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STORMCROW

And They're Off!

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New Year, New Prices

In this issue we discuss:

- **Undeniably Higher** All lithium and battery chemical prices are now moving higher. No, we do not feel there is any reason to expect prices to ricket to all-time highs, because there is a lot of excess spodumene capacity that can come into the system to dampen price increases in 2021, but we are also no longer languishing down at USD$5,000 a tonne for chemicals, and that's welcome.
- **Clean Electricity and the BEV Takeover** Following on our commentary last month regarding fuel cells, here is a slightly different take on what clean energy really means. If our fearless political leaders do decide to take the plunge and commit us all to a world of nothing but renewable energy and nothing but battery electric vehicles, never mind the limitations on the supplies of critical materials like cobalt, can we get there at all?
- **Germany's Energy Transition?** We take a brief look at how realistic it is for Germany to remove nuclear, gasoline and diesel from its energy mix – simultaneously…

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As a Matter of Introduction…

This is our sixteenth (semi)monthly newsletter! Maybe. Plus or minus one or two. Time flies when you are having fun, and critical materials and the connected industries are, at least to us, fun. While we never produced a newsletter filled with cautions about the "best cure for high prices being high prices " during the lithium heyday that extended through the middle of 2017, those who sat in on Stormcrow talks at conferences know that we were out there saying it. However, we feel even more strongly that the old maxim about the "best cure for low prices being low prices" is every bit as true and being proven truer by the day with battery material prices moving back up again.

First, for those who don't know, Stormcrow deals with the markets for critical materials. Generally speaking, what amounts to a critical material is in the eye of the beholder, but we think of them as materials that are essential to making a product with the properties intended by its designers, even if those materials are not anything like the highest-cost item on a bill of materials. As an example, think about lithium in the battery of your cell phone. That lithium costs pennies as a raw material, but if your cell phone manufacturer was forced to do without it then the resulting cell phone would bring with it a very, very different operating experience than it currently does.

Over the coming months, we are going to deal with our views of the market prospects for some critical materials, and interesting facts about others. We will talk a little (or in this newsletter, a lot) about technology and the impact, both good and bad, that it can have on demand for critical materials. We hope you find this interesting and worthwhile! Note that when not writing newsletters like this one, Stormcrow Capital functions as a corporate adviser (capital markets / financing / M&A) in the critical materials sector. We are registered as an Exempt Market Dealer in Canada *(additional disclosures included at the end of this note, for those who need help getting to sleep).*

Go Go Go!

Our green shoots of last month look a lot more robust now. Comparing prices at the end of November 2020 to those at the end of December 2020:

Battery-grade $LiOH \cdot H_2O$ UP 0.6%

Battery-grade Li_2CO_3 UP 11.0%

Battery-grade $CoSO_4 \cdot 7\,H_2O$ UP 1.8%

Battery-grade $NiSO_4 \cdot 6\,H_2O$ UP 6.8%

Since the end of December, all the above have continued to move sharply higher. With record new energy vehicle sales in China, thanks to ongoing governmental incentives, and high sales elsewhere, we don't expect the prices to fall anytime soon. As we expected, spodumene prices are moving higher as well, indicating a long-term trend in prices. There is still a lot of spodumene capacity out there, and we had a long and sustained downturn, but maybe some of the major lithium chemical producers will be able to justify the market capitalizations they have been sporting with higher earnings in 2021.

Clean Electricity is Swell, Cheap and Clean is Better

We should all by now have realized that something is happening with our climate. In the United States, even, there is growing acknowledgement that climate change is a problem, the debate is now around whether the cause is anthropomorphic or not, whether the problem is carbon dioxide or not, or, as I like to put it, whether we have to worry about it or not. In other words, if enough people can be convinced that the cause is uncertain and the solution unclear then we don't have to change anything. Convenient, but (a) in complete opposition to the scientific method and the science underlying the issue, and (b) entirely congruent with an American attitude to just about everything.

For the rest of us who have accepted the reality of the issue, our role in creating it and the problem with fossil fuels, we are stuck with a bigger problem. It might be nice to get all irate about the issue, a la Great Thunberg, but it's also singularly unhelpful. For example, Canadians live in a cold nation in the winter (there is grass showing outside where I live, outside Toronto, but there is also snow on the ground and it is below freezing today as it is probably going to be for a while). Without using some energy to keep my home warm, I am going to freeze and my home is going to become unlivable as the water pipes freeze and burst. I am happy to have a more efficient heating system and home, and I do, but there is a fiscal and physical limit to those improvements.

