VIEW FROM THE PEAK

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Mobilit-e 2022 is the first major virtual conference that *Climate Transformed,* my climate research platform, has undertaken. Climate is the most important investment narrative of our lifetime, and if the world has any hope of reaching net-zero targets by 2050, we need to electrify our modes of transportation. We are spreading the event over two weeks. The week that has just passed saw us focus predominantly on the nuts and bolts, the EV supply chain that China unsurprisingly dominates. We focused on the underlying commodity inputs, battery technology, and the struggles existing OEMs face compared to Tesla and over 200 Chinese EV brands. I came away in awe of the technologists and entrepreneurs who presented, the thought leaders who will drive the innovation needed to ensure the electric vehicle revolution. I am also petrified that their vision cannot be executed.

When you listen to Mujeeb Ijaz of Our Next Energy, Isobel Sheldon of Britishvolt, or Levi Tilleman of battery swapping firm, Ample, you will be blown away by the battery innovation the world is witnessing. The world's greatest minds are tackling vehicle electrification head-on, and they have the intellectual firepower and capital to achieve the greater range, power, and variety that EV consumers will demand when buying their first electric vehicle.

Chris Showalter, the CEO of Kabanga Nickel, will oversee the world's cleanest Nickel production in Tanzania come 2024. Chris is using technology that removes smelting from the process, and this is a platform that produces 70% less carbon than his competitors. These remarkable innovators deserve our investment dollars and our gratitude for driving forth this agenda.

My great fear is that they won't be able to scale their products because the global commodity supply chain is fragile and ill-prepared to provide them with the underlying inputs that allow them to execute. I have summarized the four essential mineral panels (cobalt, copper, lithium, and nickel) in the body of the report, but the prospect of wide-ranging, multi-year supply shortages is almost without question. Lithium is the glaring concern as there are few viable alternatives to lithium in the current battery product line. With 20%-25% CAGR likely between now and the end of the decade, and seven to ten year lead times for greenfield projects to come online, the lithium shortages we fear could see low battery output being an anchor on the entirety of the two, three, and four-wheel passenger revolution.

While the legacy of child labor in the DRC has tarnished cobalt's reputation, significant improvement has been witnessed via the efforts of NGOs, supply chain tracing companies like Circulor, and the sustainability endeavors of the London Metals Exchange. The exponential improvement in supply chain transparency and the rise of battery passports that can monitor everything from sourcing to carbon output has taken much of the reputational risk out of cobalt. Yet, we still see a reluctance to invest in greenfield projects outside of the DRC and, to a lesser extent, Indonesia. While battery innovation is focused on finding a replacement for niche

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commodities like lithium and cobalt, the technology doesn't exist to rival performance, range, weight, or safety profiles. As Jessica Fung, the chief strategist of Pala Investments, discussed on our Wednesday cobalt panel:

Practically, cobalt is a few hundred dollars, and you remove the technology risk of overheating. Compared to the prospect of a multibillion-dollar recall, cobalt is cost-effective and reliable.

We can be confident in the long-term demand profile for cobalt. You should be concerned about whether supply can keep up.

Nickel introduces enormous environmental and geopolitical risks to the battery supply chain. While Kabanga Nickel will be producing 100,000 tonnes of "clean" nickel by 2027, Indonesia will dominate the global output of nickel in the aggregate. 60% of global output will come from Indonesia, and it is currently being produced in an incredibly toxic fashion. Depending on the vehicle, 50% of carbon output produced in building an electric passenger vehicle is via battery production. North of 50% of the batteries carbon is from the nickel in each battery, so let's keep the math simple: a quarter of the carbon produced in building an EV comes from nickel, and most of that, from 2025, will come from Indonesia.

Indonesia needs to clean up its act via renewable energy sources, scaling back pyrometallurgy, and removing coal-fired power plants from the smelting process. The environmental cost is staggering, with CO2 output as high as 50 tons of carbon per one ton of nickel pig iron. It could take ten years for Indonesia to go clean. When you consider the CO2 output, Indonesian nickel is awful, but OEMs, even Tesla, have no choice currently. Clean nickel is a niche at best and will be a niche for years to come. The implications are straightforward. Global auto manufacturers will not achieve their carbon reduction targets if Indonesian nickel remains the dominant source.

As concerning is China's dominance of Indonesia's nickel output. With huge Chinese investment locking up this supply, this should be a grave concern to non-Chinese car manufacturers and governments alike. It's important to reiterate that there aren't enough projects being developed outside of Indonesia.

Indonesia is a great challenge and opportunity in the years ahead.

Supply-side shortages in copper will emerge post-2024 but won't be as dramatic as Lithium, Cobalt, or Nickel. But here is the issue. An EV cannot operate if any of these minerals are in short supply. EV waitlists are inevitable. The question I would ask is, do copper prices fall in the second half of the decade because you cannot get enough lithium for batteries? If you have a global battery shortage, you cannot produce enough electric vehicles. If you cannot produce electric vehicles quickly enough, you don't need all that copper. For an EV manufacturer, you are only as good as your tightest input. If the global supply chain works efficiently, the price of all commodities will rise. If we have bottlenecks due to lithium, cobalt, or nickel, the number of EVs produced will slow. This will be a key question in the years ahead.

