Long term strategic implications to the UK and World of the current EV battery system methodology adopted by OEMs and the closing window of opportunity for mitigation

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https://youtu.be/uLa7h-uCsb4

Abstract

For reasons we must assume are financially motivated, electric vehicle makers are integrating batteries into new vehicles as bespoke units that are not quickly changeable.

Inherent in this approach is the need to always carry a battery with the mass required for the full vehicle range, typically several hundreds of kilograms (Battery ranges are around 1 mile / kg).

The adoption of a **standard interchangeable EV battery**, around 20kg in weight (used in multiples per vehicle) has significant net positive long term benefits to society and the planet compared to the integrated battery designs being offered by the OEMs:

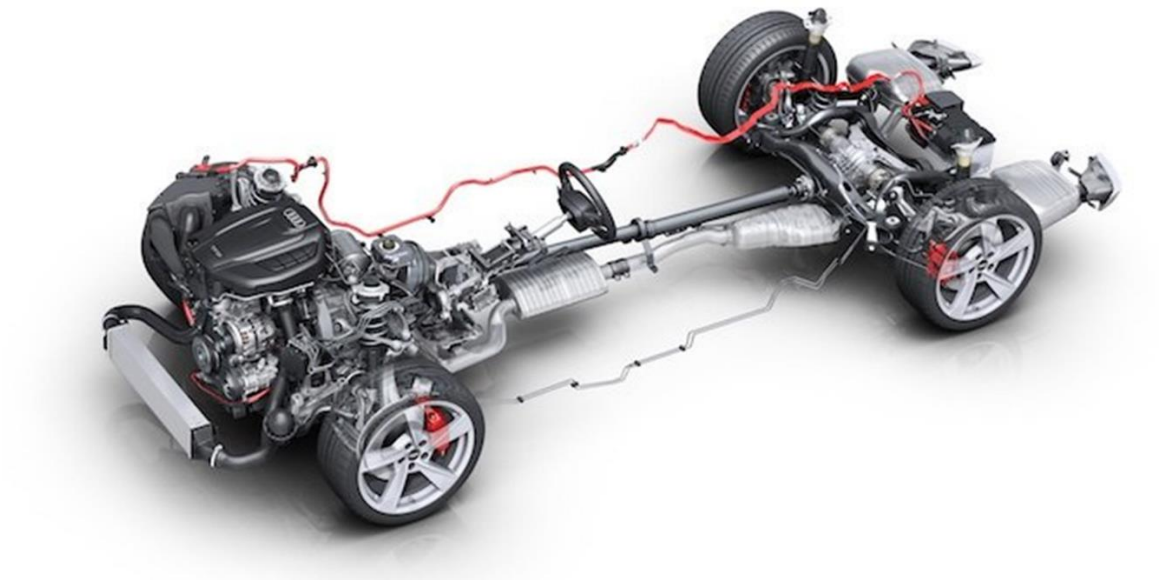
- Less battery mass being transported needlessly leading to..
    - **20% less energy consumption** leading to..
        - **20% cheaper journey costs**
        - **20% less carbon emissions (from primary source)**
        - **Thousands less deaths and serious illnesses** from PM2.5 particles from lighter vehicles
- Significant buffer energy capacity in battery change stations leading to..
    - Lower peak energy generation demand..
        - **less expensive** (less cost to pay back) and **more resilient power grid infrastructure** and therefore..
            - Lower unit energy costs leading to..
                - **Additional journey cost savings**
                - **Lower household energy rates**
- **Significantly less future recycling pain** (cheaper, easier, safer and more effective recycling and reuse, much less likely to end up as a third world problem).
- **Less raw material** – less batteries required overall and better level of reuse means lower levels of mining, processing and associated habitat destruction and carbon emissions.
- **A better experience** (quicker)
- **No range anxiety**
- **No requirement for additional home or work charge infrastructure**
- **Multiple additional uses and benefits (home and other power backup)**

The window of opportunity to act on this information afforded by the 2035 all electric EU and UK mandates is rapidly closing. Legislative change needs to come quickly given the time required to engineer the implications across the supply chain.

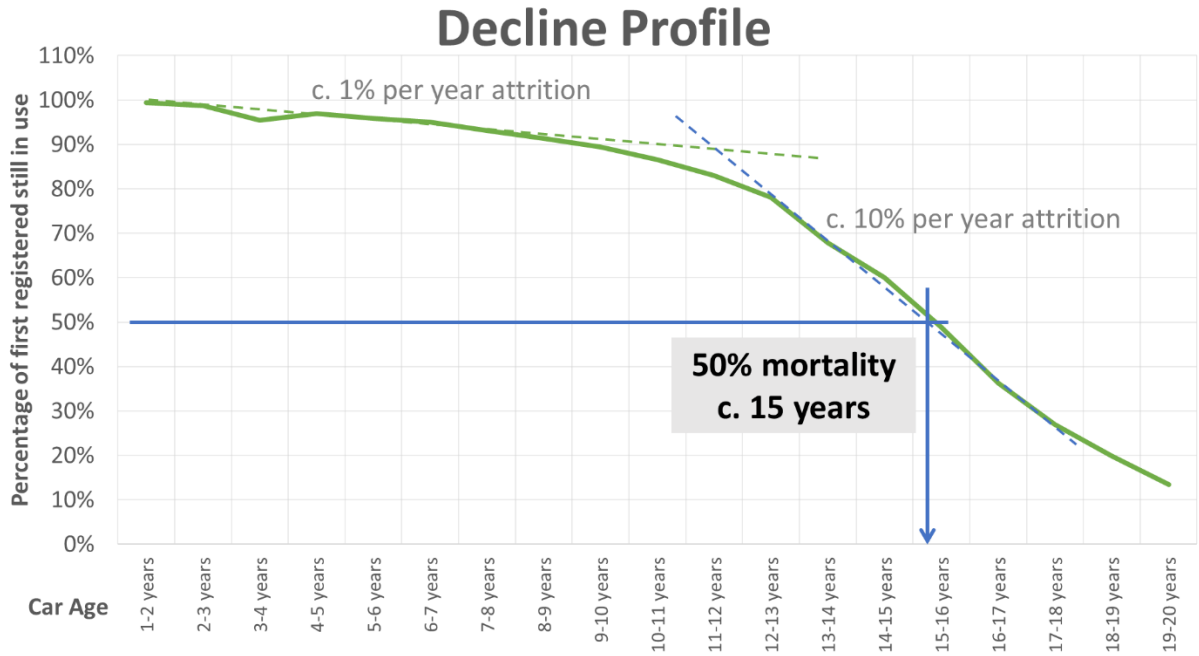
If this fails to happen it will be a significant lost opportunity and probable source of future regret.

