BatteryDesign.net

What can we learn from Battery Benchmarking?

Nigel Taylor

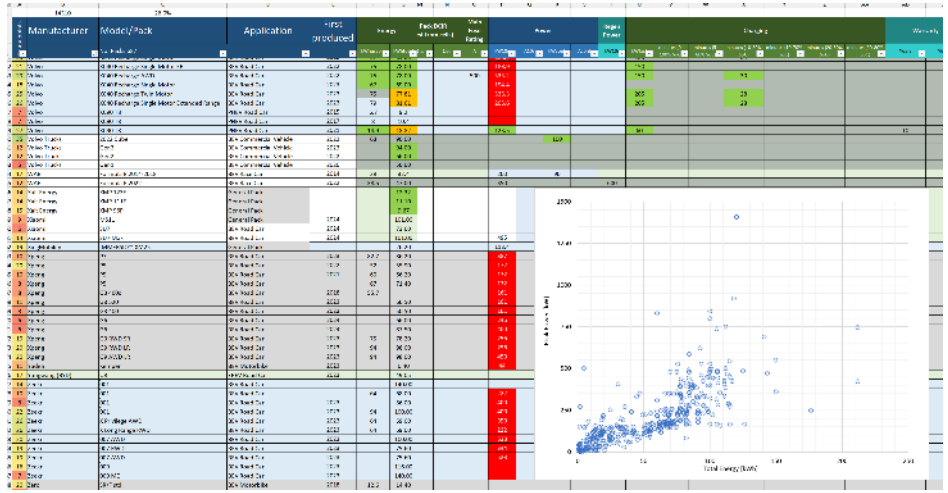
nigel@batterydesign.net

What can we learn from Battery Benchmarking?

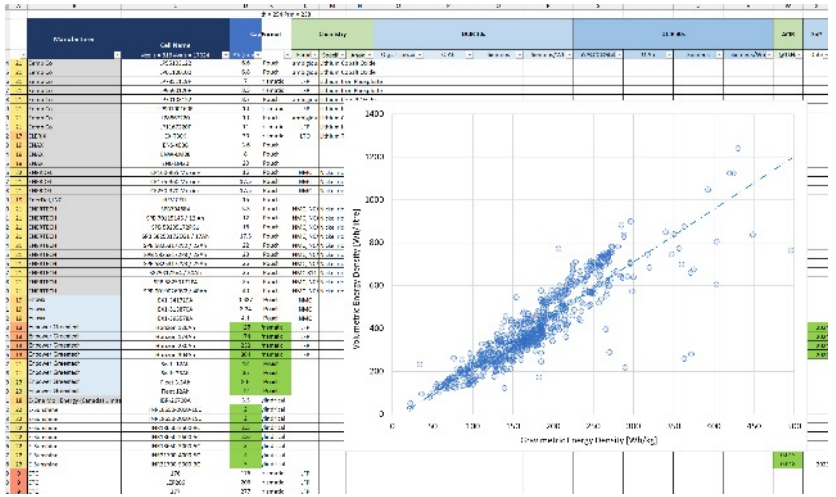
We don’t have the resources to take batteries apart, but there are lots out there who do and they share lots of data.

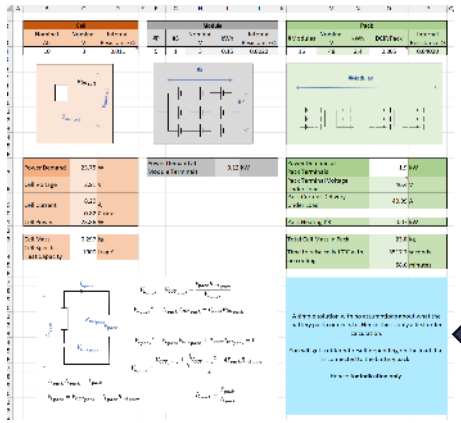
Data => Estimations / Limit Cases => Calculations

pack database



cell database





calculations

BatteryDesign.net

Tesla 2022 Model Y 4680

Early model teardown and weight of pack + interior trim and seats.

⇒ Create parts list => estimate mass => estimate 4680 pack mass

⇒ Compare to Model 3 21700 based pack

Tesla Model Y	2022 4680			
Pack				
Total energy	71.5	kWh		
Usable energy	67.5	kWh	ref 1	
Usable window	94.4%			
Nominal pack voltage	340.4	V		
Nominal pack capacity	210.15	Ah		
Maximum pack voltage	386.4	V		
Minimum pack voltage	230	V		
Configuration				
s	92	s		
p	9	p		20lb less at car level
Pack mass	445	kg		-9 kg at car level
Cell mass	294	kg		
Cooling				
Cost	$ 5,000.00			
Discharge				
Peak power	252	kW10s		227 kW @ motor
Continuous power		kW		
Charging				
5 to 80%		minutes		
peak charge power		kW		
motor regen max power		kW		
Module				
#modules	4			
#cells per module	207			
s		s		
p		p		
Cell				
#cells	828			
Nominal voltage	3.7	V		
nominal capacity	23.35	Ah		
total energy	86.40	Wh		
Maximum voltage	4.20	V		
Minimum voltage	2.5	V		
cell mass	0.355	kg		
Continuous power		W		
Peak power	304.6	W_{10s}		
Wh/kg	161	Wh/kg		
W10s/kg		W/kg		
Cell to pack mass ratio	66%			
$/kWh	$ 69.90			

References

1 https://electrek.co/2022/06/10/tesla-model-y-4680-cells-faster-charging/

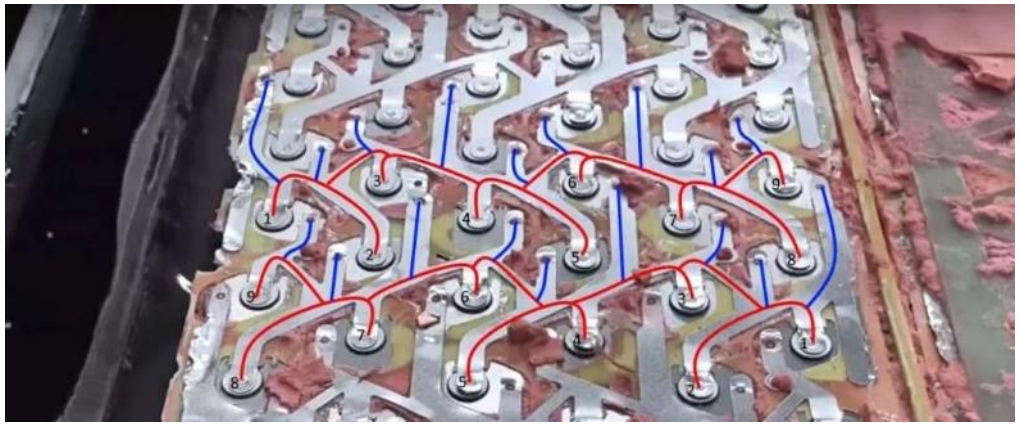
2 https://www.torquenews.com/15475/what-difference-weight-do-tesla-4680-cells-make