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Why is the supply response so tepid? BHP recently said that the supply response has been timid when considering strong prices.

Mining CapEx for battery materials is currently at $70 to $80 billion per year when should be well above $150 billion per year between now and the end of the decade to ensure that we do not have bottlenecks. We just are not spending enough on mineral extraction.

Resource nationalism is emerging. Global mining majors have a tarnished reputation. It is much more difficult to break ground on a mine. More and more delayed projects due to activism, environmental regulation, and governments appreciating the scale of the opportunity and demanding a bigger slice of the pie. That said, these are global corporations that have the infrastructure to handle this. If the return on capital is there, why is there such hesitancy?

Why are the big mining majors not committing to new projects? Hands down, the most important question to come from these panels

Why are mining majors aggressively returning cash to shareholders? BHP's recent huge special dividend deserves to be challenged. Near term, it's a remarkably constructive environment for share prices. Tremendous profitability creating shareholder value. But what about future supply? Wouldn't it be better to spend some of that cash on Greenfield projects? If the opportunity set is as glaring as many of us think, why the reluctance to invest?

While the supply of essential minerals threatens the pace of production, the existential threat comes within a common refrain. China's dominance of the battery supply chain is yet a further example of how the western world has failed to plan for the contingencies of a new global paradigm. For the past six years, since the emergence of Donald Trump and the first true challenges to Chinese supply chain dominance, the world has focused on access to semiconductors. This has been a major investment narrative that has led to the EU and the United States proposing tens of billions of dollars of investment in Fabs to localize chip production to protect themselves against China. The issue is that China makes very few chips. Taiwan makes chips, and while a tremendous amount of assembly is done in China, TSMC remains very friendly to the west. Supply shortages in the auto industry weren't driven by China issues directly, and while China's ambitions towards Taiwan are a geostrategic concern, supply concerns based on Taiwan's reliability are overblown.

When compared to semiconductors, the risks to battery supplies are enormous. 80% of batteries are assembled in China. Chinese firms are vertically integrated, exposing just how badly legacy OEMs have handled the supply chain challenges of accessing essential minerals. A geopolitical conflict between the US and China could see the supply of batteries cut off, effectively seeing GM and Ford grind to a halt. Munich faces similar concerns.

Panasonic and LG Chem will be friendly to global OEMs, but CATL is, in my opinion, the most strategically important company on the planet. China's dominance of battery cell manufacturing means the west is vulnerable to the geostrategic whims of Beijing.

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Legacy OEMs are not only facing challenges due to an over-reliance on China. Every step of the way, they appear to be underestimating the procurement challenges when the vehicles they will produce in the future will have half the parts and be dominated by chips, batteries, and software. The semiconductor shortages were of their own making, and the lack of vertical integration sees them vulnerable to essential minerals with tight supply. Why is Tesla the only manufacturer seeking vertical integration deals? Why aren't the OEM's doing the same thing? The OEMs have procurement baggage. They are used two subservient suppliers. Lithium suppliers don't need Ford, GM, and Munich. Where will Volkswagen get its raw materials from? The OEMs claim this is a battery guy problem, but a battery guy problem is a huge supply chain problem for the traditional automakers. They need to change their mindset.

For me, many legacy OEMs face extinction by the end of the decade.

The opportunity sets in the battery supply chain are remarkable if investors are brave enough to embrace it. However, if the status quo persists, we risk the EV revolution being derailed due to a lack of batteries. Global Lithium production in 2021 was roughly 90,000 tonnes. It was 150,000 tonnes of cobalt. If Exxon were to buy the entire lithium industry, it wouldn't move the needle for them. Yet, these two metals currently control the future trajectory of the EV rollout. You don't get to 40mm EV sold in 2030 without 40mm batteries with Lithium and Cobalt. The EV supply chain is only as good as its tightest commodity. You could easily see a scenario where lithium and cobalt prices rise exponentially while copper prices collapse in the latter years of this decade. Note that these bottlenecks are evolving, and you should not take this report as a recommendation that copper prices will fall in the medium term. However, unless greenfield projects are announced in the next 12-24, battery shortages later in the decade seem inevitable.

Am I the only one who thinks this? What other explanation do you have for mining majors' reluctance to commit capital in this major investment narrative?

Any EV investment strategy needs a structural exposure to lithium and cobalt. You need exposure to Indonesia Sovereign Bonds as the world's dominant nickel producer. You need exposure to the world's leading battery makers, Panasonic, LG Chem, and definitely CATL. I would avoid the legacy OEMs who continue to act like it's 1992, not 2022. While difficult, you need to find a way to expose yourself to the private companies leading the electrification of mobility. They face logistical challenges due to upstream constraints, but their innovation will take us to a greener world.

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Nickel – The Biggest Concern / Challenge

Fastmarkets' Andrea Hotter moderating a panel featuring Kabanga Nickel CEO Chris Showalter, Jim Lennon, managing director of Red Door Research, and the LME's Hugo Brodie.

