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PGIM FIXED INCOME

The Environmental and Social Trade-offs of Electric Vehicles

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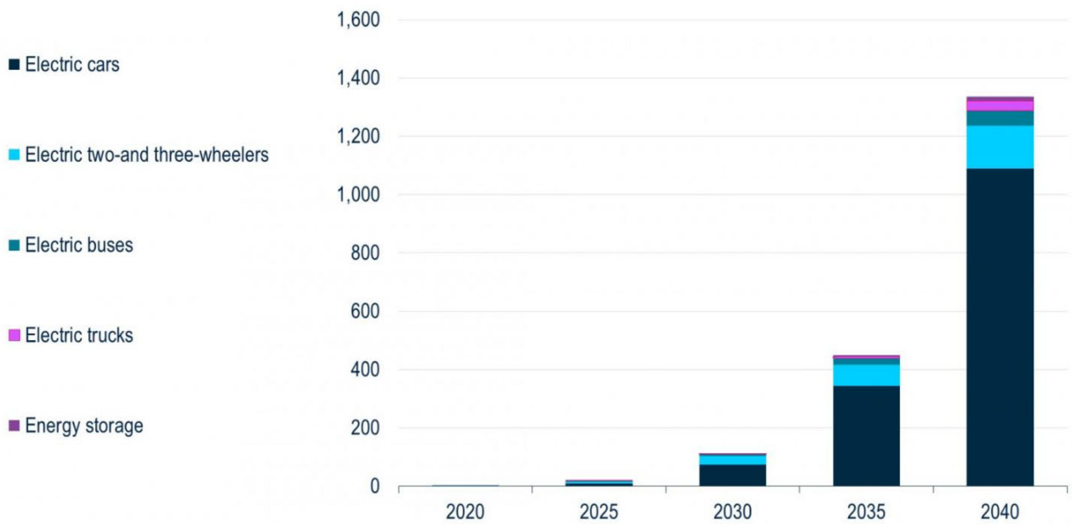
When discussing ESG for autos, the problem is often framed only in terms of exhaust pipe greenhouse gases (GHGs), and simply switching to electric vehicles (EVs) is generally portrayed as the solution. However, EVs are not a panacea as their production, disposal, and battery usage presents multiple ESG issues. There are also upstream impacts from producing the electricity that powers EVs, which is not always green. Further, GHGs are not the only emissions that matter for autos - local air pollutants linked to tire wear and braking, as well as resuspension of road dust, are additional sources pollution. The shift toward larger vehicles has slowed efficiency gains and exacerbated the non-exhaust emissions not addressed via electrification. Finally, there are social impacts from the increasing power, cost, and size of EVs. So, while EVs are clearly a key part of decarbonisation, these considerations also play a role in our proprietary ESG Impact Ratings for the auto sector, which determine an issuer's suitability for PGIM Fixed Income's ESG-oriented strategies.

The Negative Side of Batteries

EVs present a unique set of environmental and social challenges due, in large part, to their batteries. These include increased production and disposal emissions, as well as social and environmental implications from mining and processing the large quantity of minerals used in their production. At present, these impacts are limited due to the small share of EVs and the relatively young age of these vehicles. However, as the market electrifies and older EVs reach their ends of life, these concerns will surely mount (Figure 1).

FIGURE 1: Spent Batteries Expected to Grow Exponentially in the IEA's Sustainable Development Scenario



Source: IEA. As of May 2021.

