Alternatives Research
Liquid Real Assets

June 2021

Marketing Material

Commodities: Leading the way in Global De-carbonization

The recipe for a cleaner world starts with the right ingredients

IN A NUTSHELL

_ In our view, commodities will play a pivotal role in the transition to a net-zero-carbon society.
_ This transition will likely occur in several phases and incorporate a variety of commodities across each major sector.
_ In addition to the positive environmental impacts, this de-carbonization movement could provide a secular tailwind for various sectors within the commodity complex.

Executive Summary

Investors are increasingly focused on ensuring the products they buy and the companies they engage with conduct business with considerations that go beyond profits. This can be seen in the rise in investor demand for ESG-focused investment products, where considerations of environmental (E), social (S) and governance (G) factors are featured as a core part of the investment process. As an asset class, commodities have an important role to play, primarily by providing the raw materials to help reduce the environmental impact of the global economy.

As our society continues to transition to net-zero-carbon emissions, commodities will, in our view, play a pivotal role in this transformation. Commodities are the fundamental building blocks of an economy, beyond simply providing an energy source. In our analysis, we identify the stages of de-carbonization and specific commodities required to fuel that transition. It is worth noting that decarbonization is not expected to have a uniform benefit across all commodities. We expect that the drive to reduce emissions will have the potential to decrease demand for traditional fossil fuels at some point in the near future. In fact, some forecasts project that we are already past "peak fossil-fuel demand" as power generation and transport needs are increasingly filled by renewables. However, we expect the reduction in demand for traditional fossil fuels to be offset by growing demand for energy-transition metals such as copper, nickel and aluminum. Overall, we expect that achieving our goal of net-zero-carbon emissions will be a source of additional commodity demand and provide a secular tailwind for commodity prices well into the future, despite waning contribution from the energy sector as fossil-fuel demand declines in favor of renewables.

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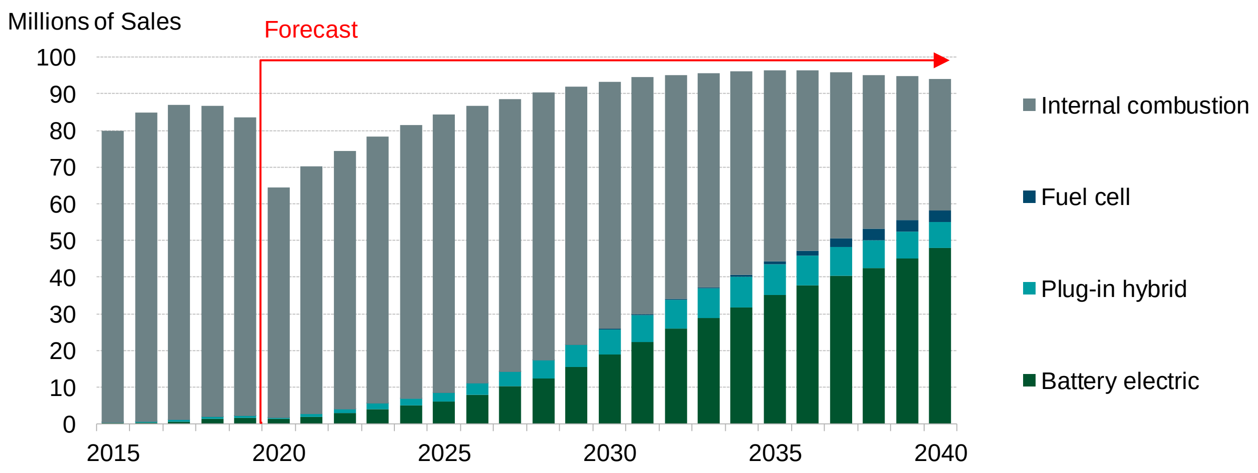
Phase One – The Build Out (next 5 years)

Currently, the global economy is intertwined with carbon based energy and materials and the transportation sector in particular stands out as a major source of carbon emissions. As the world moves towards its net-zero emissions goal, we will need to build out infrastructure that supports means of transportation which go beyond carbon based fuel. We expect this process to require significant capital spending from both public and private sectors; and it is likely that this build out process will take some time. In our view, the impacts of de-carbonization on commodities markets are likely to be evolutionary rather than revolutionary, and the transition process will take place over several phases. The first phase of transition will consist of directly replacing existing carbon-based technology with 'clean' technology. The transportation sector is a likely area for this type of activity as replacing vehicles with conventional internal combustion engines with alternative engines is the most direct and effective way to have an immediate effect on de-carbonization given transportation's overall contribution to emissions. The transportation sector is the single largest source of greenhouse gas (GHG) emissions in the United States and emissions from transportation make up more than one quarter of total GHG emissions from the United States and Europe combined.[1] We see evidence that the direct replacement process is already underway as the recent success of Tesla has spurred other automakers to develop and sell more electric vehicles.

Traditional combustion engines will remain an important source of demand for palladium, rhodium and platinum.

Despite the commitment to change and the progress already made, we expect the replacement of the internal combustion engine to take time. To demonstrate the magnitude of this challenge, we look no further than China, which has overtaken America as the largest single-country new car market in the world in recent years. The Chinese government has an explicit policy to ban all new sales of conventionally powered cars by 2035 in favor of new energy vehicles such as battery electric vehicles (BEV) and hybrids. Even with government subsidies in place in China incentivizing the shift away from internal combustion cars since 2013, in 2020, less than 10%[2] of new vehicle sales are electric vehicles. The relatively slow pace of progress despite decisive action by the Chinese government supports our view of the phased approach to de-carbonization as the most likely path.

