Energy storage solutions for low-voltage vehicle electrification strategies

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SAE Hybrid & Electric Vehicle Technology Symposium 2017

Johnson Controls

Market trends are shaping the future of energy storage in vehicles

Increasingly stringent emissions and fuel economy regulations

Closed-loop product lifecycle and material management

Consumer preference for improved vehicle efficiency but only at positive economics

Influence of consumer electronics and information explosion

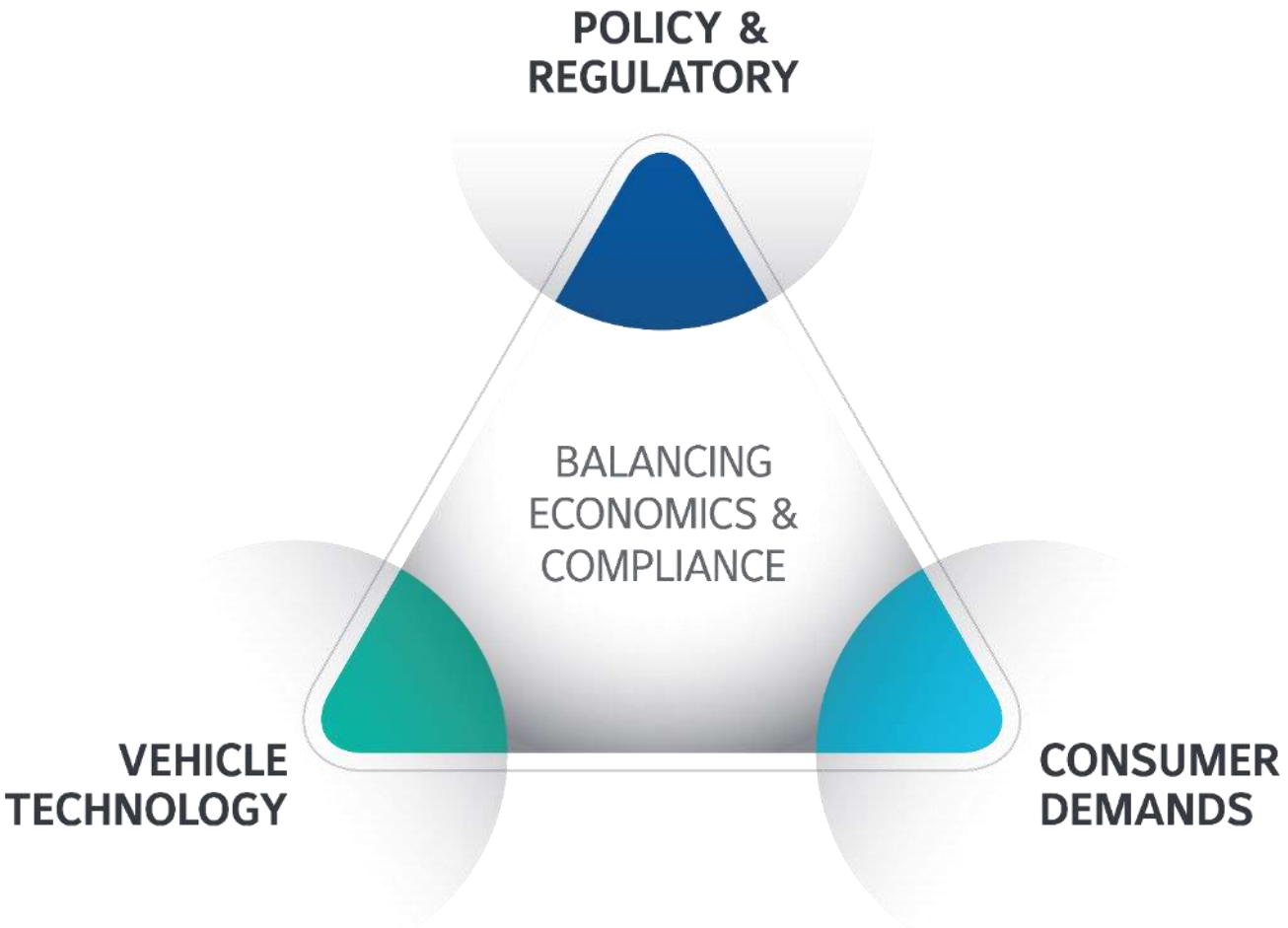
Adoption of accident avoidance driver assist technologies