Nickel overview. Last year saw an enormous jump in demand. 17% year on year, which was the fastest growth rate on record. Stainless steel consumption is 5 1/2 times bigger than batteries, yet battery demand attributed 40% of that jump while still being only 13% of the total market. Batteries consumed 360,000 tons of nickel in 2021, up from 200,000 tons in 2020. Battery demand is being driven by electric vehicle sales that also doubled year on year. Electric vehicles remain less than 10% of total sales, implying where nickel demand is heading in the decade ahead.

Indonesia has been the only source of growth in supply in the past two years. Rapid demand growth plus sluggish supply growth equals record prices.

We will have a bifurcated battery market between LFP and NCM batteries. LFP batteries: no nickel / no cobalt. NCM batteries contain the highest nickel content. Low-end batteries with no nickel, high-end batteries with much nickel content.

By 2030 there are estimates that 38 million electric passenger vehicles will be sold globally, which is a sixfold increase from current levels. This implies that more than 1,000,000 tons of nickel will be used in battery output by 2030 versus 200,000 tons in 2020.

Nickel-rich chemistry could still be north of 70% of battery content by 2030, but there are some uncertainties, including expanded use of high manganese content, hydrogen fuel cells, and LFP batteries, which could be 30% of the market.

Growth in Nickel demand has been staggering. Demand could grow by 3 million tons, including recycling, this decade.

Supply, where does it come from? Indonesia's High-Pressure Acid Bleach facilities could add 500,000 tons of nickel pig iron by 2030. Indonesian RKEF facilities could be converted, but the environmental cost is staggering, with CO2 output as high as 50 tons of carbon per one ton of nickel pig iron. Other additional production could come from existing sulfide mines, which could add another 150,000 tons of production. However, there has been no new supply in the past 20 years, and this produces low-grade nickel.

Big picture, no new smelters are getting built anytime soon.

By mid-decade, Indonesian supply will meet demand but, unfortunately, will continue to be a high CO2 output. Battery producers and OEMs are demanding green sources of nickel (however we define that), yet electric vehicle demand may force them to consume this nickel with a massive carbon footprint.

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This is the great quandary for OEMs. They will never reach CO2 reduction targets if they continue to source Nickel using traditional techniques yet EV demand in the next decade imply they have no choice.

Because of additional Chinese-funded Nickel supply in Indonesia, by 2023-2024, the Nickel market could be in a small surplus. However, large-scale shortages are likely after 2025, and from now until the end of the decade, there will be major shortages in low-carbon nickel.

Clean Sources of Nickel: Kabanga Nickel is a Tanzanian project online in 2024 and will be the cleanest nickel production so far. It removes smelting and refining (pyrometallurgy) and instead uses hydrometallurgy methods that reduce CO2 output by over 50%. Smelting is responsible for 70% of CO2 when producing nickel. OEM's will never be able to meet their carbon reduction targets if they continue to employ pyrometallurgy techniques for Nickel production.

Kabanga will also remove the need to ship heavy bulk concentrate abroad, subtracting the additional carbon output from shipping. Kabanga aims to be producing 100,000 tons of hydrometallurgy nickel by 2027. While this is positive, it doesn't come close to meeting the demands for low-carbon nickel from the global auto industry.

BHP has invested $100 million in Kabanga. They invested to take advantage of the clean production process but also because it is a development-ready project. In a world where clean nickel projects are in short supply, it will be the largest project when it comes online.

There will be enormous demand for clean sources of nickel, demanding premium pricing over the long haul. Locking up supply will be an incredibly competitive pursuit and will be hugely challenging for OEMs in the years ahead. That said, Kabanga is not forecasting a premium to the current spot even with its clean production techniques.

How green is the nickel in your battery? Nickel varies from 5 tons of CO2 to 50 to 60 tons of CO2 for pig iron production in Indonesia. The average is around 20 tons of CO2 per one ton of nickel. Again, it's important to note that there is very little LME deliverable grade nickel in a battery. More than the LME, EV manufacturers will enforce carbon standards.

Indonesia needs to clean up its act via renewable energy sources, scaling back pyrometallurgy, and removing coal-fired power plants from the smelting process. However, China has prioritized locking up supply versus environmental implications. It could take ten years for Indonesia to go clean. When you consider the CO2 output, Indonesian nickel is awful, but OEMs, even Tesla, have no choice currently. Clean nickel is a niche at best and will be a niche for years to come.

Indonesia also has a problem with tailings and deforestation. Deep-sea tailings have already been banned for all new projects that show that Western OEMs can influence standards despite a large concentration of Chinese investment. Dry stack tailings are the new approach to replace deep-sea tailings. However, it's expensive and takes time to develop.

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Where is the LME with responsible sourcing? This year the London metals exchange introduced ethical thresholds. As of June, LME recognized brands need to reveal responsible sourcing with human rights thresholds coming first. The LME has stayed away from carbon at this moment. Instead, relying on voluntary disclosures on the LME passport platform. It is important to note that only 20% of all nickel produced is deliverable via the LME standards and that pig iron is not part of the equation. If brands fail to meet the new ethical threshold standards, the LME can delete these brands. Bellamy continues to promote metals as the great enabler of the energy transition, and metals such as Nickel, cobalt, and Lithium should not be seen as dirty but as an essential part of the energy transition.