FIGURE 1: TRADITIONAL INTERNAL COMBUSTION CARS ARE EXPECTED TO LOSE MARKETSHARE TO ALTERNATIVES



Source: Bloomberg BNEF Long-Term Electric Vehicle Outlook. As of June 2020.

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks – EPA (2019) & How Are Emissions of Greenhouse Gasses by the EU Evolving? – Eurostat (2018)
[2] Bloomberg BNEF (2021)

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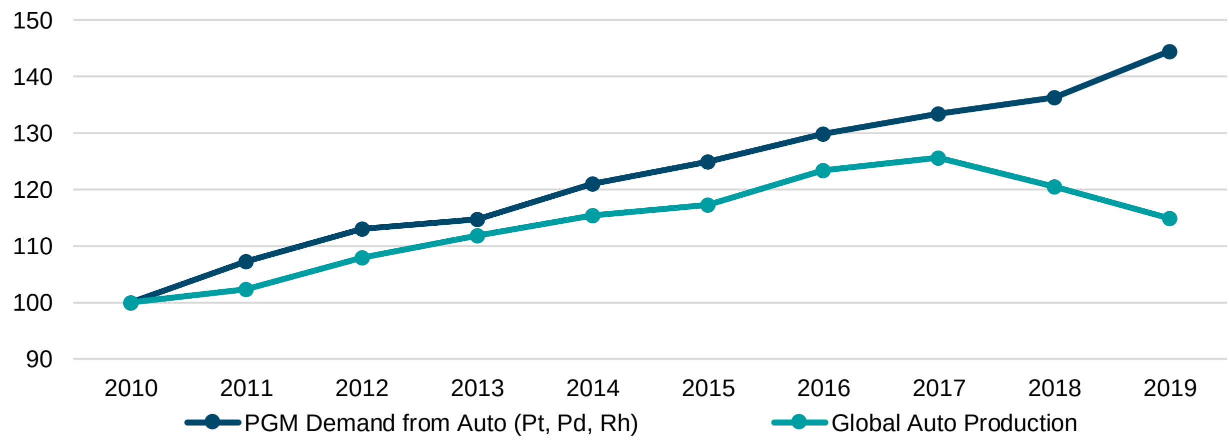
While the global vehicle fleet is being replaced (see Figure 1), we expect governments to continue to tighten emissions standards for conventional vehicles. During this phase, demand for ‘industrial precious metals’ will likely be reshaped by these increasingly strict emissions standards for traditional automobiles. These metals, which are present in the catalytic converter within the automobile’s exhaust system, are required to reduce emissions of harmful compounds such as carbon monoxide, nitrogen oxide and hydrocarbons. More stringent global emissions standards are likely to drive increased loadings of Platinum Group Metals (PGMs) such as palladium, rhodium and platinum, as regulations reduce the allowable level of harmful exhaust compound emission from traditional automobiles and alternative solutions such as reducing engine size and turbocharging are exhausted. From a market-fundamentals perspective, palladium and rhodium are already seen in deficit (demand for use in automobiles exceeds yearly production), so any incremental demand increase driven by more stringent emissions standards should support prices in the near term. The automotive demand component is of particular importance for palladium and rhodium as use in automotive applications represents ~90% of total demand for these metals.

FIGURE 2: PLATINUM GROUP METALS DEMAND IS FAR EXCEEDING GLOBAL AUTO PRODUCTION



Source: Bloomberg. As of March 2021.

We observe this trend both historically, as demand for PGMs in automotive applications has far outpaced the rate of growth in auto sales for the past decade, and more recently where the introduction of China VI standards saw required loadings of palladium and rhodium increase by c. 40% and c. 50% - 100% per vehicle, respectively.[3] In fact, we observe PGM demand continuing to grow in recent years despite a slowdown in global auto production levels (see Figure 2). Hybridization is also likely to play an increasing role in the ‘traditional’ vehicle mix, but we do not anticipate a great degree of demand destruction from this as we believe hybrids are likely to require additional PGM loadings compared to traditional combustion-engine drivetrains. The higher degree of variability in engine operating temperatures for hybrids (due to intermittent/inconsistent use during driving) means the combustion engines of hybrids typically spend more time at lower, less efficient operating temperatures. These lower temperatures are also associated with lower operating efficiency within the catalyst. Larger amounts of PGMs can be included in the catalyst to handle the decreased operating efficiency while still keeping overall emissions within allowable limits.

The intersection of growing demand for PGMs and increasing focus on ESG by the investment community is likely to lead to increased scrutiny on how and where mineral extraction occurs. PGMs are produced primarily in South Africa, Zimbabwe and Russia, so heightened geopolitical risks can cap the scope of investment in future production. Additionally, while it is not as widespread as World Gold Council’s Responsible Gold Mining Principles, we do see some evidence of adherence to standardized responsible mining criteria starting to show up in the PGM space, likely driven by increasing pressure form the investment community. The Unki Platinum mine in Zimbabwe was the first mine in the world to be audited under IRMA (Initiative for Responsible Mining Assurance), which looks at business integrity, planning for positive legacy, social responsibility and environmental responsibility, and received a positive grade. In our view, the ESG concerns for the

[3] Is automotive demand for platinum increasing or decreasing - CME Group (2020)

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companies that mine these minerals are broadly similar to other mining companies with common sources of concern centering on community relations and elevated geopolitical and environmental risks. Additionally, most PGM mines in South Africa are underground operations, meaning production relies heavily on human, rather than mechanized, production, which introduces additional concerns around worker safety. We believe the combination of challenging geographies, labor-intensive production and increasing focus on ESG topics means higher PGM prices will likely need to persist to incentivize the additional production tighter emissions standards will require.

