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STORMCROW

It's Way Past Time to Get Real

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- **Enough Wishing** – Every year, like the seasons changing, we hear about how there won't be enough lithium to make all the electric cars governments keep promising will fill the roads. Face it, we aren't going to be building those cars.

- **But We Have to Do Something** – Climate change is an existential threat to our present society. We can wait for the perfect solution to drop from the sky, which hasn't happened yet, or we can do what we can with what we have. I vote for the second option.

- **Let's Do the Best We Can with Transportation** – Transportation emits only 14% of global greenhouse gases. Even reducing that to zero won't solve climate change, and we aren't going to get it to zero. But by mandating adoption of plug-in hybrid and hybrid electric vehicles we can make a meaningful and near-term change to emissions, one that will get more meaningful every year, given the long life of vehicles in many parts of the world. It isn't perfect, but it's better than the fantasy of nothing but battery electric vehicles.

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See the end of report for important disclosures

Climate Change and the Almost-Eternal Electric Vehicle Problem…

The report from COP26 is probably long forgotten by many at this point, smothered by a horde of other, shinier and newer stories in the news cycle. However, for those of us who actually understand that climate change is the most serious existential problem our modern world has ever faced, it isn't something that can be easily forgotten. COP26 is the moment that modern science looked out upon the faces of the world's citizens and said, "You'll be sorry".

Let's recall the headline conclusion of COP26; to limit the average global temperature increase to less than 1.5°C compared to the average temperature in the late 1800's, prior to major industrialization, we must seek to cut carbon emissions by 45% by 2030, compared to carbon emissions in 2010. We further need to achieve net zero carbon emissions by 2050.

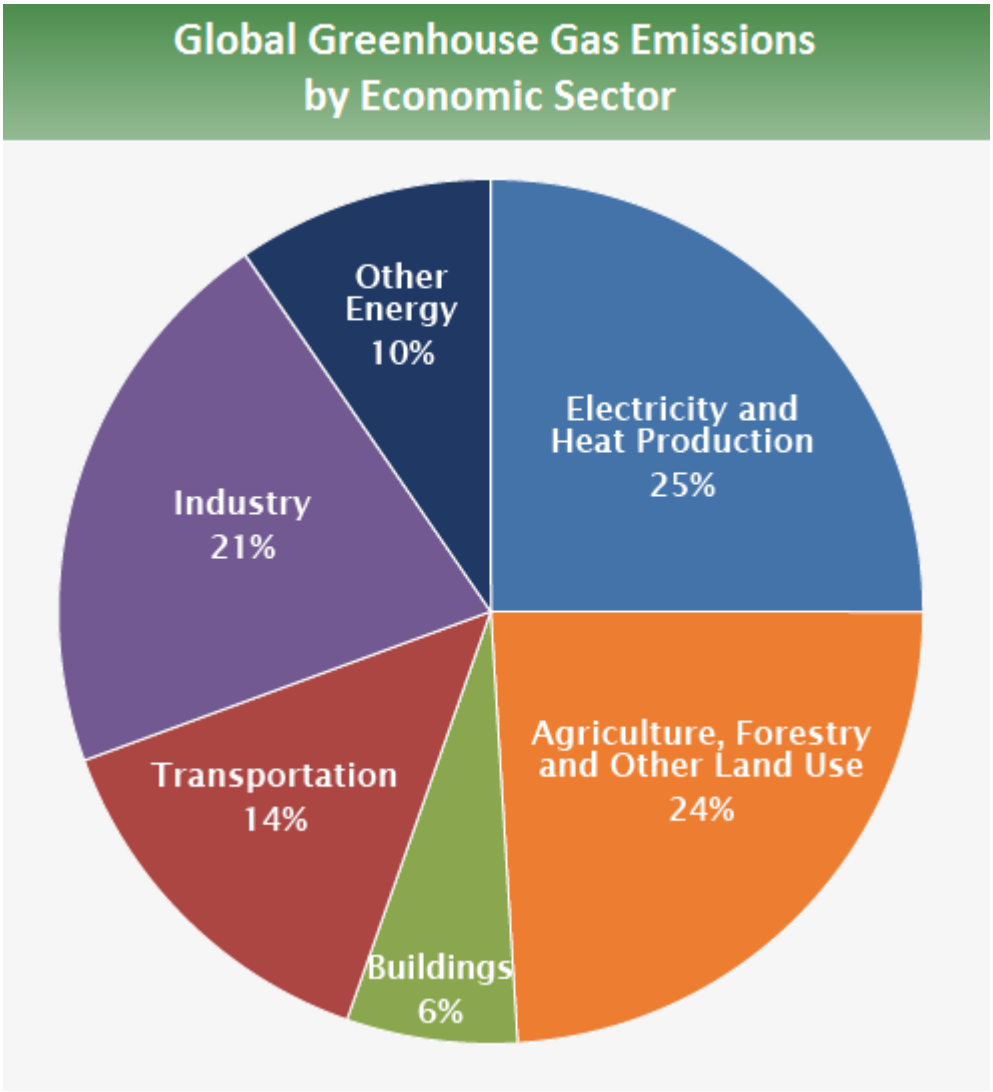
I do not believe that I will shock many by stating the obvious, which is that we are not going to manage a 45% reduction by 2030, nor will we achieve net zero levels by 2050. The "attempts" governments are making to do so resembles nothing so much as a giant accounting trick. In this case, we simply change these cells in the spreadsheet to zero and *poof!* all the internal combustion vehicles are gone and *poof!* all the coal-fired power plants are gone and the world is clean and wonderful! The real world isn't a spreadsheet. Not only does change of this scale require planning and direction, it likely requires more of certain critical raw materials than we will have when they are actually required.

