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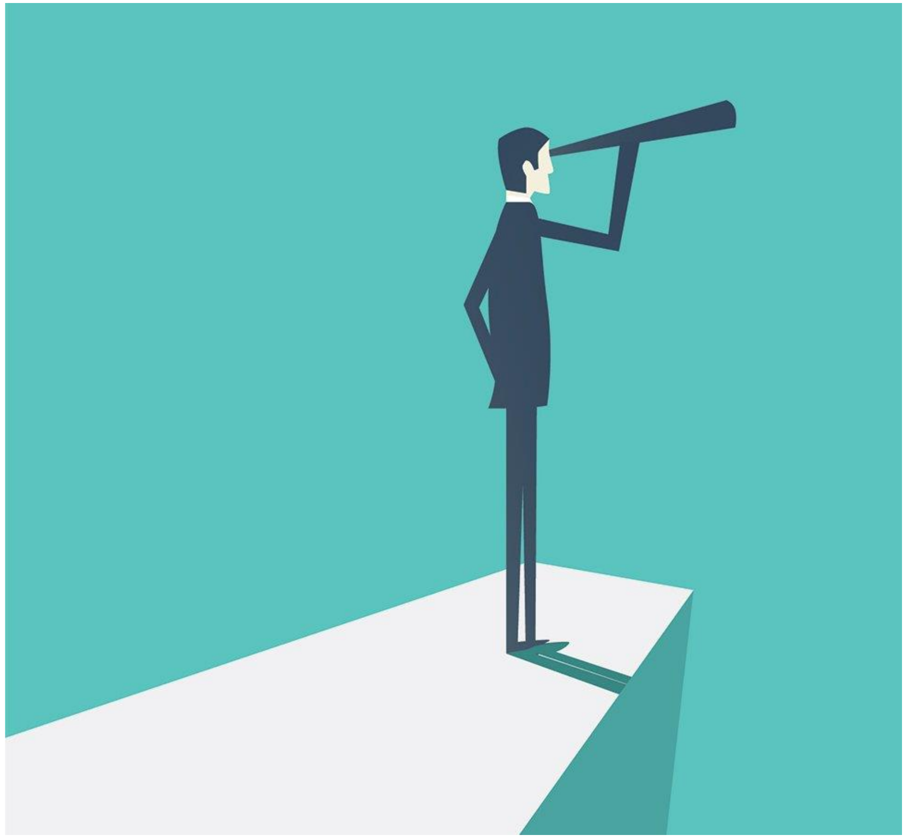
The Evolution of the Automotive Battery

Dr. S. Ndlovu, Technical Director : First National Battery

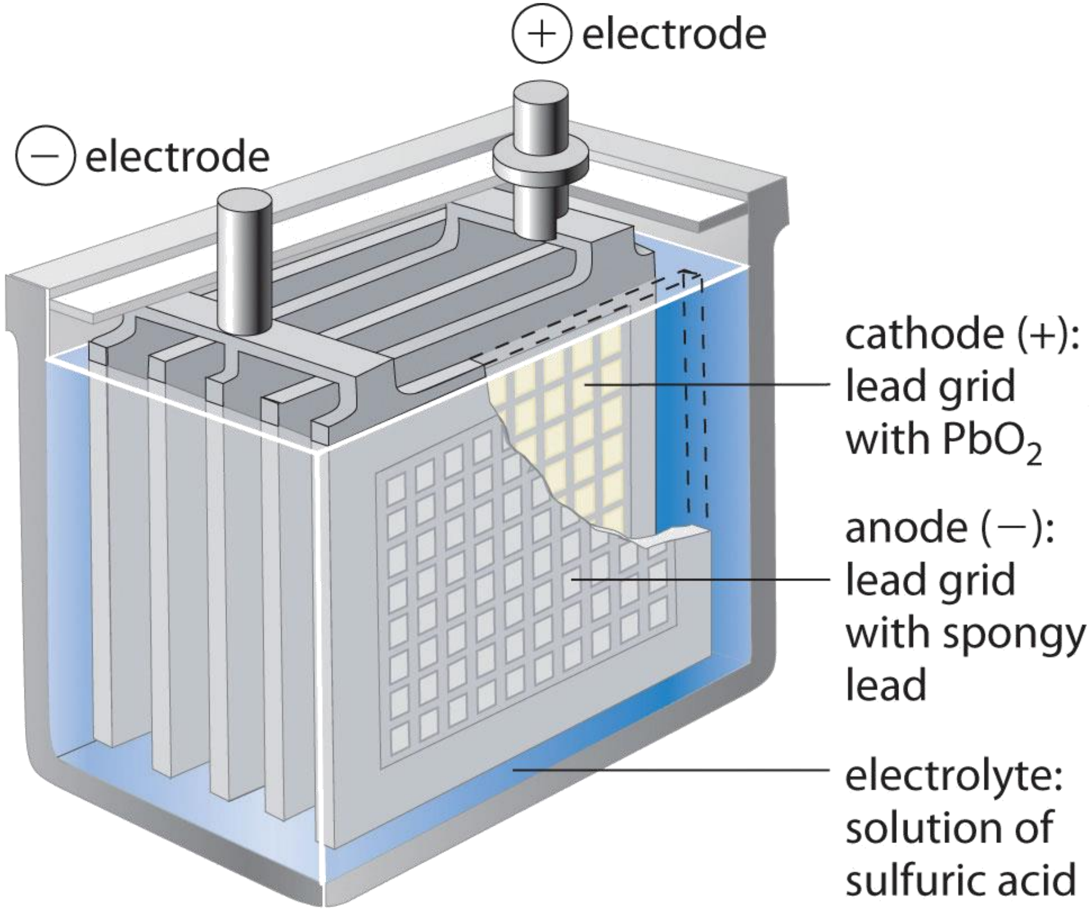
TAX
CASH
SALARIES
INTEREST
CSI SPEND
DIVIDENDS
PROFIT
CAPITAL
TURNOVER
WAGES
PENSIONS

PRESENTATION OVERVIEW



- The lead-acid battery
- Lead –acid battery development
- Key innovation drivers
- Shift to Li-ion

Pb-ACID BATTERY CHEMISTRY



Pb-ACID BATTERY CHEMISTRY

Anode	Electrolyte	Cathode		Anode	Electrolyte	Cathode
PbO_2 +	H_2SO_4 +	Pb	$\underset{\text{Chg}}{\overset{\text{Dch}}{\rightleftharpoons}}$	$PbSO_4$ +	H_2O +	$PbSO_4$
Lead dioxide	Sulphuric acid	Sponge lead		Lead sulphate	Water	Lead sulphate

AUTOMOTIVE BATTERY HISTORY

- Car batteries became widely used around 1920 as cars became equipped with electric starters
- Cars used 6V electrical systems and batteries until the mid-1950s.
- The changeover from 6 to 12V happened when bigger engines required more electrical power to start

STARTING LIGHTING IGNITION

SLI BATTERY GRID ALLOY DEVELOPMENT

HIGH MAINTENANCE

Antimony Alloy

- Strong
- Good cycling ability
- **High water loss**

Low Antimony

- Good cycling ability
- Lower water loss

Hybrid

- Low Sb positive, Ca negative
- Water loss lower than low antimony

Calcium

- **Very low water loss**

LOW MAINTENANCE

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GROWING ENERGY REQUIREMENTS IN THE CAR

Developments in 1980s – 1990s required more electrical power

- Reduced exhaust emissions
- Better fuel economy
- Improved safety
- Increasing comfort and convenience - seat warmers, entertainment systems, air conditioners etc.
- Premature ageing due to acid stratification and inhomogeneous current distribution