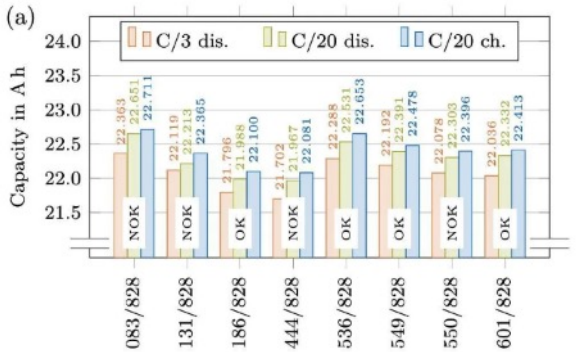
s	p	Total Pack Energy kWh	Usable Energy kWh	SoC window
92	6	47.7		
92	7	55.6		
92	8	63.6	67.5	106.15%
92	9	71.5	75.9	106.15%
92	10	79.5		

Tesla Model Y with 4680 cells weighs 4480lb and with 2170 cells weighs 4500lb [ref 2]

Weight Estimate		
Battery+seats+console+c	1198	lb
arpet	543.4	kg
Model 3 Front seat	44.8	kg
Front seat rails	10.6	kg
Carpets + underlay	23.5	kg
Centre Console	10.8	kg
Inner floor structure	8	kg
Wiring	0.5	kg
Battery	**445**	**kg**
Note: Model 3 Battery weight	*481*	*kg*

Pack capacity from declared cycle testing. Cell configuration from teardown.





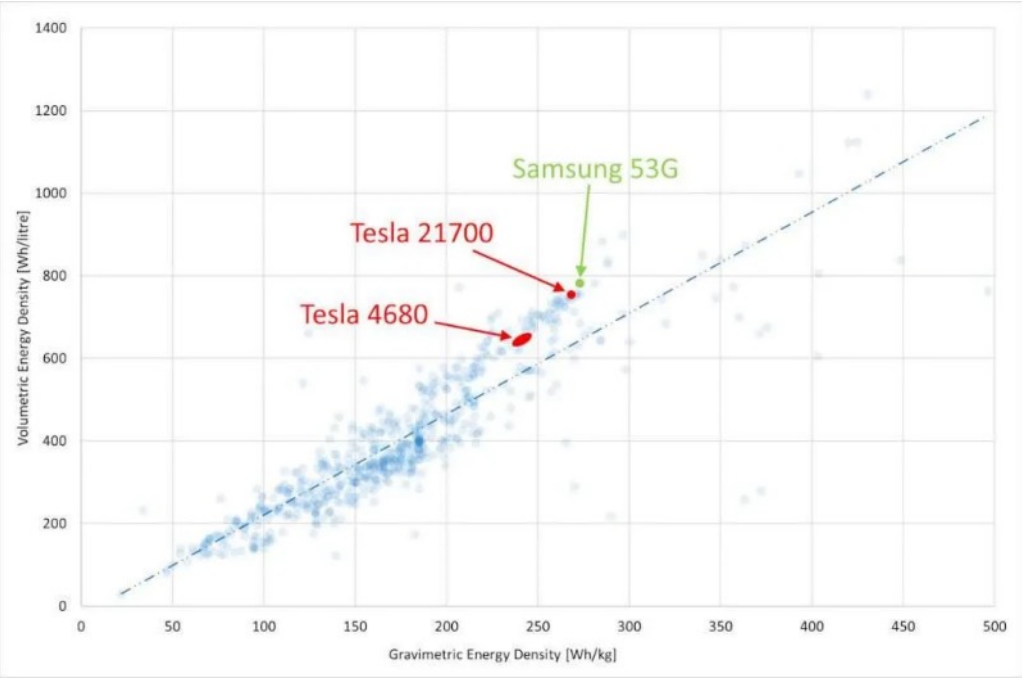
Capacity tests from a number of cells [7]:

- Capacity: 22.31Ah at C/20 discharge
- Capacity: 22.41Ah at C/20 charge
- Capacity: 22.08Ah at C/3 discharge

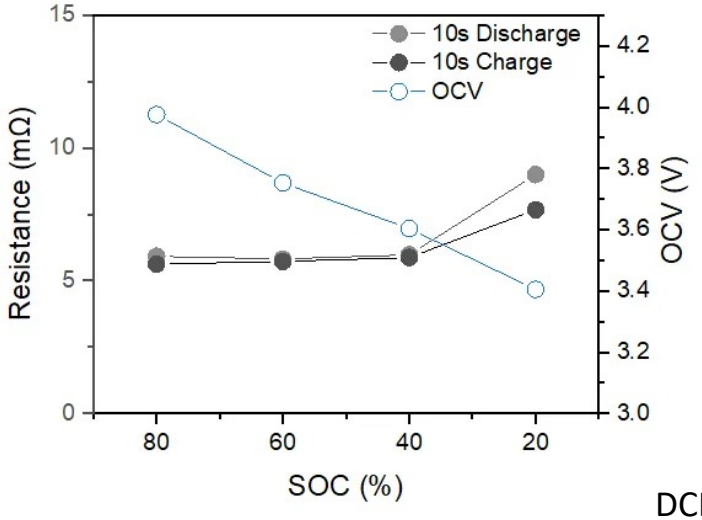
Ank, Manuel, Sommer, Alessandro, Abo Gamra, Kareem, Schöberl, Jan, Leeb, Matthias, Schachtl, Johannes, Streidel, Noah, Stock, Sandro, Schreiber, Markus, Bilfinger, Philip, Allgäuer, Christian, Rosner, Philipp, Hagemeister, Jan, Rößle, Matti, Daub, Rüdiger, Lienkamp, Markus, Lithium-Ion Cells in Automotive Applications: Tesla 4680 Cylindrical Cell Teardown and Characterization, Journal of The Electrochemical Society, Volume 170, Number 12

Tesla 4680 Cell

How does this cell compare?