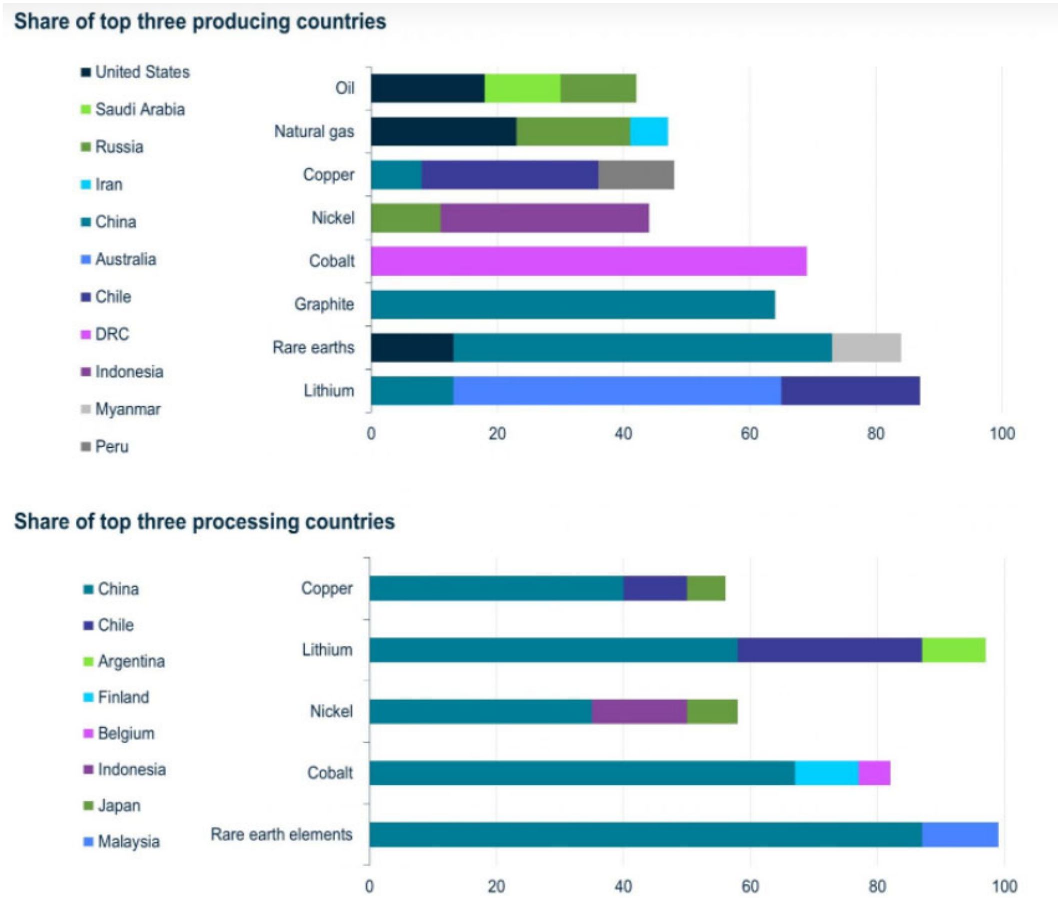
While tailpipe exhaust comprises the bulk of overall auto emissions, production side emissions from purchased materials are also significant. One study estimated production emissions for the average car at around 4 tCO2, with disposal adding another 1 tCO2.[1,2] Assuming the average American drives 13,500 miles per year and owns her car for 12 years, this equates to around 31 gCO2/mi over the life of the car (versus average U.S. tailpipe-only emissions of 356 gCO2/mi in 2019).[3,4]

However, this total rises considerably for electric vehicles due to battery production. For example, the battery in a Nissan Leaf is estimated to add a further 17 gCO2/mi to production emissions, while the larger battery in a Tesla Model 3 is estimated to generate 19 gCO2/mi equivalent.[5] Larger and more powerful vehicles require larger batteries, thus creating more emissions from battery production. Companies are starting to address these emissions (including by pairing their battery production facilities with renewables), however, they generally remain high.

In addition to production impacts, batteries also pose toxic waste challenges. The International Energy Agency (IEA) estimated the world only had capacity to recycle around 180,000 batteries in 2019, versus around 500,000 new EV batteries put into operation that year. That said, some regulations to eventually require battery recycling are taking form, and a lot of work (and billions of dollars) are being invested by the industry in this area. Controlling the battery into the end of its lifecycle is becoming an important part of many OEM's long-term resource strategies, and significant R&D is going into more-recyclable battery chemistries and design. However, battery recycling remains difficult and much of the science is still in its infancy.

Moreover, at around five times the amount used in an internal combustion engine (ICE) car, the large mass of minerals used in EV production raises potential environmental and social concerns. Many of these minerals are sourced from developing countries and processed in China (Figure 2). Issues around artisanal mining for cobalt are perhaps the most well-known, but most metal & mineral production raises the possibility of numerous environmental and social harms. Concerns about supply chain security is spurring developed countries to launch strategies to increase domestic production, but such projects can take many years, and are already facing stiff resistance from communities near proposed mines.

FIGURE 2: Minerals in Batteries Sourced Mainly from Developing Countries, Processed in China



Source: IEA. As of May 6, 2021.

Upstream Fuel Emissions

The impact of EVs on overall carbon emissions also depends in large part on the source of the electricity used. According to the EPA, average emissions intensity of power varies from 256 gCO2/kWh in "best performing" markets like California, to 811 gCO2/kWh in parts of the Midwest, with a national average of 473 gCO2/kWh.

For context, this results in a range of 66 gCO2/mi to 210 gCO2/mi for a Tesla Model 3 LR, with an average of 122 gCO2/mi (Figure 3). Although considerably better than the U.S.'s 2019 average for all autos (356 gCO2/mi), this is still far from zero emissions.