Considerations of OEMs motivation for integrated battery design

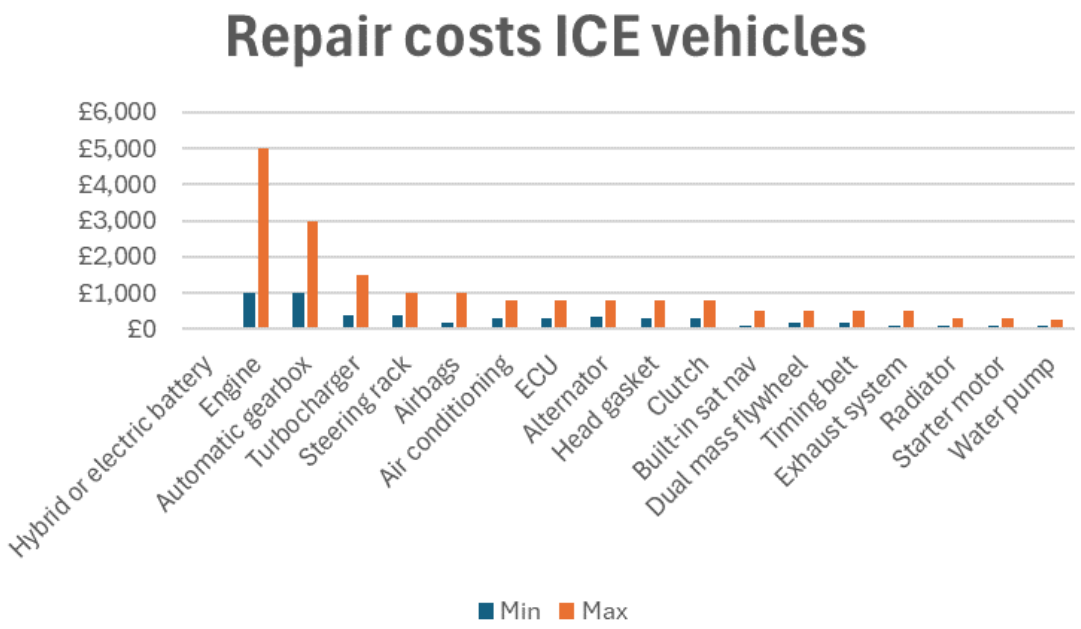
Internal combustion powertrains are extremely complex machines comprising many different systems. The parts in these systems wear during use or degrade over time and eventually fail in a statistically predictable way.

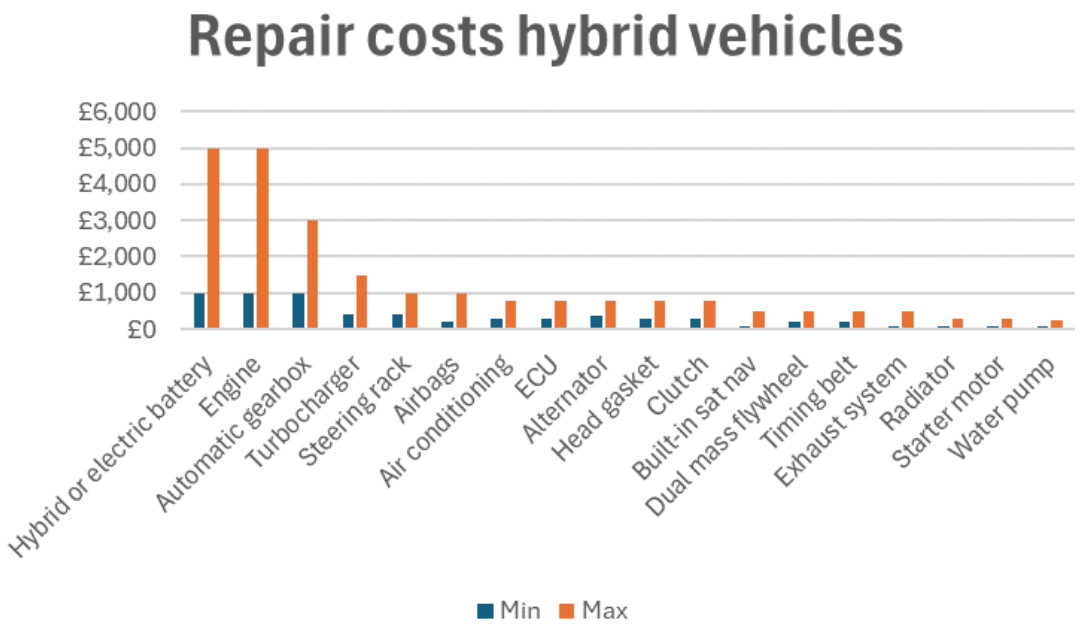


After an initial decline rate of 1% per year for about 12 years cars quickly start to be scrapped by about 10% per year as critical parts fail and replacement costs exceed the vehicle value.

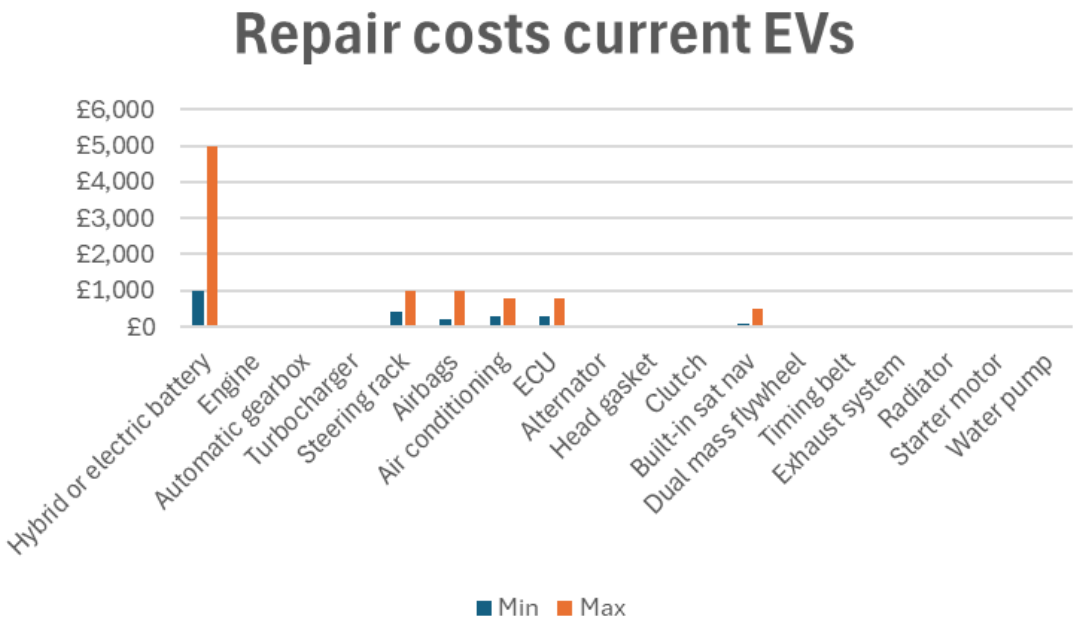


There are multiple points of expensive failure with finite life expectancies meaning ongoing repair costs will eventually lead to the vehicle being broken for parts once costs exceed the current resale value.

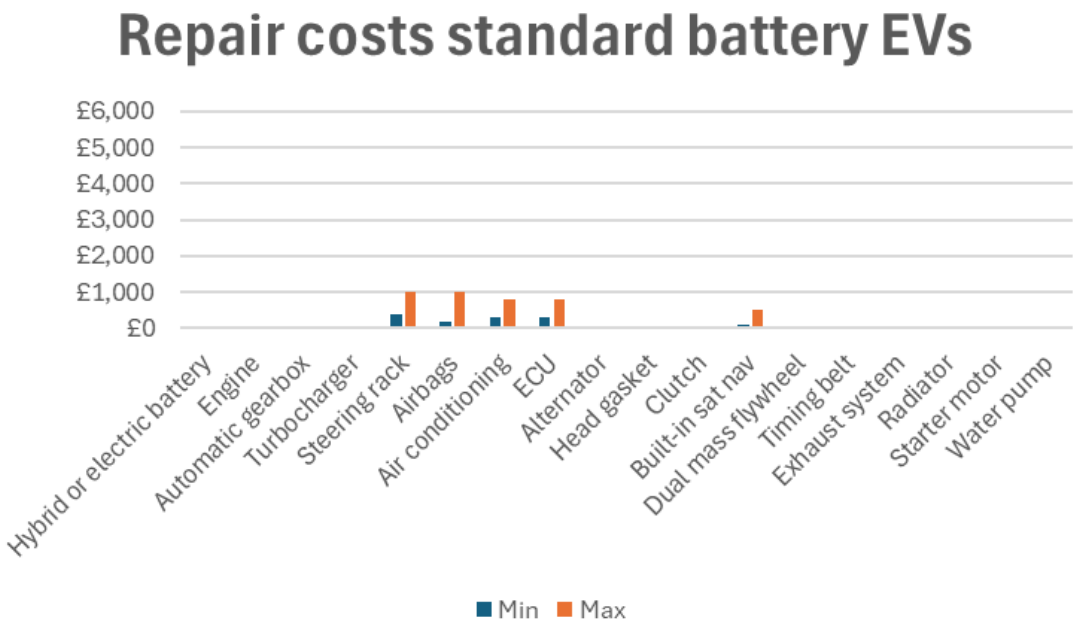




Even though there are many less failure points, the degradation of an expensive integrated battery is certain with use, this more or less guarantees older EV vehicle write offs, and thus indirectly maintains ongoing new vehicle demand.



