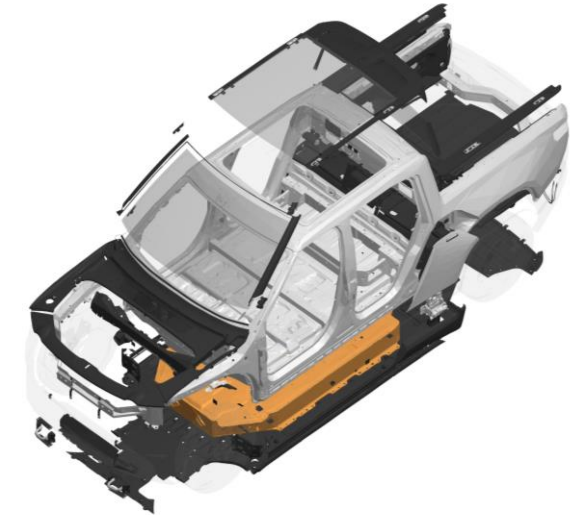
Nominal Battery Voltage [V]	341.3
Energy [kWh]	66
Weight [kg]	468.8
Dimensions [mm <sup>3</sup> ]	2140 x 1480 x 315
Country of Production	USA
Cell Chemistry	NMC 811
Cell Type	Cylindrical



