



Electric Buses – A Decade of Development



Electric Buses – A Decade of Innovation & Learning

- **EV Solo introduced in March 2009**
 - 50 miles range
 - 35 passengers
 - 80 kWh
- **Latest generation EV bus into service in March 2019**
 - 150 mile range
 - 60 passengers
 - 240 kWh
- **A decade of operation. Lots of lessons learned**



A Decade of EVs – Key Lessons Learned

- Battery electric buses deliver
- Less charging is more
- Efficiency remains king
- Innovation is accelerating
- Costs are coming down



Lessons Learned – EV Buses Deliver

- **>95% availability**
- **15 hour operation today**
- **Suitable for a wide range of duties**
 - Park & ride to TfL operation
- **Oldest vehicles in service 9 years**
- **100,000 miles plus**



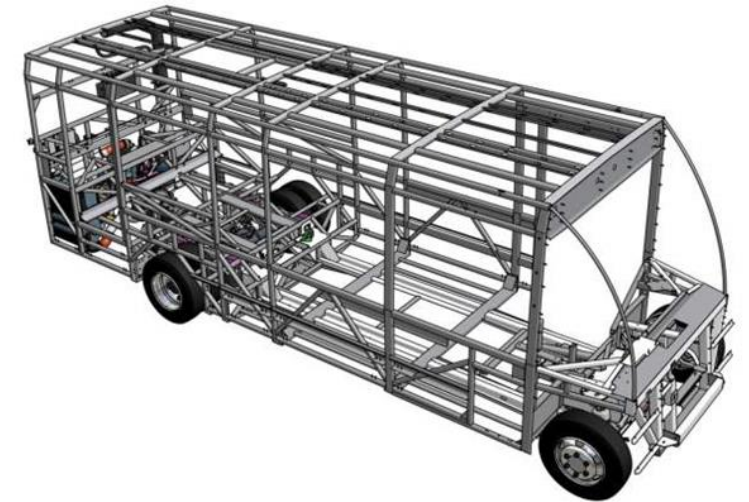
EV Lessons Learned – Less Charging is More

- Charging ages batteries
- The faster the charge the shorter the battery life
- Charging a culture shock for operators
- Fast charging or high charge demand is expensive
- Low density batteries limit range & need fast charging to deliver service
 - Vicious circle of weight & complexity
- Focus on overnight charging via more energy with no weight penalty



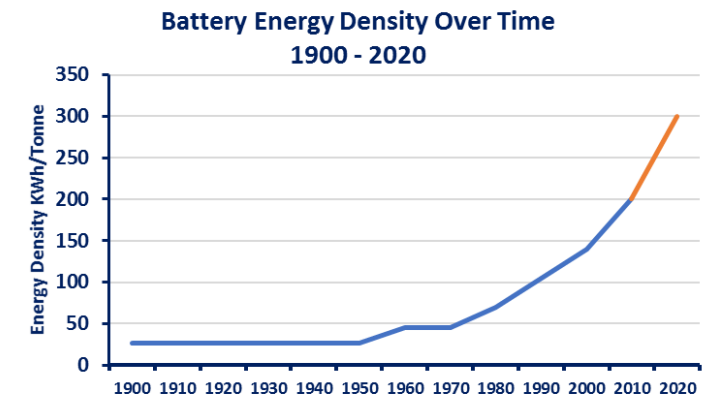
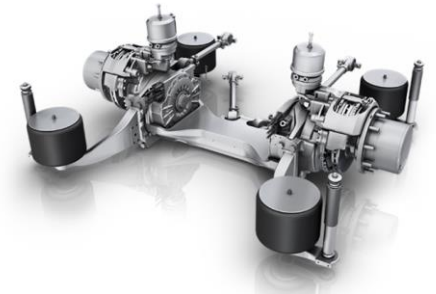
EV Lessons Learned – Efficiency Remains King

- Bus battery energy a precious resource
- Zero Emission heating an added challenge
- Energy = weight, cost, charge demand & infrastructure
- EV Future based on lightweight platforms with efficient drive lines & systems



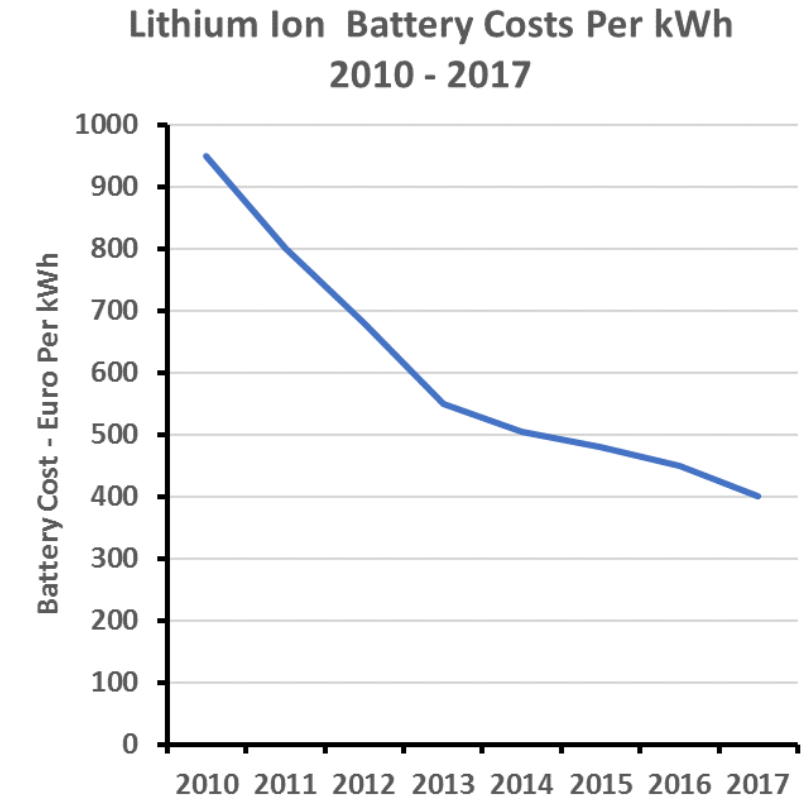
EV Lessons Learned – Innovation is accelerating

- Clean air agenda driving innovation
 - Zero emission at point of use
 - Electrification of cities
- Rising global OE EV involvement fuelling innovation
 - Drive line
 - Batteries
- Tier 1 suppliers replacing boutique engineering start ups
- Battery chemistry evolving rapidly
 - Energy density doubling every 15 years
 - >150% increase in energy carried for <5% weight increase



EV Lessons Learned – Costs are coming down

- **Battery 50% of EV premium**
- **Battery costs per kWh more than halved 2010 – 2017**
 - kWh increases have masked trend
- **Prediction of €100 Per kWh by 2025**
- **€100/KWh reduces EV premium by 35%**
- **Volume supply base will bring additional savings**
- **WLC reducing through extended warranties**



EV Development – The Next Decade

- 30% increase in available energy
- >200 zero emission miles on a single charge
- Battery packs future proofed for chemistry change
- Leased packs with second lives & whole life warranties
- Whole life cost less than diesel
- lower cost fast charging?
- Technology will deliver

