

GEOLOGY AND MINING

Drivers of Global Mineral Demand: 1900–2050

Martin Lynch[†]

Unit 1-44 Farrall Road, Midvale, Greenmount Western Australia 6056, Australia

Editor's note: The aim of the Geology and Mining series is to introduce early career professionals and students to various aspects of mineral exploration, development, and mining in order to share the experiences and insight of each author on the myriad of topics involved with the mineral industry and the ways in which geoscientists contribute to each.

Abstract

The global demand for minerals has long been known to be characterized by periods of high demand followed by periods of low demand. These are often referred to as cycles. There are cycles of short (multiyear) duration and cycles of long (multidecade) duration. This paper seeks to explain the driving forces behind the long-duration cycles. There have been five such cycles since 1900. Four of them were in the 20th century, and the fifth was the China mining boom, which lasted from about 2000 to 2015. I interpret the main driver of these cycles to be the pace of urban, or suburban, construction. When this is proceeding at a rapid pace, global mineral demand is high. When construction activity slows, mineral demand slows with it.

In the 20th century it was the nations of Europe, North America, and, later in the century, the Soviet Union and Japan that were home to most of the world's construction activity. Their economic fortunes drove the century's four long-duration cycles. The century began with a 30-year period of high demand driven by the transformation of these economies from predominantly agriculture based to predominantly urban industrial. It

ended with a nearly 30-year period of low demand as these same economies, having already urbanized, moved into being predominantly service-based economies, which have a lower per capita mineral demand. At the beginning of the 21st century, China took the lead with its remarkable transformation from an economy that was farm based to one that was urban industrial, which drove global mineral demand to a high level.

I argue that the world is now heading into a 30-year period of low urban construction-driven demand as China turns away from reform, India discovers that its economic success is built on weak foundations, and the "advanced countries" continue with their metals-lite transformation toward ever more sophisticated service activities. However, urban construction may be about to be displaced as the principal driver of global mineral demand. This new driver is the restructuring of global energy systems, or, to be more specific, the shift from hydrocarbon-based energy to solar and wind-based energy. Producing energy from solar and wind is far more materials-intensive than from hydrocarbons. Will this shift propel global mineral demand back to high?

growth—steel and copper. These two are representative of the overall state of global mineral demand and are staple ingredients in all sorts of buildings, infrastructure, and machinery.

2. The numbers used are for an alloy and metal produced from global mine production. The total global consumption of an alloy/metal includes recycled alloy/metal, but such recycle-inclusive data only became available in the 1980s for steel, and even more recently for copper. Thus, global mine production is used as a proxy for global demand for much of this paper.
3. The data for global mined copper production has been taken from the United States Geological Survey (USGS), a consistent data series going back to 1900 (Kelly and Matos, 2014). The data for crude steel production for 1900–79 has been taken from the Steel Statistical Yearbook 1980, published by the International Iron and Steel Institute; the World Steel Association compiled data since 2008.
4. The years 1939 through 1949 are omitted because global demand for copper and steel showed a sharp swing upward in 1939–42 as World War II heated up, and then a sharp swing downward in 1946–49 as armies were demobilized. These swings muddy the picture in understanding the economic drivers of global mineral demand.

The 20th century is divided into four distinct periods of global mineral demand growth (Fig. 1).

1. There was high growth during 1900 to 1929, and this high-growth period can be extended back to the mid-1880s. The reason this period begins in 1900 and not in 1880 or 1890 is because from 1900 onward, the global demand data is consistent in the way the USGS derived the data.

Introduction

Everyone working in the mining industry is likely aware of the cyclical nature of mineral demand. These cycles can be of short duration; for example, there may be a few years of strong demand followed by several years of much weaker demand. A more important cyclical pattern can be seen over much longer time periods. This paper will seek to explain why these longer cycles happen and what they can tell us about mineral demand over the next 30 years.

The Demand Cycles of the 20th Century

The best place to start this discussion is by looking at the global high- and low-growth periods during the 20th century (Fig. 1).

Four notes regarding Figure 1 are needed:

1. The figure records average annual demand growth rates for the one mainstream alloy and metal of

[†]Author e-mail: martin@solahartmidland.com.au

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		1900-29	1929-38	1950-75	1975-2000
Global mineral demand growth rate	<i>high or low</i>	high	low	high	low
Steel	<i>% per yr</i>	5.1	−0.3	5.2	0.9
Copper	<i>% per yr</i>	4.8	0.1	4.6	2.5

Fig. 1. Growth rate of steel and copper.

2. There was a period of very slow growth from 1929 to the eve of World War II. Students of economic history will recognize 1929 as being the start of the Great Depression; I will return to this later.
3. The period from 1950 to 1975 saw a return to high global demand; it is known as the period of the postwar boom.
4. The postwar boom ended in the mid-1970s, and the period from 1975 to 2000 was one of slow demand growth once again.

What accounts for these very different demand growth periods? The short answer is that during the high-growth periods, there was rapid urbanization (1900–29) and rapid suburbanization (1950–75). In other words, the driver of these high demand growth periods was widespread and large-scale construction. The low-growth periods coincided with slowing of construction activity.

The Global Regions

This paper has so far referred to “global demand growth.” However, the global mineral demand in the 20th century was almost entirely confined to the countries of Europe and the so-called European offshoots, principal among them being the United States. Several other countries contributed later in the century, mainly the Soviet Union, Japan, and, later still, Taiwan and South Korea. As for the rest of the world’s countries, their mineral demand in the 20th century was of little importance on a global scale. The exception here is China, which started to become globally significant in the 1990s.

Therefore, to be more specific about the causes of the high demand growth periods of the 20th century, they were driven by rapid, widespread, and large-scale urban construction in the countries of Europe, North America, and some of the nations of northeast Asia. This group will from now be referred to as the “advanced countries.”

However, the advanced countries now no longer dominate global mineral demand. During the first decades of the 21st century, China emerged as the new mineral demand powerhouse of the world. Global mineral demand is now dominated by two regions: the advanced countries and China. The other regions of the world remain largely unimportant when it comes to global mineral demand, and the reasons for this will be discussed later in this paper.

In addition to the advanced countries and China, there are five other global regions. Each, along with its total population as of 2015, is shown in Figure 2.

Two of these regions are individual countries, and the rest are groups of countries. Some of the groups are self-explanatory, but at least three need definition:

1. The advanced countries comprise the nations of Europe including Russia, the European offshoots (USA, Canada, Australia, and New Zealand), and finally, the most economically advanced nations of northeast Asia (Japan, Taiwan, and South Korea).
2. Southeast Asia includes the nations of ASEAN (Association of Southeast Asian Nations) and also Bangladesh.
3. The Kazakhstan-Morocco Crescent includes the nations of Central Asia, the Middle East, and North Africa, as well as Pakistan and Turkey.

