Electric Vehicles Storage Technologies and Range

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Introduction

Within 8 years all cars sold will be electric and autonomous. This is the view of notable futurist Tony Seba from Stanford University. Not everyone agrees of course, with BP estimating that only 6% of the global car fleet will be electric by 2030, equivalent to 100 million vehicles. To consider the validity of these predictions and hence impacts on electricity grids, it is useful to look at how battery electric vehicles (BEV) compare to internal combustion engine vehicles (ICE) and hydrogen fuel cell vehicles (HFC). The prediction from Tony Seba is based on an exponential uptake of autonomous BEVs, a trend that has resulted in sales of BEVs increasing from 17,000 in 2011, to 780,000 in 2016, Figure 1.

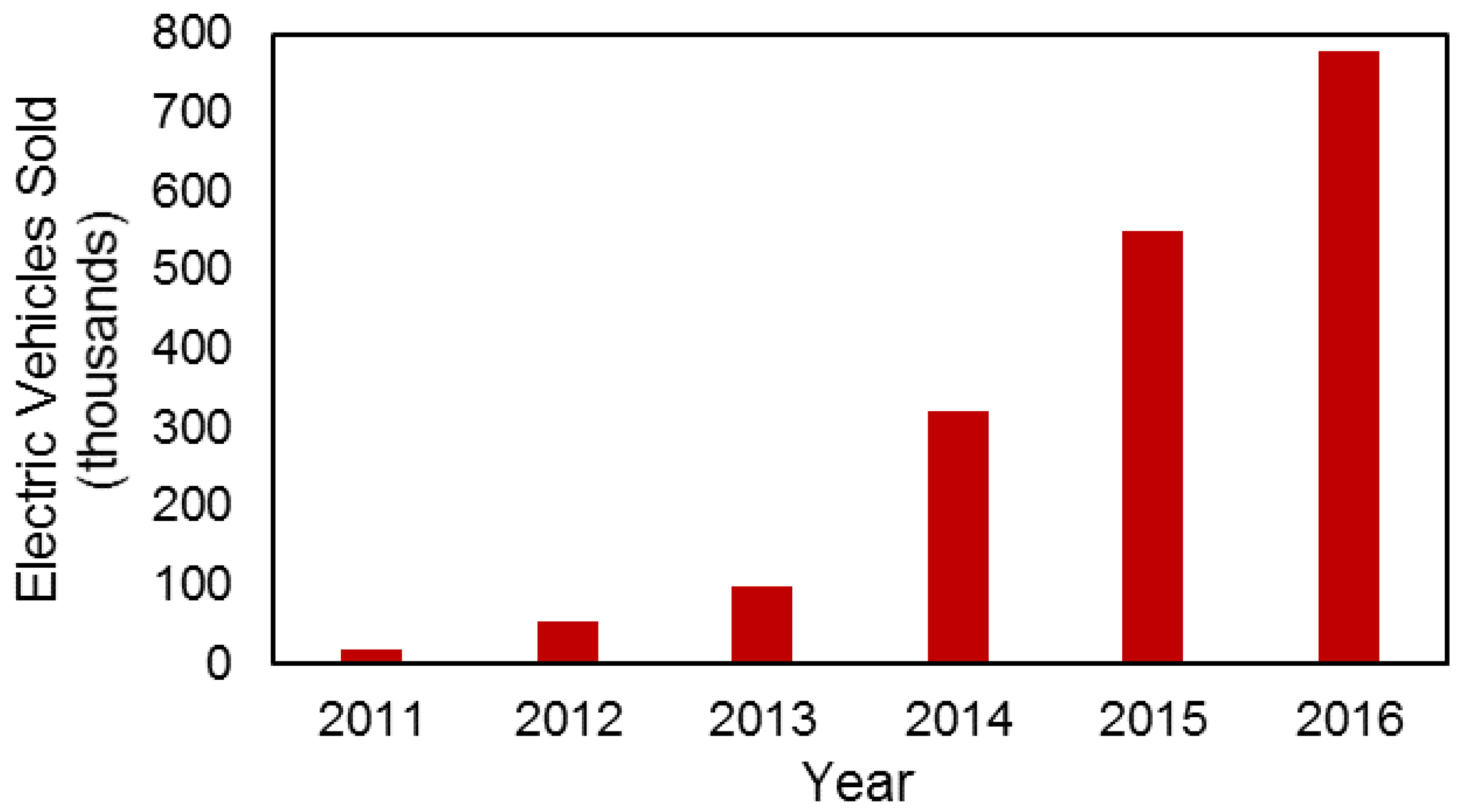

Figure 1: Sales of electric vehicles on average have more than doubled year on year since 2011.