Interchangeable batteries would significantly disrupt this model. People would likely keep their vehicles for longer on the basis that they still do the job they were purchased for and don't require expensive costs to keep on the road.



Easily replaceable batteries disrupts the OEMs business model of electric vehicle planned obsolescence that drives their new vehicle sales.

As such it is a threat to the overall size of the sector in the long term – without expensive bespoke battery replacements there are few systems left to fail and the replacement costs will be much less likely to lead to scrappage.

Standard Interchangeable Battery

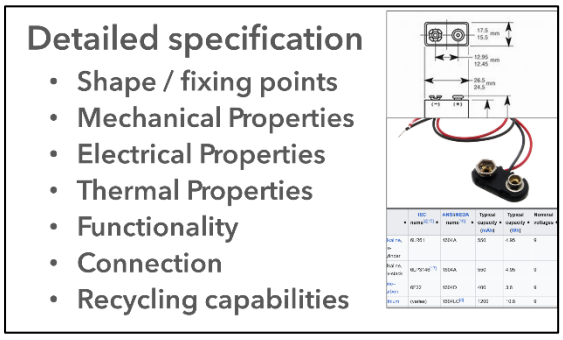
In place of a single integrated battery unit, battery slots provide the option to add range as required and shed weight when it is not.

With current battery technology a notional 20kg lithium battery (reasonably manageable size and mass) would store around 5 KW hours (6.5% Tesla Model 3 2170 capacity) giving a range of 17 miles (27 km) or more depending on the size of the vehicle and total mass of batteries installed.

Range performance per kg will no doubt increase as cell technology evolves, but crucially within the same specification envelope, i.e. in a similar fashion to regular AA and other batteries today.

By defining a standard battery the rest of the supply chain can with confidence start to develop the infrastructure to make, change, charge and recycle them.

The battery could (with the right equipment) provide home backup in the event of power failure, 5 KW hours is about half the average daily home energy use.



Standardisation reduces costs because it increases volumes which means a higher level of process automation and cheaper parts costs.

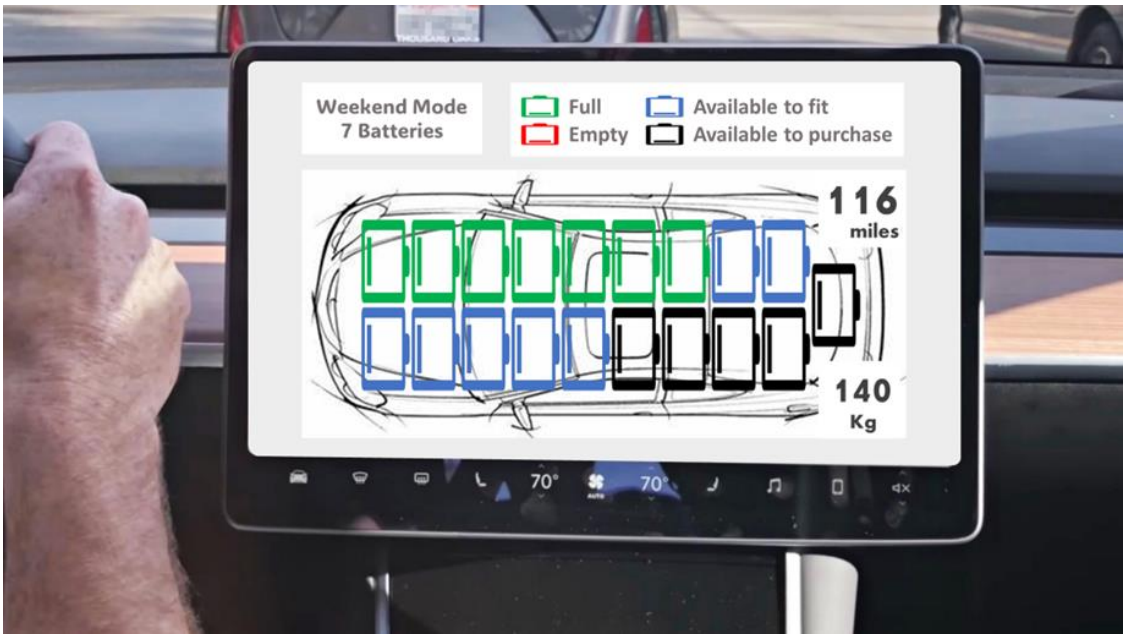
Standardisation opens the market to direct competition which ensures lowest prices.

Vehicles can then be developed with a number of battery slots which don't actually need to be populated for everyday use, significantly reducing the mass of the vehicle and associated energy requirements.

Swap Stations

Reliable automated battery change hardware at a scalable affordable cost is an engineering task within the scope of the engineers working in the automotive and other similar sectors, not a feat of impossible difficulty.

When the car arrives over the battery swap station the number and position of the batteries to be changed is communicated automatically based on the profile chosen.

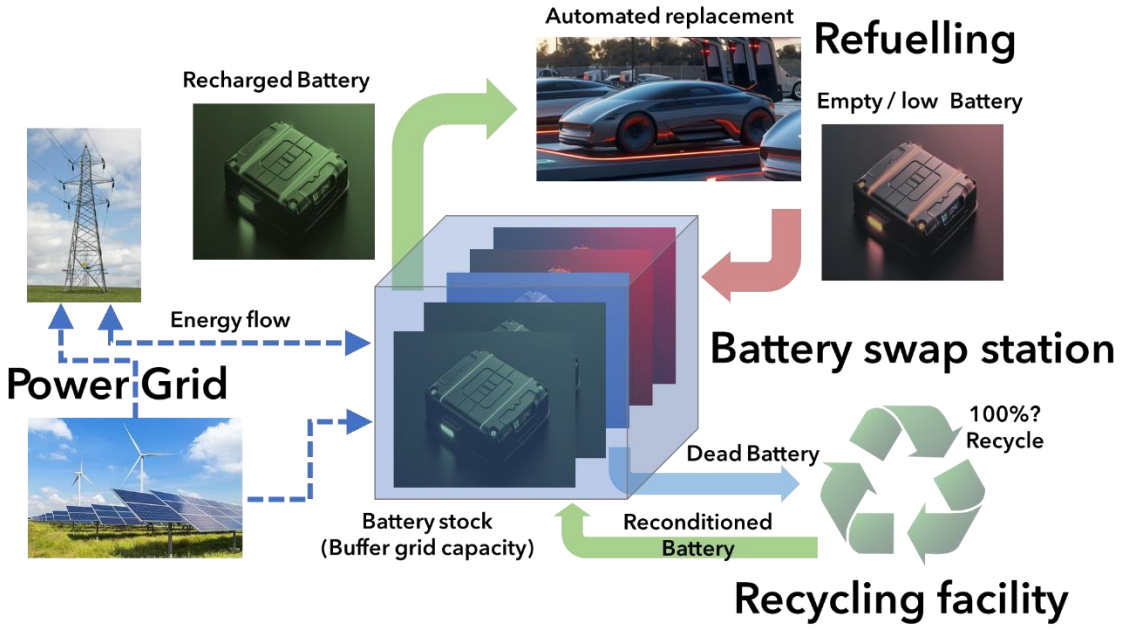


The driver does not need to leave the vehicle.