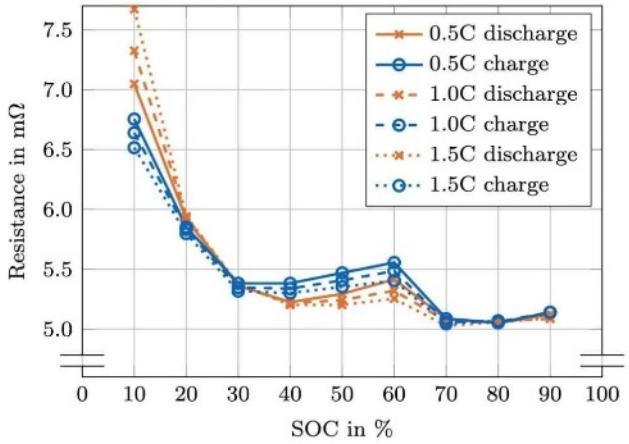


This was an early cell and we know that it is all about lowering the cost.



UC San Diego analysis, The Limiting Factor & Laboratory for Energy Storage and Conversion, UC San Diego, Ying Shirley Meng, UC San Diego

DCIR ~5.4mΩ to 7mΩ @50% SoC



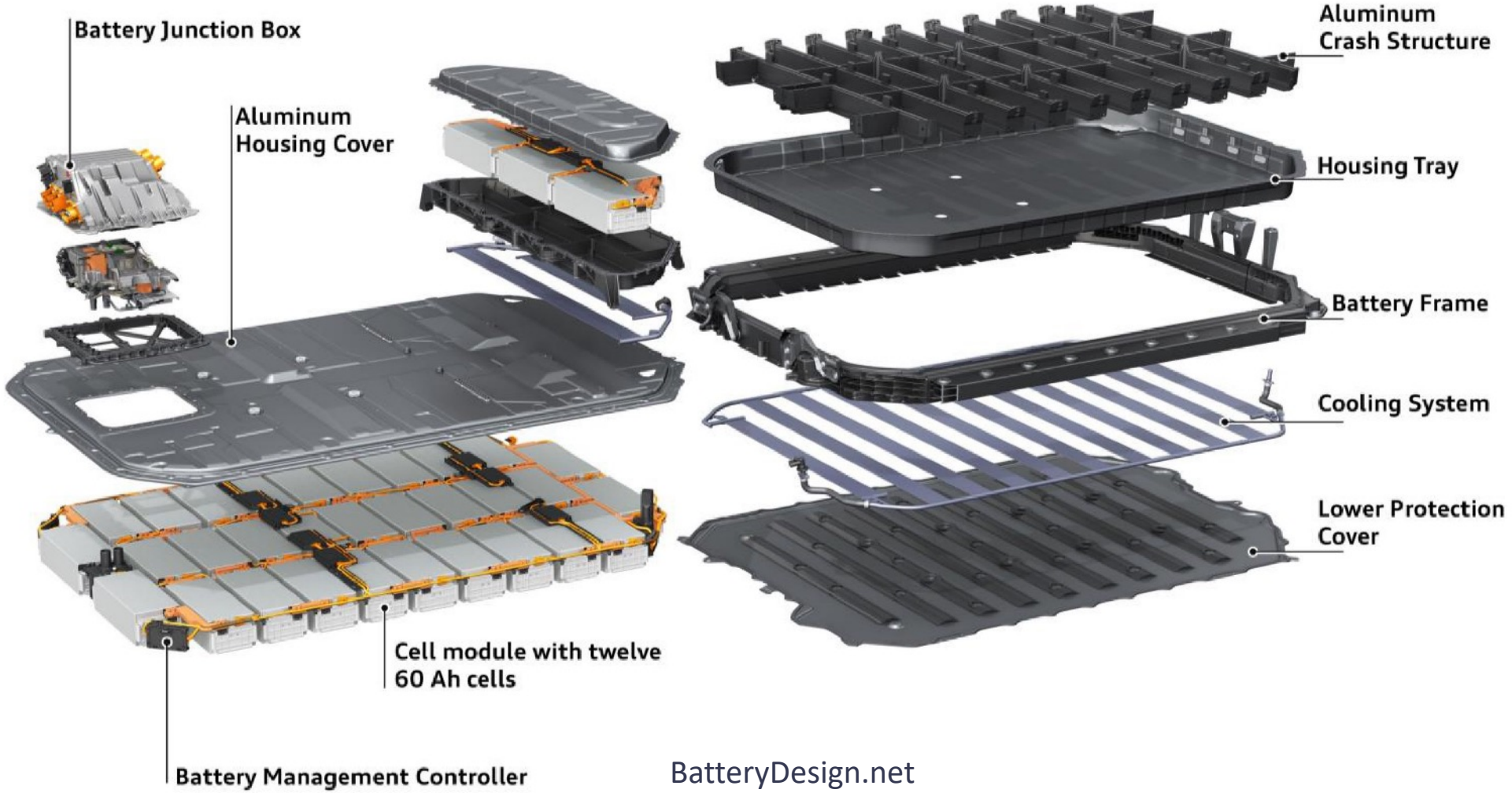
Ank, Manuel, Sommer, Alessandro, Abo Gamra, Kareem, Schöberl, Jan, Leeb, Matthias, Schachtl, Johannes, Streidel, Noah, Stock, Sandro, Schreiber, Markus, Bilfinger, Philip, Allgäuer, Christian, Rosner, Philipp, Hagemeister, Jan, Rößle, Matti, Daub, Rüdiger, Lienkamp, Markus, Lithium-Ion Cells in Automotive Applications: Tesla 4680 Cylindrical Cell Teardown and Characterization, Journal of The Electrochemical Society, Volume 170, Number 12

BatteryDesign.net

If we know the cell DCIR we have the ability to then look at discharge limits and to estimate heat rejection requirements.

