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Analysing the practicality of Lithium-Ion batteries

Academic Skills

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1 Introduction

In this essay, we will be discussing the technological developments of Lithium-Ion rechargeable batteries, their advantages and disadvantages against competing technologies, and what the near future may hold for further developments in the area.

Since the commercial emergence of Lithium-Ion batteries in 1991, significant improvements in their energy capacity and cost to consumer have been made. Lithium-Ion batteries have benefited from a three-fold increase in capacity, whilst decreasing ten-fold in cost (Chagas et al., 2019), greatly improving their usability for a range of industries we rely on.

As of 2021, 93% of adults own a personal mobile phone (Office for National Statistics, 2021) and between 2020-2022 the percentage of total car sales comprised of Electric Vehicles (EV) has more than tripled, from 4% to 14% (International Energy Agency, 2023).

There is no arguing that our reliance on cheap, reliable rechargeable batteries is steadily increasing. My aim in this essay is to ascertain if Lithium-Ion batteries are strong contenders in fulfilling these criteria universally for portable electronics.

2 Background

2.1 Pre-commercial period

In 1976, chemist Stanley Whittingham in conjunction with oil and gas corporation ExxonMobil developed the first rechargeable Lithium-Ion battery (Pereira et al., 2015). Although the components used would differ from later commercial adaptations, this method paved the way for fabricating Lithium-Ion batteries.

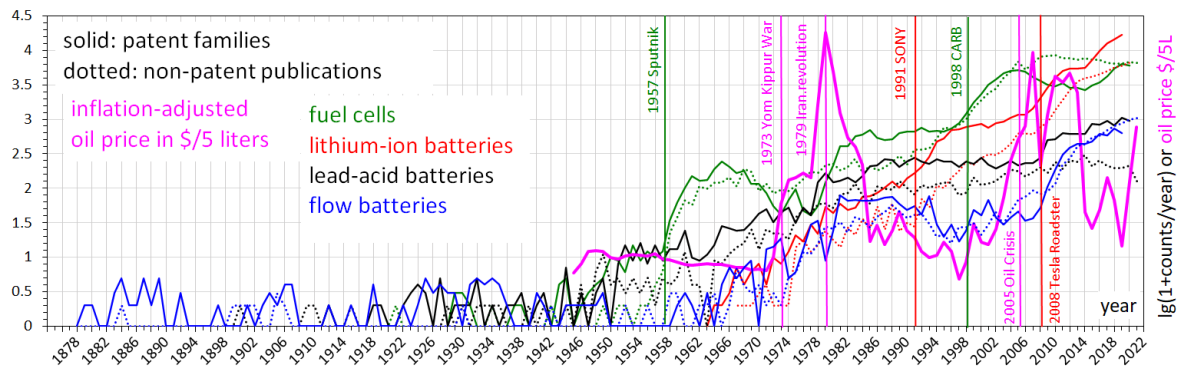


Figure 1 - Num of publications about power sources per year (Tolmachev, 2022)

Throughout the 1970s and 1980s, non-commercial development of Lithium-Ion technology persisted (Figure 1).

2.2 Commercial Period

Bringing us to 1991, Sony Group Corporation, in conjunction with Asahi Kasei Corporation, developed and commercialized Lithium-Ion batteries to use in mobile phones (Sony, 2016).

As seen in Figure 1, this prompted a huge increase in publications on Lithium-Ion batteries, suggesting a trend of exponential innovation in the area.

It is curious to note that, as depicted in Figure 1, publications on Lithium-Ion battery technology seem to increase shortly after increases in oil price, this potentially suggests that, since their inception, researchers have been exploring the possibility of Lithium-Ion batteries as an adjacent technology to mitigate our reliance on oil for mobile practices.

2.3 Advancements in EV technology

In 2008 Lithium-Ion technology became viable enough for use in automotive applications. Tesla's Roadster model became the first all-EVs to be mass produced and road legal (Shahan, 2015). This once again resulted in an increase in publications on Lithium-Ion batteries (Figure

1) which expedited the developments made in the field. As of 2014, batteries developed by Amprius Corporation for commercial use had an energy density of 650Wh/L, a substantial increase on previous iterations (Anthony, 2014).

With the introduction of EVs, some hesitancy towards adopting them is attributable to their lower range, combined with their higher charging time, compared to a standard petrol or diesel vehicle, where refuelling takes a marginal amount of time.

3 Discussion

Based on the trends present in Figure 1, there is a high interest in Lithium-Ion battery technology. There has been a consistent upward trend in developments and publications on the subject.