Personal mobility implications of urbanization and high density cities

Changing attitudes toward transportation and vehicle ownership

Rapidly accelerating capability to gather and process large amounts of data

Finding the right balance between regulations, consumer expectations and cost



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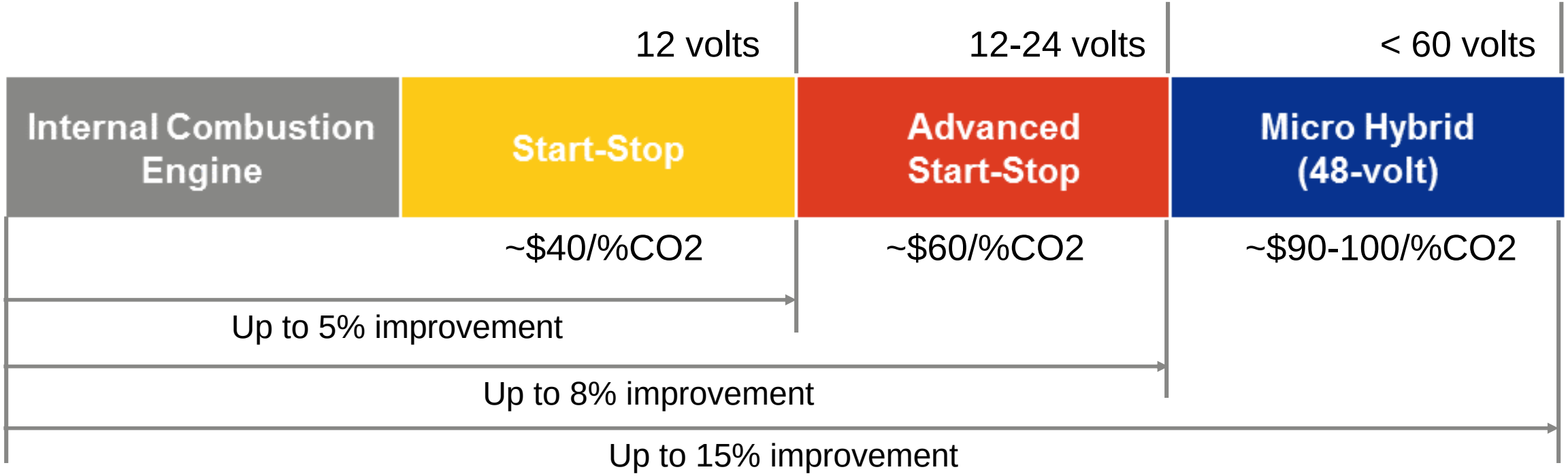
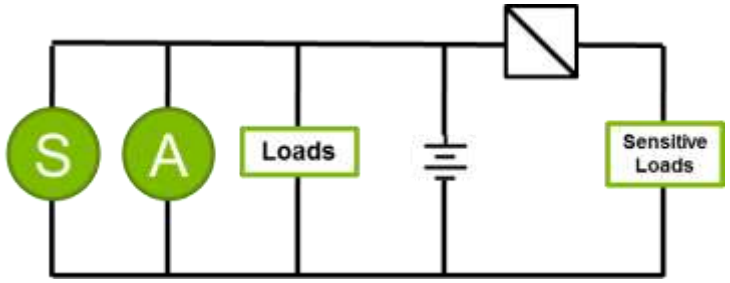
Low-voltage electrification offers incremental efficiency at costs that can trigger significant mass adoption

Low voltage electrification options



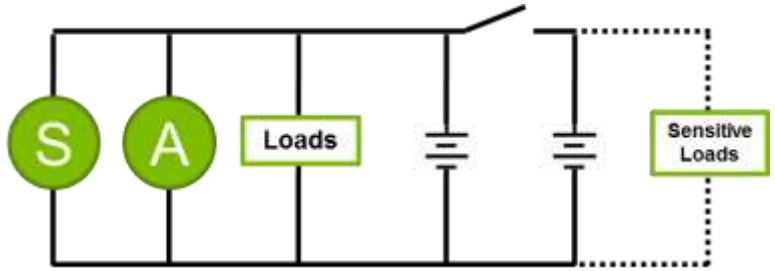
Role of the battery system in low voltage electrification applications

Start-Stop



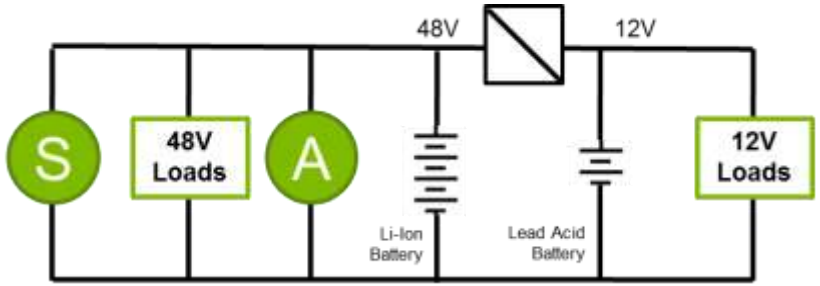
- Standard ICE functions, plus
- Support engine-off loads
- Engine warm starts
- Light regeneration

