PURPOSE CAPITAL
IMPACT FUND

Environmental Impact of EVs

EV Research

6th July 2021

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1 Executive Summary

1.1 Impact Summary

As a signatory to the Paris Agreement, New Zealand has a Nationally Determined Contribution (NDC) which commits us to reduce greenhouse gas emissions to 30% below 2005 levels by 2030. Our NDC is considered internationally to be inconsistent with holding global temperature increases to below 2 degrees let alone the Paris Agreement target of 1.5 degrees by 2050.

Methane from agriculture and waste (over 40% of New Zealand's emissions) will only be mandated to reduce by 10% below 2017 levels by 2030 and 24-47% by 2050. This puts huge pressure to fully decarbonise our 2nd most emitting industry – transportation if we are to even meet our insufficient NDC.

To achieve our 2050 GHG emissions obligation, the Climate Change Commission (CCC) states that 100% of new light vehicle registrations must be EVs by 2035.

Catalysing the uptake of EV's in NZ thus reducing carbon emissions as quickly as possible could be one of the most impactful investment the Purpose Capital Impact Fund (PCIF) makes.

2 Impact

2.1 Impact Description

2.1.1 Impact Introduction

"Transport makes up almost 33% of total long-lived gas emissions in Aotearoa. Action to reduce these is critical if Aotearoa is going to reach its climate targets."

Climate Change Commission New Zealand

"In 2018, 2 million electric cars were sold globally. If electric car ownership rises to 16-23 percent of total passenger km at a first cost of USD4.5-5.8 trillion, by 2050, 11.9-15.7 gigatons of carbon dioxide from fuel combustion could be avoided as well as USD15.3-21.8 trillion in fuel costs."

Project Drawdown – The most comprehensive plan ever proposed to reverse global warming

2.1.2 New Zealand Climate Change Commission Advice: Rapidly Adopt EVs

In the report Ināia tonu nei: a low emissions future for Aotearoa, the Climate Change Commission (CCC) details their advice to the New Zealand Government on its first three emissions budgets and direction for its emissions reduction plan 2022 – 2025.

Transport makes up almost 33% of total long-lived gas emissions in Aotearoa. Action to reduce these is critical if Aotearoa is going to reach its climate targets.

There is an opportunity to decarbonise transport by 2050. This can be achieved by investing in the right infrastructure and systems, encouraging changes to behaviour, and adopting technologies that are available now and improving fast.

CCC have recommended three areas for the Government to focus on to reduce greenhouse gas emissions from transport. They are:

1. ***Reducing the reliance on cars (or light vehicles)** and supporting people to walk, cycle and use public transport. Government needs to support this change with clear targets, plans to meet those targets, and substantial increases to funding.*
   Local government plays an important role in changing how people travel, and it needs more support from central government to do the job well. This includes enabling them through legislation, removing regulatory barriers, and providing increased and targeted funding.
2. ***Rapidly adopting electric vehicles (EVs)**. Ambitious policies are needed to address supply and cost constraints, and bring more EVs into the country. Aotearoa should import more efficient vehicles until EVs are widely available and affordable.*
3. ***Beginning work now to decarbonise heavy transport and freight**. Government should develop a national low-emissions freight strategy, that includes moving more freight by rail and sea. It*

should also encourage the production and use of low-emissions fuels, such as biofuels, electricity, and green hydrogen.

It was acknowledged in the CCC recommendation that electrifying light vehicles and rapidly improving the energy efficiency of the light vehicle fleet will play a crucial role in meeting emissions budgets and the 2050 target. The below table details the recommended EV adoption path set out by the CCC, as advice to current & future NZ Government for NZ to meet our 2050 emissions obligations.