## Low Integration Case

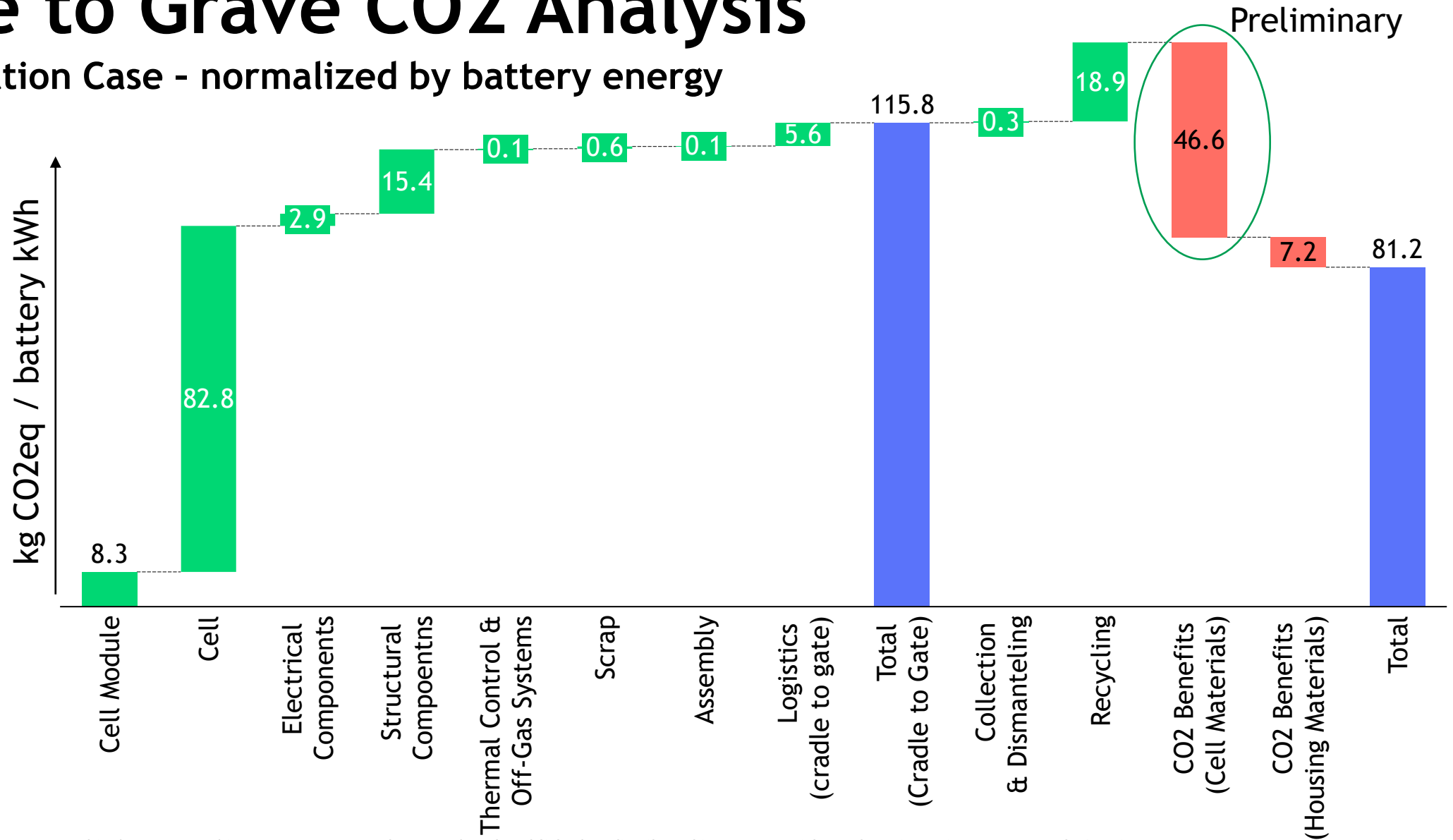
### Key Performance Indicators

Nominal Battery Voltage [V]	392
Energy [kWh]	141 (labeled)
Weight [kg]	793
Dimensions [mm <sup>3</sup> ]	2155 x 1355 x 225
Country of Production	USA
Cell Chemistry	NCA
Cell Type	Cylindrical



# Cradle to Grave CO2 Analysis

Low Integration Case - normalized by battery energy



# Details of the Analysis

## Low Integration Case: Battery Housing - Enclosure Top



					[kg CO <sub>2</sub> -eq]
Material			Required Quantity [kg]	Produced Quantity [kg]	
Steel, standard, sheet 2mm (39% recycled)			33.76	17.00	101.809
Production	Qty.	Machine	Cycle Time [s]	Energy Use [kWh/h]	
Stamping	1	Blanking Press - 1500T	4.0	737	0.475
Stamping - long brackets	4	Blanking Press - 1500T	3.2	737	1.497
Stamping - short brackets	8	Blanking Press - 1500T	3.2	737	2.995
Stamping -dot brackets	6	Blanking Press - 1500T	3.2	737	2.246
Cleaning	1	Cleaning - Batch	1.0	60	0.010
Welding	1	MIG - Turntable 2 KUKA - Robot Unload	300.0	58	2.805
Cataphoresis Painting	1	Electrophoresis line - with 8x120kW on line ovens	75.0	523	6.320
Handling/Visual inspection/packaging	1	Packaging	8.0	1	0.001
<b>Total Production</b>					<b>16.349</b>
<b>Scrap</b>					<b>8.626</b>
<b>Logistics (Mexico to USA)*</b>					<b>41.548</b>
<b>Total Carbon Footprint [kg CO<sub>2</sub>-eq]</b>					<b>168.332</b>

