2030 Battery R&D Roadmap for Hybridization and E-Mobility

Rene Schroeder
EU Affairs Manager

31 January 2017

About the association and members

- **Manufacturers and supply chain** of automotive and industrial **batteries**. Represents industry at EU level.
- With **52 members from across the continent** comprising more than **90% of the battery industry** in Europe.
- **Exchanges expert information** to stakeholders incl. renewable energy storage and electrification of mobility.
- Systems: **Lead, Lithium, Sodium, Nickel.**
- **30,000 jobs in EMEA**: industrial base.

Membership

Battery Manufacturers

Membership

Battery System Integrators & Supply Industry

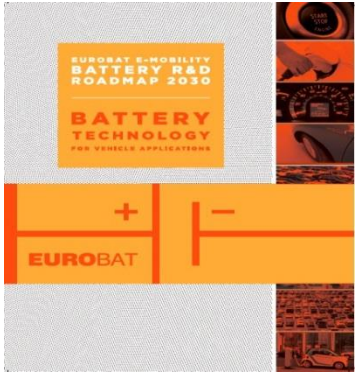
Hybridisation and electrification

<u>Hybridisation and electrification of transport are needed to meet EU CO2 emissions targets</u>, by installing of the start-stop and micro-hybrid batteries now on virtually all new ICE.

Hybridisation and electrification offer important opportunities in terms of job creation (2,35M jobs by 2050), economic growth, energy security, health and environmental protection.

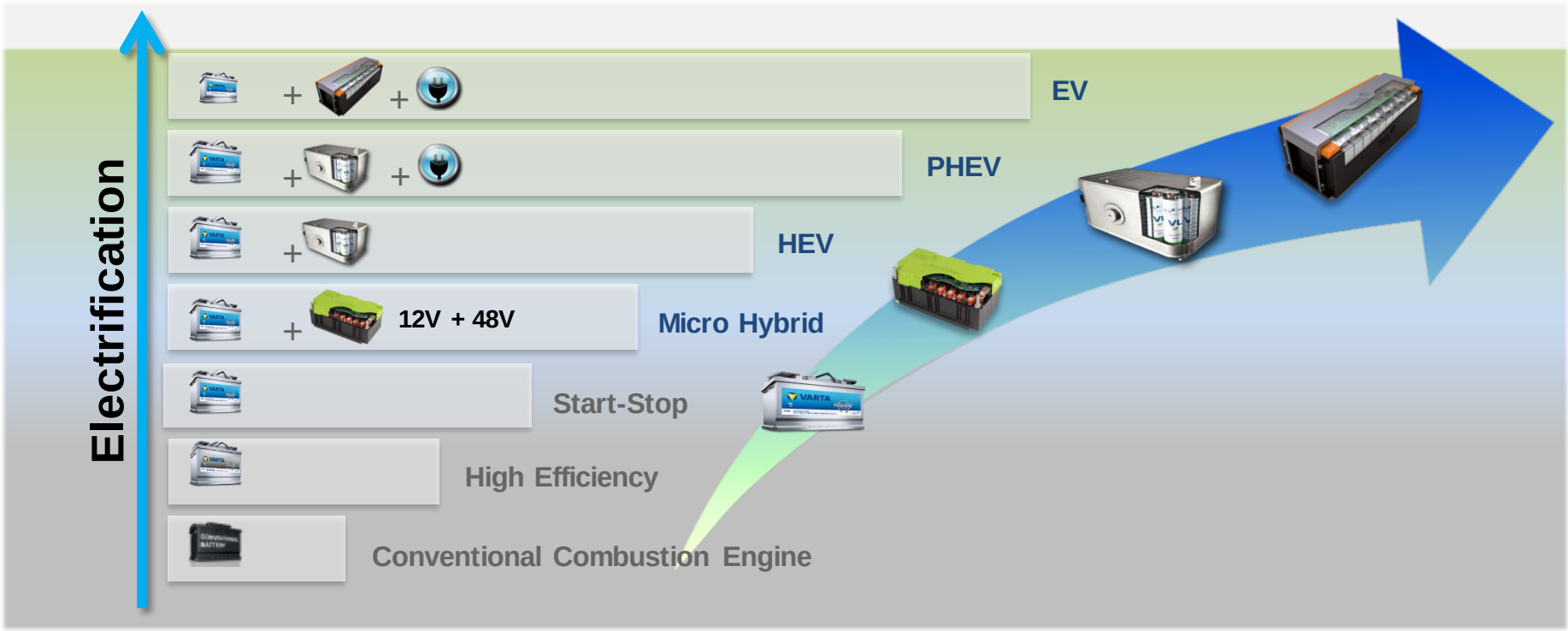
Technological improvements of battery technologies will further enhance the performance, affordability and reliability of hybrid and full electric vehicles.

