Ultra-fast charging urban delivery vehicles

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VEHICLE ELECTRIFICATION EXPO

BATTERY CELLS & SYSTEMS EXPO

29th and 30th June 2022, The National Exhibition Centre (NEC), Birmingham, UK

This is MAHLE Powertrain

> **Engineering consultancy**
>
> Locations worldwide

Allotrope Energy's Cell Technology

Allotrope technology: carbon within Li-ion battery

- Three cell derivatives:
  - Electric double layer capacitor (EDLC)
    - Highest power density
  - Lithium carbon cell
    - Good power and energy compromise
  - Lithium-ion capacitor
    - High energy density

Property	Units	EDLC	Lithium carbon	Lithium-ion capacitor
Power density	kW/kg	70	15	8
Gravimetric energy density	Wh/kg	22	60	105
Volumetric energy density	Wh/litre	26	80	200
Cycle life	cycles	>1 M	~100 K	1 - 2 K

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- This study investigates the potential for the use of:
  - Lithium-ion capacitor for an urban delivery van
  - Lithium carbon cell for a delivery scooter

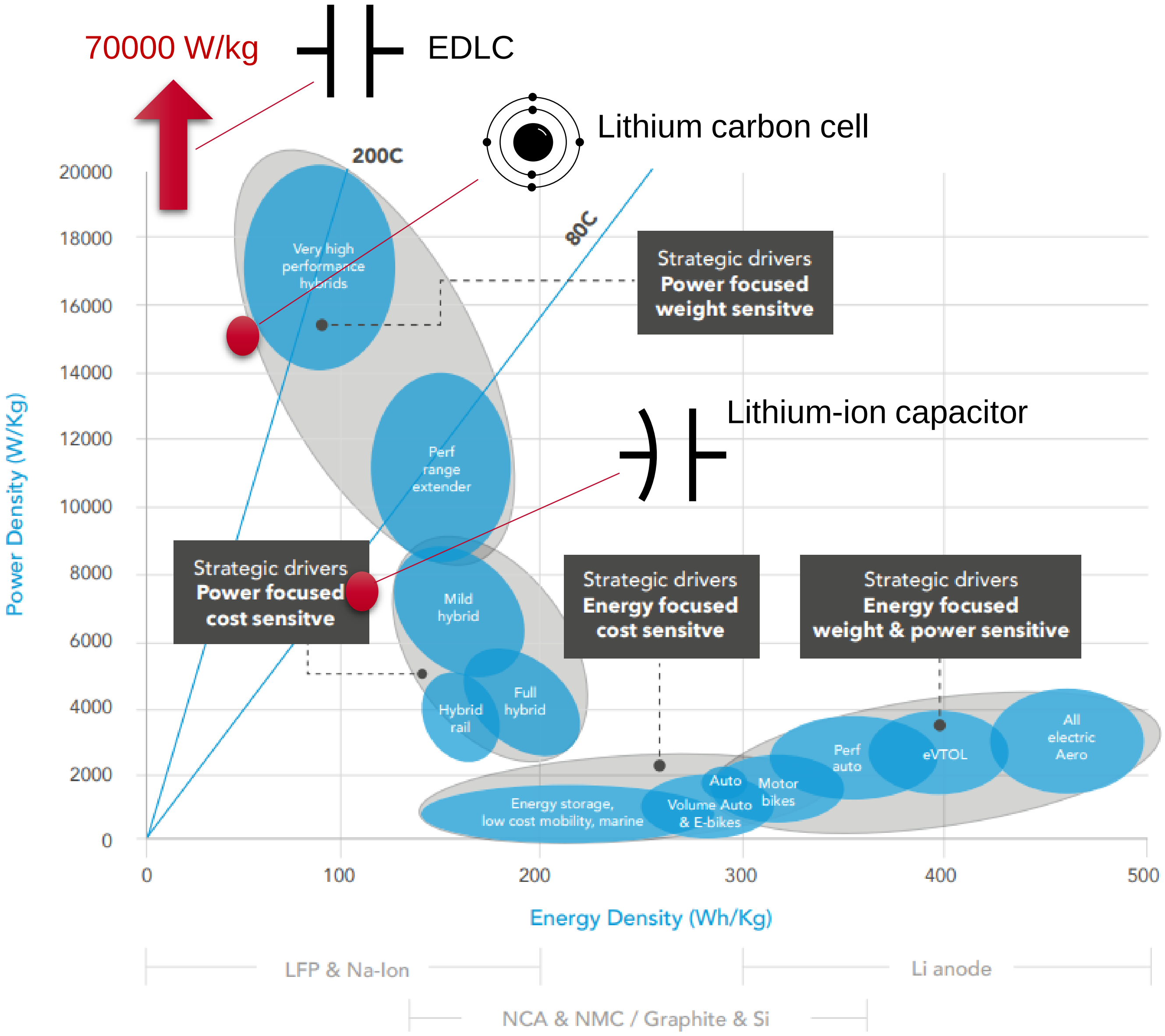

Figure from: Discussion Document for the UK Battery Community: From Research and Manufacturing to Application and End of Life – Enabling Electrification Across Sectors, Battery Targets and priorities across sectors, 2020 to 2035, Published by Warwick Manufacturing Group, October 2020
https://warwick.ac.uk/fac/sci/wmg/business/cenex/Battery_Manufacturing_Targets_and_Priorites_2020-2035_Report_WMG_APC_IUK.pdf