Increasing penetration of battery electric vehicles (BEV) could drive strong demand for copper and nickel.

During the early stage of the transition, we expect policy support and public desire to reduce emissions to drive increasing sales of BEV as the most attractive replacement for traditional automobiles. As with any standalone electric device, batteries will be required to fuel electric cars. In contrast to a traditional car, the battery pack takes on increasing importance in a BEV, accounting for the largest portion of the car, by weight. As electric vehicles become increasingly popular, new electric-grid infrastructure will be necessary to bring electric power to these vehicles. The need for additional electric-grid infrastructure is driven by two key concerns as energy delivery shifts from pumps to plugs. Firstly, shifting the energy delivery will require larger footprint charging stations to reach the same level of access and availability as gasoline stations. In addition, the ever-increasing number of BEVs will continue to increase electrical-load demand, requiring additional investments in grid capacity. Industrial metals play a significant role for both individual automobile and grid-infrastructure requirements.

Among base metals, we expect rising penetration rates of BEV and the required infrastructure buildout to drive strong demand for metals such as copper and nickel. While the timing of and ultimate extent to which BEV will displace demand for traditional internal-combustion-engine cars and trucks remains a matter of debate, it is almost certain that we will see BEV play an increasingly important role in the overall transport mix. We anticipate copper demand to benefit from rising BEV penetration as a typical BEV requires 3-4x the amount of copper versus a traditional internal combustion automobile due to additional battery and wiring requirements. Against the backdrop of higher copper loadings, current projections could see copper demand from BEV rise from less than 1% of total copper demand to over 4% within a decade. Increasing BEV proliferation will also likely drive demand for other metals, such as nickel and cobalt, which are used in the battery pack.

Focusing on copper, the primary sources of global demand outside of transport are construction, industrial equipment & electronics and infrastructure, which we expect to remain robust. Chinese demand, which represents ~60% of total refined demand, is more heavily weighted toward power-grid infrastructure, property and consumer durables/electronics such as air conditioners. Grid investment to support the growing BEV fleet should provide a boost for copper consumption both onshore in China and globally, though the pace of the rollout could push the bulk of demand to Phase Two. Rising urbanization rates in China will likely keep demand from property and consumer durables healthy as well. Overall, copper remains relatively supply constrained and our expectation is for the robust demand environment to keep the market fundamentally supported.

In our view, energy commodities will benefit from increasing transportation requirements. The shift toward renewable power generation should benefit metals such as copper and aluminum.

During the Build Out phase, we expect geographical differences between the locations of required resources and the production and consumption centers where those resources are needed to continue to drive robust shipping, trade and transport activity. For example, in historical production regions such as South/Central America and Africa, refined copper production has exceeded local demand, resulting in extra material that typically leaves the country in the form of exports, represented by the green bars in the chart below (Figure 3). While these regions are resource-rich, they are not necessarily where the downstream manufacturing activities within the global economy take place. Much of this activity has taken place in Asia, specifically China, where local sources of copper are scarce. This means the needs of Chinese fabricators have historically been met by importing refined and processing mined copper from resource-rich regions. The red bars in the chart

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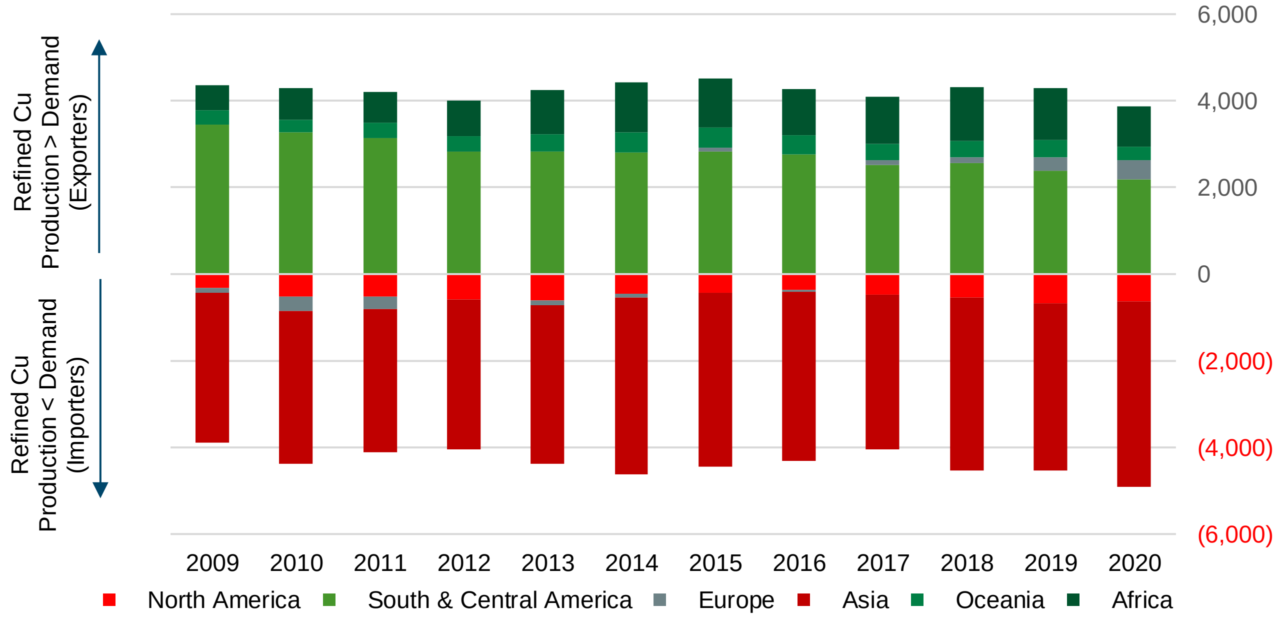
below represent the degree to which local demand for refined copper from fabrication and manufacturing outstrips local refined supply. It is clear that material must flow between regions that are "long" copper (green bars) to regions that are "short" copper (red bars). Balancing these market conditions and facilitating rising levels of manufacturing activity should continue to require mass movement of raw materials. Further, due to relatively limited penetration of low-carbon alternatives in a "status-quo" scenario, much of this activity will take place via traditional fossil-fuel-based means in the near term. Forecasts vary, but demand for traditional oil & gasoline still has the potential to grow over the next several years, despite increasing penetration rates of BEV amongst passenger cars.[4] However, global policy action on climate change could potentially put a damper on further demand growth depending on scope and timing.