So, as a society, it becomes incumbent on us to make choices with respect to the right way to generate the energy we use. I am putting this together because while I have seen one or the other of these sets of data assembled for various purposes, I haven't seen them juxtaposed. And I believe the result of doing that is illustrative.

So, first, what is the 'greenest' way to generate electricity? That is a very thorny question. The immediate knee-jerk response is "renewables!". But renewables are not perfectly and completely green. Large-scale hydroelectric projects are huge assemblages of concrete and steel and copper. They are usually built a long way from anything, so demand very long strings of copper wires to move the electricity to where people need it. They flood large tracts of land. At least they don't produce CO_2 while in operation, except as a by-product of required maintenance and the like. On the other hand, a natural gas-fired turbine DOES output CO_2 when generating electricity. But it is burning mostly CH_4, so while it burns carbon and makes CO_2 it is also burning hydrogen and making water. The turbine is an assembly of steel and copper, but this is an energy dense device and so it doesn't require nearly the same scale of concrete and land use to generate energy.

You can see that properly accounting for what source of electricity generates what amount of CO_2 is tough. It is also going to vary from geography to geography, jurisdiction to jurisdiction. But the calculation has been made by researchers from the International Panel on Climate Change (IPCC):

Exhibit 1 – Emissions from Various Sources of Electrical Energy (World Average)

Technology	Median Emissions (gCO_{2eq}/kWh)
Coal	1,044
Natural Gas	601
Biomass (Crop Residues)	229
Geothermal	41
Hydropower	27
Nuclear	13
Concentrated Solar Power	28
Solar PV (rooftop)	42
Solar PV (utility)	50
Wind (onshore)	13
Wind (offshore)	13

Source: IPCC AR5 WG3 (2014)

From the above, we see that coal, unsurprisingly, has a hefty level of CO2 emissions, and that some renewables are better than others. Perhaps most surprisingly, nuclear power is, on average, regarded as amongst the cleanest energy sources available.

However, this covers off the "physical" portion of the limitations we mentioned, above. Now we need to consider the financial aspect. That, too, has been covered in as great a detail as required by several groups, including Lazard. We choose to use similar values developed by IPCC analysts:

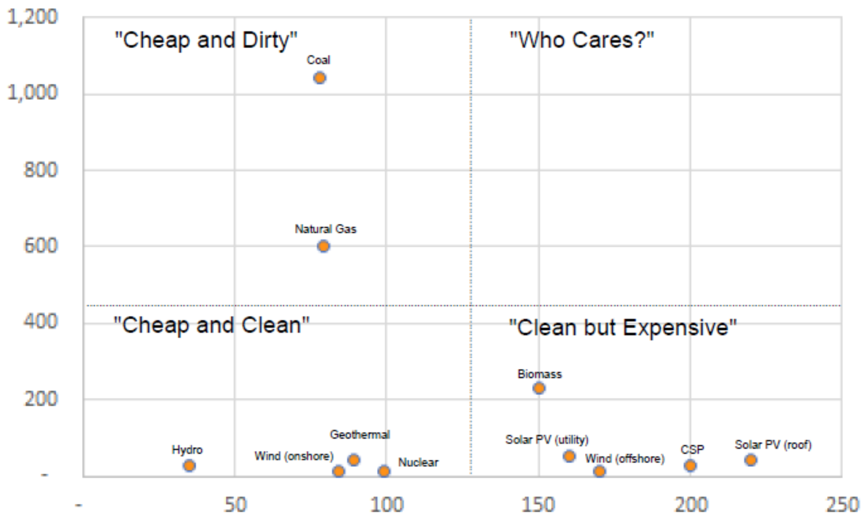
Exhibit 2 – Average Levelized Cost of Electrical Energy (USD/kWh)

Technology	LCOE (USD_{2010}/MWh)
Coal	78
Natural Gas	79
Biomass (Crop Residues)	150
Geothermal	89
Hydropower	35
Nuclear	99
Concentrated Solar Power	200
Solar PV (rooftop)	220
Solar PV (utility)	160
Wind (onshore)	84
Wind (offshore)	170