Advanced Start-Stop



- Start-stop functions, plus
- Moderate regeneration (~3 kW)
- System redundancy for coasting
- Improved power quality

Micro Hybrid (48-volt)



- Adv. Start-Stop functions, plus
- Strong regeneration (~12 kW)
- Enabling greater energy management

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Battery requirements for low voltage electrification

Most important

Still important

- Safety – Meet requirements and consumer expectations
- Vehicle cost impact – Maximize benefit to cost ratio
- Discharge power density – Reliable cold cranking, high power loads
- Charge power density – Maximize brake regeneration
- Cycle life – Maximize lifetime throughput to deliver vehicle efficiency
- Temperature – Wide operating temperature range for real-world performance
- Weight – Minimize system weight
- Volume – Minimize system volume
- Packaging location – Sensitivity to heat, occupant safety
- Energy density – Maximize useable energy
- Recyclability – Enable a closed-loop approach to materials

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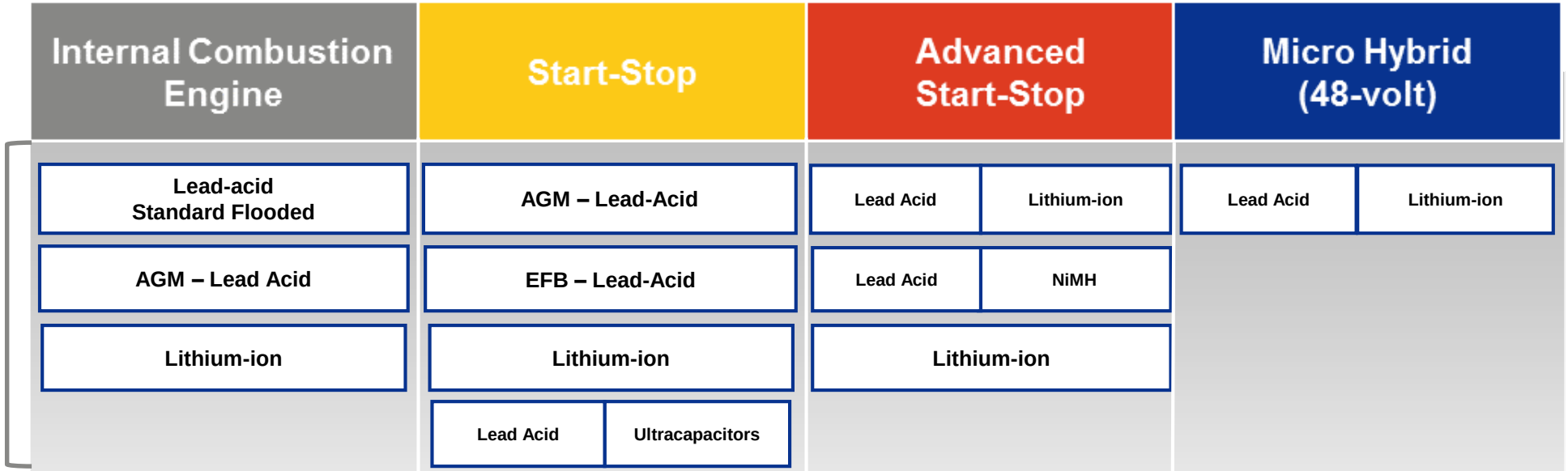
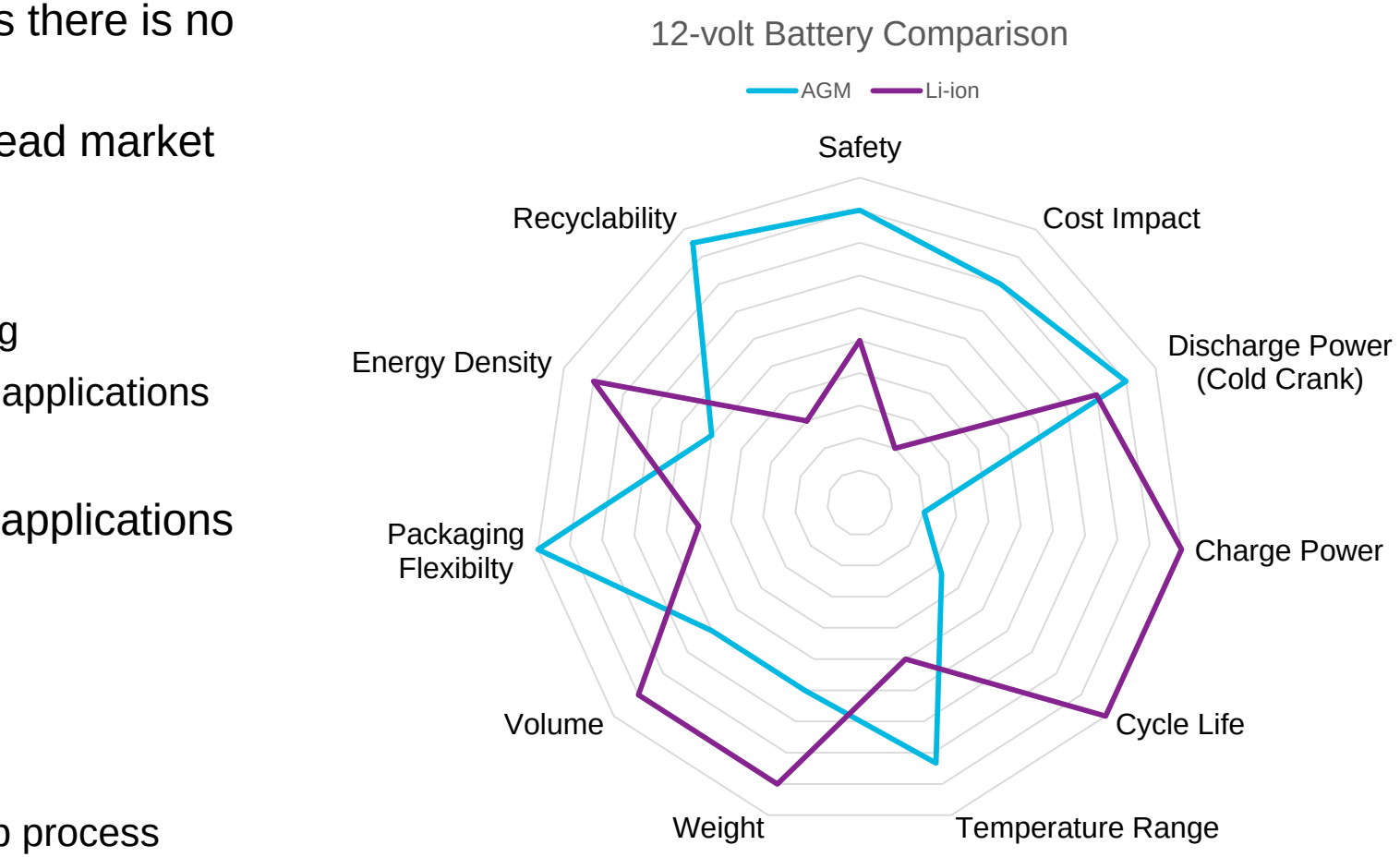
There are a range of technologies in-market and in development to meet these challenges

