Onboard Energy & Conversion

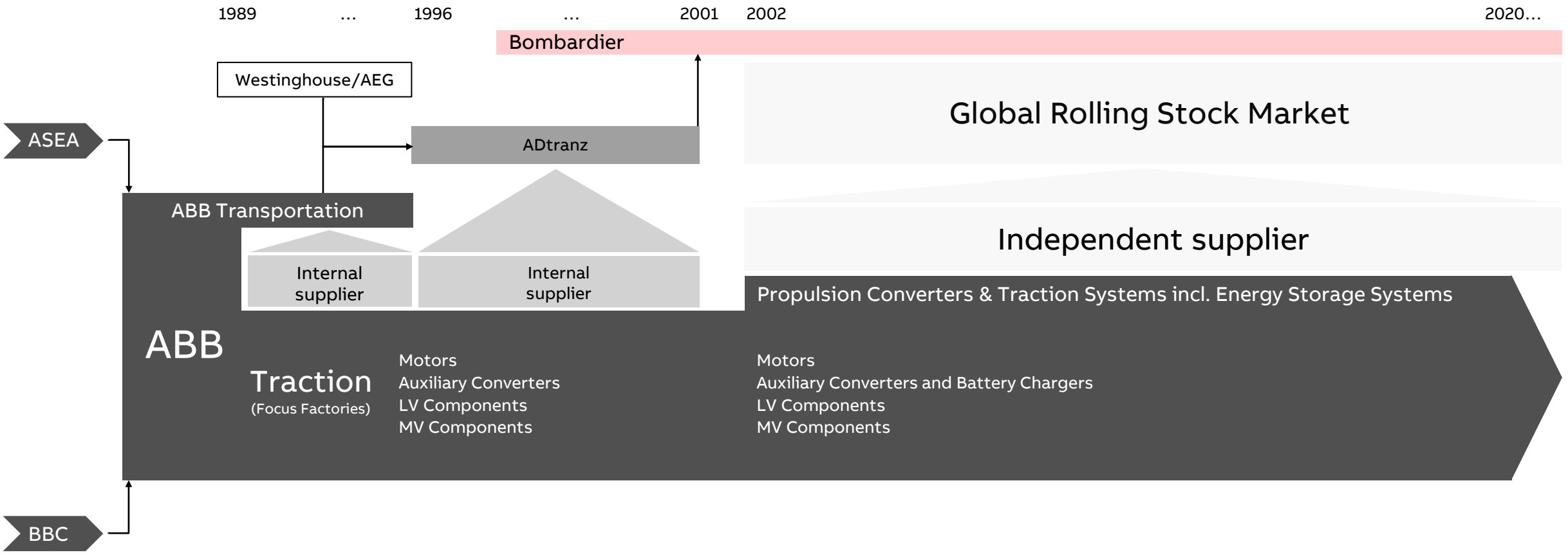
Introduction

Liam Martin
Product Manager, North America, Traction Division
ABB Inc., Mechanicsville VA

- Joined ABB in 2013, in Montreal, Canada
- Currently based in Virginia, at ABB's Traction facility
- Member of APTA Passenger Rail Safety Standards committee
- Contribute to FRA's Rail Safety Advisory Committee Fire Safety Working Group