EUROBAT Reports



- 2014 Review of Battery Technologies for Automotive Applications
- Suitability of battery technologies in automotive sector
- EUROBAT e-mobility Roadmap looks at up to 2030
- Identifies 6 R&D priority areas for improvements
- **Together the Reports give a comprehensive picture of battery technologies for all vehicle applications**

Automotive Technology Portfolio



Class 1 –Conventional vehicles (including start-stop and basic micro-hybrid vehicles)

- Battery required to start the engine and supply the complete 12V electrical system (starter-lighting-ignition).

- Can also provide start-stop functionality, as well as the entry class of braking recuperation and passive boosting (resulting in 5-10% fuel efficiency improvements).

BATTERY REQUIREMENTS FOR A CLASS 1 PASSENGER CAR	
Cold Cranking	500-800 CCA to reliably start an engine down to -30°C
Calendar Life	5 years requested from OEMs
Voltage range	12V required for compatibility with on-board electronics
Safety	Battery close to engine, so must be resistant to hot temperatures
Low cost	Cost-efficiency paramount for mass-market applications
Manufacturing Base/Resource Availability	Must be sufficient to fulfill mass-market demand

Class 1 –Conventional vehicles (including start-stop and basic micro-hybrid vehicles)

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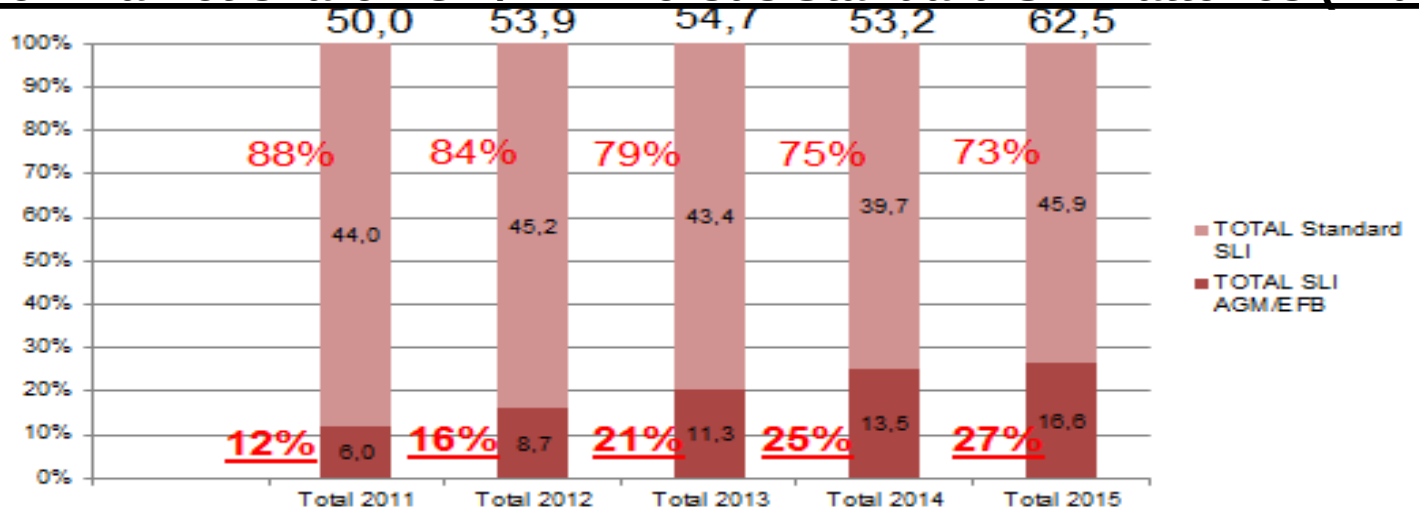
- For technical reasons, **the 12V lead-based battery is the only available mass-market battery system for Class 1 vehicles for the foreseeable future.**
- Its excellent **cold-cranking ability, 12V compatibility and low economic package** set it apart from other technologies.
- **Alternative technologies (esp. lithium-ion) still need improvements** in cold-cranking ability and cost level to be a viable mass-market alternative.
- **Vehicles in this class comprise well over 250m vehicles in Europe, and so socioeconomic considerations are especially important.**

