Lithium cells and other battery factors influencing EV’s

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Scope of today

- Alternative Lithium chemistries of the future
- Potential advantages
- Issues to overcome
- Impact on the design of batteries
- Other influencing factors
- What that means to the specification of future vehicles

Biography

- George Paterson, Director of Sales
- 28 years in industry of which 7 years as Engineering Manager with Axeon
- Last 4 years in sales roles
- 11 years experience with batteries
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About Axeon

ECC
The Electric Car Corporation Plc

MODEC
QUIETLY CHANGING THE WORLD

Over one million vehicle miles driven since 2007

JAGUAR

PHEV packs

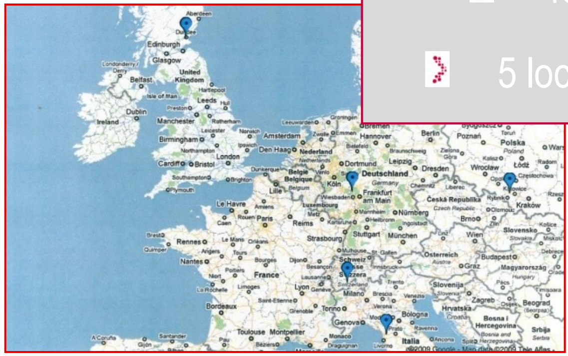
- New technology development project funded by TSB
- Design and development of PHEV packs for JLR

Company overview

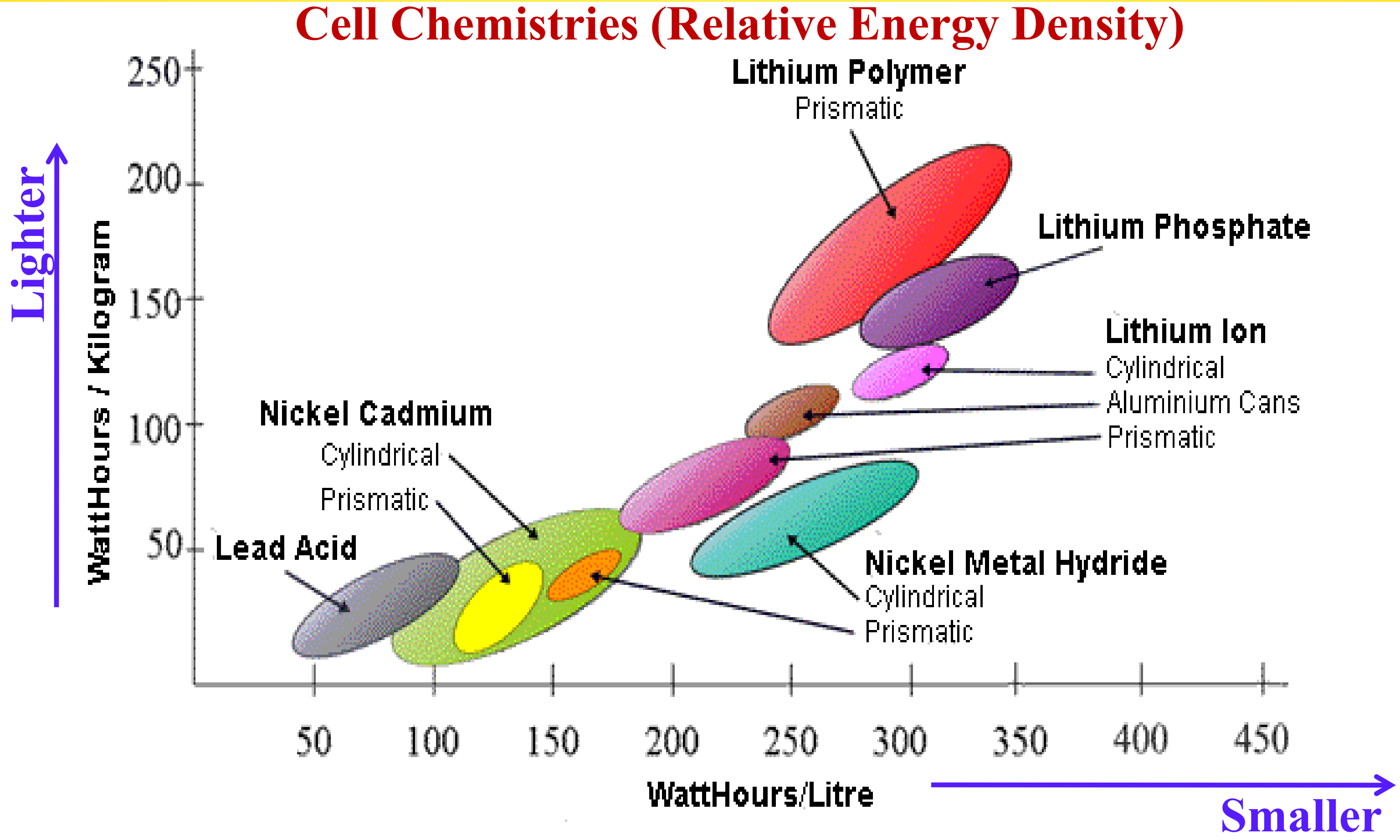
- Dundee HQ
- £65m revenue (2009)
- 450 employees
- 5 locations in Europe