For the most part, the countries in each region are geographically close to each other and share, to various degrees, cultural, linguistic, and demographic makeups. The main exception to this is the advanced countries, with these nations, taken together, being the drivers of global mineral demand in the 20th century.

The seven global regions have been defined because later in this paper, a forecast is made of global mineral demand growth to 2050. To forecast demand for over 300 individual

countries would be an unwieldy exercise. The seven regions serve the purpose of making the discussion more manageable.

The Stages of Economic Development

Having introduced the notion of global regions, I will now introduce an economic framework that is helpful in understanding why the high- and low-growth periods of the 20th century happened. This framework also helps when it comes to forecasting global mineral demand.

In short, during the course of their economic development, all countries move in distinct developmental stages, from being farm-based economies to being advanced services-oriented economies. This is a notion first tackled comprehensively by Walter Rostow in his 1960 book, *The Stages of Economic Growth*. The model used here is influenced by Rostow but does not closely adhere to his stages.

In the model used here, the advanced countries, being the leaders of the global economy, have progressed through three stages so far. The first of these is called the Urban Stage, the

Global region	Population in 2015
	<i>'000s</i>
China	1,410
India	1,400
Advanced countries	1,310
Sub-Saharan Africa	1,089
Southeast Asia	804
Kazakhstan-Morocco	782
Latin America	630
TOTAL	7,425

Fig. 2. Populations of Global Regions in 2015. The use of 2015 population data is used to calculate per capita alloy/metal consumption, since the available data on global alloy/metal demand is from 2015. The advanced countries include Europe, Russia, USA, Canada, Australia, New Zealand, Japan, Taiwan, and South Korea. Southeast Asia includes the nations of the Association of Southeast Asian Nations and Bangladesh. Kazakhstan-Morocco includes Central Asia, the Middle East, North Africa, Pakistan, and Turkey.

second is the Household Stage, and the third is the Innovative Services Stage.

Each stage has a 30- to 40-year duration in a country, after which there is a period of transition before the next stage commences. In the following sections, I consider each stage in some detail.

The Urban Stage

The central dynamic of this stage is the shift of unskilled and underemployed farm laborers off the farm and into much more productive city-based factory and service jobs. The trigger for this is often the introduction of mechanization on farms, which creates a surplus farm workforce, which then moves to the cities. These new arrivals in the city need housing, and the factories and offices in which they work need buildings, machinery, and infrastructure. It is a time of rapid construction and huge demand for minerals. The process of taking surplus laborers from farms and putting them to work as more productive workers creates much wealth for a country. It is also a self-reinforcing process because as farm mechanization increases, more factories and workers are needed. As a result, the urban population increases, and more labor and materials are needed to provide this population with its needs. This in turn draws more labor from farms, and as that additional labor reaches the cities, still more urban construction is needed.

How quickly a country progresses through this stage depends first and foremost upon the availability of a cheap and orderly workforce. In many countries, this workforce is readily available on farms. In some cases, such as in the United States, farms were equally in need of workers, and the Urban Stage relied on mass immigration (Abramitsky and Boustan, 2017). In China, which passed through the Urban Stage between 1980 and 2020, there was a huge domestic workforce of surplus farmers ready and waiting. Of course, a labor force alone is not enough. Metals and energy, investment capital, and capable managers are also needed, as well as specialist equipment for use in constructing and operating the more advanced types of factories. Because this specialist equipment is only available from foreign countries, during the Urban Stage, a country needs a way to earn foreign currency. It is partly for this reason that effort is

put into establishing a factory system that produces cheap, labor-intensive goods for export. China is a standout example of a country that developed such an export base, although there are many others, with the USA, Japan, Taiwan, and South Korea foremost among them in chronological order.

One of the characteristics of the Urban Stage is that it produces a great disparity in income levels. A wealthy elite of bankers and industrialists (or Robber Barons as they were known in late 19th-century America) is created, which is supported by a middle class of professionals and bureaucrats. But the majority of people are low paid and tend not to have much of a social safety net. As a result, they become thrifty and save a lot. These savings are useful because they help fund the urban construction effort.

The Urban Stage does not last forever. At some point the growth rate of urban construction slows down. There is still a lot of construction and factory building going on, but the rate stabilizes. As a result, there are fewer city jobs available for those who have not yet left the farm. The countries of North America and Western Europe were the first to embark on this stage, beginning it in the 1870s and largely completing it by the 1910s (<https://www.statista.com/statistics/269967/urbanization-in-the-united-states/>). In the final decade, nearly half of the region's population lived in towns and cities, up from less than 20% in 1860.

The Household Stage

When the Urban Stage reaches its end, the country needs to find another way to keep economic growth going strong. The country needs to move from the heavy investment activity that characterizes the Urban Stage to a more household-consumption-based mode of growth. In other words, it needs to move into the Household Stage.

A country successfully enters this stage when two shifts occur. The first is that the average worker becomes better educated and more highly skilled, with more effective machinery and other tools with which to work. This increases worker productivity. The second shift that must happen is that the average workers and their families get a higher share of the wealth in the economy and a greater sense of confidence in the future. To help this along, worker

protections, including trade unions, are legislated. For the same reason, a social services system—comprising education, health, unemployment support, and a range of other areas—is improved and expanded.

With more disposable income, and the confidence to spend it, the average family is willing to purchase more goods that will benefit them personally. They are also prepared to pack their bags into the car and shift out into a more spacious house in one of the newly built outer urban developments, or “sub-urban areas” as they are sometimes called. This shift to the suburbs becomes the primary driver of the economy (Wagner and Wagner, 2010). The country's residential accommodation stock is completely overhauled as workers upgrade from their cramped apartments to free-standing houses, which are more spacious. By the end of the Household Stage, most households also have two cars in the driveway, or in the underground carpark, and are well equipped with refrigerators, air conditioners, and all the other modern comforts.

All of this happened in the 1950s and 60s in the countries of North America and Western Europe. It was a golden age when working families became better educated and skilled, had much-improved access to healthcare and other facilities, found well-paid jobs with some degree of legislated worker protections, and moved from their crowded inner-city tenements out into the newly created suburbs. The whole process was called the postwar boom.

The Household Stage comes to an end when households are no longer spending a growing amount of money on household goods. This happened in the United States and Western Europe by the mid-1970s. It was time for a new mode of economic growth.

The Innovative Services Stage

The term “Innovative Services” is intended to convey the notion that this new stage of economic development relies on the creation of a new set of services for people and on the development of better products from existing services. To simply call it the Services Stage would convey the wrong idea, because service jobs have always been a large part of any urban economy. In 1900 in the United States, there were many more people employed in service jobs than in manufacturing.

Drivers of Global Mineral Demand: 1900–2050 (cont.)