Statistics: SLI

Evolution market share AGM/EFB versus Standard SLI Batteries (M units)



Conclusions: - Increase market share AGM/EFB to be continued
- Standard SLI still substantial part of the market

Europe = EU28 + Norway + Switzerland, exclusing TR and RU/CIS
OEM + OES (= Deliveries to OE manufacturers in the defined countries) + IAM (= Country of goods delivered)
Automotive batteries = For passenger cars and Light commercial vehicles, excluding heavy commercial
EUROBAT member participation only (8)

Class 2 - Hybrid vehicles (advanced micro-hybrid, mild-hybrid and full-hybrid vehicles)

- The installed battery is required to store energy captured during vehicle braking, and use it to boost acceleration.

- In full hybrid vehicles the battery can also be expected to provide a level of vehicle propulsion.

BATTERY REQUIREMENTS FOR A CLASS 2 PASSENGER CAR	
Voltage range	48V-400V
Energy content	0.2-1.5kWh
Discharge Power	10kW-80kW
Recharge Power	10kW-50kW
Cold cranking	5-7 kW pulses of 5 second duration
Capacity turnover	10,000 cycles required in full HEVs
Calendar life	Over 10 years requested by OEMs
Safety	Battery Management System required to manage high voltages
Weight and volume	As light and small as possible

Class 2 - Hybrid vehicles (advanced micro-hybrid, mild-hybrid and full-hybrid vehicles)