Whether Lithium-Ion batteries are viable for universal applications in portable rechargeable technologies is unclear. Researchers appear to believe so, as indicated by the impressive development of the technology since its inception, and the branching it has experienced once the technology was capable of increasingly complicated applications. For the most part, it has proved more than adequate.

As for mobile devices, such as laptops and smartphones, Lithium-Ion batteries are practical. Top-range flagship phone models such as the iPhone 15 Pro boast all day usage despite their small size, weight, and impressive processors (Lovejoy, 2023). Laptops and similar mobile electronic devices benefit from the same.

3.1 Concerns in adoption of Lithium batteries for EVs.

The biggest challenge for Lithium-Ion batteries presently are EVs. From their origin, there have been concerns from consumers regarding their battery life (Eberle and von Helmolt, 2010), the scarcity of charging points compared to conventional petrol stations and their high initial cost compared to conventional cars (Wang et al., 2021). Furthermore, the extraction of lithium raises environmental and human rights concerns. The extraction and manufacture of lithium produces mining waste that is significantly hazardous (EPA, 2013). An abundance of the Earth's lithium reserves lay in what is referred to as the "Lithium Triangle" (Halpern, 2014). Chile, Bolivia and Argentina are rich in Lithium and often suffer from human rights violations towards its occupants (Marchegiani et al., 2019).

EVs have no emissions, however, the electricity generated to power them may still be produced from fossil fuels. The National-grid can only support a practical maximum of 30% of its power being generated from green energy due to constraints in transmitting it across the UK (Nagley, 2023). Fast chargers provide a compromise for EV's slower charging, but they also put stress on the grid, and as society pushes for more EVs, it will only increase.

3.2 Developments made to mitigate downsides of EVs

3.2.1 EV range and charging discussion.

There have been developments to mitigate some of these concerns. Many newer EVs boast higher ranges, such as the Tesla Model S Long Range Plus, which on a full charge can travel 390 miles (EVD, 2023).

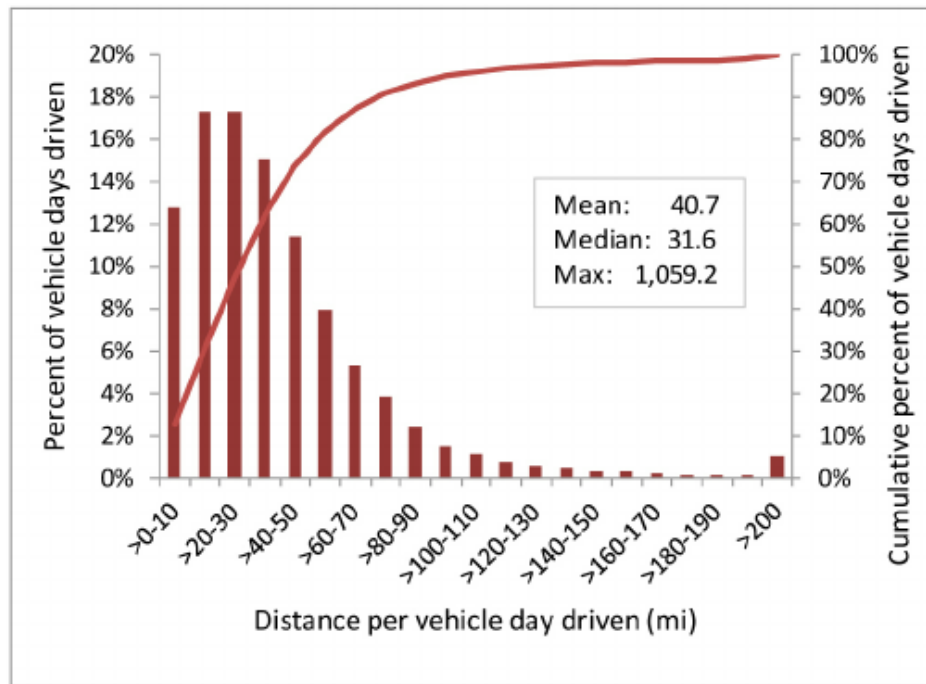


Figure 2 Distance driven per day versus percentage of vehicle days driven. (Smart et al., 2013)

This proves to be sufficient for the most part; the median distance driven daily is 31.6 miles, as can be seen in Figure 2.

On the topic of charging points, it is important to keep in mind that many EVs owners have home charging setups, pulling power from their mains.