The sales growth has been driven by improvements in driving range and recharging infrastructure, along with consistent reductions in battery cost, from improved chemistries, requiring less raw material.

Energy Storage

Recently improvements have slowed and Li-ion battery energy density still lags petrol by a factor of 30. The effective range density of BEV's is only 7 times lower however, due to the more efficient motors and regenerative braking, Figure 2.

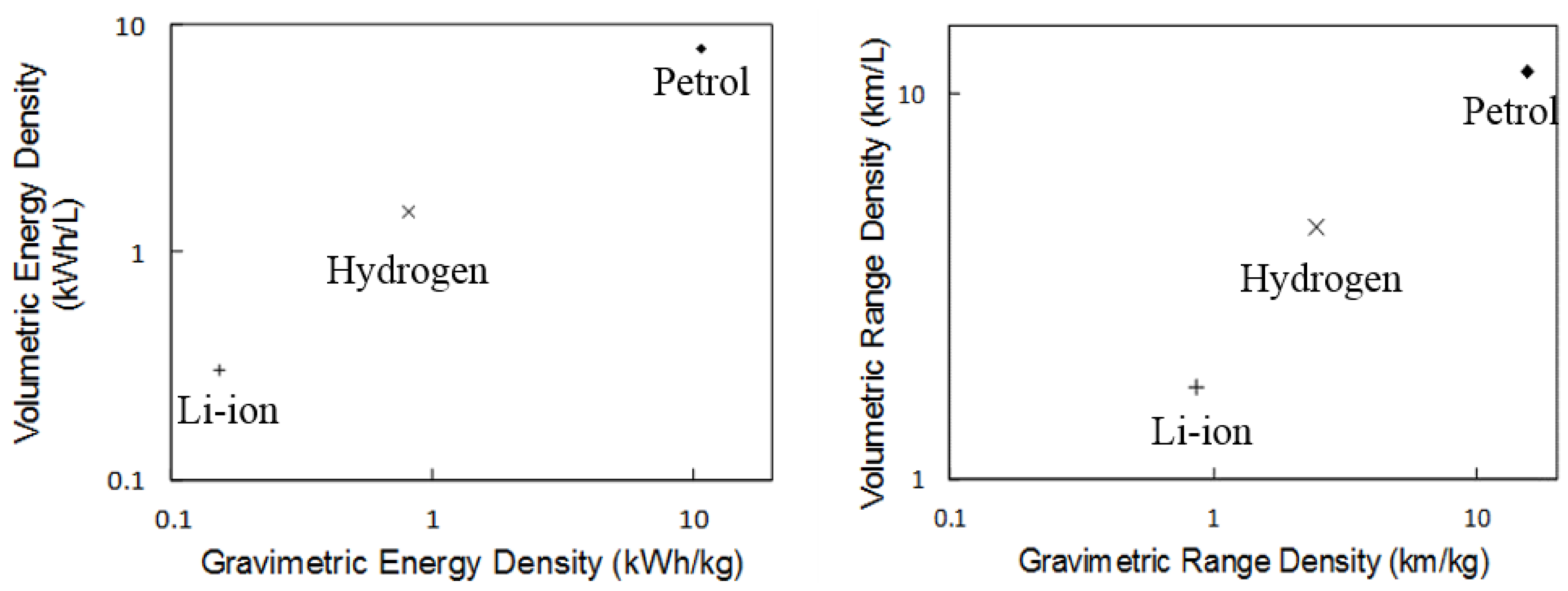

Figure 2: The energy density of the major storage types varies widely, by comparing the efficiency of vehicles with different drivetrain types, the estimated range density was found.