FIGURE 3: COPPER SUPPLY-AND-DEMAND IMBALANCES BY REGION



Source: Bloomberg. As of March 2021.

Turning away from the transport sector, while electricity via renewable sources has gained ground in recent years, fossil fuel continues to be the primary energy source for electricity generation. To further migrate electricity generation to renewable sources, we expect well-known technologies, such as wind and solar, to play a major role. Both wind and solar electricity generators require higher copper intensity per unit of energy produced than the conventional means of power generation. We expect the replacement of carbon-based power production and overall growth in power-generation levels worldwide to provide a demand boost for copper as de-carbonization continues to take hold.

We expect rising protein consumption and associated feed requirements to drive strong demand for grains like corn and wheat as well as soybeans.

Agricultural and livestock commodities are likely to be exposed to competing structural changes in production and consumption drivers during the early phase of de-carbonization. When taken together, agricultural and livestock commodities are responsible for 25% of global greenhouse-gas emissions through a combination of direct emissions in the production process and de-forestation.[5] Despite this surprising finding, we expect grains to benefit in the near term.

[4] Oil 2020 Analysis – IEA (2020)

[5] Chapter11 - AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU) (2014)

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During this phase, an important driver of demand for grains will come from increased use in raising livestock protein. We observe that as countries improve their living standard, protein consumption tends to increase as well. China's shift in protein consumption is a good example of this phenomenon. From 1980 to 2020, per-capita Chinese income rose more than thirty-fold. During the same time frame, the per-capita consumption of pork almost tripled.[6] We observe similar trends of rising protein consumption in other emerging markets such as Russia and Brazil. As the global economy continues to improve for developing and frontier countries, we expect this trend in rising protein consumption to continue globally, driving increasing demand for grains as animal feed.

However, raising livestock protein is also a major contributor to GHG emissions, and so could face potential headwinds. Given the inherent difficulty and sensitivity around influencing practices related to food production, we anticipate early efforts to reduce our carbon footprint from food to primarily focus on consumption habits. For example, actions incentivizing a more plant-based diet have the potential to contribute greatly to reducing net overall emissions as livestock raising has a higher carbon footprint relative to plants for a given amount of nutrition. While there would be some impact on demand for grains from policies intended to dis-incentivize meat consumption in favor of plant-based alternatives, this would be offset by rising demand for grains as a primary food source. The net effect would also favor grains over livestock during this phase.

Supply response is likely to be muted, despite growing demand, driving tight markets.

From the supply perspective, in the early part of the transition, we do not expect to see large-scale supply responses from producers, particularly among the base and industrial precious metals. Following an extended period of depressed commodity prices, capital investment across the natural-resources extraction space has remained at or near decade-low levels. This lack of investment has caused the project pipelines that typically foster production growth to become sparse. This fact, combined with lengthy lead times for new project approval and implementation, leaves the risk for prices across the complex as a whole to the upside, in our view.

Among agricultural commodities the potential for supply to increase may come through the adoption of advanced planting and farming techniques such as drip-irrigation technology, precision planting and the use of modified seeds. We have seen these techniques drive rising yields and production in developed markets such as the United States and Europe. However, the agricultural supply response is ultimately limited by seasonality, available land and overall adoption rate/application of such advanced techniques. In some places, farmers might be unwilling, or unable, to utilize techniques such as precision planting and targeted fertilizer application in the near term due to high costs or limited availability. Currently governments in emerging markets such as India are taking action to deploy techniques to improve yields, but the transition will take time. Finally, while we expect energy commodities to experience supportive demand conditions during phase one, we are not likely to see a return to price levels that incentivize a large-scale supply response.

The Paris Agreement's "ratchet mechanism" should see announcements of more stringent climate-policy responses, but implementation will take time.