They included teachers, public servants, domestic helpers, bankers, nurses and doctors, transport workers, and retail and wholesale workers. What the Innovative Services Stage relies upon is the creation of new types of services and products.

Shifting into the Innovative Services Stage requires a restructuring of the economy, just as the shift from the Urban to the Household Stage requires restructuring the economy. To understand what restructuring is required, it is necessary to make clear that the Household Stage requires quite a lot of government intervention in the economy. This is because keeping spending power in the hands of the average householders, as opposed to in the hands of corporations and wealthy individuals, is contrary to the natural order of things in a market economy. Left to itself, a market economy will tend to deliver the bulk of profits to those with the greatest bargaining power, and that means the wealthy. To keep those profits more evenly distributed, there is a need for government intervention.

But government intervention comes at a cost. It tends to stifle the operation of the free market, which in turn reduces the creativity of people working within that free market. For the Innovative Services Stage to flourish, the spirit of creativity and innovation has to be liberated. For this to happen, it is necessary to roll back some, or even much, of the government intervention.

Thus, toward the end of the 1970s, reformist politicians in the advanced countries were coming to power on a platform of deregulation, promising to unleash business creativity once more. Margaret Thatcher was elected Prime Minister of the United Kingdom in 1979, and Ronald Reagan was elected President of the United States in 1980. They were the standard bearers of these new deregulation policies. They set about lowering tariffs, lowering taxes, and challenging union power. Their policies were dubbed “supply side” economics (Gwartney, 2002) because they took the emphasis off maintaining demand in the economy and placed the emphasis on improving the supply and quality of goods and services.

At about the same time, and in an unrelated development, a revolutionary technology—the computer—entered the mainstream economy. It was a stroke of good fortune, because the computer was the perfect engine to power the new

economic stage. It had the capability to do for the services sector what the electric motor and the internal combustion engine had done for the agricultural and manufacturing sectors. That is, it would make the provision of services much more efficient and, at the same time, would greatly increase the range and quality of services that could be delivered.

The advanced countries moved from the Household Stage into the Innovative Services Stage during the 1980s. The growth in services has since then been widespread and far reaching. About four out of five workers in the advanced countries are now employed in innovative service jobs. Many of those jobs did not exist in 1970, or at least the jobs are very much changed from what they looked like in that year.

The Innovative Services Stage has delivered good economic growth since the 1990s, even if that growth has not hit the highs of the previous stages. But after 40 years, the stage has basically reached its end. This is not because the innovative creation of new services and products has slowed down. Far from it. Computer-based innovation continues at a strong, even accelerating, pace. But two things are happening. The first is that the national wealth has become too unequally distributed, so households no longer have the spending power to drive the economy. Second, the productivity improvements which once were achieved by the application of the computer are no longer happening. The Innovative Services stage has run its course. It is time for something new.

Perils of the transition from one stage to the next

The transition from one stage of economic development to the next always meets with determined pushback from entrenched interests who are benefitting from the current economic arrangements. There is also the problem that the new economic stage is unknown territory. How does the nation set itself up to successfully enter the new stage? No one really knows. For these reasons, the transition from one stage to the next is perilous and often fails.

The Urban-to-Household transition has been particularly difficult. In fact, my interpretation of observations and history shows that many countries fail to achieve it. The reason it is so difficult is that it relies on working-class

households receiving a higher share of the national wealth and benefiting from social services and labor protections. For this to happen, the wealthy elite have to agree to pay them (the working class) more, and the governing class has to put in place a social safety net which underpins confidence in the future so that the workers spend their money. For such changes to be achieved without civil upheaval, the country has to be blessed with a very forward-looking governing class, and also with a wealthy elite that holds the well-being of the average people in at least similar esteem to themselves. Unsurprisingly, therefore, the transition usually involves a fair degree of civil upheaval. Or economic stagnation. Or both.

A few examples from history help illustrate this point. The United States had completed its Urban Stage in the early 1910s. The next decade was interrupted by the First World War and then by a short postwar economic depression. It took until the early 1920s for the economy to shift into what looked like the Household Stage, with household spending during the 1920s so strong that the decade has been called the Roaring Twenties. The stock market rose 500% between 1920 and 1929 because people had convinced themselves that consumer spending was set to increase, and increase substantially, every year. It seemed that the transition from the Urban to the Household stage had gone without a hitch.

The trouble was that the United States had only partly achieved the transition. The productivity of its workforce had registered huge increases, particularly in the factory system. Much of this was due to the work of two men: Henry Ford and Charles Taylor. These two invented, respectively, the moving assembly line and the practice of time and motion studies. Taken together, these two innovations greatly lifted productivity in workplaces all across the western economies. A further huge boost was added by the widespread adoption of electric motors in many previously unautomated settings. The American economy of the 1920s was a consumer goods production powerhouse.

However, when it came to the distribution of wealth, the United States of the 1920s was still operating in the Urban Stage. The income of the average working household was rising but not very fast, and there was no broad-based

social services structure to speak of.

As a result, there was a large increase in the production of consumer goods, but only a modest increase in the income of the great majority of consumers. It was an unsustainable situation. The day of reckoning was postponed by the fact that prices for manufactured goods were falling and so could be afforded by most households. It was also pushed back by the creation of two new industries—advertising and consumer credit—whose sole purpose was to increase household spending. During the Roaring Twenties, many households were spending money they did not have (Little, 2021).

The day of reckoning finally arrived at the end of that decade. By that time, most households had acquired most of the new consumer goods. There was one automobile driving around for every five people in the United States, meaning that on average, every family had a car. Most also had a radio, and, for those with electricity, a vacuum cleaner and a washing machine. With fully stocked households, by the late 1920s, household spending in the United States was clearly slowing down.

This came as a shock to stock market investors. They had been working under the assumption that the consumer-driven growth was never ending. When it became apparent that this assumption was wrong, they sold their stocks, thereby causing the great stock market crash of October 1929. It was the start of the Great Depression.

The Depression dragged on through the 1930s, defying the best efforts of President Franklin Delano Roosevelt. He had correctly perceived that the depression was caused by a mismatch between production capacity and the ability to consume that production. He tried to fix this mismatch by offering a New Deal to the American people. He raised government spending in an attempt to lift consumption, but the money made available was simply not enough. That changed when war was declared in Europe, and the United States soon shifted into wartime production. The huge military expenditure that followed quickly soaked up the country's excess production capacity and unemployed workers. By 1941, the Great Depression was a thing of the past.

When the war was over, the United States reentered the Household Stage, successfully this time. The success was due in large part to the reforms

legislated in the midst of the Great Depression by Roosevelt, and then to further reforms enacted by Presidents Truman and Eisenhower in the postwar years as a way of saying thank you to the returning servicemen and women. Those reforms were designed to share America's wealth more equally and to create a social services structure to support the working-class family. Taken together with further productivity improvements, these reforms provided the foundation from which the United States launched into the postwar boom. So it was that the United States eventually made the transition from the Urban to the Household Stage.

