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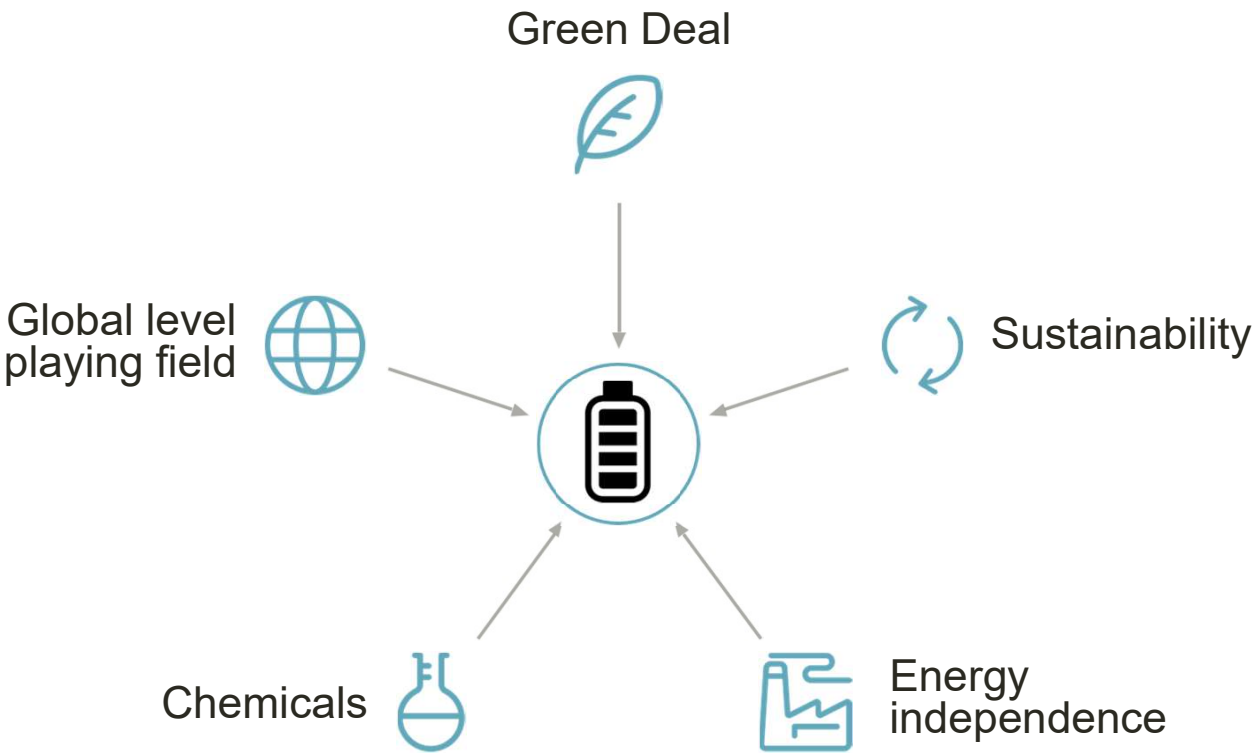
Batteries: at the centre of EU policymaking



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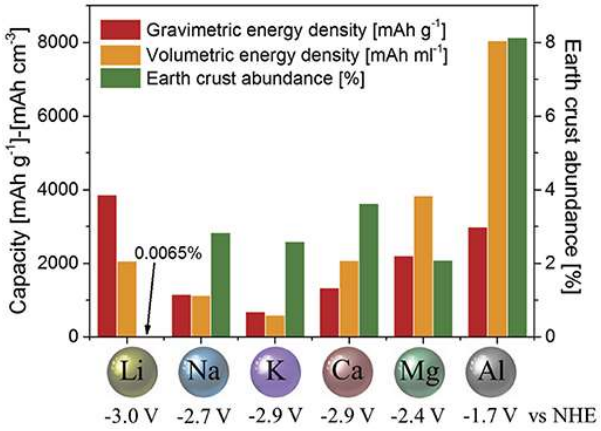
Sustainable batteries in their full life-cycle



Elia et al. (2016) © 2016 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

Sustainable batteries are: produced with the lowest possible environmental impact, using materials that have been obtained in full respect of social and ecological standards, long lasting and safe and that can be repaired or reused and repurposed.

This will be achieved by:

- Sustainability and safety requirements for batteries.
- Performance and durability requirements.
- Labelling and information requirements e.g. on hazardous materials.
- End-of-life management – increased separate collection, recycling and materials recovery.

This will support development of circular and resource-efficient approaches, reduce dependency on virgin materials and the environmental impacts of their extraction and contribute to renewable energies achieving climate neutrality by 2050.

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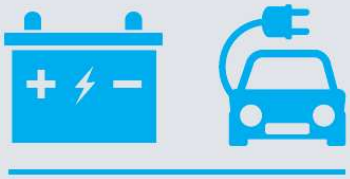
Battery end-user application R&D focus area

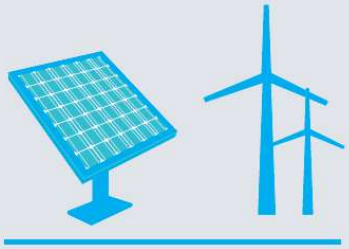
AUTOMOTIVE

Batteries contribute to the decarbonisation of the European transport sector - reducing CO_2 emissions via start/stop batteries and innovative solutions in xEVs



STATIONARY ENERGY

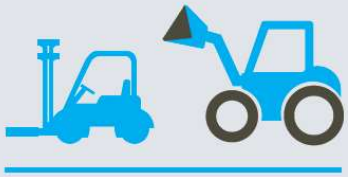
Batteries are indispensable for storing renewable stationary energy coming from solar and wind farms in on grid and off grid solutions.They also contribute to a more stable and reliable grid.



