

Managing Partners:

LEIGH R. GOEHRING
ADAM A. ROZENCWAJG



DR. JEVONS OR: HOW I LEARNED TO STOP WORRYING AND LOVE DEMAND

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“It is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth.” William Stanley Jevons, *The Coal Question*, 1865.

The emergence of the “Magnificent Seven” has dominated all investment thinking. Owning these seven mega-cap growth stocks has become mandatory for survival in today’s investment world. These seven stocks alone now constitute almost 30% of the S&P 500’s weighting and advance daily in price.

Waking up after a fitful night’s sleep, dominated no doubt by worries over underperformance tied to being underweight this group, a portfolio manager gazing into the mirror, might debate what “Magnificent Seven” stocks must be purchased the coming day.

“NVIDIA has pulled back a little here; the stock is expensive here, but everyone agrees AI will be taking over the world...” On the other hand, they muse: “Microsoft looks a bargain at only 30x earnings [only twice its long-term earnings growth!] and aren’t they doing AI too—look, they just hired that AI guru from chatGPT to run their AI business?” Then again, “Meta’s multiple is below its estimated growth rate and thankfully, Mr. Zuckerberg has stopped wearing those silly glasses—isn’t the Metaverse just another form of AI?” Or maybe Amazon: “Now there’s a great way to play AI—even though the stocks trade at a PE of 40, everyone forgets that almost all their earnings come from server farms and cloud computing—remember: you want to own the retailers of picks and shovels, not the miners—I think my grandfather told me that.” Google and Apple are also considered. Ultimately, our sleep-deprived investor considers Tesla – maybe both the stock and the product. “After all, the IEA reiterated how EVs are taking over the world. Everyone in my neighborhood has a gleaming \$100,000 Model S – one certainly does not want to be left out. It’s settled then: today, I buy Tesla—both the car and the stock.”

Seldom, if ever, would our investor think about energy.

If our hypothetical investor were to think about energy (doubtful), it would likely be from the short side. Traditional energy sources are already on the funeral pyre, at least according to the gloomy World Energy Outlook 2023 released by the IEA (International Energy Agency). The appetite for oil, gas, and coal investments has supposedly peaked. The new kings – renewables -- are expected to be crowned before this decade ends. Why invest in a sector with such a dismal outlook? Adding to one’s (already overweight) Amazon position is far easier. All growth, all good! Energy stocks--with their bleak prospects—garner zero interest.

Unfortunately, our hypothetical investor is not alone. The market’s enthusiasm for energy stocks remains negative. Despite outpacing tech stocks since March 2020, energy stocks account for less than 5% of the S&P 500, well below the 14% historical average.

Looking at the outstanding shares of energy stock ETFs, we can see that investor interest continues to fall. The preferred ETFs (XLE, XOP, and OIH) have all significantly shrunk their share counts over the past two years. Despite being the star performer, energy investments are more related to short covering than sustained investor buying—which just doesn’t exist. In contrast, investors continue to add to mega-cap tech positions. Despite last year’s 35% drop in the NASDAQ composite, open interest in the QQQ ETF (which tracks the Nasdaq 100 Index) has increased by 20%.

The imagined struggle of the institutional investor closely mirrors reality. The consensus call is to pile onto tech stocks. Any remaining energy investments must be promptly sold to fund further purchases of the QQQ. It’s better to sell now than be stuck later.

But what if the opposite scenario unfolds? What if the IEA projections have erred and energy demand continues to surge in the coming years? After all, the IEA has a history of being ridiculously pessimistic in its demand forecasts. The agency has underestimated demand in 12 of the past 14 years by an impressive 820,000 b/d on average (excluding COVID-impacted 2020).

As we will discover in this essay, the IEA’s flawed methodologies persist. Analysts who revere the IEA’s forecasts are also prone to these errors. Case in point – LNG analysts have consis-

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tently undershot demand predictions since 2010. Projections of surging supply outpacing demand and breaking LNG's historical oil-linked price have fallen flat, with demand often exceeding expectations.

Historically, producers sold LNG under long-term contracts with a price linked to crude oil. By the late 2000s, traders established a robust spot market. Most pundits believed that surging supply would overwhelm demand while a freely trading spot market would break LNG's historical oil-linked price. The most bearish argued that prices would ultimately fall to LNG's marginal cost of \$1 per MMBtu supplied by low-cost Qatari gas. Despite their cries, the bearish case never materialized. Stronger-than-expected demand absorbed the new supply (much of it from Australia and the US), and the spot market rarely deviated from the 6:1 oil price link. Experts again significantly underestimated demand.

Our prediction contradicts the conventional narrative – we believe energy demand will continue to beat expectations well into the next decade.. This presents considerable investment implications. The widely accepted belief that demand will peak sends investors scrambling to sell their existing energy positions. The recent IEA's bleak World Energy Outlook only reinforces this perspective. We, however, believe that demand will maintain its upward trajectory

When the realization dawns that oil and gas demand is not in free fall, investors will be forced to confront how little the industry has invested to offset declines. According to our modeling, global oil markets have already fallen into a “structural deficit” masked by massive releases from government-controlled strategic stockpiles.

Such an awakening will stun investors, whose energy exposure hovers near zero. Thus, the day will soon come when that same investor stands before the mirror preparing for the day and says: “Today, I must buy energy shares -- a lot.”

THE JEVON'S PARADOX
WAS BORN: IMPROVED
EFFICIENCY INCREASES
CONSUMPTION.

While every investor is familiar with Moore's Law (often misapplying it to areas such as the cost of renewable energy), hardly anyone knows about the Jevons Paradox. They would be wise to learn. In 1865, an English economist, William Stanley Jevons, detailed his eponymous Paradox in his book *The Coal Question*. Jevons noticed how improved steam engine efficiency actually led to much greater coal demand. At the time, economists were worried that England was running out of coal. Many argued that improved efficiency would temper demand and forestall a crisis. Jevon dismissed this logic, correctly concluding that improved efficiency would accelerate demand by promoting increased adoption. Jevon's Paradox was born: improved efficiency increases consumption. The mechanics were two-fold. First, better efficiency encourages more significant use. Secondly, as the same input unit generates more output, economic growth accelerates, increasing overall consumption. Although Jevons' work dramatically advanced micro- and macroeconomics, the world has abandoned his invaluable lessons entirely. This does not make them any less relevant.

For decades, we have been fascinated with energy demand. Unlike supply, which is much more tangible, predicting demand is an abstract exercise. Analysts model supply, tally reserves, count rigs, and total capital spending. With demand, we must ponder how societies develop, regions urbanize, and individuals consume. And yet, getting demand right has never been more critical.

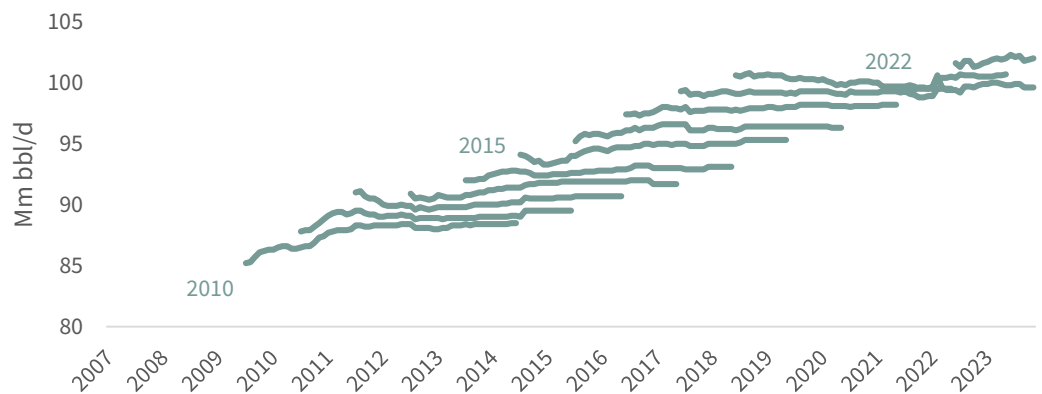
While many clients we meet with understand the absence of resource capital and the resulting supply shortages, they cannot invest owing to their worries about demand. In the near term, they are concerned about an impending recession. In the long term, they worry about “peak demand.” We vehemently disagree with both. So long as investors fail to appreciate Jevons’ lessons, demand will constantly surprise to the upside. Educated investors stand to benefit tremendously.

Three real-world examples help breathe life into the Jevons Paradox. First, while the average fuel economy of modern automobiles has surged in recent decades, gasoline demand never faltered. Motorists instead chose to drive larger SUVs and drive much further. Second, the energy required to heat and cool a home has collapsed as more efficient windows and HVAC systems have proliferated. Homeowners have taken the savings and doubled the size of the average American home, offsetting any efficiency gains. Finally, as we write this essay, we are aboard an Airbus A350-ULR en route to Singapore. The 9,500 mile journey is made possible by the highly efficient Rolls-Royce Trent XWB-97 engine, which consumes 25% less fuel compared with the previous engines. Once again, instead of reducing jet fuel demand, passenger miles have skyrocketed in recent years, resulting in record demand.

The IEA is leading the bearish chorus. In their most recent World Energy Outlook 2023, published in October, the IEA lays out its “Announced Pledges Scenario” for global energy demand. Between 2022 and 2030, the IEA estimates demand (which it oddly calls Total Energy Supply [TES]) will fall by 1%. By 2040, it will fall by 3.2%. These numbers are not possible given our understanding of global energy consumption. Our models tell us the IEA uses fundamentally flawed mythologies that introduce a systematic downward bias. Their bias has been apparent since at least 2010. Over that time, the IEA has chronically underestimated global oil demand in twelve of the fourteen years (including COVID-impacted 2020). Excluding 2020, the IEA increased demand by an incredible 800,000 b/d on average from its initial expectation. If the IEA’s error were a country, it would be the world’s 21st largest oil consumer.

EXCLUDING 2020, THE IEA INCREASED DEMAND BY AN INCREDIBLE 800,000 B/D ON AVERAGE FROM ITS INITIAL EXPECTATION. IF THE IEA’S ERROR WERE A COUNTRY, IT WOULD BE THE WORLD’S 21ST LARGEST OIL CONSUMER.

FIGURE 1 IEA Demand Revisions Over Time

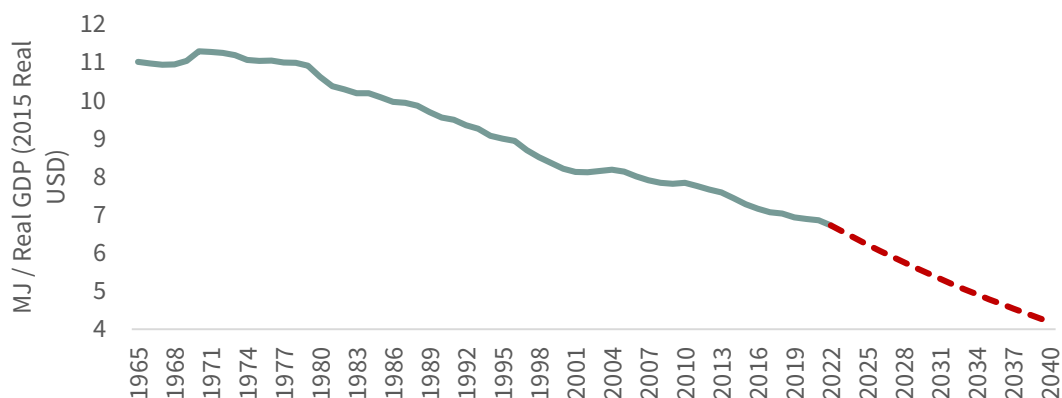


Source: IEA.

We believe the IEA’s error stems from its faulty understanding of energy intensity (the inverse of efficiency). Energy intensity, defined as Total Energy Supply per dollar of real GDP, has improved dramatically over the last six decades. In 1965, it took 13 megajoules (MJ) to

generate one US dollar of real GDP. By 2022, the same real dollar required less than 7 MJ – a reduction of nearly 40% or almost 1% per annum. The IEA expects these trends will accelerate dramatically. Based on their projections, energy intensity will take only seventeen years to fall as much as it did over the past six decades. From 7 MJ today, the IEA expects a dollar of real GDP will only require 4 MJ by 2040 – an incredible decline of nearly 3% annually.