Allied Vehicles
Driving For Perfection

Volume production; conversion of a range of types of EVs



Why Lithium ion?



- High coulomic efficiency ⇒ 100%
- Green
- Low self-discharge

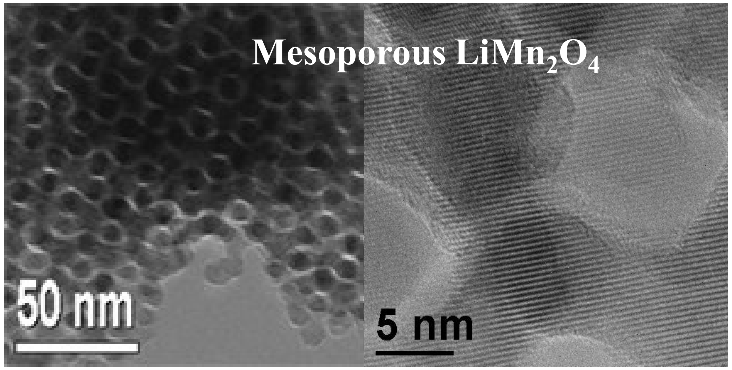
Cell Chemistry - The Challenges

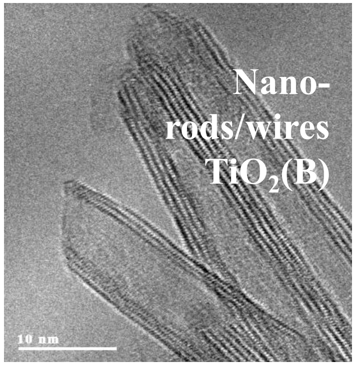
- Reduce cost – materials (raw and synthesis)
  - ⇒ reduce by 50% per kWh?
- Improve safety – short circuits
  - ⇒ thermal run away, over-charge, over-discharge
- Cycle life – cycle life 10,000s for HEVs
- Calendar life - 10 years (transport)
- Power Density – HEV, PHEV
- Energy Density – PHEV, EV, load leveling

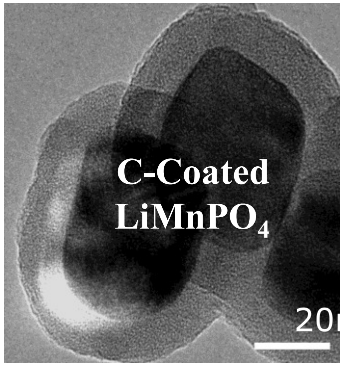
Cell Chemistry – HEV Future Developments

- Materials Chemistry Challenge → New Advanced Battery Materials
- **High Power Density HEV – Future?** → “Nano-Materials”
  - High surface area – Internal = Meso-porous materials

    External = Nano-tubes/wires

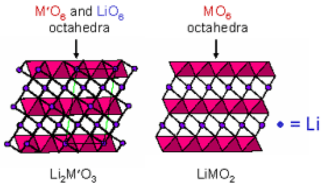






  - Next generation nano-phosphates – Li-[Transition Metal]-Phosphates {Mn/Co/V}
  - Hurdles– cost, energy density
- Surface coatings SiO_2 , RuO_2, etc

Alternative EV Battery Chemistries



High Energy Density EV – Future ? →

- Lithium Transition Metal Oxide Cathodes
  - **E.g. Layered $xLi_2MnO_3 \bullet (1-x)LiMO_2$**
  - An electrochemically inactive ($Li_2M'O_3$) component is integrated with an electrochemically active ($LiMO_2$)component to provide improved structural and electrochemical stability.
  - High energy density, High cell voltage, Long cycle life.