Source: IPCC AR5 WG3 (2014)

There is a correlation between these values and that correlation is negative, which should be encouraging but unsurprising. In other words, the higher the cost of the electricity generation, the lower the emissions. But the correlation is weak, only -0.333. This means that only about 11% of the variation in emissions is 'explained' by cost. So there is room for a given technology to be clearly superior to others in terms of both cost and related CO_2 emissions. If we plot the two sets as x-y coordinates, the result is, I think, informative:

Exhibit 3 – LCOE (USD_{2010}/MWh) vs. Emissions (gCO_{2eq}/kWh)



Source: IPCC

If we divide the graph into rough quadrants (because people like quadrants) then we have four interesting zones. Historically, we concentrated on cost. We built energy plants that made electricity in the cheapest way possible. We have only recently begun to be willing to build energy projects that might be more expensive but produce lower levels of emissions, including greenhouse gases.

If we concentrate on the lower left 'quadrant', the area we call "Cheap and Clean", we have four possible technologies. Of the four, onshore wind power is not baseload. The wind blows when it will but is typically more reliable at dawn and dusk. This is not when most businesses or even individuals require electricity. Integrating some wind into the generating fleet it not difficult, providing other baseload assets are available to supplement wind when it is not available. But onshore wind is not, of itself, a replacement for, say, a currently operating coal plant.

Hydropower can replace coal, of course. But the siting of a large-scale hydropower project is a limiting factor. Building a massive dam at an amenable site on a large river, flooding vast areas of a province or state and then building the power lines to carry this electricity is, in this era, difficult to do. While run-of-river projects are easier to envision and complete, they are limited in scale and a lot more expensive per MWh on a LCOE basis.

Geothermal is also a baseload technology and is more geographically flexible than hydroelectricity, but not infinitely so. If you are unlucky enough to be situated where useful reservoirs of heat are very deep below ground or where the geology is not amenable to drilling wells to tap those deep heat reservoirs, then you are out of luck. Costs will balloon significantly, project scale will suffer, or both.

Nuclear power has its own siting issues, given the need for cooling water. In addition, the social distrust around nuclear, however irrational, is a significant factor in the west. However, as much as nuclear is both clean and cost effective, it can and should be considered. And since I actually live less than 2 km from a large operating nuclear plant and they have been an exemplary neighbor that powers a large part of the City of Toronto but also are quiet and pollution-free, I may be biased. As an added benefit, I know more about the radiation levels in and near my home and at my local beach, both ambient and otherwise, then just about anyone else that doesn't have a nuclear facility nearby; how is the radon level in YOUR basement?

If what we wish to discuss is how a nation such as China should be replacing their coal plants, then the answer is that they should be doing things somewhat different from what the press has been emphasizing in the west. First, yes, China is building significant amounts of onshore wind. But they should also be developing the technology to harvest geothermal power from any amenable area in China. Given recent projects such as the Three Gorges Project on the Yangtze River, it is apparent that China is running out of easy hydropower projects to add to the mix. But the easiest approach, and perhaps the approach that we in the west should be promoting and assisting with, is a Chinese transition away from coal and towards nuclear. For China, the construction itself would result in significant economic growth as a form of infrastructure renewal, as well as dramatically improve air quality in many locations. For the rest of the world, wholesale conversion of Chinese coal plants to nuclear would dramatically lower global greenhouse gas emissions.

Now, whether China, which is not blessed with a lot of conventional uranium reserves, would be willing to make their domestic electricity generation dependent on foreign supplies of uranium is another question. Ascertaining how to make everyone happy while encouraging this transition is well above my pay grade but the numbers are simple enough to work and there is no easy or rapid way to remove as much CO_2 from the air as replacing Chinese coal plants with nuclear plants. None.

One other quick thought. Let's examine what I have heard in the past when I've brought up the issue of wind or solar not being a baseload production technology. Someone will always look at me like they are the smartest person to ever walk the Earth, wave their hand and say, "Sure, but we can always use batteries!" Which would be a terrific argument if batteries were free and grew on trees. So let's say we do want to use batteries and we want to make our new windfarm as reliable as a coal plant (bearing in mind that coal plants are not 100% dispatchable either, since they suffer breakdowns once in a while, too).