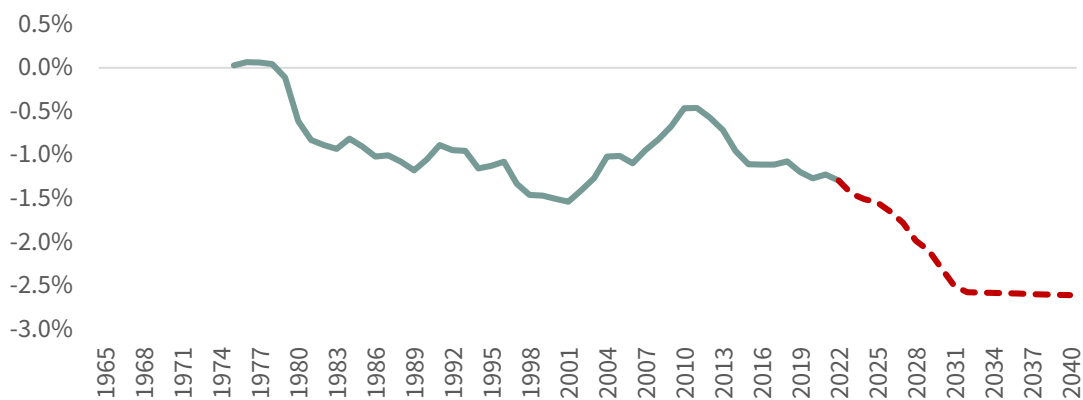
FIGURE 2 Energy Intensity of Real GDP



Source: BP, IEA, World Bank.

The IEA’s analysis has three critical flaws. First, while the chart above seems to reflect a reasonable extrapolation, it implies a massive acceleration in efficiency gains. From 1980 to 2022, on a 10-year rolling basis, energy intensity improved by approximately 1% per year. The IEA assumes this improvement accelerates nearly three-fold – something we believe is impossible.

FIGURE 3 Yearly Decline in Energy Intensity



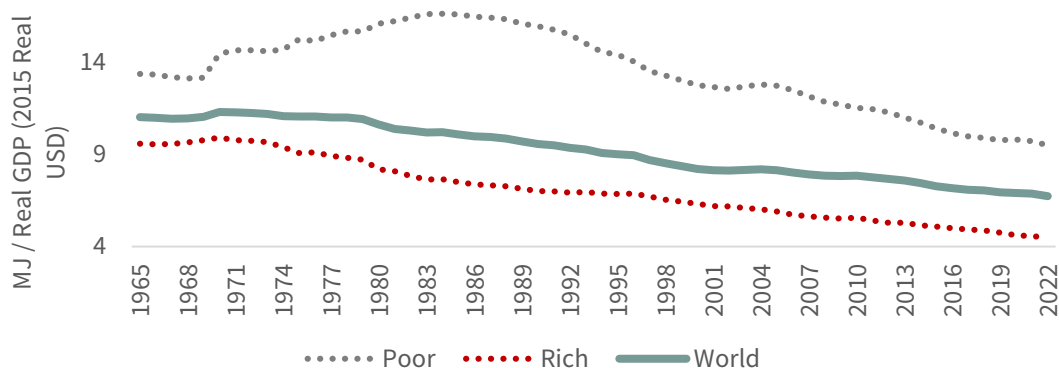
Source: BP, IEA, World Bank.

NEVER IN HUMAN HISTORY HAS IMPROVED EFFICIENCY RESULTED IN LESS DEMAND – THE COMING TWO DECADES WILL BE NO DIFFERENT.

Second, the IEA’s projections fly squarely in the face of the Jevons Paradox. Over the past six decades, although (or indeed because) energy efficiency improved by 40%, energy demand per capita nearly doubled while total energy demand rose four-fold. According to the IEA, over the next seventeen years, a similar 40% improvement in efficiency will lead to a nearly 15% decline in per capita demand and a 3% decline in total demand. Never in human history has improved efficiency resulted in less demand – the coming two decades will be no different.

Third, the IEA fails to account for recent memory's most significant growth driver: the rise of emerging markets. At any given moment, global energy intensity is the aggregate of countless smaller markets, each with wildly different needs. Although one dollar of real GDP requires 7 MJ globally, China (and most emerging economies) takes nearly 10 MJ, while the US (and most of the developed world) takes less than 5 MJ. While every country has become more efficient over time, the difference between emerging and developed economies remains stark. Global energy intensity is the sum of each country, weighted by its proportion of global real GDP.

FIGURE 4 Energy Intensity of GDP by Wealth



Source: BP, IEA, World Bank.

WITH MORE GROWTH FROM ENERGY-INTENSIVE ECONOMIES, GLOBAL ENERGY PER DOLLAR OF REAL GDP SHIFTED HIGHER THAN EXPECTED.

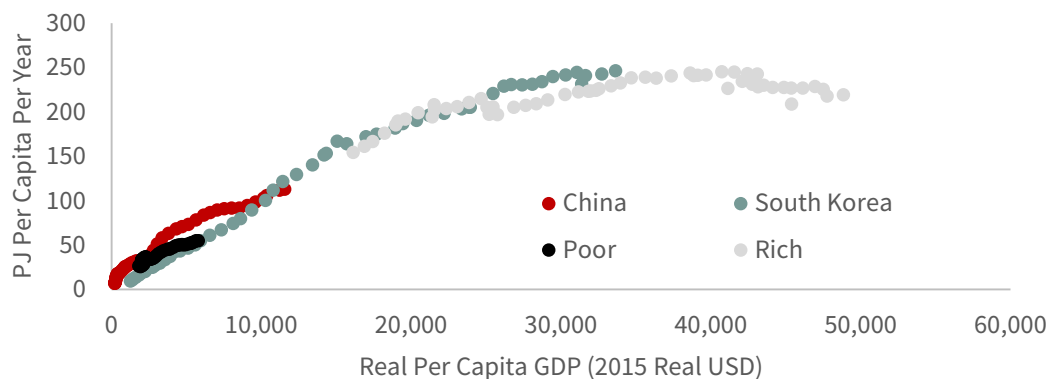
For decades, emerging markets represented a low and constant share of global GDP. In 1970, poor countries represented 30% of real GDP; 35 years later, little had changed. A significant shift occurred around 2005 as numerous Asian countries entered a period of accelerated economic growth. By 2022, poor countries had gone from 30% to 45% of global real GDP and will soon exceed 50%. Emerging markets have been even more impactful as a proportion of total growth. Despite representing only one-third of global output, emerging markets delivered two-thirds of all growth since 2005.

With more growth from energy-intensive economies, global energy per dollar of real GDP shifted higher than expected. For example, although energy intensity in developed and emerging markets fell by a quarter between 2005 and 2022, global intensity fell by only 17%. Had emerging markets remained at only one-third of global output instead of growing to 45%, total energy demand would be nearly 10% lower than it is today. Just as emerging markets started to become a more significant source of growth (between 2005 and 2010), the IEA started chronically underestimating demand.

The IEA's error is about to get much worse. By 2040, emerging markets will go from 45% to 53% of global GDP, representing nearly 70% of all growth. Despite this accelerating shift towards more energy-intensive economies, the IEA predicts global intensity will fall by nearly 40% -- twice the improvement compared to the last seventeen years. For this to be possible, emerging-market energy intensity would have to fall by 50%, and per capita demand would have to fall by 10%, doubling per capita income. The Jevons Paradox teaches this is not possible: even if the efficiency gains were achievable, economic output would accelerate, more than making up the difference.

Our demand models are fundamentally different. We believe economic development drives energy demand, and our models capture that relationship explicitly. The result is our S-Curve demand model, where we plot per capita energy demand against real GDP. When an economy is very poor, it consumes little energy; any growth goes towards subsistence. As it reaches middle-income, its energy demand grows materially. Finally, energy demand begins to flatten at \$20,000 of real per capita GDP.

FIGURE 5 S-Curve of Demand



Source: BP, IEA, World Bank.

Our S-Curve holds well across different regions and times. In 1965, South Korea had a \$1,300 real per capita GDP and consumed 9.4 petajoules (PJ) per person. By 2010, Korean GDP had grown to \$25,000, while energy demand reached nearly 220 PJ per person. Four decades earlier and an ocean away, US real GDP hit \$23,000 while energy demand was 250 PJ per person – remarkably similar. China currently sports a real GDP of \$12,000 and consumes 113 PJ – comparable to Korea in 1994 in terms of GDP and energy demand. For China to exit the middle-income trap and top \$20,000 per capita, the S-Curve suggests its energy demand must grow by at least 60%.

Once an economy reaches \$20,000 per capita, energy demand still grows, albeit much slower. After \$40,000 per capita, the economy is mainly saturated, and energy demand stays essentially flat, with efficiency gains offsetting economic growth.

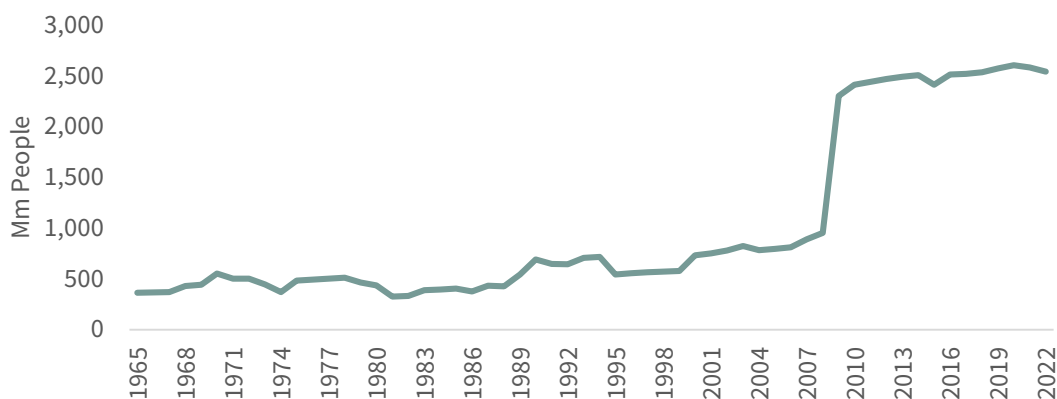
Therefore, countries between \$5,000 and \$20,000 per capita real GDP are the most significant when studying growth trends. While an economy’s real per capita GDP is less than \$5,000, energy consumption is inconsequential; consumption begins to flatten when it is above \$20,000. For most of the twentieth century, people between \$5 and \$20,000 per capita GDP remained relatively constant at 500 mm. While new countries would enter the bloc (such as Brazil in 1975), others would leave (such as Japan in 1981). Between 2000 and 2010, the population of energy-hungry consumers surged from 600 mm to 2.4 bn, and by 2022, the number had reached 2.6 bn. A third of the world’s population is now in the “sweet spot” of energy demand growth, representing half of all economic growth. Never before have so many people simultaneously been in a period of energy-intensive economic growth. So long as this is true, global energy demand will remain a tailwind.

Using the IEA’s methodology, between now and 2040, global energy demand is projected to fall by 3%, with real GDP per capita growing by 40%, demand per GDP (somehow)

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falling by 40%, and population growing by 15%. Using our S-Curve, energy demand will increase by 35%, assuming the same real GDP and population growth rate. Poor countries will go from \$6 to \$9,000 per capita GDP, causing energy demand to surge 43% per capita. With 16% population growth, emerging market energy demand should rise nearly 70%.

FIGURE 6 Population Between \$5-20,000 Real per Capita GDP



Source: World Bank.

Even if developed countries' energy per capita fell by 20% (something we believe impossible), global energy demand would still increase by more than a third.

While the IEA assumes global energy demand will peak around now, our model predicts it will grow by 217 EJ between now and 2040, representing the fastest seventeen-year period of growth in human history.

Nor are we concerned about a recession over the near term. First, our real-time models confirm demand remains robust. Even if a severe coordinated slowdown took hold, we believe the impacts would be less painful and shorter-lived than most analysts expect. There have been four global recessions since 1965: 1975, 1982, 1991, and the Global Financial Crisis (GFC) in 2009. In the first three instances, global energy demand fell by 1%, driving average per capita energy demand lower by 4.4%. Energy per capita took eight years on average to recover to pre-recession highs. The GFC was much worse in terms of economic dislocation. Global per capita GDP fell by 2.5% -- nearly three times the average of the previous three worldwide recessions. However, because of the rising influence of energy-hungry emerging market economies, per capita energy demand only fell by 2.9% -- one third less than in the previous three recessions despite a nearly three times sharper slowdown in economic activity. Instead of taking eight years, per capita energy demand surpassed the pre-crisis high by 2010. If we experience another global slowdown (of which we have no evidence presently), the impact would be much less than people expect.