Probably less than a minute later the process is complete, the full batteries minus any residue energy removed is totalled up and charged, potentially automatically.

Integrated Battery Energy System

Distributed battery storage and recharging facilities could be extremely usefully integrated into the power distribution network in such a way that energy can be borrowed back during peak requirements with little to no latency, i.e. immediately as required. This means lower peak power generation growth is required as the demand for electric vehicles increases, which is infrastructure costs that are ultimately paid for by the consumer.



The standard design and high enough volumes allow dead batteries to be converted back into working ones in automated facilities not stripped for parts or repurposed manually.

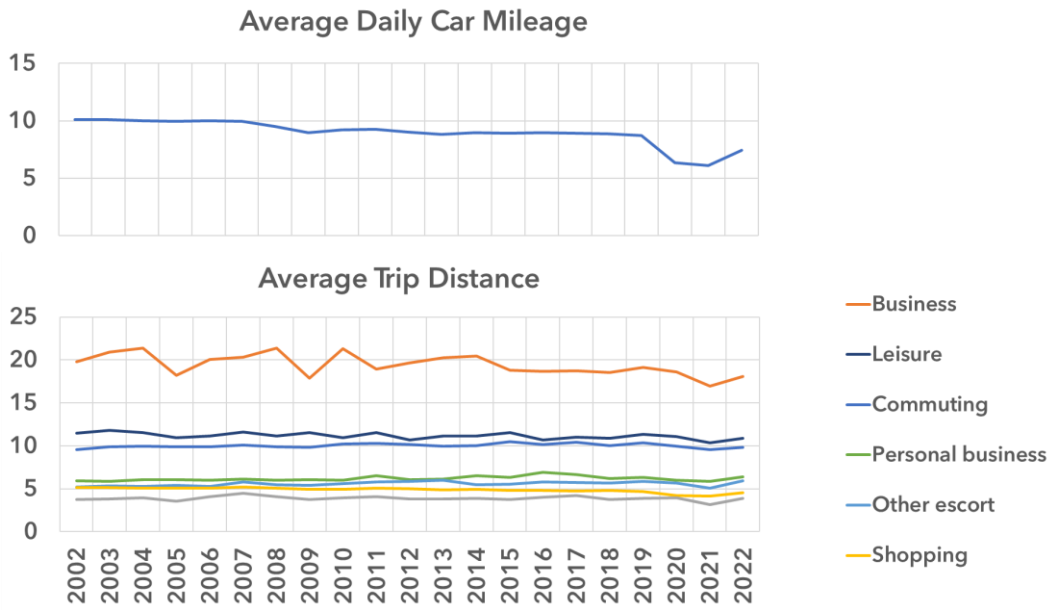
The underground battery carousel and charging system can be installed virtually anywhere that has suitable power and vehicle access, without the restriction of petrol or diesel facilities, meaning they probably will be in more locations. They can potentially be powered off the main grid in remote areas. They are fully automated and only require manual intervention for maintenance and battery removal for recycling.

Each battery swap station needs to carry enough batteries to ensure recharging can be completed before reuse.

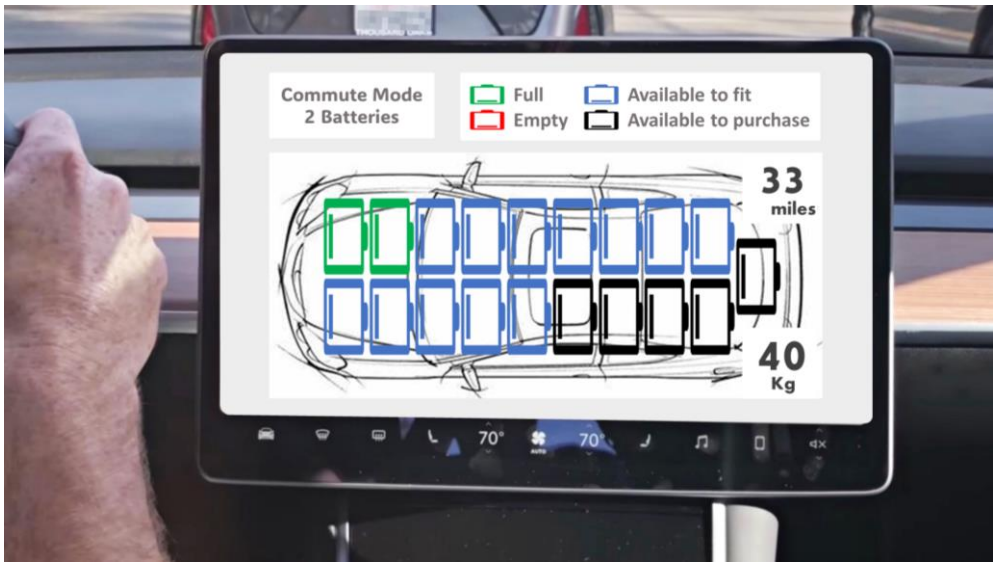
For example, if in peak times an average of 2 batteries are being replaced every minute and the charge time is 20 minutes then 40 batteries are required.

Excess heat generated from charging might usefully be used for a multitude of other purposes, circumstances permitting.

Energy Consumption



Most people only travel a short distance each day, and they want to save money and reduce emissions (when it's easy to do so). They will presumably choose to not carry around anymore heavy batteries than are actually required for normal use, plus a bit of contingency.



For the vast majority that might be just two batteries weighing 40 kg.

Integrated batteries are a not insignificant mass to be transported needlessly. As it currently stands, the average EV motorist will be moving an excess of perhaps ¼ tonne over 7000 miles each year (If everyone is driving electric that is 300 billion miles in total).

Very roughly this will consume about 75 TWh of electricity or about **50% of the total currently installed renewable energy output in the UK**. **Needlessly**.

Home and Work Charge Points

Plugging a vehicle in at home for charging rather than waiting at a garage is not always practical. Not everyone owns the property or can guarantee their overnight parking location and that it is close enough.

The average cost of installing an electric car charger is around **£1,000.**

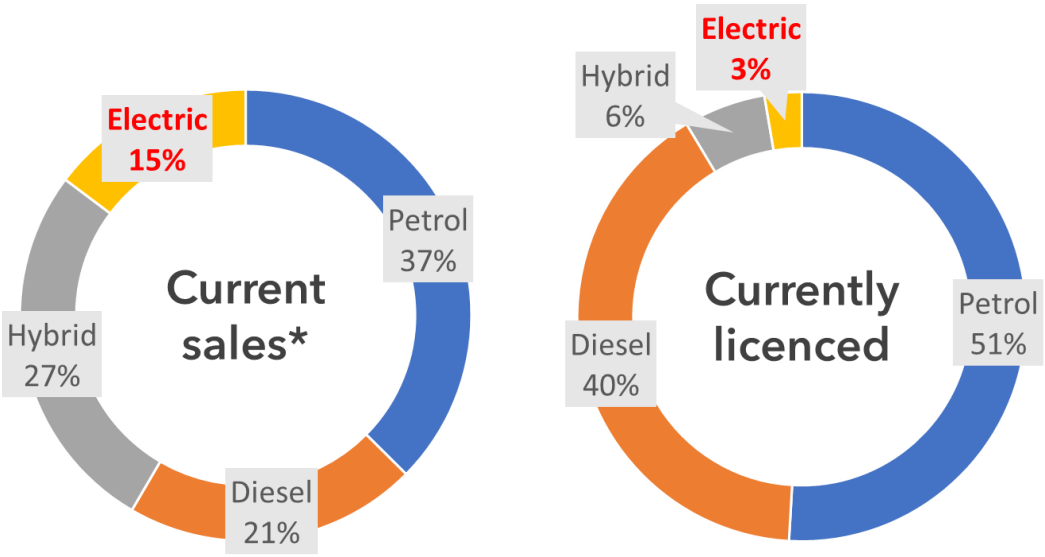
Assuming millions will be required this equates to **billions of unnecessary costs**.