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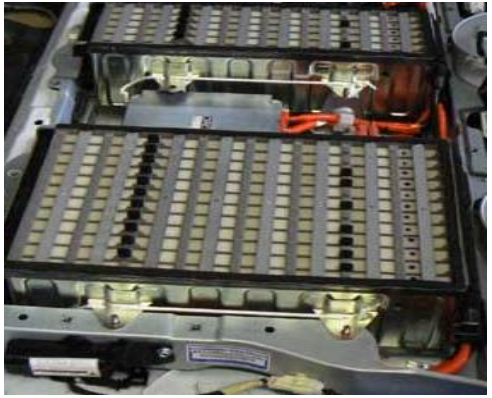
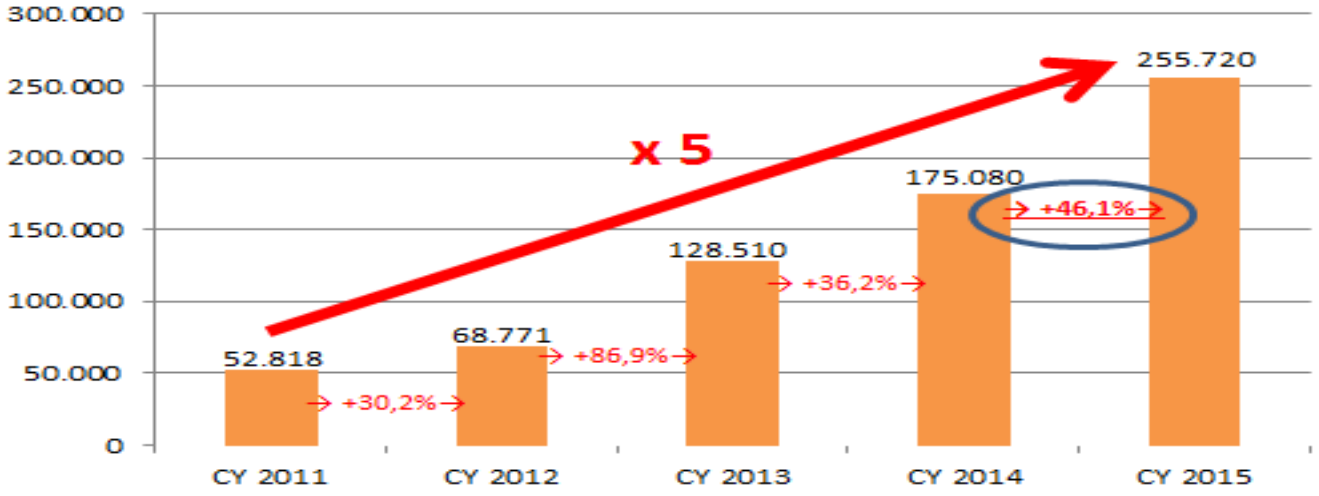
- Several battery technologies are able to provide hybrid functionality in different combinations, with **nickel-metal hydride and lithium-ion batteries coping best as requirements increase**, due to their fast recharge, good discharge performance and life endurance.

- Although nickel-metal hydride batteries have so far been the technology of choice in full-hybrid vehicles, **the decreasing costs of lithium-ion systems continue to improve their competitiveness**. Nickel metal hydride batteries are disadvantaged by heavier weight, lower energy density and lower deep-cycling capacity.



Statistics: HEVs and PHEVs production



- **Small in values but significant increases every year**
- **Strong increase (+46%) expected for 2015**
- **All (p)HEV have a secondary on-board L-A battery**

(Sales estimates in units – large Europe). Based on HIS/Polk OEM light vehicle production data - large Europe (including Ukraine, Turkey, Russia, Kazakhstan and Uzbekistan) - update 1Q2015)

Class 3 – Plug-in hybrid vehicles and full electric vehicles

- The installed battery must provide sufficient energy for significant levels of vehicle propulsion, either for daily trips (20-50km) in plug-in hybrid vehicles or as the only energy source in full electric vehicles (100km+).

- In plug-in hybrid vehicles, the battery must also perform hybrid functions (i.e. regenerative braking) when electric drive is depleted.

BATTERY REQUIREMENTS FOR A CLASS 3 PASSENGER CAR	
Voltage range	250-500V
Energy content	14kW for 100km driving range
Discharge power	Up to 100kW
Recharge power	Up to 50kW
Cold cranking (PHEV only)	5-7kW pulses of 10 seconds in duration
Capacity turnover	High depth of discharge required (i.e. 80%)
Calendar life	Over 10 years requested by OEMs
Safety	Battery Management System required to manage high voltages
Weight and volume	As light and small as possible
Manufacturing base/resource availability	