ABB in the rail industry

Since 2002 a growing independent subsystem supplier



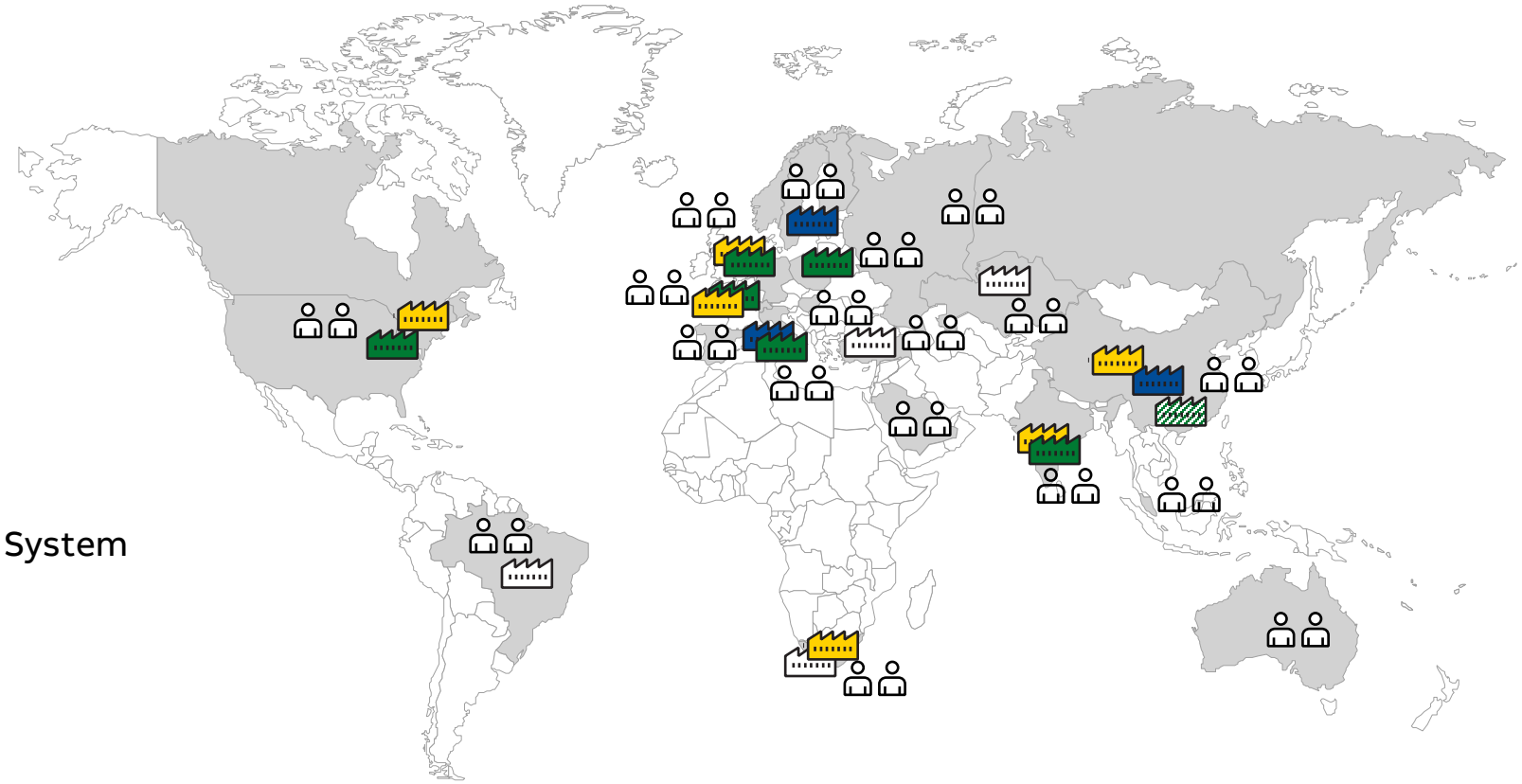
Global Traction footprint

Production and local engineering centers

- 100,000+ Employees globally
- ~$28B revenue
- >130 years of history

ABB in the US

- Headquartered in Cary NC
- 20,000 employees
- >$14B investment since 2010



Production and local engineering centers

- Traction transformer
- Traction converter and Energy Storage System
- Traction converter partner factory
- Traction motor
- In planning stage
- Sales and Service Team