FURTHER DEVELOPMENT NEEDED

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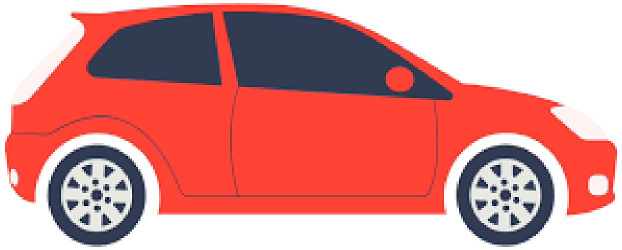
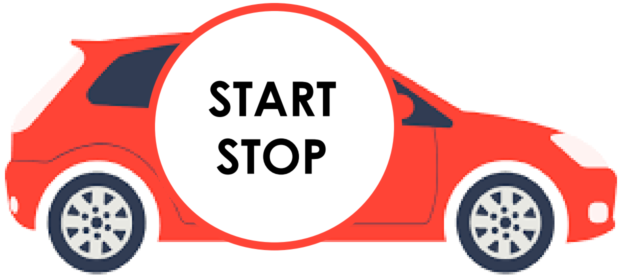
START-STOP SYSTEMS ENTER THE MARKET

STANDARD VEHICLE



START STOP VEHICLE



1, 500 ← Engine starts P/A* → 17, 500

* Based on 15 000 km P/A of CBD travel

KEY CHALLENGES: CHARGE ACCEPTANCE, CYCLE LIFE

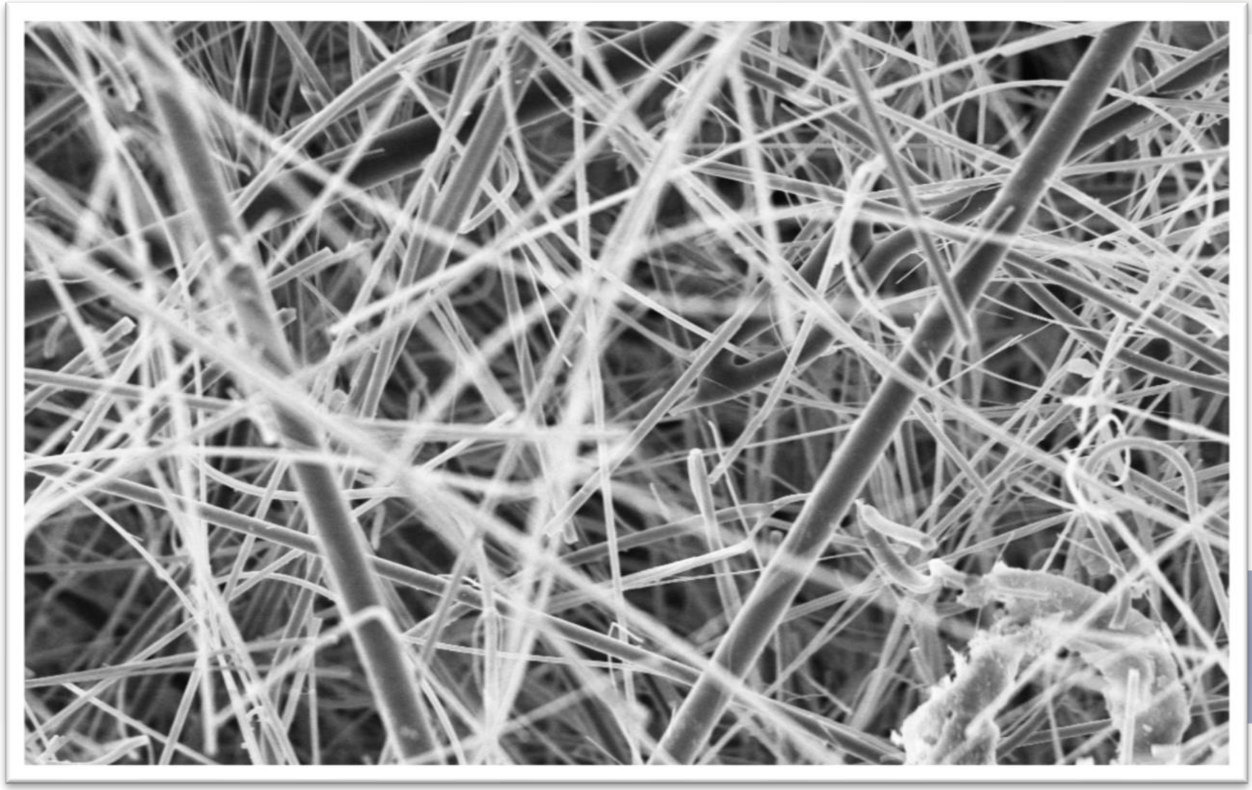
AGM BATTERY TECHNOLOGY

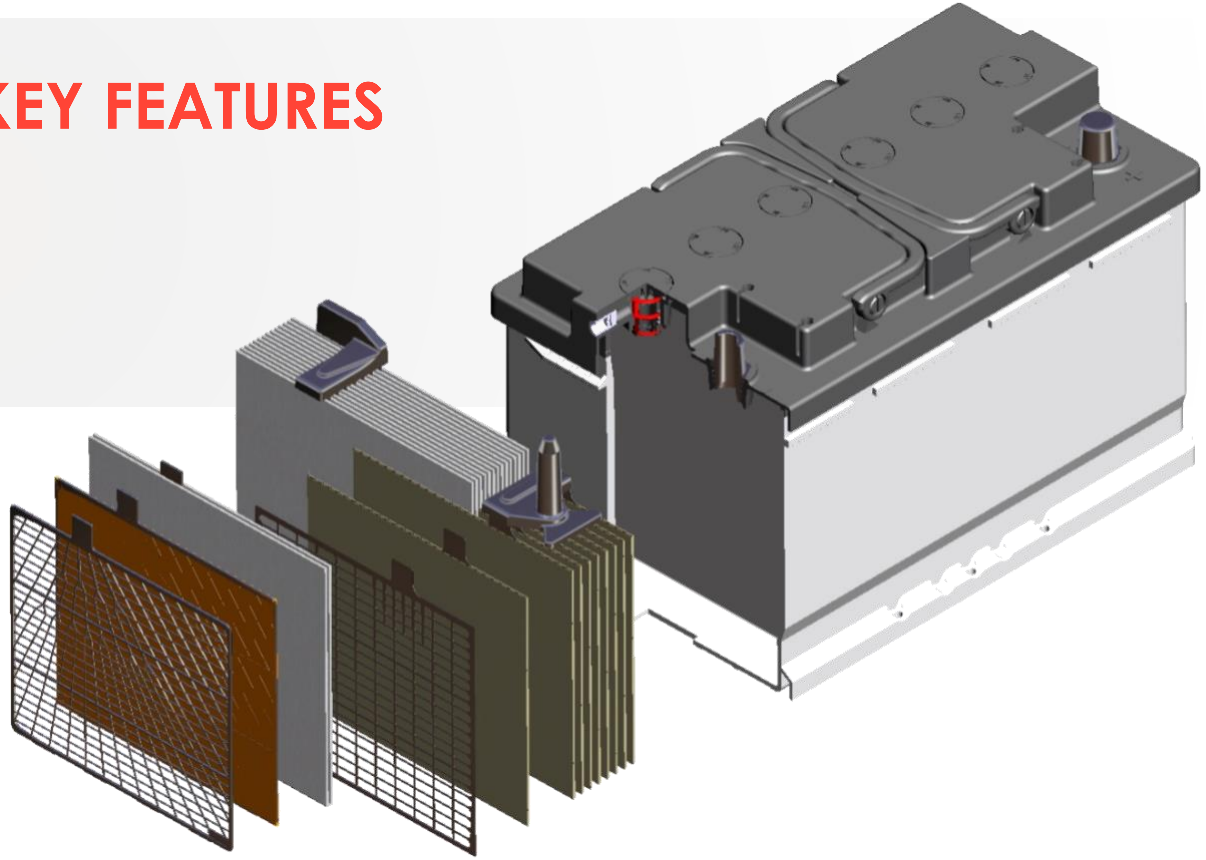
Glass mat separators

Recombinant lid technology and

Higher pack pressures to facilitate improved cyclic lifespan.