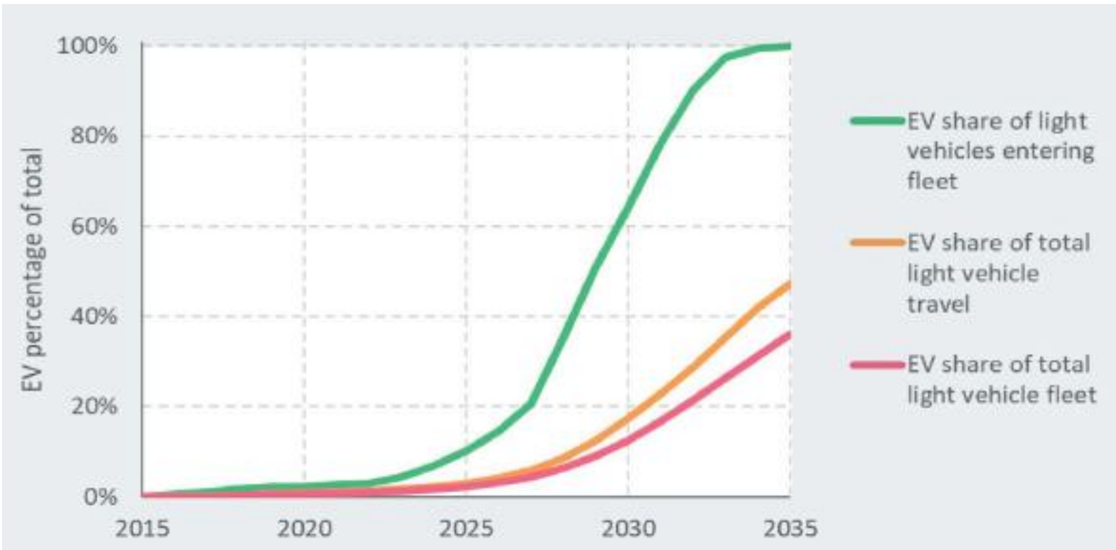


Figure: Uptake of light EVs in the demonstration path. Source: Climate Change Commission Report

Box 5.1 outlines the real-world situation for one of the three key opportunities for reducing emissions (The 3 key opportunities being: the shift to EVs, reduction in the use of fossil gas, and changing farm management practices).

Source: Climate Change Commission Report

Box 5.1: The shift to electric vehicles

EVs will be a key technology for decarbonising transport. To meet our recommended emissions budgets, Aotearoa would need to stop importing ICE vehicles between 2030 and 2035. This is in line with decisions by other developed countries and with the latest modelling by the International Energy Agency.

In considering what is technically achievable, we must consider the constraints around the supply of EVs. About 50% of vehicles imported into Aotearoa are used and about 90% of these used vehicles come from Japan. The speed with which Japan rolls out EVs will affect how quickly we can roll out EVs here in Aotearoa in the short term. Historically EV uptake in Japan has been low. However, Japan is aiming for all vehicles entering their fleet from the mid-2030s to be low-emissions vehicles. We have reflected these constraints in our recommended emissions budgets.

We heard from some submitters during consultation that our assumptions for EV uptake were too ambitious given these supply constraints. In our final advice, we have amended our assumptions and have highlighted different paths that could achieve our recommended emissions budgets (see *Chapter 7: Demonstrating emissions budgets are achievable* for more detail).

If EV supply was to be lower, we could still achieve emissions budgets by rolling out more conventional hybrids, by importing more new EVs as opposed to used EVs, and through more behaviour change in how, and how much, we travel.

It is also possible that EV supply could be higher than we have assumed, particularly in the second and third emissions budget periods, given how rapidly the EV market is developing. EV uptake in Europe has rapidly increased in response to policy, and despite the COVID-19 pandemic new EV markets are emerging in other countries. Several vehicle manufacturers announced plans in early 2021 to produce only EVs (see *Chapter 6: Reducing emissions from transport, buildings and urban form* in the *2021 Supporting Evidence*).

Policy will play an important role in speeding up EV uptake. The Act requires us to recommend emissions budgets that are achievable. At this point in time, we cannot be confident that EV uptake will be faster than we assume. However, we would welcome faster uptake if it was possible, and could revise future emissions budgets if circumstances change and new information comes to hand.

More detail on how policy can help speed up the shift to EVs is discussed in *Chapter 14: Policy direction for transport*.

CCC Recommendation 18

Recommendation 18

Accelerate emissions reductions from the light vehicle fleet

We recommend that, in the first emissions reduction plan, the Government commit to:

Accelerating emissions reductions from the light vehicle fleet.