In contrast to the United States, the Soviet Union did not manage the Urban-to-Household transition at all. It had entered the Urban Stage in the late 1920s when Josef Stalin dragooned his countrymen into a forced march to industrialization. So successful had Stalin and his henchmen been that by the 1960s, the country was ready to make the transition to the Household Stage. The problem was that the Soviet leadership was not ready. So pleased were they with their expertise in managing the country as an Urban Stage economy that they wanted it to continue forever. In any case, the Household Stage, with all its consumerism and freedom of action, did not appeal to these aging survivors of the Stalinist era. So, they ignored the warning signs and kept on building more dams and bridges and making more steel. When Mikhail Gorbachev came to power in the mid-1980s, the Soviet economy was on the verge of collapsing under the weight of its mountains of excess steel. He wasted no time in enacting a raft of reforms designed to achieve a last-ditch transition to the Household Stage, but it was too late. The Soviet Union disintegrated in 1991 (Maranzani, 2018).

Not every failure to make the Urban-to-Household transition leads to something as eventful as the Great Depression or the collapse of the Soviet Union. Many countries simply stall somewhere between the two stages. This has happened so often that it has been given a name: the Middle-Income Trap. The "Middle-Income" part of the name derives from the fact that the country has lifted itself out of poverty but has not progressed to wealthy country status. The Trap part of the name derives from the fact that the country is trapped between lower-income manufacturing

countries, which are better at making low-cost goods, and higher-income manufacturing countries, which are better at making more complex goods. It has, therefore, no competitive advantage in the world of manufacturing. Without this manufacturing engine propelling it along, the economy slows down and remains permanently at a considerable distance behind those nations—the advanced countries—that have made the transition.

Those nations that do successfully make the transition will eventually catch up to the advanced countries. Apart from the countries of North America and Western Europe, who entered the Household Stage after the Second World War, there have been relatively few countries that have done this. The four most prominent are the island nations of east Asia: Japan, South Korea, Taiwan, and Singapore.

Far more nations have failed to make the transition and have instead become stuck in the Middle-Income Trap. They include most of the countries of Latin America, North Africa, and the Middle East, as well as several in Southeast Asia. They get stuck because their government, and the upper stratum of society as a whole, fails to initiate and push through the reforms necessary to fund the social infrastructure that is needed to put real purchasing power into the hands of the average people.

Causes of Periods of High and Low Mineral Demand Growth in the 20th Century

The framework for economic development discussed in the previous section provides the necessary foundation to explain the causes of the high and low periods of global mineral demand in the 20th century.

1900 to 1929: High demand growth

The driver of this period was the rapid urbanization of the United States and the countries of Western Europe. The initial impetus came from farm mechanization, which created a push-and-pull mechanism. The productivity gains from using farming machinery pushed surplus laborers off the farm, and the factories that made the farming machinery pulled these same workers into the cities where the factories were located. This continuing influx into the cities (<https://www.statista.com/statistics/>

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269967/urbanization-in-the-united-states/) created a construction boom that lasted over four decades, starting in the mid-1880s. The growing city-based factory system also brought with it the need for national transport, electrical power, and communications networks, so that the city-made goods could be distributed to the rest of the country. All of this required great quantities of metals, energy, and other materials. It was a 45-year period of high growth in global mineral demand.

1929 to 1938: Low demand growth

This was the decade when the United States and the countries of Europe were in the grip of the Great Depression. The stock market crash of 1929 stopped investment in its tracks and frightened the average family so much that they stopped spending. Factories closed, taxation revenue dried up, and national governments, being forced to balance their books, cut back on whatever projects they were funding. It was a 10-year period of low to nonexistent growth in global mineral demand.

1950 to 1975: Return to high demand growth

These were the years of the postwar boom. Once the Second World War was over, grateful national governments across North America and Europe enacted policies designed to put money and career opportunities into the hands of the returned soldiers and the many others who had contributed to the war effort. There was also a renewed push on nation-building projects such as road networks and a greatly expanded education and health system. The improved roads allowed young families to move out of the cramped inner cities and build homes in new housing estates in what became known as suburban developments. This then drove a sustained surge in new home construction and related infrastructure. Along with that came a whole host of new factories devoted to manufacturing household goods. The result was a 25-year period of steadily increasing global demand for minerals, energy, and other materials.

1975 to 2000: Weaker demand growth

The postwar boom could not last forever, and it came to an end by the mid-1970s amid widespread industrial strife and persistent inflation.

By this time, the average family in the advanced countries was well supplied with a spacious house and plenty of material goods. Their spending interests started to shift to self-improvement via education, better medical care, tourism, and the purchase of investment properties and other financial assets. As a result of this, I interpret that the construction of new homes and infrastructure networks—the driving force for metals and materials demand—fell away. The 25 years after 1975 saw weak growth in global mineral demand.

Emergence of China as the Driver of Global Mineral Demand

Then along came China. Starting probably in the 1990s, the country really burst onto the global minerals scene in the early 2000s, creating a frantic 15-year period that has become known as the China mining boom (<https://www.statista.com/statistics/263770/gross-domestic-product-gdp-of-china/>). The world entered another period of high demand growth for minerals between 2000 and 2015 (Fig. 3). China, almost alone, was responsible for this demand.

Where did this China boom come from? It started in the late 1970s with the death of Chairman Mao, who had presided over China for most of the time since the Communists came to power in 1949. His primary achievement over the period was that the Communist Party had become ever more firmly entrenched as the ruling institution in China. By the time of his death, the Party was unchallenged in its rule over the country.

But Mao had neglected and mismanaged the development of the national economy so much so that in 1976, the year he died, the living standards of the Chinese people were no better than they were in 1953, and their living

standards were low in 1953. Realizing that popular discontent was reaching serious levels, Mao’s successors lost no time in embarking on a program of national economic reform. To put it in terms of the economic framework discussed above, in the late 1970s, China entered the Urban Stage. In the four decades that followed, the country achieved economic growth that was the wonder of the world (worldbank.org).

The 1980s

The first major step was land reform, but some background to this is needed. The Communist Party, not long after it had taken power, had forcibly moved all Chinese farmers onto giant collective farms. The idea was to mechanize these huge farms and create efficiencies in agricultural production, copying the methods of the Soviet Union. Just like in the Soviet Union, the collective farms in China did not work. Indeed, instead of propelling China into the Urban Stage (as was intended), all they really achieved was the creation of hundreds of millions of dispossessed and demoralized farmers who wanted to return to the days when they and their immediate families ran their own half-hectare farms and benefited from the fruits of their own labor.