KEY FEATURES





ABSORBENT GLASS MAT

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AGM BATTERY ADVANTAGES

- AGM has very low internal resistance & high charge acceptance
- Perfect for advanced start-stop systems in which the battery needs to be quickly recharged, through the energy provided by the regenerative braking system
- Capable to deliver high currents on demand and offers a long service life
- AGM is maintenance free, non-spillable
- 3x the endurance of conventional batteries

FIRST NATIONAL battery™
WORLD CLASS BATTERY MANUFACTURER

ONLY SOUTH AFRICAN AGM BATTERY SUPPLIER

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EFB TECHNOLOGY

- Carbon additives in the plate manufacturing process.
- Improved cycling performance compared to conventional flooded batteries.
- Support for a high number of engine starts and extended engine-off periods.
- Improved charge acceptance compared to conventional flooded batteries.
- Suitable for entry level start-stop vehicle technologies.

Lower tier option to AGM batteries

ENHANCED FLOODED BATTERY

Pb-ACID BATTERY COMPARISON

SLI

- Maintenance Required
- Free flowing electrolyte
- Conventional applications
- 120 Cycles @50% DOD
- Economical

EFB

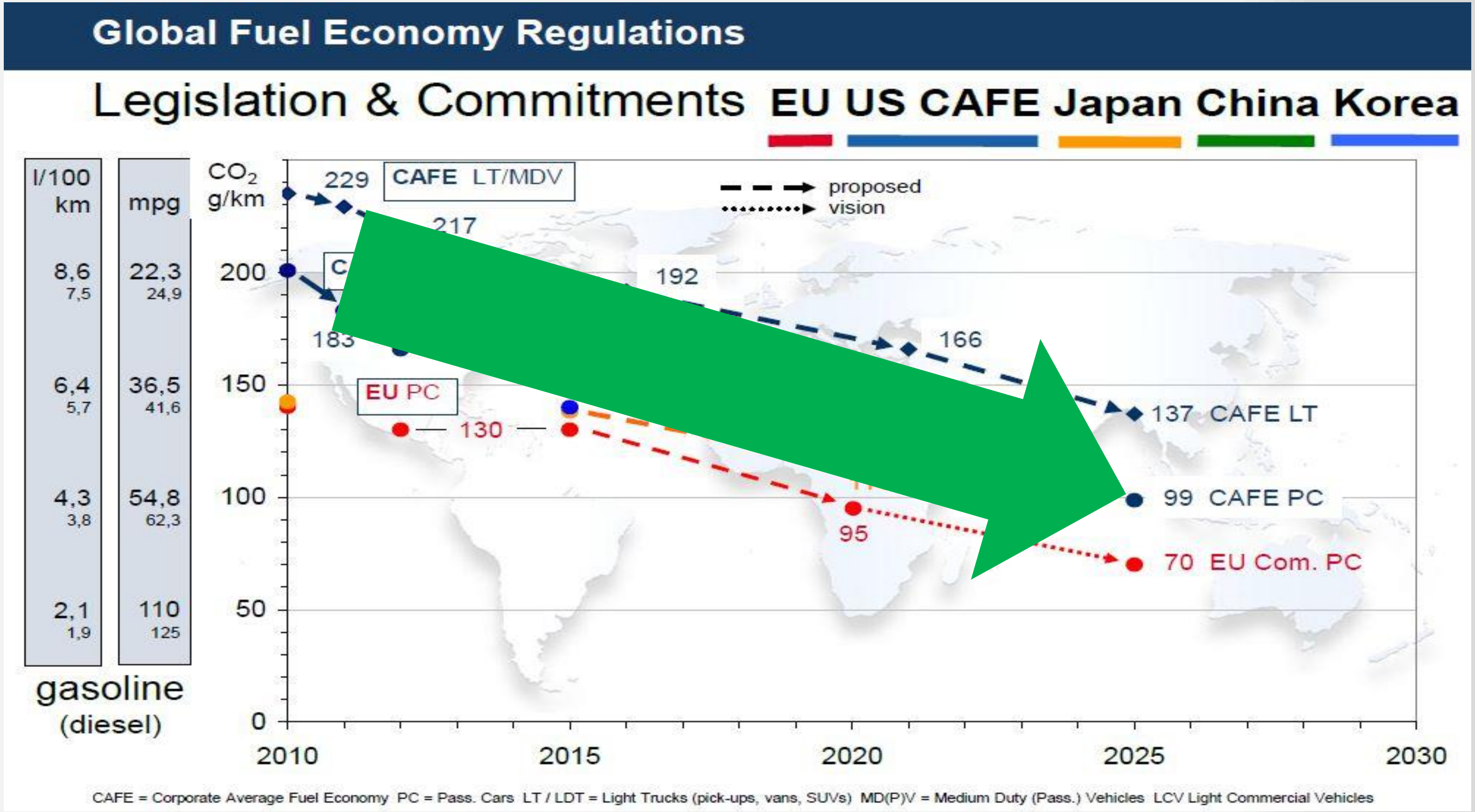
- Low Maintenance
- Free flowing electrolyte
- For start-stop applications
- Improved Charge Acceptance
- Up to 25% increased cranking power
- 240 Cycles @ 50% DOD
- 2x improved life cycle
- Lower tier option to AGM batteries

AGM

- Maintenance-Free
- Immobilized electrolyte
- For start-stop and advanced applications
- Rapid/Dynamic charge acceptance
- Higher cold cranking performance – 35% improvement
- 360 Cycles @50% DOD
- 3x improved life cycle