This should include the Government:

1. Setting a time-limit on light vehicles with internal combustion engines entering, being manufactured, or assembled in Aotearoa. The time limit should be no later than 2035 and, if possible, as early as 2030.
2. Setting an emissions efficiency standard for light vehicle imports and steadily strengthening this to improve overall efficiency of the light vehicle fleet.
3. Accelerating the uptake of electric vehicles (EVs) by introducing a range of measures, including:
    a. A policy to reduce the relative upfront cost of EVs until they reach price parity with internal combustion engine (ICE) vehicles.
    b. Supporting EV leasing, purchasing and sharing schemes to improve equitable access. Regard needs to be given to ensuring that Iwi/Maori, and those in low income and vulnerable groups have the opportunity to access electric mobility.
    c. Enabling ways to bulk procure electric vehicle fleets, working with the private sector and public sector procurement to do so.
    d. Encouraging battery refurbishment, repurposing, and recycling systems, working with the private sector to do so. (See also Recommendation 13 in *Chapter 13: Policy direction that cuts across sectors* and Recommendation 22 in *Chapter 16: Policy direction for waste*.)
    e. Enhancing the roll out of EV charging infrastructure to ensure greater coverage, including at marae, multiple points of access, mandatory smart charging, and fast charging. (See also Recommendation 19, and Recommendation 20 in *Chapter 15: Policy direction for energy, industry and buildings*).
4. Determining how the tax system could be used to discourage the purchase of ICE vehicles and support the adoption of low-emissions vehicles.

Note: Recommendation 19, part 2 would also deliver emissions reductions from the light vehicle fleet.

2.1.3 Benefits of EVs

The benefits of Electric Vehicles to New Zealand are immense.

Below are some of the benefits of the Electric Vehicle revolution if 50% of the New Zealand vehicle fleet were to convert to EVs or PHEVs:

- *NZ could import $2 billion less of oil per year.*
- *NZ would save $370m in health costs per year.*
- *NZ would be employing more people in New Zealand to produce more renewable electricity.*
- *NZ could reduce emissions by a whopping 6 billion kgs of CO2 per year.*
- *NZ's streams and rivers would receive fewer oil pollutants.*
- *There would be much less road noise*

Source: Ecotricity

2.1.4 Life Cycle Assessment of Electric Vehicles (EECA)

It's frequently debated by some whether EVs are better for the environment than diesel/petrol cars. There is significant evidence to suggest that EV are indeed better for the environment than petrol or diesel powered vehicles, an example of one such study is detailed below.

The New Zealand Government agency, Energy Efficiency and Conservation Authority (EECA), commissioned ARUP and Verdant Vision, to conduct a Life Cycle Assessment (LCA) to compare the environmental impact of electric vehicles (EVs) with internal combustion engine vehicles (petrol and diesel). The EECA LCA Report confirms that EVs are better for the New Zealand environment than petrol or diesel powered vehicles, across the life cycle of the vehicle as well as in use. The key points summary of the LCA Report can be read below.

As it is commonly pointed out, it is not only the effects of motor vehicle operation that must be considered when evaluating competing technologies. For example, a low carbon footprint will count for little if the vehicle in question has an overall higher 'embodied carbon' content (that is, its manufacture requires a more carbon intensive process), or if other impacts upon the environment or human health are unacceptable. A proper comparison will therefore take into account the impacts of the processes involved in the entire 'life cycle' of a vehicle — the so-called 'cradle-to-grave' journey of which the vehicle's operation is but a part.

In order to examine the life cycle impacts of each vehicle upon the environment and upon human health, eight 'impact categories' were examined. These were:

- *Climate change (the overall impact of a vehicle technology in terms of carbon dioxide equivalent emissions);*
- *Particulate matter (the levels of fine particles, known to be harmful to human health, produced);*
- *Photochemical production (emissions that contribute to smoke and smog levels, which are known to be harmful to human health);*
- *Cumulative energy demand (the total energy used in the life cycle of the vehicle);*
- *Resource depletion (whether the production and operation of the vehicle brought about significant depletion of natural resources compared to our reserves, notably rare-earth, precious or industrial metals, and fossil fuels);*
- *Human health toxicity (whether the processes involved with the extraction of raw materials, vehicle manufacture, use, maintenance or end-of-life disposal produced substances that were harmful to human health);*
- *Ecotoxicity (as above, but considering the impact of these processes upon other organisms and ecosystems); and*
- *Air acidification (whether the production and operation of the vehicle leads to the emission of substances such as sulphur dioxides, nitrogen oxides and other nitrogen compounds that can lead to the acidification of water bodies and vegetation).*

In the following image, the impact categories highlighted in grey signify those categories with high uncertainties associated with its results.