We want to leave you with our corollary to the Jevons Paradox: only high energy prices reduce demand. The IEA paints a bearish picture in which improved efficiency reduces aggregate demand and persistent low energy prices. We would offer a different take: economic output and, by extension, energy demand will surprise to the upside until high energy costs reduce overall activity. In such a world, what assets would you prefer to own?

Natural Resource Market Commentary – 3Q2023

After a weak second quarter, commodity prices firmed in the third. Commodity-related equities were also strong. The heavily energy-focused Goldman Sachs Commodity Index rose 12.8%, reflecting oil's rebound. The Rodgers International Commodity Index, which has significant metal and agricultural exposures, rose 9.1%. The S&P North American Natural Resource Stock Index, which is heavily energy-weighted, rose 7.8%, while the S&P Global Natural Resources index, with its heavier metal and agricultural exposure, rose just 3.4%. The broader market, meanwhile, was weak. Reflecting continued worries over further interest rate hikes, the S&P 500 stock index fell 3.2%, and the MSCI All Country World Index fell 3.8%

Oil

Oil rebounded strongly in the third quarter. Sales from the US Strategic Petroleum Reserve ended in the last week of June, and we believe it was no coincidence that oil bottomed simultaneously. The West Texas Intermediate oil price slumped to \$67 per barrel on June 28 before surging almost 40% over the following twelve weeks. By the end of September, WTI almost reached \$95. Slackening SPR sales were only partially responsible for the oil price rally. Oil demand continued to grow far above expectations. For all the talk of recession and Chinese slowdowns, demand continued to surpass initial expectations. Since the beginning of 2023, the IEA has revised 2023 demand estimates higher by 600,000 b/d. Led by an impressive 1.2 mm/b demand surge in China, the IEA expects global demand to grow by 2.3 mm b/d this year. As investors realize demand is here to stay, prices should rally sharply.

Natural Gas

After rebounding in the second quarter, North American and international natural gas rallied. US natural gas rose 5%, while European and Asian natural gas rose 8% and 16%, respectively. Both European and Asian natural gas currently sit at \$16 per MMBtu. Oil trades at \$15 per MMBtu when converted into natural gas equivalency. With Henry Hub gas at only \$3.10 per MMBtu, the US gas molecule trades at an incredible 80% discount to global energy prices. We have written that we believe North American natural gas prices will converge with international prices.

Since first writing about “convergence” in our 1Q22 essay “The Gas Crisis is Coming to America,” the trade has been pushed out because of North America and Europe’s highly mild winter weather. The Freeport LNG export terminal also caught fire in 2022, knocking out two bcf per day of LNG exports, or a significant 2% of total US demand. As US inventories swelled, North American natural gas fell nearly 80% from the 2022 peak of almost \$10 per MMBtu. We believe these headwinds were temporary and are now behind us. Excess US inventories have primarily been worked off, while operators expect to add six bcf/d of new LNG export capacity in 2024.

Convergence is getting closer, leaving us wildly bullish on US natural gas. Seldom are we presented with a commodity whose price can rise five-fold in a very short period. Investors

should take note.

Coal

Coal prices were mixed during the quarter. US-based coal continued to trade lower. Illinois and Central Appalachian basin coal fell approximately 7%. International coal prices, on the other hand, were solid. As measured by the Newcastle export price, Australian thermal coal rose 25%. South African thermal prices, as measured by the Richard's Bay export price, rose 23%. Australian metallurgical coal rose the most, advancing by 40%.

Over the past decade, no industry has been more capital-starved than global coal. And yet, coal demand continues to confound skeptics by displaying unexpected strength. Coal-related equities literally “caught fire” in the third quarter. The S&P 1500 Coal & Consumable Fuel Index surged 55%, the best-performing commodity-related equity group. For those unencumbered by ESG pressures, we continue to recommend coal equity exposure. From through to peak, coal equities have been the best-performing sector in every commodity bull market since 1900. This pattern seems to be repeating itself. Since June 2020, coal equities have advanced almost 2000%, trouncing the 110% return of the S&P North American Natural Resource stock index, the 70% return of the S&P Global Natural Resources stock index, and the 46% return of the S&P 500.

FROM THROUGH TO PEAK, COAL EQUITIES HAVE BEEN THE BEST-PERFORMING SECTOR IN EVERY COMMODITY BULL MARKET SINCE 1900. THIS PATTERN SEEMS TO BE REPEATING ITSELF.

Uranium

Uranium advanced 25% during the third quarter, from \$56 to \$70 per pound. Changing psychology, geopolitical events, and tightening fundamentals combined to push prices to a 15-year high. Mounting worries over climate change and the considerable problems in renewable energy -- please read our Renewable section -- are shifting global attitudes towards nuclear power. Sweden just announced plans to build ten new reactors. “The climate transition requires a doubling of electricity production in the next twenty years, and nuclear power plays a decisive role for us to succeed in this,” said Sweden’s climate minister in August. Given Sweden’s focus on renewable energy, their renewed commitment to nuclear is notable.

A Wagner-backed coup in Niger, combined with a warning that Cameco faced mine issues and would reduce output by 8%, left fuel buyers anxious. Niger produces 5% of global uranium, and investors are now worried their supply will be diverted to Russia for processing and enrichment, stoking already elevated concerns around the security of supply.

Evidence suggests that quickly mobilized Fukushima inventories have finally been worked off. The opaque Fukushima stockpiles have long depressed prices. The Sprott Physical Uranium Trust raised almost \$60 million during the quarter but could only source 300,000 pounds of uranium -- \$15 million at the prevailing price. Sprott’s balance sheet now sports an elevated cash balance of \$60 mm, yet they have not been able to buy any physical volumes for a month. We believe this is because buyers have fully depleted the remaining Fukushima inventories.

In our last letter, we predicted how the next leg in the uranium rally would be “chaotic.” This is now unfolding. Uranium prices surged by 20% in September alone. We believe the uranium

bull market has only started, with years left to run.

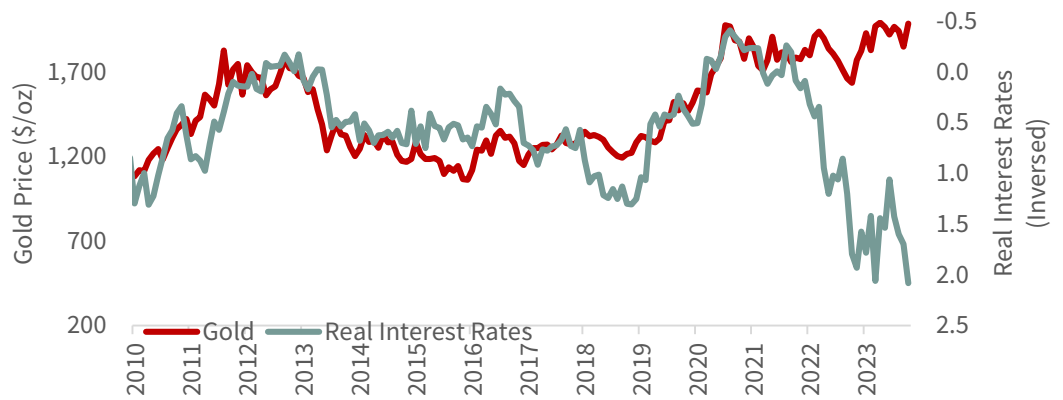
Gold

Both gold and silver pulled back during the third quarter. Gold and silver fell by 4% and 8%, respectively. Precious metals-related equities were also weak. Gold stocks, as measured by the GDX ETF, fell 11%, while silver stocks, as measured by the SIL ETF, fell 8%. Strength in the US dollar broadly put downward pressure on precious metals.

Since silver's furious catch-up rally in the summer of 2020 (a classic sell-signal), it has paid handsomely to avoid precious metals investments. Since August 2020, gold stocks have fallen over 30%, and silver stocks have fallen nearly 50%. Over the same period, a broad-based natural resource equity portfolio nearly doubled. A considerable divergence has emerged in gold, signaling that the two-and-a-half-year correction may be over.

Gold and real interest rates have historically moved in opposite directions. Typically, higher real rates have pushed Western investors to sell their gold, pushing prices much lower. Conversely, Western investors flocked to gold when real rates fell, increasing prices.

FIGURE 7 Gold and Real Interest Rates



Source: St. Louis Fed, Bloomberg.

Over the past eighteen months, this relationship has broken down. Gold has remained flat despite a surge in real interest rates, from sharply negative to sharply positive. Western investors, true to form, have become massive sellers. Over the past three years, the eighteen physical gold ETFs have shed 760 tonnes. The last time interest rates moved higher, between 2012 and 2016, the same ETFs shed 1,000 tonnes. However, in the past period, gold fell by 45%, whereas more recently, a comparable level of Western selling pushed prices lower by only 2% from the all-time high reached in the summer of 2020. What changed? Please read our Gold section to find out more.

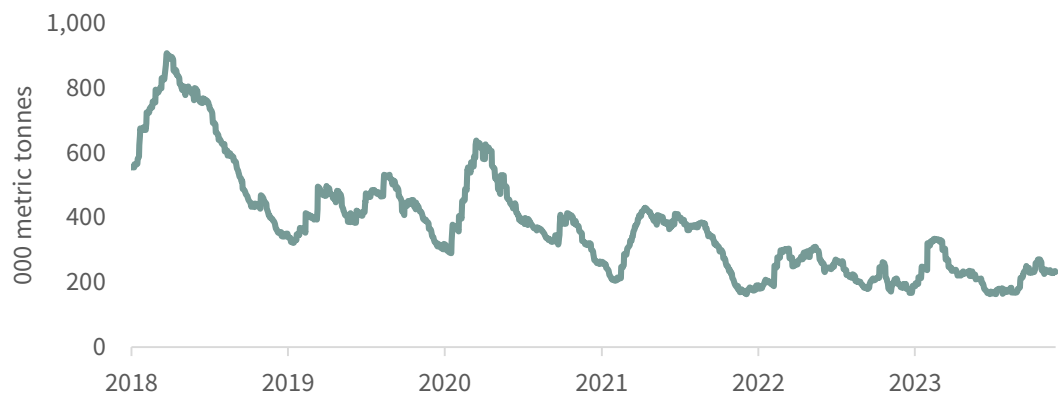
We were right to get out of precious metals investments following silver's sell-signal in the summer of 2020. While gold and silver continue to correct, we believe the pullback is nearly over.

Base Metals

Base metals were mixed during the quarter. Nickel and zinc prices were up more than 10% each, aluminum fell nearly 10%, and copper was flat. Although investors remain concerned about problems in the Chinese property sector, there has been little direct impact on the underlying base metals fundamentals. Quickly mobilized copper inventories in exchange warehouses rose after reaching near all-time lows earlier this summer but are still 70% below the 2018 highs.

Copper demand remains strong. According to the World Bureau of Metal Statistics (WBMS), demand surged over 6% year-on-year for the first eight months of 2023. Surprising to many, China is leading the rise. For the first eight months of 2023, year-over-year copper demand is up an incredible 11%. Although the consensus believes China's economic activity is weak, we do not see confirmation in the copper data.

FIGURE 8 Copper Exchange Inventories



Source: Bloomberg.

Indian consumption is also accelerating rapidly, advancing an incredible 30% year-on-year over the first eight months of 2023. We have often estimated that Indian consumption would surprise to the upside this decade. Based upon our modeling of emerging market economic growth and its relationship to a country's installed copper base, we conclude India is precisely where China was in 1999-2000, just before consumption exploded. Recent data confirms our analysis.

Global mine supply continues to disappoint, advancing only slightly year-on-year. Starting in 2016, we predicted the global copper mine supply would disappoint as we progressed through this decade, as significant new copper developments would not offset depletion, which is firmly embedded in older mines. Even with further expansions at Ivanhoe's Kamo-Kakula project in the DRC and the additional underground operations at Rio Tinto's Oyo Tolgoi in Mongolia, we do not expect the overall mine supply to grow materially over the next several years.