INCREASING BATTERY PERFORMANCE

CARBON DIOXIDE EMISSION TARGETS



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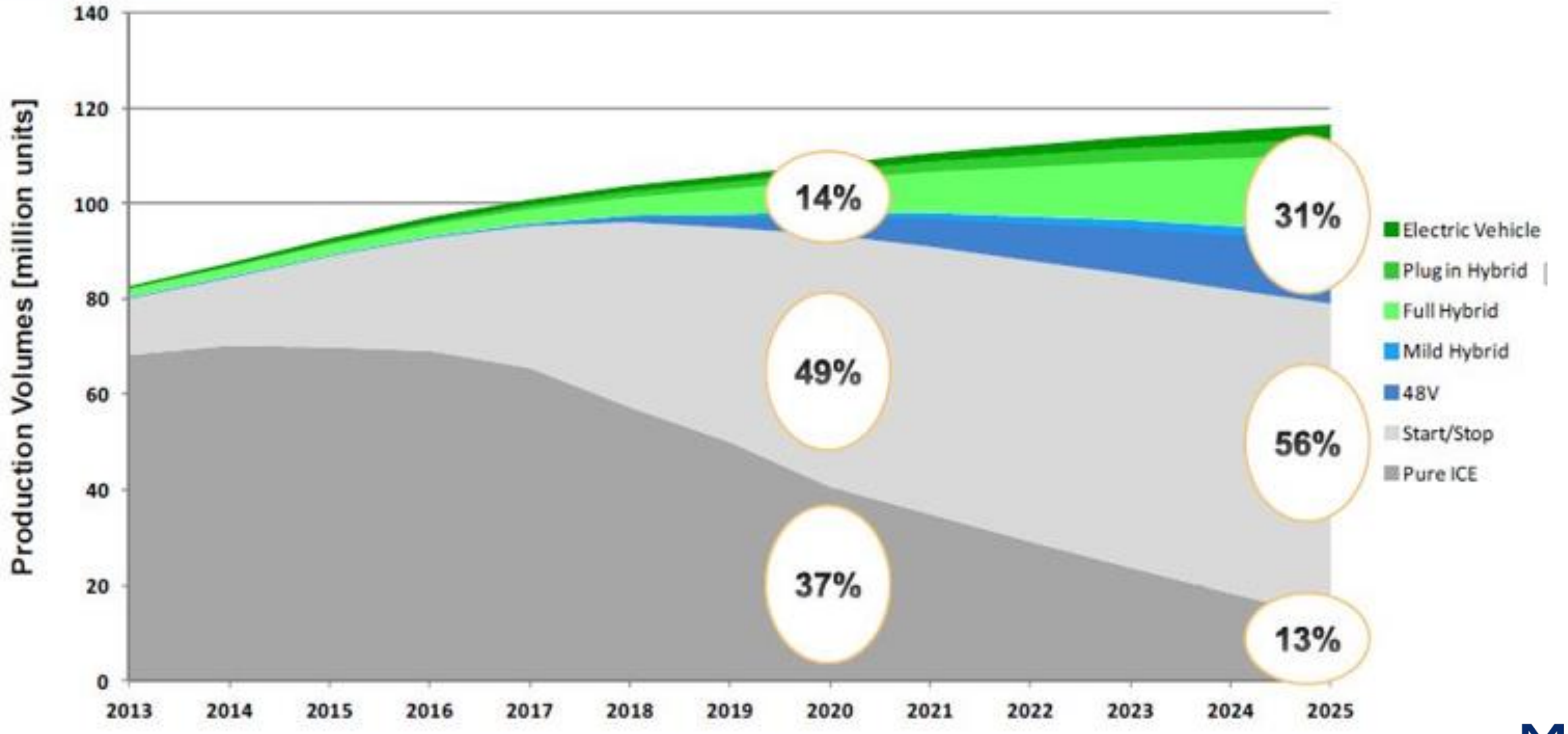
PRODUCT TRENDS – ELECTRIFICATION IN CARS

Volume Scenario

Global Passenger Vehicles / Light Vehicles Engine Production
More than 30% of the vehicles world wide will have an electrified powertrain



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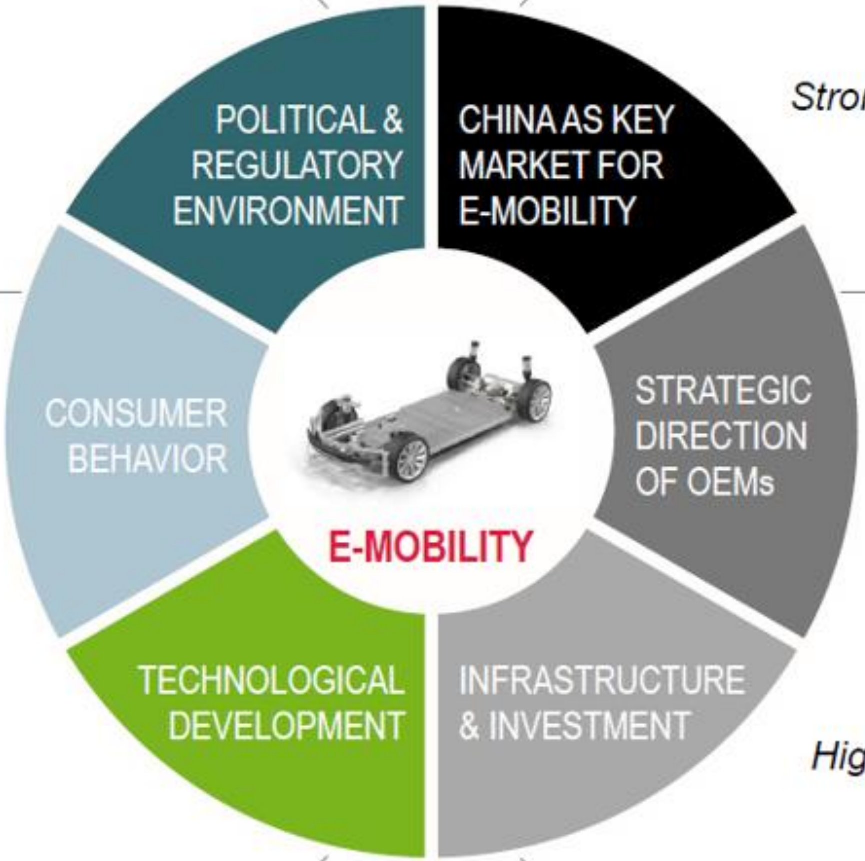
SIX KEY DRIVERS OF E-MOBILITY

Tightening emission targets
State subsidy programs
Privileges in licensing and road traffic

Biggest automotive market worldwide with >23mn sold vehicles p.a.
Strong political support of e-mobility development

Change towards e-vehicles
Benefit from subsidies
Usage of new mobility concepts



Fulfilment of emission targets
"Dieselgate" scandal
Leading position in e-Mobility & "green" image

Development on battery technology and increase of electrical range
Reduced electric vehicle cost
Fast charging to reduce charging time

Develop of charging infrastructure
High government funding and OEM investments regarding e-mobility
Restrictive in conventional technologies

Source: FEV

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MOVE TO HIGH VOLTAGE BATTERY REQUIREMENTS

E-mobility performance class overview for passenger vehicles

		Mild Hybrid			Full Hybrid/Plug-in		EV (Batt/RE/FC)			Unit
		12 V	48 V	HV	mid	Power	Small car	Medium car	Sports car	
max. EM Power	motor-based	4	12	20	60	100	60	100	180	kW
max. EM Speed	motor-based	50	150	150	200	300	200	300	500	Nm
DC voltage	max. (generator-based))	15	60	200	400	450	400	400	450/800	V
	min. (motor-based)	12	36	120	300	250	300	300	300/600	V
max. current	DC	333	333	167	200	400	200	333	550/280	A
	AC	350	500	500	600	800	250	450	1000/500	A
Speed/crankshaft speed ratio or max. EM speed		3	1	1	1	1	10 – 15 k/min		bis 20 k/min	
Power ratio max./duration		2	2	2	2	2.5	1.5	1.5	2	