The study found:

- *Significant reductions in emissions with global warming potential are available over the life cycle of PEVs. A reduction of carbon dioxide equivalent (CO2-eq) emissions approaching 60% will be realised over the full life cycle of the vehicle for a BEV compared with a petrol vehicle. When looking only at the electricity consumed by a BEV driven in New Zealand, a BEV will produce close to 80% less CO2-eq emissions compared to a petrol vehicle, a figure that will only improve supposing New Zealand meets its policy targets for the reduction of the carbon intensity of electricity production. The total amount of energy used during the entire life cycle of the vehicle (cumulative energy demand) was around 40% less for the BEV than for the petrol and diesel vehicles.*
- *The study found that there are no significant differences across the technology types with regard to net resource depletion, although it should be noted that the levels of uncertainty in these findings was high. While it is easy enough to state with confidence the ameliorating effect on fossil fuel resource depletion of using PHEV or BEV technology, for example, it is somewhat harder to*

quantify the depletion of other resources, such as the minerals used in battery and electric motor manufacture. Nonetheless, it was concluded that the differences in net resource depletion were not significant, and sensitivity analysis found that improvements in battery technology (such that battery life is extended) and in the rate of recycling of the materials used in batteries and motors will improve the comparative mineral resource performance of PEVs.

- *The study into resource depletion impacts also helped to dispel two myths about PEVs:*
  - *Whilst PEVs do contain rare earth materials in small amounts (as do most petrol and diesel vehicles), the study findings show that the resource depletion impact of rare earth metals was not a significant issue compared to other minerals or resources;*
  - *The lithium salts used in lithium-ion batteries for current PEVs on the market are neither a rare-earth nor even a precious metal. The study also found that the resource depletion effect of the amount of lithium in PEVs was insignificant compared to other minerals or resources.*
- *PEVs produce lower particulate emissions than petrol and diesel vehicles.*
- *Diesel, plug-in hybrid and battery electric vehicles all indicated lower smog-forming potential (photochemical oxidation) than petrol vehicles.*

As with resource depletion, there was considerable uncertainty in the assessment methods used to gauge human health toxicity, eco toxicity and air acidification, which reduces the confidence of the study results in these impact categories. The results did, however, indicate that BEVs have the lowest impact for eco toxicity and air acidification, and that at any rate, human toxicity impacts were very small across all vehicles.

Overall, the comparative life-cycle assessments indicated that there are very worthwhile gains to be made by encouraging the uptake of PEV vehicle technologies in New Zealand, particularly with regard to reducing the carbon intensity of the New Zealand economy.

