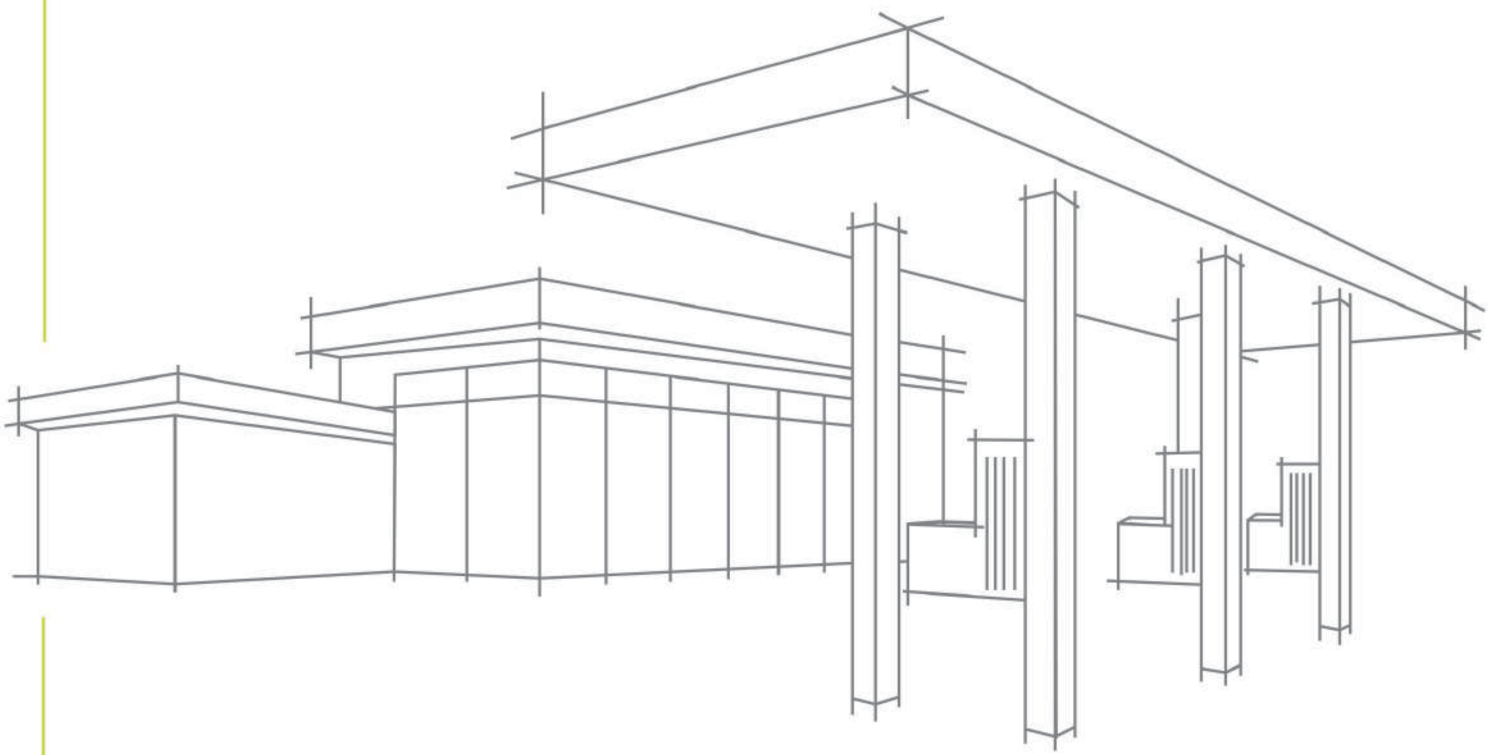
WHITE PAPER

LOW EMISSION VEHICLES, AN AUSTRALIAN PERSPECTIVE PART 1



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WHITE PAPER

Low Emission Vehicles, An Australian Perspective - Part 1

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AT A GLANCE

- This paper addresses electric vehicles including hybrids (HEV), plug in hybrids (PHEV) and battery electric vehicles (BEV).
- Whilst PHEV and BHEV have no tailpipe emissions, on a life cycle analysis (LCA) basis, there is no such thing as a zero-emission vehicle.
- Based on the Australian electricity generation mix, PHEV are likely to achieve lower LCA greenhouse gas emission reductions than BEV over the next 10-20 years.
- When combined with renewable fuels, PHEV could achieve equivalent emission reductions to a BEV using 100% renewable electricity.
- Hybrid electric vehicles (HEV) currently outsell PHEV and BEV electric vehicles by a factor of 14 and are likely to remain a part of the vehicle fleet for many years. Comparable emission reduction can however be achieved through the development and use of renewable fuels.

