An outline paper on the technology of electric vehicles

Ian M B Scott CEng CSci CPhys FInstP FIOSH

The author is a Chartered Physicist, Scientist and Engineer and an independent writer, researcher and technical author, specialising in aspects of applied physics, forensic chemistry and safety engineering.

1 INTRODUCTION

Electric vehicles are being seen everywhere on streets in cities around the world. Estimated global EV sales in 2019 were 2.2 million cars with predictions rising to 11.5 million vehicles in 2025. (The Times, 17 January 2020). EV offer fast, efficient and pollution free travel in built-up areas and make no visible contribution (at the 'exhaust pipe') to vehicle emissions from the burning of fossil fuels. Of course, there may be emissions to atmosphere at source where the electricity is generated but addressing these issues is a wider debate. EVs are also now extensively used for taxis and public service vehicles in cities and experiments are underway with goods vehicles, for local deliveries and for longer distance haulage using electrical power.

Photograph 1: Hybrid EVs make a popular choice as a taxi

Electric vehicles offer many benefits, they are seen as sustainable solutions to transport pollution and a very ‘green alternative’ but they also have some disadvantages when compared to conventional carbon fuel powered vehicles.

This paper is one of three related published papers which look at current EV technology, issues around recycling batteries used for motive power in electric vehicles and, in more detail, issues surrounding the recycling of lithium-ion batteries in the wider industrial and commercial sectors.

2 ADVANTAGES AND DISADVANTAGES OF ELECTRIC VEHICLES

All-electric vehicles offer many benefits, including high energy efficiency, reduced emissions, and strong performance, with additionally low maintenance. Drawbacks may be imagined as limited range or duration (‘Range Anxiety’), a long time needed to ‘re-fuel’ meaning a delay to a journey, higher initial purchase costs and significant battery replacement costs or re-cycling charges, when this becomes necessary in the life of the vehicle. Many of the same benefits of all-electric cars also apply to plug-in hybrid electric vehicles, although one recent review (The Times 15 February 2020) commented that roadside chargers for electric vehicles could cost 9 times as much as the price paid for electricity if the recharging was undertaken at home from a domestic supply, although it is acknowledged that roadside charging stations may utilise faster charge rates.

2.1 Battery life and warranties

Like any battery-powered electronic device, electric vehicle batteries do not have an unlimited lifespan. As a battery ages it degrades, and consequently will hold less charge when “full.” High temperatures and overcharging, among other factors, contribute to faster battery degradation over shorter time.

Most electric vehicles come with a battery performance warranty, generally guaranteeing anywhere between five and eight years of use, or around 100,000 miles of driving with the car battery maintaining above a certain percent of its original capacity. Depending on how much you drive and how long you plan on owning your vehicle, warranties on battery life and degradation are an important factor to consider.

Deeper discharges lead to more rapid battery degradation. EV battery warranties are most applicable for shorter range vehicles. This is because a regular commute might only drain a small percentage of a long-range battery, but that same commute might constitute a "deep discharge" on a lower-capacity battery, which degrades battery life more significantly over time.

2.2 What causes reduced electric car battery life?

Electric vehicle battery life can be impacted negatively in several ways:

High temperatures. Operating an EV in high temperature climates can degrade the battery. Additionally, parking an EV in the sun for long periods of time can have similar degradation effects.

Overcharging/high voltages. Charging an EV beyond its voltage limit can increase internal resistance in the battery. Most batteries have built-in battery management systems (BMS), so overcharging is rarely an issue, but it is good practice to not charge your battery right up to 100% routinely.

Deep discharges/low voltages. Draining most of a battery's capacity frequently, or completely draining an EV battery, reduces battery capacity over time.

High discharges or charge current. 'Pulling' too much current from a battery routinely or regularly may have detrimental effects on battery life. When possible, avoid aggressive driving patterns that might pull high levels of current from your battery all at once.

All EV batteries will degrade over time but avoiding these situations can help you maximise EV battery life. Current battery technology is designed for extended life (typically about 8 years or 100,000 miles). Some batteries and can last for 12 to 15 years in moderate climates, or eight to 12 years in extreme climates.