The hardware is inevitably going to be imported.

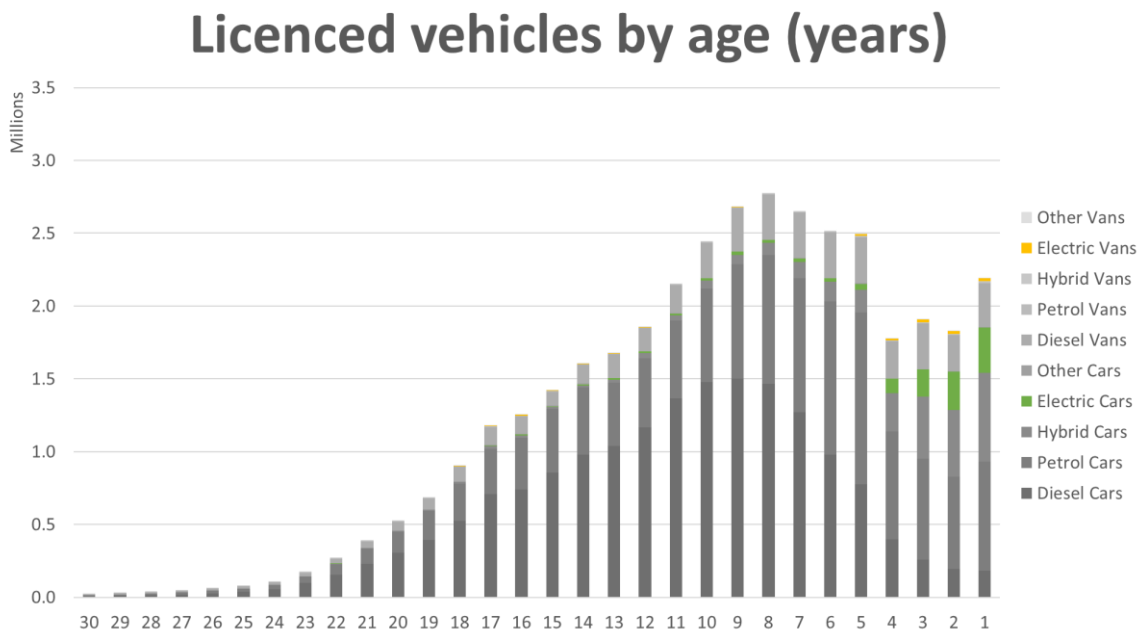
They are not required with interchangeable batteries.

Future EV Projections

Currently fully electric vehicles make up 15% of the 2.4 million annual sales (*based on new registrations) and only three percent of the 38 million cars and light vans on the road today.

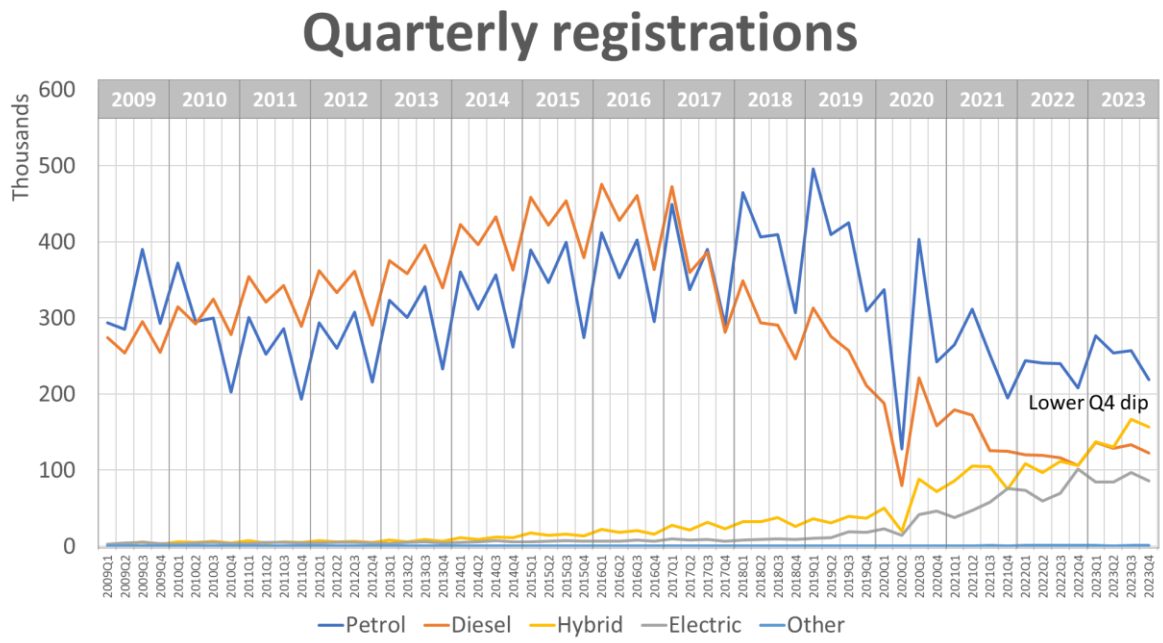


If we look at the vehicles on the road by age and fuel type we can see why only 3% are currently electric.

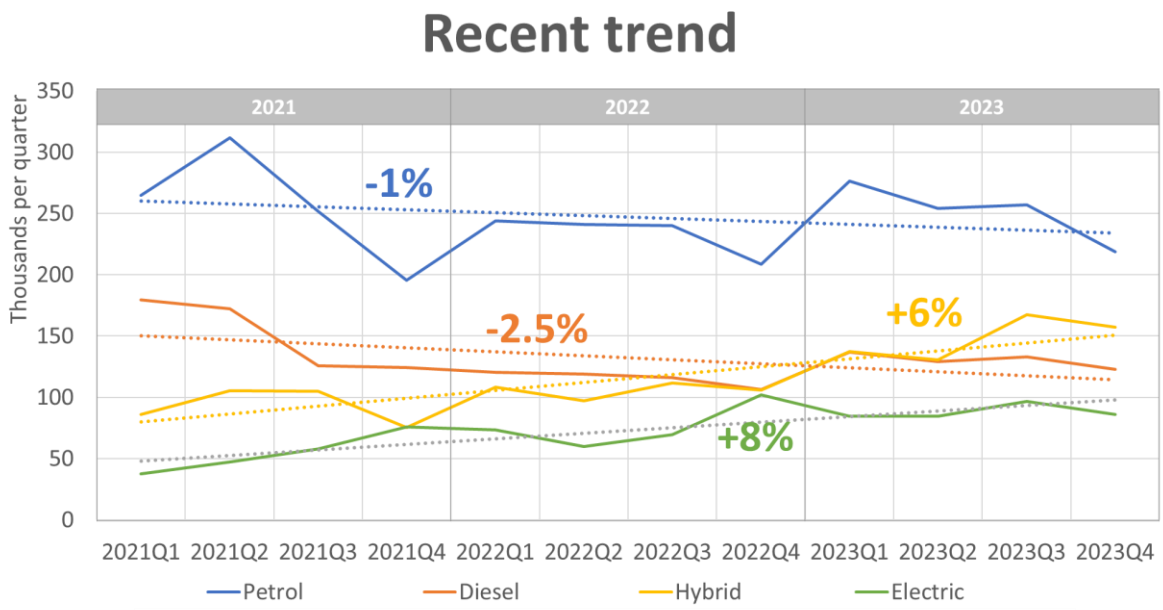


There is a long tail of older predominantly ICE vehicles.