1.0 INTRODUCTION

This white paper is the first of a two-part series looking at the types of low emissions vehicles currently on offer in Australia and which, in the current energy mix context, represents the lowest emission option in the most cost effective and feasible manner. Part 1 of the white paper will focus on electric vehicles and hybrid vehicles. Part 2 will discuss hydrogen vehicles.

The term “zero emission” has widely been used to promote battery electric vehicles. Whilst zero tailpipe emissions reduce pollution in large cities, it does not represent the full picture in terms of emissions. For any vehicle it is important to understand the net life cycle greenhouse gas (GHG) emissions, in order to measure the impact on climate change and achieving net zero by 2050.

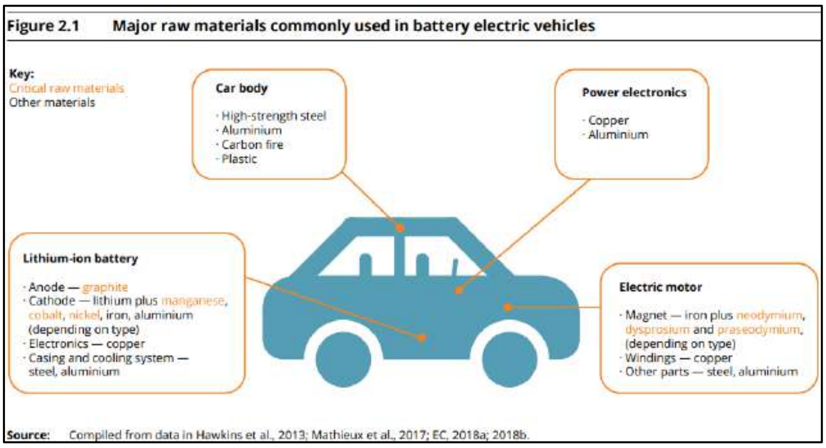

Figure 1: BEV Materials [1]

Life cycle analysis (LCA) accounts for emissions during the extraction of raw materials, vehicle manufacturing, fuel production and utilisation, as well as end of life treatment [1]. For example, electric vehicles require a range of raw materials as shown in Figure 1. On a LCA basis, there is no such thing as a zero-emission vehicle.

There are different varieties of electric vehicles including: - hybrid electric vehicles (HEV), plug in hybrid vehicles (PHEV) and battery electric vehicles (BEV). Whilst all these vehicles have an electric drive powered by a battery.

- HEV have an internal combustion engine (ICE) that charges the battery or directly drive the wheels when needed. The battery cannot be charged externally by plugging in to an external power supply.
- PHEV have a battery that can provide 50-80km of range which can be recharged via plugging in to external power. They also have a petrol driven internal combustion engine that can also be used to recharge the battery whilst driving or directly drive the wheels when needed.
- BEV vehicles operate only on the charge within the battery with a typical range of 200-600km. They can only recharge via plugging in to an external power supply.

HEV have been available for the longest period of time and are by far the biggest seller today with 70,466 sold [2] in 2021 versus 5,149 BEV and 3,372 PHEV.

The Australian Electric Vehicle Market Study [3] predicts PHEV and BEV electric vehicles will represent 30% of the existing vehicle fleet by 2040 under existing government policy. Market share of both varieties is expected to progressively grow. We will discuss battery electric vehicles first and then move on to hybrid vehicles.

2.0 HOW GREEN ARE BATTERY ELECTRIC VEHICLES?

The general public is gaining an increasing awareness of LCA when considering zero emission claims from electric vehicle car makers. When recharging a BEV, the source of power generation is critical. Electricity generation in Australia is still largely dependent on fossil fuels and is responsible for 33% of national GHG emissions [4]. Despite significant investment in solar and wind, 76% of our electricity is still generated from fossil fuels, compared to 90% in 2000 [5].