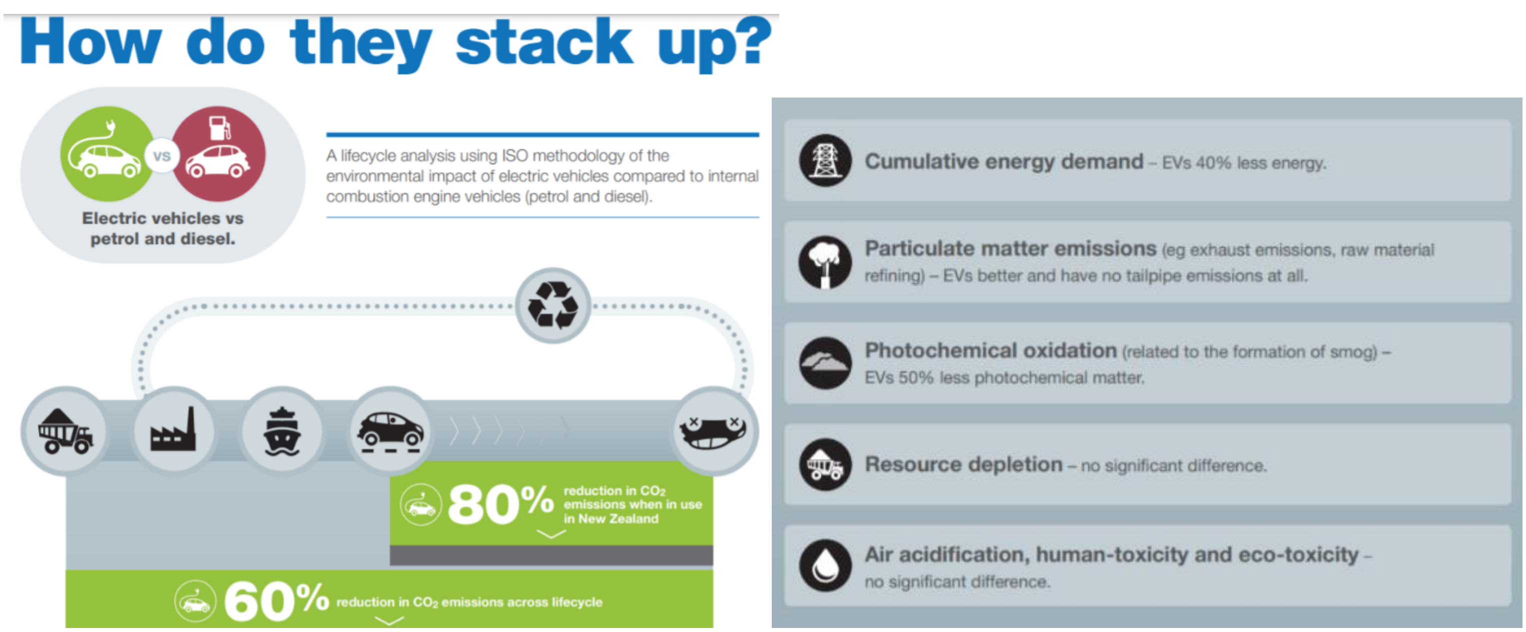


Image Source: EECA LCA Report Infographic

2.1.5 Influence of national electricity grid over the use phase (European Federation for Transport & Environment AISBL):

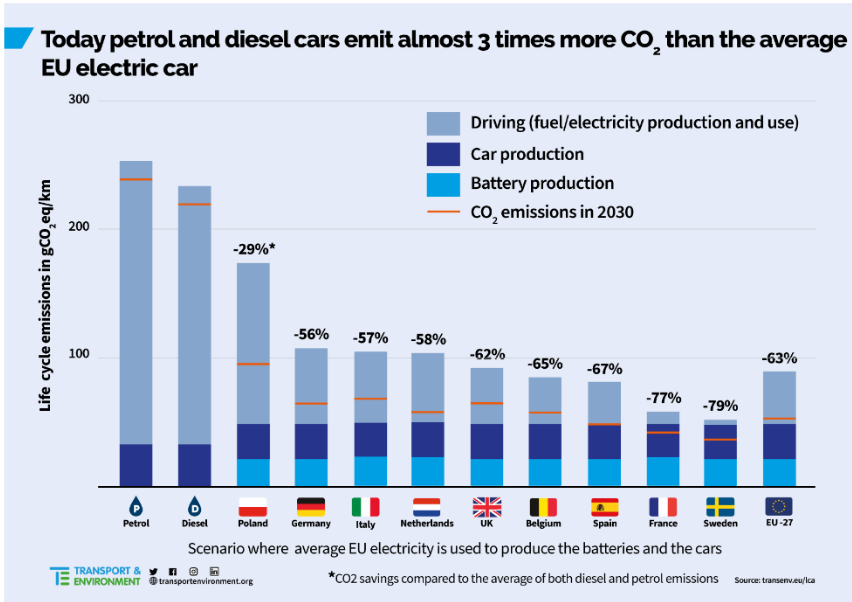


Figure: Influence of national electricity grid over the use phase

Source: How clean are electric cars? - European Federation for Transport & Environment AISBL

2.1.6 EVs reach carbon parity in one or two years (European Federation for Transport & Environment AISBL):

After production, electric cars quickly 'repay' their carbon debt' compared to equivalent conventional cars. It takes about one to two years of driving an electric cars to reach parity with diesel and gasoline (after approximately 23,000 km, see Figure 6 below). For electric cars with a battery produced on clean electricity and running on clean electricity, the excess carbon debt would be paid back after less than one year of driving (about 13,000 km). (European Federation for Transport & Environment AISBL)

2.1.7 100% Renewable Carbon-Neutral-Certified Electricity supplying some EV Charging Networks

Ecotricity, NZ's only supplier of 100% Renewable certified carbon-neutral electricity, and supplies come EV charging networks electricity. Ecotricity purchases/generates the same amount of wind, hydro and solar electricity that they supply customers. Ecotricity measures and offsets all emissions for both organisation and product. This activity enables them to carry a CarboNZero certification.

EV's electricity carbon footprint will be net-zero if the are charged on ecotricity's powered chargers. These networks would be 0.000 kg CO2e/kWh, which will be lower than those EVs who charge their car via other electricity retailers. This compares to the NZ grid electricity footprint of 0.11 kg CO2e/kWh. As a result, Ecotricity-powered EVs will have a smaller carbon footprint than other EVs charged by grid electricity.