3 HOW DO ELECTRIC CAR BATTERIES WORK?

The energy storage system in electric cars comes in the form of a battery. Battery type and composition can vary, depending on if the vehicle is all-electric (AEV) or plug-in hybrid electric (PHEV).

‘All-electric’ vehicles have an electric traction motor in place of the internal combustion engine used in liquid fuel powered cars. AEVs use a traction battery pack (usually a lithium-ion battery) to store the electricity used by the motor to drive the vehicle's wheels. The traction battery pack is the part of the car that must be plugged in and recharged, and its efficiency helps determine the overall range of the vehicle. However, it is also possible to charge the battery in an ‘all-electric’ vehicle by regenerative braking, using kinetic energy to charge the battery when the vehicle is braking.

In plug-in hybrid electric vehicles, the electric traction motor is powered by a traction battery pack much like an AEV. The primary difference is that the battery power is augmented by running a liquid fuelled combustion engine. PHEVs run on electric power until the battery is depleted and then switch over to fuel which powers an internal combustion engine. The battery, usually lithium-ion, can be recharged by (1) being plugged in, through regenerative braking, or (2) by using the internal combustion engine. The combination of battery and fuel gives PHEVs a longer range than their all-electric counterparts.

3.1 Types of electric car batteries

There are four main kinds of batteries used in electric cars: lithium-ion, nickel-metal hydride, lead-acid, and ultracapacitors.

3.1.1 Lithium-ion batteries

The most common type of battery used in electric cars is the lithium-ion battery. This kind of battery may sound familiar as these batteries are also used in most portable electronics, including cell phones and computers. Lithium-ion batteries have a high power-to-weight ratio, high energy efficiency and good high-temperature performance. In practice, this means that the batteries hold a lot of energy for their weight, which is vital for electric cars. Less weight means the car can travel further on a single charge. Lithium-ion batteries also have a low “self-discharge” rate, which means that they are better than other batteries at maintaining the ability to hold a full charge over time.

Additionally, most lithium-ion battery parts are recyclable making these batteries a good choice for the environmentally conscious. This battery is used in both AEVs and PHEVs, though the exact chemistry of these batteries varies from those found in consumer electronics.

3.1.2 Nickel-metal hydride batteries

Nickel-metal hydride batteries are more widely used in hybrid-electric vehicles, but are also used successfully in some all-electric vehicles. Hybrid-electric vehicles do not derive power from an external plug-in source and instead rely on fuel to recharge the battery which excludes them from the strict definition of an electric car.

Nickel-metal hydride batteries have a longer life cycle than lithium-ion or lead-acid batteries. They are also safer and tolerant to abuse. The biggest issues with nickel-metal hydride batteries is their high cost, high self-discharge rate, and the fact that they generate significant heat at high temperatures. These issues make these batteries less effective for rechargeable electric vehicles, which is why they are primarily used in hybrid electric vehicles.

3.1.3 Lead-acid batteries

Lead-acid batteries are only currently being used in electric vehicles to supplement other battery loads. These batteries are high-powered, inexpensive, safe, and reliable, but their relatively short calendar life and poor cold-temperature performance makes them difficult to use in EVs. There are high-power lead-acid batteries in development, but the batteries available now are only used in commercial vehicles as secondary storage.

3.1.4 Ultracapacitors

Ultracapacitors are not batteries in the traditional sense. Instead, they store polarized liquid between an electrode and an electrolyte. As the liquid's surface area increases, the capacity for energy storage also increases. Ultracapacitors, like lead-acid batteries, are primarily useful as secondary storage devices in electric vehicles because ultracapacitors enable electrochemical batteries to level their load. In addition, ultracapacitors can provide electric vehicles with extra power during acceleration and regenerative braking.