Source: ZVEI

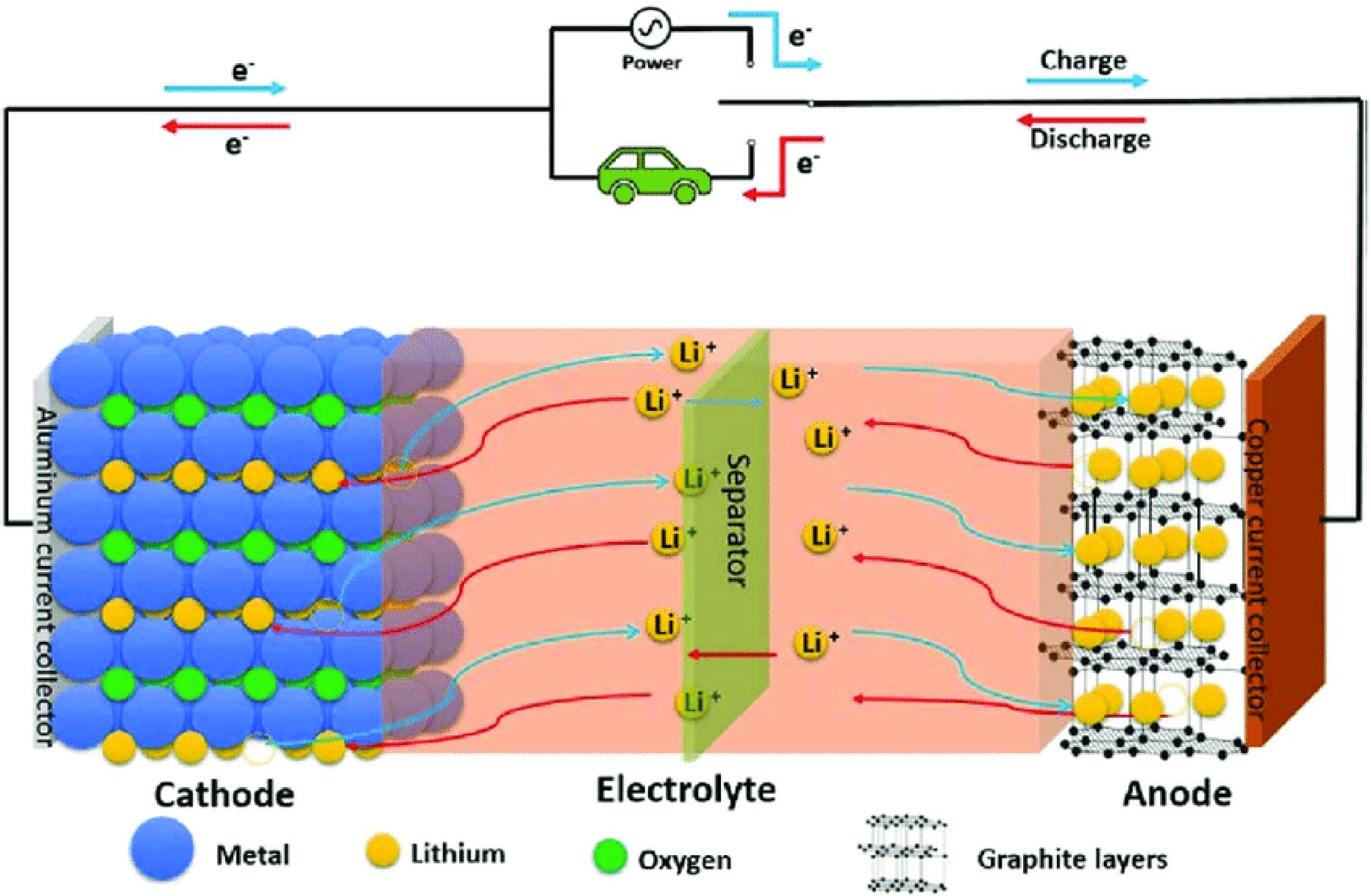
6 V

12/24 V

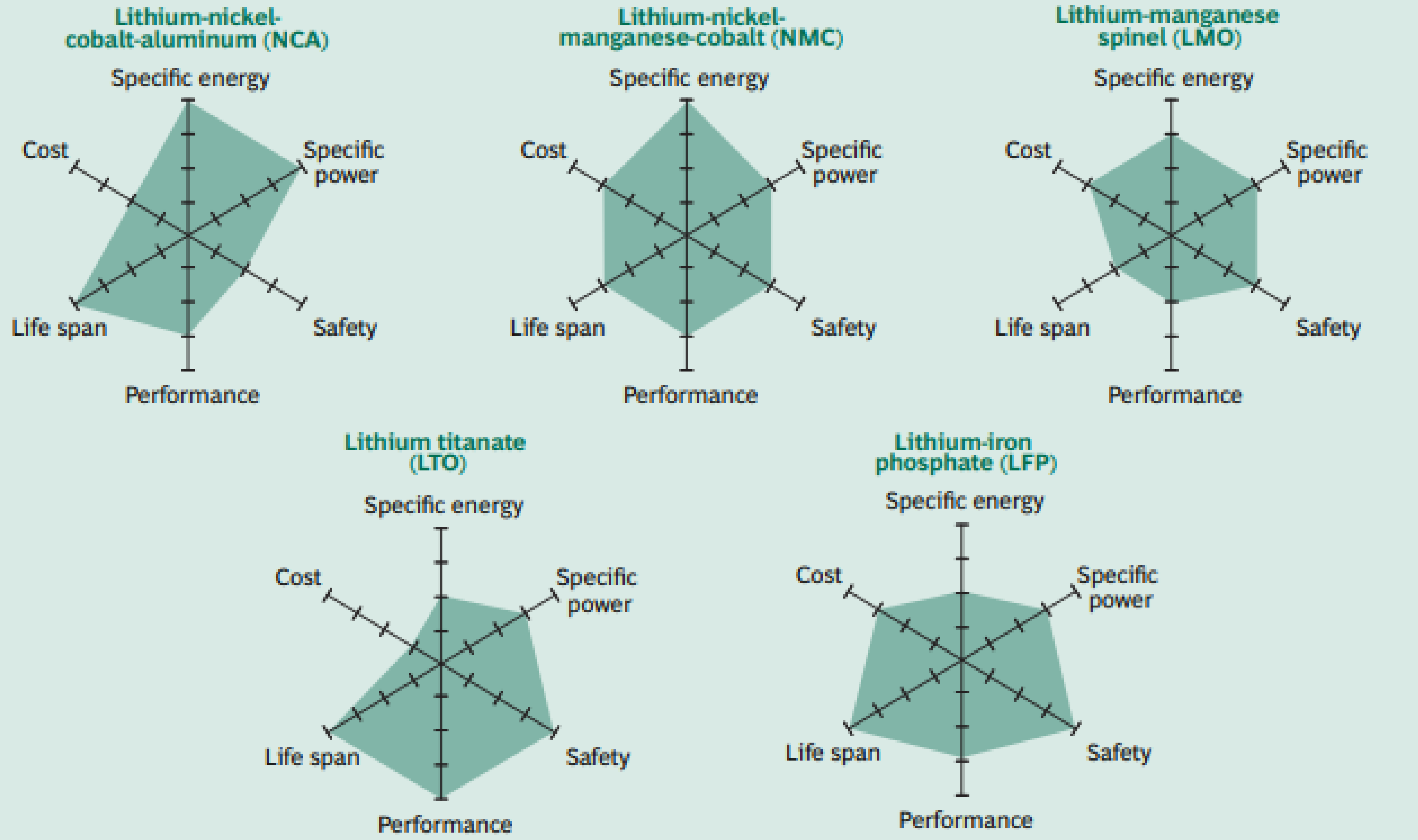
48 V

>300 V

WHAT IS A LITHIUM ION BATTERY?