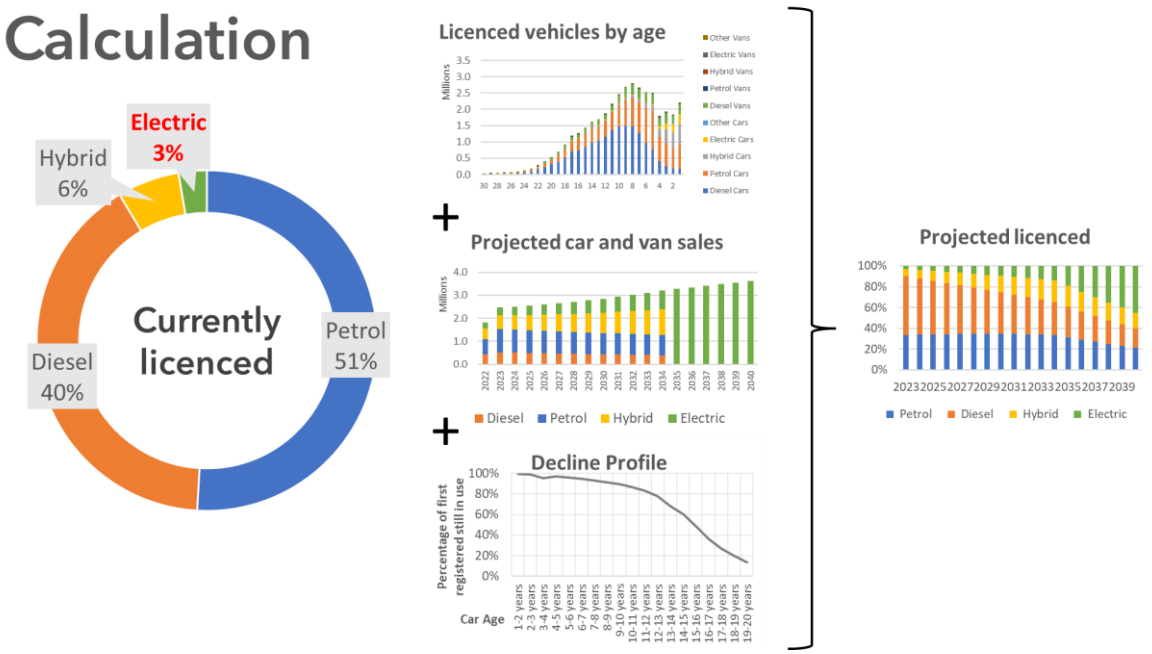
Looking at new vehicle registrations over time we can see a pronounced shift from diesel to petrol in 2018 and an increasing rise of hybrid and fully electric vehicles.



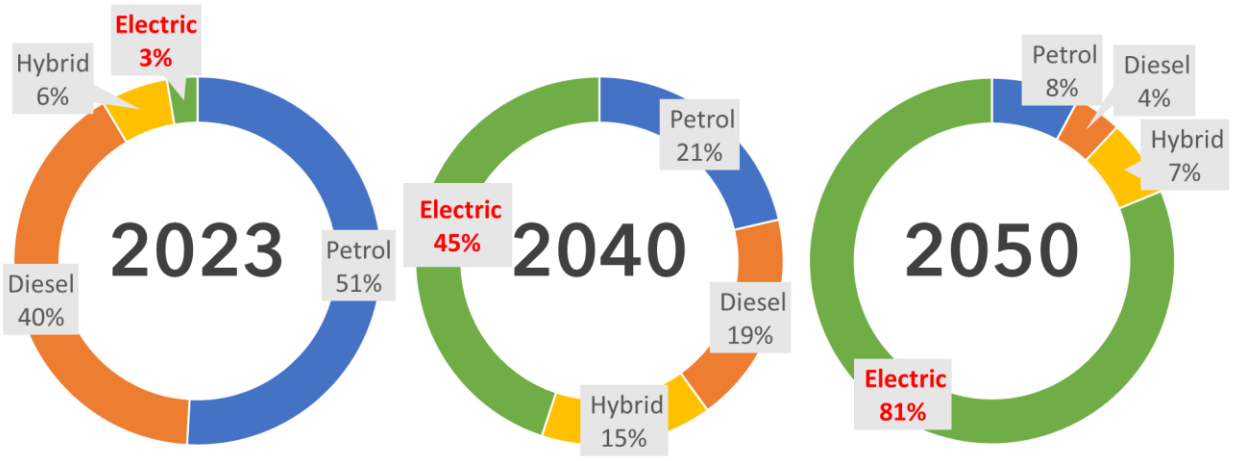
Looking at the most recent period post pandemic, sales of new diesel and petrol cars and vans are decreasing slowly at 2.5 and 1 percent respectfully whilst sales of hybrid and electric are rising at a slightly faster rate of 6 and 8 percent.



Projecting car and light goods van sales into the future based on the current trajectories and applying suitable decline curves it is possible to roughly calculate the expected number of EVs on the road in the future.

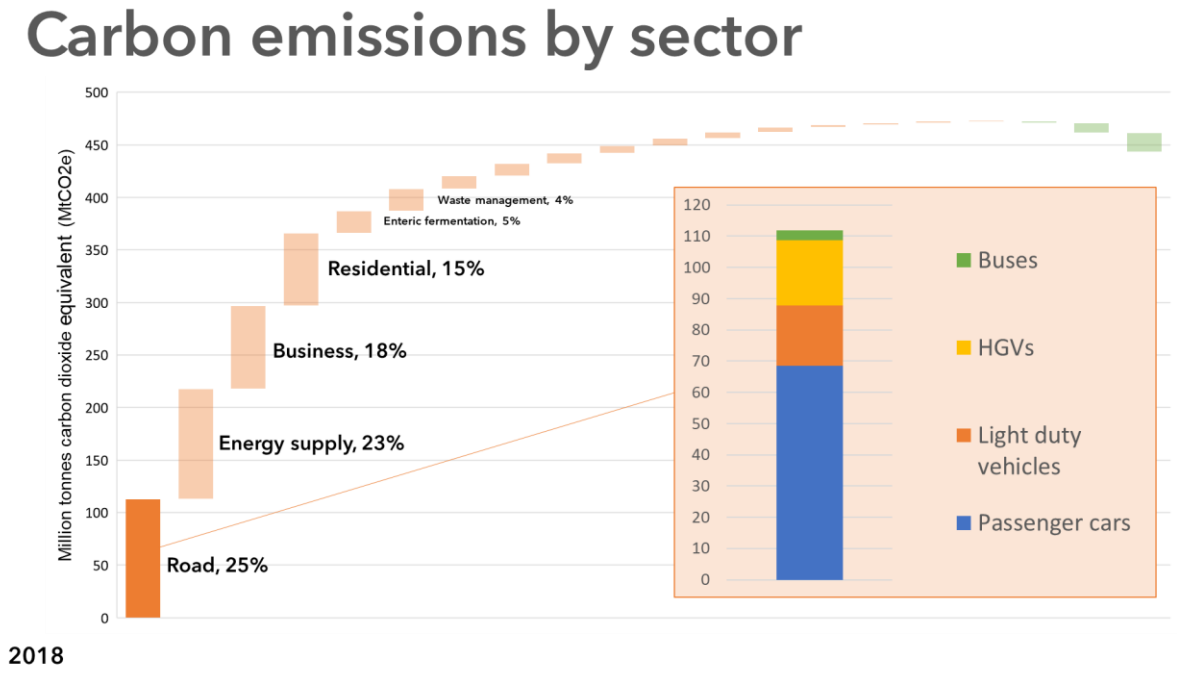


By 2040, 5 years after the introduction of fully electric vehicles, only 45% of vehicles being driven will be fully electric, rising to 81% by 2050.