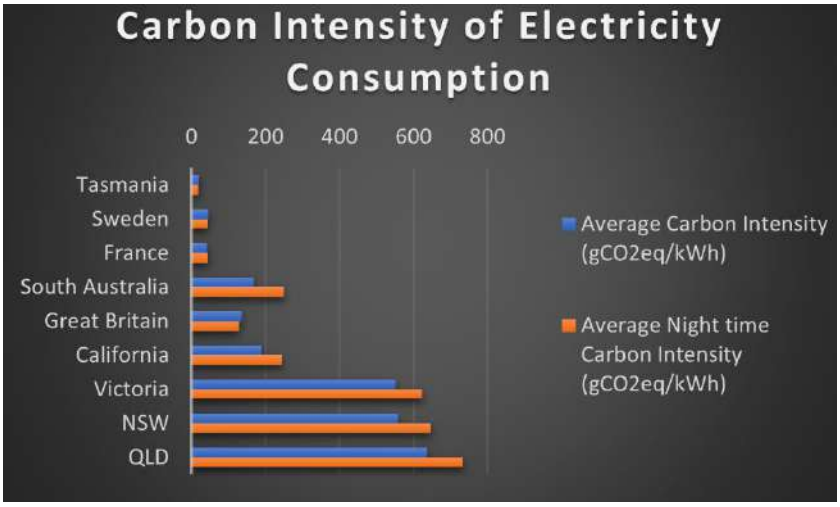

Figure 2: Source app.electricitymap.org/map

Notably, Tasmania leads the way with world's best performance with hydroelectric, wind and solar production providing almost 100% renewable power 24 hours per day. However, Tasmania has only 2% of the Australian population. Victoria, New South Wales, and Queensland have some of the highest emission power generation in the world [6], several times greater than that of France and Great Britain. Whilst Queensland has a target to reduce fossil fuel electricity generation to 50% by 2030, 100% renewable electricity across Australia is still many years away.

The time of day that a BEV is recharged can make a significant impact on the emissions comparison between a BEV and conventional ICE vehicle. Trials undertaken by the Victorian government [7] have found households with an electric vehicle generally charged at night, with fleet vehicles mostly charged during business hours.

Queensland has the highest installed production capacity of solar panels in Australia [8], and one of the best climates to maximise their utilisation, however solar typically peaks at 40% of the power mix during daylight hours. During evening peak periods and overnight the mix changes to 90% fossil fuels generation (predominantly coal) [9].

Figure 3 shows that a BEV recharged using electricity generated from coal has higher net emissions from a greenhouse house gas (GHG) perspective than an existing internal combustion engine running on petrol or diesel.

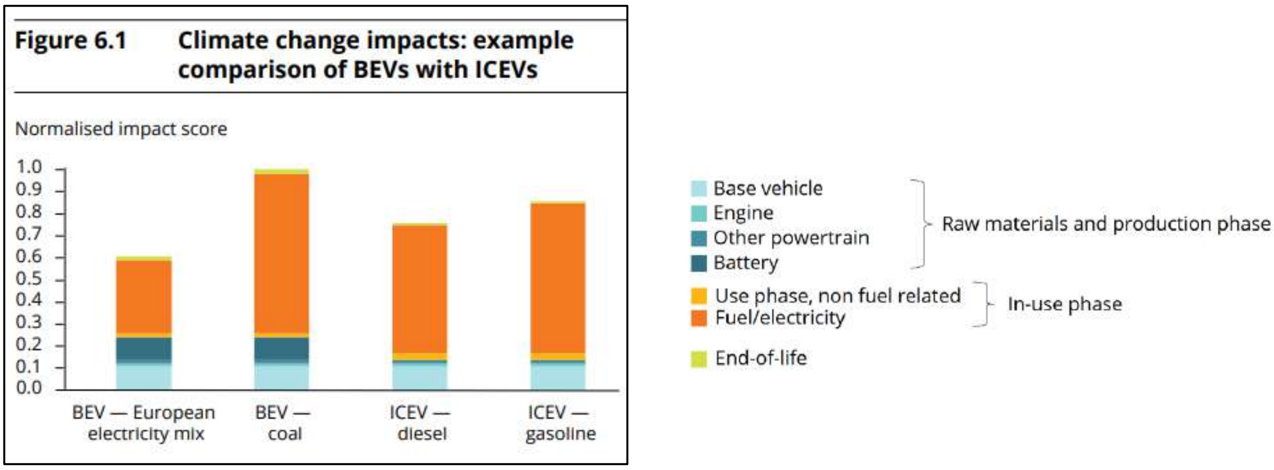

Figure 3: Comparison of BEV and ICEV Ref [1]

So, whilst a BEV could have a very green emission footprint in Tasmania, the same vehicle may have similar or even higher emissions than a conventional internal combustion engine vehicle on the eastern coast of Australia where recharging from the standard grid / current energy use mix, particularly at night.