MOTIVE POWER

MATERIAL HANDLING

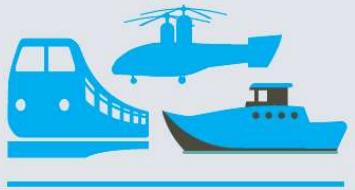
Batteries are a perfect fit for powering industrial vehicles such as forklifts and cranes, while also reducing noise and emissions.



MOTIVE POWER

OFF-ROAD TRANSPORTATION

Batteries are widely used in rail, marine and air transportation. The concepts of smart charging of road vehicles to support the energy system is also relevant for off-road because their wide deployment and large energy capacities



- Extract of key applications grouped around four areas: automotive mobility, material handling and logistics, off-road transportation and stationary energy storage.
- Each battery technology has a substantial development potential driven by the requirements of different applications.
- No single battery chemistry or technology can meet all the challenges of end-user demand

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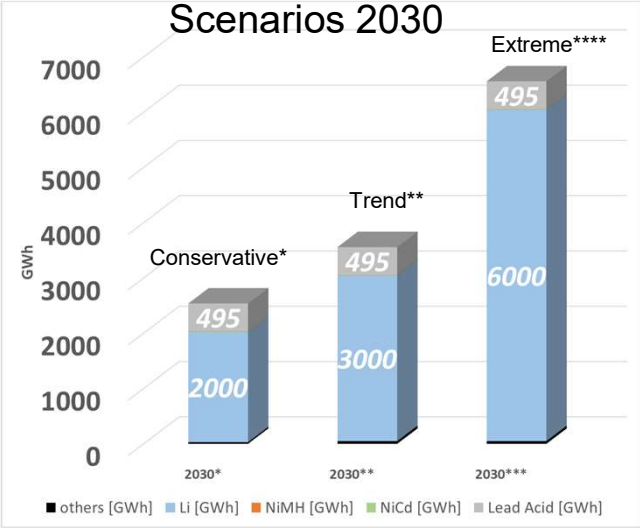
Global Market and Technologies

"By 2030, lithium-ion and lead-acid batteries represent the dominant technologies."



Global Battery Market 2030 (before REPower EU)The most likely scenario in 2030**

State of the Art	PbA, Pb-C, Thin Plate Pure Lead	NCM, LFP , LMO,NCA, LCO (C; LTO; Si/C)	NiCd, NiMH	NaS, NaNiCl (Hightemp.)
>2023	Pb-Bipolar		NiZn / NiFe	Na-Ion (RT)
>2025		All Solid State		
>2030		Li-Sulfur		
		Li-Air		

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Remarks and Outlook

- ✓ **All battery technologies are complementary**: each have specific features and **significant development potential**
- ✓ Having different technologies has strategic advantages with regard to the availability of raw materials to enhance the competitiveness, self-sufficient sourcing and manufacturing
- ✓ **Developing all battery** chemistries will maximize the contribution to meet the zero-pollution targets.
- ✓ **High development potential** for advanced Li-Ion; Gen. 4. Solid-state; Gen. 5 post-Li-ion.
- ✓ **New technologies are also required**. Sodium-ion room temperature batteries (Na-ion RT) represents the most promising future technology in terms of cost, raw material availability and performance.

Innovation Area 1 – Automotive Mobility

Innovations in Energy Storage for the decarbonisation of the Transportation Sector