The land reform of the early 1980s gave the farmers their wish (Powell, 1992). In the space of a few years, China’s 50,000 or so collective farms were split up into hundreds of millions of family-run farms. The result was a huge injection of energy into the farmers and an economic boom in the Chinese countryside. In all of the many rural towns and villages, factories were opened for manufacturing simple goods for farmers. Chief among the goods were woollen clothing, bicycles, and spare parts for irrigation pumps and other pieces of small machinery. Over

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Global mineral demand growth rate	high or low	high	low	high	low	high
Steel	% per yr	5.1	−0.3	5.2	0.9	4.4
Copper	% per yr	4.8	0.1	4.6	2.5	5.0*

Fig. 3. Global metal demand. *Note that while the copper demand growth was 2.9% in 2000–15, this was to an extent artificially low because the demand for copper was constrained by lack of supply. If sufficient supply had been available, I suggest that demand growth probably would have been higher, perhaps as much as 5% per year during this period, and that number is used in the figure.

the decade, this led to a great increase of Chinese domestic consumption of metals and materials. Steel consumption nearly doubled from 30 million tonnes in 1981 to 55 million tonnes in 1990 (International Iron and Steel Institute, 1991). But China was so opaque to the outside world that the rest of world did not even notice that it was happening.

The 1990s

The Chinese leadership had initiated a second important reform in the early 1980s by opening up four so-called Special Economic Zones, or SEZs. The purpose of these was to attract foreign manufacturers to set up factories on Chinese soil and manufacture goods for export. In this way, Chinese manufacturers would learn how to run modern factories.

The SEZs took a long time to get started. By the end of the 1980s, only one zone, Shenzhen, had made any real progress, and its success relied on the fact that it was located only a few hours' drive from Hong Kong. As the 1980s progressed, the price of land and labor soared in Hong Kong, so local manufacturers increasingly saw the benefit of shifting their factories to Shenzhen.

In the 1990s, however, the pace of SEZ development rapidly accelerated. The main driver was a change in US attitudes to Japan's trade practices. For decades, successive Japanese trade practices gave Japanese manufactured exports an unfair advantage in the US domestic market versus domestically made American goods. This unfair advantage had finally made such damaging inroads into US manufacturing that the Reagan administration lost patience. The result was that low-cost exporters based in Japan and Taiwan lost their price advantage in the American market. The only solution for them was to find a new, less expensive base of operations outside of Japan and Taiwan. Many of them, especially the Taiwanese, relocated to the Chinese Special Economic Zones. Later in the decade, they were joined by an increasing number of US and European manufacturers. By the late 1990s, China was easily the world's leading manufacturer of export goods.

The result was a boom in construction and manufacturing in all of the Chinese coastal provinces. Over the decade, this caused another great

increase of Chinese domestic consumption of metals and materials. Looking again at steel consumption, it tripled from 55 million tonnes in 1990 to 153 million tonnes in the year 2000 (International Iron and Steel Institute, 2001). This time some of the more observant people in the global minerals business did take notice, but they did not see it as much of an opportunity. China, they thought, was not going to keep growing at that pace.

The 2000s

They were wrong about that. Through the decade of the 2000s, the Chinese economy kept growing at 10% per year. It seemed impossible. What was driving this unheard-of economic performance?

The driver of it all was a risky reform undertaken in 1997 (Lin et al., 1998, 2001), aimed at making China's bloated and corrupt city-based, state-owned enterprises more competitive. One of the problems with these businesses was that they were not really businesses at all. Instead, they were Mao-era social welfare providers who derived their income from the sale of manufactured goods or some other product. These companies were required to provide housing, education, medical care, and almost everything else to their workforce and their families. In an effort to make them more competitive, the leaders of the Communist Party had decided to remove these social welfare obligations from the companies. The workers would have to look after themselves. And, for good measure, they would have to buy the company-owned apartment they were living in. After all, the apartments were in poor shape and were too costly to maintain. On the plus side for the workers, the asking price was very low.

It was a classic case of a policy with unintended consequences. Far from being a burden to the workers, the opportunity to buy their own apartment was a life-changing gift. Chinese cities were teeming with farmers from the countryside who had come to work in the burgeoning factory sector. They needed somewhere to live. So, the apartments were rented out for good money. Using the rental income and drawing on savings accumulated over many years, an apartment owner could put down a deposit on a new apartment. It would be bigger than the old one and located in a new high-rise building. This sudden demand for new

apartments kick-started the biggest construction boom the world has ever seen. China's cities became a forest of high-rise buildings. The country's domestic miners and smelters were soon overwhelmed, and Chinese traders began fanning out around the globe, in search of new supplies.

Metal prices leapt upward. This time the world really did take notice. The China mining boom had begun. The decade saw increases in metals and materials consumption that were truly breathtaking. Returning to Chinese domestic steel consumption, in 2000 it was 153 million tonnes, and by 2010 it was 600 million tonnes, a four-fold increase (World Steel Association, 2011), and 20 times over three decades.

The 2010s

The construction boom in China's cities carried on for years. Of course, as with every other economic development, it could not last forever. But the Chinese government wanted it to last forever and decided to keep it going. To that end, the government, through a variety of means, provided large amounts of inexpensive capital to the apartment builders. And when that was spent, there was still more capital available, as long as they kept building. It was not only the apartment building companies that received it. Almost any project could access the inexpensive capital as long as the project involved steel, cement, and cranes.

So, in the 2010s, China kept the mining boom going through cheap money and official encouragement. Yet even with all that stimulus, the pace of demand growth eventually slowed, and metal prices reduced. By 2015, the China mining boom was over.

What Will Global Mineral Demand Growth Look Like to 2050?

The recent China-driven period of high mineral consumption growth—the China boom—has now come to an end. In this section, I will consider what may come next. A simplistic way of looking at things would suggest that the world is heading for a period of low mineral demand. After all, that has been the pattern of the past 120+ years. A period of high growth has been followed by a period of low growth, which has then been followed by a period of high growth once more.

Drivers of Global Mineral Demand: 1900–2050 (cont.)

	Steel	Copper	% global consumption		Population	Urbanization
	kg/capita	kg/capita	Steel	Copper	million	% population
Advanced countries	400	7.1	33%	40%	1,310	86
Latin America	132	1.2	5%	3%	630	92
Kazakhstan-Morocco	97	1.2	5%	4%	782	82
China	495	7.0	43%	43%	1,411	56
India	67	0.8	6%	5%	1,402	34
Southeast Asia	143	1.3	7%	5%	804	45
Sub-Saharan Africa	19	0.1	1%	0%	1,089	48
World	217	3.1	100%	100%	7,428	61

Fig. 4. Per Capita Consumption, 2015. Note: Data from www.statista.com/statistics/.