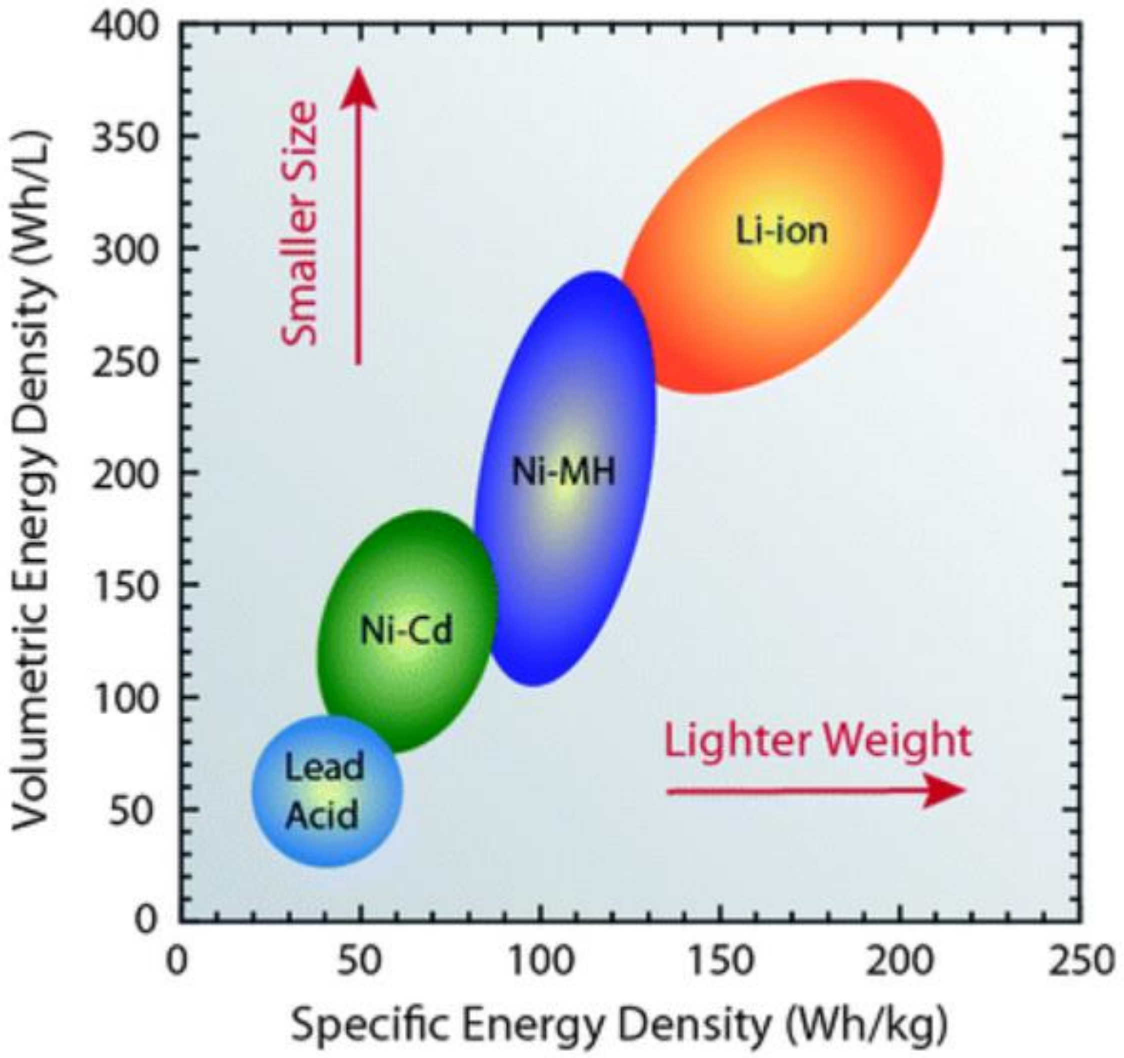


DIFFERENT LITHIUM ION CHEMISTRIES

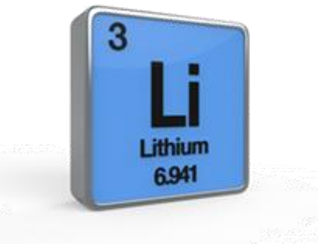


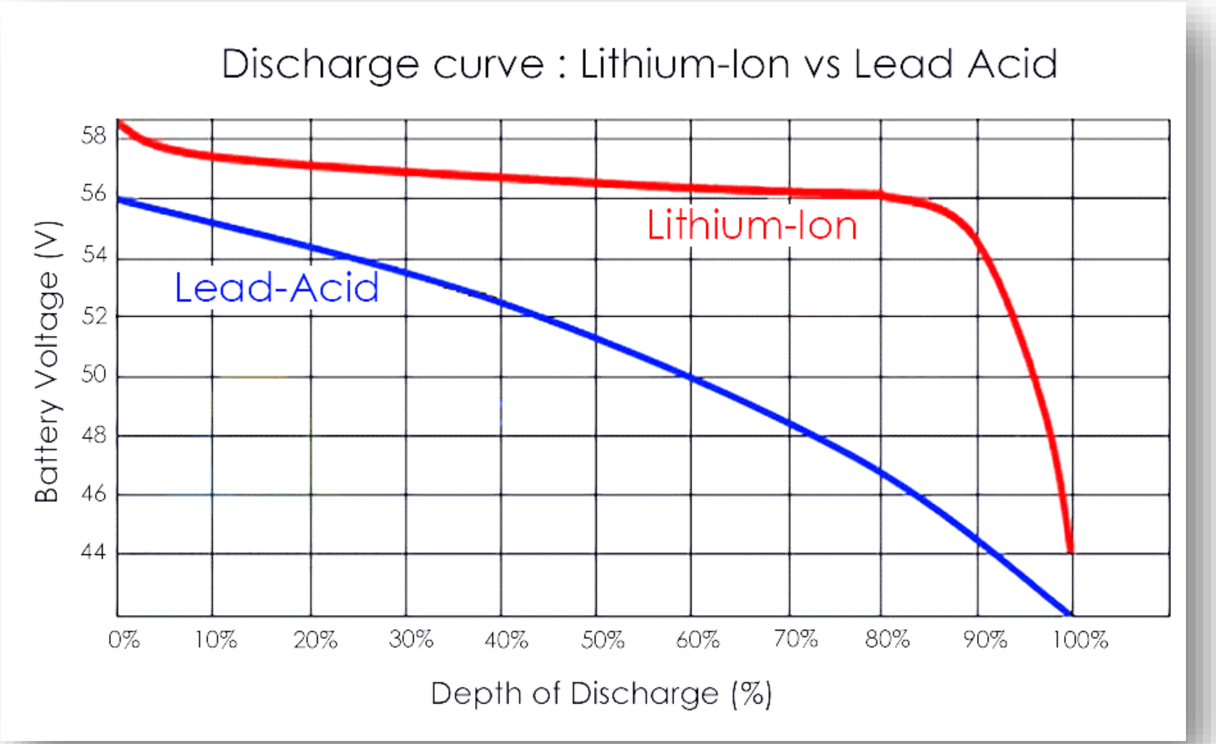
Source: BCG research.
Note: The farther the colored shape extends along a given axis, the better the performance along that dimension.