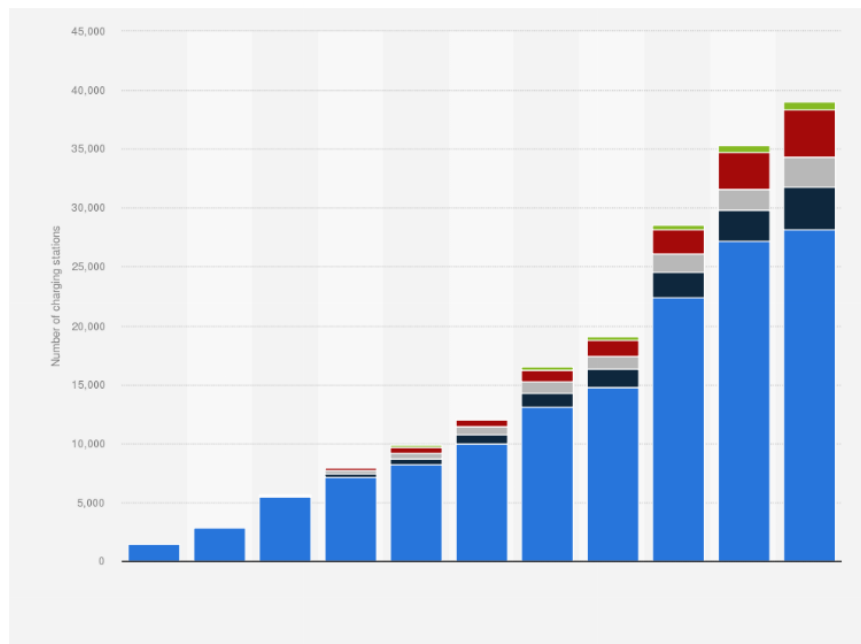


Figure 3 Number of EV charging stations in the UK 2011-2021 (Carlier, 2023)

Regardless, the amount of EVs charge points in the UK has increased from ~1500 in 2011 to over 28,000 in 2021, as can be seen in figure 3. It is important to note that this does not include special charge points such as the proprietary Tesla charger. This 18-fold increase

does seem to suggest the infrastructure is reaching a viable point for general use of EVs in the UK, especially considering that, as of 2022, there are only around 7000 petrol stations in the UK (Hughes, 2022).

3.2.2 Environmental concerns

The extraction of lithium and hazardous waste consequently released into the environment remains an issue. Due to the complexity of the extraction process it is unlikely that it will ever be environmentally friendly. Of course, the same applies to general petrol and diesel vehicles, which release harmful materials on combustion. There is one silver lining regarding lithium batteries that is worthy of mention. EVs batteries have a general lifetime of 10 years, with some staying fit for purpose for up to 20 (National Grid Group, 2022). However, batteries that can no longer hold enough capacity for the purposes of an EVs can still be used in other applications. Generally, EV batteries are deemed unfit for purpose once their capacity has been reduced to below 70%. That still affords plenty of storage for other applications, such as home batteries for homes fitted with solar panels (National Grid Group, 2022). Lithium-Ion batteries can also be recycled, lowering the amount of lithium we would need to extract in the future.

70% of the electricity generated in the UK comes from fossil fuels, as the grid is mixed. This means that EVs are only charged with 30% clean energy. This issue needs to be remediated by upgrading our grid to handle larger contributions from clean energy sources. All the power generated by conventional cars is from fossil fuels, and there are situations that improve the carbon footprint of EVs.

Homeowners with the means of home energy production can charge their EVs from their generators. EVs are also able to sell excess energy stored back to the grid (Li et al., 2015), this alleviates peak-time demand, which employs more fossil fuel burning.

Regarding peak-time demand, energy providers host schemes for cheap charging scheduled around low-demand times (OVO, 2023), when more energy is generated by renewables. This alleviates peak-time demand, further reducing non-renewable dependency.

4 Conclusions

Based on the discussion above, it is safe to say that Lithium-Ion batteries, for the purpose of small to medium portable electronics, are more than acceptable. Their decent power capacity, rechargeability and cost make them ideal for powering these devices.

As for EVs, at this moment there are a lot of obstacles making them less convenient than conventional automotive transport. The infrastructure is not yet at an acceptable place for widespread EV use, the national-grid is not currently able to handle vehicles fast-charging in large numbers, and the cost is out of the median household income's budget. However, judging by the speed in which we have had advancements in this technology since its inception, it is likely that the technology required to make EVs affordable and convenient will come to fruition, especially considering the worldwide push towards EVs and the accelerated rate of their adoption.

All in all, Lithium-Ion batteries have the potential to be used universally as power sources for portable devices, including EVs. At this point in time, the technology is not quite there for a seamless and un-compromising experience across the board. However, it seems likely that in the coming years this will change with the appropriate improvements to infrastructure, and further developments in the field.

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