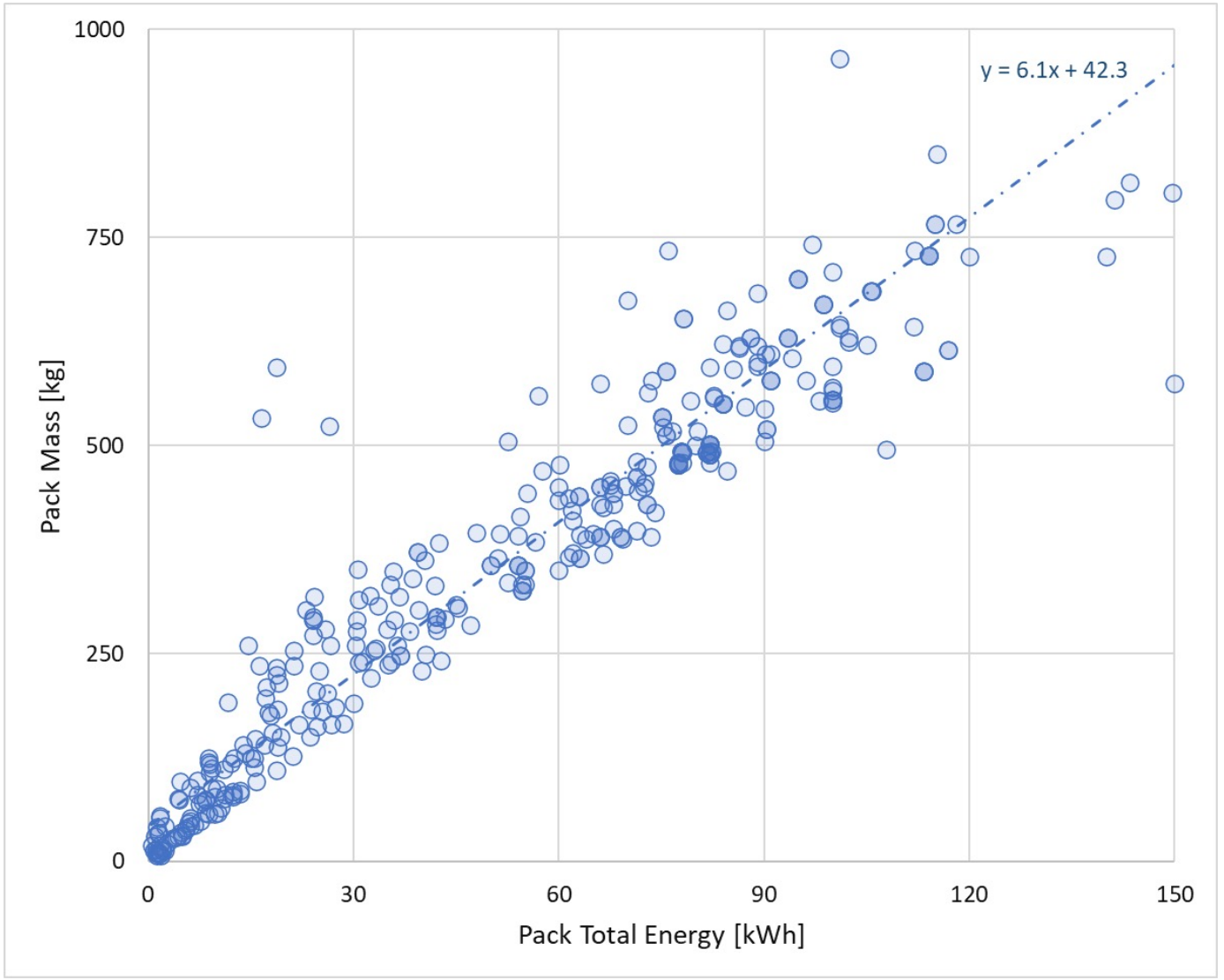
What can we learn from Battery Benchmarking?

actually



BatteryDesign.net

Battery Pack Weight



BatteryDesign.net

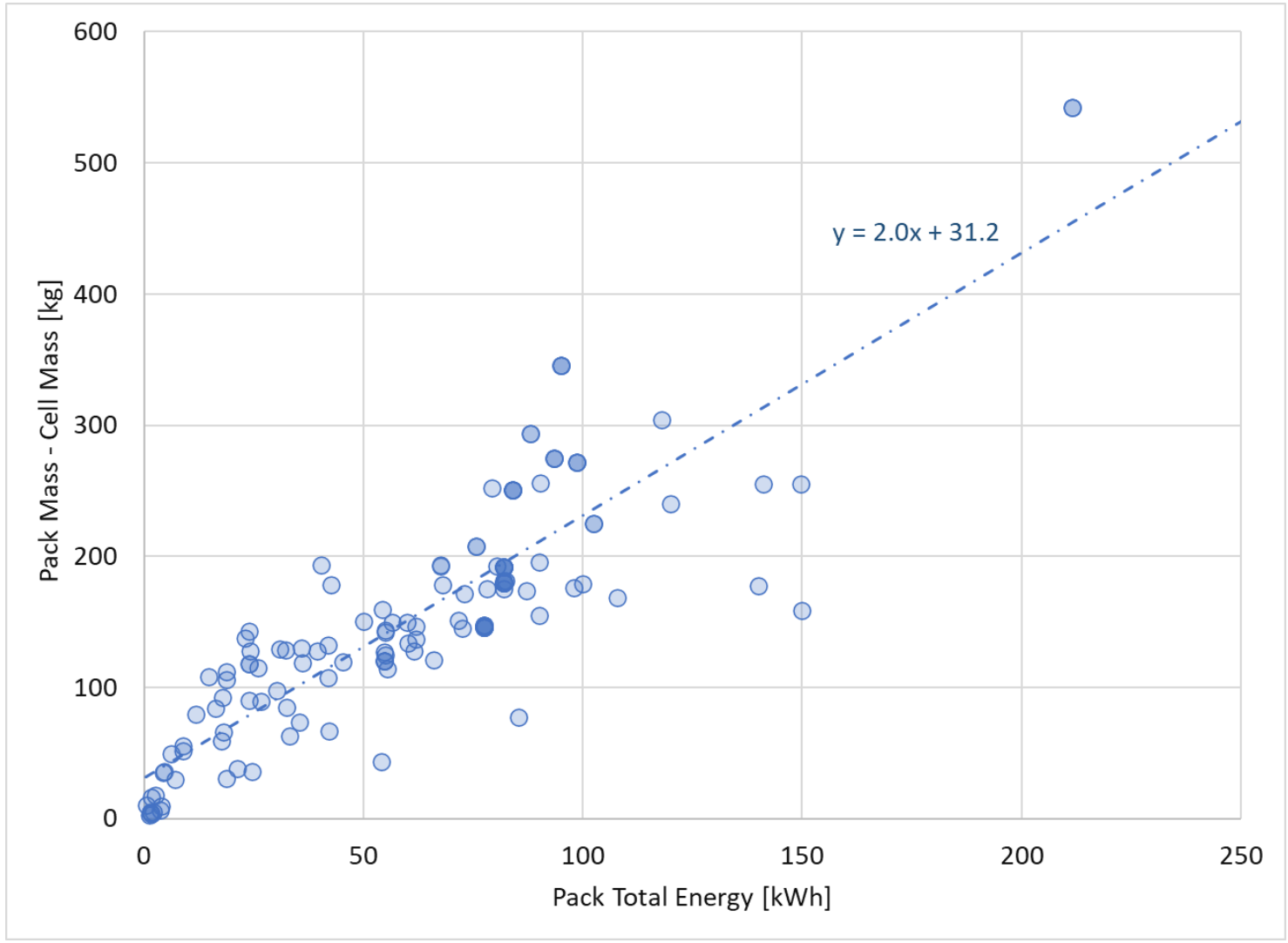
Lots of data >400 values in database.