- Alloys of Li with Silicon (Si) or Tin (Sn)
  Nexilion, Sony Corporation (C/Sn/Co))
  - Amorphous Alloy - Very high energy density / capacity
  - However very large volume expansions that need to be accommodated
  - Limited size/capacity cells produced commercially so far

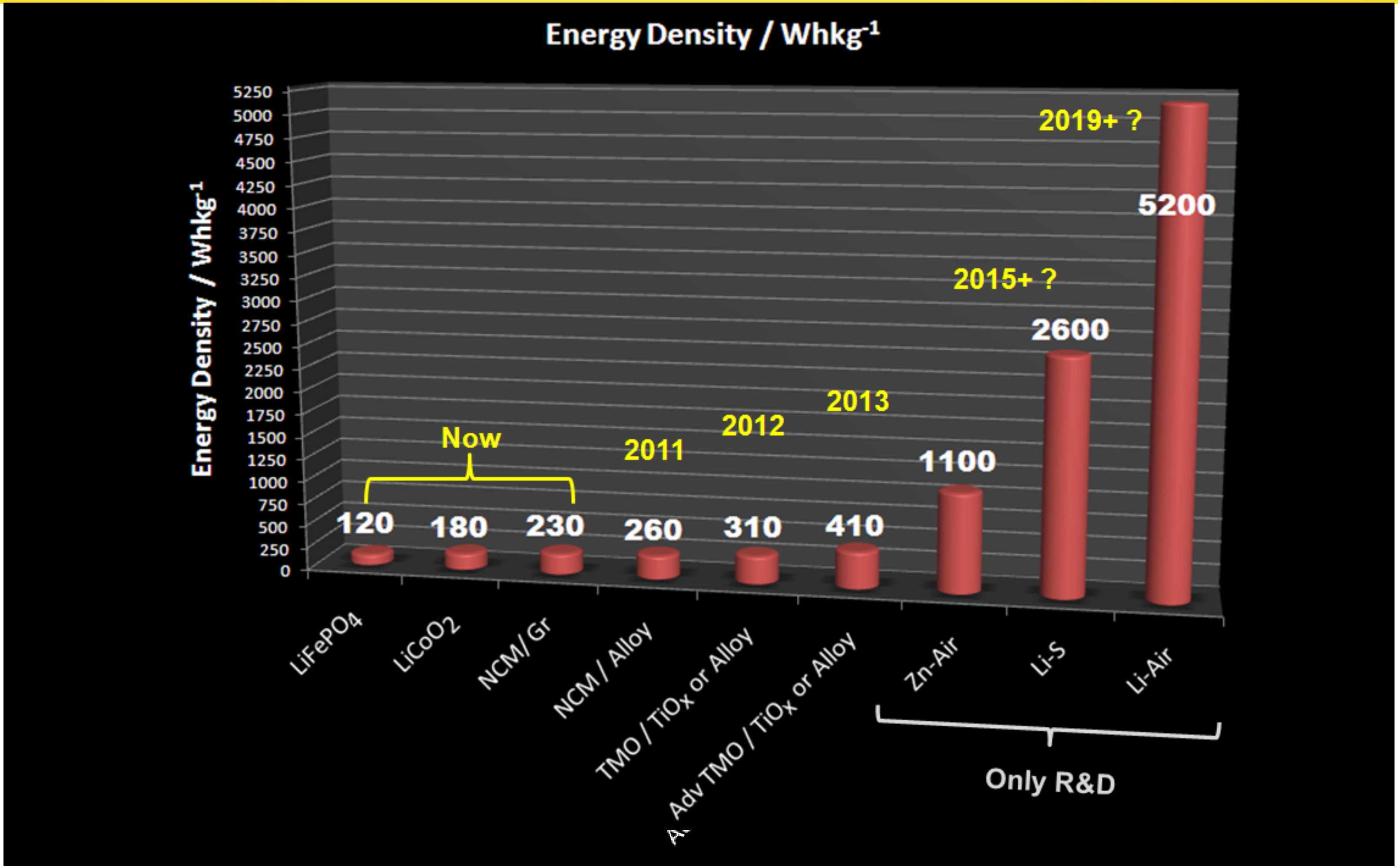
New Improved Electrolyte - Higher operating voltages

- The use of high V cathodes limited by the solvent oxidation >4.4 V *vs.* Li/Li$^+$. Requires new electrolytes → **Ionic liquids** show most promise.
- Poor conductivity limits rate capability.