Note that Nickel pig iron trades at a significant discount to LME grades.

The Nickel Institute is developing a CO2 methodology that will complement the LME's human rights-based sustainability standards.

Geopolitical risks. The big geopolitical risk regarding batteries revolves around China being 80% plus of all battery cell production. The United States and EU supply localization efforts will be an ongoing development.

The next big geopolitical issue revolves around the concentration of Nickel production in Indonesia. By 2025-2026, 60% of nickel output could come from Indonesia. With huge Chinese investment locking up this supply, this should be a grave concern to non-Chinese car manufacturers and governments alike. It's important to reiterate that there aren't enough projects being developed outside of Indonesia.

Will OEM's move further upstream? Most of the investment in Indonesia is Chinese vertical integration. Very few projects are being developed outside of Indonesia as the capital payback can be 10 to 15 years. Indonesian projects, however, can see full capital payback in two to three years for battery-grade nickel with a cost per ton of $20,000 to $30,000 and less than $20,000 for a non-battery-grade nickel.

China is all in on Indonesia.

Will higher prices prompt substitution? This is always a concern for minors.

Lithium is a bigger concern than nickel longer-term but substituting for sodium-ion is not likely in the next five years

Stainless steel is currently 80% recycled scrap, so this is not competing in the battery space. Stainless demand will likely grow at 5% year on year over this decade, while batteries could be as high as 25% year on year.

Conclusion – Clean Nickel shortages are by far the biggest risk to OEMs achieving emission reduction targets, and I see no way this can be achieved. Clean nickel will trade at dramatic premiums in the years ahead, and greater supply chain transparency shines a light on this

structural flaw in the EV supply chain. Indonesia's dominance, its cozy relationship with China, and China's dominance in battery output should be viewed as one of the great economic vulnerabilities facing the United States, in particular in the next decade. Forget clean output; Ford and GM may struggle to get enough dirty nickel in the second half of the decade.

When it comes to the battery supply chain, the fragility of US and European OEMs should not be underestimated.

Lithium - Metal of the Century

Henry Sanderson of Benchmark Minerals moderates this opening panel on Commodities day, where he discusses Lithium with Joe Lowry, President of Global Lithium LLC, and Utkarsh Singh, CEO at BatX Energies.

Overview. China's Dominance: We are Seventeen months into the bull market. Chinese prices are up 48% this year. Price gains need context. $ 60,000 plus China prices show China's dominance. Realistically, Tesla isn't paying this, but it shows the arms race in China. We have bifurcated markets. China and the rest of the world.

China has always been the most volatile lithium market. Price spikes 2005-2008, 2015-2018. The reasons for this are simple. China is the largest EV market, and China dominates cathode production. China will always have the highest lithium prices when the price is high and the lowest when prices are low.

Supply: Where does the supply of lithium come from? It will continue to grow from current sources. We've had several electric vehicle false starts. This time, electric vehicle demand is real.

Last year the lithium market grew by 9.6% to approximately 90,000 tonnes. Capacity is coming back online, but a couple of new mines won't break the market because demand growth is so strong. It takes ten years for a Greenfield lithium project to come online. We are facing structural deficits, and EV waitlists are destined to grow.

Chinese suppliers of lithium. Enormous Tibet deposit? China is resource-dependent on lithium. Chinese deposits tend to be low grade. Theories about a Chinese supply disruption are overblown. This is why China will continue to be a huge investor in Africa, as they are for most essential minerals. Africa has a long history of lithium production. Zimbabwe has produced lithium for decades, but infrastructure remains a major impediment. Oversupply isn't happening this decade. New Africa projects are coming later in the decade, but it won't be enough to match anticipated demand. Recycling is simply not enough. Again, do not lose sight of the seven to 10 years for a Greenfield project to come online.

Recycling. It helps. CATL has recently announced that 90% of its lithium is recovered. Sounds a little dubious but shows their commitment to the recycled product. A circular approach is developing via recycling. Recycling technologies are so important to prevent en masse shortages.

How hard is it to produce battery-grade lithium from recycling? Not as hard as you would think. Hydromet technology is utilized, but the focus has always been on cobalt because that is the highest cost input. Historically lithium has been ignored, but high prices will solve this.

A major source of the recycled product will come from Gigafactories. A seldom-discussed issue is that rejection rates from new gigafactories can be as high as 30%. This has been lost lithium molecules. But they can be recycled, and expectations are growing that most recycled lithium will come from gigafactory rejects.

Recycling in China and India is booming. This will be a major driver for emerging market supply. India is looking to compete with China manufacturing, especially for local demand for batteries. India's first gigafactories are coming.

Lithium carbonate prices are currently higher than hydroxide. LFP batteries are the driver, and this is historically a weird situation but a reflection of China's dominance.

Can you recycle an LFP battery? The answer is yes because a) good second life utilization and b) you can restore the cathode directly.