We remain bullish on copper over the next several years. However, we are concerned that our enthusiasm, first outlined in 2016 with copper only slightly above \$2.00, has become universally accepted.

Particularly worrisome is that some of the biggest commodity consulting firms that have sported abysmal track records in their various price predictions—have now all become universally bullish.

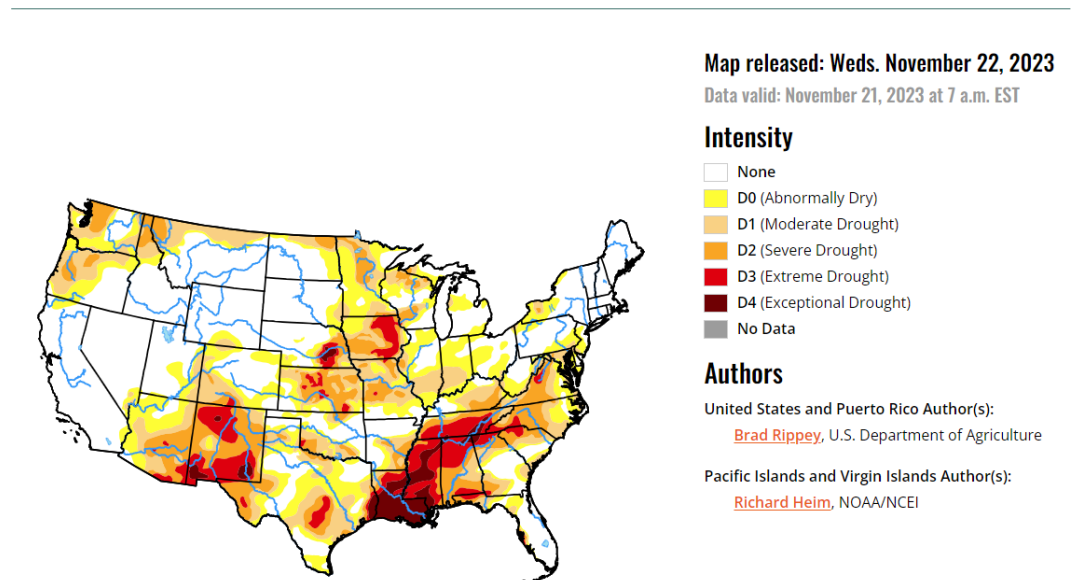
Several new technologies could change how the industry prospects for and produces copper. Could these new technologies spell the end of the bullish move? They are several years away, but their potential is real. Few analysts have incorporated these new technologies into their models, just like SX/EW copper took nearly everyone by surprise in the 1990s. Please read the Copper section to learn more.

Agriculture

Grain prices were weak in the third quarter as rain in the US Midwest eased further drought fears. Corn fell 14%, soybeans fell 15%, and wheat fell 18%. After pronounced weakness in the second quarter, fertilizers stabilized and rebounded in the third quarter. Urea (the solid form of nitrogen) and phosphate rose 32% and 19%, respectively, while potash prices were flat.

The 2023 North American growing season was dry across the Midwest, and corn and soybean yields have already seen significant weather-related impacts.

FIGURE 9 US Drought Monitor



Source: NOAA / NCEI.

The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC.

At the beginning of the planting season in May, the USDA's World Agricultural Supply and Demand Estimates (WASDE) report estimated that corn yields would reach 181.5 bushels per acre- significantly above 2021's record of 176.7. In the latest WASDE report, the USDA has reduced its corn yield estimate to 173 bushels per acre. Although the USDA vastly overestimated yields, they also underestimated acres planted. The May report estimated that farmers would only plant 92 million acres of corn and harvest 84 million. Instead, corn planted and harvested reached 95 mm and 87 mm, respectively. Total US corn production is now estimated at 15.06 bn bushels, only 1.3% lower than their original estimates. The USDA estimates that 2023-2024 corn ending stocks will reach 2.2 bn bushes, comfortably above the extremely low readings between 2020 and 2022.

Soybean yields were also revised lower. In the May report, the USDA estimated soybean planted and harvested acres would reach 87.5 mm and 86.7 mm, respectively, with yields reaching a record 52 bu/ac. Total US soybean production was expected to reach 4.5 bn bu, leaving ending stocks at 335 mm bu. By October, the USDA had revised planted and harvested acres down to 83.6 and 82.6 mm, respectively, with yields only reaching 49.6 bu/ac. Total soybean production was revised to 4.1 bn bu, with the estimated 2023-2024 ending stocks only reaching 220 mm bu. Although not yet approaching dangerous levels, when adjusted for consumption, days of inventory are now reaching levels last seen in 2003-2004 and 2011-2013 – two periods during which soy prices more than doubled.

With the US harvest now 75% complete, we expect little in the way of further revisions. Attention now shifts to the southern hemisphere. Although the ongoing severe drought in the Amazon River basin has garnered intense interest, few have commented on the impacts on northern Brazilian grain-growing regions. Since September 1, the heart of Brazil's grain region has experienced record heat, along with a severe lack of rainfall. The 30-day weather forecast predicts abnormal heat and dryness will continue through the end of November, which is unsuitable for the planting season.

While it is hot and dry in the north, Brazil is experiencing excessive flooding in the south, hampering its planting.

Brazil's problems are due to the current El Niño -- which has recently transitioned into El Niño Modoki, when warming equatorial Pacific Ocean water shifts from the Eastern Pacific to the Central Pacific. The strong El Niño Modoki explains the dry conditions in the northern and the west-central growing regions and is expected to last through the first half of the southern hemisphere growing season.

Brazil has become a significant grain producer over the past twenty years and now produces 60% more soybeans than the US. Its exports reached 100 mm tonnes, representing 60% of the total seaborne market and twice the US exports.

Brazil now ranks third in corn production, behind only the United States and China. Its corn exports total 50 mm tonnes, equal to the United States, representing 25% of all seaborne corn. While weather conditions could improve in Brazil, the strengthening El Niño Modoki suggests this is unlikely. Given the arid conditions persisting in the central United States, El Niño-related dryness in India and Southeast Asia, and the recent problems in Brazil, we believe the global agriculture crisis that began when Russia invaded Ukraine will continue.

Although controversial, we believe we are beginning to see the first adverse effects that will accompany the upcoming cooling cycle. As we have discussed extensively in previous letters—and a topic we discussed at length at our fall 2022 investor conference—we believe that one of the biggest beneficiaries of global warming over the last thirty years has been global agriculture—something accepted by few. Conversely, we believe the cooling cycle, now begun, will produce years and years of weather patterns extremely disruptive to global agriculture. Are we beginning to see those disruptive patterns emerging now? We think we are.

Please read the Agricultural section of the letter, where we discuss how these disruptive weather patterns now impact essential grain markets and how a new disruptive force, the financial player, will enter global agricultural markets.

The Green Mirage: Unmasking the Harsh Realities of Renewable Energy Investments

In late 2021, we made a bold and deeply contrarian call: we predicted massive capital flows into renewable energy could potentially become history's worst malinvestment ever. Our call looks correct three years later and the consequences have emerged with a vengeance.

Over the past six months, several notable wind and solar projects have been canceled, delayed, or impaired due to rising costs. Stocks that were once market favorites have now pulled back hugely. Wind turbine manufacturer Orsted is off 73% from its peak and 47% this year alone. Renewable provider Nextera is off 50% from its peak and 30% this year. Hydrogen maven Plug Power is off an incredible 95% from its peak and 68% this year. The Invesco Solar ETF is off 58% from its peak and 35% this year.

In recent months, Orsted has taken a \$4 bn write-off on its offshore US wind projects, canceled its Norwegian projects, and fired its CEO. In November, Siemens withdrew its wind turbine manufacturing plant in Portsmouth, Virginia. A September UK offshore wind concession auction failed to attract a single bid. Renewable proponents, who claim costs are lower than conventional energy sources, argued the relatively high 44 GBP tariff was insufficient to encourage wind development.

Two massive wind farm projects off the coast of New Jersey have been canceled. Two partially completed wind farm projects off the coast of Rhode Island and Massachusetts are now on hold as the developers wrestle with regulators on tariff structures, now made obsolete because of rapidly rising construction and installation costs.

As The Wall Street Journal published on November 12th, "The Path to Green Energy is Getting Messier."

In 2016, we asked ourselves an important question: what role should renewable energy play going forward? If one studies the history of energy, its production and consumption, new technologies with superior energy efficiency always displace old technologies with inferior energy efficiency. As the pundits argued, if wind and solar were ideal forms of energy with superior energy efficiencies, we would be forced to leave behind our oil and gas investments and embrace renewables, as renewables would ultimately displace all hydrocarbon-related energy production.

TWO MASSIVE WIND FARM PROJECTS OFF THE COAST OF NEW JERSEY HAVE BEEN CANCELED. TWO PARTIALLY COMPLETED WIND FARM PROJECTS OFF THE COAST OF RHODE ISLAND AND MASSACHUSETTS ARE NOW ON HOLD AS THE DEVELOPERS WRESTLE WITH REGULATORS ON TARIFF STRUCTURES, NOW MADE OBSOLETE BECAUSE OF RAPIDLY RISING CONSTRUCTION AND INSTALLATION COSTS.

WE WERE AMAZED THAT SO FEW ANALYSTS OR POLICYMAKERS HAD QUESTIONED THE ENERGETICS, OR EROI, OF WIND AND SOLAR AND SOUGHT THE ANSWERS OURSELVES.

As energy investors, it was imperative for us to develop a framework to judge renewables and their actual cost structures.

We have read excellent works by Professors Charles Hall and Vaclav Smil on energy efficiency or energetics. Professor Hall developed the energy return on investment concept, or EROI, which measures how much input energy is required to generate a unit of usable power output – the key energetic measure of efficiency. Professor Smil, a prolific author, writes captivantly about the history of energy advancement. We ultimately developed our lens through which to judge renewable energy. We also noted that a new energy technology had never replaced an incumbent without having superior energetics. We were amazed that so few analysts or policymakers had questioned the energetics, or EROI, of wind and solar and sought the answers ourselves.

Despite being heralded as the future, wind and solar have terrible EROIs. Compared with coal or natural gas, sunlight and wind are not energy-dense. Compare the energy from a gas stove with a stiff breeze or a sunny afternoon; they are different orders of magnitude. Since renewable energy density is so low, their size must be enormous to generate the same output. A modern windmill stands 80 stories tall with rotor blades that are 600 feet in diameter. A 100 MW solar installation, enough to power 20,000 households, requires a staggering 139 million square feet of PV solar panels. Large size means copious raw materials, which consume enormous energy. As a result, the energy required to generate output is very high, and the EROI is low. A combined cycle natural gas plant enjoys an EROI of 30:1, compared with the best wind and solar at 10:1 and 5:1, respectively. Unfortunately, wind and solar are intermittent and must be “buffered” by either building redundant capacity or through grid-scale battery backup, reducing their overall EROI further to as low as 3-5:1. Based upon our framework, wind and solar could never replace conventional energy given their inferior EROI.

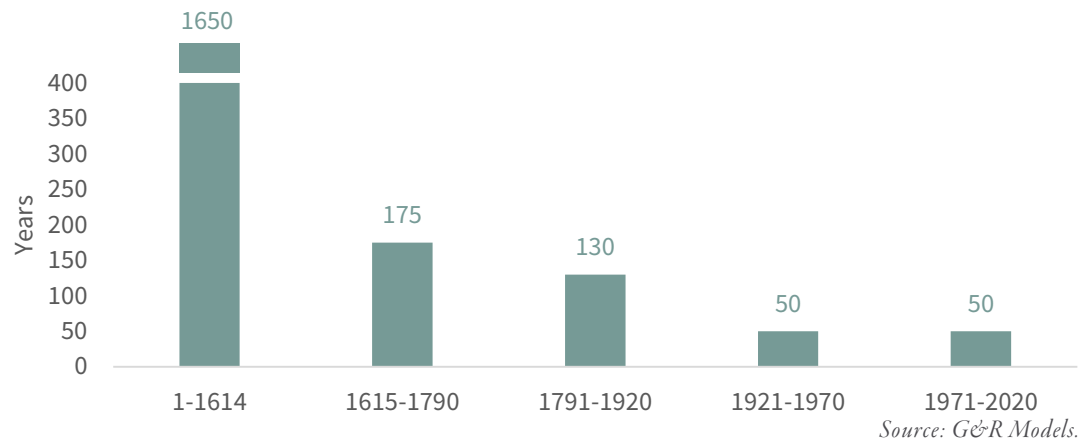
We recorded countless podcasts, including a 45-minute-long video entitled “History of Energy.” At the fall 2022 Grant’s Interest Rate conference, we also extensively presented why renewables would never be successful. Our presentation was entitled: “The Great Renewable Disaster: Inside the European Petrie Dish.” Readers who are also Grant’s Interest Rate subscribers, we recommend you listen to our presentation.