USA Presence – Richmond VA

Buy-America Compliant Manufacturing

Converter Families

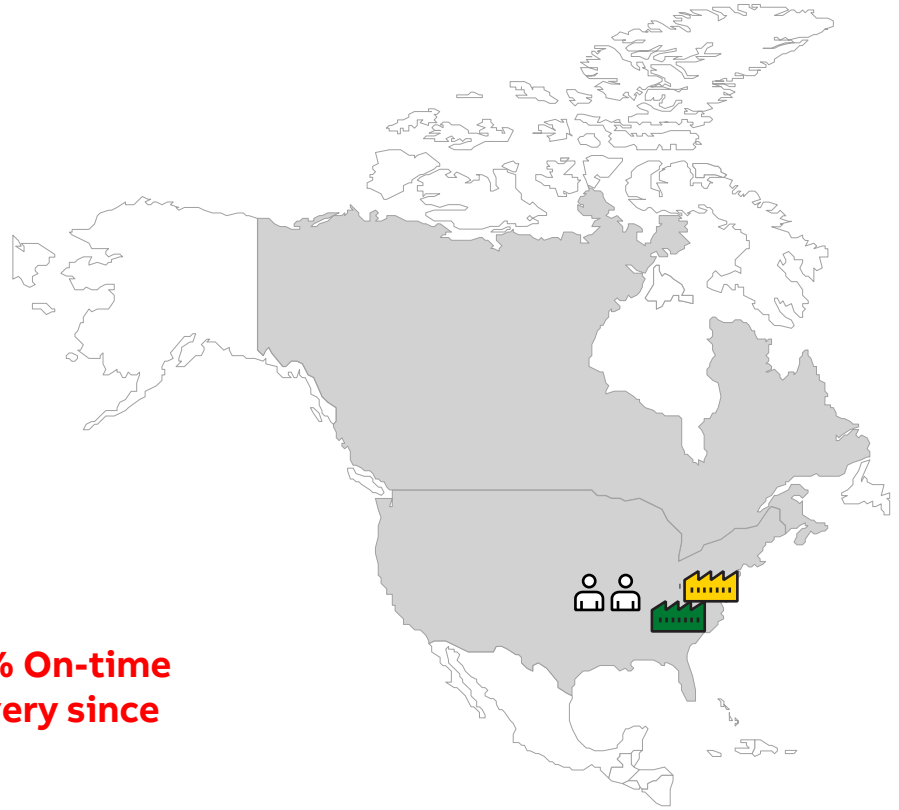
- Traction converters (BORDLINE CC400, CC750, CC1500)
- Battery Charger Assemblies
- Routine and Type Test capabilities up to 2500V for both water and air cooled units, with local PEBB Test and Repair
- Auxiliary and ESS Battery localization within strategic outlook

Functions

- Sales
- Product Management
- Project Management
- Project Engineering
- Procurement & Logistics
- Production
- Testing
- Service and Commissioning within US

Quality Systems Employed

CMMI Level 2
ISO9001
ABB Traction-Turgi is IRIS Certified
Alstom and Stadler Supplier Qualified



100% On-time Delivery since 2018

Energy Storage Systems

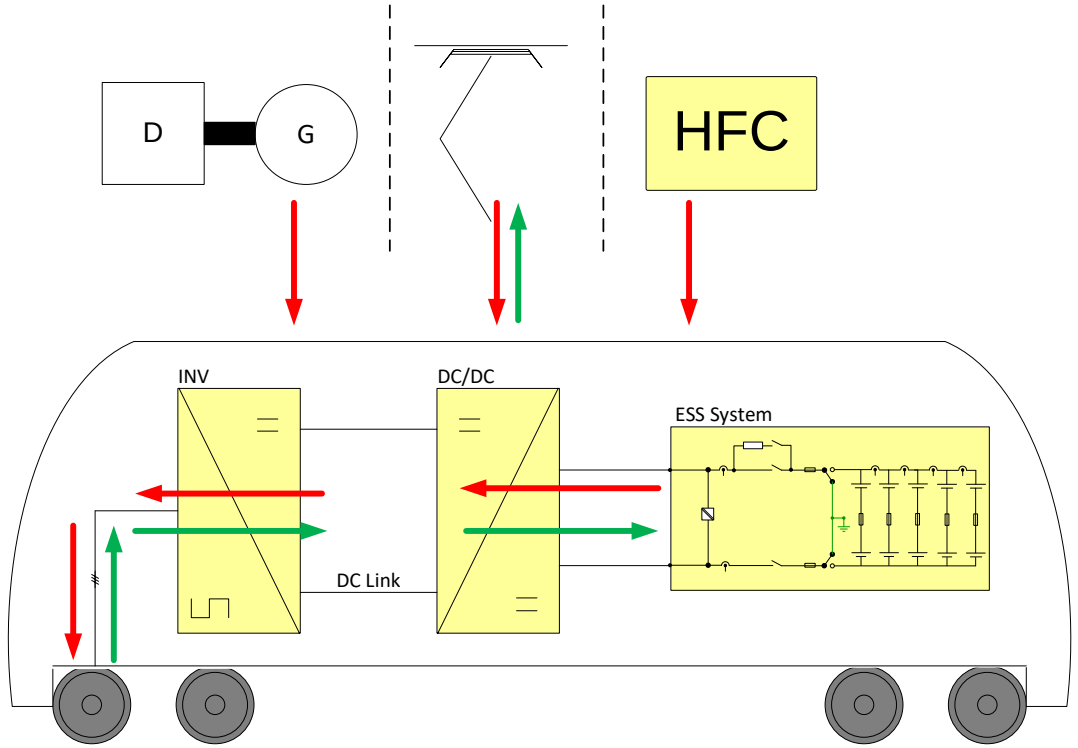
General Overview

Vehicle Energy Management

Multiple energy source compatible

Streetcar Onboard Power Considerations

- Move toward converters which are source-independent, allowing flexible adaptation to many applications, paired with safe, long-life battery technology
- Energy capture/re-use – regenerative braking into batteries or overhead line
- Right-sized infrastructure investment (catenary and sub-stations)
- Off-wire segments possible, with flexible charging possibilities
- Aesthetic advantage – catenary only where it makes sense