ENERGY DENSITY OF DIFFERENT BATTERY SYSTEMS

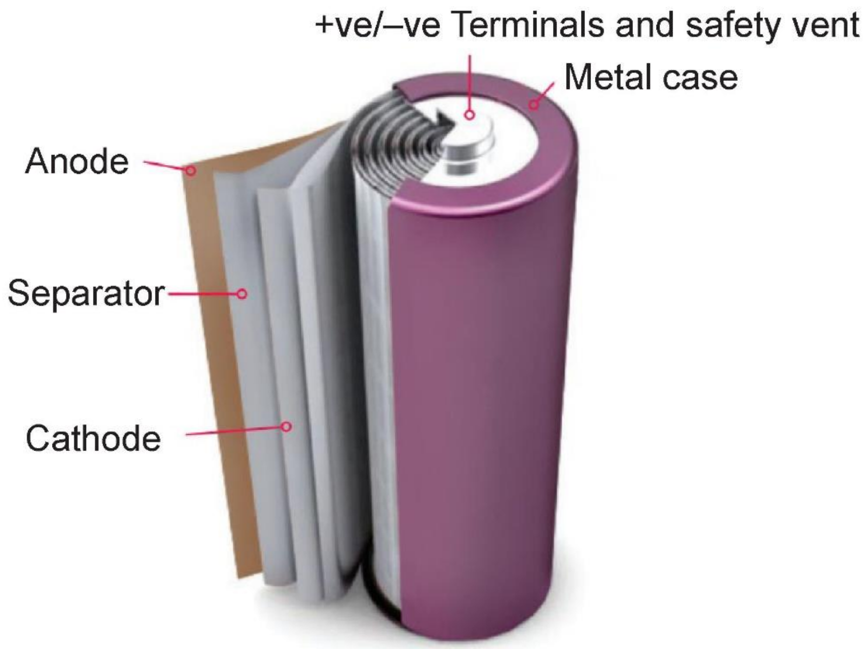


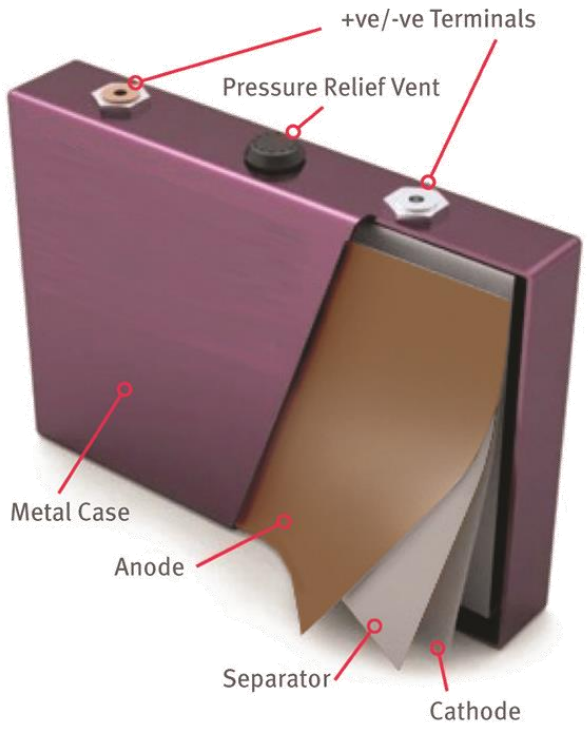
- High energy density
- Size & Weight Advantages
- Peukert's Losses & Voltage Sag – virtually non-existent

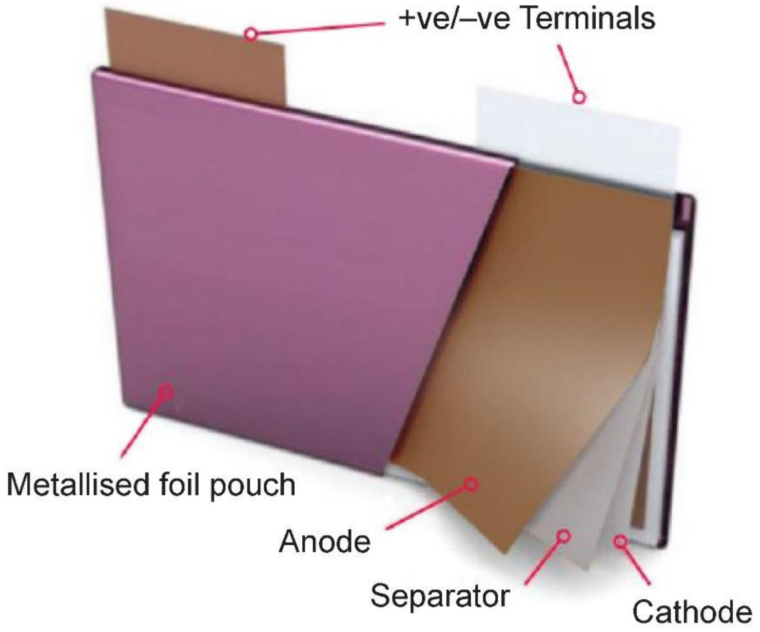




LI-ION BATTERY CELL DESIGNS







CYLINDRICAL CELLS **PRISMATIC CELLS** **POUCH CELLS**

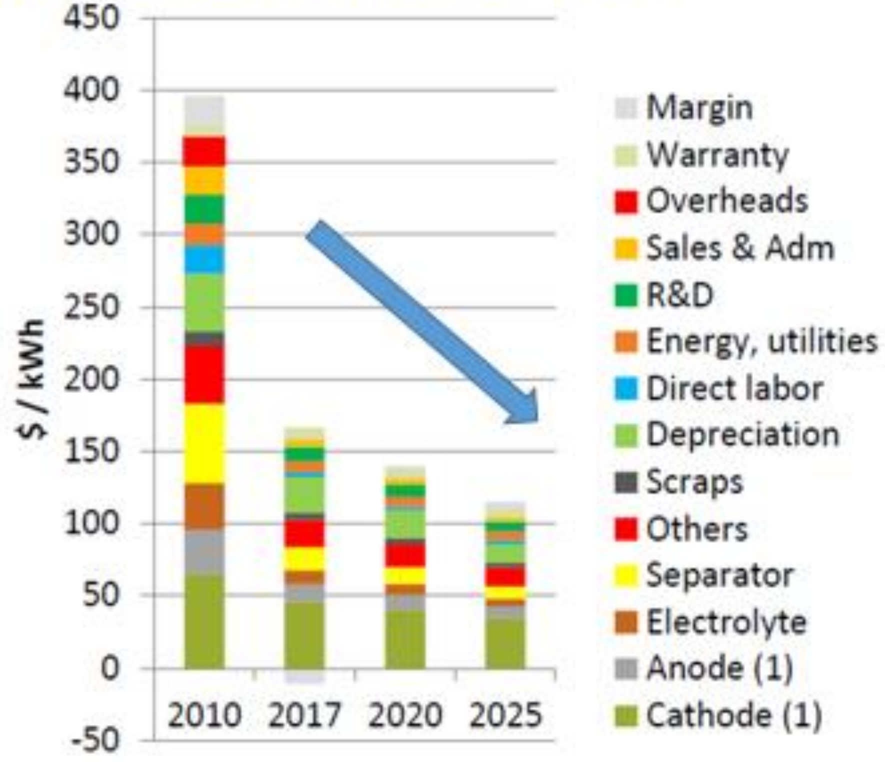
PROS & CONS OF LI-ION VS LEAD-ACID BATTERIES

- **High energy density**
- Relatively low self-discharge
- Low maintenance
- Size & Weight Advantages
- Superior useable capacity
- Extended cycle life
- **Fast and efficient charging**
- Very little wasted energy

- **Expensive**
- **Transportation problems**
- Needs Circuit Protection
  - protect from over-charge & over-discharge
- **Safety risk**
- **Poor recycling**
- Immature te**c**hnology
- Deep Discharge