Battery products and technologies available in market today

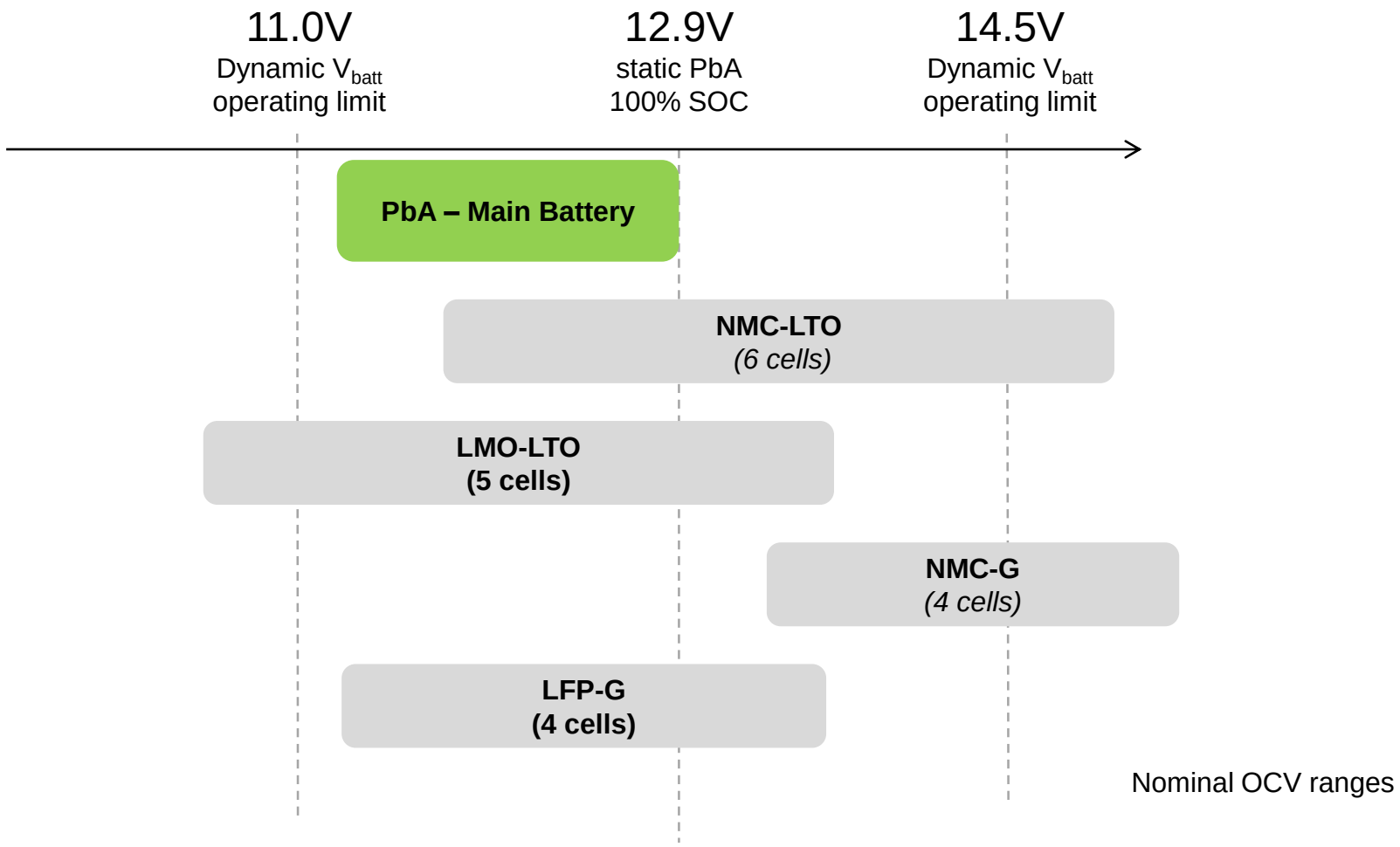


Current products for 12-volt applications – AGM Lead-Acid and Lithium-ion

- For single battery architectures there is no perfect solution
- AGM Lead-Acid continues to lead market
  - Safe
  - Low cost
  - Proven, reliable engine starting
  - Sufficient cycle life for current applications
  - Closed-loop product lifecycle
- Lithium-ion entering for select applications
  - Low weight
  - Increased cycle life
  - Superior charge power
  - Challenging price point
  - Limited options for closed-loop process

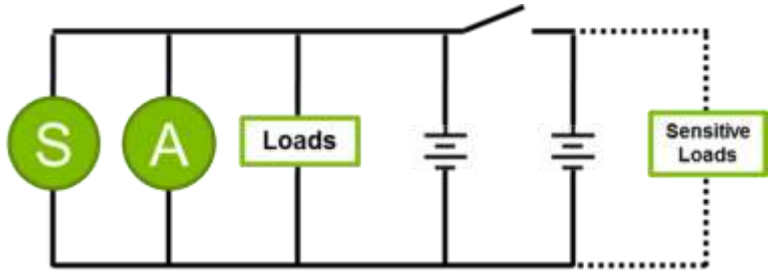


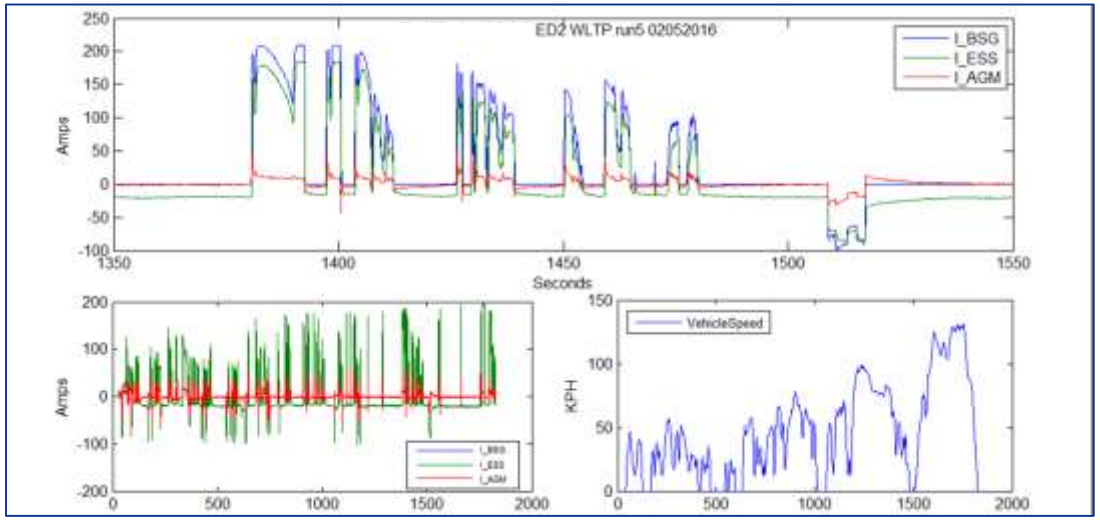
Voltage compatibility is not equal among Lithium-ion technologies