\*Not normally added on a part by part basis

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# Details of the Analysis

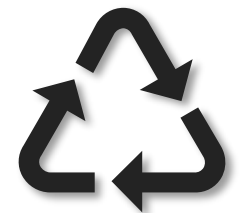
## Recycling Model

90% of metals and cathode / anode materials recovered

### Recycling Metals (Battery Housing etc)

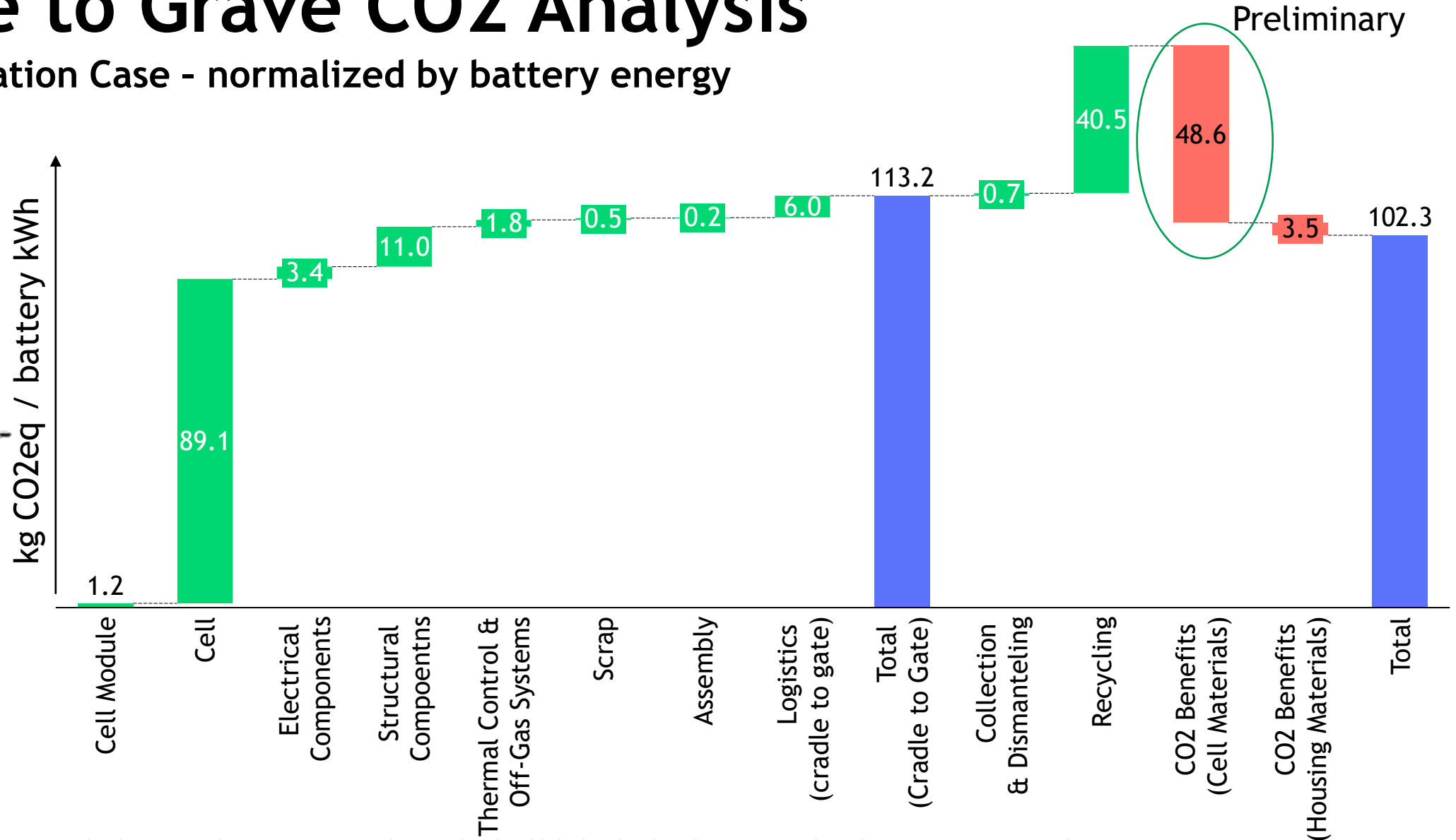