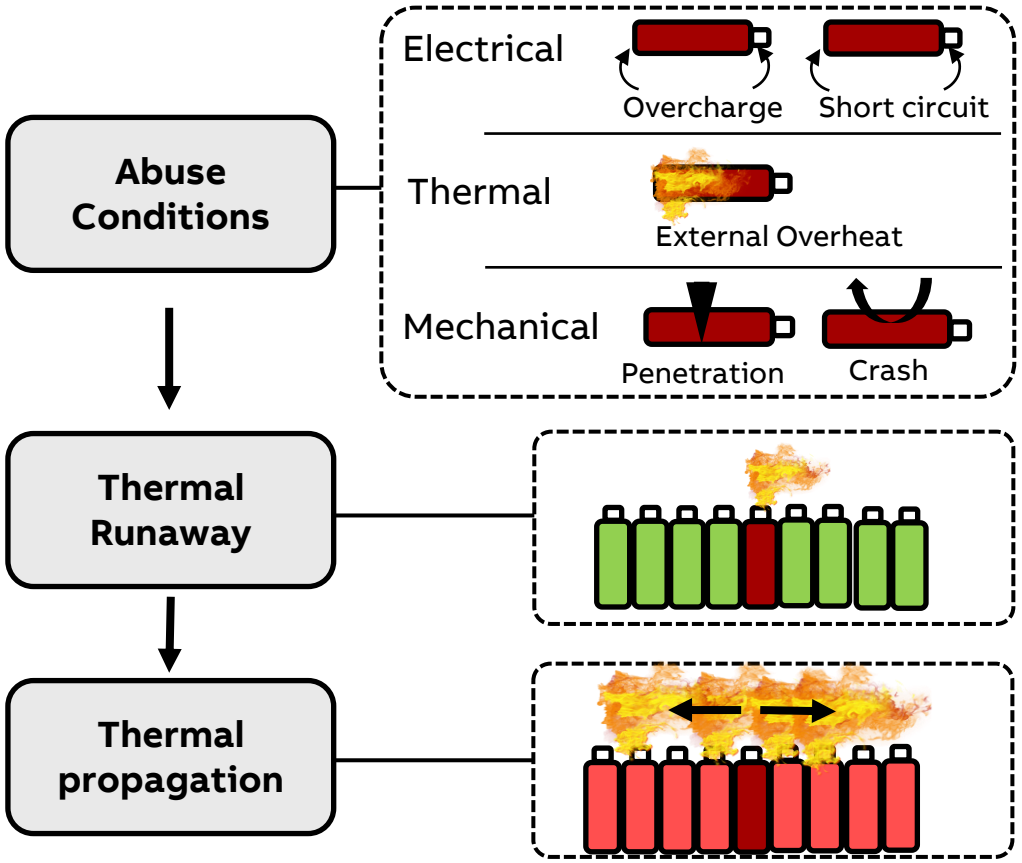
Lithium-ion batteries

Safety considerations

Safety considerations: Cell selection & module design

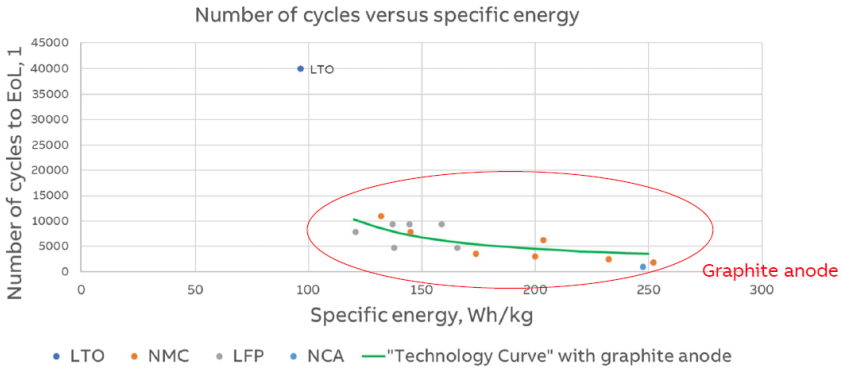
- A variety of abuse cases can trigger a thermal runaway event and cascade into uncontrolled propagation.
- Careful cell selection is necessary as behavior, and immunity to abuse varies across technologies.
- Module design must consider that a single cell failure can occur and might propagate to neighboring cells.
- Additional safety measures are necessary at module and system level to reduce the risk of thermal runaway