A spread of ~200kg @100kWh in pack mass across the various applications.

Battery Pack Weight

Cells +

- modules
- thermal
- HV electrical
- LV harness
- sensors
- BMS
- HV control
- connectors
- case
- mounts



On average: 31.2kg for the BMS, connectors, fuses, contactors.

Module, case, cooling, busbars ~2x Total kWh

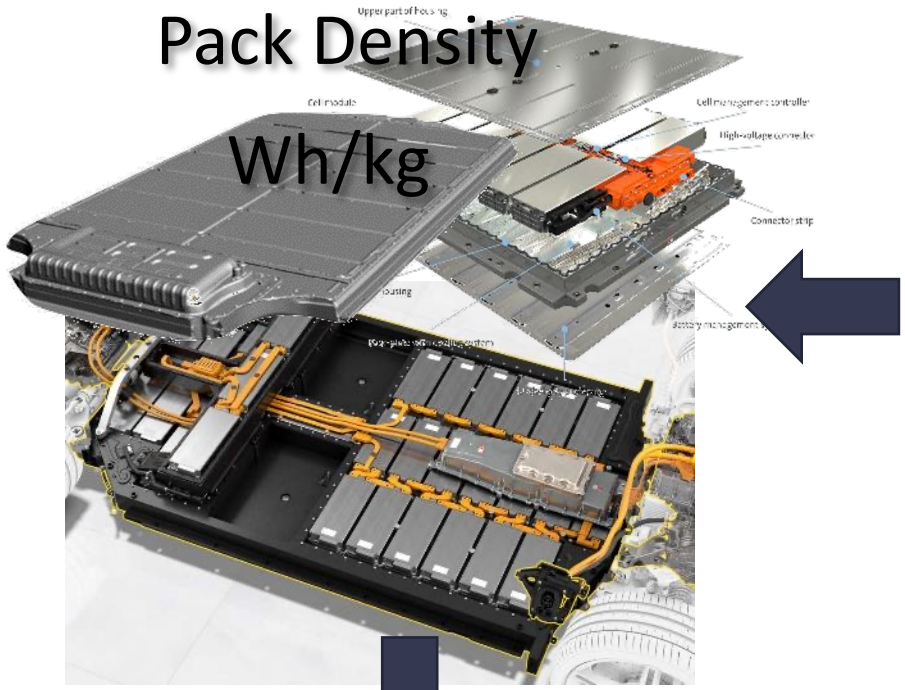
https://www.batterydesign.net/battery-pack-mass-estimation/