Every recycler needs to be ready for all sorts of cathode recycling. LFP battery recycling is happening in China but not in many other places.

Replacing Lithium: Are there surprise technologies that could derail lithium demand? Sodium-Ion? Probably not for a decade. Solid-state batteries are not ready to disrupt, and sodium ion is not far along. Gigafactories are designed for lithium-ion. The sunk cost argument. You can modify a gigafactory, but it is not easy to switch your mindset once you have stable production.

India: The transition to electric vehicles is slow for emerging markets and dominated by two and three-wheelers. That said, demand for Lithium in India will be huge in the next ten years. This will underpin global prices. India is the next great growth market. 2070 net-zero is a long way away, but the electric vehicle push is beginning. There are 30% EV subsidies, making them affordable for the middle class. Battery swapping initiatives have been announced.

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In India, two and three-wheelers are a huge opportunity. Lithium inputs for two and three-wheelers are much less than four-wheel passenger vehicles, but the overall demand will be enormous. Adoption in the emerging world will be less about environmental concerns and more about the oil price.

Where will India get its lithium from? There is so much demand from many powerful nations. It's difficult to know where. India has been focusing on other technologies such as non-lithium options and recycling. No one is comfortable relying on China. But currently, India has no choice. 90% of cells in India come from China. They are just cheaper than Panasonic and LG Chem.

Australia. Does China have a supply problem due to poor relations with Australia? Australia will develop new supply chain. For years China was the only game in town for converters. Australia will have many options and will be courted by all the OEM's. Loads of quality converters are being produced in Western Australia. A large potential rival for China is why the China Africa bridge is so important to Beijing.

Struggling OEMs. Why is Tesla the only manufacturer seeking vertical integration deals? Why aren't the OEM's doing the same thing? The OEMs have procurement baggage. They are used two subservient suppliers. Lithium suppliers don't need Ford, GM, and Munich. Where will Volkswagen get its raw materials from? The OEMs claim this is a battery guy problem, but a battery guy problem is a huge supply chain problem for the traditional automakers. They need to change their mindset. Lithium does not behave like a commodity. It behaves like a specialty chemical. It will not behave like iron ore and have cyclical swings in the next five years.

M&A. When is it coming? It makes so much sense for Rio and the other major producers to acquire the small players. That said, pure plays are rare. And it is not as easy as you think. It remains a relatively small market. If Exxon were to buy the entire lithium industry, it wouldn't move the needle for them.

Lithium is a vital industry, but it remains a relatively small one in the context of global energy.

Conclusion: The laws of supply and demand are rarely defeated. Unless sodium-ion batteries can develop at a rate few can see, the prospect of structural Lithium shortages could see a log jam and significant electric vehicle waiting lists. Difficult to see how prices don't move exponentially higher in the years to come

Cobalt - High Demand and Controversy

The LME's Alice Lim, Jessica Fung from Pala Investments, and Caspar Rawles from Benchmark Minerals.

Cobalt overview. Currently, the cobalt market is finely balanced. However, like most minerals in the battery supply chain, post-2024 is likely to see cobalt in a structural deficit. We have never seen a demand spike-like with batteries, and cobalt is no exception. Expectations are for 12% CAGR do barn growth out to 2030. Lithium is likely to see 22% to 25% over the same. Cobalt is a

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relatively small market with 150,000 tons of current production. And there will be a continued role in lithium-ion batteries.

The historical context of cobalt sustainability issues. The human rights issues in the DRC with child labor and labor abuses are well noted. NGOs have highlighted these issues with ASM (artisanal small mines) and larger-scale projects. The London metals exchange now requires ethical and human rights thresholds via its responsible sourcing requirements. This is but one part of an effort to mitigate risk in the battery supply chain. The LME platform focused initially on human rights, placing cobalt at the center of this new initiative.

Despite the tarnished image of cobalt mining in the DRC, many companies have made great strides to ensure risk mitigation and acceptable global standards. Tesla is but one leading company that has announced responsible sourcing. Much progress has been made, but there is more work to come. the DRC supply chain, the risk is much less problematic than it once was

Structural supply shortages in battery minerals. Simply put, if we don't have access to the materials, we cannot transition to electric vehicles. We need something in the vicinity of $600 billion-plus of global investment across the battery supply chain by 2030. If we want to be net-zero by 2050, we must eradicate the internal combustion engine by 2040. High commodity prices will help encourage investment, but it is not that simple. We need stakeholder alignments between regulators, producers, and investors. Policy plays a key role, whether it's via carrots or sticks. Industry must ensure supply and provide investors with an appropriate level of return. All three stakeholders need to work together.

We have huge issues with the extraction industry. It is very difficult to get a project off the ground. Funding, permits, and more stakeholders than ever. It can take years to get permitted. Greenfield cobalt projects can take 7 to 10 years outside of the DRC. We have no choice but to invest. During the China super cycle of 2004 and beyond, $1 trillion of investment went into iron ore, steel, aluminum, and many other basic building blocks to meet Chinese demand. The EV revolution and energy transition will ensure that demand, particularly in the battery space, is structural, and without investment, supply will remain incredibly tight.