Recent bus battery fires have enjoyed much news coverage…



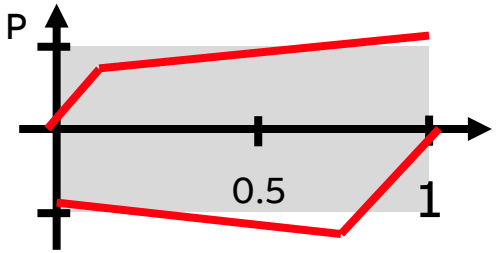
Li-ion cell chemistry comparison

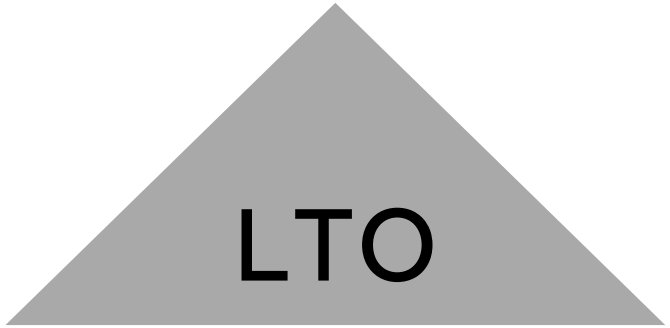
Key LTO benefits



Lifetime:

- Best cycle life by far of all Li-ion chemistries, even during deep cycles
- No calendar aging
- Best choice for applications with **many cycles/day and high lifetime target**





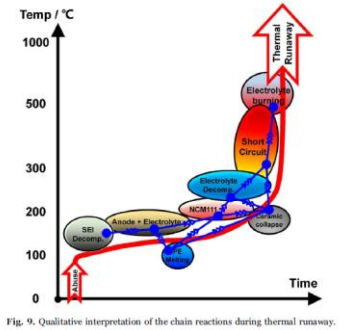


Fig. 9. Qualitative interpretation of the chain reactions during thermal runaway.

Power:

- Excellent bi-directional power
- Safe to charge at low temperatures

Safety:

- Low risk for internal short circuit and very high thermal runwaway temperature
- Stable performance during entire lifetime
- Best choice for applications with **high safety requirements, such as underground**