A great wind farm has a capacity factor of about 60%. That is, it will make about 60% of the energy it would make if it were operating as designed 100% of the time.

Which, of course, means that 40% of the time it isn't putting out the power it should because the wind isn't blowing fast enough, or it's blowing too fast and the turbines are shut down for their safety or the turbines are broken and awaiting repair. The average cost of electricity from an onshore windfarm is USD$84 per MWh, in 2010 USD, according to the IPCC. If we can be simplistic about it, the LCOE for lithium batteries used in utility-scale storage applications, according to Lazard, is USD$124 per MWh. Now, we need the whole MWh of energy from the windfarm, because we need it to be available to either charge the battery or go to the customer. But the 40% of the time that we can't supply the customer from the windfarm, then we need some electricity from our battery. So in a GREAT location for wind, the cost of making the onshore windfarm dispatchable is going to amount to USD$134 per MWh. That moves the cost of the windfarm with battery out of our "Cheap and Clean" quadrant and into the "Clean but Expensive" camp. And yes, producing the batteries resulted in extra CO_2 emissions; by our scribbling, it amounts to maybe another 35-75 grams CO_2 equivalent per kWh, so the use of batteries with onshore wind stays in the "Clean but Expensive" camp, albeit not as clean as we might have hoped.

Slouching Towards Utopia

Regarding the above, so what? Why worry about any of that at all? Well, let's look at what Germany is planning to do to both its transportation and electricity generating fleets.

Germany plans an ambitious program that will see it close down its nuclear reactor fleet by the end of 2022. This will be done primarily by relying on the French nuclear reactor fleet for the importation of a lot more reliably-generated electricity and by building renewables. In 2020, the entire German electrical fleet's capacity was 211.31 GW. If that entire fleet could produce all its power as designed 100% of the time, then Germany could produce as much as 1,852 TWh of electrical energy per year, which would be great.

Unfortunately, Germany actually produced only 516 TWh of electrical energy in 2019. That's because the German fleet has a fair bit of solar (which doesn't work at night) and wind (which doesn't work when the wind isn't blowing) in the mix. So Germany also imported a lot of fossil fuel that it uses to make electricity. German nuclear reactors in 2019 produced 61 TWh of the 516 TWh total, but color that electricity gone next year. Fossil fuels were 40% of the total in 2019, renewables were 46%, but the cold hard fact is that generating ever more energy from renewables becomes increasingly harder to do once you are at a high level, as you've used up all the good sites for wind and solar farms already. So our conclusion is that Germany is going to have a hard time trying to produce more electricity with lower carbon emissions. Especially if they plan to try to do this without nuclear power.

But now think about this: Germany also plans to ban the sale of vehicles powered by fossil fuels by 2030. Remember the predictions from some US investment banks that we could reach a battery electric vehicle 'utopia' someday? Germany in 2030 will be it. So let's look at the energy consumption of German transportation. Harder to do this, as current data are harder to come by, but we will try. In 2020, average gasoline consumption in Germany is estimated at about 495,790 barrels per day (from the US Energy Information Administration). Diesel consumption was 38.7 million tonnes annually in 2017 and recent German news reports have said diesel use has been (surprisingly, to the authors of the articles) slightly up to flat for years, so we will stick with the 2017 number.

Let's also assume that the efficiency of use of energy generated from diesel and gasoline to push a car or truck down the road is pretty poor, say 40% of the lower heating value of the fuel. So some simple arithmetic tells us that the energy used in Germany to push passenger vehicles down the road with gasoline in 2020 was the equivalent of 102 TWh. The amount of energy generated from diesel to push some light-duty vehicles but a lot of transport trucks down the road in 2020 was the equivalent of 183 TWh. Now, remember, the electrical energy used to charge a battery is not 100% available for use. In fact, the round-trip efficiency (what you eventually get to use from the battery compared to the amount needed to charge the battery in the first place) is going to be around 80% for passenger car applications. Let's be charitable and call it 85%. So the above 285 TWh of electrical energy equivalent needed to push fossil-fueled cars and trucks down the road would be replaced by 335 TWh of electricity if that whole fleet were composed of battery electric vehicles.