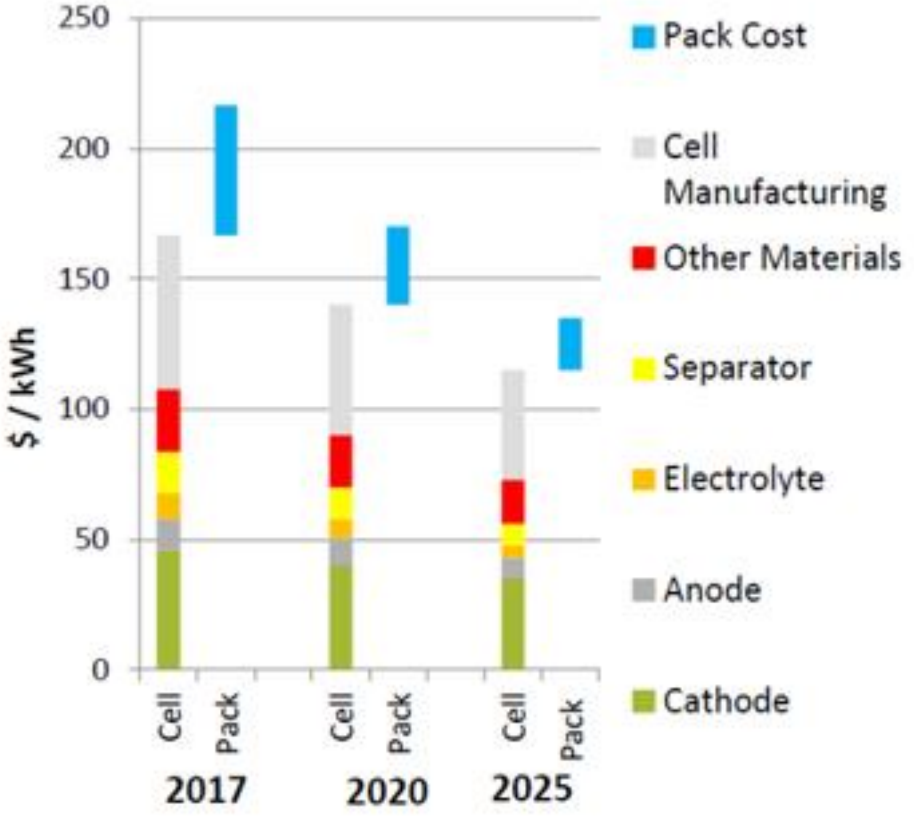
DECREASING COST OF LI-ION TECHNOLOGY

LIB cell average **cost** (40 Ah pouch) (EV design ; NMC cathode)



(1) Active materials only
Source: AVICENNE ENERGY 2018

LI-ION BATTERY PACK **COST** FOR EV



** For Production > 100 000 packs/year*

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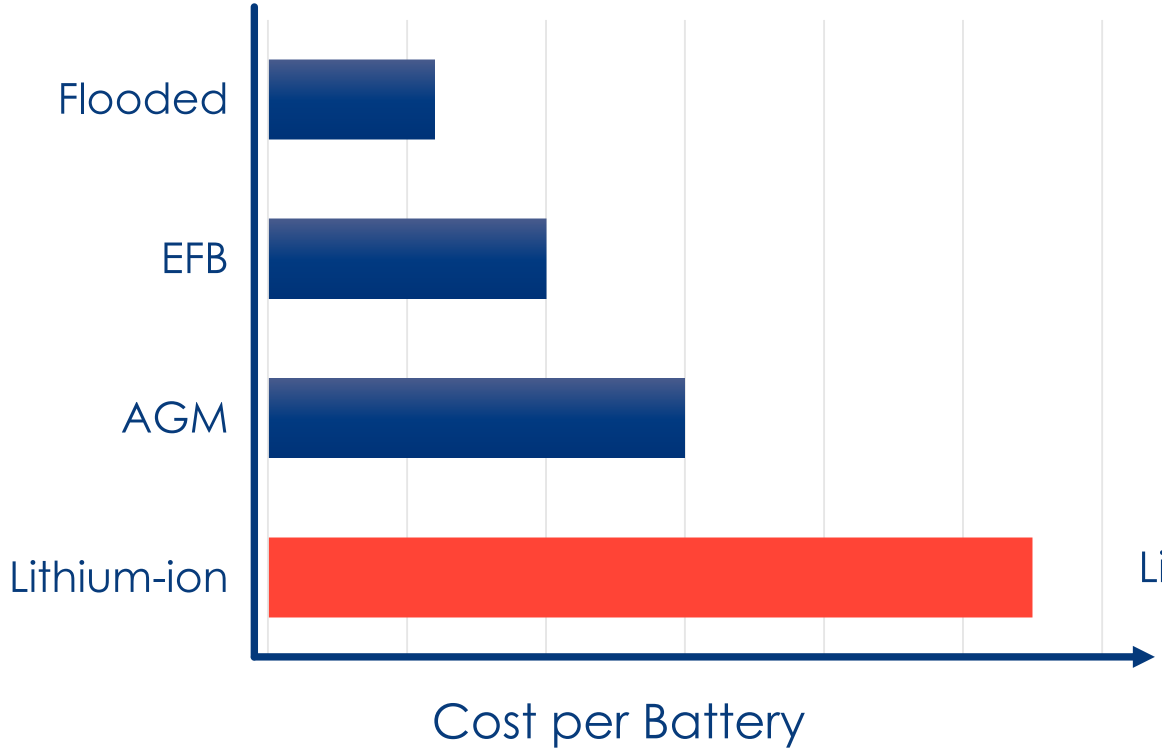
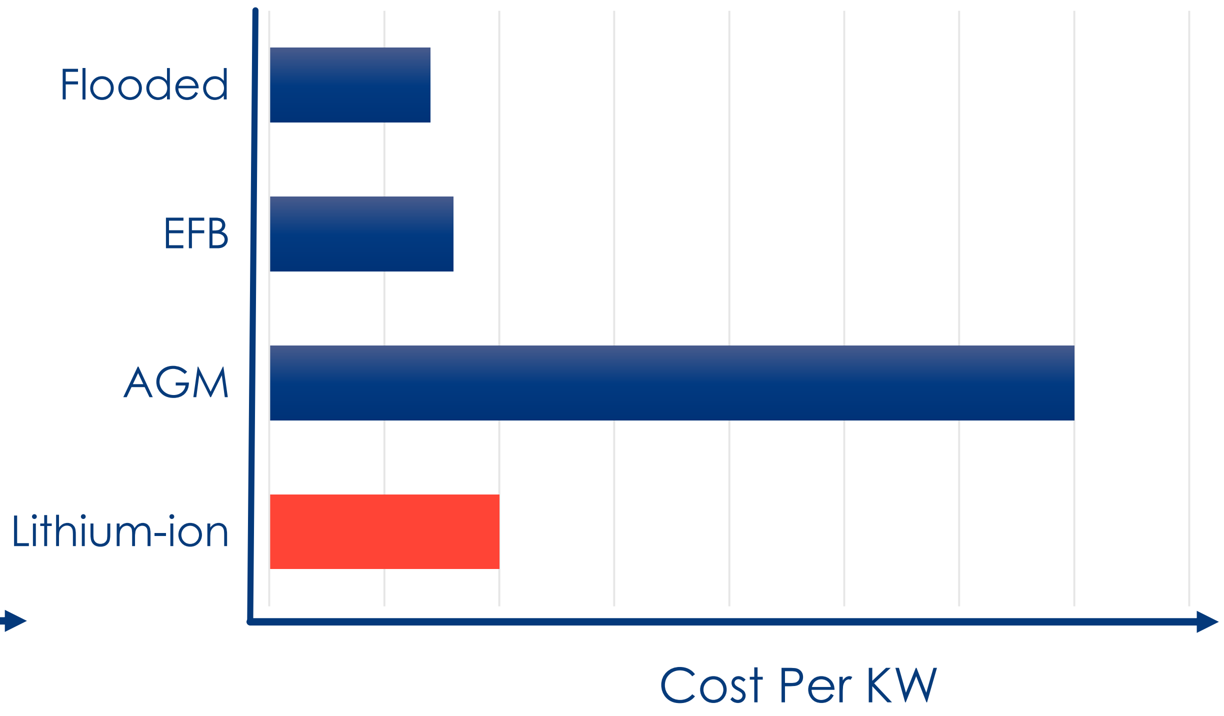
COST OF LI-ION vs LEAD-ACID TECHNOLOGY

INITIAL COST PER BATTERY CAPACITY



TOTAL LIFE CYCLE COST



LI-ION: COMPETITIVE LIFE CYCLE COST

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CONCLUSION

Pb-Acid is here to stay but…Li-ion is the technology of the future!

THANK YOU

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