The very good news is that life will go on, whether we achieve the above targets or not. How good and how easy that life will be is another story. Perhaps the best news from the COP26 report is that even if we can't hit the goal of a 45% reduction in emissions by 2030, any amount of carbon emission reductions will help, and the sooner those reductions are made, the better.

So, instead of whining about how our world won't be made perfect and using this as an excuse to do nothing, it is long past time that we start thinking about what sort of carbon reductions we can realistically make. We need to include in our planning the fact that we will only have a limited amount of certain critical materials available to implement those changes. And we also, as a precondition, need to ensure that we don't crush economies and destroy people's lives even more thoroughly than climate change can through our desire to do "the right thing".

As Sun Tzu has always advised, we must know our enemy. Well, here are the sources of global carbon emissions, as pictured in the IPCC 2014 report:

Figure 1 – Global GHG Emissions by Sector



Source: IPCC 2014

This is being written shortly after I returned from a major lithium conference. If someone who understood nothing more than that climate change was a serious threat was dropped into the middle of that conference, then they could be forgiven for thinking the problem has been solved. Apparently, all we need to do is to have everyone start driving an electric vehicle, greenhouse gas emissions will plunge and our world will be saved.

For those who can actually tell that one number is larger than another, the above chart reveals a small problem with this plan. We need to reduce emissions dramatically, as in 45% by 2030. But global emissions from the entire transportation sector are only 14% of the total. Admittedly, these figures are not exact as they are estimates and not measurements. But the reduction we need to achieve is nothing like as small as 30%, and the relevant slice of the pie chart for the Transportation sector, above, is definitively not as large as even 20%. There is a significant shortfall, here.

And even if we reduced all direct emissions from Transportation to zero, which is impossible with the technology we will have available to us by 2030 (or even 2050), given that it is the energy density of fossil fuels that manage to keep pushing long-distance trains down the tracks and jet aircraft through the sky, we should also understand that a good fraction of the electricity that will power all these newly electrified vehicles is going to come from carbon-emitting sources. Partly reducing emissions from the Transportation sector will help, but we need to be realistic about what we can do emphasizing this alone. We also need to understand that a wholesale and misguided attempt to reduce Transportation emissions to zero by 2050 might be deflecting attention and effort away from better places to make more substantial emissions reductions.

Presentation after presentation at the conference I attended showed projections such as 40,000,000 battery electric vehicles (BEVs) being sold by 2035, or some such. Then there was inevitably a projection showing a widening supply gap between the lithium required to meet this goal and the amount of lithium that will likely be supplied by dates in the future. And hands were wrung and cries of “What shall we do?” echoed in the halls.

The simple answer is that we won’t manage to sell 40,000,000 BEVs in 2035, period. We simply won’t have the raw materials to make the necessary batteries, no matter how many ‘Gigafactories’, a term I have grown to loathe, are built. So we need a strategy to do the most with what we will have.