### Recycling Battery Cells



# Cradle to Grave CO2 Analysis

High Integration Case - normalized by battery energy



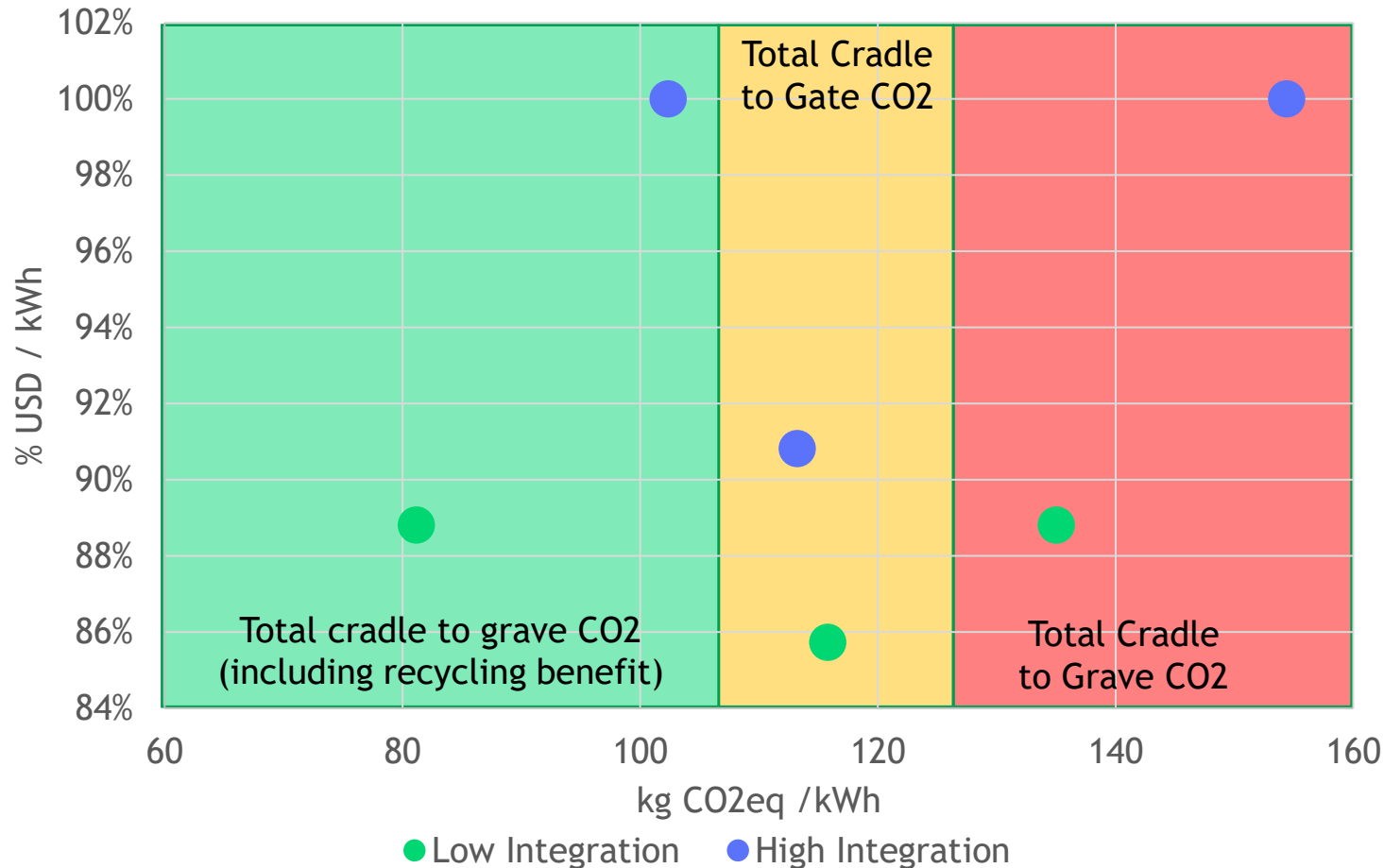
# Overall Comparison



High Integration Case	Low Integration Case
Energy [kWh]	
66	141
Energy Density [kWh/kg]	
0.14	0.18
Specific Energy [kWh/L]	
0.10	0.22
CO2-Footprint [kg/kWh]	
102	81