Dual battery, dual chemistry systems are a good option

- Let the individual chemistries do what they do best
- Significant increase in throughput
  - Lithium-titanate provides high charge power
  - AGM battery still cycles but less aggressively
- Cost impact of lithium-ion is minimized
  - Focused only on supporting charge/discharge power
  - Capacity of 10 Ah compared to 60-70 Ah for single battery
- Voltage alignment allows for reduced system complexity
  - Passive or switched connection
  - No DC/DC converter required
- Redundancy to improve reliability for safety-critical functions

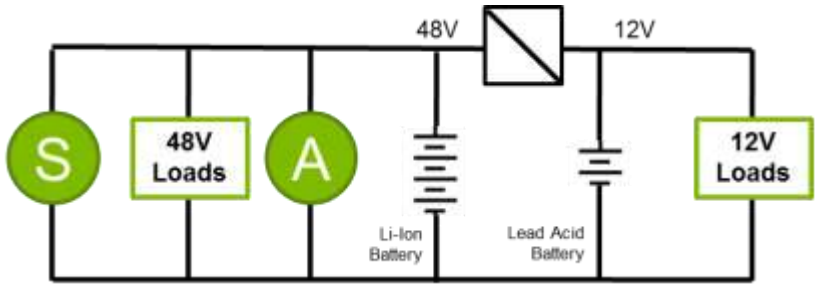


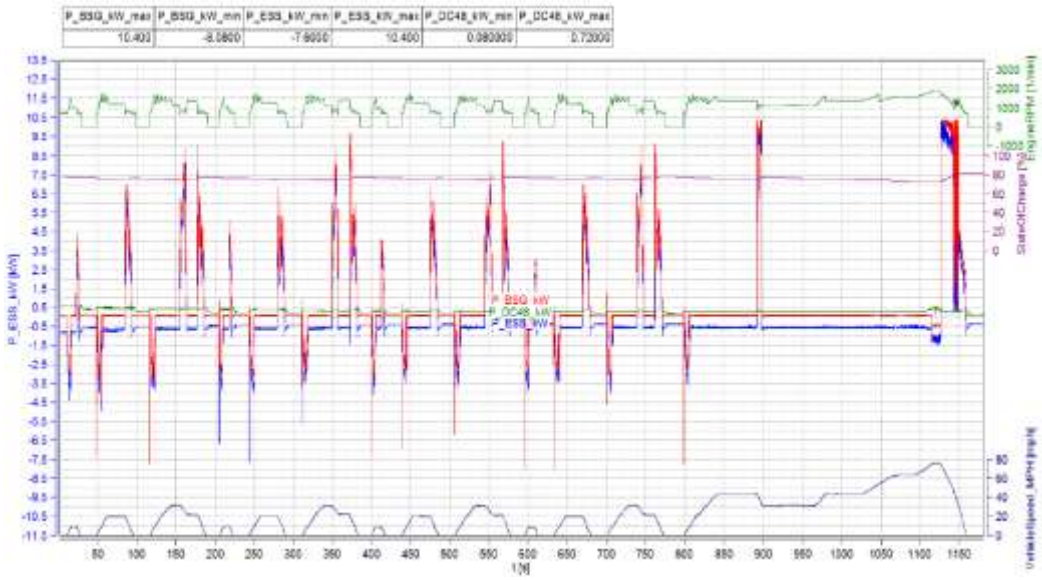


AGM and LTO Dual Battery Performance
WLTP Drive Cycle

Approach to 48-volt Micro Hybrid is similar

- First gen systems continue to use lead-acid as primary battery
  - Engine starting
  - Overall reliability
- 48-volt system being used in different ways
  - Powernet to support component electrification
  - Microhybrid functionality to improve efficiency
- Chemistry choices for lithium-ion less constrained
  - Voltage alignment challenges eliminated by DC/DC
  - Initial choice has been NMC-Graphite
  - Long term choice still open based on best value
- Second gen systems will push toward more power and energy
  - Stronger hybridization
  - Greater component electrification