The Paris Agreement contains several "weigh stations" along the road to more environmentally friendly global policies and two of these are set to occur before 2025. Due to this, it is likely that global authorities will begin announcing climate pledges and implementation measures by the later stages of the Build Out phase, but it is likely to take time for these measures to transition from pledge to reality. The time lag between announcement and implementation is partly what underpins our positive view on energy in the near term as it will take time for renewables to take market share, despite the best of intentions, and overall energy demand is expected to continue to grow over the next several years. However, we do anticipate implementation of more stringent climate policies to begin to weigh on demand for traditional fossil fuels, such as oil, as we move through the next phases of de-carbonization.

In summary, for the Build Out phase, we expect an initial shift in our relative preferences for individual industrial metals and agricultural commodities. In particular, copper, nickel, palladium and platinum will likely benefit from the de-carbonization process taking place in the transport sector. In the agricultural sector, we expect corn and soybeans to benefit the most from

[6] Pork consumption - Gro Intelligence (2021); GDP per capita – Bloomberg (2021)

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the shift towards increased consumption either as a primary food source or from higher protein consumption as living standards continue to improve. Despite recent progress, we expect energy commodities to still play a key role in the power generation and transport sectors. As this phase matures, the global economy should move past the initial rollout of current generation technologies and the focus will likely shift to scaling up these technologies and introducing low-carbon alternatives to harder-to-reach areas such as power generation.

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Phase Two – The Scale Up (next 10 to 15 years)

As the drive toward de-carbonization continues, we are likely to see increasing market-share gains for low- and zero-carbon technologies at the expense of traditional fossil fuels. What differentiates this phase, however, is that this shift is likely to continue to exert influence not only on relatively faster-moving sectors of the global economy, such as personal transport, but also across those that have traditionally been slower to change, such as power generation. The reasons for the slower pace of transition are varied, including: high levels of capital intensity or a high degree of regulatory influence. While we anticipate the combination of the continued desire for low-emission means of propulsion and production to eventually put pressure on demand for traditional fossil fuels, we expect these same structural drivers to support growing demand for metals, driving prices higher.

Infrastructure to support growing BEV fleet is likely to support demand for copper in our view. Battery technology should play a major role in the relative demand differences between metals – we currently expect nickel to be the primary beneficiary.

During this phase we anticipate continued demand for low- and zero-emission forms of transport and expect hybrids and BEVs to become an increasingly larger share of the existing automotive fleet as well as new sales, at the expense of traditional internal-combustion-engine vehicles. While an increasing market share of hybrids will likely continue to provide a source of incremental demand growth for platinum, palladium and rhodium, it is unclear whether or not this will be enough to offset lost demand due to the displacement of traditional internal combustion cars and trucks by BEVs. Due to this uncertainty, our overall outlook for PGMs is more muted than during the Build Out phase.

We expect the proliferation of BEVs to continue to support copper demand and prices. Aside from copper consumed in the production of the BEVs themselves, we expect the large-scale charging-infrastructure requirements to deliver incremental demand for copper in this phase. By some estimates, copper demand from charging stations alone could increase consumption by 250% in 2030 versus 2019.[7] We also expect aluminum to benefit as the typical BEV contains twice as much of the material versus a traditional internal combustion automobile due to light-weighting and range requirements. In fact, transportation demand is an even larger driver for aluminum than copper, with aluminum transportation demand representing ~25% of total demand. We also expect aluminum to benefit from a strong fundamental backdrop as aluminum production is extremely power- and emissions-intensive, which should effectively limit supply growth in a world focused on de-carbonization. China, which has historically been the greatest source of aluminum production growth, has already announced a hard cap on total aluminum production.

Finally, of particular importance for nickel will likely be the evolution of battery technology and the adoption rate of various battery chemistries. One feature of metals markets historically has been the rising price and/or limited availability of a material driving engineering innovation to reduce future consumption of that material. We have already seen this take place in cobalt, where supply concerns and price spikes have pushed automakers towards chemistries that have as little cobalt as possible. The extent to which prices and supply react to increasing demand during the Build Out phase will likely influence which battery chemistry becomes most ubiquitous and thus, which metals stand to benefit the most. This is of particular importance as the range of demand scenarios can vary greatly with different battery chemistries (see Figure 4).

[7] EV sector will need 250% more copper by 2030 just for charging stations - mining.com (2019)