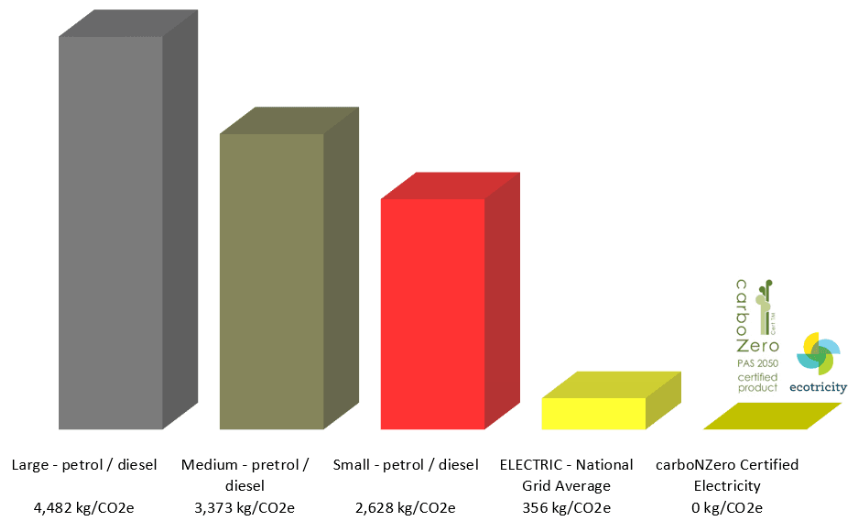


Figure: Fuel Emissions per annum per Type of Vehicle [kg CO2e per annum], Source: Ecotricity

2.1.8 Project Drawdown: Electric Cars

Project Drawdown identifies electric cars as one of the 100 solutions to achieve carbon drawdown, excerpt below:

"Electric motors supplant gasoline or diesel engines, which are polluting and less efficient. EVs always reduce car emissions—dramatically so when powered by renewable electricity.

Since the first electric vehicle (EV) prototype was built in 1828, the central challenge has been making good on a lightweight, durable battery with adequate range. In its absence, internal combustion engines have dominated the automotive landscape since the 1920s, and the atmosphere has paid the price.

Luckily, there are now more than 1 million EVs on the road, and the difference in impact is remarkable. Compared to gasoline-powered vehicles, emissions drop by 50 percent if an EV's power comes off the conventional grid. If powered by solar energy, carbon dioxide emissions fall by 95 percent. The "fuel" for *electric cars is cheaper too. EVs will disrupt auto and oil business models because they are simpler to make, have fewer moving parts, and require little maintenance and no fossil fuels.*

What is the catch? With EVs, it is "range anxiety"—how far the car can go on a single charge. Typical today is a range of 80 to 90 miles, long enough for most daily travel. Carmakers are closing in on ranges of 200 miles, while keeping batteries affordable.

The rate of innovation in EVs guarantees they are the cars of the future. The question is how soon the future will arrive." - Project Drawdown

2.1.9 Air Pollution: ICEs vs BEVs

"You wouldn't wrap your mouth around the exhaust of a petrol or diesel powered car because it will literally kill you... You don't need to be a rocket scientist to extrapolate the effect that petrol and diesel cars have on the air quality of the atmosphere & thus effects on human health" – Nick Pacey

Excerpt from the European Federation for Transport & Environment AISBL:

"Switching from an ICE to a BEV instantly eliminates all toxic tailpipe pollution such as nitrogen oxides (NOx), carbon monoxide (CO) and hydrocarbons (HC) - not just particles. This is down to there not being a polluting combustion process. As these pollutants are only emitted from cars, out of the engine, if there is no engine there are no emissions.

One of these harmful pollutants, nitrogen dioxide (NO2), is responsible for over 50,000 premature deaths per year in Europe. It causes respiratory and cardiovascular disease and can be a death sentence for those suffering from asthma. Recently, a UK court ruled that air pollution, including NO2, contributed to the death of Ella Adoo-Kissi-Debrah, a nine-year-old asthma sufferer living in London. She was living just 30 metres away from the South Circular road - one of the city's busiest and most polluted.

NO2 is a big problem in cities where heavy traffic emits toxic fumes right next to where people breathe, go to school and live. Nitrogen oxides (NOx) emissions from conventional cars, which includes both NO2 and NO (NO is converted to NO2 in the air and therefore both gases contribute to air pollution), is the main reason why many urban areas in Europe are still choking on air that exceeds legally mandated air quality limits.