48V ESS Performance
NEDC Drive Cycle

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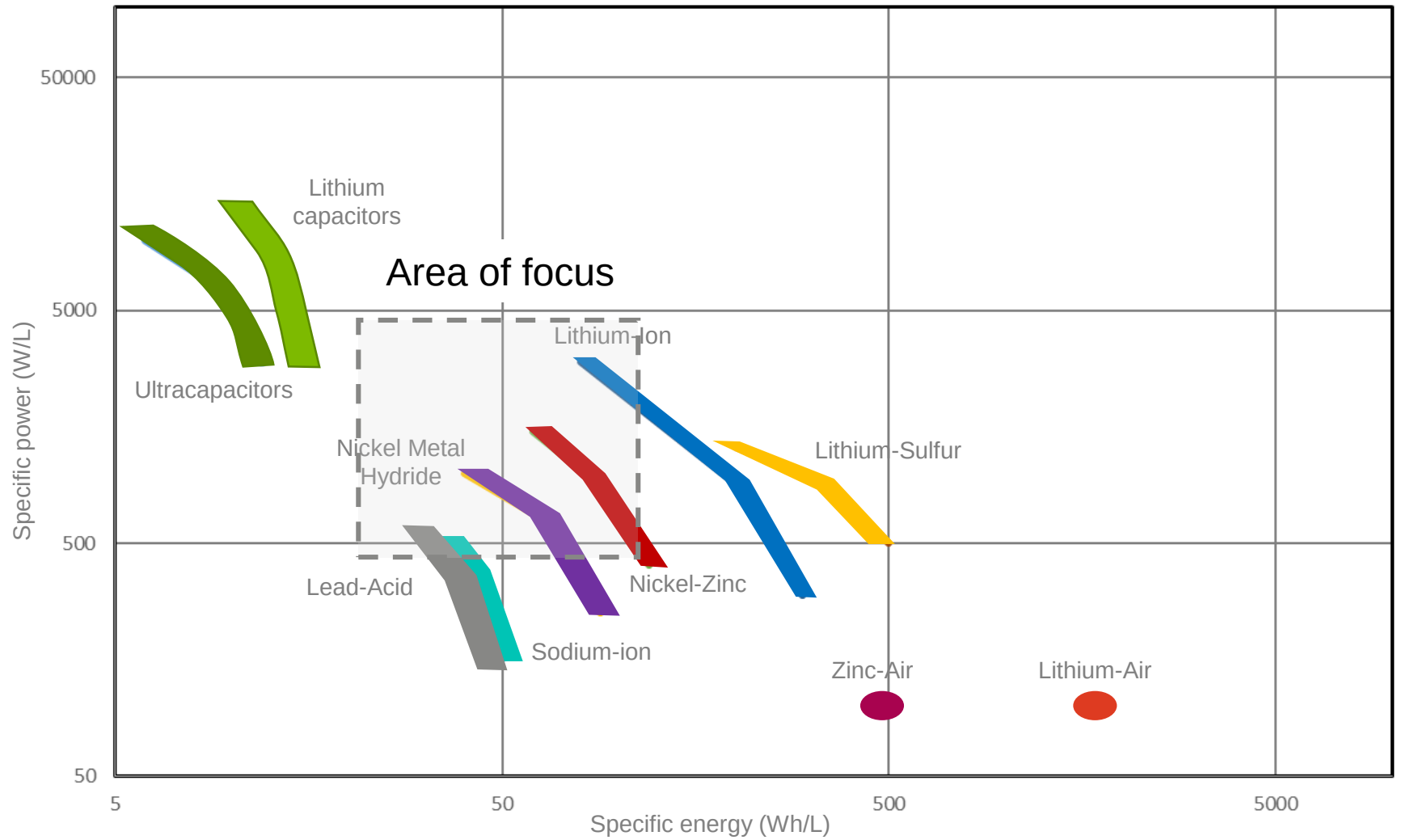
Are the choices limited to legacy lead-acid and lithium-ion?