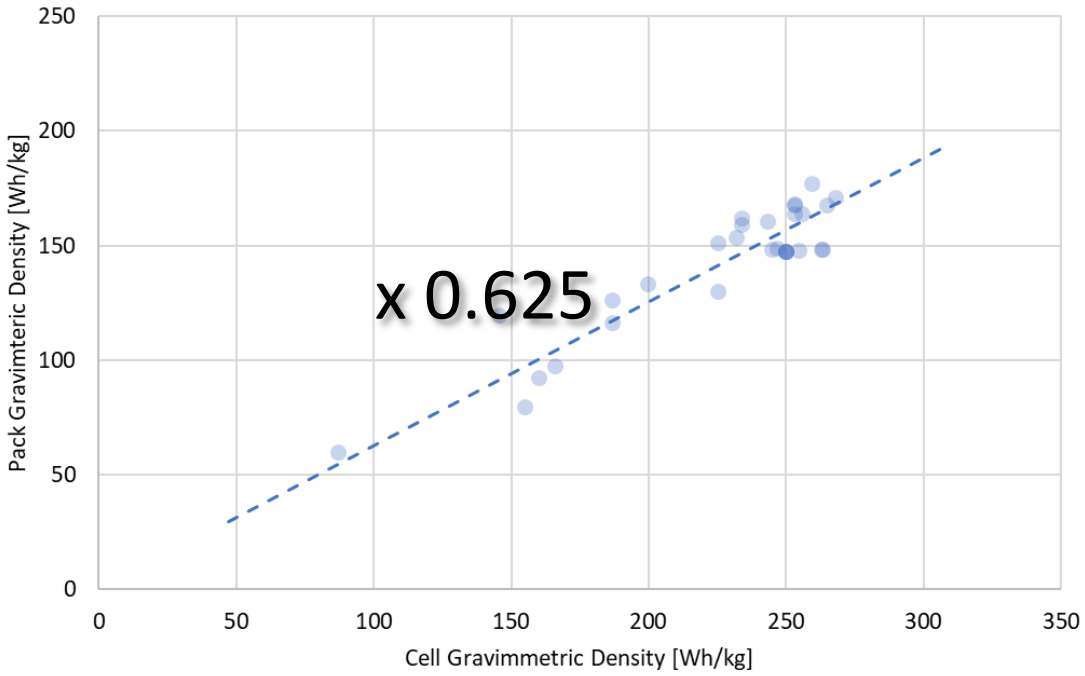
BatteryDesign.net

Pack Mass Estimation

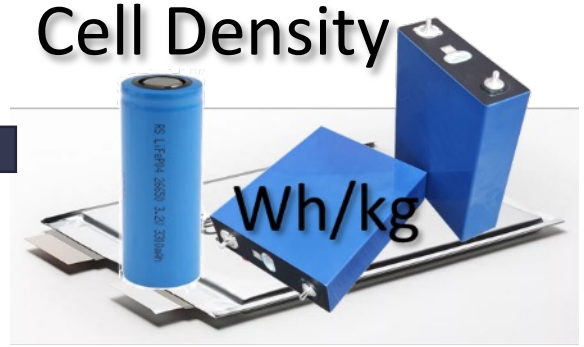
Pack Density

Wh/kg



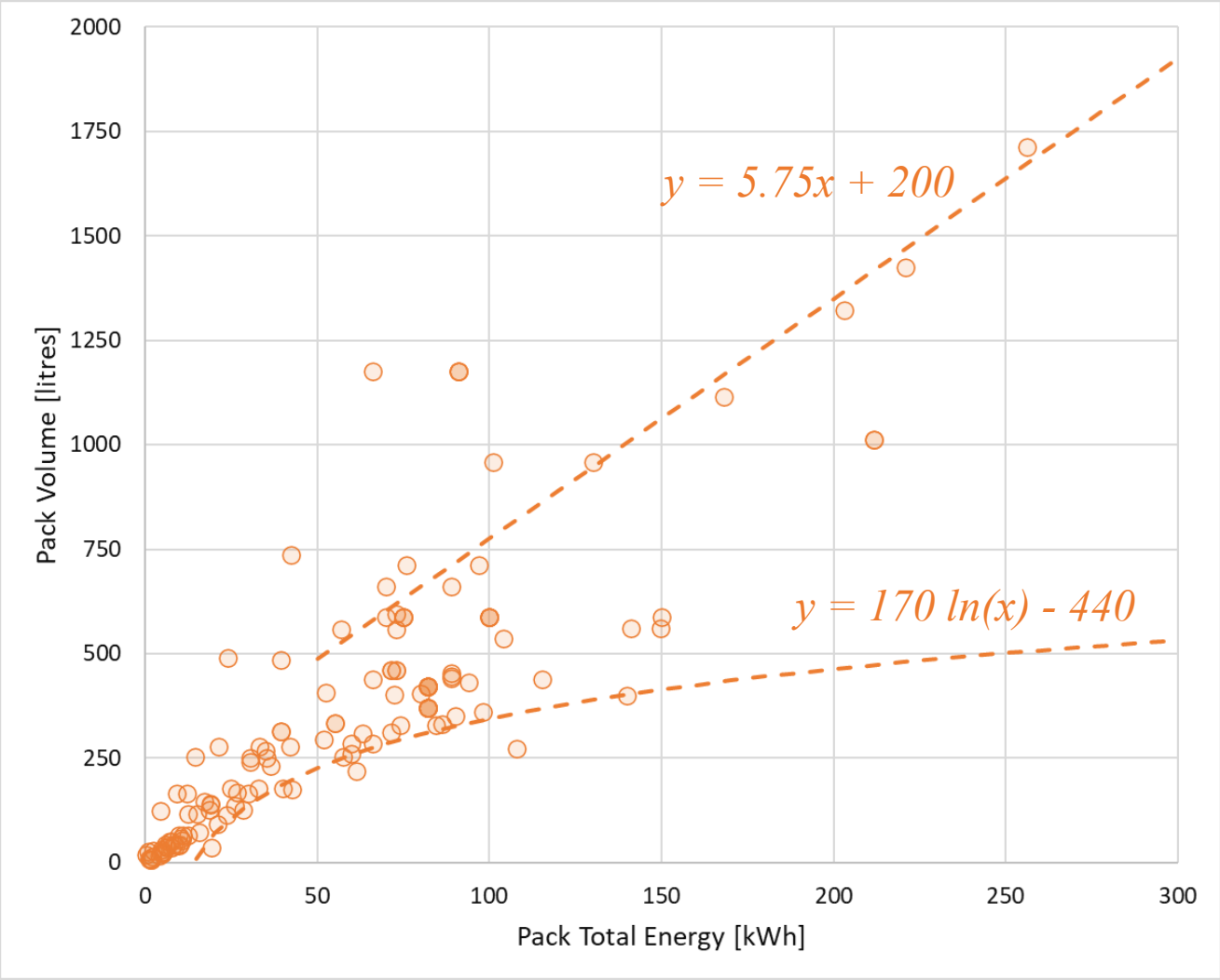


Cell Density



Pack Energy / Pack Density = Pack Mass

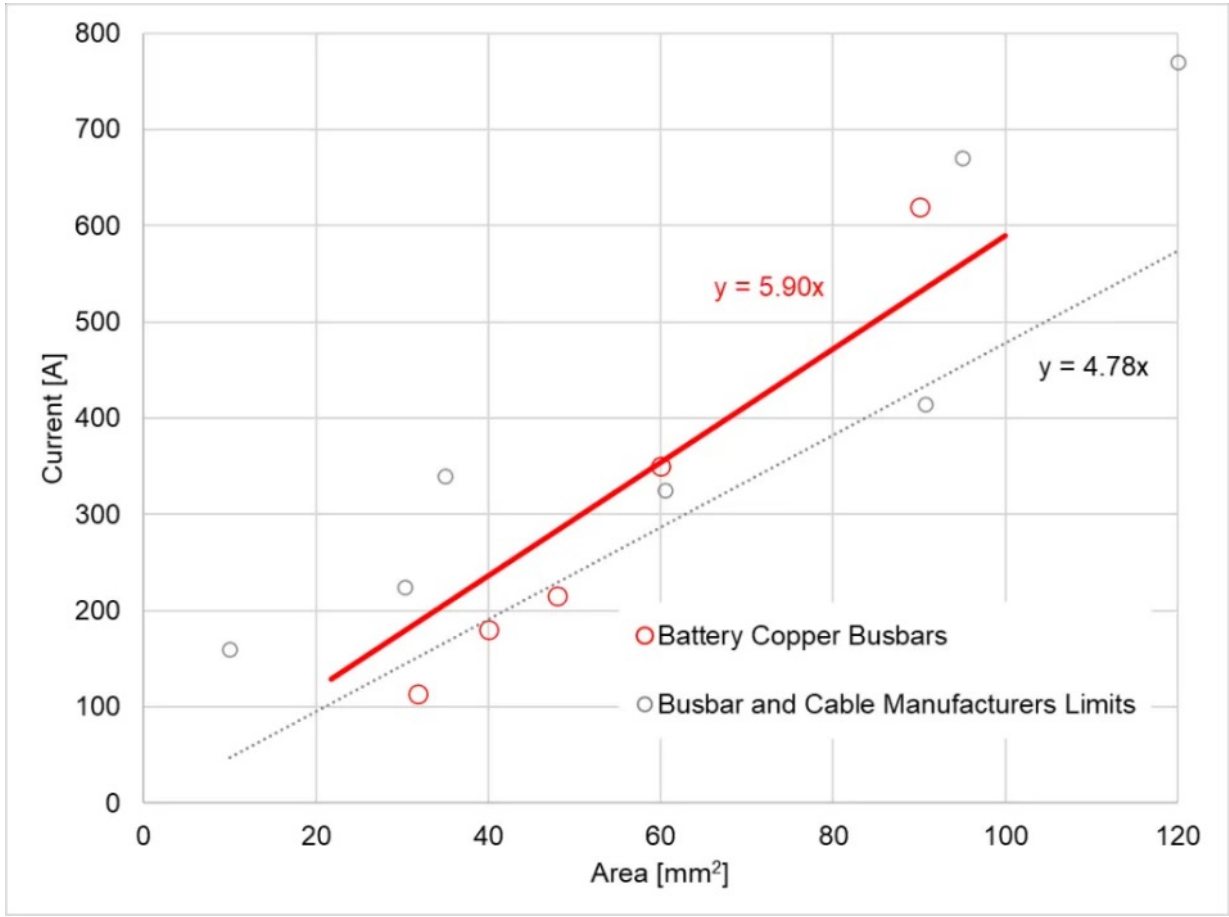
How big are battery packs?