ICE car engines also emit other pollutants which contribute to poor air quality. These include carbon monoxide, hydrocarbons, ammonia as well as other less known but toxic and cancer causing chemicals including benzene and polycyclic aromatic hydrocarbons. Car makers themselves acknowledge that it is not possible to eliminate harmful emissions from the engines of conventional cars. There is no technology available which can completely remove pollutants made during the combustion process before they are emitted out of the exhaust. Even future e-fuels (made from renewable electricity instead of fossil fuels) will not solve the problem." - European Federation for Transport & Environment AISBL

2.1.10 Jonathan Porritt on Air Pollution

Fossil fuels pollute our air – So what? It's normal...

Introducing Jonathan Porritt, a world renown environmentalist to remind us of the health problem air pollution creates (not to mention environmental problems) and provide context to the magnitude of the problem.

Air Pollution: A Far Deadlier Killer Than COVID-19

"Around three million people have died of COVID-19 over the last 15 months; according to the latest research, around eleven million have died of air pollution related directly to the burning of fossil fuels. That's one in five of all deaths during that time; in China and India, it's closer to one in three.

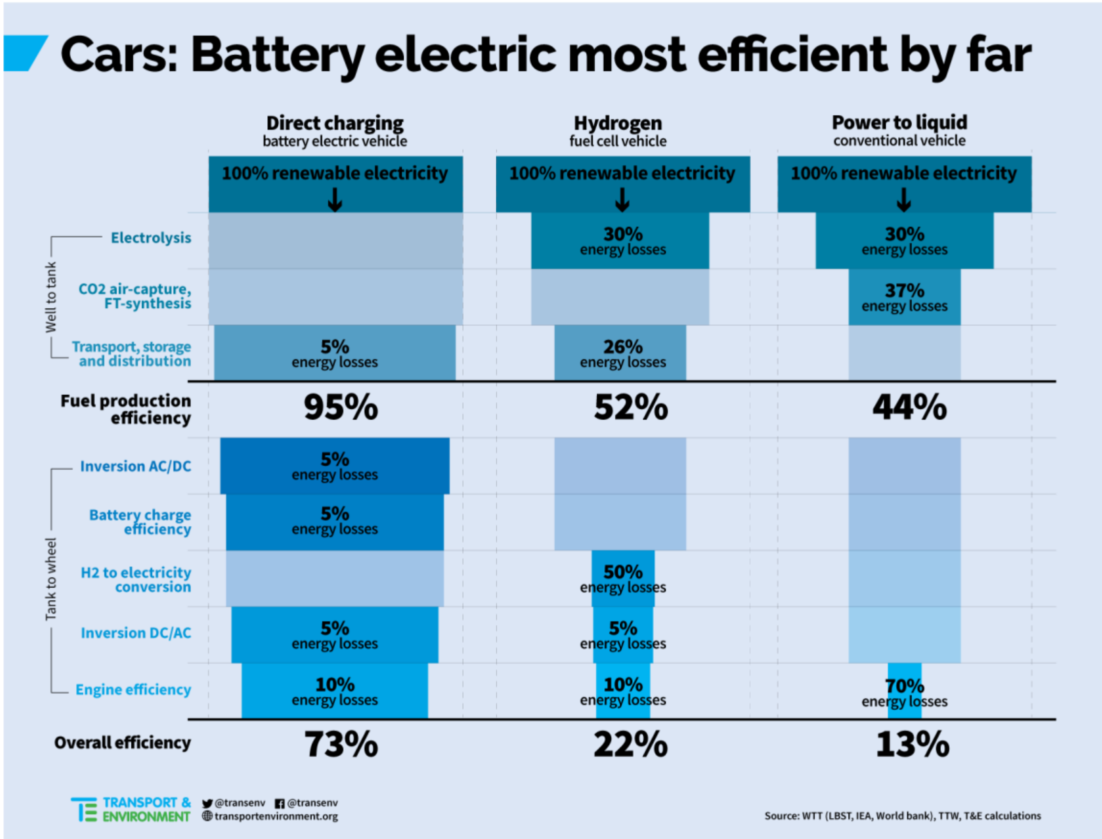
It's not just the number that's shocking. It's the relative invisibility of those affected. The trauma and lasting loss for families and friends of those who die in this way is no less than for those coping with the death of a loved one from COVID-19. But somehow, we've normalised it, back-burnered it to the extent that we don't have to engage emotionally.