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Increasing Use of on Demand Delivery Services

On Demand Delivery

- Increase in online shopping
- Online fast food delivery growing quickly too

amazon
ebay
Takeaway.com
deliveroo
UBER eats
JUST EAT

Project overview

Current Approach:
250-300 km driving range
75 kWh battery
7h charge @ 11 kW, 80% in 30min on fast charge

Right-sizing batteries

- Traditional battery electric vehicles have large batteries to enable long range
- Batteries:
  - Heavy
  - Expensive
  - Can have a low lifetime if regularly charged quickly
- Urban delivery vehicles typically only require a low range (<60 km)
- This study investigates ultra-fast charging battery system concept
  - Optimised for urban vehicles
  - Full charge in 2-5 minutes
- This system uses Allotrope’s battery technology
  - Similarities to supercapacitors, but with greater energy storage

Concept:
20-60 km driving range
4-15 kWh battery
2-5 min charge

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Case Study: Urban Delivery Van

Urban parcel delivery van

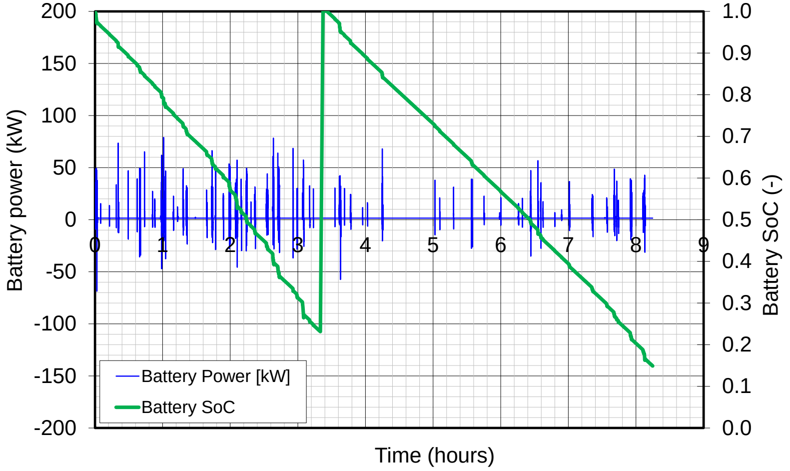
- Typically only 1 journey per shift
  – Without a regular return to base

- Representative daily usage
  – City centre: 20 km (London basis)
  – Suburbs: 60 km

- Requirements
  – 20-60 km range = 4-15 kWh
  (winter heating may increase this)

- 20 kWh battery required for full shift

- **10.5 kWh** usable capacity if a short mid-shift recharge can be accommodated (in winter)