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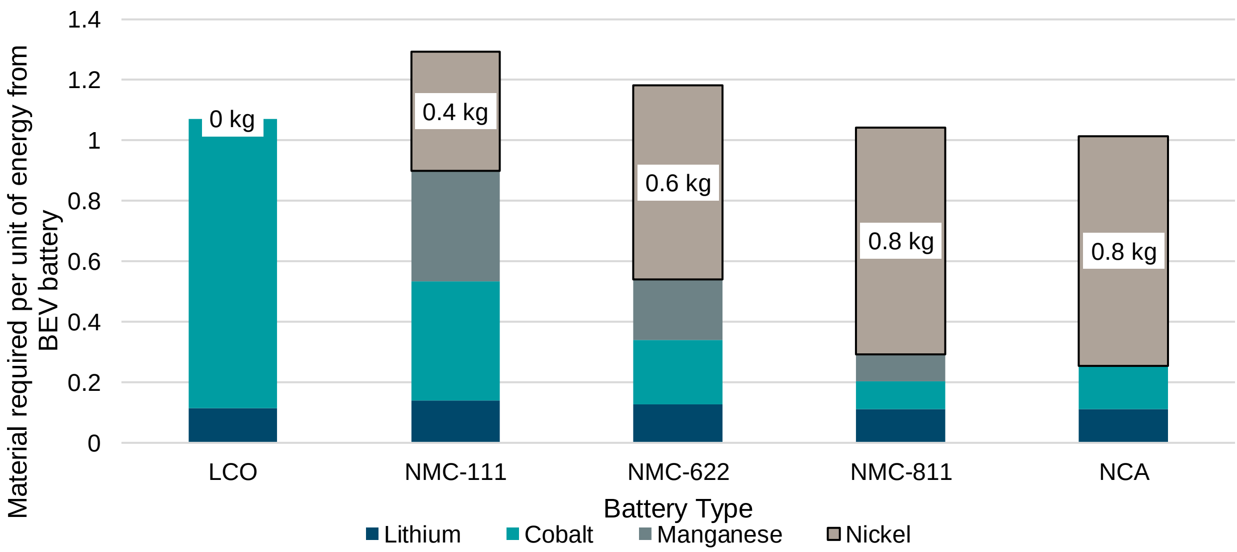
FIGURE 4: DIFFERENT BATTERY CHEMISTRIES CAN HAVE VASTLY DIFFERENT METALS INTENSITIES



NMC = Nickel/Manganese/Cobalt; LCO = Lithium/Cobalt; NCA = Lithium/Nickel/Cobalt/Aluminum

Source: Fu et al., Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals. As of October 2017.

Among currently available alternatives, nickel content required for BEV battery packs can vary from zero percent in Lithium Ion Phosphate (LFP) to eighty percent in Nickel Manganese Cobalt (NMC) 811. Figure 4 shows various popular battery chemistries and the associated volume of minerals required. Primary factors influencing adoption rates for the various chemistries are a combination of energy output (kWh), weight and input cost. Energy output and weight are of particular importance when it comes to the range characteristics provided by a particular battery pack. The need to remain competitive against fellow BEV producers and versus traditional internal-combustion cars and trucks should push manufacturers towards the optimal combination of weight, power and cost. Using a representative 100kWh battery pack, global demand for battery-grade nickel could range from just over 700,000 tons in a scenario that favors low-nickel-content chemistries like NMC-111 to over 1.4 million tons if high-nickel-content chemistries win out. We currently expect a combination of range requirements, cost and material availability to favor chemistries that are high in nickel content during this phase.

Increased local availability of scrap for energy-transition materials, such as copper, may reduce demand for traditional transport fuels. Biofuels and bioenergy should continue to support demand for grains and grain oils.

As stated in the introduction to this phase, we expect areas of the economy outside transportation to begin to be increasingly influenced by the de-carbonization drive. The share of renewables in power generation is likely to begin to erode demand for traditional fossil-fuel-based methods, leaving us less positive on traditional energy commodities in the medium term. Power generation from coal likely peaked several years ago and total fossil-fuel contribution to the power-production mix is expected to experience a decline for the next several decades. We are likely to see recycled volumes for energy-transition metals such as copper and aluminum increase as the market share for BEVs continues to rise and the existing fleet begins to be cycled out and scrapped. Further, the increase in scrap availability is likely to occur locally, potentially reducing the need for fossil-fuel-heavy transportation and shipping activity. We expect the rollout of renewable power generation to continue to drive demand for metals such as copper due to typically higher metals intensity for renewables-based power generation versus traditional fossil–fuel-based alternatives.[8] Here, too, the form of deployment matters; for example,

[8] World Bank - Growing Role of Minerals & Metals to a Low Carbon Future (2017)

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direct-drive offshore wind generation consumes approximately 3x the copper of onshore variants so the future path of copper consumption from wind turbines has a wide range of outcomes depending on adoption rates.

During this phase, we believe the focus for the agriculture sector has the potential to shift to the production- and non-food-consumption-related use side of the equation. Specifically, the contribution of biofuel and bioenergy to the propulsion and power-production sectors is likely to increase. Bioenergy, particularly if paired with carbon-capture technology, will likely have the greatest impact to global emissions during the early stages of the Scale Up phase as it displaces traditional fossil-fuel-based sources of power production, such as coal. However, as the share of renewables in the overall power-production mix increases, the net contribution of bioenergy is likely to decline as it begins to compete not with traditional fossil fuels, but with other renewables such as wind and solar. While incremental demand from the power-production sector may wane, we expect biofuels to play an increasingly important role, particularly in areas that appear difficult to penetrate with current battery technology such as long-distance shipping and industrial transport. Demand for grains should benefit from the shift towards renewable fuel for transportation as many governments consider plant-based fuel, such as ethanol and bio-diesel, to be a renewable energy source. While plant-based fuel still emits carbon into the atmosphere, it does avoid the need for fossil fuel. The demand for biofuels in transport has the potential to grow to 2-3 million barrels per day by 2025 versus just 273,000 barrels per day in the year 2000. Increasing adoption of bioenergy and biofuels has the potential to drive rising demand for agricultural commodities such as corn and sugar (used in ethanol) and grain oils, such as soybean oil, assuming current technology prevails. In addition, meeting the increased level of demand will likely continue to put pressure on land, water and fertilizer resources, potentially causing prices for the aforementioned commodities to increase.