Our views were controversial. For most of history, society relied upon biofuels for energy: crops for food and fodder and wood for heat and construction materials. We estimated that such an energy economy had an EROI of 5:1. Given the low energy efficiency, economic growth was nearly impossible. We estimate it took sixteen centuries to double real per capita GDP, equating to an increase of 0.04% annually. The slow growth made sense when looking through the lens of energy. We estimate that energy consumption averaged 17 GJ per person yearly for most of human history. Given an EROI of 5:1, 3.5 GJ was spent generating energy. Food consumed 4 GJ per person annually, while other necessities, such as animal fodder and shelter, consumed 10 GJ per person. There was no surplus energy available, and with no surplus energy, economic growth proved impossible.

As London grew in the seventeenth century, it ran out of easily accessible wood and was forced to burn coal for heat. The improved energy efficiency was immediately apparent, and Britain’s EROI jumped to 10:1. The energy needed to make energy dropped, allowing for material surplus energy for the first time in human history. Surplus energy allowed for

economic growth; almost overnight, activity accelerated. After having taken sixteen centuries to double, real per capita GDP doubled again in 175 years, then 130 years, then 50 years, then 50 years again.

FIGURE 10 Years to Double Real Per Capita GDP



Coal gave way to oil and natural gas, each with ever-improving EROI. The result is today's modern world, in which developed economies consume 175 GJ of energy per capita annually – a ten-fold increase compared with the historical norm. Surplus energy, meanwhile, went from nil to nearly 150 GJ per capita annually – a seventy-fold improvement over the last 375 years.

Transitioning to wind and solar, with EROIs closer to biofuels than fossil fuels, would mean immediately lowering surplus energy by nearly 40% and returning to an energetic system incapable of delivering any real growth. We concluded this was not feasible.

While we focused on renewables' poor energetic efficiency, analysts were fixated on their falling costs. According to Bloomberg, solar costs have fallen 80% since 2010, from \$40 to \$7, while wind costs have fallen 40%, from \$9 to \$5 per MWh. The industry claimed that Moore's Law had crept into renewable energy. They claimed prices would continue to fall and eventually compete with conventional energy within a matter of years.

It seemed strange that costs could compete with natural gas combined cycle turbines if the underlying energy efficiency were so poor: undoubtedly, the better the EROI, the lower the cost. We built a model to help explain the dramatic fall of renewable expenses and found our answer.

The last decade was notable for meager energy costs and extremely low-interest rates. The rise of shale production, beginning in the early 2010s, pushed most energy prices lower by nearly 90%. Interest rates, meanwhile, reached the lowest level in history, with \$17 trillion of debt sporting negative nominal interest rates by 2019. Renewable energy is hugely energy and capital-intensive. Therefore, it is no surprise that costs fell drastically throughout the 2010s.

We concluded that between 50 and 70% of the fall in wind and solar energy's LCOE was attributable directly to lower capital and energy costs. We wrote:

If our models are correct and energy prices and capital costs rise going forward, the impact

on renewable energy will be dramatic. We calculate that solar costs could increase from 7 cents to 20 cents per kWh while wind costs could rise from 4.5 cents to 6.0 cents per kWh. Nearly a decade of cost savings would be wiped out in both cases.

Instead of falling to meet conventional energy requirements, we predicted renewable costs would rise – an incredibly contrarian view at the time. This is precisely what is happening today. While many articles cite rising interest rates and materials (a function of higher energy), they treat these cost pressures as temporary. We disagree. A decade of abundant energy and loose liquidity helped mask renewables' poor efficiency. That is now over.

In their latest, highly cited Levelized Cost of Energy report, the investment bank Lazard acknowledges the rising cost of renewables. According to their numbers, solar's average LCOE rose nearly 60% between 2021 and 2023, wiping out eight years of improvement. The high end of their solar range surged by an incredible 135% over the same period. For wind, the average cost rose 32%, with the high-end of the range advancing 50%, again wiping out eight years of improvement. Despite the unexpected cost increase, the pundits continue to get it wrong. In their recent report, Lazard sensitizes various forms of energy across a 25% fuel price adjustment; however, the analysis seems to capture only direct fuel usage. Gas, nuclear, and coal all increase, but solar and wind costs remain fixed. This is simply incorrect. As we have seen over the last two years, renewable costs are disproportionately impacted when energy prices rise due to their relatively inferior energy efficiency. Although they do not directly consume fuel, renewable energy consumes considerable "embedded" energy in all the steel, cement, and copper required.

Over the past nine years, the IEA estimates \$3.5 trillion was invested in wind and solar generation, all of which we believe should be categorized as malinvestment. This spending generated less than 3,500 TWh, a mere 12% of total electricity generation. In 2022 alone, nearly \$600 bn was spent to add 500 TWh. The capital intensity of last year's installation was almost 20% greater than the average over the previous nine years. So much for Moore's Law.

With deficits soaring and energy becoming more scarce and expensive, how much longer can we continue down the renewable path?

OVER THE PAST NINE YEARS, THE IEA ESTIMATES \$3.5 TRILLION WAS INVESTED IN WIND AND SOLAR GENERATION, ALL OF WHICH WE BELIEVE SHOULD BE CATEGORIZED AS MALINVESTMENT. THIS SPENDING GENERATED LESS THAN 3,500 TWH, A MERE 12% OF TOTAL ELECTRICITY GENERATION. IN 2022 ALONE, NEARLY \$600 BN WAS SPENT TO ADD 500 TWH. THE CAPITAL INTENSITY OF LAST YEAR'S INSTALLATION WAS ALMOST 20% GREATER THAN THE AVERAGE OVER THE PREVIOUS NINE YEARS. SO MUCH FOR MOORE'S LAW.

Uranium: New Market Star

In 2018, uranium assets were widely considered to be stranded assets. Following the 2011 Japanese earthquake and tsunami, utilities closed nearly one-third of all nuclear power reactors. At precisely the wrong time, Kazakhstan, responding to high prices between 2000 and 2010, brought on almost 20 mm lbs of low-cost in-situ uranium production. The market shifted into severe surplus, and prices collapsed nearly 90%, from \$140 to \$18 per pound between 2011 and 2018.

We wrote our first bullish essay in the fourth quarter of 2017, with spot uranium trading at a 14-year low. We explained how the price of uranium had reached unsustainable levels. What made us so sure? Only two primary uranium producers were left; spot prices had left significant amounts of their production below their cash operating cost.

Cameco, the Canadian producer, changed hands for \$9.00 per share, 25% below its tangible

book value. Nearly a third of this book value was in cash. JP Morgan announced Kazatomprom's IPO in November 2018. The deal was first offered at \$15 per share, but when demand failed to materialize, they downsized it and lowered the price to \$11.60. The stock immediately broke the deal price and fell to a low of \$8.50 on its second trading day. If uranium prices stayed below \$20 per pound, we argued, there would not be a uranium industry within a few years. No uranium producer could justify any reinvestment back into their businesses at such low prices.

Soon after we wrote, evidence emerged proving we were right: Cameco and Kazatomprom announced they would curtail production at their flagship operations. Although Cameco had long-term contracts struck at higher prices, they felt it was more prudent and cost-effective to purchase spot uranium to fulfill their obligations rather than produce out their excellent (and irreplaceable) McArthur River mine. Concurrent with Cameco's announcement, Kazatomprom, the world's largest uranium producer, announced they would curtail 20% of their high-cost production. Given such low prices, the industry could not survive—proof was handed to us.

Few investors thought uranium companies had any future whatsoever; even fewer predicted they would become some of the best-performing stocks in the market. Since the end of 2018, Cameco and Kazatomprom have advanced four-fold, compared with 77% for natural resource stocks broadly, 97% for the S&P 500, and 161% for the tech-heavy Nasdaq composite. Smaller uranium development companies have surged as well. On October 29th, 2023, Bloomberg led with the bold headline: "Hedge Funds Pile Into Uranium Stocks Poised for Dramatic Gains."

Shares outstanding of the Global X Uranium Miners ETF (URA) have exploded four-fold since late 2020. So, where do we go from here?

Although investors are no longer unanimously bearish, we believe the sector will outperform going forward. For the first time in history, uranium is in a large structural deficit, which will take years to correct.

As we outlined in our last letter, the market slipped into a steep primary deficit in 2020, at which point mine supply no longer covered reactor demand. However, investors remained completely unaware for another three years as secondary supplies from post-Fukushima commercial stockpiles filled the gap. Although the market is opaque, we believe utility buyers have completely worked off these stockpiles, revealing for the first time the structural deficit that has been developing for several years.

The Sprott Physical Uranium Trust, a Canadian closed-end vehicle that buys and holds physical uranium, has been able to source only small amounts in recent months, leaving it with \$60 mm of unwanted cash on its balance sheet.

In recent months, European utility buyers, who not long ago expected to decommission many of their reactors, have scrambled to secure uranium for replacement fuel rods now that these reactors' lives have been unexpectedly extended. They have found it challenging to secure physical volumes, which has helped push the spot price above \$80 per pound for the first time since 2008. US utilities, meanwhile, remain woefully under-contracted for the 2025-2028 period. Prices will likely move much higher when they finally return to the market. At this month's COP28 climate conference in Dubai, the United States will officially pledge

to triple world nuclear power capacity by 2050, from 400 GWe to 1.2 TWe. Uranium mine supply would need to grow four-fold from 125 mm lbs to over 500 mm lbs U₃O₈ annually to meet this projected demand. The United Kingdom, France, Sweden, Finland, South Korea, Ghana, Japan, Morocco, Poland, Romania, and the UAE are also expected to join the pledge.

Despite the favorable outlook, we find it helpful to consider what factors will eventually spell the end of the uranium bull market. Demand destruction is unlikely. Uranium demand is highly price-inelastic. Unlike in a coal or natural gas power plant, nuclear reactors are much more sensitive to capital costs, with fuel making up only 5% of total expenditures. Particularly once a reactor is running, the operator is willing to pay almost any price for the fuel necessary to keep it running. Furthermore, regulated utilities own most nuclear reactors and can pass fuel costs to rate-payers.

Instead, uranium will likely peak once high prices increase mine supply. In November, the Saskatchewan provincial government approved NextGen's Arrow deposit, the first approval in 30 years. We hold NextGen in our portfolios. Arrow is slated to commence production in 2028, although we believe the timeline is optimistic and will likely start later. Arrow is a world-class deposit slated to produce 20 mm lbs per year – large but not nearly enough to meet future demand. The US used to be the world's largest uranium producer, although it produces de minimis volumes today. In 1980, the US produced 40 mm pounds of uranium, and many of these former operations remain fully permitted and are being rehabilitated. The first in-situ project—UR Energy's Lost Creek, is scheduled to produce as soon as next year, although volumes will only be 2-3 mm lbs per year. Kazatomprom has announced it will increase production by 15 mm lbs next year, although we are skeptical. A potential sulfuric acid bottleneck could make reaching their goal impossible. We are trying to schedule a trip in 2024 to learn more and will report back. Adding to this supply, Paladin's Langer Heinrich mine, long shut because of low prices, is scheduled to restart in 2024 and will add 6 mm lbs to 2024 uranium supply.

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Although supply will ultimately undo the uranium rally, it will take years to ramp up, given years of chronic underinvestment in the industry. Prices will likely move much higher.