xEV battery innovation

- from Micro, Mild to Full HEVs and BEVs
- And for commercial Vehicles Stand-by


12V Start-Stop & Micro-Hybrid


12V Auxiliary for xEV


48V Mild Hybrid


12V-24V HCV Stand-by


Full HEV BEV

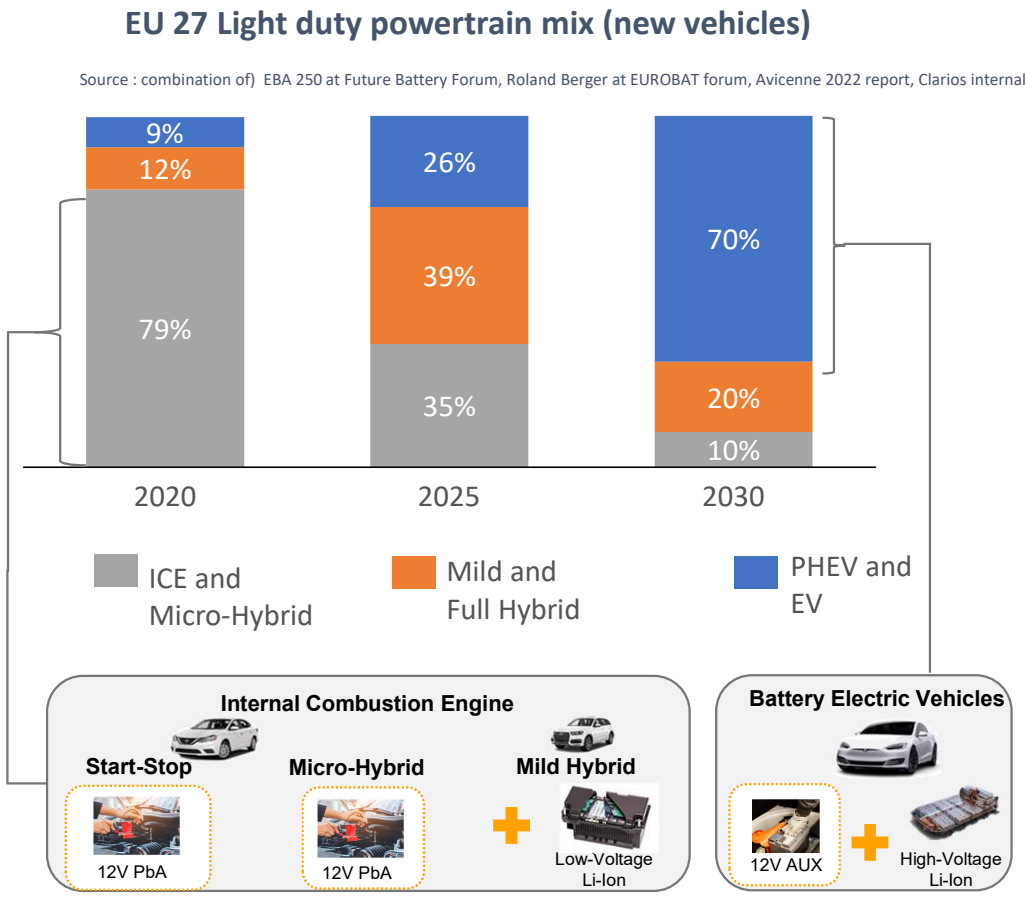
Dr. Christian Rosenkranz

VP Gov & Ind Relations EMEA, Managing Director Clarios Germany GmbH & Co KG

Market Forecast for M1, N1 vehicles in EU 27

Market Forecast EU 27 in 2030 :

- Segment of classic Internal Combustion Engine vanishing in new cars through 2030
- Electric Vehicles in selceted EU countries announced up to 100% of new sales.
- 12V power net (and storage device) remains for all platforms
- Segment of Low Voltage < 60V to be contributing app 20-30 % of new vehicles – rest PHEV and BEV



Vehicle Electrification and Decarbonisation

Benefits of Vehicle Low Voltage (< 60V) Power Net :

- State of the art application : 12V Micro-hybrid
  - Including Start stop &
  - PSOC – partial state of charge (recuperation)

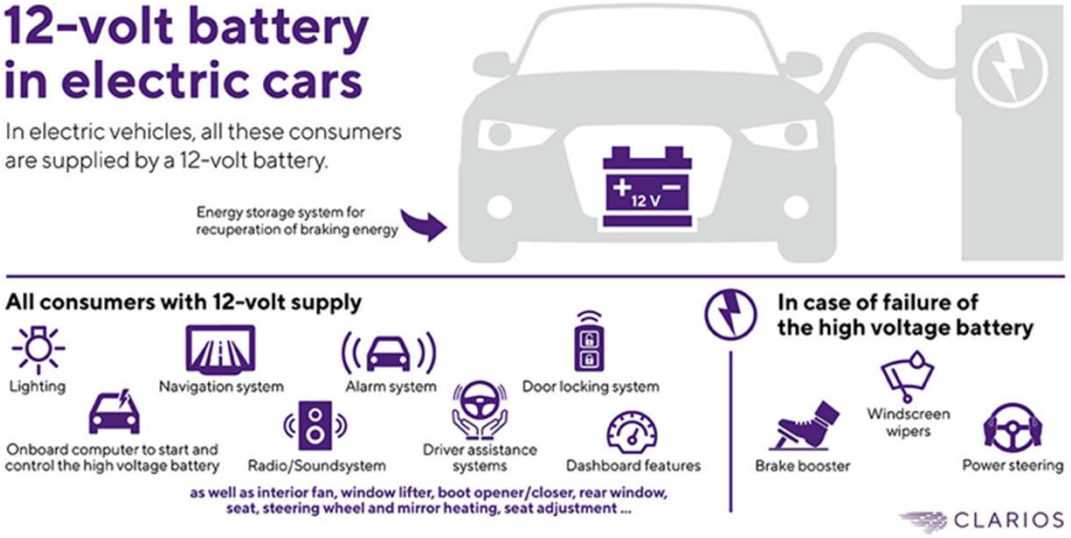
- Decarbonisation effects :
  - 12V Micro-hybrid : up to 8% CO2 savings
  - 48V Mild-hybrid : up to 15% CO2 savings

- Role of 12V batteries is changing to an auxiliary application (see graphic to the right)

12V Micro-Hybrid

12V Auxiliary

48V Mild Hybrid



CLARIOS

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12V Micro-Hybrid & Auxiliary

12V Micro – Hybrid & Auxiliary:

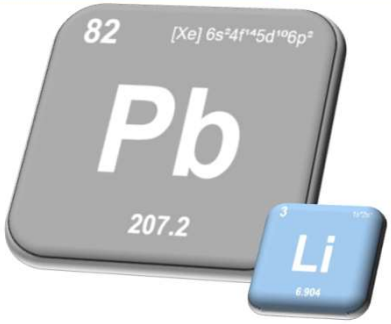
- 2030 market share prediction
  - 97% Pb
  - 3 % Li-Ion

Main Innovation areas for Pb :

- Recuperational Charging
- Increasing cycle Life

Main Innovation areas Li :

- Broadening the temperature window
- Recycling efficiency



12V Lead-Acid Batteries		12V Lithium Ion Batteries	
ADVANTAGES	DISADVANTAGES /	ADVANTAGES	DISADVANTAGES /
Affordability Intrinsic Safety & Reliability Recycling Resilience in Supply Chain	Power Density Recuperational Charging Weight Increasing cycle Life	Weight advantage Recuperational Charging (LTO) Cycle Life Power Density	Cost compared to Pb Broadening the temperature window Recycling efficiency (LFP) Standardization of design