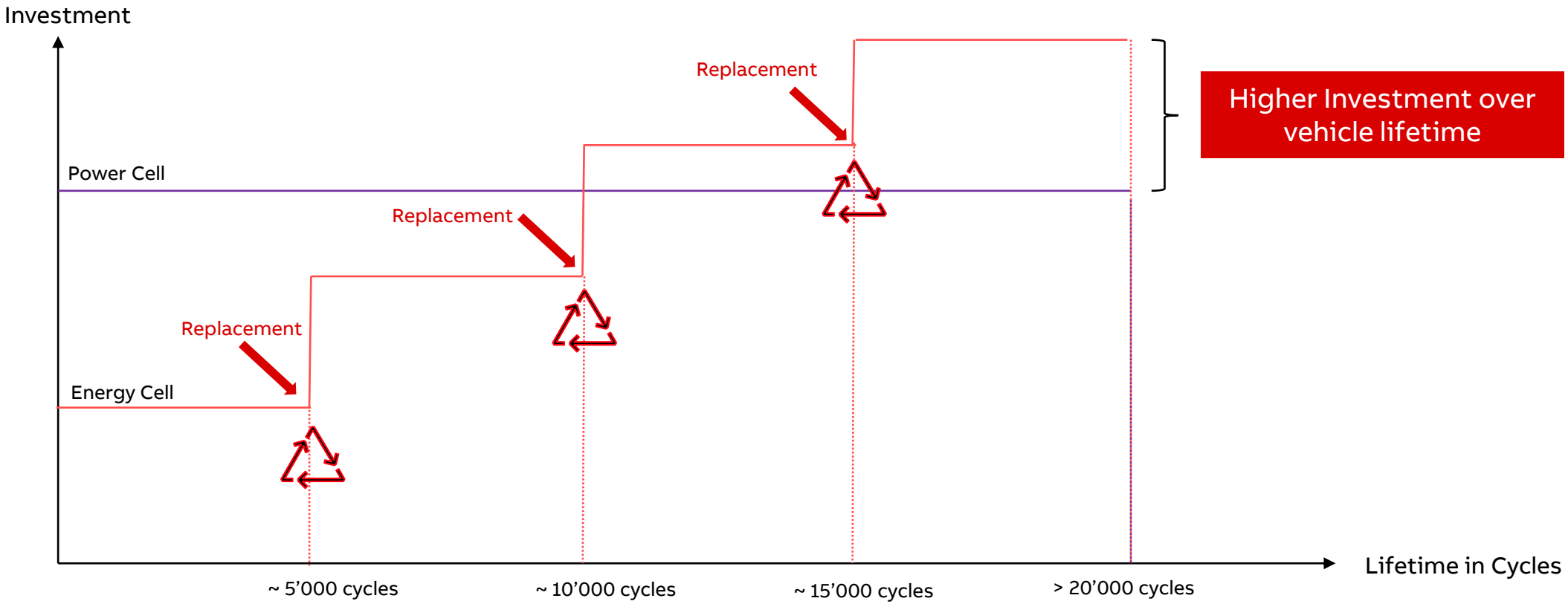
BORDLINE® ESS

LTO Advantages

The safest chemistry on the market	**High level of inherent safety**
Excellent low temperature performance	**Charge & discharge possible even at - 30°C**
High power capability	**Fast charging & full recuperation**
Very high cycle life, > 20’000 Cycles	**Reduced total cost of ownership**
Wide SoC range without power restriction	**More usable energy**
Lower internal resistance	**High energy efficiency**

BORDLINE® Energy Storage Systems

Total cost of ownership: Initial Investment vs. Lifetime



Li-ion Cells - Lifetime

Cycle life

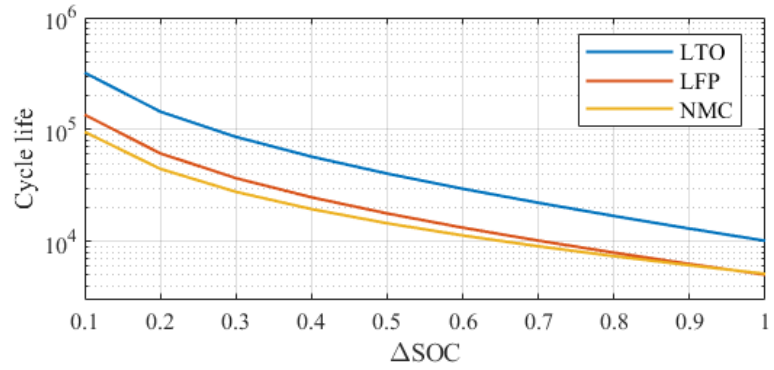
Cycle life of lithium-ion batteries is very limited:

- NMC: 2000 – 4000 cycles @ 100% ΔDOD
- LFP: 3000 – 6000 cycles @ 100% ΔDOD
- LTO: >20’000 cycles @ 100% ΔDOD

NMC and LFP cycle numbers are unfeasible for many applications, and this could result in earlier replacement of the battery system – false economy.

LTO is the only chemistry which can be used at high (or even full) ΔDOD regularly.