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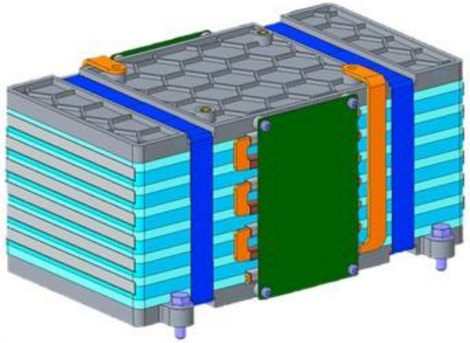
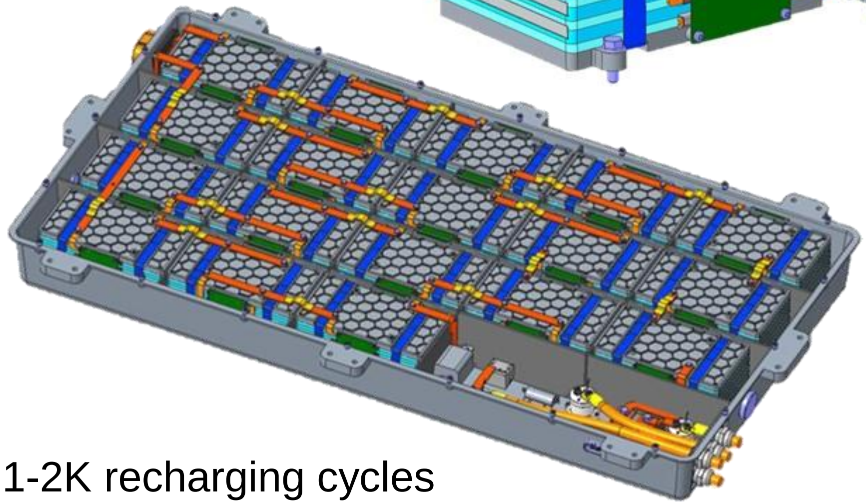
Urban Delivery Van Cell and Pack Specifications

Battery cell and pack specifications for urban delivery van using Lithium-ion Capacitor cells

- 14 cells per module
  - 7 S – 2 P format
  - Max voltage 22.4 V
- 18 modules in pack
- 10.5 kWh useable capacity





- 1-2K recharging cycles

Parameter	Units	Cell	Pack
Cell type	-	Lithium-ion capacitor	
Capacity	kWh	0.05	10.5
Maximum voltage	V	3.2	400
Minimum voltage	V	1.6	280
Output power	kW		100
Charging power	kW		210
Charging time	minutes	3 (20C)	3
Cell mass	kg	0.47	120
Configuration	-	-	126 S – 2 P

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Case Study:
Fast Food Delivery Scooters

Fast Food Delivery Scooters

- Typically small engines with little emissions aftertreatment
  - Bad for inner-city air quality
  - Noisy

- Take away meal service typically on a point-to-point basis
  - Regular return to base

- Typical London usage:
  - 5 hour shift pattern, 2-3 deliveries per hour, 4 km per trip

- Therefore, per shift: 10-15 deliveries, 30 to 50 km
  - 25 km range suitable target

- eMoped energy consumption is around 20 Wh/km
  - 0.5 kWh useable pack capacity required for 25 km

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Scooter Cell and Pack Specifications

Battery cell and pack specifications for urban delivery scooter using Lithium Carbon cells

Parameter	Units	Cell	Pack
Cell type	-	Lithium carbon	
Capacity	Wh	6.5	500
Maximum voltage	V	3.2	58
Minimum voltage	V	1.6	38
Output power	kW		1.5
Charging power	kW		20
Charging time	seconds	90 (40C)	90
Cell mass	kg	0.13	9.5
Configuration	-	-	18 S – 4 P