The DRC. It has the potential to recalibrate its economy by dramatically raising its GDP per capita. The DRC is the cornerstone of cobalt supply. It has always been logistically difficult and, when combined with a dubious human rights record, has kept many investors from taking advantage of a significant economic opportunity. Greenfield projects can still take five years, and expansions of existing facilities take two to three years. While quicker than other parts of the world, there are still sizable delays in bringing new projects to market in the DRC.

How can the DRC attract investment? The artisanal mining sector needs to be formalized. There must be guarantees about royalty terms. More investment is coming, especially from China. Copper and cobalt wealth is located in the South, and this wealth needs to be spread across society to the poorer northern regions.

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How are NGOs, charities, and organizations like the LME being a force for change? Throwing money at the problem simply does not work. Initiatives need to take into account attitudes towards education. How do you keep kids at school and prevent them from working in the mines? Cultural issues need to be taken into account. The solutions are not just economic.

Non-cobalt battery tech. Where are we in the innovation phase? Cobalt is one of the most expensive battery components, but there are good safety reasons for its continued use. Removing cobalt is a high-risk strategy. Currently, there are few options apart from cobalt. LFP batteries (cobalt free) are gaining traction in China, but with lithium over $60,000, the cost advantage of LFP batteries is mitigated. LFP will be part of the solution, but they won't replace cobalt. Sodium-ion batteries are not commercially available. CATL is undertaking a large push, but sodium-ion batteries are cloudy in the next several years. NSM technology is still around, but none of these are solutions for the problem of a major technology risk of removing cobalt because of the thermal stability that cobalt provides.

Practically, cobalt is a few hundred dollars, and you remove the technology risk. Compared to the prospect of a multibillion-dollar recall, cobalt is cost-effective and reliable.

OEM's and procurement issues. Cobalt and lithium producers don't need Detroit and Munich as much as the typical OEMs need stable access to cobalt and lithium. The OEMs have treated suppliers as subservient in the past. The chip shortage has shown that this doesn't work for the EV supply chain. Cobalt producers could still sell their products without an EV revolution. However, it is this EV revolution and the demand from OEM's that makes cobalt and the other battery inputs so exciting.

We wouldn't have the supply growth without EV demand. EVs are a global game-changer, so the OEM's and the cobalt producers need each other if record prices are to persist.

Should we think about cobalt as a commodity and all the cyclicality inherent with that? Arguments are made that Cobalt and Lithium should be treated as specialty chemicals, and they will not have the violent price swings as we've seen in previous cycles. While they are still commodities over the next five years, demand is structural, and supply shocks are unlikely. We are in the midst of a period of structural demand, and while this may be a very long cycle, cobalt is still a commodity that will be affected by structural changes in supply and demand.

Battery passports. A battery passport traces battery components from the mine through processing and, finally, the recycling/decommissioning of that battery. The LME passport traces responsible sourcing, but other passports can also trace carbon output. The technology around supply chain transparency has improved remarkably in the last several years. Companies have come to realize the importance of traceability. If you can't measure it, you cannot manage it, hence the importance of battery passports. Traceability puts us on a path to end greenwashing.

ESG compliance is expensive. Do bigger companies have an advantage because of the cost of monitoring and tracing? Small models still don't produce sustainability reports. It is estimated

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that only 37% of lithium miners produce ESG reports. They are expensive to produce and even more expensive to comply with. At the end of the day, these costs are passed on to consumers.

As well as the state cost of compliance, inflation in the battery supply chain is rampant. It is currently an arms race with labor shortages, the cost of transitioning to renewable energy, and extraction equipment leading to a dramatic cost increase in bringing a mine to market.

Does this imply that big companies are destined to dominate? They can cope with the high cost of ESG compliance. They have access to capital, can share resources, and have scalability. Bigger can be better. That said, we still need small firms that are prepared to take technology risks to keep these large firms honest.

We need to find new ways to bring supply to the market. The old techniques won't produce enough to deal with the EV battery revolution.

Conclusion. Supply chain tracing and battery passports will go a long way to eradicating the human rights issues facing the DRC and the cobalt industry. Cobalt remains an essential part of the battery supply chain, a safe and reliable thermal safety valve. While battery innovation is omnipresent, and cobalt prices are likely to move higher in the years ahead, I feel that structural shortages in lithium will be the catalyst for new technology adoption, not the cost or the human rights record of cobalt.

Copper - Unpacking EVs raw materials.

Featuring Michael Widmer, Bank of America's head of metals research, Robert Ewards, CRU Group, Richard FU, Shanghai Pudong Development Bank, and Geordie Wilkes, head of research at Sucden Financial.

Copper overview. The essential component for electric vehicles. Batteries, inverters, wire, charging stations. Four times the amount of copper as a standard four-wheel ICE and up to 11 times more for commercial vehicles. By 2030 there'll be 20 million global charging stations using 250% more copper than in 2019. Eighty kilos of copper per standard four-wheel vehicle in 2021. Electric vehicles were 2% of global refined copper consumption, with estimates of 10% by early 2030.