3.0 CURRENT CHALLENGES OF CHARGING WITH A BEV

For comparison, a Tesla Model 3 LR has an 82kWh battery capacity and an official range of 602km, similar to a conventional vehicle. Current base purchase price for a new vehicle is $77,150 [10], approximately two times the cost of a comparable vehicle with an internal combustion engine.

In relation to the recharging time for a BEV, the cost and the energy efficiency vary significantly with the source of power and type of charger you are using. Charging the Tesla at home is likely to be cheapest at ~$22 based on a 2021 national supply chain average price of 27.43¢/kWhr [11]; however, the charging time is significant with a full charge taking 34 hours using a conventional 10A circuit or 23 hours from a new dedicated 15A circuit installed by an electrician. Faster charging is possible with a custom 30A (7.2kW) circuit, however this typically requires a new switchboard and network supply connection upgrade.

For charging outside of the home, a new network of superchargers is slowly being established, ranging from 22kW to 350kW. However, using a bigger charger does not necessarily mean your car will charge proportionally faster or for the same price. Even using a 300kW charger, the Tesla will only accept 180-200kW until it is 40% charged reducing sharply down to < 50kW above 80% charge [12]. Cheaper BEV such as the Hyundai Kona and Kia e-Nero peak about 70kW falling away to 25kW at 80% charge.

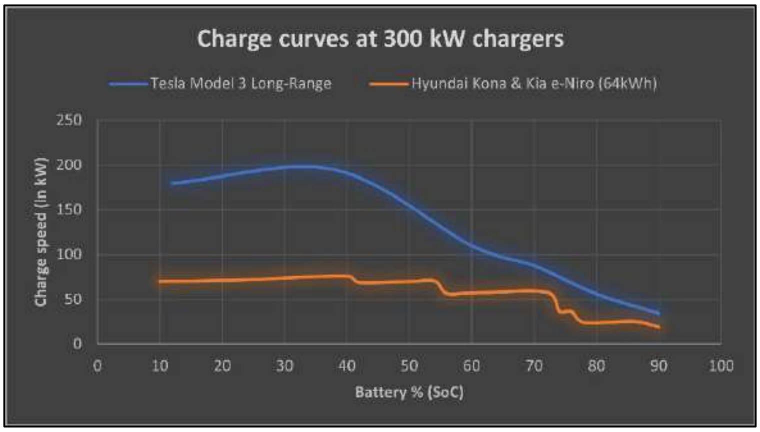

Figure 4: FastNed Ref [12]

The cost for charging with superchargers varies with who operates the facility. Tesla, [13], currently quote $0.47/kWhr, nearly double what you will pay at home. However, this varies with the supplier with pricing varying from $0.30-$0.60/kWhr [14]. So, a full charge for the Tesla from zero will likely cost in the order of $25 - $50 depending on whose supercharger you use.

In addition to cost, it is important to consider charging time and driving range. The user experience is more akin to a mobile phone, not like petrol where you get the same mileage throughout.

While battery technology continues to improve, it is generally observed that batteries discharge from 10% to zero very quickly and chargers become slower as the overall charge level increases, as reflected in Figure 4. This can result in users operating the vehicles between 20-80% battery for the quickest charging convenience and peace of mind not to get stranded.

If you are touring, being able to access a powerful supercharger along the highway is critical. The Queensland electric superhighway, [15], comprises a combination of 22kW and 50kW chargers which take roughly 1-2 hours to achieve a 50% charge. Notably, testing by Which Car found that the Tesla could be charged to 64% within 16 minutes using a 350kW supercharger [16]. However, similar to conventional ICE vehicles, published fuel economy and range data is not reflected in the real world. Despite conservative driving, actual range found by Which Car was 465km versus the published 602km [10].