Lithium-Air Batteries – High Energy Density?

- Potentially 10 x Energy Density compared to current Li-ion tech
- Use of porous cathode, small % catalyst allows rechargeability
- Hurdles – cycle life, rate capability.
- **“Battery 500” project :** IBM, UC Berkeley and five US National Labs
- Electric vehicle battery that gives up to 500 miles per charge
- IBM believes its nano-scale semiconductor fabrication techniques can increase the surface area of the lithium-air battery's electrodes by 100 times.
- ⇒ achieve range goal
- 2 year feasibility study

Relative theoretical energy densities



Dynamite = 1375 Wh/kg
Wood = 4000 Wh/kg
Petrol = 12000 Wh/kg – highly energy inefficient

EVs, HEVs, & PHEVs have different battery requirements

- Electric Vehicles:
  - All electric, battery power/electric motor, 70 – 130 mile range
  - Energy density important, 15-50kWh typical
- Hybrid Electric Vehicles:
  - Internal combustion engine is main drive, 400 mile range
  - Battery recovers some of the braking energy
  - Electric motor and battery provide power boost
  - Power density important , 0.5-5kWh typical
- Plug-in Hybrid Electric Vehicles:
  - Battery/electric motor drive, with internal combustion engine electricity generator
  - 30 mile range on battery, then internal combustion engine used to provide extended range.
  - Both energy and power density important, 10-25kWh typical

Possible current/future cell options

	Short Term	Medium Term	Long Term
City EV	Large Format LFP $LiMn_2O_4$	NCM / TMO Pouch	Silicon/Tin-alloy
Urban Delivery EV	Large Format LFP	NCM / TMO Pouch	Rechargeable metal air systems
PHEV	NCM Pouch (Possible TSB Project)	NCM / TMO Pouch	
Performance HEV	Small Format LFP	Small Format LFP	Advanced Nano-Material electrodes

Future High Energy Density Chemistries

Zn-Air Batteries

- Discharge powered by the oxidation of zinc with oxygen from the air
  - Usually primary and used for hearing aids.
  - Secondary Zinc-air technology is being pursued by ReVolt Technologies.

Lithium-Sulphur Batteries

- High capacity but may years of development have not solved problems.
  - Discharge products (lithium thiolate) soluble in electrolyte leading to self discharge
  - Is the focus of Sion Power and Oxys Energy, etc.

Li-Air Batteries

- R&D stage only, potentially 5 × 10 energy density of today's Li-ion cells.
  - Recharge achieved by use of porous composite carbon and catlayst $+ve$ electrode.
  - Fledgling technology with only demonstrated limited capacity retention on cycling.