FIGURE 3: Average Upstream Fuel Emissions for EVs and Hybrids

Manufacturer	Model	Fuel or powertrain	Tailpipe + total upstream CO_2			Tailpipe + net upstream CO_2		
			Low	Avg	High	Low	Avg	High
GM	Bolt	EV	73	136	232	20	82	179
Nissan	Leaf 62 kWh	EV	80	148	254	23	91	197
Tesla	Model 3 LR	EV	66	122	210	4	60	148
FCA	Pacifica	PHEV	213	267	351	128	182	267
Ford	Escape	PHEV	152	199	273	94	142	215
Honda	Clarity	PHEV	129	178	255	72	120	197
Toyota	Prius Prime	PHEV	131	160	205	82	111	155
Volvo	XC90	PHEV	305	359	444	221	275	359
Average sedan/wagon			**346**	**346**	**346**	**277**	**277**	**277**

Source: EPA, 2019. Net Upstream CO2 is equal to the total upstream emissions for the EV minus the upstream emissions from extracting/processing fuels (rather than burning them) that would be expected from a comparably sized gasoline vehicle to allow for a like-for-like comparison. This is because upstream fuel-production emissions are typically not included in ICE tailpipe emissions statistics.

Air Pollution

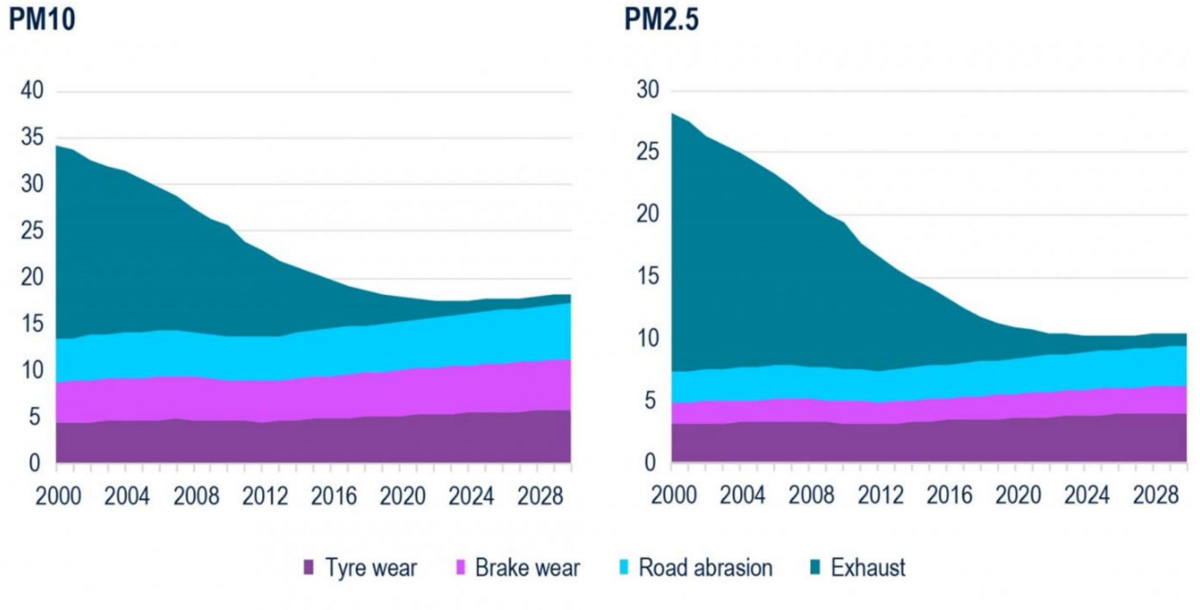
Although GHGs get all the attention, they are generally not as damaging in a local context. In contrast, emissions in the form of particulate matter (PM) nitrogen oxides and sulphur oxides can cause significant health harms to those locally exposed to them. These can be reduced by lowering tailpipe emissions, yet other sources of auto pollution exist, including tire and clutch wear, brake dust, and road wear/resuspension of road dust - all of which are often impossible to address via electrification.[6]

And these emissions are material. One analysis suggests dust from brake pads can produce levels of key air pollutants comparable to, or even higher than, diesel engines.[7] Another analysis found that emissions from tire wear could be equal to, and potentially as much as 1000 times worse than, exhaust emissions for certain pollutants.[8] Such findings are further supported by a study on Non-Exhaust Emissions (NEEs) in the UK that indicated "particles from brake wear, tyre wear and road surface wear currently constitute 60% and 73% (by mass), respectively, of primary PM2.5 and PM10 emissions from road transport" (Figure 3).[9]

This may be surprising at first, but given that brakes, tires, and road surfaces tend to be made of synthetic chemicals (many of them based on petroleum), it becomes more intuitive.

When it comes to NEEs, vehicle size matters as heavier vehicles tend to put more wear on brakes, tires, and roads, as well as contributing more to road dust suspension. And EVs tend to be large and heavy as batteries lend themselves to a larger frame and can add 300-600 kg to total weight. This is significant. For instance, analysts at Morgan Stanley (using data from Emissions Analytics) estimated that an extra 300 kg would cause 20% more tire wear. Similar results could be expected for wear on roads and brakes.