At 2.5 kWh/kg, a BEV battery will have the same range density as petrol, with Li-Sulphur and Metal-Air batteries capable of surpassing this value, Figure 3.

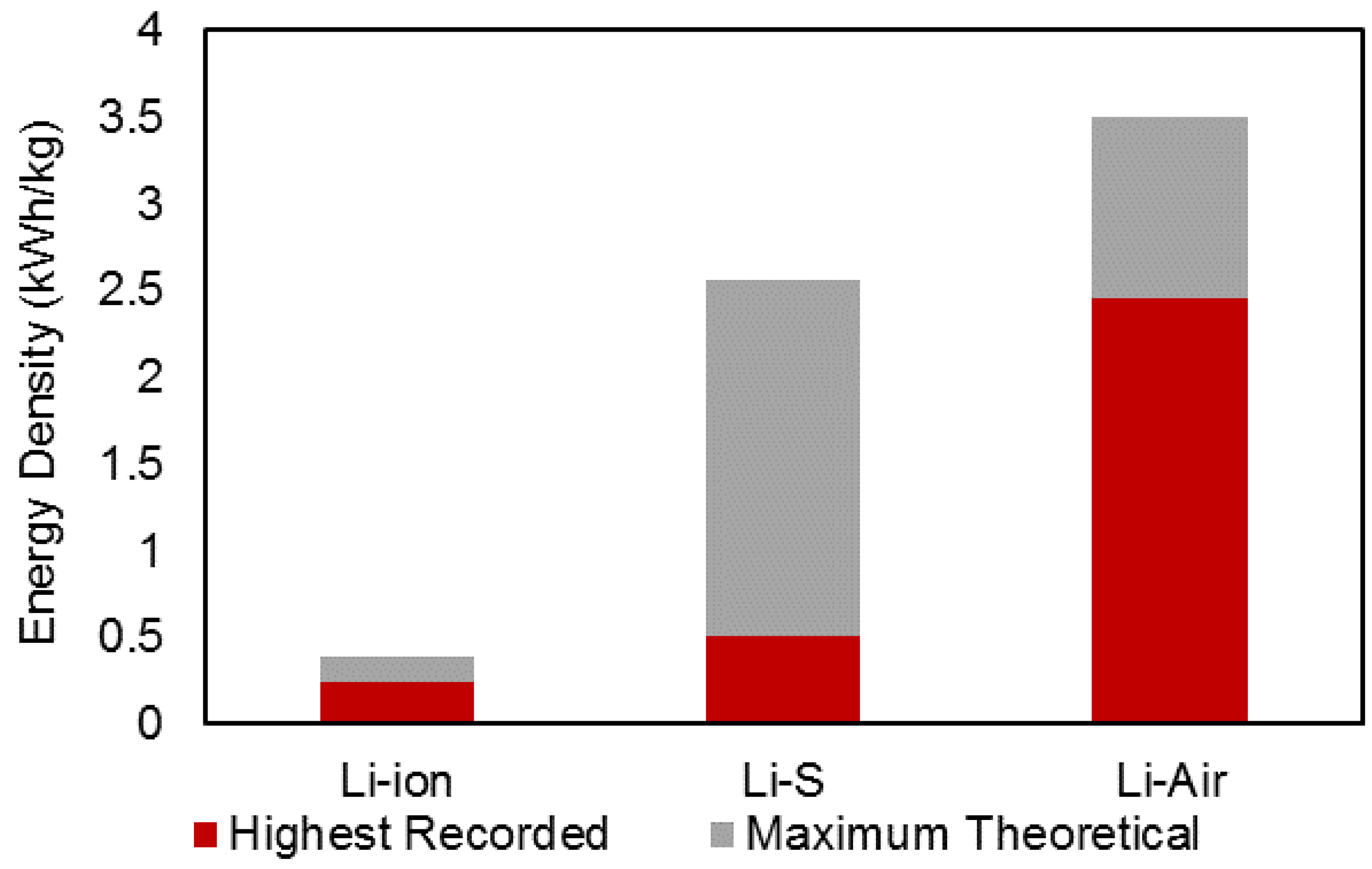

Figure 3: Energy densities for selected leading and promising battery types.