There are options but the focus is different than for Electric Vehicles



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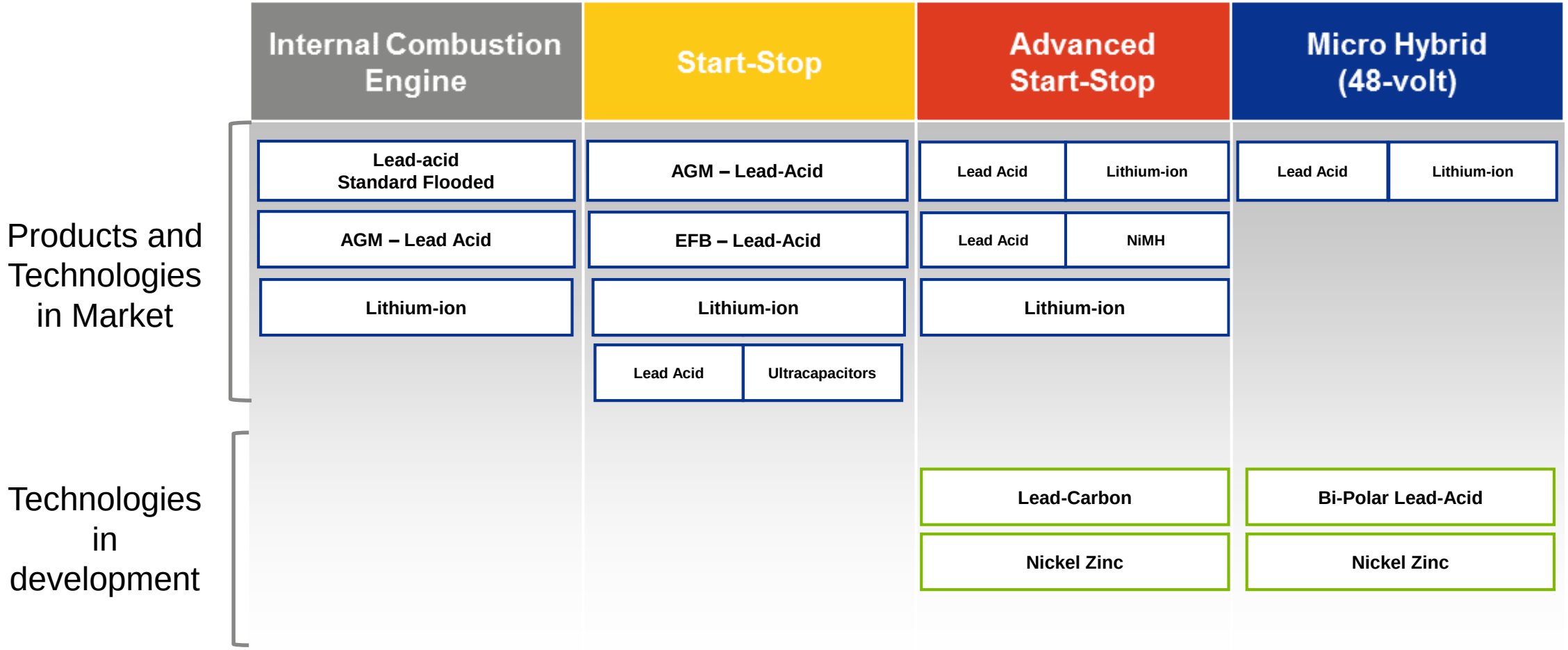
Technologies in development have potential to provide incremental value