We can see a range and the trend of those limits.

Pack volume data is much harder to acquire and a lot of variation in how it is measured => lower confidence and the need for more data.

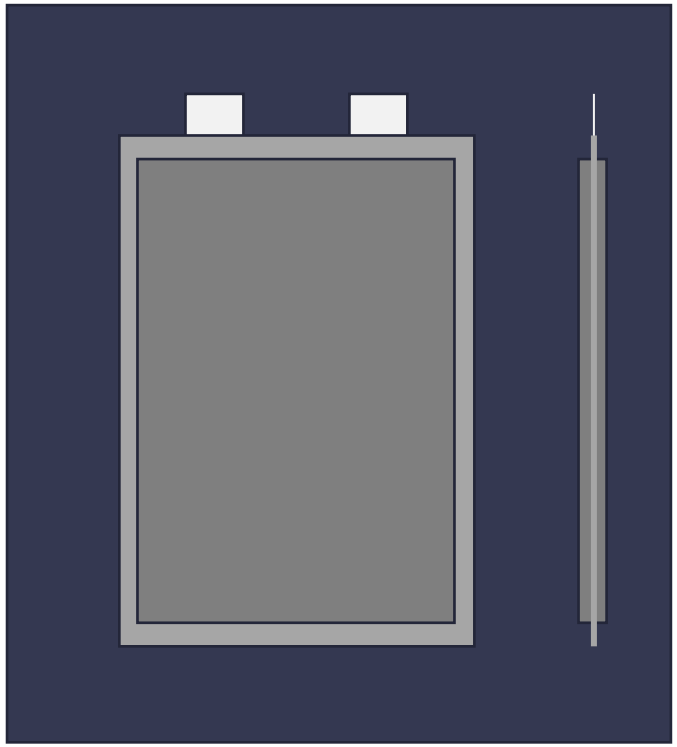
Busbar Sizing



Copper busbars in battery packs sized at around 5.9A/mm^2

Pouch Cell Cooling Development

Top Tabs



Lower DCIR
More uniform discharge
Improved underfloor package

Opposing Tabs, reduced height to suit automotive underfloor

More robust wrap
Lower module height
Lower ΔT

One piece outer wrap, electrical tabs closer to cooling plate

Innovations: engineering design

Some innovations are subtle and an amalgamation of good engineering,
eg **Hyundai Ioniq 5**, **Kia EV6**, **Genesis GV60 (E-GMP)**.

Single outer cell wrap.

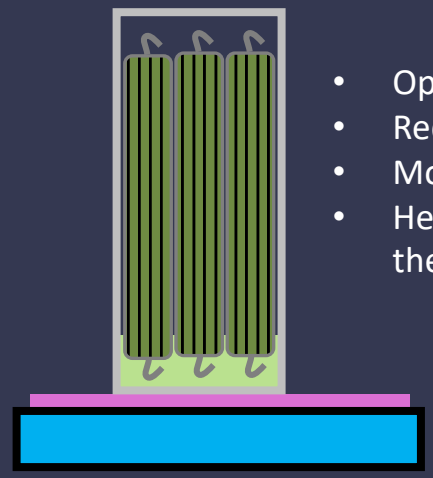
Shifted tabs down the cell, closer to coolant.

Shared fixing bolts.

Bottom of cells interface directly with coolant plates.

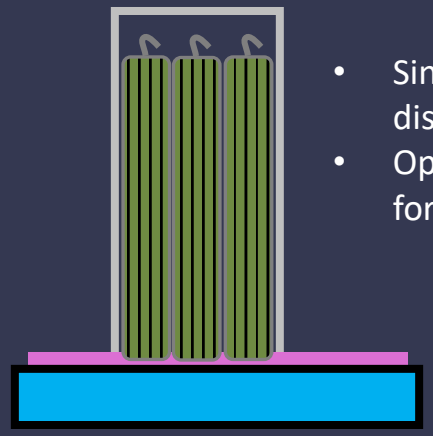
Plastic module case with no base.

Pouch Cell Cooling Development



- Opposing tabs
- Reduced cell height
- Module case wrap around cells
- Heat transfer material in base of the module

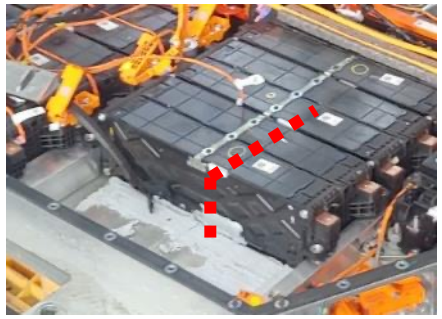
- Cheaper
- Lower Z-height
- Lower weight
- Better thermal control

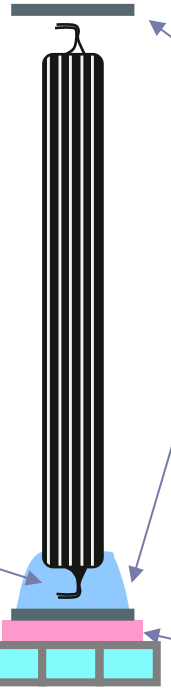


- Single outer cell wrap reduces distance to cooling plate
- Open module base removes need for second layer of TIM

Innovations: engineering detail

Let's look at a section through the module and cell
Hyundai Ioniq 5 / Kia EV6 / Genesis GV60 (E-GMP)





Module case - aluminium

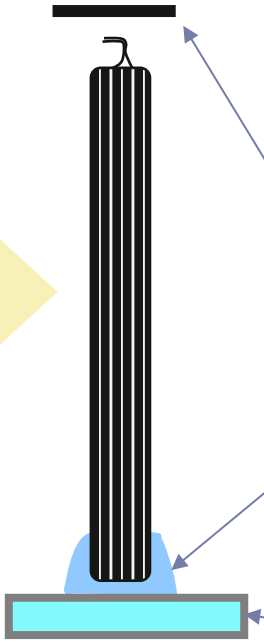
Silicon thermal glue to connect cell to module case

Coolant plate

Silicon thermal glue or pad

E-GMP

- one piece cell wrap
- simpler module case
- moved cell closer to coolant
- Tabs moved closer to coolant
- optimise cell DCIR