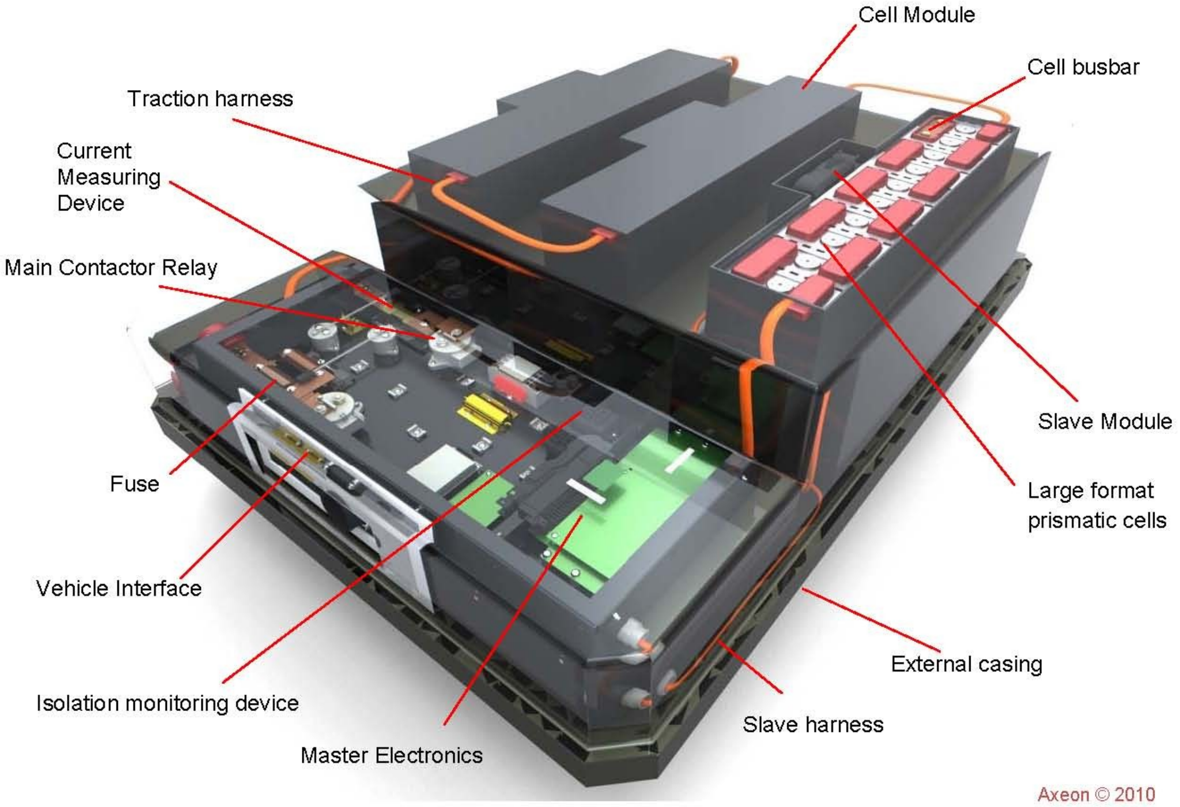
Lithium Rechargeable Cell Constructions No Standards

- **Plastic case.** Robust. Easy packaging, Inexpensive. Stacked or jelly roll electrodes.

- **Cylindrical/Prismatic metal case (steel / aluminium).** Robust, Easy packaging, Expensive, Jelly roll or stacked electrodes. High energy density, Good heat dissipation,

- **Pouch cell.** Vulnerable, Inexpensive, Design freedom on dimensions, Difficult packaging, High energy density but reduced by packaging, Can be prone to swell and leak, Less danger of explosion (cell bursts), Good heat dissipation

Typical Battery Assembly



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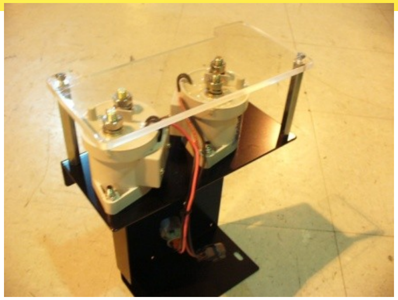
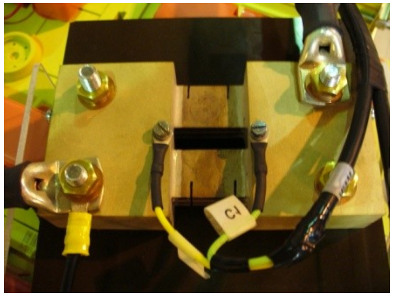
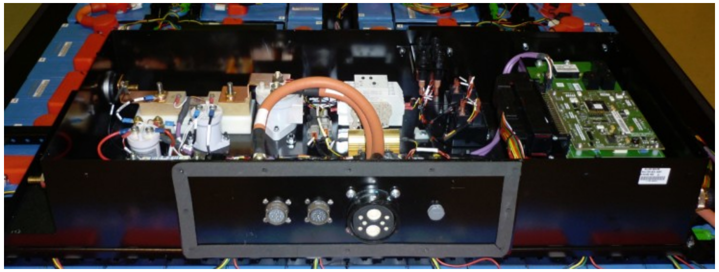
Main Parts of a Battery

- Battery Management System
- Contactors for switching
- Current shunt to measure amps in and out of the battery
- Busbars and traction cables
- Connectors
- Fuses
- Complete HVFE