I’m going to humbly suggest that strategy with respect to transportation, and that is that governments in major industrialized nations push as hard as they are able, and likely much harder than they would like, to require those buying new vehicles to purchase a hybrid or plug-in hybrid vehicle. Now, to some that is going to seem a cop-out. Selling new vehicles that will continue to consume fossil fuels is anathema to some when every new vehicle “could” be purely electric. The flaw in this logic, though, is that EVERY new vehicle simply CANNOT be purely electric, because that’s impossible.

Let’s think about how many new BEVs we could build using the lithium we might have available. First, let’s assume that our big old BEV will contain a 80 kWh lithium battery. The battery will be based on the cathode active material NMC 622. Based on a reasonable

recent figure for energy density from a major manufacturer of these materials, 40,000,000 vehicles with a 80 kWh battery (a total of 3.2 billion kWh, or 3.2 TERAwatt-hours!; take THAT, you mere "GIGAfactories") will require 4.9 million tonnes of NMC 622 cathode active material. That much NMC 622 would contain 1,875,000 tonnes of lithium carbonate equivalent (LCE). Since 2021 production was something like 523,000 tonnes LCE, total, we are nowhere in the same league as that output. To get to that level by 2030, compound annual growth in output must be at least 18%, assuming existing applications don't require more material by 2030, too. There are very few examples of anything in human history where growth in output has increased by 18% per year for nine years. Let's face facts; this is not going to happen.

Several presenters at the recent conference gave an estimate that looks to set a 2030 "realistic" limit on production of about 1.6 million tonnes LCE, total. Let's assume that the 2021 level of 523,000 tonnes, more or less, is used for other purposes. That means that if we use the remaining 1.1 million tonnes LCE to make nothing but 80 kWh battery packs for BEVs, we can build something like 23 million of them. At least its not an order of magnitude less than our target of 40 million, but it doesn't get us anywhere close to making half of all new vehicles sold run on electricity, alone.

So, time for Plan B. And Plan B means that we need to stretch our lithium. Let's say that we are selling a mix of plug-in hybrid electric vehicles (PHEVs) with 15 kWh lithium batteries and hybrid electric vehicles (HEVs) with 3 kWh batteries, in a ratio of about 2:1. Why is this a good thing? Time for some subjective data, with the caveat that a sample size of just me is going to be illustrative but not quantitatively useful. Your mileage, literally, may vary.

I recently started driving a PHEV. It contains a 14 kWh battery and a 67 kW electric motor along with a small, turbocharged gasoline engine. On most weekdays, my wife and I use roughly 50-75% of the battery capacity. A good rule of thumb for selecting a battery size in a new energy vehicle is to ensure that, quite often, you can use the full capacity of the battery. Obviously, when we need to travel farther than the 60 km or so allowed by the battery, we can rely on the gasoline engine for the rest of the trip. Admittedly, using gasoline instead of electricity is more expensive, but it is much more convenient to not have to stop to recharge the battery (also an option, if time and location allows). And over our last two gasoline refueling stops, we traveled a measured 3,595 km and used a measured 53.7 liters of gasoline. That is a measured fuel economy of 1.49 liters per 100 km, in metric terms, or 158 mpg in US terms. Now, we also used 727 kWh of electricity, but at CAD$0.08 per kWh (because we could trickle-charge the small battery overnight when electricity is cheap), we still paid less for the electricity than another 30 liters of gasoline would have cost us at the time.

Now, our old internal combustion version of the same model (an ICV, for short), powered by nothing but a larger turbocharged gasoline engine, returned a lifetime mileage of 11.13 liters per 100 km, or about 21 mpg in US terms. So using a PHEV instead of an ICV has resulted, in one short period of ownership, a reduction in gasoline consumption of more than 85%. Which isn't bad.

Even stranger, we didn't pay much more, if anything at all, for a PHEV with almost every option in the catalog compared to a ICV with almost every option in the catalog. We ended up with something that works as a BEV most days but can run like an ICV if you are forced to make long trips and don't have time for recharging. And it has reduced our daily fuel consumption, and resulting carbon emissions, dramatically. Plus, we can build five of these PHEVs and use less lithium than making one much more expensive and much more limited BEV.