CLARIOS

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12V / 24V – HCV Stand-By

12V Micro – Hybrid & Auxiliary:

- 2030 market share prediction
  - 98% Pb
  - 2 % Li-Ion

Main Innovation areas for Pb :

- Increasing cycle Life

Main Innovation areas Li :

- Vibration resistance

12V/24V Lead-Acid Batteries		12V/24V Lithium Ion Batteries	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
Similar to 12V but also… Endurance in tough environment (mounting to vehicle frame) Vibration resistance	Similar to 12V but also… Deep discharge window (maximum DoD) Cycle Life	Similar to 12V but also… Depth-of-discharge DoD window (usable energy content) Spec energy content	Similar to 12V but also… Vibration resistance Cost / kWh

CLARIOS

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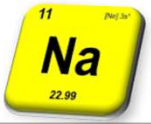
Full-Hybrid & BEV

Li-Ion is the technology of choice through 2030 with variety of electrochemistries.
Innovation comes mainly from material research :

- **Cathode** Innovations:
  - NMC with Ni-rich chemistries
  - LFP as alternative to avoid critical raw material constraints and embrace regional mining & refining
- **Anode** :
  - Carbon w/ Si-doping (up to 80%) for spec energy increase challenge : avoidance of electrode expansion
  - Lithium metal anodes in combination w/ solid-state: challenge of surpression of short circuit surpression by dendrite growth and Li-Plating

- „**Electrolyte**“
  - Solid state (polymer, sulfide, oxide) -> challenge at electrode-electrolyte surface to surpress dendrite growth

- **Innovation in Post-Li-Ion** technologies
  - LiS – self discharge surpression caused by Polysulfide shuttling
  - Me-O - break throughs in cycle life and round-trip efficiencies



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>2023	Pb-Bipolar		NiZn / NiFe	Na-Ion (RT)
>2025		All Solid State		
>2030		Li-Sulfur		
		Li-Air		

EXIDE TECHNOLOGIES | ENERGIZING A NEW WORLD

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BATTERY INNOVATION WEBINAR – 15 November 2022

R&D Area 4: Stationary energy storage – UPS, TLC, Off-grid

Dr. Holger Fricke

Director Basic Research R&D EMEA – Exide Technologies

Stationary Energy Storage

Uninterrupted Power Supply

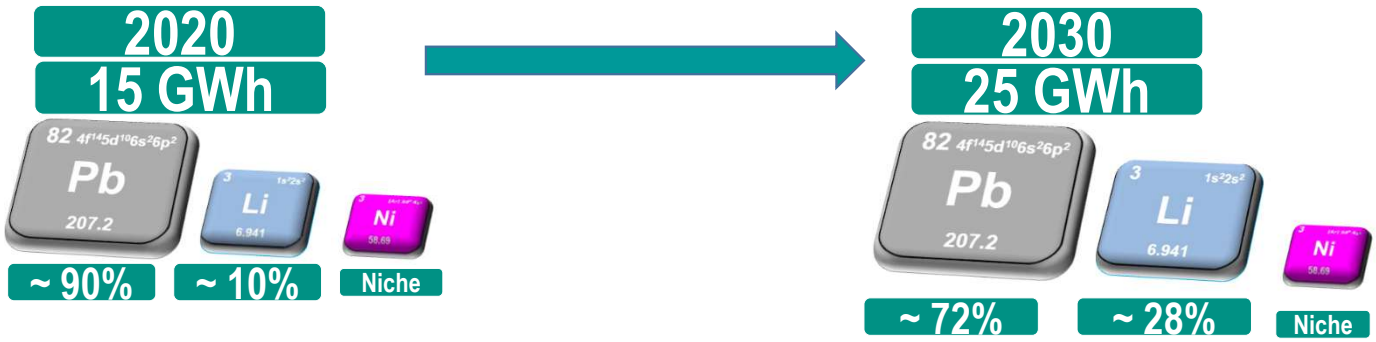
Telecommunication

Residential and Commercial Storage Behind the Meter

Utility Grid Scale Storage

Off-grid applications

Uninterrupted Power Supply – UPS



Market drivers:

New data storage centers, extended service, digitalization, virtual power plants

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Battery innovation webinar – area 4 stationary energy storage

Uninterrupted Power Supply – UPS

Key performance indicators

- POWER DENSITY
- LOW COST
- SAFETY
- END-OF-LIFE MANAGEMENT
- RELIABILITY
- ENDURANCE – short to long, depending on application and geographic region
- HIGH TEMPERATURE ROBUSTNESS

Innovation potentials

Lead acid

- POWER DENSITY
- CYCLE LIFE
- MAINTENTANCE FREE PRODUCTS
- HIGH TEMPERATURE ROBUSTNESS

Lithium

- COST REDUCTION
- SAFETY
- END-OF-LIFE MANAGEMENT
- HIGH TEMPERATURE ROBUSTNESS

Telecommunication - TLC

Market drivers:

5G roll-out, increase of wireless communication

EXIDE TECHNOLOGIES | ENERGIZING A NEW WORLD

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Battery innovation webinar – area 4 stationary energy storage

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Lithium

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- SAFETY
- END-OF-LIFE MANAGEMENT
- HIGH TEMPERATURE ROBUSTNESS

Batteries in Off-grid applications

- Electrification of isolated rural areas, areas with poor grids, islands
- **Battery Energy Storage & Back-up for Telecom towers** – domestic to Industrial to Community scale
- Stand-alone solution or in combination with diesel generators and/or renewable energy sources like Solar and Wind energy

Batteries in Off-grid configurations – mainstream Technologies by 2030:

Off-grid applications

Key performance indicators

- CYCLING/PARTIAL-STATE-OF-CHARGE CYCLING
- LOW CAPEX
- SAFETY
- END-OF-LIFE MANAGEMENT
- RELIABILITY
- LOW MAINTENANCE
- ROBUSTNESS IN HARSH CONDITIONS

Innovation potentials

Lead acid

- ENERGY DENSITY
- CYCLE LIFE
- MAINTENTANCE FREE PRODUCTS
- OPERATIONAL STRATEGIES (BMS)

Lithium

- COST REDUCTION
- SAFETY
- END-OF-LIFE MANAGEMENT
- DESIGN LIFE

BATTERY INNOVATION WEBINAR – 15 November 2022

- R&D Area 4: Batteries for residential and commercial storage behind the meter
- R&D Area 4: Batteries for utility grid-scale energy storage in front of the meter

Maik Cordes, VP Sales Automotive, maik.cordes@freyrbattery.com

Valentin Rota, Director Sales Energy Storage, valentin.rota@freyrbattery.com

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Clean battery solutions

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Battery Energy Storage Systems (“BESS”) definitions

Residential

1 kWh to 30 kWh per installation

kWh scale

Commercial & Industrial

>100 kWh and <2 MWh per project

MWh scale

Utility-Scale

1 MWh to 1 GWh+ per project

GWh scale

Behind-The-Meter (BTM)

Front of-The-Meter (FTM)

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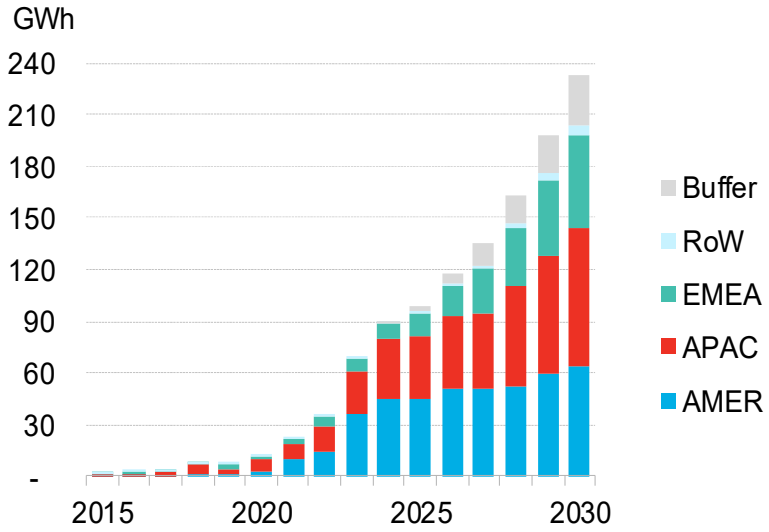
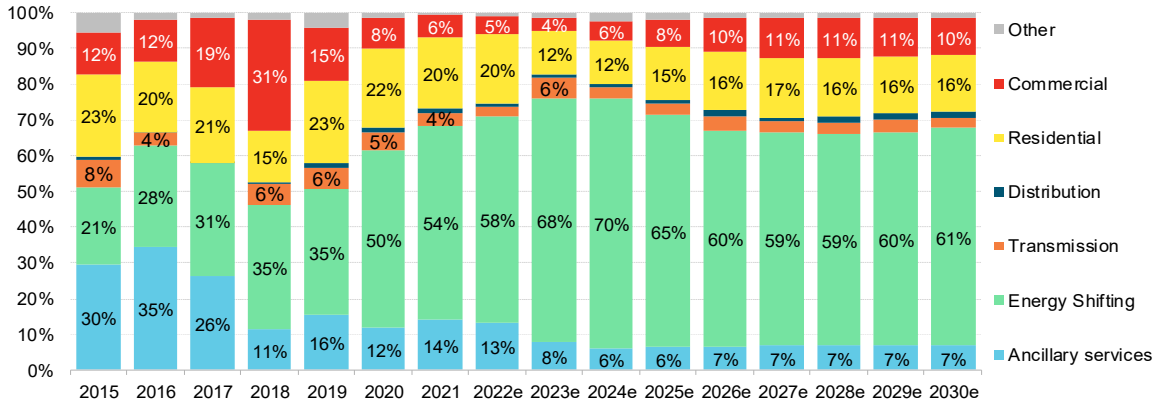
BESS deployments are growing at pace
They will play a vital role in variable renewables grid integration

Annual BESS deployments per region



- Europe represents ≈ 1/4 of the deployments
- Global growth dynamic primarily based on economics, technical improvements and policy-making

Annual deployments per use case / application



- Typical BESS duration is today comprised between 1-hour to 4-hour globally
- In Europe, 2-hour duration is most representative and trending towards longer duration
- This is due to the fact that energy shifting is increasingly driving deployments