But the discussion so far has sought to explain these high and lows in terms of the economic development of global regions. There is no preordained pattern of high-low-high. That is just the way that things have worked out. To get a proper insight into what global mineral demand growth may look like to 2050, it is necessary to look at each of the global regions and examine how they are likely to develop over that period.

Before embarking on this analysis, it should be stressed that the following discussion considers *global* demand growth as a whole. While it may be that a particular region will see rapid growth in its urbanization, this will not necessarily have an impact on the global scale, since the regions are quite different in their 2015 baseline of mineral consumption (Fig. 4). High demand growth in a particular region will have a lot less impact globally if that region is starting from a low base. China had little impact on global demand in the first 20 years of its very rapid Urban Stage development. It was only when it reached a certain level of consumption, and continued with high growth, that it began to move the dial on a global scale.

Having made these observations, what are the current levels of metal demand in each of the regions?

Figure 4 shows each global region and its per capita consumption of both steel and copper in 2015; only two out of the seven regions—the advanced countries and China—dominated global metal consumption, accounting for 76% of steel consumption and 83% of copper. At the other end of the scale, Sub-Saharan Africa barely registers.

What explains this stark difference

in consumption across regions?

Although the degree of urbanization may be thought to be the most important factor, the data in Figure 4 shows that it is not.

Latin America is the most urbanized region in the world after North America (<https://www.statista.com/statistics/270860/urbanization-by-continent/>) but has metal consumption well below the advanced countries and China. Sub-Saharan Africa has an urbanization rate nearly the same as China, but its metal consumption per capita is far less than that of China (estimated at about 5 and 2% of China for steel and copper, respectively).

Therefore, the urbanization rate alone is not the critical factor. Instead, the critical factors are the nature of that urbanization and the wealth of the urbanized households. To be more specific, the critical factors are as follows:

- The percentage of high-rise buildings in the residential accommodation mix;
- The percentage of manufacturing in the Gross Domestic Product (GDP) mix; and
- The annual consumption expenditure per household.

To illustrate these differences, consider Latin America and China. Most Latin American cities are sprawling low-rise urban agglomerations, whereas Chinese cities are notable for their densely packed forests of high-rise buildings. As for manufacturing, China's factory base—providing for the world—far outweighs that of Latin America. Regarding household expenditure, there is probably not too much separating the two regions, but the first two factors are sufficient to account for the difference.

Given the large differences between regions in current levels of metal consumption, it appears that over the next 30 years, the only regions truly capable of driving a meaningful shift in global mineral consumption are the advanced countries and China. Thus, these two regions are the main focus of the discussion when it comes to forecasting global mineral demand growth to 2050. Some readers may be asking: What about India? Isn't India going to be the next China? Because that question is often asked, India will also be a focus of the discussion in the rest of this section.

China

We start with the economic outlook for China to 2050. Since the middle of the last decade, it has become clear that China has reached the end of its Urban Stage. It is now time for the country to shift economic gears and move into the Household Stage. The trouble is, like many countries before it, China appears to be failing in this endeavor. Numerous signals indicate that China is headed for a prolonged period of economic stagnation, and this may lead to other disruptions.

For a shift to the Household Stage to succeed, I argue that more economic power has to be placed into the hands of the common people, and the economy must be restructured to provide the means to supply the wants of the common people. Indeed, China's success over the past 40 years has been built on handing power to the people:

- The driver of growth in the 1980s was the policy of allowing individual families to run their own farms outside of the Agricultural Commune system.
- The driver of growth in the 1990s was the policy of allowing individual Chinese businesspeople to set up private manufacturing businesses outside of the state-owned enterprise system.
- The driver of growth in the 2000s was the policy of allowing individual families to own their homes and rent, buy, and sell them on the free market.

Many such “power to the people” opportunities remain. They include the following:

- Allowing Chinese families to own their farmland and buy and sell it as they wish;

- Creating an independent legal process so that Chinese businesspeople have protected rights; and
- Establishing a financial system that lends money on the basis of the economic merit of projects.

None of these policy reforms appear likely to happen for political reasons, and so China presently remains in the Urban Stage. This is not the only barrier to China making a successful transition to the Household Stage. There are at least two others:

- The population is aging; the workforce is both aging and declining, and soon the population itself will be in decline. Whereas other countries might seek to attract youthful immigrants to offset this, this appears unlikely to happen in China. The result will be a smaller and less energetic workforce, required to give more and more of its productive time to supporting the retired population.
- Advanced countries support was indispensable to China's rapid economic rise and will be required for the next transition; at present this support is evaporating.

To sum up, the economy in China of the 2020s is beginning to reflect that of the Soviet Union of the 1970s. Major reforms will be needed propel the economy into the Household stage.

India

There is no doubt that India has been a high-growth economy, particularly over the past two decades (data.worldbank.org), although the growth has been about half that of China. Prior to that, it was an economy known for its sluggish economic growth. The change from sluggish to high growth came with the assassination of Rajiv Gandhi. With his death, the Nehru-Ghandi family, which had dominated Indian politics since the late 1940s, lost power. It was replaced by reformers, chief among them being the new Prime Minister, Narasimha Rao, and his Finance Minister, Manmohan Singh. They set about dismantling as many as possible of the myriad regulations, which were effectively choking off investment and innovation. The result was a sustained surge in economic activity, which continues to this day. In terms of the economic model discussed above, with the introduction

of the Rao-Singh reforms, India could be said to have entered the Urban Stage of economic growth.

The style of India's Urban Stage is, however, very different from that of China. China's growth came from empowering common workers, starting with giving them stewardship of their own farms, followed by better-paid jobs in factories and then, for the urban dwellers, allowing them home ownership for a low price. India's growth, in contrast, is built on providing better-paid jobs for the well-educated middle class. The Indian farmer, poorly educated and living far from the city, is not participating in this. The fruits of the economic reforms are confined to the top 20% of the population.

The most important reason for this is that the Rao-Singh reforms focused on the regulations governing retail outlets, import and export trade, and such issues as communications infrastructure. They did not tackle the much thornier and deep-seated matters of management-labor relationships and land ownership. As a result, the business services sector is doing very well. All a business in this sector needs is a reliable Wi-Fi connection, a floor or two in a high-rise city block, and a reliable group of English-speaking graduates. Manufacturing, on the other hand, is not doing as well. Large-scale manufacturing needs a large workforce and a large block of land in an urban area, well-supported by transport and other infrastructure. One problem with this is that a workforce of over 100 people brings with it a heavy load of regulation. Another problem is that securing a large piece of land in an urban location is no mean feat. This tends to restrict the size of manufacturing operations to subeconomic scale. Then there is the challenge of getting access to needed infrastructure, which is difficult to build because the construction of transport and utilities infrastructure requires access to land and a wide range of permits. There are many ways that manufacturers can be blocked by a landowner's refusal to sell or allow access to needed land, which is why access to land in urban areas is one of the highest hurdles facing India's economic progress today. In China, that was never an issue, since landowner rights were never a factor where the government owns the land.