While Li-ion will never reach range parity with petrol, BEVs powered by Li-ion batteries may still dominate the market as electric motors are more efficient, produce more power per weight, are cheaper, have lower wear, require less ancillary devices, produce full torque at low RPM and do not emit particulates or GHG.

Comparison of Vehicles by Powertrain Type

By comparing one popular model of each powertrain type, we can see how they compare in today's market, Figure 4.

	Full Range (km)	Energy Input in 5 min (kWh)	Range Added in 5 min (km)	Efficiency (km/kWh)	Fuel Cost ($NZD/yr)	Price ($USD)
Toyota Corolla (ICE)	676	470	676	1.4	2,100	18,500
Toyota Mirai (HFC)	502	167	502	3	800 (est.)	57,500
Nissan Leaf (BEV)	242	4	24	6	350	29,990

Figure 4: Relative performance and cost of selected models representing each powertrain type.

Many consumers considering BEVs have range anxiety, as the range and charging rate of BEVs is well below the alternatives, but the gap is closing quickly. When fuelling and maintenance costs are considered, the total cost of ownership of BEVs is generally lower than that of ICE vehicles.

The Toyota Mirai HFC has comparative range and refilling time with the Toyota Corolla ICE, which leads many to believe HFCs are more likely to replace ICEs than BEVs. However in addition to the lower vehicle efficiency than BEVs, the overall system efficiency is three times lower, at below 30%. This will lead to higher running costs and much greater expenditure on refilling infrastructure, Figure 5.

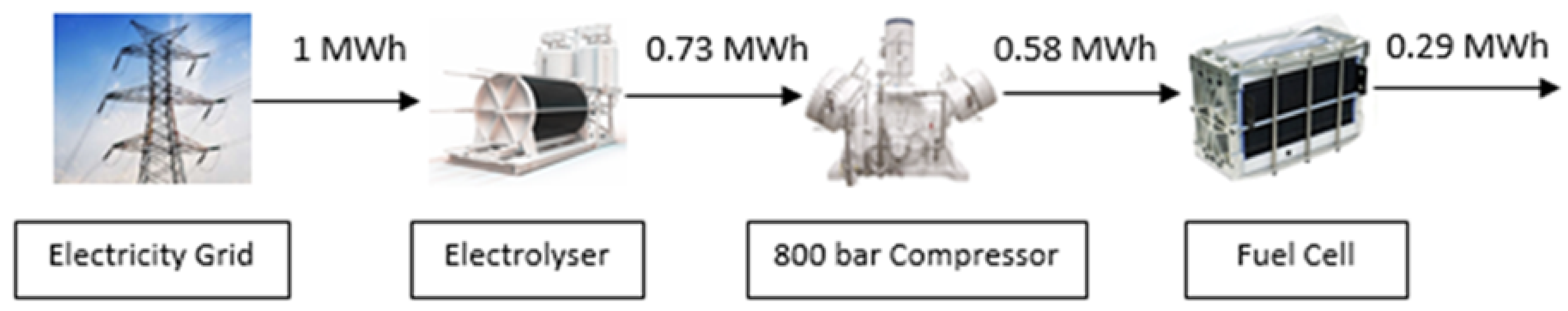

Figure 5: Overall fuel cell system efficency declines considerably at each of four steps.

For BEVs to become the dominant technology, it is critical to increase the charging rate to require stopping times close to what is required for ICE and HFC. Currently Tesla has the world leading fast charging capability at 145kW. Higher power charging of 350 kW is planned, equivalent to 35 km/min of range. Higher charging rates make the electrification of heavy duty trucking a distinct possibility, a sector where the potential fuel and maintenance savings is even higher. Rapid uptake of BEVs will have a limited impact on electricity demand, well below currently consented capacity additions of wind generation. However, if large numbers of cars and trucks travel long distances and recharge quickly, there will be significant loads on the grid in localised areas. Dealing with this challenge may involve pricing incentives to charge at off-peak times and the use of stationary storage to offset loading.