Source: BloombergNEF

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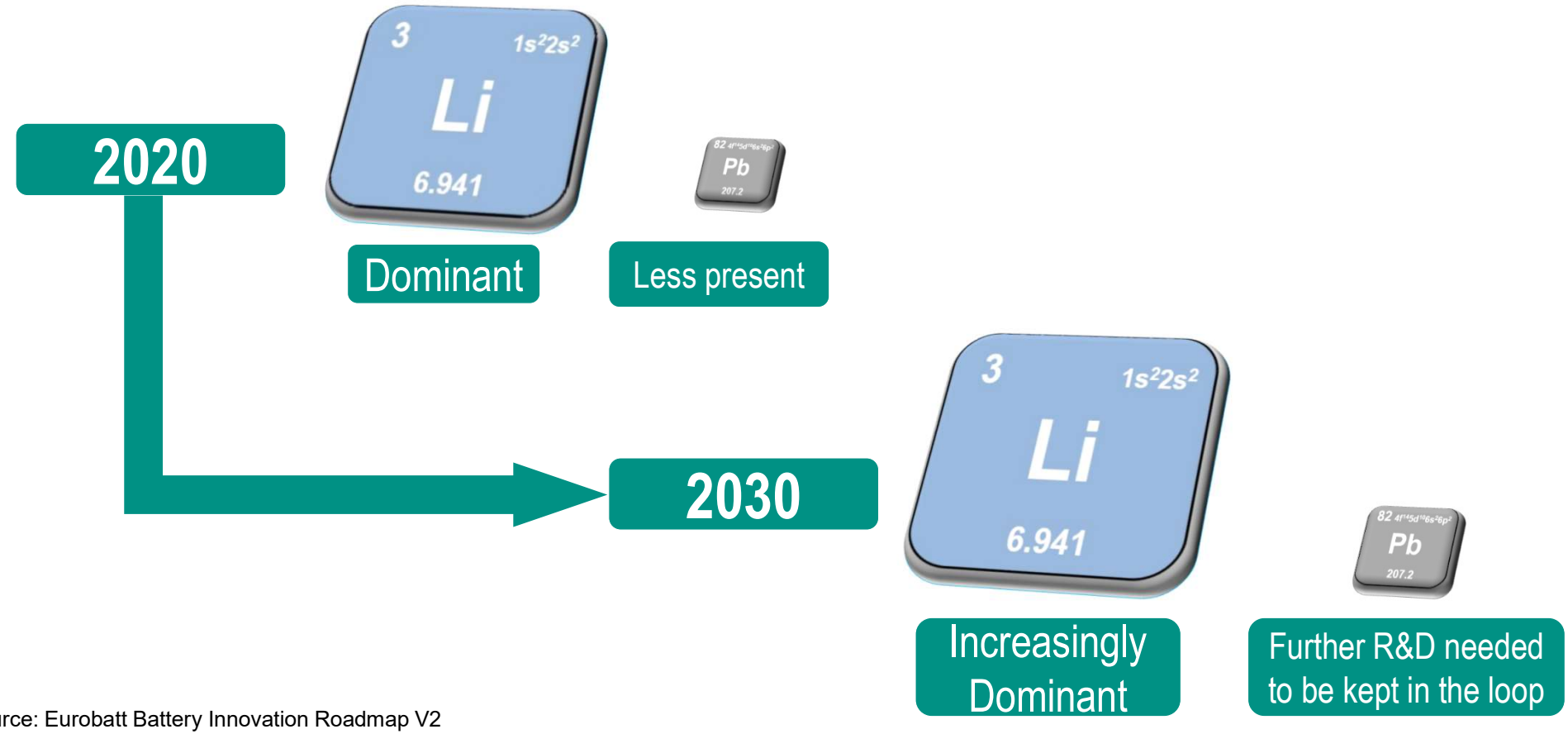
Residential and Commercial ESS - Behind-The-Meter



Source: Eurobatt Battery Innovation Roadmap V2

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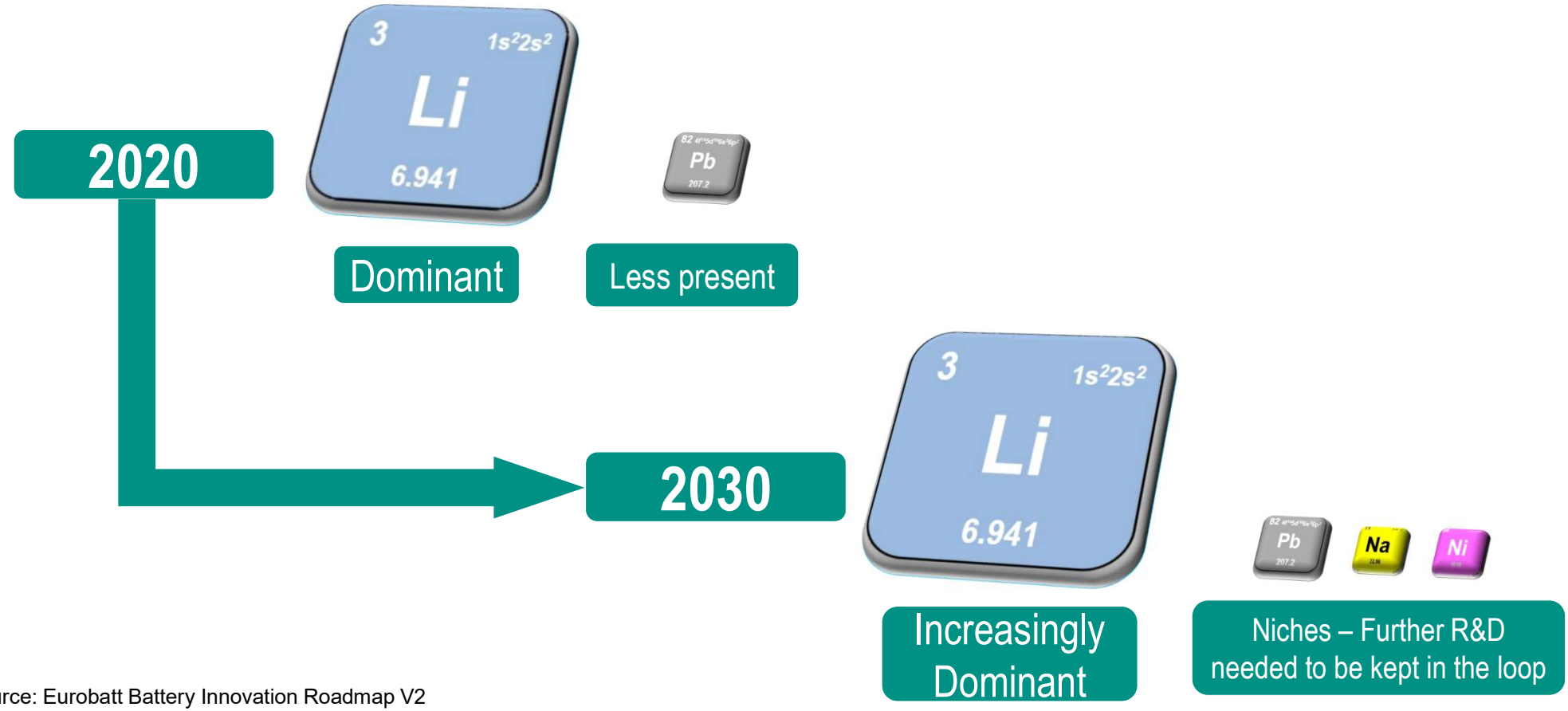
Utility grid-scale ESS - Front-of-The-Meter