Let's say that we try building that ratio of 2:1 PHEVs to HEVs with our limited lithium supply. Further, because we are making smaller batteries and aren't restricted to trying to cram as much energy into a limited space as we can, which pretty much necessitates using a high-nickel cathode active material like NMC (short for lithium Nickel Manganese Cobalt oxide) 622 or NMC 811, we can use something even less expensive (and less lithium-consumptive) like lithium iron phosphate (LFP). Using LFP means we don't need large additional amounts of nickel or cobalt. Given an average battery size of only 11 kWh, now we can produce up to a whopping 209 million vehicles (139 million PHEVs and 70 million HEVs) with our 1.1 million tonnes of available LCE, and we have no concerns at all about supplies of nickel or cobalt.

So, which of our critical material-constrained options has the bigger impact on carbon emissions? It isn't a contest, not even close. Assuming the global fleet was something like 1.2 billion vehicles in 2021 and growing to 2 billion vehicles by 2050, along with an average global vehicle life of about 20 years, selling nothing but BEVs doesn't even dent global emissions. In fact, what our cheap-and-dirty model shows is that we are selling MORE ICVs each year, through 2030, than are being retired from the fleet. By 2030, the carbon emissions from global transportation will have become LARGER than they were in 2021, about 1,100 bps greater in terms of the total amount from Transportation. That's lower than they would be if every single vehicle sold were an ICV, but that's cold (warm, given climate change?) comfort given there will be no positive effect, at all, on carbon emissions. Which begs the question, what's the point?

But if those hypothetical PHEVs and HEVs in our Plan B can reduce gasoline consumption by something like 60% (by encouraging the right buyers, those whose driving loop benefits most from a PHEV, to purchase a PHEV versus a HEV) and we sell a combined 508 million PHEVs and HEVs between now and 2030, then we reduce emissions, compared to the

2021 level by 200 bps, a 1,300 bps improvement over what we do selling nothing but "perfect" BEVs. We don't need to scramble to produce an impossible amount of lithium and we can get where we need to go, quickly enough. The cumulative effect of all these vehicles being in the fleet continues to allow us to gain on the only-BEV model, every year. And we do not need to endanger economic growth or force individuals to adopt vehicles that are ill-suited to their needs.

I will also point out that 80 million vehicles using a 11 kWh battery comes to 880 million kWh of required storage, as opposed to our originally conjectured 40 million vehicles using a 80 kWh battery for 3,200 million kWh. We also might actually be able to build the required Gigafactories (hate that term…) by 2030 or some reasonable time, as well.

Now, the other major reason to encourage PHEVs and HEVs over BEVs is also simple, and also related to scarcity. But this time it's the scarcity of electricity. In our western society, we are busy shutting down sources of electricity. Companies are closing down coal-fired generating stations, which is good. This is largely an economic decision made because of the availability of cheap natural gas, with a little encouragement from increasingly stringent emissions regulation. However, western governments have been on an anti-nuclear kick and have been shutting down nuclear stations rather than refurbishing them and extending their operation or, perish the thought, building new ones. When was the last time you heard of governments in North America or Europe ADDING significant generating capacity to the grid? When was the last time you heard about them shoring up the grid and making it more robust and able to carry more electricity?

In 2021, the US consumed 614 billion liters of gasoline. I haven't seen vast ponds filled with gasoline all over the landscape, so I am going to assume all that gasoline was burned in vehicles. Americans in 2021 also used 203 billion gallons of diesel, same assumption. If we look at an ICV model like a Honda Civic, combined mileage is something like 7.1 l/100 km. 614 billion liters of gasoline could move a fleet of Honda Civics a total of 8.6×10^{12} kilometers. If we look at a small EV like the Tesla Model 3, it uses approximately 72 Wh per km to travel down a (combined city and highway) road. So driving a fleet of that model of Tesla for 8.6×10^{12} kilometers will use 623 TWh of electricity.

Now, the actual electricity required is a little bit higher, because some electricity is lost as heat during charging and discharging the battery; the faster we charge or discharge, the more is lost. This loss is similar to what would happen if everyone spilled some gasoline every time they filled up the gas tank of an ICV. Let's assume the round-trip efficiency of the batteries in use is about 85%. In that case, to replace all that gasoline would require about 733 TWh of electricity.