Autonomous Advantage

Fully autonomous vehicles may increase the usage of vehicles by a factor of ten, making the marginal cost of vehicles the primary consideration. Autonomous driving is a lot closer than many realise – a large number of cars are already able to drive themselves in a range of conditions. Autonomous vehicles have safety advantages over human driven vehicles, including far more sensors, sensors that are constantly vigilant, and a computer dedicated to the task of driving, Figure 6.

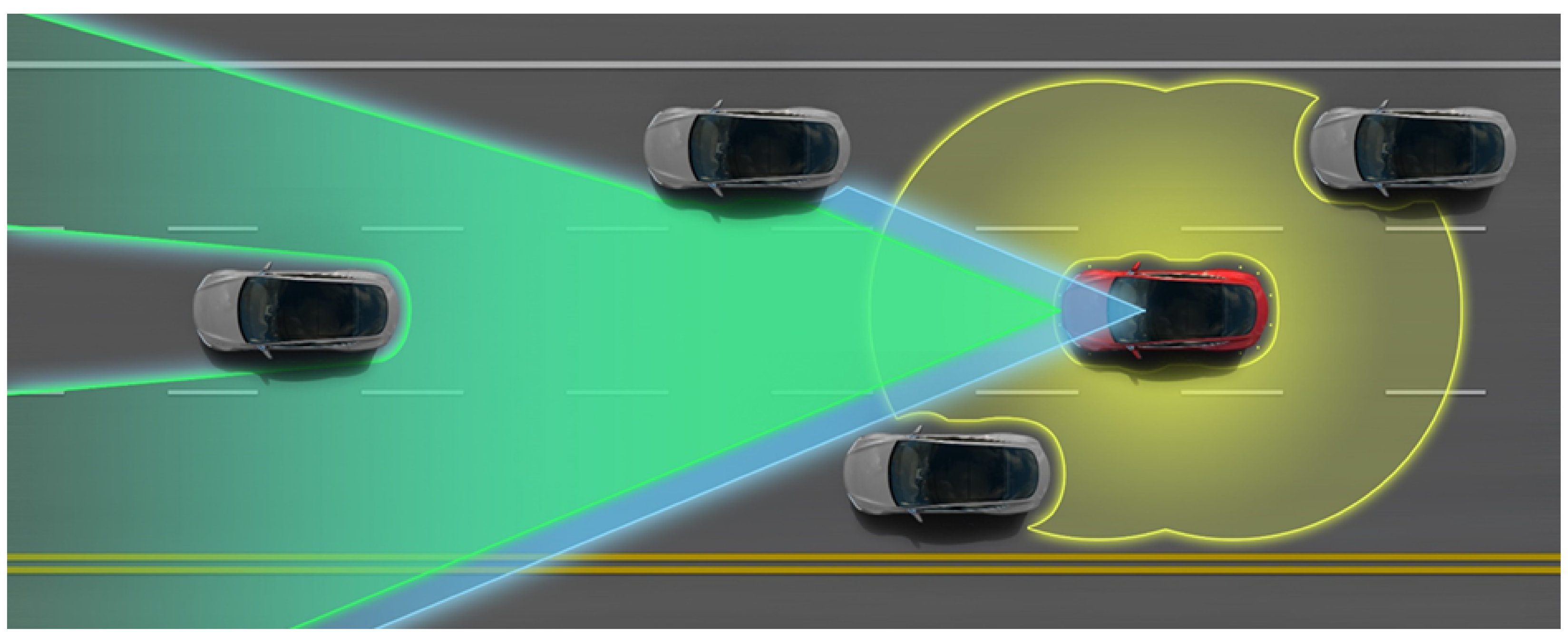

Figure 6: Tesla autopilot hardware, radar is green, front camera blue, ultrasound sensors yellow.

Conclusions

BEVs loom as the only technology that can simultaneously reduce greenhouse gas and small particulate emissions. They will provide lower maintenance and fuel costs, particularly if full autonomy is achieved. Whether this transition is complete by 2025 remains to be seen, but BEVs appear set to dominate car sales in the near future.