There is a risk that bioenergy/biofuels are less favored given potential issues around food scarcity and price impacts of using food as fuel. However, the threats to food security can be mitigated through a coordinated approach to bioenergy/biofuel production – something that seems more likely as bioenergy/biofuels become a larger share of the energy mix and there is increasing federal influence. By choosing where and how energy crops are planted, such as designating plantings in areas that are already covered by existing irrigation infrastructure or where land is not suitable for food crops and incentivizing production towards crops with the best combination of input/output yields, the total impact to food production can be managed. There is also the potentially negative impact of taking no action. A model comparison study by the Intergovernmental Panel on Climate Change (IPCC) found that the aggregate effect on food prices from large-scale bioenergy deployment was an increase of approximately 5%. Using the same models, food prices saw a 25% increase from adverse climate impacts on crop yields. While careful planning and coordinated action will be required, the deployment of bioenergy and biofuels is likely to be a net benefit, rather than a net cost.

Supply could be brought online, but will require higher prices in our view.

One threat to the bright outlook for commodities in the medium term is that there is the potential for a supply response over this horizon, particularly in the metals sector. Beyond the next several years, there will be the opportunity for producers to secure project approvals and add incremental supply to the market. However, new resources across much of the globe are compromised in some way – either requiring large-scale capital and infrastructure investments to bring to market or being located in less desirable or less stable geographies. The potential difficulty in maintaining and growing production has been highlighted recently in copper by events taking place in Latin America. From a political perspective, bills to allow governments to share in a larger portion of the profits when commodity prices rise have gained traction in Chile and Peru, which combined account for almost 40% of global copper production.[9] This is a marked shift, as Latin America has traditionally been considered lower risk from a geopolitical risk perspective with more stability in royalty and taxation arrangements, and highlights that even “safe” supply can be put at risk. In response to the proposals, mining companies with operations in the region have begun to discuss delaying capital investment needed to maintain and grow production in the country, casting doubt about the future availability of the copper needed to facilitate the de-carbonization drive. Copper is just one example, but there are supply risks across many of the metals needed to realize climate-policy goals.

Importantly, the drive toward carbon reduction will not only impact commodity consumption, but also production. We have already begun to see some capital investment being spent not only to replace depleted resources, but to produce future

[9] Bloomberg (2020)

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volumes more cleanly. Examples include replacing traditional fossil–fuel-powered mining equipment with battery electric substitutes and installing renewable power-generation capacity at the mine site to replace diesel-powered generators. We expect that such measures will become increasingly necessary as the investors and consumers place greater importance on reducing carbon emissions across the entire value chain. These effects are also likely to drive up production and capital costs across the sector given the additional spending that will be required. The two impacts from this are that go-forward decisions at any given commodity-price level are less likely and that higher prices will be required to incentivize additional production to be brought online to offset the additional cost requirements. This incentive-price effect is likely to cushion the overall impact to commodities from incremental increases in supply.

We believe improving liquidity and stability in carbon credit trading will be required to see widespread usage in the commodities space.

One potential avenue to reduce emissions from carbon-intensive processes such as power production, smelting and refining of metal and steel production is through the use of emissions allowances. Through the purchase of emissions allowances, such as EUAs in Europe, carbon emitters can offset the pollution they create with current production methods, while working on new, cleaner modes of production. There is also the potential to utilize emissions allowances alongside traditional commodities in order to offer more environmentally friendly exposure to the sector. However, we believe the viability of this solution will require some time before it can be applied sector-wide. Current liquidity in the emissions-allowance market remains limited, especially when compared to traditional commodities such as oil, where the market size can be up to 3x as large. Additionally, historical over-allocation of allowances has required several market-distorting interventions in the past. Both of these factors have prevented emissions allowances from widespread inclusion in traditional commodity indices, which account for the predominant amount of commodity investment. As the drive toward de-carbonization intensifies, we could see liquidity in emissions allowances improve, increasing their role in the commodity landscape.

We expect the Scale Up phase to be characterized by a continuation of trends established in the Build Out phase along with seeing the de-carbonization drive permeate new segments of the economy. The form of implementation during the Scale Up phase will be of particular importance as it has the potential to drive relative preferences between commodities. While we anticipate that an increasing share from renewables will likely leave energy commodities less favored, we expect other sectors to experience demand growth, leaving the overall outlook bright for the asset class. The Next Generation phase of de-carbonization and energy transition is likely to see technological advancements and alternatives to current-generation implementations continue to support demand and drive changes in relative preferences.

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Phase Three – The Next Generation (15 years and beyond)

In order to ensure further progress against de-carbonization goals the global economy will likely have to develop and implement newer and more efficient alternatives to what is currently available. In particular, as energy production shifts away from primarily fossil-fuel-based to increasingly renewables-based, the area of energy storage is likely to take on increased importance. Similarly, we expect transportation to remain a source of increasing demand for commodities as fossil-fuel-free alternatives continue to take market share and new technologies drive additional consumption. While new technologies should bring increased efficiency and scale, they could also create problems that are likely to continue to require commodity-intensive solutions to solve.

Higher variability in renewable sources of power generation may drive expansion in grid battery storage, resulting in additional demand for metals.