3.1.5 Features of EV batteries

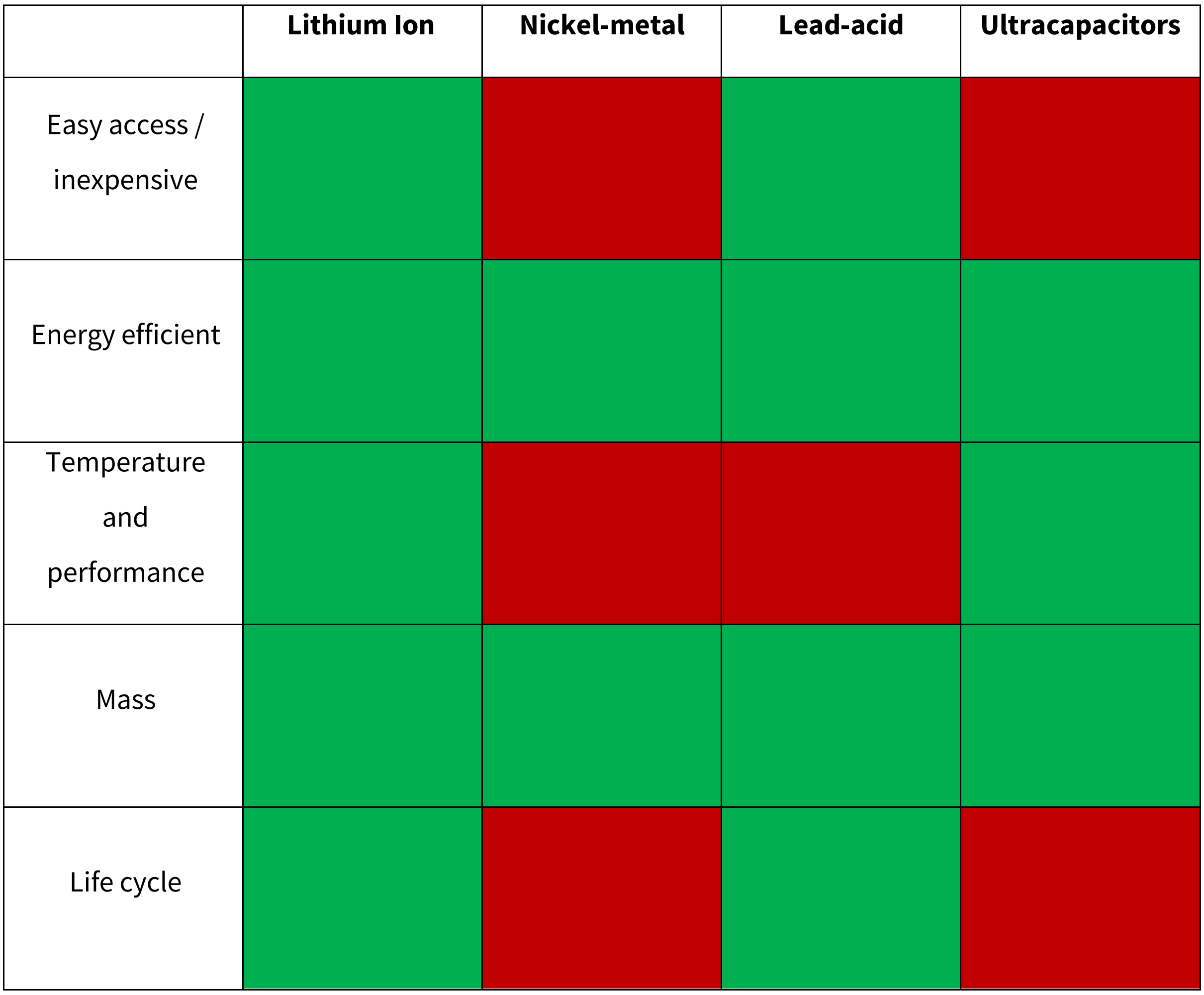

Figure 1: EV Battery features. Green is good or a beneficial condition

Although there are many types of traction or power batteries available to manufacturers the industry appears to be focussing on lithium-ion cells. Intrinsically, there are high values in the materials used in production and recycling is a strong option for sound commercial and technical reasons. However, the issues associated with giving new life to batteries and their components are not free from risk or safety related issues and these are discussed at length in the next paper in this series.