Improvements on existing technologies provide the most opportunity

Advanced Lead-Acid

- Bi-Polar construction
  - Improved cycle life and vibration resistance
  - Aligned well with higher voltage applications
  - Need to resolve challenges with failure modes
- Lead-Carbon
  - Improved charge acceptance
  - Reduced energy density causes trade-offs
  - Cost doesn’t align with value delivered in current form

Ultracapacitors

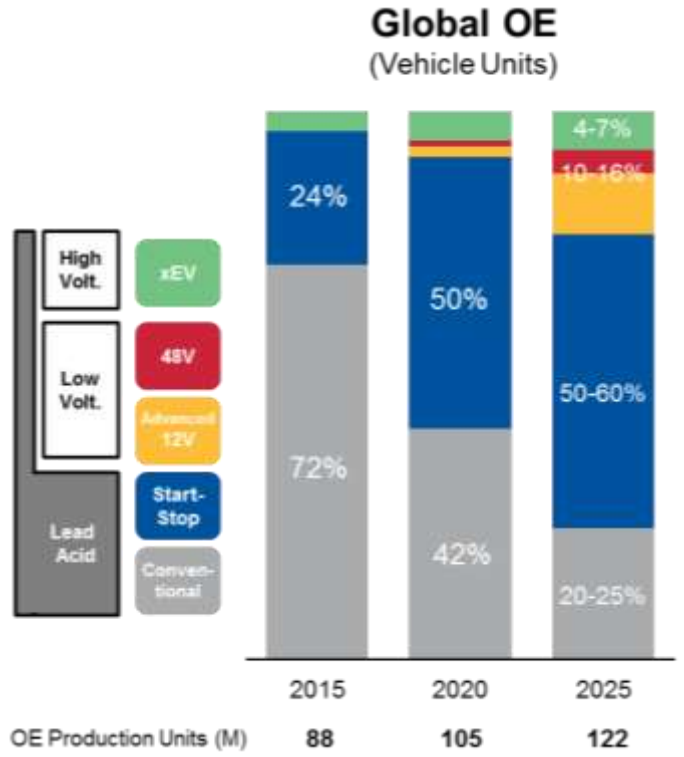
- Very good power and life
  - Superior charge power
  - Strong cycling capability
- Low energy content
  - Useable energy not sufficient to deliver brake regeneration
  - Scaling up drives cost
- Voltage alignment requires system complexity and cost to implement
- Being used in targeted applications for specific functions

Nickel Zinc

- Potential for high power and energy density comparable to lithium-ion
- Improved safety over lithium-ion
- Historically challenges around life due to dendrite formation on zinc electrode
- Not currently at significant scale so low cost potential is uncertain

Choices for low-voltage energy storage will be critical

- Low-voltage electrification will be required to deliver required efficiency gains on mass-market vehicles in the next decade
- Battery requirements for low-voltage electrification are different than long-term electric vehicle needs
- In 12-volt applications, the boundaries defined by existing charging strategies limit choices of lithium-ion chemistry
- In 48-volt applications, the profile looks more like and HEV but with greater power intensity
- There are other chemistry choices that could challenge the incumbency of lead-acid and lithium-ion, but there is more work



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