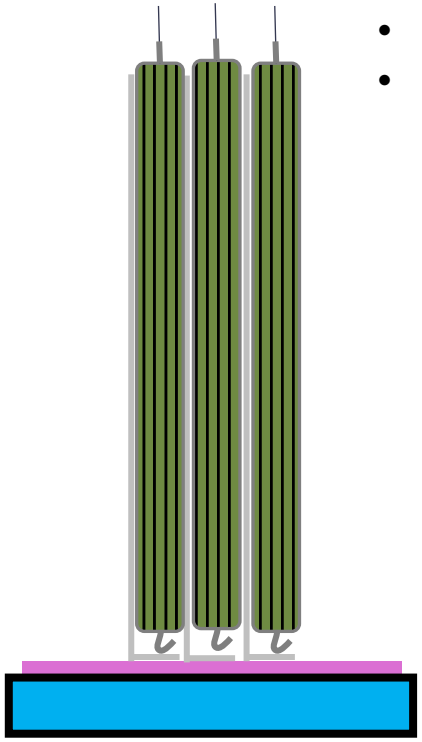
Module case - plastic

Silicon thermal glue to connect cell to coolant plate

Coolant plate

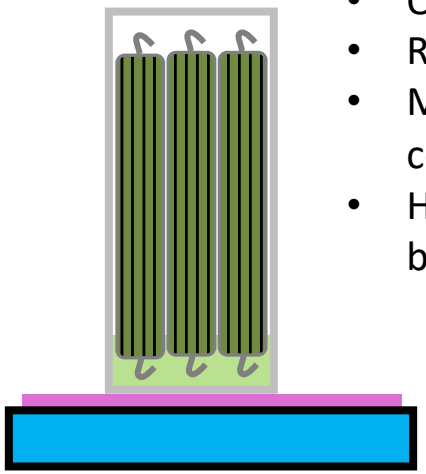
Achieves 223kW charge power for 11 minutes

Pouch Cell Cooling Development



- Heat transfer plates
- Top tabs

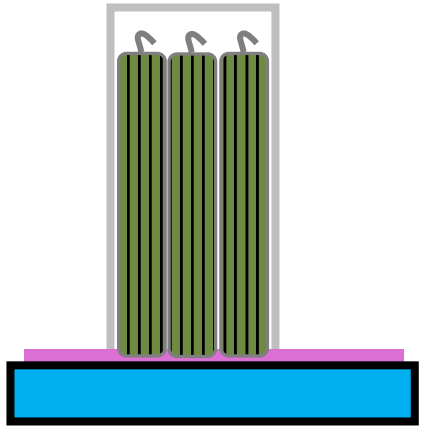
Lower ΔT
Lower mass
More compact



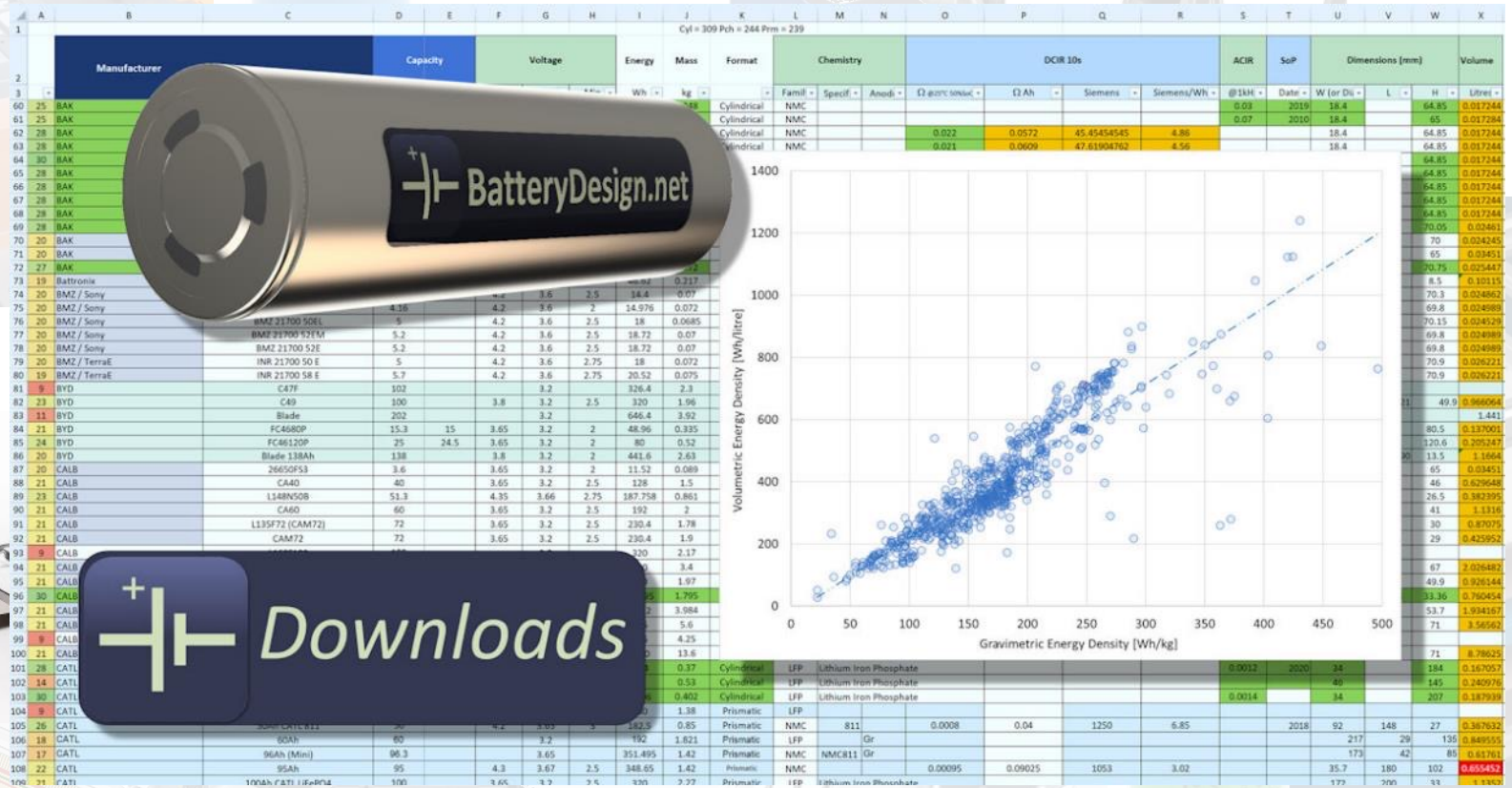
- Opposing tabs
- Reduced cell height
- Module case wrap around cells
- Heat transfer material in base of the module

Closer to coolant
Simpler cell wrap
Less TIM

- Single outer cell wrap reduces distance to cooling plate
- Open module base removes need for second layer of TIM



What can we learn from Battery Benchmarking?



BatteryDesign.net