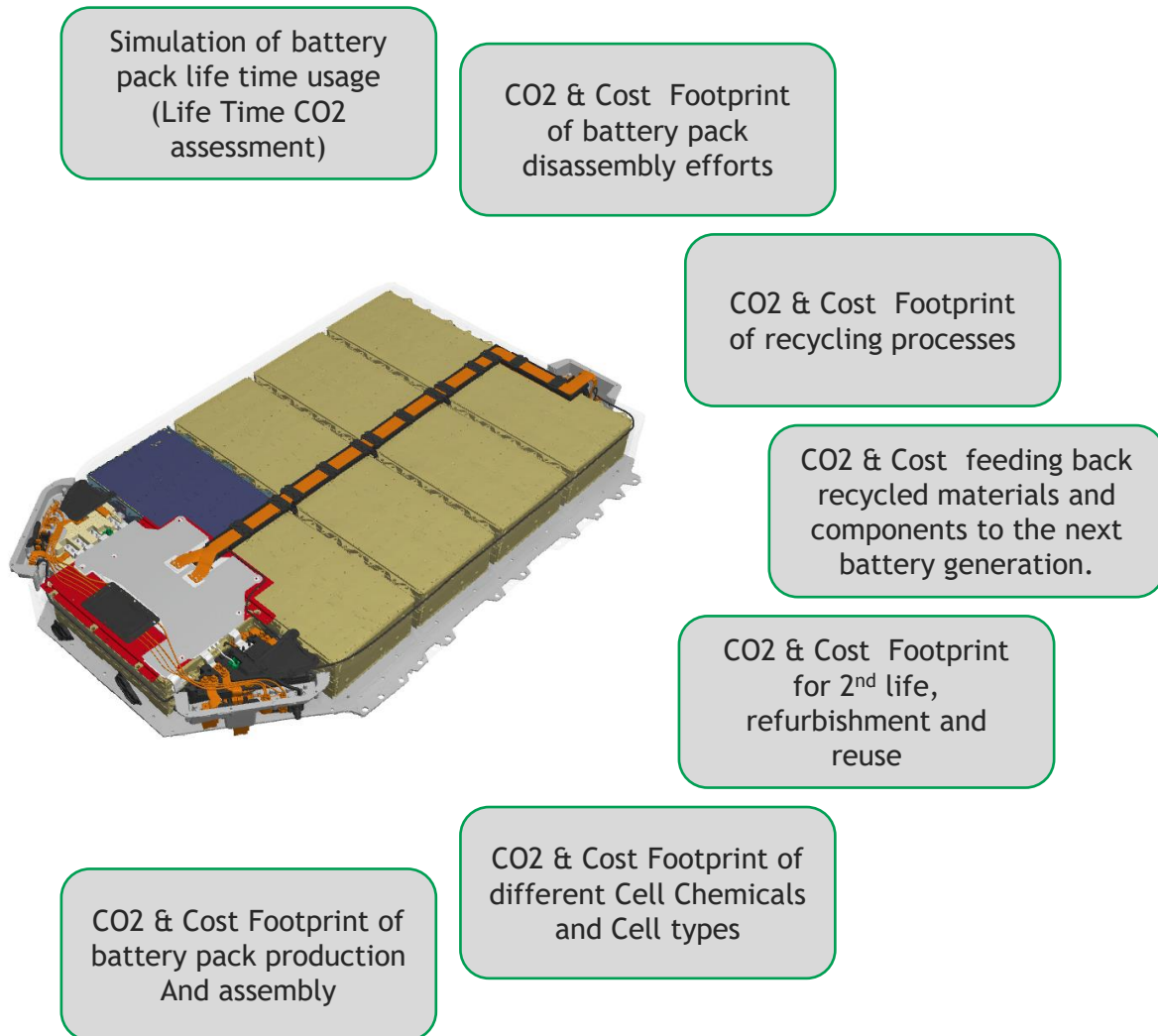


# Main Findings



- Per kWh of battery the High Integration solution has a slightly lower Carbon footprint and significantly higher cost than the Low Integration solution when only Cradle to Gate emissions are considered
- However, when end of life is taken into account, the High Integration solution performs worse in terms of both carbon and cost

# Conclusion



- A2MAC1's detailed teardown analysis and market research allow us to provide detailed, bottom-up CO2 calculations considering:
  - raw material (incl. mining)
  - cell chemistry and design
  - production and tear down (disassembling)
  - recycling rates
- With the insights drawn from this analysis, particularly in combination with our cost and performance insights, A2MAC1 can evaluate the sustainability of different battery design choices and determine best practices
- In the current example calculation, we demonstrated the importance of holistic cradle to cradle evaluations when design for sustainability or benchmarking the pros and cons of different design choices



# Thank you

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**Miranda Jarvis**

Sustainability Lead

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*Decode the future*