We leave you with a prediction. As US utility buyers realize that decades of ample secondary supply are gone, they will panic, scramble to secure volumes, and drive prices much higher. Eventually, they may be induced to approach the various financial vehicles, including the Sprott Physical Uranium Trust, to seek the uranium they need. Ultimately, they might be forced to pay large premiums to spot prices to secure long-term supply. We believe this will likely mark the top of the uranium bull market. This could be many years away; until then, we believe the uranium price rally will persist.

The Great Convergence: North American Natural Gas and the Looming Shift in Global Energy Economics

North American natural gas is the cheapest energy molecule on the planet by as much as 75%. Over the next twelve months, we believe this discount could close entirely, boosting US gas prices as much as four-fold. As we go to print, Henry Hub gas costs \$3.00 per mcf

while European and Asian gas is \$14 and \$16.50 respectively. One barrel of oil contains between six and eight mmbtu, so dividing oil by the midpoint of seven generates its energy-equivalent price of \$10 per mcf.

FIGURE 11 Henry Hub Discount to WTI Oil on Energy Equivalent Basis



Source: Bloomberg.

Today’s discount is nothing new; North American gas has traded 60-80% below world prices for nearly a decade with good reason. The shale

gas revolution tilted the North American natural gas market in structural surplus. Since 2005, the US gas supply doubled from 54 to 104 bcf/d. Conventional production fell by 56% from 50 to 22 bcf/d, while shale production ramped to over 80 bcf/d – or 80% of total supply. The United States would have faced an acute gas shortage without the shales as conventional natural gas production had declined steeply. Instead, surging shale gas production produced a prolonged (and huge) disconnect to world prices. However, our models tell us that the shales are likely plateauing and the discount to world prices will narrow quickly and most likely disappear.

Cheap US gas has caused demand to surge. Gas-fired electricity generation increased by 127% from 14 to 33 bcf/d, while industrial use increased by 20% or three bcf/d. Most notably, the United States went from being one of the world’s largest gas net importer, at two bcf/d per day, to the largest net exporter, at 12 bcf/d per day – a swing of 14 bcf/d. Despite the surge in new demand, shale supply continued to outpace consumption and the market remained stuck in a structural surplus. Between 2005 and 2023, rolling twelve-month US natural gas inventories (to adjust for seasonality) increased by 50% from 2 tcf to 3 tcf.

Given such strong demand, if shale production ever faltered, the discount between US and world prices would close quickly, what we call convergence. Our models suggest the North American gas market will switch from structural surplus to structural deficit in six months. The results would be profound. The US consumes 90 bcf/d domestically; a move from \$3 to \$10-12 would cost US industry and consumers a combined \$350 bn, or 1% of GDP.

We first outlined our convergence thesis in late 2021. However, an extremely warm winter in the United States and Europe and a fire that rendered the Freeport LNG export facility inoperative pushed the trade out by a year. We argued that the Marcellus, Haynesville, and associated gas from the Permian were all set to plateau and roll over. These three basins accounted for an incredible 58 bcf/d of growth since 2005; US production would have

declined without them. However, despite their vast size and robust growth, they are not immune from the geological realities of depletion and field exhaustion. Immense is not the same as infinite, we like to say, and eventually, their production will decline.

The first two shale gas plays to be developed, the Barnett in Texas and Fayetteville in Arkansas, caught everyone off guard when their growth slowed, flattened, and rolled over. In December 2009, Exxon agreed to buy XTO Energy, a premiere Barnett producer, for nearly \$40 bn. Before the recent announcement to purchase Pioneer Natural Resources, XTO was Exxon's most significant transaction since buying Mobil in 1999. Exxon paid four times XTO's PV-10 value plus debt, suggesting Exxon felt they could markedly grow reserves and production in the Barnett. Instead, Barnett production rolled over twenty months later, and today, it stands 65% below its November 2011 peak. Exxon has now written off half the value of its XTO purchase price.

What lessons can be learned from the Barnett and Fayetteville? We used our shale neural network to uncover hidden indicators, suggesting when production might plateau and decline. The neural network estimates the ultimate recovery of a well given the subsurface geology and well design. By tallying what had been produced and what remained to be developed, we evaluated the recovery for the entire basin. We estimated that Barnett and Fayetteville had reserves of 23 and 10 tcf, respectively. Notably, production in both fields plateaued once half their reserves had been produced – twelve tcf for the Barnett and five tcf for the Fayetteville.

The neural network predicts the Marcellus will eventually produce 135 tcf – one of the largest gas fields in history. The field has made 79 tcf to date, or nearly 60%. According to our models, Marcellus produced 50% of its recoverable reserves in May 2022; on schedule, production flattened. From December 2021 to June 2023, Marcellus dry gas production declined by nearly one bcf/d – the first time the field fell over eighteen months. Although preliminary data indicates a slight recovery in July and August, we believe it will prove temporary. While some analysts believe the pause in Marcellus growth is a function of pipeline bottlenecks, we disagree. If it were an infrastructure issue, we would not expect any impact on productivity. If top-tier drilling inventory depletion were to blame, productivity would fall. According to the EIA, per-well productivity in the Marcellus has slowed dramatically since peaking in 2021, which is confirmed by what our neural network tells us. We strongly believe top-tier drilling inventory depletion is the culprit.

Our neural network predicts that Haynesville will recover 73 tcf, of which 36 tcf, or 50%, have been produced. The field has exhibited strong growth in recent years, but we believe this will now moderate going forward. In fact, over the short term, declines are almost guaranteed. The basin is deep and highly over-pressured, meaning wells are expensive to drill and complete. As prices pulled back, producers curtailed development, laying down 40% of the rigs in the basin this year. With 45 rigs turning today, production is almost sure to fall. Most analysts believe growth will resume once prices advance. Our neural network tells us that 2022-2023 will be the production peak for the field.

Meanwhile, the Permian basin is suffering depletion problems of its own. We discuss the field in greater depth in the Oil section, but in summary, we do not expect it to be a significant growth driver in the future.

Supply issues are now in place and enough for convergence to occur. However, demand

factors make convergence a near certainty in 2024. Six additional bcf/d of LNG export capacity are scheduled for operation in late 2024 and 2025. After years of surging supply, few are worried about where the gas will be sourced. Our models tell us that there is no way production can grow to meet this additional export demand. Driven by supply and demand trends, North American natural gas is about to enter a structural deficit for the first time in 20 years.

If we are right, we would not be surprised if President Biden issued an executive order limiting exports to lower the natural gas price. If exports were limited, it would have a knock-on effect on Europe, which has come to rely on safe, secure US LNG to offset lost Russian volumes.

North American inventories have repaired much of the surplus accumulated after winter's mild weather. Stocks peaked at 300 bcf above ten-year averages in May and have been declining since, presently standing at only 100 bcf above average. Unfortunately, weather is always a wild card with natural gas. Another mild winter will forestall (but not prevent) convergence. If weather is seasonable, we expect inventories will end the withdrawal season in a mild deficit to seasonal averages, making it very difficult to replenish stocks to a level that can accommodate the new LNG demand.

Natural gas equities have some of the best return potential in the resources universe. Range Resources – our most significant gas holding – trades at \$33. Its debt-adjusted SEC PV-10 per share from the 2022 10-K is \$94 – or three times the stock price. Critics will argue that last year's 10-K reflected \$6 gas – twice today's price. This is true; however, using the depressed spot prices, Range still represents a modest upside. If natural gas converged with world prices, and Range was able to realize \$10 per mcf, its PV-10 would be \$182 – five times today's stock price.

We have been early with our convergence call; however, we are confident that convergence will occur in 2024. Most fundamentals, including stagnating Marcellus production and Haynesville production, have progressed exactly as we predicted. Our timing error was mainly due to last winter's mild temperatures. Investors are getting a second opportunity to put this trade on—we believe the rewards versus the risks are hugely positive.

Rising Rates and Robust Gold Demand?

Real interest rates and gold have always moved in opposite directions. When real interest rates rise, gold falls, and when real rates fall, gold rises.

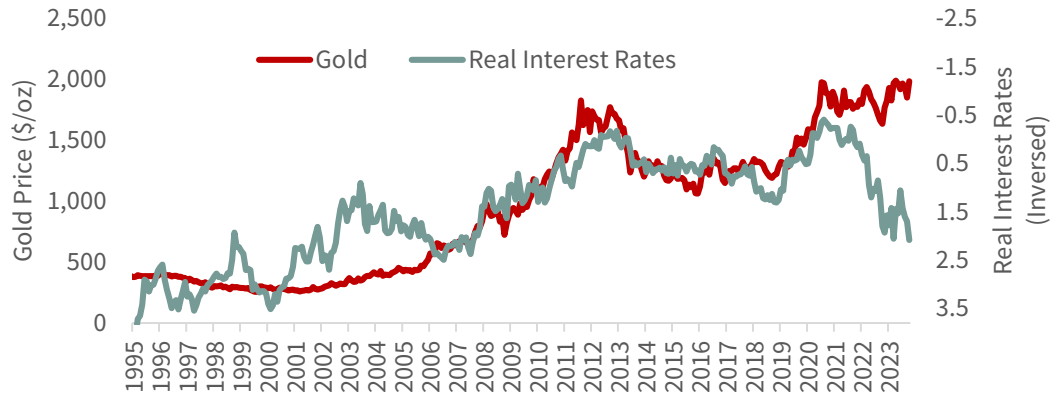
Over the last three years, this relationship broke down. Real interest rates bottomed at -2.3% in the summer of 2021 and surged to +2.9% by late 2023 – the highest rate in twenty-five years. Given the record surge in real rates, gold should have suffered a punishing bear market. Instead, gold is only 2% below its 2020 peak despite a 400 bps rise in real rates.

What does this divergence signal?

Western investors are behaving as they have in the past rising real rate cycles: they are selling gold. We track eighteen physical gold ETFs, and the relationship between real rates and

gold accumulation is clear. The last time real interest rates rose was between 2012 and 2016, during which period Western investors liquidated over 1,000 tonnes from the physical ETFs, causing gold to fall 45%. Since the summer of 2020, real rates have again surged, and Western investors have predictably shed 760 tonnes of gold. Somehow, gold remains near its all-time high.

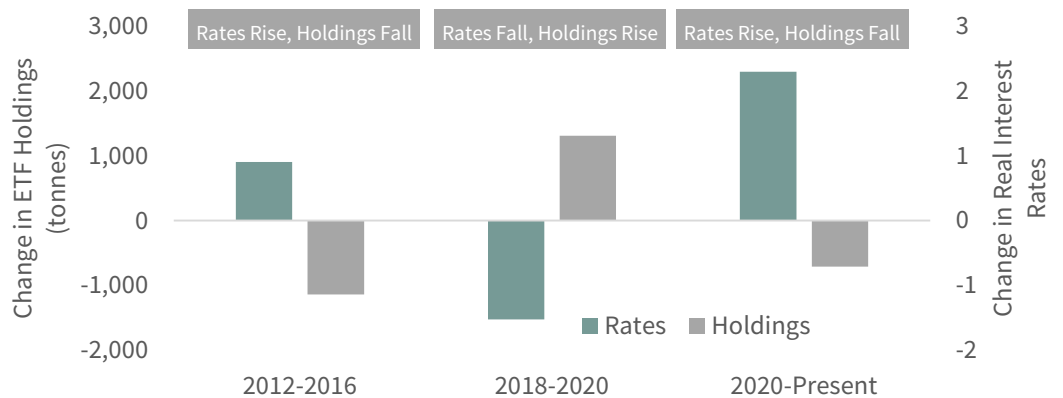
FIGURE 12 Real Interest Rates & Gold



Source: St. Louis Fed, Bloomberg.

The difference is central banks. Over the last several years, central banks have gone on a massive gold-buying spree. Last year, central banks accumulated 1,136 tonnes – a record as far back as our dataset goes. This year, they have continued to accumulate. For the first nine months of 2023, the World Gold Council (WGC) reports central banks purchased an additional 800 tonnes of gold, with 337 tonnes coming in the third quarter alone. Year-to-date, central bank gold purchases are up 14% compared to last year. China remained the most significant gold buyer, purchasing 78 tonnes in the third quarter. For the first nine months of 2023, the PBOC bought a massive 181 tonnes.

FIGURE 13 ETF Holdings & Real Rates



Source: St. Louis Fed, Bloomberg.