Only rarely is this all-but-invisible killer brought into the public eye, as happened with the death in 2013 of Ella Adoo-Kissi-Debrah, a nine-year-old girl who lived near the South Circular Road in Lewisham. The Coroner's finding was devastatingly clear: 'I will conclude that Ella died of asthma, contributed to by exposure to excessive air pollution.'"

2.1.11 Addressing the negatives about EVs and other points of note

- We acknowledge that EVs aren't a perfect solution, but we believe they are a significant improvement to petrol and diesel cars in terms of environmental impact.
- We also acknowledge that there will be negative unintended externalities, noting that the construction & maintenance of roads is still required with EVs.
- We recognise that business as usual, ie New Zealanders clinging on to car ownership and doing a straight switch to EVs powered by renewables isn't the answer to our transportation woes. In reality, a whole suite of changes that have to happen such as: walking, cycling, e-bikes, ridesharing, asset sharing, public transport, as well as downshifting our consumption.
- It's no secret that batteries have their downsides, ie raw material extraction & processing, but there appears to be some genuine activity starting to happen around battery recycling as the world wakes up to need to de-CO2e & de-NOx the transportation sector.
    - Watching a Tesla Battery Day Keynote video will provide a sense for the level of innovation and environmental improvements in battery/EV production.
    - How Tesla's Battery Mastermind Is Tackling EV's Biggest Problem - CNBC
      Former Tesla CTO and Elon Musk's right-hand man, JB Straubel, started Redwood Materials in 2017 to help address the need for more raw materials and to solve the problem of e-waste. The company recycles end-of-life batteries and then supplies battery makers and auto companies with materials in short supply as EV production surges around the world.
    - 5 Innovators making the electric vehicle battery more sustainable – World Economic Forum

2.1.12 Battery Electric Vehicles (BEVs) vs Hydrogen Fuel Cell Vehicles (HFCEVs) vs Conventional Vehicles (ICE - fossil fuel)



https://www.transportenvironment.org/challenges/cars/

For light vehicles (i.e. any car you can drive on a standard class 1 drivers license), it's our current view that hydrogen make no sense.

Some of the challenges with Hydrogen:

- Significant Infrastructure investment
- Hydrogen system level efficiency: when compared to battery electric vehicles, c.3 times more electricity is required by hydrogen powered vehicles to drive the same distance. This is due to BEVs having an efficiency of 73% vs HFCEVs having an efficiency of 22%.
- Fuel cells require 30-60g of Platinum (Pt) per car, R&D could lower this to 10g/car. 2018 Global Platinum production ~200 tonnes. 120 tonnes of platinum @30g/day yields 4M cars. There are 4B cars on earth. Platinum availability will limit manufacturing volumes
- Hydrogen embrittlement – Hydrogen is a very difficult fluid to store, which can lead to pipes and tanks having to be frequently replaced.

3 Appendix – Project Drawdown – The worlds leading resource for Climate Solutions – www.drawdown.org

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ELECTRIC CARS

REDUCE SOURCES › Transportation › *Electrify Vehicles*

11.87–15.68	$4.48–5.79	$15.30–21.82
GIGATONS	TRILLION $US	TRILLION $US
CO2 EQUIVALENT REDUCED / SEQUESTERED (2020–2050)	NET FIRST COST (TO IMPLEMENT SOLUTION)	LIFETIME NET OPERATIONAL SAVINGS

Electric motors supplant gasoline or diesel engines, which are polluting and less efficient. EVs always reduce car emissions—dramatically so when powered by renewable electricity.

IMPACT: *In 2018, 2 million electric cars were sold. If electric car ownership rises to 16-23 percent of total passenger km at a first cost of $4.5-5.8 trillion, by 2050, 11.9-15.7 gigatons of carbon dioxide from fuel combustion could be avoided as well as $15.3-21.8 trillion in fuel costs. Our analysis accounts for emissions from electricity generation and higher emissions of producing electric cars compared to internal-combustion cars. Electric cars are several thousand dollars more expensive, but we include slightly declining electric cars prices, expected due to declining battery costs.*

VIEW TECHNICAL SUMMARY

SOLUTION SUMMARY*

Since the first electric vehicle (EV) prototype was built in 1828, the central challenge has been making good on a lightweight, durable battery with adequate range. In its absence, internal combustion engines have dominated the automotive landscape since the 1920s, and the atmosphere has paid the price.

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* excerpted from the book, Drawdown