The ultimate source of power production for the new de-carbonized economy will be of the utmost importance. It will do little to progress society towards emissions-reduction goals if the electricity to charge a massive BEV fleet ultimately still relies on fossil-fuel-based power-generation techniques. We expect that this concern will continue to drive the shift toward renewables started in the Scale Up phase. As a result, we anticipate demand for base metals such as copper and aluminum (used in applications such as wind turbines) to remain strong. Increasing market share for solar will likely also drive strong demand for silver, which is used in photovoltaic panels. However, the shift is also likely to be accompanied by additional challenges that must be solved. Chief amongst these is energy storage, where traditional fossil-fuel-based alternatives have historically had an advantage due to the transitory nature of most renewables – solar can be compromised by cloud cover, wind by seasonal patterns and hydro by changes in flow rates and water levels. To combat this problem traditional approaches to renewables energy storage have favored pumped hydro energy storage (PHES), which relied upon specific geography rather than commodity-intensive installations. However, it is unlikely that this technique can serve the needs of an ever-growing demand for renewables-based energy storage due to space and geographical constraints.[10] Likely alternatives to PHES are grid-scale battery solutions, which would require vast amounts of lead, lithium, nickel, cobalt and zinc, depending on battery chemistry market share.

Fuel cells could potentially tighten supply and demand for platinum, increasing prices.

The declining market share of internal combustion cars and trucks is likely to put pressure on pricing and demand for PGM commodities like platinum and palladium during the Scale Up phase. However, it is possible for demand to recover in the Next Generation phase, particularly in platinum, if hydrogen fuel-cell electric vehicles (FCEVs) become increasingly prevalent. Where the decline of diesel closes the door on the future of platinum, FCEVs open a window. Under current technology, FCEVs use 10x the amount of platinum in the chemical reaction required to create electricity versus a traditional diesel automobile.[11] Fuel cells are already attracting attention and investment with several models already commercially available. There have also been commitments toward implementing the technology from major global corporates such as Hyundai, who intends to build 700,000 fuel-cell stacks by 2030.[12] Against the backdrop of current production levels, this degree of demand growth would be more than enough to offset potential losses from declining diesel market share. Crucially, the proliferation of FCEVs would reverse the supply-and-demand fortunes of platinum and palladium, likely driving the former into deficit from current surplus.

An impediment to the widespread adoption of FCEVs is the hydrogen delivery infrastructure. As of mid-2020, there were only 23 operating hydrogen stations in the United States; meaning it is not currently a practical solution for the majority of

[10] World Bank - Growing Role of Minerals & Metals to a Low Carbon Future (2017)

[11] Bosch goes for platinum-light fuel cells _ Reuters (2019)

[12] Hyundai to build China factory as part of hydrogen vehicles push (2021)

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transport needs. Further, the method of production for hydrogen matters when considering FCEV's overall contribution to de-carbonization. Currently ~99% of hydrogen production requires burning of fossil fuels -- natural gas (~76%) or coal (~23%) -- in the production process. Hydrogen production from renewables, known as “green hydrogen,” currently represents the smallest share, but would be the most effective way to reduce GHG emissions. In our view, both of these shortcomings will likely be addressed by the events described in the other sections of this paper and ultimately drive rising demand for FCEVs. If we take BEV as an example, we already see an appetite for building out necessary charging (“refueling”) infrastructure, so there is clearly an appetite for these types of investments if they contribute to broader de-carbonization goals. While hydrogen produced from fossil fuels currently enjoys a price advantage over green hydrogen, declining costs for renewables as they gain scale should contribute to closing the gap and ultimately drive green hydrogen production to take on a larger share. As the shift to green hydrogen evolves, the de-carbonization benefits of fuel-cells grow, which should, in turn, incentivize infrastructure expansion.

While the Next Generation phase presents the most uncertainty, it also brings with it the most opportunity. There are likely to be technological innovations in the future that are not part of the current pathway to a lower-carbon economy. Because of this, estimating the impact to commodities supply, demand and prices is particularly challenging in this phase. However, if history is any indication, it is likely that any large-scale transition will require commodity-intensive infrastructure solutions and that commodities are to remain an integral part of any new technological advancements.

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Conclusion

The societal transformation from a fossil-fuel economy to a net-zero-carbon-emission economy will likely occur through several phases as evolving political agendas and consumer behaviors influence overall adoption. However, it's clear that throughout each phase, commodities have a role to play in this transformation. Overall, we expect that achieving our goal of net-zero-carbon emissions will increase commodity demand across the broad commodity complex and provide a secular tailwind for commodity prices well into the future.

Phase	Transformation	Commodities in Focus
Phase 1 The Build Out	Battery Electric Vehicles (BEV)	Copper, Nickel, Aluminum
	Hybridization / Fuel Cell Electric Vehicles	Platinum, Palladium, Rhodium, Platinum
	Low Protein Diets / Livestock feed	Corn, Soy, Wheat, Lean Hogs, Live Cattle
	Transport & Shipment Requirements	Oil, Diesel Fuel
Phase 2 The Scale Up	Bioenergy & Biofuels	Corn, Sugar, Soybeans, Soybean Oil
	BEVs / Charging infrastructure	Copper, Aluminum
	Electric batteries	Nickel
Phase 3 The Next Generation	Fuel Cell Electric Vehicles	Platinum
	Grid Scale Battery Storage	Lead, Lithium, Nickel, Cobalt, Zinc
	Onshore/Offshore Wind & Solar Power	Copper, Aluminum, Silver

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