We believe strong central bank buying will continue. We commented on the relationship between radical commodity price under-valuations and monetary regime changes in past letters. Please refer to our 1Q23 essay, “The US Reserve Currency & Commodities,” for an

in-depth discussion. The last three periods of radical commodity undervaluation (late 1920s, late 1960s, and late 1990s) saw a significant change in the global monetary regime.

In 1930, Britain left the classical gold standard, which had been in place for almost 200 years. The shock caused the US to devalue the dollar by 60% in 1933 and later default by eliminating the gold convertibility clause embedded in all Treasury debt. In 1968, President Johnson removed the requirement that gold back 25% of each US dollar. By 1971, President Nixon closed the US gold window and ended the Bretton Wood's gold exchange regime entirely. The era of exchanging currencies into gold was over, and commodity prices spent the next decade soaring.

The 1997 Asian currency crisis ended the pegging of major Asian currencies to the US dollar. After their currencies collapsed, these countries (most conspicuously China) suppressed their exchange rates, turning current account deficits into substantial current account surpluses, ultimately leading to the great housing price bubble and the Global Financial Crisis.

Although few historians have documented the relationship between commodity bear markets and monetary regime shifts, we believe low commodity prices ultimately lead to changes in the global monetary order.

The 1920s experienced a considerable commodity bear market—prices from 1920 to 1930 fell by 70%. The result was a decade of deflation, particularly in agricultural commodities.

The lack of inflationary pressure allowed the Federal Reserve to experiment with the first attempts at what today we would call quantitative easing. First, in 1924 and again in 1927, the Fed lowered rates despite strong domestic economic growth to help support Britain's attempt to go back on gold at the pre-World War I rate.

Excessive US monetary growth destabilized the financial system, resulting in the 1929 stock market crash, a global banking crisis, and, ultimately, the Great Depression.

Throughout the 1960s, commodities (especially oil) drifted lower, again becoming radically undervalued. Like in the 1920s, the lack of inflation allowed the US to run simultaneous monetary and fiscal expansions to fund the Vietnam War and President Johnson's "Great Society" program. Expansionary monetary and fiscal policies again produced massive distortions. US dollar holdings by foreign countries soared, and equity markets exploded in a prolonged period of significant speculation. The result was the collapse of the Bretton Woods Gold Exchange Standard, once the US could no longer honor its commitment to exchange US dollars gold at the \$35 per ounce rate.

Finally, in the 1990s, a severe commodity bear market allowed the US to put the "Green-span Put" in place. The Federal Reserve could meet every consecutive financial crisis with low interest rates and money printing, with minimal inflationary impact. Loose monetary policy again resulted in massive financial speculation, the eventual collapse of the Long-Term Capital Management hedge fund, the Asian currency crisis, Russia's default, and, ultimately, the dot-com bubble's collapse.

Our research tells us the necessary conditions for a monetary regime change are back in place. The huge bear market in the commodities last decade allowed the Fed to experiment with three periods of quantitative easing, resulting in an unprecedented six-fold increase in

its balance sheet, with minimal inflationary pressure.

However, with global tensions now straining a financial system already severely distorted by zero interest rates and the return of persistent inflation, we believe a monetary regime change is imminent.

The big question is what will emerge to replace today's fiat floating-exchange rate US dollar reserve currency system.

We believe a new monetary system will emerge in which countries can trade bilaterally in currencies other than the US dollar, settling their current account imbalances using gold.

Brazil has already agreed to settle its Chinese soybean and iron sales in renminbi, while Saudi Arabia is also considering settling its Chinese oil sales in renminbi. Total Energies has agreed to sell LNG to China, settled in renminbi.

China's closed capital account makes it impossible to repatriate excess renminbi. However, if current account imbalances were settled by selling renminbi for gold at the Shanghai International Gold Exchange, then imbalances could be settled entirely outside China's closed capital account.

China's ultimate goal is to weaken the reserve currency status of the US dollar. Given its closed capital account, this goal is nearly impossible. However, if renminbi imbalances were settled in a liquid, easily convertible asset class, like gold, then China would be on its way to weakening the grip of the US dollar as a global reserve currency.

After decades of excessive monetary growth and globalization, trade imbalances now dwarf the size of the global gold market. If a new monetary system emerged in which gold was used to settle trade imbalances, central banks would have to continue accumulating gold, driving prices higher.

Although real interest rates continue to inch higher, and Westerners continue to sell gold, all this selling is being met by Central Bank purchasing. Once Western investors stop selling gold and begin accumulating, their buying will quickly bump up against Central Bank demand.

FIGURE 14 GDX Performance



Source: Bloomberg.

The next leg of the gold bull market will begin at that moment. We are getting closer and closer, and we continue recommending investors maintain significant precious metals

exposure. Physical gold has significantly outperformed precious metals equities, as Western investors have been selling both physical and equities.

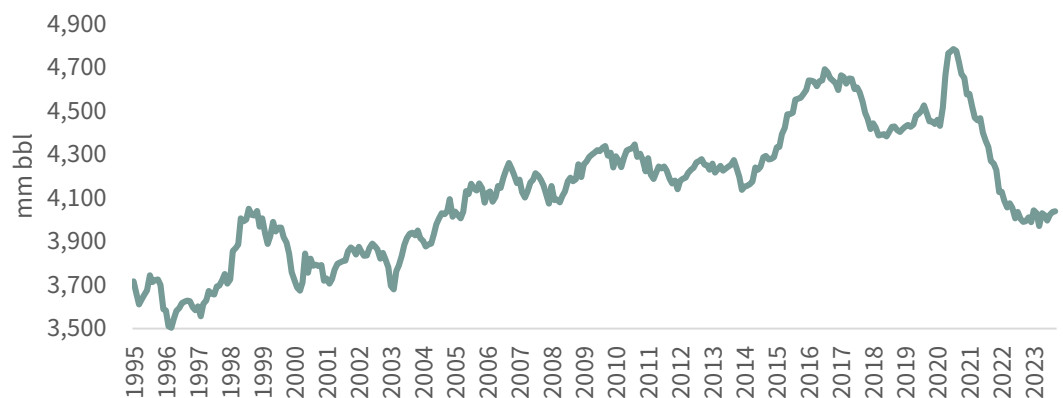
Gold stocks (as measured by the GDX ETF) are down almost 30% from the 2020 peaks. Silver stocks, as measured by the SIL ETF, have pulled back even more—they have now pulled back 40%, and both represent excellent value.

Oil: From Uninvestible to Must Own

There are notable similarities between the uranium market twelve months ago and today's oil market. Almost overnight, uranium went from uninvestible to must own, and we believe oil is about to do the same. Uranium slipped into structural deficit for the first time in its history; however, a temporary secondary supply source obscured the shortage. Crude oil, too, has fallen into a structural deficit for the first time ever. Throughout the two oil crises of the 1970s, OPEC maintained ample spare capacity. Similarly, during the bull market from 1999 to 2008, the market was temporarily tight but never in structural deficit.

With uranium, a sizeable commercial stockpile accumulated following the 2011 Japanese earthquake and tsunami hid the reality that reactor demand exceeded mine supply beginning in 2019. Earlier this year, the buffer was exhausted, the latent tightness became apparent and prices surged. Crude demand exceeded production as early as 2021; however, massive releases from government strategic reserves masked the deficit throughout 2022 and the first half of 2023. Over that period, global SPRs released nearly 300 mm bbl, equating to a massive 500,000 b/d – the most significant release in history. The US stopped releasing its SPR in the last week of June, and oil rallied from \$67 to \$90 per barrel. Although it has recently pulled back to \$75, we believe it is a temporary correction in an otherwise strong bull market.

FIGURE 15 OECD Petroleum Inventories



Source: IEA.

Adjusting for SPR releases, inventories have fallen by 800 mm bbl over the last three years – or by 750,000 b/d, representing the sharpest decline in oil market history.

Several news outlets declared oil assets worthless less than two years ago. EV demand suppos-

edly meant peak demand was imminent, while potential forthcoming environmental liabilities left valuations worthless. Analysts often spoke of “stranded assets.” The IEA pronounced energy companies must not invest one more dollar in hydrocarbon assets. In our 3Q20 essay, “Investing in the Uninvestible,” we pushed back, predicting that oil assets would soon be the “must-own” asset class of the decade. Today, our prediction is starting to happen everywhere except in the public equities. We believe this mispricing creates current investment opportunities.

Mineral and royalty ownership is a distinctly American phenomenon. In the United States, individuals can privately own the mineral rights underlying the surface real estate. In most countries, mineral rights are owned by the government. When oil companies drill for oil or gas, they lease the subsurface mineral rights in exchange for an upfront payment and an ongoing royalty (typically 1/8th of all production). The operator has a period to drill a well, after which the royalty exists so long as the well remains in production. Over time, surface and mineral rights are often separated and can change hands repeatedly. The robust, albeit often inefficient, mineral and royalty market is dominated by oil veterans. Royalty interests, in general, have appreciated dramatically. While prime Permian acreage could be had for \$5,000 per net royalty acre a few years ago, the average price has since surged to closer to \$25-30,000. What was once uninvestible has quickly become must own.

Oil corporate buyers have also changed their tune. In recent weeks, Exxon announced it will purchase Pioneer Natural Resources (our largest oil holding). Chevron will buy Hess, with both transactions totaling \$120 bn – the most significant period of industry consolidation in memory.

What do the royalty buyers and corporate oil executives know that the public market is missing? Perhaps that prime undrilled acreage is quickly running out. Pioneer holds, by far, the best undeveloped Permian acreage, according to our neural network. While most companies have, at best, three to five years of Tier 1 drilling inventory, Pioneer’s has nearly doubled. We have always believed that Pioneer would eventually be acquired for its irreplaceable acreage position. Chevron’s motivation for buying Hess has more to do with offshore potential in Guyana. We have long argued that offshore assets would see a development boom as the absence of high-quality shale potential became apparent and have held approximately 10% of our portfolio in offshore-related names.

We believe these transactions signal an essential shift in the oil industry. First, only a few years ago, Engine Number 1 would have blocked Exxon from making any hydrocarbon-focused acquisition. Despite owning a mere 0.03% of the common stock, the climate-activist investor gained three Exxon board seats after several firms representing vast amounts of passive index ETF capital backed the effort. No longer. While Engine Number 1 retains its three board seats, something in the board room psychology has changed. Second, the acquisition attests to just how little undrilled acreage remains. In 2017, Exxon famously purchased the Bass brothers’ nearly 300,000 acreage position in the Permian for \$6.6 billion. At the time, it was thought Exxon would boost production to 2 mm b/d within a few years. Chevron, similarly, acquired a vast non-operated acreage position in the Permian, hoping to increase production. Six years on, neither transaction worked out as planned, leaving both companies needing multi-billion dollar acquisitions to help offset declines in their legacy assets.

We believe the difference between Tier 1 and Tier 2 locations was underappreciated in both instances.

Our neural network has informed our views on shale production for several years. We became acutely aware of the importance of high-quality shale acreage and dwindling supply of undrilled locations. In 2018, the industry was busy telling investors it had improved at drilling shale wells. While productivity per well had surged between 2015 and 2017, our neural network told us the improvement was primarily driven by where companies were drilling wells (high-grading their Tier 1 prospects) and less by advances in their drilling and completion techniques. The industry was not turning Tier 2 into Tier 1 – as widely claimed – but instead was hollowing out the best Tier 1 areas. We concluded the Bakken and Eagle Ford had produced half of their reserves and were at risk of plateauing, while the Permian had several years of growth ahead, albeit at slower rates.

All three major shale oil basins declined during COVID-19 as oil prices turned negative. Just as we predicted, the Bakken and Eagle Ford have been unable to regain their previous highs. Aside from the Permian, production in all of the shales has now fallen by nearly 1 mm b/d or 25% from the pre-COVID high.

The Permian has made a new all-time high (just as we predicted); however, this is starting to slow dramatically. According to the Energy Information Agency (EIA), the Permian has only grown by 17,000 b/d over the last six months, 90% below its long-term average six-month growth rate of 250,000 b/d. We now calculate the Permian has also produced half of its reserves and expect sequential growth to turn negative within the next few months. With a growing degree of confidence, we expect 2024 will be the peak in Permian production. Over the last fifteen years, the US shales have represented all non-OPEC growth. In the previous five years, the Permian has dominated US shales. If correct, we are entering an unprecedented period of tightness in global oil markets.