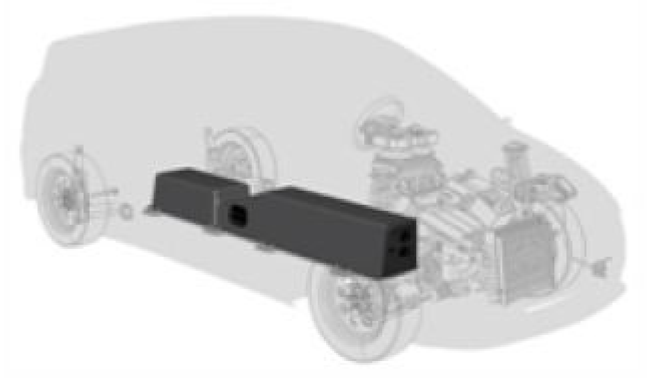






Battery Housing

- Currently steel used in many designs.
- New high strength, lightweight steels and processes being developed for batteries.
- Aluminium fabrications and sections being developed for batteries with integrated thermal management.
- Increasing use of composites and carbon fibre used for high specification batteries, especially in performance cars.



Summary of components for a LiFePO4 27kWh battery

- Current mass 380Kg
- 10% of a battery volume and weight is BMS and HV components
- Another 5-10% is taken up with wiring and bus-bars
- 15-20% is in the housing and support structure
- 25-35% of battery weight is non cell content

Battery Charging

- In theory you can charge a battery in 10 minutes, BUT:
  - Fast charging not always practical. Charging a 50kWh battery in 10 minutes would require a 300 kW power supply. However 50kW DC chargers are beginning to roll out
- Most EVs are used in city areas so 160 km range is more than adequate
- Lithium batteries can be charged at anytime, they do not suffer memory effect
- So, If opportunist charging is available then perhaps smaller capacity, lighter and less expensive batteries are the answer for urban environments

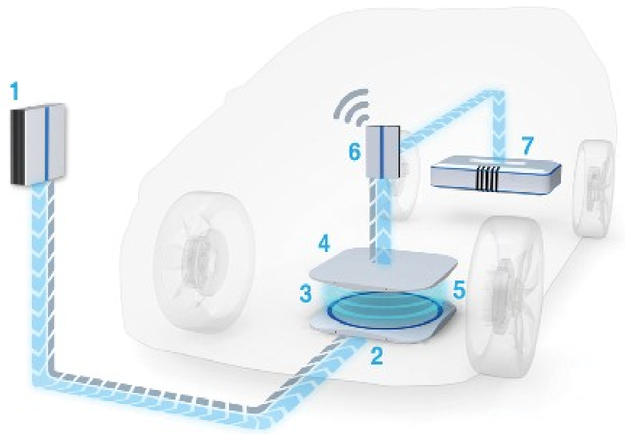
International Telecommunication Union

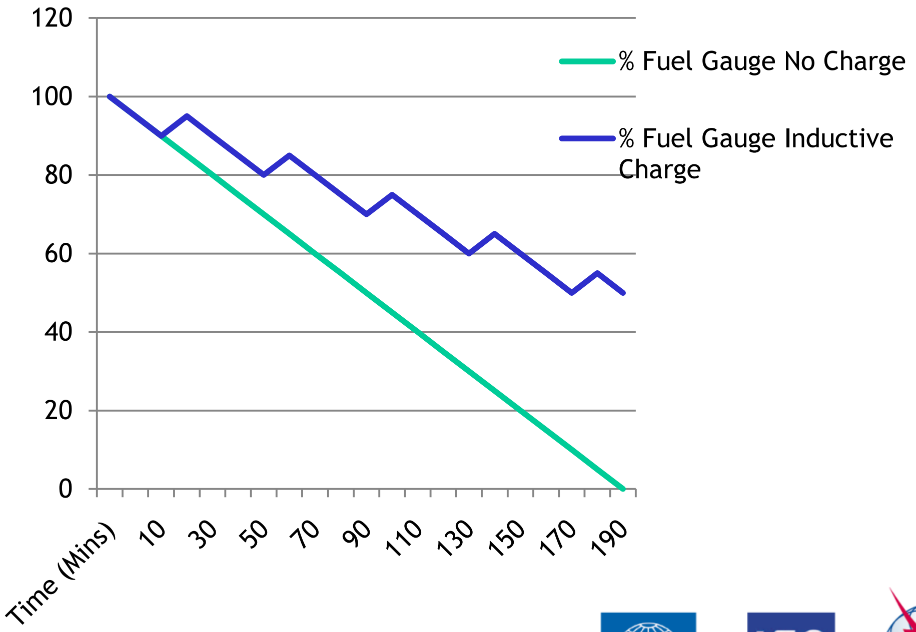
Fast Charging

- 50kW DC fast charger
- Could fully recharge small City EV in 30 minutes
- Or provide short boosts
- Located at service stations and supermarkets
- Battery capacity could be reduced, less cost, weight and size
- HV components and bus-bars have to be rated accordingly
- Cells may have to be actively cooled during charge