Source: Eurobatt Battery Innovation Roadmap V2

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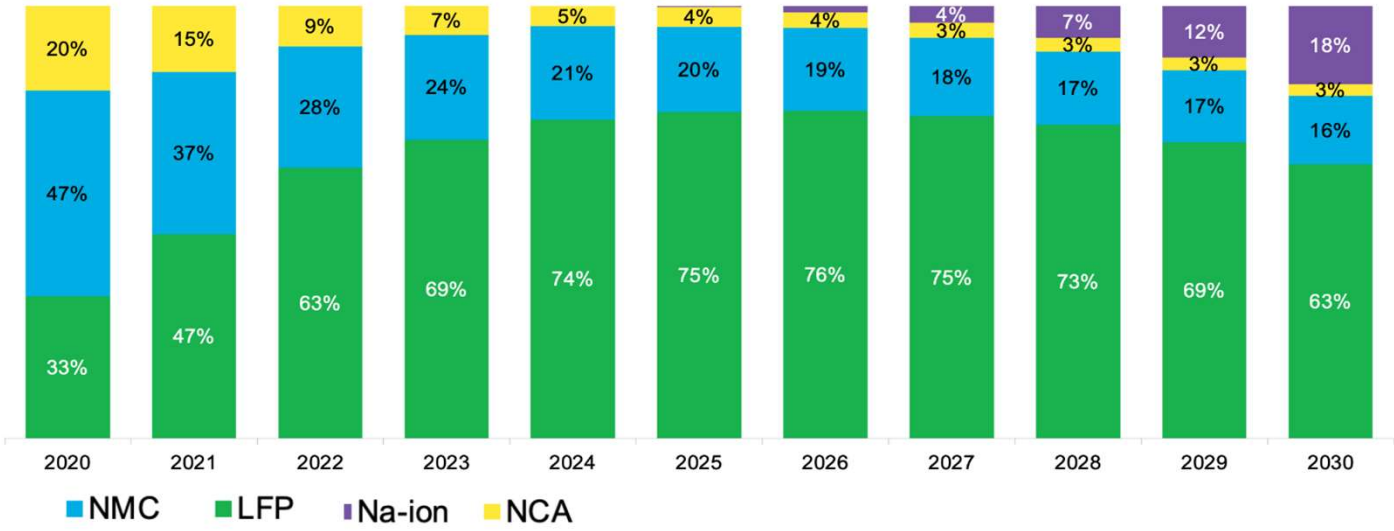
Different chemistries are represented in BTM/FTM energy storage deployments

Past and future deployments per battery chemistry types



- Lithium iron phosphate (LFP) represents today most deployments thanks to its high cycling, increased safety and lower cost features
- Lithium nickel manganese cobalt (NMC) is mainly used in high power / high density applications

Source: BloombergNEF

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Stationary Energy Storage : Key Performance Indicator and Innovation Areas

A) Key Performance Indicator: "Levelized Cost of Storage ("LCOS")

$$\text{Levelized Cost of Storage [€ / MWh]} = \frac{\text{CAPEX [€] + OPEX [€]}}{\text{Energy Throughput over lifetime [MWh]}}$$

LCOS is a key performance indicator used to compare different stationary storage technologies.

It represents the "cost of cycling 1 MWh". The lower the LCOS value, the better.

B) Innovation Areas

1. Decrease the LCOS numerator
   - Reduce CAPEX - reduction of the EUR/kWh cost is a key driver
   - Reduce OPEX
2. Increase the LCOS denominator:
   - Increase cycle life
   - Increase design lifetime
   - Improve performance

$$\text{LCOS} = \frac{\text{CAPEX [€] + OPEX [€]}}{\text{Energy Throughput over lifetime [MWh]}}$$

LCOS is a good quantitative proxy but not a perfect tool, as it does not capture important qualitative elements such as CO2 / GHG footprint, safety or domestic manufacturing and sourcing for example which are becoming increasingly important.