Carbon Emissions

Given that the emissions from cars and vans makes up roughly 20% of total UK CO2 emissions, the quicker we make the switch to electric the better.



People are going to be much more likely to switch to electric if the service proposition is better than they get today with ICEs, not worse.

Current owning and driving EVs is rightly perceived as being more difficult and potentially troublesome than for the petrol or diesel counterpart.

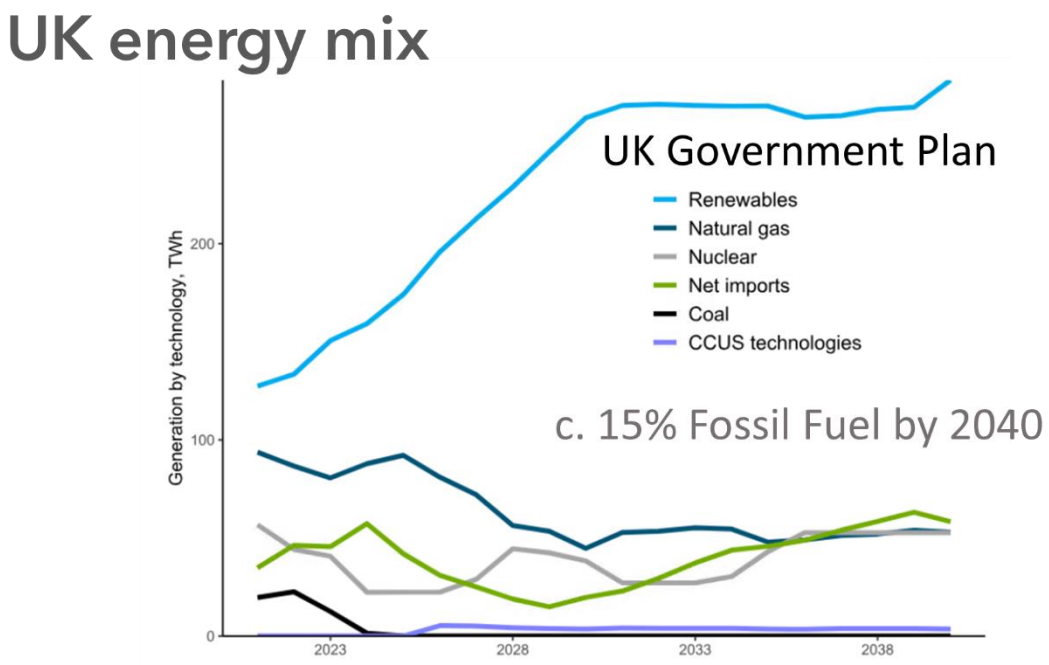
It is valid for people to ask why, when we are living in such a technologically advanced age, are we going backwards with the personal transport experience?

There are reasons why people are not switching faster to electric.

Interchangeable batteries would be the opposite (once scaled) and offer a better refilling experience than ICEs today and no range anxiety.

Even after going mostly electric, it is worth remembering that whilst we still use fossil fuels in the energy mix, electric cars are just proxy carbon emitters, the higher the energy use the more carbon is emitted.

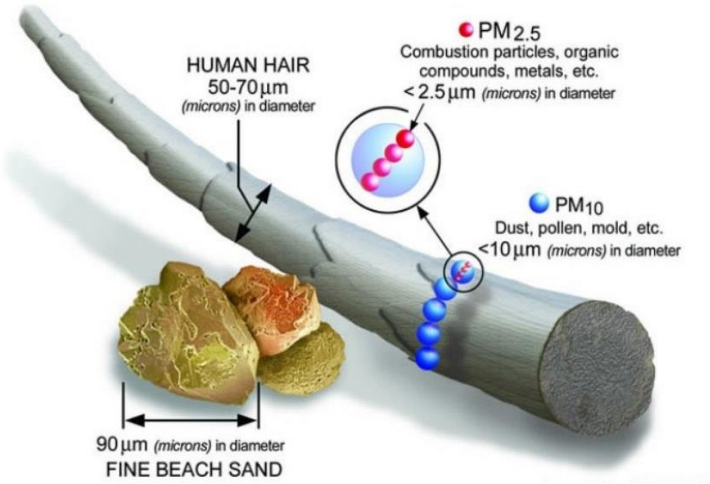
By empowering people to choose how much battery weight to carry it is possible to consume less energy and emit less proxy CO2.



UK government projections for energy mix and overall requirements show that by 2040 about 15% of the energy mix is still from hydrocarbons.

Heath issues associated with PM2.5

There are a frightening number of health issues associated with breathing in small particulates in the air, termed PM10 and PM2.5 for their size in microns.

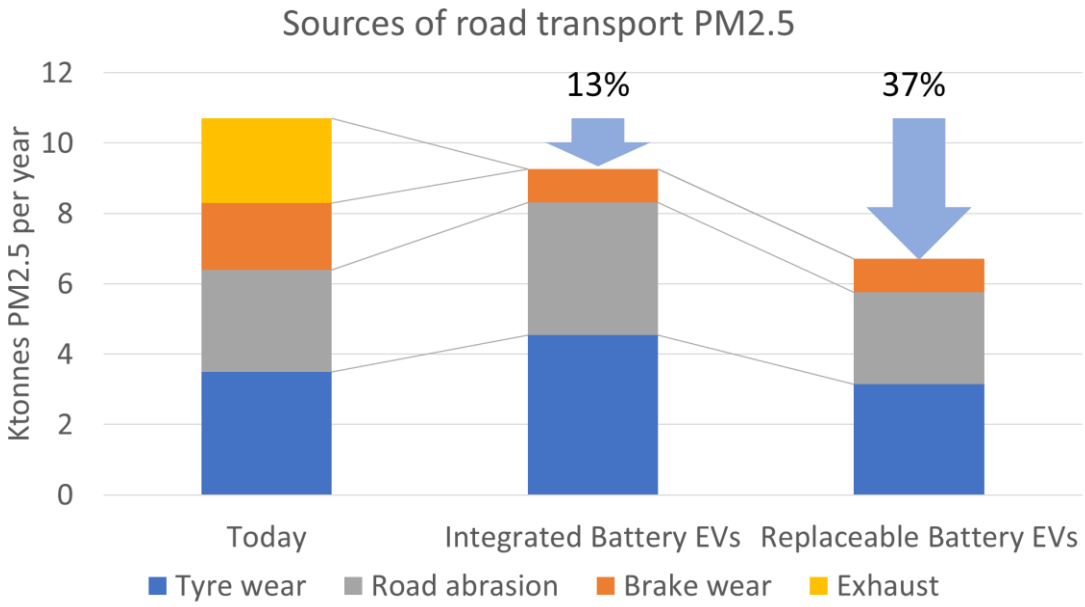


Tens of thousands of life's are cut short, over 100 thousand serious illnesses and millions of days lost each year due to respiratory issues associated with PM2.5. Not to mention the associated cost to the NHS.

Studies have estimated that transport related particles contribute about twelve percent to these figures.