FIGURE 4: Air pollution from NEEs on the Rise



Source: Defra / UK Air Quality Expert Group.

Capacity constraints and the shift to larger vehicles

Although electrification is clearly a key part of all decarbonisation pathways, there are constraints on adding new renewable power capacity (in terms of cost, space, materials, time, etc.), and the construction of this new capacity raises its own environmental and social concerns. So, reducing energy demand is frequently the cheapest and most efficient means of emissions abatement. Part of this can be achieved via vehicle electrification. However, other efficiency measures and demand reductions are also needed.

A shift towards larger vehicles, even if they are electric, could therefore impede net zero ambitions if attention is not paid to the amount of electricity they consume. For example, a BMW i4 M50 (a sedan) requires under 30 kWh per 100 miles. By comparison, the new Ford F150 Lightning requires useable battery capacity of about 50 kWh per 100 miles travelled, which is nearly twice as much. The iX xDrive 50 (BMW's upcoming electric crossover) fares better at around 35 kWh per 100 miles, but this is still around 18% more electricity per mile than BMW's sedan. And of course, other modal options like public transport or active mobility generally require much less (if any) energy per passenger-mile.

Social Concerns

Although we do not have space to delve into them deeply, autos generally present numerous social issues, many of which are made worse by EVs. These include the increasing amount of space devoted to roads and parking, especially in dense urban areas that lack adequate public space and affordable housing. The proportion of surface area devoted to cars in city centers can sometimes exceed 50% today and, as car footprints grow, this could increase further. In addition, although the long-term trend for U.S. traffic casualties over the last several decades has been improving for people inside of cars (despite progress slightly reversing in recent years), the trend has been clearly worsening for pedestrians and cyclists over the past decade or so. Primary causes for this include the growing size and weight of vehicles,[10] which makes collisions deadlier, as well as increasing power and acceleration speeds.[11] Both of these are particularly acute for most EVs (whose silence presents further risks). An additional environmental knock-on effect here is that reduced safety for non-drivers raises real concerns for people considering shifts to active modes of transport (e.g. walking or cycling) and discourages many from doing so. Lastly is cost. As most of the major automakers have been reducing or even eliminating their lower-end offerings, the affordability of cars has already been strained. The extra premium required for EVs only stretches this further.[12] Although taxpayer subsidies in the U.S. and elsewhere help reduce this burden, the cost is simply spread out across the tax base at large (including those who do not buy EVs) instead of being eliminated.

ESG Considerations

Although EVs are a key component of all decarbonisation pathways, their environmental and social impacts should not be overlooked. While batteries provide a route toward net-zero GHG emissions, they present a range of production and disposal concerns. Further, electrification alone does not address the localized air pollution challenges increasingly posed by non-exhaust emissions. And the shift toward larger and more powerful vehicles is limiting efficiency gains while raising new systematic challenges. Finally, autos in general, as well as EVs contribute to numerous social issues. So, while EVs are clearly a step toward net-zero emissions, they are not a silver bullet, and present numerous environmental and social challenges that are key considerations when assigning ESG Impact Ratings and determining suitability for ESG-oriented strategies.

[1] Transport & Environment. "CO2 Emissions from Cars: The Facts," April 2018.

[2] Annual improvements to this were estimated at around 1% per year.

[3] U.S. Department of Transportation, May 31, 2022.

[4] The Wall Street Journal. "Americans are Keeping Their Cars Longer, as Vehicle Age Hits 12 Years," June 14, 2021.

[5] CarbonBrief, "Factcheck: How electric vehicles help to tackle climate change." May 13, 2019.

[6] Regenerative braking can reduce (though not eliminate) braking pollution, but its effectiveness varies considerably depending on a number of variables, including whether drivers brake slowly enough to make use of it.

[7] Kings College of London. "Air Pollution from Brake Dust May Have Some Harmful Effects on Immune Cells as Diesel Exhaust," January 9, 2020.

[8] Emission Analytics. Pollution from Tyre Wear 1,000 Times Worse Than Exhaust Emissions," March 6, 2020.

[9] Air Quality Expert Group. "Non-Exhaust Emissions from Road Traffic," 2019.

[10] A larger vehicle has more momentum and is more likely to drag a pedestrian under its wheels given its greater height.

[11] Most pedestrian deaths occur at intersections and acceleration speed has been shown to be a key factor in these cases.

[12] This premium can result from several factors, including the cost of batteries, the shortage of EV supply, and the fact that most EV models are larger and/or more high-end.

Source(s) of data (unless otherwise noted): PGIM Fixed Income, as of October 3, 2022

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