BATTERY INNOVATION WEBINAR

15 November 2022

R&D Area 2: Motive power - material handling and logistic application

R&D Area 3: Motive power – Off-road transportation

Andrea Saletti

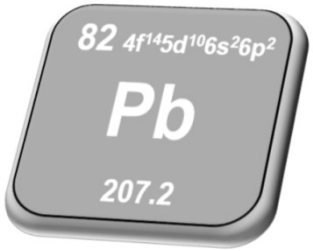
Technical Director Lead-Acid Batteries – Midac Spa

MOTIVE POWER

MATERIAL HANDLING & LOGISTICS	OTHER OFF-ROAD TRANSPORTATION
 Forklifts / Pallettrucks	 Sweeping machines, construction/demolition machines, golf carts, AGVs, harvesting trolleys
 Order Pickers	 Railway
 Reach Trucks	 Marine
 Side Loaders	 Aviation

2020

35 GWh



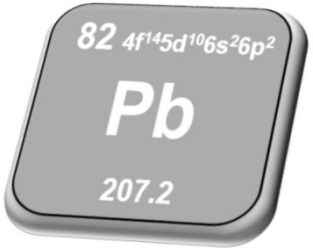
~ 90%

~ 10%

Niche

2030

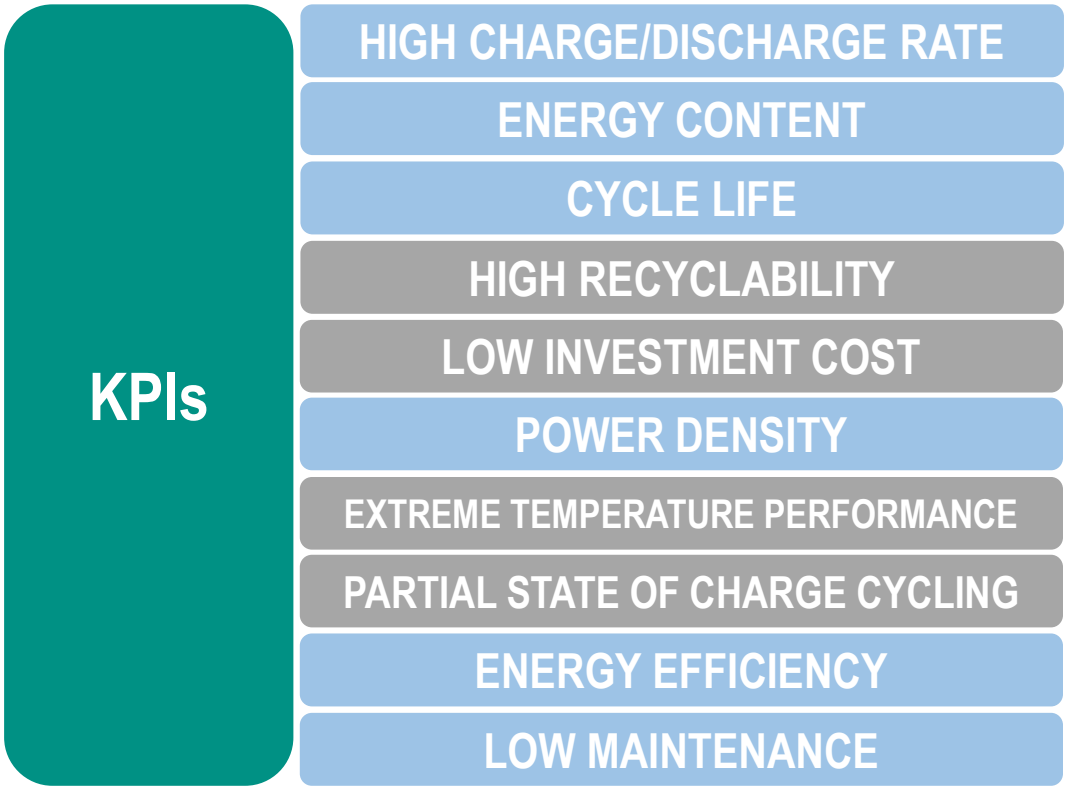
67 GWh



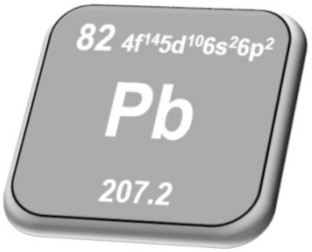
~ 51%

~ 49%

Niche


KPIs
HIGH CHARGE/DISCHARGE RATE
ENERGY CONTENT
CYCLE LIFE
HIGH RECYCLABILITY
LOW INVESTMENT COST
POWER DENSITY
EXTREME TEMPERATURE PERFORMANCE
PARTIAL STATE OF CHARGE CYCLING
ENERGY EFFICIENCY
LOW MAINTENANCE

Innovation potential



- Increasing of cycle life
- Reduction of charging time
- Maintenance free
- Increasing of digitalization (IoT)

Innovation potential

- Reduction of cost
- Increasing of safety
- Standardisation
- Recycling

Off-road industrial vehicles

Derived from traction batteries and they share most of the features

Market in 2030 ➔ 3.3GWh

Current market dominated by Lead-based batteries but many li-based application is available

RAILWAYS

Application for rolling stock:
- Emergency lighting
- Emergency power supply
- Auxillary services
- Cranking

INNOVATION POTENTIAL:
Hybridization and electrification of low-speed and low distance vehicles

Li-based ➔ 100%

MARINE

Waterborne transport ➔ 13% of the overall EU greenhouse gas emission

Large scale ship BEV/HEV propulsion 100% Lithium-based

Small vessels covered with Pb (HEV 48V) and Li (BEV)

Auxiliary batteries covered by the main technology with different rate

AVIATION

Aviation industry ➔ over 1 Billion tons of CO_2 per year.

No technology available for propulsion of commercial aircraft

Auxiliary batteries covered mainly by Pb and Ni but transition towards Lithium has started

eVTOL ready to be place on the market in the near future will be powered by Lithium batteries