Figure 5: Queensland Charging Superhighway

One of the other considerations of the BEV, is degradation of the battery over time and the need for replacement. The Tesla Model 3 LR 82kWh battery comes with an 8-year warranty that guarantees 70% retained capacity. So, after this time, your range may be reduced from 465km to 325km. Replacement costs are not cheap with recent estimates at $US13,000, [17]. Tesla claims that batteries should last over 300,000 miles, so if you can live with the reduced range, this major expense could be delayed.

4.0 INTEGRATING BEV CHARGING INFRASTRUCTURE INTO EXISTING SERVICE STATIONS

Public charging infrastructure for BEVs is critical for longer / more frequent road trips. Service stations, including large side-of-highway travel centres, are seen as logical locations to incorporate this charging infrastructure given both their location and their current customer service offering (driver rest amenities, convenience items etc).

Figure 6: Tesla Supercharging Facility

TfA Project Group (TfA) have designed service stations and travel centres in Australia for over 25 years. In recent years, we have worked on numerous projects that include the installation or future provision for electric charging infrastructure into both new and existing service stations.

Notably, the existing metropolitan service station model does not readily lend itself to public EV charging. Where a typical service station can refuel eight (8) traditional petrol / diesel cars at once, the addition of a single 50kW charger (1 hour to 60% charge a Tesla 3) will overload many existing switchboards. To install multiple superchargers will often require not only a new switchboard but also an upgrade to the street transformer and network supply connection to the site. In the short-term existing sites are not practical for more than 1-2 small chargers and 1-2 cars at once. New sites are typically being planned for at least 1 x 50kW EV charging capacity.

5.0 UPGRADING ELECTRICITY GENERATION, THE GRID, THE NETWORK AND THE TRANSFORMERS – HOW FAST AND WHO PAYS?

BEV recharging can add significant additional electrical loads to the grid. ANU research [18] has calculated that electric vehicles have the potential to make up at least 25% of the grid's demand if one million electric vehicles were plugged in at the same time. While this is unlikely to occur anytime soon, given the current rate of electric vehicle uptake in Australia, it is important to remember that one million vehicles only represent approximately 7% of the vehicle pool in Australia.

Figure 7: Street Transformer

External grid upgrades and costs will dictate if service stations can be retrofitted with EV chargers in a cost-effective manner. The Franklin St charging hub in Adelaide 2017 has 2x22kW AC chargers, 2x50kW DC fast chargers and 4x125kW Tesla Superchargers. This development was equivalent to adding 100 new homes to the local distribution network [7].

Bottlenecks occur at the local street transformer (typically 50-250 kVA) and feeders (5-10 MVA), which are also known as low voltage power lines. They also occur at Zone substations (30-60 MVA) [7] where electricity is regulated from high voltage long distance transmission to low voltage for local distribution.

The Low Emissions Technology Statement 2021 identified electric vehicle battery charging as one of the first enabling infrastructure priorities. Subsequently the government has announced the upgrade of infrastructure to support 1.7 million electric vehicles (~11% of the passenger vehicle fleet) by 2030 through a $250 million future fuels fund.

6.0 HYBRID ELECTRIC VEHICLES

Figure 8: Mitsubishi Eclipse PHEV

Hybrid electric vehicles (HEV) and plug in hybrid electric vehicles (PHEV) are currently cheaper to purchase than a BEV and provide the dependability of being able to operate the vehicle on conventional fuels, whilst using about half the fuel of a conventional internal combustion engine vehicle.

From an operating cost perspective, BEVs are cheaper to run if you charge at home and can tolerate the recharging time and shorter range. However, when factoring the frequent use of superchargers, there is less difference in operational cost. A Toyota Camry Hybrid which is approximately half the price ($37,000) of the Tesla, achieved 5.6L/100km during testing, [19] versus 17.6kWhr/100km for the Tesla. If you were to use superchargers to recharge your vehicle this equates to an equivalent petrol price of up to $0.95-$1.89 per litre depending on where you charge.

Many people purchase a BEV to do the right thing to reduce greenhouse gas emissions. So, the big question is the comparison from an emissions reduction perspective. There have been numerous studies performed, [20], and a surprising finding is that similar emissions reductions can be achieved with all vehicle technologies. There is no single technology that represents a silver bullet for greenhouse gas reductions, particularly given the current Australian power generation mix.