~100K recharging cycles

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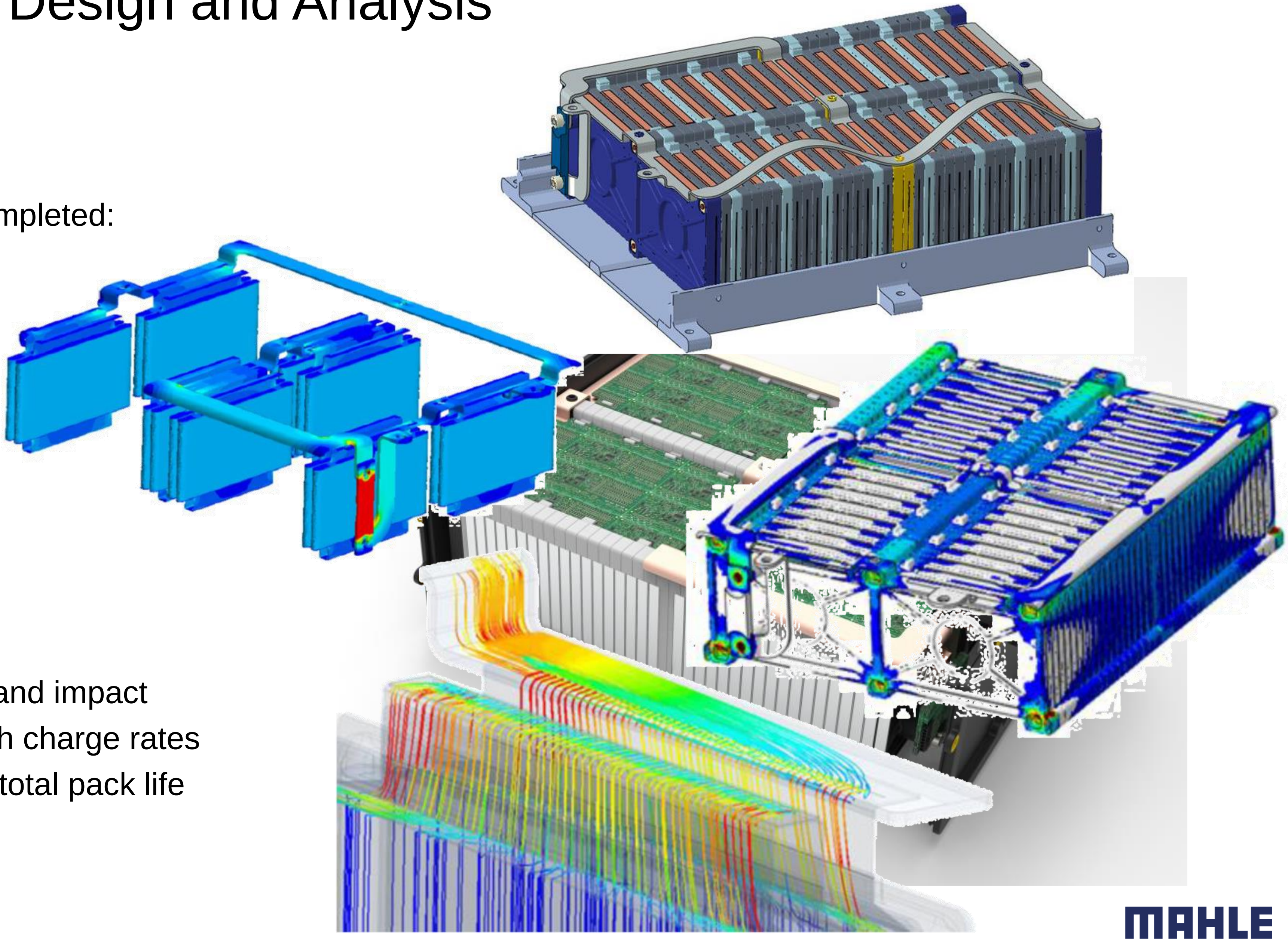
Battery Pack Concept Design and Analysis

Battery pack design and analysis

- Concept design for battery pack completed:
  - 15 kg mass (9.5 kg of cells)
  - Integrated BMS
  - 0.5 kWh capacity
  - 58V maximum voltage
  - 20 kW charging power
    - Full recharge in 90 seconds



- Detailed analysis to ensure
  - Mechanical integrity for vibration and impact
  - Busbars sizing is sufficient for high charge rates
  - Cell compression is adequate for total pack life

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Conclusions

Conclusions and outlook

- Allotrope Energy's novel Lithium Carbon cell technology could enable ultra-fast charging rates to be achieved
- MAHLE Powertrain have used Allotrope's cell specifications to design an ultra-fast charging, aggressively downsized battery packs for two urban delivery applications
  – Battery pack concept design extensively analysed to ensure thermal stability and mechanical integrity
- **Rapid charging ability could reduce pack storage requirements for all applications**

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Thank you for listening

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