Doing a similar thing with diesel means that we'd need another 213 TWh of electricity to replace the diesel energy. That's a total of 946 TWh of electrical energy required for charging vehicles, under the assumption that, just because they are now driving BEVs, people aren't going to drive less (there's an argument to make that they might drive MORE if its cheaper and cleaner to do so, but that's another story).

In 2021, the United States generated a grand total of 4,116 TWh of electricity. That means our crude estimate of required electricity to replace gasoline and diesel and still allow people to drive to work and the store and everywhere else will demand an additional 23% of generated electricity. There is no spare generating capacity in the United States that can generate another 23% of electricity every year, it doesn't exist. And trying to get all that electrical energy to people's homes during overnight hours so that they can all recharge their BEVs is, with the present US power grid, impossible (nor will building a lot more solar photovoltaic generating capacity help EVs recharge overnight, for obvious reasons).

If there is a strategic plan between national and regional governments plus industry in any western nation to not only build all the new (clean!) electricity generating stations to produce this electricity, but also to coordinate the infrastructure improvements to the electrical grid to allow homes to consume up to twice the power they currently do, I must have missed it. If we are depending on "the market" to save us, well, we are then likely going to spend a few years living with frequent intermittent blackouts while power companies and investors get used to the fact that the world has changed. Government could do a lot more to give us a smooth transition, but they aren't. At least not yet.

Case in point, the Great State of California, which recently did a piece of virtue-signaling to the entire world that rivals any ever done. The Governor of California, Gavin Newsom, announced what is, truly, a historic initiative. California has now passed a law that says that the sale of new gasoline-powered vehicles will be illegal in the state beyond 2035. So not only will gas-guzzling pickup trucks with big V8 engines no longer be sold, but even my fuel-sipping PHEV would be illegal as it contains a gasoline engine. But as we are finishing the editing on this piece, on 1 September 2022, the California government has also asked all Californians, due to a massive heat wave in the southwestern US, to conserve electricity and NOT charge their EVs this (long, holiday) weekend. Irony.

All the above should make it pretty clear that we need to provide a buffer to the electrical grid while adjustments get made. We already have those buffers for transportation energy, they're called gasoline and diesel. And the right tool to lean on that buffer while also using electricity and dramatically curtailing emissions from transportation is called a HEV or a PHEV. If you actually want to make a difference with respect to climate change,

with the constraints of our economy and the material we will actually have to make a change, then mass adoption of HEVs and PHEVs is the right answer.

A (Depressing?) Summary

Realistically, our society simply can't make a wholesale and rapid change to BEVs. First, we don't have the lithium (and, likely, other critical materials) to build all those batteries. Second, even if we did, we would suddenly find ourselves without enough electricity to charge them and still keep the rest of society functioning in the matter it is, currently (pun very much intended).

Our best guess as to the maximum availability of lithium by 2030 is that we might have some 1.1 million tonnes more LCE to play with. Making assumptions about battery sizes, we could use that lithium to make (and sell?) 23 million BEVs a year in 2030 and likely reduce global carbon emissions in 2030 compared to today by not one gram (carbon emissions from the global vehicle fleet would likely increase). Or we could require that every single new vehicle sold in the world be either a HEV or PHEV and not even use up the 1.1 million tonnes LCE we might have. Now, because the global fleet is growing, we would only drop emissions marginally by 2030 compared to today, but we would be gaining on that amount every year as old ICVs are replaced by new HEVs, PHEVs and even BEVs. We would also end up with a much more flexible transportation fleet and give governments, power companies and car manufacturers time to adapt to a changing world.

Neither of those options meets the goal of cutting carbon emissions by 45% by 2030, but since transportation only contributes about 14% of global carbon emissions, concentrating only on battery electric vehicles wasn't going to save us, anyway. And since we have to start somewhere, it might as well be in a way that can make an actual difference.

And as for the balance of what we need to do to save ourselves, so to speak, there are ways to get it done, ways that also don't require crushing economies. We need to look at reductions in carbon emissions from energy generation, industry and buildings to get close. It can be done, without destroying our economies or stifling economic growth. But if we can't even get our act together to do the best and most realistic things possible with respect to reducing emissions from transportation, there probably isn't much point in worrying about other industries.

Over to you, our fearless political leaders. Do what needs doing (for once).

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