The same problems with land extend into India's agricultural regions. There

has been little to no reform of the rights of landowners and tenants. Absentee landlords rule over tenant farmers whose earnings are too low for them to ever hope to buy their own farms. Without any ownership, there is little incentive to improve the farm because the benefits flow to the owner and not the farmer who is doing the improvements. As a result, agricultural productivity remains low, and workers are required to stay on the farm. An attempt several years ago to achieve even minor reforms around land ownership met with determined and organized resistance and were abandoned (Kazmin, 2015). Nor can these tenant farmers head to the city to take a position in a factory, since factory jobs are in low supply.

This is a large part of the reason that India has the lowest rate of urbanization of any of the global regions (Fig. 4). This will only change when meaningful steps are taken to reform rural and urban land ownership rights and labor relations laws. In a contentious and overly democratic political environment such as exists in India—in contrast to China—these reforms are difficult. Until then, India's economic growth will be restricted to only a minor portion of the population.

The advanced countries

Having discussed the outlook for China and India, I now turn to the advanced countries. The main point to make here is that, while these economies are major consumers of metals and materials, they have long since left behind their materials-intensive stages of economic development. The growth sectors in these economies are now predominantly involved with innovative services such as communications, banking, education, medical care, entertainment, and tourism, all of which are low in terms of their metal and materials requirements. The demand for housing and durable consumer goods is growing by virtue of the population becoming wealthier, but for the existing population, the demand is not much higher than the replacement level. The main driver of *growth* in metals and materials consumption in these economies is immigration, because new arrivals need homes, furnishings, vehicles, and all of the other goods involved in establishing a life in a new country. In the majority of the countries of the region, immigration is at most 2% of the population in any

Drivers of Global Mineral Demand: 1900–2050 (cont.)

one year and is generally considerably lower. The growth rate in demand for metals and materials in the Advanced Countries is likely to be driven by immigration as well as the restructuring of energy systems, and I expect it will settle at the 2% level or lower.

The Impact of Urban Mining

The demand for metals in the various regions of the world has been examined, and now the issue of metal supply from recycling will be considered. Global demand for a metal is satisfied by production from both newly mined ore and recycled scrap. To forecast the demand for metal from newly mined ore requires an appreciation of whether the contribution of recycled scrap will depart from historical levels or whether it will stay about the same.

Recycling is familiar to everyone. However, few people know how important the contribution of recycled metal is to global metal markets, partly because it is rarely mentioned.

In 2015, recycled steel was estimated to have contributed 34% to overall global steel consumption (Bureau of International Recycling, 2017). For copper, the recycled contribution was estimated to be 21% (International Copper Study Group, 2017). This means that the tonnage of scrap steel recycled in 2015 was equivalent to the steel smelted from all of the iron ore produced in Brazil and India. The amount of scrap copper which made its way into new products was equal to the copper smelted from all of the mines of the African Copperbelt plus China.

Because most of this scrap comes from urban areas, the cities of the world are, in effect, steel and copper resources, hence the term “Urban Mining.” As the data shows, these urban mines are already significant contributors to total global supply. It is expected they will become even bigger contributors in the next thirty years.

In considering this, the most useful place to start is looking at the dynamics of scrap generation. All products have an average life expectancy. For example, a metal container used for storing food or drink has an expected life of about two months. An automobile has an expected life of about 15 years. For a suburban house, the expected life is about forty years. A bridge or railway has a life expectancy of around 100 years.

It is possible to calculate an average expected time in use for a metal if the percentage of the metal that goes into each category of products is known. Steel is estimated to have an average time in use of about 28 years. Copper is similar, with an average time in use of about 25 years. Average time in use estimates indicate how much scrap will be generated in a particular year. It requires only a knowledge of how much of the metal was consumed 28 years ago for steel, or 25 years ago for copper.

This is a good start, but having an estimate of the quantity of old scrap generated in any year is not enough. It is also necessary to have a good estimate of how much of that old scrap will actually be brought back into use. This is known as the end-of-life recycle rate. Like the average time in use, this rate varies for different metals. It also varies between different regions and countries.

Many estimates have been made of end-of-life recycle rates. Globally, a commonly used estimate for steel's end-of-life recycle rate is 60 to 70% (International Iron and Steel Institute, 2001). This is a high rate; the easiest way to dispose of old automobiles, heavy pieces of machinery, or the steel beams used in tall buildings is to recycle them through a scrap merchant. For copper, the global end-of-life recycle rate was estimated to be 50% in 2015 (International Copper Study Group, 2017). More recent estimates suggest the rate is slowly increasing. These end-of-life recycle rates will almost certainly rise if the cost of CO₂ emissions rise and, in the case of copper, scarcity drives prices higher.

The other factor that will determine the influence of urban mining on future metal consumption is the rate of growth in overall metal demand. The slower the growth rate in global metal demand over a long period of time, the higher the contribution of recycled metal to total global production, inclusive of mining.

Experience bears this out. The decades from 1970 to 1990 were slow demand growth years for global steel. As a result, about 42% of steel produced globally was sourced from scrap by the end of that period. In contrast, between 1995 and 2015, global production of steel grew at a very fast rate, and as a result, 34% of global crude steel was sourced from scrap by the end of that period (Bureau of International Recycling, 2017). The slower the demand

growth for a metal over a period, the higher will be the percentage of it sourced from scrap.

The contribution of recycled metal to total consumption is straightforward to calculate once the time in use, end-of-life recycle rate, and total consumption are known or forecast, for a year. All of these parameters are known for 2015 and are forecast for 2050. Figure 5 shows the actual (in 2015) and forecast (for 2050) contribution of recycled metal to total global consumption for steel and copper. The forecast is derived from *Oversupply: Global Mining to 2050* (Lynch, 2021).

The conclusion here is that urban mining will be a much more important factor in global metal production in 2050 than it is today. Over half of steel consumed in three decades is expected to come from recycled steel, and more than 2 in every 5 tonnes of copper consumed in 2050 is expected to have been recycled, double the present (2015) rate.

Restructuring Global Energy Systems

Before considering the forecast to 2050, there is a potential driver of global mineral demand that merits attention. The thesis of this paper is that the fundamental driver of global mineral demand since 1900 has been the pace of urban and suburban construction, as well as the transport, water and sewage, communications, and energy infrastructure, without which these urban and suburban areas could not function. It is my view that this will remain the principal driver for the next century.

What about the potential impact of the gathering shift in the structure of global energy systems from carbon-based fuels to renewable energy? There are some claims being made that to achieve this shift in its entirety, the demand for copper will become far higher—perhaps two or even three times higher—than it is today. The same is also said for nickel and manganese,

	2015	2050
Steel	28%	58%
Copper	21%	41%

Fig. 5. Contribution of recycled metal to total global consumption.

not to mention the many metals that will be needed for new technology, lithium being a prime example. Is the world on the verge of a renewable energy-driven boom in metal demand?