When it comes to electric vehicles, the emissions from electricity generation are critical. Figure 9 shows that a PHEV running on petrol can achieve lower net emissions than a battery electric vehicle (EV_EU_28mix) operating on the typical electricity mix in Europe in 2019. This is notable as European electricity generation has much lower emissions that that in Australia with only 44% of electricity generated from fossil fuels [21], compared to 76% in Australia.

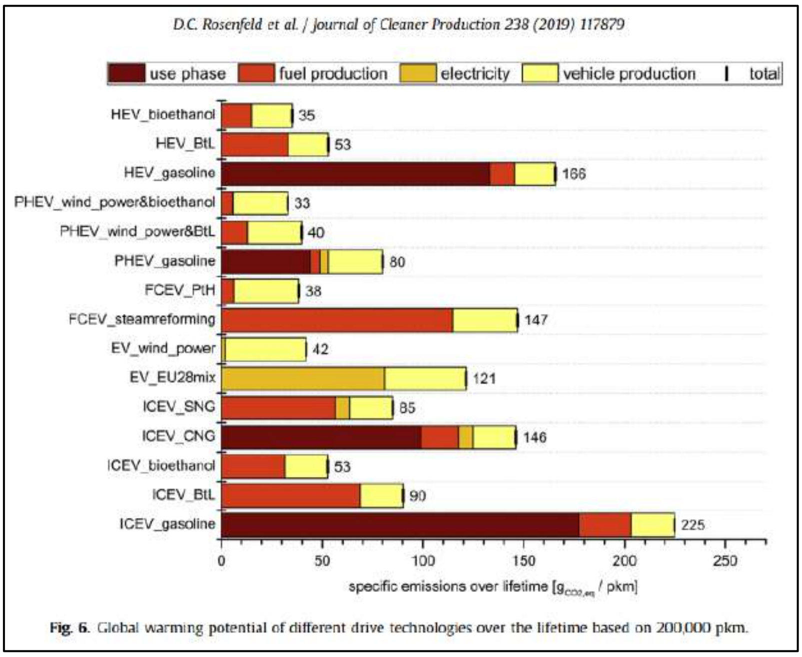

Figure 9: Comparison of Advanced Fuels Ref [20]

Notably, PHEV emissions can be halved again by using biofuels such as ethanol and biomass to liquid renewable fuels. The Australian Bioenergy Roadmap has identified biofuels and renewable fuels as a major opportunity over the next ten years which may encourage production and availability locally. TfA have been involved in the manufacture, storage and handling of biofuels for over 20 years.

Renewable fuels technology is more expensive than conventional fuels, however it is commercially available and can be used as a drop-in replacement for petrol and diesel in hybrids and existing internal combustion engine vehicles. PHEV combined with biofuels or renewable fuels can provide emission reductions comparable to a BEV using 100% renewable electricity many years ahead of Australian electricity generation becoming 100% renewable.
For consumers, the driver experience is similar to existing vehicles without the need for consumers to purchase a much more expensive BEV.

For government substantial costs associated with new electrical infrastructure to support metropolitan recharging could be deferred and progress to convert existing power generation to renewable forms would not be set back by increases in electrical demand due to BEV recharging.

7.0 CONCLUSIONS

The cost of a BEV is currently about twice the price of a conventional ICE or hybrid electric vehicle with the same range. Whilst the running cost is less than half that of an ICE vehicle if you charge at home, you have to accept regular overnight charging for a reduced range. Superchargers are still limited in availability and typically twice as expensive to use, comparable in cost to operating a hybrid electric vehicle.

From a lifecycle analysis greenhouse gas emission perspective,

- In Tasmania, where 100% renewable electricity is available, BEVs are considered to achieve the greatest emission reductions today.
- In all other Australian states and Territories, plug in hybrid (PHEV) vehicles are considered to achieve the best greenhouse gas emission reductions, until electricity generation is substantially converted to renewables.
- When combined with renewable fuels, PHEV vehicles could achieve equivalent emission reductions to BEV using 100% renewable electricity.
- Hybrid electric vehicles (HEV) currently outsell PHEV and BEV electric vehicles by a factor of 14 and are likely to remain a part of the vehicle fleet for many years. Comparable emission reduction can however be achieved through the development and use of renewable fuels.

Part 2 of our white paper will focus on hydrogen refuelling vehicles.

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