Inductive Charging

- System could be buried in the road surface
- Located at major junctions where traffic stops
- Can be used for taxis and buses as well as private EV’s
- Location at supermarkets and car parks
- Battery capacity could be reduced so less cost, weight and size



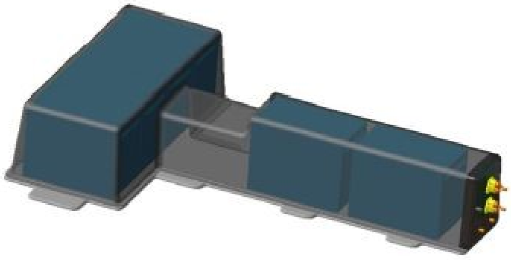


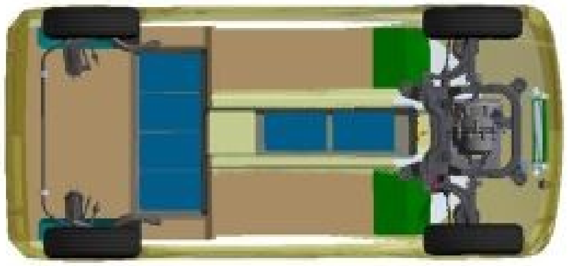
Typical EV battery for mid-sized car

- 27 kWh LiFePO4 battery
  - 380Kg
  - Volume 0.3 m^3
  - Range 160 km
- 27 kWh NCM battery
  - 270Kg
  - Volume 0.2 m^3
  - Range 175 km
- 27kWh Li Air battery
  - 70Kg (HV components still required)
  - Volume 0.15 m^3
  - Range 200 km

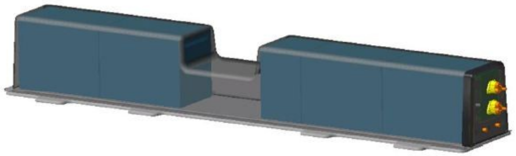
Future pack concepts

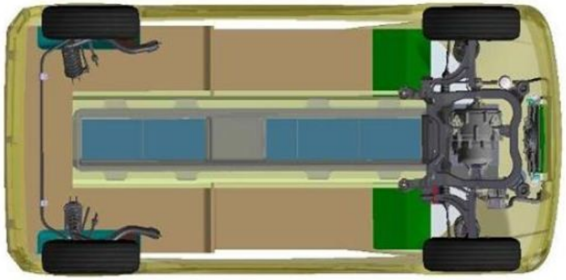
2010
35kWh
250km



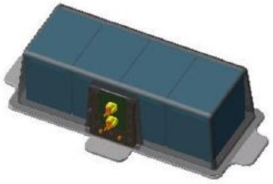


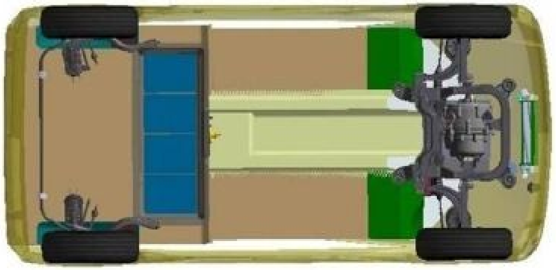
2015
35kWh
250km





2025
66kWh
500km





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Summary

- Improvements in cell chemistry will make batteries, smaller, light and cheaper giving improved range and performance
- Electronic components within a battery also have to advance to save space and weight
- Charging methods can have a big impact on the size of batteries
- New materials and processes for the construction of battery housings will be required to fully benefit from advancements in cells
- Combining all the above will revolutionise EV's, HEV's and PHEV's of the future
- Target of 0.5kWh/Kg by 2030 would give a 27kWh battery a weight of 54Kg and 42l expected range 200km

Thank You