This is not the first time since 1900 that the basic technologies underpinning a certain form of infrastructure have changed in some significant way. In transport, road-based petrol- and diesel-powered motor vehicles had risen from relatively unimportant in the advanced countries in 1900 to being the principal form of transport by 1930. Air travel also became a major part of the transport mix by the 1970s. In telecommunications, similar shifts have happened. The telephone and radio rose from being barely in existence in 1900 to being a fundamental part of the urban landscape by 1930. Television did the same by the 1960s, and the Internet did the same by the 1990s.

Even in energy infrastructure, significant shifts have happened. Electricity grids were uncommon in 1900 but became part of the backbone of the economy by 1930. Natural gas and nuclear energy have since become significant parts of the global energy mix. Now it is possibly the turn of renewable energy.

Will the shift to renewable energy drive the world back to a high rate of metal demand growth over the next 30 years? I think this is unlikely, although the mechanism in favor of this happening is twofold:

- The need to reduce, and even eliminate, the production of greenhouse gases—in particular CO₂—can only be fulfilled by restructuring the global energy system, and a large part of this restructuring will rely on the construction of renewable energy production facilities.
- The production of electricity via renewable energy systems requires much more metal and materials per MW than does the production of electricity using hydrocarbon-based fuel. A recent International Energy agency (IEA) report estimates that coal-based production of electricity requires 2,500 kg of minerals per MW of production capacity, while solar power requires nearly 7,000 kg (IEA, 2021). The same report estimates that onshore wind farms require more than 10,000 kg per MW of capacity.

This does not include the battery storage that will be needed to smooth out the “lumpy” nature of renewable energy production.

The metals that will see significantly increased demand from renewable energy facilities and battery storage include already mainstream, high-production metals such as copper, nickel, and zinc; and also currently lower-volume metals such as lithium, chromium, and cobalt.

However, there is a lot of doubt about the pace of the shift. In part, this is because the shift is not really consumer driven, as has been the case in past infrastructure shifts. For a shift to renewable energy to happen at a rapid rate, it probably/possibly needs to be mandated by national governments, and that requires a political will that doesn't seem to exist at present. There is also the lack of any real clarity about what technologies will be best and what metals and materials will ultimately be needed.

The forecast in the next section does include a significant shift upward in copper demand due to electric vehicles and wind turbines. However, the assumption is made that in many of these applications, copper may be substituted by aluminium, to some extent at least.

The Global Outlook to 2050

Having discussed the situation to the present, it is now time to make a forecast of the outlook for global metals demand to 2050. In a recent book, *Over-supply: Global Mining to 2050* (Lynch, 2021), I have gone into detail about the expected demand for mainstream metals (Fig. 6). According to this forecast, the world is now in a low-mineral-demand period, likely to 2050.

The forecast has a central case. The main elements are as follows:

- The Chinese economy will, over the next 30 years, be much less an

engine of growth than it was during the past 30 years. This will be driven by demographic decline and, more importantly, a central government that favors the status quo over economic reform.

- The Indian economy will continue with its strong growth for about another 15 years and then will slow down as its main engine—the export of business services—loses its potency due to competition from artificial intelligence.
- The advanced countries will remain in the economic slow lane for the next 20 years, and the main drivers of these economies will be in metal-lite services sectors.
- Three of the other four regions of the world—Latin America, the Kazakhstan-Morocco Crescent, and Sub-Saharan Africa—will contribute little in the way of metal demand growth over the next 30 years, being stuck in longstanding social and political quagmires.
- Southeast Asia will be the one region of the world where economic growth rates continue above the historical average, mostly due to the emergence of a group of countries—Vietnam, Myanmar, Bangladesh, and Cambodia—which will succeed China in the provision of low-cost manufactured goods to the rest of the world.
- There will be a steadily growing level of action to mitigate climate change, and this will shift all countries toward renewable energy and away from coal with time, and at variable rates. But this will only become a sharp rather than a steady shift if the impact of climate change really becomes apparent to political leaders during the 2030s and 2040s.
- The contribution of recycled metal to metal consumption will reach heights not previously experienced.

Of course, forecasts are always wrong, particularly when looking forward decades. It is a matter of by how

		1900-29	1929-38	1950-75	1975-2000	2000-15	2015-50
Global mineral demand growth rate	<i>high or low</i>	high	low	high	low	high	low
Steel	% per yr	5.1	−0.3	5.2	0.9	4.4	0.9
Copper	% per yr	4.8	0.1	4.6	2.5	5.0*	1.8

Fig. 6. Global metal demand with forecast for the period from present to 2050.

Drivers of Global Mineral Demand: 1900–2050 (cont.)

much. There are three major assumptions underlying this forecast; if any are incorrect, the world could be pushed into significantly higher demand growth. These assumptions are the following:

- The Chinese Communist Party (CCP) has lost its interest in economic reform and is determined to cling onto its Urban Stage economic model. If this is incorrect and the CCP returns to the reformist mode that characterized the Deng Xiao Ping era, this will most likely push the Chinese economy headlong into the Household Stage and, in turn, return China to the high levels of demand growth seen in recent decades.
- The Indian government will not tackle the necessary reforms in its labor and land markets. By contrast, if they do successfully tackle these reforms, it could propel India into a Chinese-style Urban Stage of development. This would likely create several decades of high demand growth as India urbanizes from last place in the seven regions (Fig. 4).
- The advanced countries are beyond the stage of materials-intensive economic development. This could be proven wrong if global warming proceeds as many predict and reaches a stage where the urban environments of the world need to be restructured. The advanced countries region, being the wealthiest and most technologically advanced region of the world, would most likely be the first to take action in the restructuring of urban environments, and this would return the region to high growth in metal demand, both alloyed steel and copper as well as numerous high-technology metals.

One final point to make is that I expect the period following 2050 is likely to be one of higher growth in mineral demand. This is because in the post-2050 (or so) period, I expect that economic reform is likely to resume in China, and I suggest that the necessary reforms will probably finally be pushed through in India; plus, climate change will most likely have reached crisis point. The latter will force a

restructuring of urban and other environments across the globe, if society demands that this be done.

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Martin Lynch

is a graduate of the University of Queensland where he obtained a B.E. in chemical engineering. For the past 15 years, he has run a small business specializing in solar hot water and solar energy production and storage. Prior to that he had worked in operational and analytical roles in several mining companies, including Rio Tinto (1990–2002) and Iluka Resources. He has an interest in how the business of mining is driven by events and trends in the broader economy. He has written several books on this subject, including *Mining in World History* (2001) and *The Mining Boom of 2004* (2021).