		UK all sources	Transport (12.4% of total)
Mortality	Life-years lost	327,769	40,643
Mortality	Premature deaths	30,018	3,722
Infant mortality	Premature deaths	70	9
Chronic bronchitis	Cases	25,582	3,172
Bronchitis in children aged 6–12	Cases	102,386	12,696
Respiratory hospital admissions	Cases	11,652	1,445
Cardiac hospital admissions	Cases	4,523	561
Asthma symptom days in children	Days	1,171,559	145,273
Restricted activity days	Days	40,809,466	5,060,374
Lost working days	Days	6,097,215	756,055

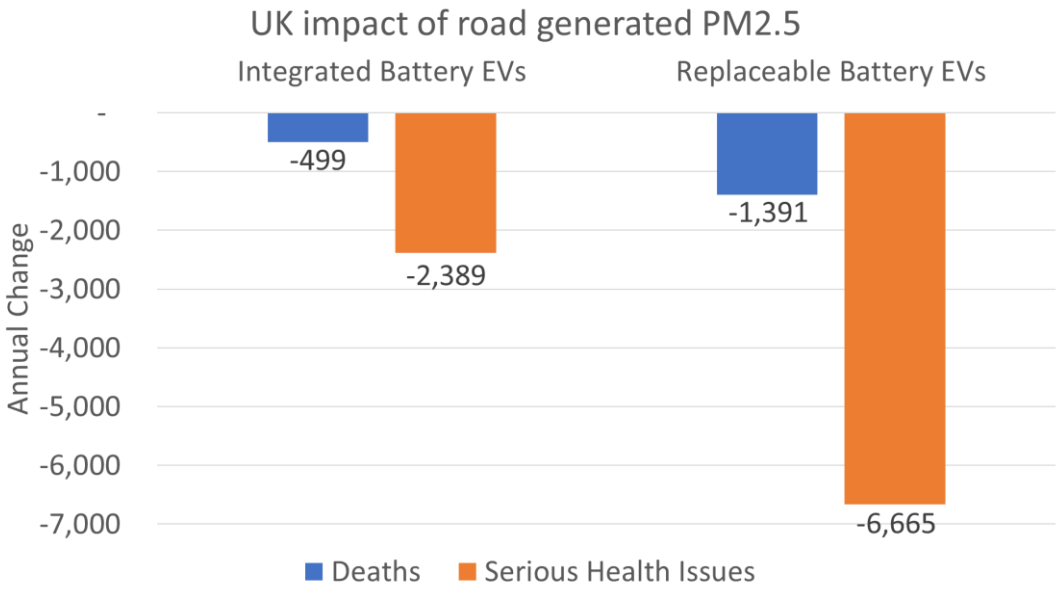
The breakdown of where the particles originate suggest a reasonably even split between brake dust, tyre and road particulates and exhaust emissions.

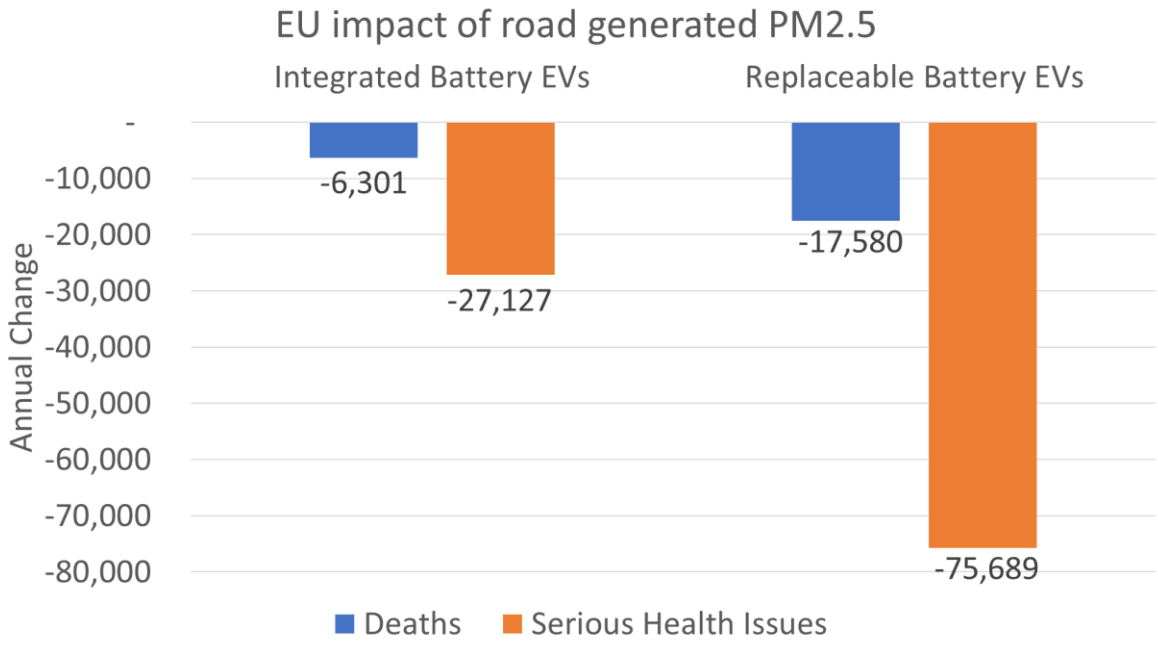


According to one tyre manufacturer electric vehicles chew through their tyres 30% faster than their ICE counterparts, PM2.5 emissions will be commensurately increased although brakes dust is reduced by 50% due to regenerative braking. Overall there is a 13% reduction in road transport related PM2.5 emissions with current EV battery designs.

Assuming a 10% reduction of average vehicle mass under the interchangeable battery scenario, there are commensurate reductions in particles from tyre and road abrasion and a net reduction in road transport related PM2.5 emissions of 37%.

Reducing PM2.5 particles will saves lives and serious health issues.




EU impact of road generated PM2.5
Integrated Battery EVs
Replaceable Battery EVs
Annual Change
-
-10,000
-20,000
-30,000
-40,000
-50,000
-60,000
-70,000
-80,000
-6,301
-27,127
-17,580
-75,689
Deaths
Serious Health Issues

Recycling and reuse

At some point in the 2040s 2 million plus batteries a year will need to be recycled with a multitude of different configurations, making this even more of a challenge and possibly dangerous. There have been several recent lithium recycling factory fires.

There will likely be expensive one-off shipping costs involved in battery recycling with current designs and questionable overall recycle rates.

It is debatable whether any of the raw materials recovered from the batteries will be used in the manufacture of new vehicles, thus perpetuating the demand for more raw materials and the associated mining, refining, processing, manufacture and transport environmental impacts and costs.

Standard battery configuration enables safer and more automated used battery processing back into use and has a much lower environmental footprint.

Conclusions

There are many advantages to society from standard interchangeable EV batteries over bespoke integrated batteries being developed by the manufacturers.

	Bespoke batteries	Standard interchangeable battery
Ability to home charge	☹ Not universal	☺ More options and no real need
Home charger costs	☹ c. £1k	☺ Likely to be significantly cheaper
Charging wait	☹ Upwards of 20 minutes	☺ Minutes
Range anxiety	☹ Current barrier to adoption	☺ Gone
Vehicle costs	☹ More expensive, significant battery costs	☺ Less expensive than ICEs with minimal batteries installed
Residue value	☹ High depreciation currently	☺ Low depreciation and longer vehicle decline curves
Electric adoption	☹ Range and charge anxiety slowing growth	☺ More incentives and lower entry costs if sold with limited batteries
Energy usage and carbon emissions	☹ Higher than necessary because of the additional mass	☺ Estimated to be 20% less and therefore 20% less CO2 emissions from primary source
PM2.5 (very fine particles) respiratory health issues	☹ Road and tire abrasion increased	☺ 37% less than today for road transport
Energy costs	☹ Various tariffs, some high costs for rapid charging	☺ No requirement to pay extra. Lower infrastructure costs to absorb
Buffer energy	☹ More complex to redirect millions of individual electric vehicles	☺ Swap stations provide valuable buffer energy capacity
Recycling issues	☹ Multiple battery designs to recycle likely leading to lower process efficiency and therefore cost and overall effectiveness.	☺ Reasonable opportunity to achieve a near closed system with high levels of efficiency and reuse rates

However, this can only likely be influenced at an EU level through appropriate legislation, the vehicle manufacturers will never collectively agree to do so without external influence.