So, to recap:

- In 2020, Germany's domestic electricity generating fleet made 516 TWh of energy. That already includes 152 TWh from wind and 51 TWh from solar, which likely means the best onshore wind and probably most of the best solar sites are occupied.
- The German government is going to shut down 61 TWh of domestic generation from nuclear power very soon. So we are down to 455 TWh.
- There is no overarching and heavily subsidized master plan to bring gigantic new power projects online. There is no 'Three Gorges Dam'-like project in Germany.
- By 2030 the German government says that no fossil fuel cars will be sold, so they will need a new 335 TWh of electrical energy to replace the energy previously supplied by gasoline and diesel to push cars and trucks down the road.

- There is no massive program of clean mass transit being constructed to obviate the need for Germans to drive their own vehicles.
- The existing 455 TWh of domestically-generated electricity per year is already insufficient. While Germany remains a net exporter of electricity, Reuters reports that German exports of electricity dropped 12% in 2020 compared to 2019 to levels of 52.5 TWh. But electricity imports rose by 38.8% over the same period to 33.6 TWh, most of this from France. This is because wind and solar cannot be relied on to be available when needed, but nuclear power largely can.
- Germany could expand the share of electricity generation for coal and natural gas from the existing levels of 24% and 12%, respectively, but this would counteract the intended reduction in carbon emissions from the transportation fleet converting to electricity.
- There is almost certainly going to be a mismatch between the availability of renewable electricity and the time at which citizens would want to charge a vehicle. For example, many are likely to want to charge a battery electric vehicle overnight at home, but solar output is, to put it mildly, lower at night. This means the electricity deficit will grow dramatically, electricity will necessarily become even more expensive and power outages will likely become more common.

To say that all this sounds ludicrous is to denigrate the term. And other countries in Europe are rushing to do the same sorts of thing, including shutting down nuclear stations while planning to ban the sale of fossil-fueled vehicles, compounding the problem. France had really better get busy building new nuclear reactors.

Let's look at how the quick answer from the political left to all these sorts of problems, renewables, is able to fill the gap, at least in Germany. In 2019, several groups in Germany started to sound the alarm over the fact that new German onshore wind power construction was "collapsing". In 2019, Germany built roughly 2 GW of new onshore wind capacity. The collapse was described as "temporary" by some, but the real problem is that once you build a number of wind farms in good locations, you are then left with building the next wind projects in lousier and lousier locations, which means lower and lower rates of return and who wants to invest in that? Offshore wind has more available sites but is more expensive to build and is only slated to add 730 MW of capacity per year to 2030.

The capacity factor of onshore wind averages less than 35%. Yes, some projects do really well, with capacity factors above 60%, but anything like those locations have already been used in Germany. Offshore wind is better, but numbers from the studies of British offshore wind averages around 40%. So let's say that between now (2021) and then (2030) German companies and various levels of government get to commission 20 GW of new onshore wind at a 35% capacity factor and 7.3 GW of new offshore wind at a 40% capacity factor. By 2030, they will have added a total of 87 TWh per year from all those wind farms, so only 40% more electricity production than they are shutting down in 2021 and 2022 with the cessation of nuclear plant operation.

There are some options. One is that German drivers had better stop driving and learn to bicycle a lot more. And Germany had better institute a really serious draught horse breeding program because they are going to need more than the former truckdrivers pulling all those enclosed cargo trailers down the roads between towns (Question: What are the lifecycle carbon emissions of a draught horse?). The second is that Germany gets really serious about an electricity grid overhaul that includes a lot of new nuclear reactor builds, but time is running out on that sort of program given we are only ten years from 2030 and Germans do not regard nuclear energy as desirable. The last option is that government invents some kind of an excuse to modify and delay their poorly conceived initial plan, like they graciously allow hybrid vehicles in the mix in spite of them containing a gasoline engine and they postpone making the transportation fleet 100% pure electric.

But there has to be some modification to the German plan for transitioning to electric transportation, because the answer to the question of whether you can shut down nuclear plants, emphasize renewables and convert your transportation fleet to pure electricity all at the same time is:

Exhibit 4 – The Answer to the German Question

Source: Paramount Pictures and DreamWorks Animation (2010)

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