By 2035 2.5 million tonnes of refined copper will be used in the electric vehicle process, 3 million tons including scrap.

Where does it come from? If we desire the electrification of mobility, we need much more copper than is currently available or proposed.

By region: Europe: slowly waking up. Europe now appreciates the necessity of securing raw material supply. Large developments regarding recycling.

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The United States: playing catch up. Currently, way behind the rest of the world, with only 700,000 registered electric vehicles. The Biden administration is supportive with the infrastructure bill allocating $15 billion for EV adoption and $5 billion for charging stations. (whether this becomes law is debatable). This is a drop in the ocean versus long-term infrastructure requirements. Given the starting point, targets of 50% electrification by 2030 appear ambitious.

China: the global leader. Way ahead of the pack! 200 electric vehicle brands. 52% of the global EV market. 3.3 million EVs sold in 2021, up 50% from the 2.2 million in 2020. China is turning off subsidies (30% removed) for passenger vehicles. At the margin, it will hurt adoption, but EV is an unstoppable force. Promoting new technologies, especially batteries, to move away from lithium and cobalt. Unlikely near term.

Current goals are 20% EV sales by 2025, 40% by 2030, and 50% by 2035. Personally, I see China banning ICEs well before then, and I believe the adoption estimates are way too low, even without subsidies.

Mining CapEx for battery materials: Currently, it's $70-$80 billion per year, should be $150 billion per year between now and the end of the decade to ensure that we do not have bottlenecks. We just are not spending enough on mineral extraction.

Resource nationalism in mining. Global mining majors have a tarnished reputation. It is much more difficult to break ground on a mine. More and more delayed projects due to activism, environmental regulation, and governments appreciating the scale of the opportunity and demanding a bigger slice of the pie.

The role of copper recycling: Copper is one of those materials that can be recycled repeatedly. It is estimated that 1/3 of global usage is recycled. Surprise, surprise, China dominates scrap! The US is a net exporter of scrap. China's scrap imports have declined precipitously in the past 15 years from 6 million tons to 1.5 million tons. China has strengthened its classification standards, and scrap tends to be treated in other Asian countries before arriving in China. The scale of the use of scrap will be very price-dependent, but it is clear that scrap is getting much more difficult to come by. The level of impurities is a major issue. Do you have to re-smelt the scrap? Huge cost and carbon consequences for downstream products.

Are there viable substitutes to copper? It is a very tight picture all around. Aluminum is the obvious substitute, contingent on the price ratio between copper and aluminum, which currently stands at approximately three. We are seeing some substitution with Tesla employing shielded aluminum cable and an aluminum rotor in its Model Y. Substitution is a long lead time. There is a strong argument against substitution, i.e., If they could substitute, they would have already. Copper is copper,/aluminum is aluminum.

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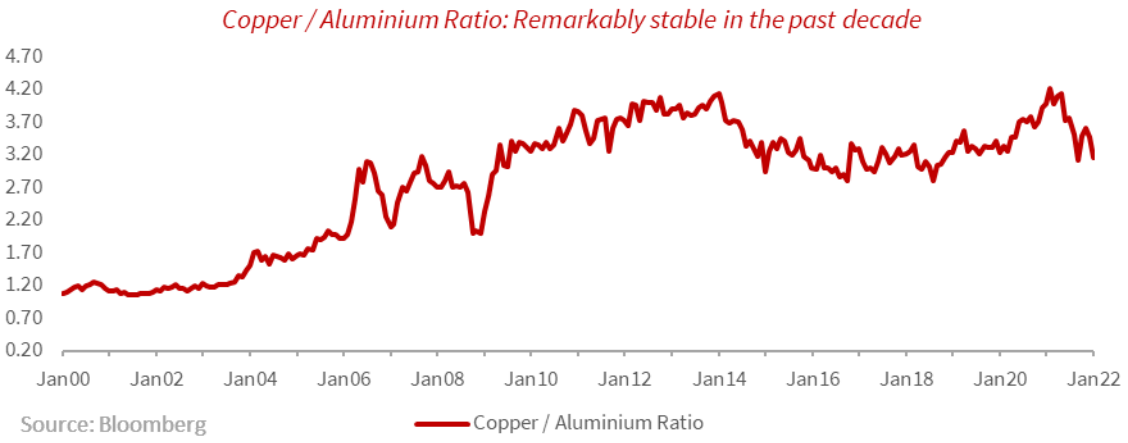

Price forecasts consensus of north of $15,000 a ton in the next several years. Structural demand into a wavering supply side. One argument against significantly higher prices is that miners are currently very profitable, with cash extraction costs between $4000-$5000 per ton.

New mine capacity: Who is doing it and where? Indonesia and the DRC are our obvious examples (see appendix for a list of new projects coming online). After 2024, there is not much of a pipeline, with no new 100,000 ton projects currently being worked upon. This is a huge supply gap post-2025.

BHP recently said that the supply response has been timid when considering strong prices.

Why are the big mining majors not committing to new projects? Hands down, the most important question to come from these panels

ESG, battery passporting, new LME rules, cost inflation, and permitting delays. It's simply much more complicated today than it has ever been.