Class 3 – Plug-in hybrid vehicles and full electric vehicles

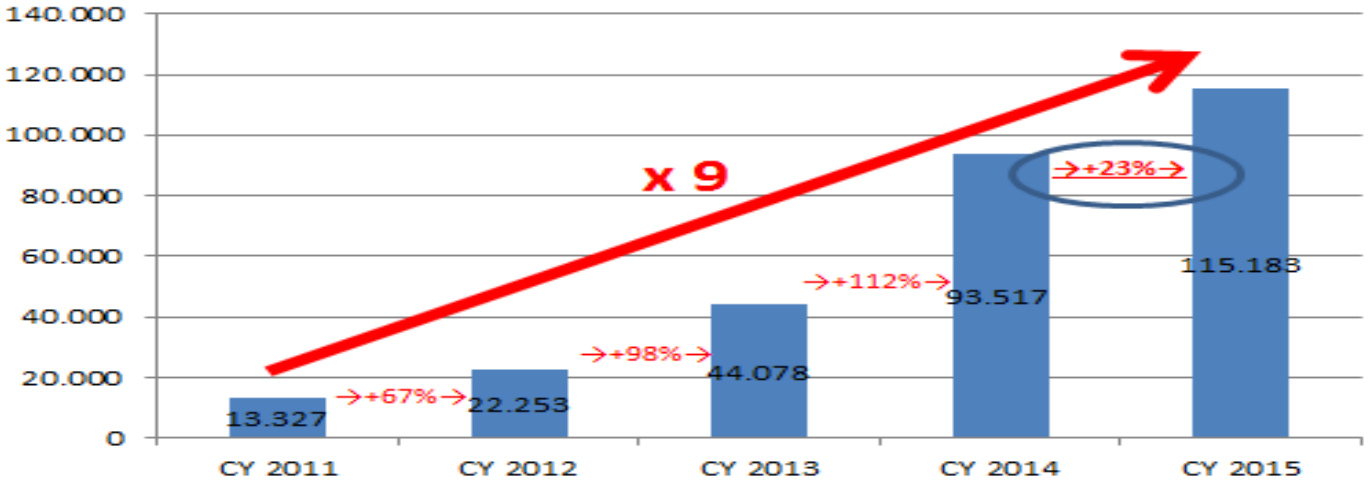
- Due to the need for high energy density, **Class 3 passenger vehicles are propelled predominantly by lithium-ion battery systems, w**hich are additionally set apart by their fast recharge capability and good recharge/discharge power.

- **Lithium-ion batteries are the only commercially available battery technology capable of meeting OEM requirements** for passenger cars according to EV driving range and time. Other battery technologies cannot deliver the required level of performance.

- For commercial applications, heavy duty vehicles and harsh environments, sodium-nickel chloride batteries are a competitive option.

- Future challenges related to adaptation of the value chain and availability of resources (lithium).

Statistics: EVs production



- **Dominated by Li-Ion**
- **Small in values, but 100% market increases in 2013 and in 2014**
- **Expected slow down of growth, still reaching 23% for 2015**
- **All EVs have a secondary L-A battery on-board**

(estimates in units – large Europe). Based on HIS/Polk OEM light vehicle production data - large Europe (including Ukraine, Turkey, Russia, Kazakhstan and Uzbekistan) - update 1Q2015)

Battery technologies and key priorities to 2030

Advanced lead-based batteries

- For start-stop vehicles and micro-hybrid vehicles
- Key priorities: improve performance and lower cost for the mass Micro-Hybrid vehicle market

Lithium-ion batteries

- For electric vehicles and all types of hybrid vehicles
- Key priorities: increase energy density, power density and to lower cost, with different performance priorities for each application

Sodium-nickel chloride batteries

- For commercial and professional vehicles, LCV to Heavy duty, in pure electric and plug-in hybrid configuration
- Key priorities: production process, systems integration, cost reduction are the primary development targets for this technology

EUROBAT E-mobility Battery R&D Roadmap 2030

Advanced lead-based batteries: priorities

Technological performances

- Battery chemistry
- Battery design

Lower cost

- Use of high volume cost optimized carbon materials as additives
- Fully automated processes for new advanced designs
- Usage of secondary materials
- Lifecycle approaches to optimize battery design

System Integration

- Advanced thermal solutions
- BMS to adjust the state of charge to real working conditions

Production Process

Already automated, improvements:

- Active material preparation
- Cureless plate production
- Close loop formation

Safety Parameters

Lead-based batteries are safe due to the use of non-flammable electrolytes

Recycling

Close to 100% of lead-based batteries are recycled in the EU in a closed loop system

- Thank You -

For more information
Contact rschroeder@eurobat.org
Or visit www.eurobat.org
+32 276 116 53

@eurobat_org