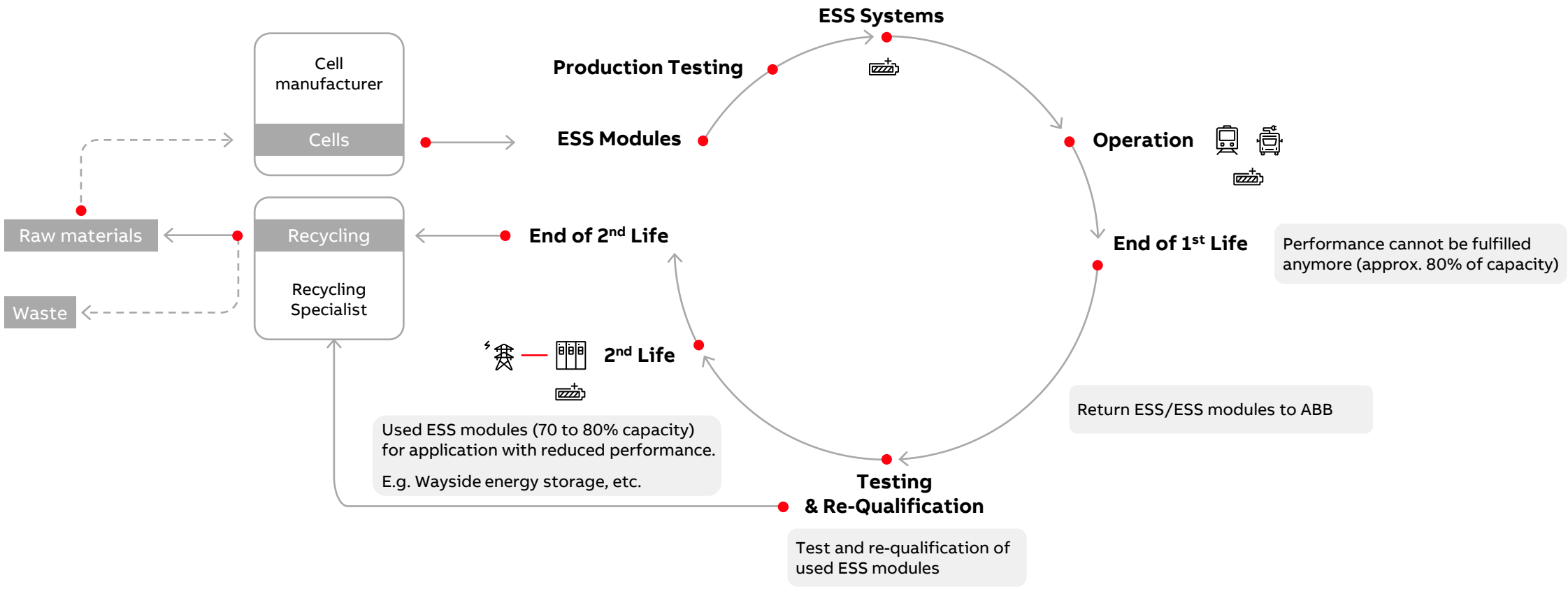
- **NMC** is cheaper, however
  - Thermal runaway concerns
  - Limited cycle life – **Replaced often**
  - Limited charging rate – **Greater charging time**
- **LTO** has a higher initial investment, but:
  - Is far safer
  - Very high cycle life
  - Higher charging rate – **Less charging time**



Göhlich et al., “Conceptual Design of Urban E-Bus Systems with Special Focus on Battery Technology” in *Proceedings of the Design Society: International Conference on Engineering Design*, vol. 1, pp. 2823-2832, 2019

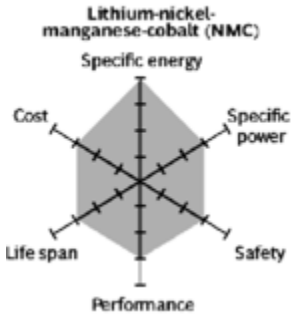
ESS Life Cycle

From production till end of life, 2nd Life concept & recycling concept

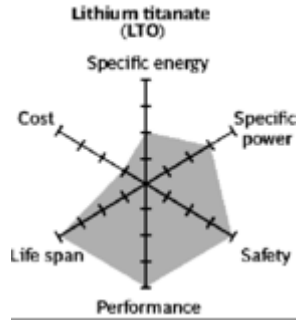


Key Takeaway

Power Battery vs Energy Battery



Streetcars are not endpoint-charged buses on rails.
Treat the application first.
Then consider the capital cost.



NMC ← Energy density

Life + Performance → LTO

Application	Vehicle
Single/Two Charge(s) per day	Bus, depot charging
Long route duration	Bus, depot charging
Low number of charging cycles	Bus, depot charging
Constant ESS use	Bus
Safety	**Not ideal** for passenger transport

Application	Vehicle
Several charges/day	Streetcar, or Bus Rapid Transit
Short recharge time needed	Streetcar, or Bus Rapid Transit
High number of charging cycles	Streetcar, or Bus Rapid Transit
Intense, intermittent ESS usage	Streetcar, or Bus Rapid Transit
Safety	Safer for passenger transport

Images: The Boston Consulting Group, “Batteries for electric cars”

Speaker

Contact Info

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