Why are mining majors aggressively returning cash to shareholders? BHP's recent huge special dividend. Near term, it's a remarkably constructive environment for share prices. Tremendous profitability creating shareholder value. But what about future supply? Wouldn't it be better to spend some of that cash on Greenfield projects?

OEM's: where are the partnerships? Tesla, yes, but who else? It's an overriding theme of the conference that the OEM's are behind the curve across the entirety of the EV supply chain for battery minerals to chip supply. They have enormous problems in the long term.

Conclusion: Supply-side shortages will emerge post-2024 but won't be as dramatic as Lithium, Cobalt, or Nickel. But here is the issue. An EV cannot operate if any of these minerals are in short supply. EV waitlists are inevitable. The question I would ask is, do copper prices fall in the second half of the decade because you cannot get enough lithium for batteries? If you have a global battery shortage, you cannot produce enough electric vehicles. If you can produce electric vehicles quickly enough, you don't need all that copper. For an EV manufacturer, you are only as

good as your tightest input. If the global supply chain works efficiently, the price of all commodities will rise. If we have bottlenecks due to lithium or geopolitical stress points due to China's dominance in battery cell production, the number of EVs produced will slow. This will be a key question in the years ahead.

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Appendix 1

Major Copper Projects Pipeline. MINING.com Editor | October 11, 2021. A report from Fitch Solutions.

	Mine	Country	Primary Company	Reserves/ Resources (mt)	Mine Life (yrs)	Total Allocation Capex ($m)
1.	Kerr-Sulphurets-Mitchell (KSM)	Canada	Seabridge Gold	460.0	44.0	12,100
2.	Oyu Tolgoi	Mongolia	Turquoise Hill Resources	355.0	31.0	11,952
3.	Cascabel	Ecuador	SolGold	1,192.0	66.0	10,064
4.	Frieda River	Papua New Guinea	PanAust Ltd	604.0	33.0	7,870
5.	Izok Corridor	Canada	MMG Ltd	21.4	No data	6,500
6.	Galore Creek	Canada	Teck Resources	128.4	18.5	6,185
7.	Tampakan	Philippines	Alcantara Group	2,940.0	17.0	5,900
8.	Baimskaya	Russia	KAZ Minerals	139.0	25.0	5,500
9.	Twin Metals (Nokomis)	US	Antofagastana	291.4	25.0	5,411

In first place is Seabridge Gold's KSM project in British Columbia, Canada, with a capex allocation of $12.1 billion. In November 2020, Seabridge refiled the technical report: Proved Reserves: 460mnt; Mine Life: 44 years. The project includes Kerr, Sulphurets, Mitchell, and Iron Cap deposits.

Rio Tinto-controlled Turquoise Hill Resources' massive Oyu Tolgoi expansion in Mongolia takes second place, with an $11.9 billion capex. The project has been plagued with delays and cost overruns, but Turquoise Hill is expected to commence production at the project in October 2022. The $5.3bn underground development at the mine remains on schedule to be completed by 2022; Rio Tinto has 50.8% interest in Turquoise Hill Resources. Proved Reserves: 355mnt; Mine Life: 31years.

SolGold and Cornerstone Resources' jointly held Cascabel project in Ecuador is in 3rd place with a capex allocation of just over $10 billion. Measured Resources: 1192mnt; Mine Life: 66years; The project includes Alpala deposit; Expected Production: 150kt/yr Proved Reserves: 604mnt; Mine Life: 33years; Expected Production: 175kt/yr.

Coming in at number 4 is the Freida River project in Papua New Guinea, with a $7.8 billion allocated capex. Proved Reserves: 569mnt; Mine Life: 20 years.

MMG's Izok Corridor project in Canada's Nunavut's Bathurst Inlet is in 5th place with a $6.5 billion allocated capex. Indicated Resources: 21.4mnt; The project includes Izok Lake and High Lake deposits.

Teck's Galore Creek project in British Columbia, Canada in 6th place with a $6.1 billion capex allocation. In October 2018, Novagold Resources sold 50% stake in the project to Newmont Corporation. Measured Resources (Newmont Corporation's 50% stake): 128.4mnt; Mine Life: 18.5years; Expected Production: 146.1kt/ yr.

Alcantara Group's Tampakan project in the Philippines holds seventh place with a $5.9 billion capex. However, in August 2020 the Philippine government has canceled an agreement with Alcantara Group to develop the mine. Estimated Production: 375kt/yr; Resources: 2940mnt; Mine Life: 17years.

Kaz Minerals' Baimskya project in Russia has a $5.5 billion capex allocation. KAZ is expected to complete bankable feasibility study for the project in H121; Mine Life: 25years; Measured Resources: 139mnt; Expected Start Year: 2027; Expected Production: 250kt/yr.

Rounding out Fitch's list is Antofagasta's Twin Metals project in Minnesota. Antofagasta has submitted a plan to state and federal authorities for the project; Measured Resources: 291.4mnt; Mine Life: 25 years; The project includes Maturi, Birch Lake, Maturi Southwest, and Spruce Road deposits.

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