There is a remarkable parallel between Exxon's purchase of Pioneer and XTO Energy in 2009. Exxon purchased XTO for its best-in-class Barnett acreage – the most productive shale gas basin. Despite their best due diligence, the Barnett peaked less than eighteen months after the acquisition and has since fallen by 65%. We believe they are purchasing Pioneer at a similar moment – within months of the Permian peaking. However, in one notable way, the Pioneer acquisition could not be more different than XTO. Exxon acquired XTO during a strong energy bull market. Energy shares represented nearly 15% of the S&P 500; commodities were as expensive relative to financial assets as in decades. As a result, Exxon had to pay nearly four times XTO's SEC PV-10 value (a standard measure of discounted future cash flows that every energy company has to publish in its 10K). Today, we are near the bottom of a grinding energy bear market. Instead of 15%, energy stocks make up less than 5% of the S&P 500. Compared with financial assets, commodities are as cheap as ever. In today's market, Exxon had to pay less than 1.7x Pioneer's SEC PV-10. At the top of the cycle, a marquee transaction was more than twice as expensive as it is today. As a result, while we believe the Permian will underperform Exxon's expectations, much like the Barnett 15 years ago, they are unlikely to require a \$20 bn impairment as they did with XTO.

True industry insiders are all telling you to buy oil assets. The public market remains paralyzed with fear. Investing in the uninvestible requires a contrarian outlook and a strong stomach. However, we believe the benefits are well worth the risk.

Copper Technological Trends Loom

We have just returned from a week of traveling in Asia, and every investor wanted to discuss copper. The overall opinion was nearly unanimous: over the short term, investors are deeply concerned about a recession; over the long term, they are consistently bullish. We have the opposite view: we are incredibly bullish over the short term but are becoming more concerned over the long term as new technologies risk bringing on additional supplies.

We first turned bullish in early 2016, when copper was \$2.00 per pound, and every investor worried about a persistent surplus. Our models suggested demand would accelerate, driven by continued consumption in China and India, along with new demand from copper-laden renewable energy. We were the first to call copper the quintessential green metal in our 2Q16 letter -- a wildly contrarian view at the time. At the same time, as demand was set to accelerate, we worried that mine supply would stagnate. Although several new mines had just come online in 2014 and 2015, our models suggested depletion had firmly taken hold in global copper mine supply. For several years, the average processed grade of existing copper mines had steadily fallen – a classic sign of depletion. Extrapolating these trends into the future, new mine supply seemed unlikely to offset depletion, resulting in limited overall production growth. S&P Global published a wildly bullish essay in 2022, entitled “The Future of Copper,” echoing many of these same arguments. Seven years after we wrote our analysis, our once widely contrarian views are now commonplace.

Where to go from here? Our 1Q and 2Q2023 letters explained how we had become concerned that so many people agreed. Since then, we believe much of the enthusiasm and investor interest surrounding copper has cooled. Since the end of March, copper has fallen by 10%, while copper stocks are down by 12%. Many investors remain bullish in the long-term but are pessimistic about copper’s prospects over the next several months, owing to fears about a recession and a Chinese slowdown.

We disagree. In the near term, we believe copper fundamentals remain incredibly favorable. Despite worries about a slowdown, Chinese demand is up 12% year-on-year for the first nine months of 2023. Indian demand has accelerated sharply and is now up 36% over the same period. Mine supply, meanwhile, remains challenged. Disruptions in Chile have been complicated by Panama’s recent decision to revoke First Quantum’s operational contract for its massive Cobre Panama mine, representing 350,000 tonnes per annum or nearly 2% of world supply. Even with Kamoakakula phase II and Olu Tolgoi underground set to come online, we expect global mine supply will be muted. Easily mobilized inventories are dangerously low. On a days-of-cover basis, inventories are now at 3 days – a level historically associated with sizeable near-term price spikes. Several outlets have recently reported a surge in the copper contango, suggesting this may be a sign of oversupply. This analysis is incorrect. A commodity’s contango is a function of interest rates, storage, and borrowing costs. Common wisdom dictates that when a commodity is in oversupply, storage costs increase and borrowing costs decrease, steepening the contango. However, with copper presently, most of the steepening results from rising interest rates. With rates having increased 500 bps over the last two years, it is only natural the contango has steepened. We do not believe this is a sign of over-supply.

While investors are concerned about the near term, they are extremely bullish in the longer term. We remain more cautious. In recent weeks, we have spent time visiting and speaking

with several new technology companies that could usher in vast new, unexpected sources of mine supply over the next several years. Given how little mining technologies have advanced in recent decades, such advancements would be most overdue.

Compared with the oil industry, the mining industry has seen remarkably little technological progress in recent decades. That is about to change. The differences are staggering. In the oil industry, specially equipped ocean vessels shoot seismic surveys in 10,000 feet of water that penetrate another 20,000 feet below the seabed floor. These seismic surveys contain enough resolution to distinguish between sandstones, carbonates, and salt domes -- a notorious reflector of seismic signals once considered impenetrable.

On the other hand, a hard-rock exploration geologist transported from the nineteenth century would be mostly familiar with modern exploration. Geologists roam the Earth, looking for examples of altered outcrops. When a particular rock looks dissimilar from its surroundings, the geologist eagerly chips off a sample with his hammer and heads back to camp for testing. If the sample registers anomalous copper grades, the team digs a trench, takes more samples, and finally (maybe) drills a hole to test the hypothesis.

Induced polarization was introduced in the 1990s to aid in discovering large, widely disseminated copper porphyry deposits. An electromagnetic charge is run through the subsurface and collected through sensors. The IP charge is distorted when it hits sulfide-bearing mineralization, and by studying the results, a team of geologists can estimate the likely presence of a copper porphyry. By the middle 2000s, 70% of all copper mine supply came from porphyry deposits, most of which were discovered with induced polarization. Unfortunately, IP can only penetrate a few hundred meters below the surface before its signal becomes so severely distorted as to be unreliable. Unsurprisingly, most copper porphyries sit within 200 m of the surface. Any deeper deposits have been found by luck, usually when a skarn comes to the surface, allowing the geologists to chase it down to the porphyry below.

We believe that is about to change. Robert Friedland, the mining magnate behind three of the most important deposits in the last century, and his team at iPulse have spent the past 25 years developing Typhoon. We visited their laboratory in Toulouse, France, in October. Typhoon uses ultracapacitors and semiconductors to release a massive pulse of electricity over an extremely short period. The device emits the same current as a nuclear power plant, albeit for a billionth of a second. The massive pulse creates a huge electromagnetic signal, similar to an induced polarization survey. However, unlike IP, Typhoon can penetrate thousands of meters below the surface with extremely high resolution. For the first time in history, exploration geologists can see to depths never before imagined.

A precursor to Typhoon, known as Zeus, made the world-class Hugo North discovery at Oyu Tolgoi in Mongolia, now operated by Rio Tinto. Typhoon has been licensed exclusively to Ivanhoe Electric, our largest copper position, and another Friedland company, and their results to date have been impressive. Typhoon helped discover Arizona's billion-tonne Santa Cruz deposit – an area that has been extensively prospected and mined for over a century. Typhoon also helped discover Tintic in Utah and expand Hog Heaven in Montana – two other historic mining areas long thought to have been thoroughly picked over. How many other porphyry deposits lay hidden just beyond the reach of conventional IP?

Ivanhoe Electric was awarded a concession to explore 48,500 km² in Saudi Arabia – the world's most prospective new copper region. Saudi sits at the intersection of two prominent

copper trends: the Tethyan Belt, which is responsible for every major copper deposit in Europe, and the eastern extension of the Nubian Shield, which is responsible for the significant deposits along Africa's eastern coast. The country has an extensive structure, critical for mineral formation, but is primarily covered by sand, rendering conventional prospecting difficult. We visited Saudi in January 2022 and were taken by its exploration potential. The Kingdom only recently opened the country up for exploration, and Ivanhoe Electric was awarded the first major concession, mainly because of its exploration technology. A large-scale Typhoon survey is scheduled for early 2024.

Several new technologies could change mineral processing as well. Copper deposits come in two major forms: sulfide and oxide ores. All copper deposits start as sulfide ores, but a small percentage are oxidized when rainwater percolates through the ground and oxidizes the sulfide ore. Mill operators liberate the sulfide copper by crushing and grinding the rock into a fine powder and using chemical reagents to separate and isolate the copper. For years, oxide deposits were undeveloped until the industry introduced a new technology known as heap leaching and solvent extraction electrowinning (SX/EW) in the early 1990s. The oxide ore was placed on a large, lined pad and sprayed with acid, leaching the copper from the waste. Metallurgists treated the so-called pregnant solution electrochemically to produce a pure copper cathode.

Every sulfide deposit has an economic cut-off grade that determines whether crushing and processing the rock is worthwhile. Operators place ore below the cut-off grade in a low-grade stockpile heap. Crushers, SAG, and ball mills are both capital and operationally expensive, so the choice of cut-off grade is critical in determining the economic viability of the mine; no one wants to squander scarce mill capacity with sub-economic ore. Jetti Resources claims to have unlocked the "holy grail" of mineral processing, having discovered a cheap technique to leach low-grade sulfide stockpiles. Instead of crushing the rock, the operators place the low-grade material onto a heap leach pad like oxide ore. Jetti injects a reusable reagent into the chemical stream that helps liberate the copper from the sulfide ore, with minimal crushing or grinding required. Although estimates vary, Jetti expects to produce 1 mm tonnes annually by the decade's end. BHP is testing Jetti at Escondida – the world's largest copper mine in Chile.

While Jetti seeks to unlock low-grade sulfide stockpiles in the near term, Friedland's team at iPulse believes it has made cut-off grades a thing of the past. The same electrical pulse that allows for imaging deep underground can also be used to tear rock apart using a small fraction of the energy of a conventional mill. iPulse showed us a working prototype of a system that, one day, can replace crushers and SAG mills entirely. High-powered pulsed energy turns the hardest rock into a slurry paste, using one-tenth the energy of a conventional crusher, SAG, and ball mill by exploiting the ore's reasonably low tensile strength. A SAG mill, on the other hand, must overcome the much stronger compressive strength to crush the ore. If iPulse is successful, then even the lowest grade ore can be economically crushed and run through flotation tanks, which are a small fraction of the overall capital of a mill, and enjoy much higher recoveries than a heap leach.

How much incremental copper can Typhoon, Jetti, and iPulse produce? No one knows for sure, but there is a historical precedent. When the industry introduced oxide heap leaching in the 1990s, it grew to represent well over 20% of all copper production within ten years. Introducing the new technology severely depressed copper for most of the decade, eventu-

ally bottoming at 60 cents – the same real price as in the depths of the Great Depression some seventy years earlier.

No analyst has any of this in their projections – and we think they would be wise to start paying attention. These technologies will likely not change copper balances soon, so we remain bullish. However, over the medium term, their potential must not be overlooked.

Seeds of Crisis: The Tumultuous Journey of Global Crops

“Export restrictions imposed by India and other major producers, coupled with more extreme weather, are threatening the global supply of a staple food relied on by millions of people.” Financial Times, October 24, 2023

We have argued that the 2020s will see multiple agricultural crises develop. One current example is the ongoing rice crisis. The prospect for India’s rice crop has substantially dimmed due to an erratic 2023 monsoon (possibly impacted by the developing El Niño). In the latest WASDE report, the USDA estimates the Indian rice crop will be 4 mm tonnes, 3% smaller than last year. In response to surging prices, the Indian government has further restricted rice exports. Over the last decade, India has become the world’s largest rice exporter, representing over 40% of all seaborne trade. The expansion of its export ban caused global prices to surge.

Making matters worse, Thailand, Myanmar, Vietnam, and the Philippines are all experiencing dryer-than-normal growing conditions (again El Niño-related), leading Myanmar and the Philippines to either ban or severely tax rice exports. The result is that international prices surged 50% year-over-year, leading to a near-crisis in many poor countries where rice is a staple. Volatile weather conditions, along with “food nationalism,” are something we will see more and more as we progress through this decade. Given the adverse weather conditions emerging in Brazil and Southeast Asia, next year could see a surge in nationalism as countries attempt to insulate themselves from rising prices.

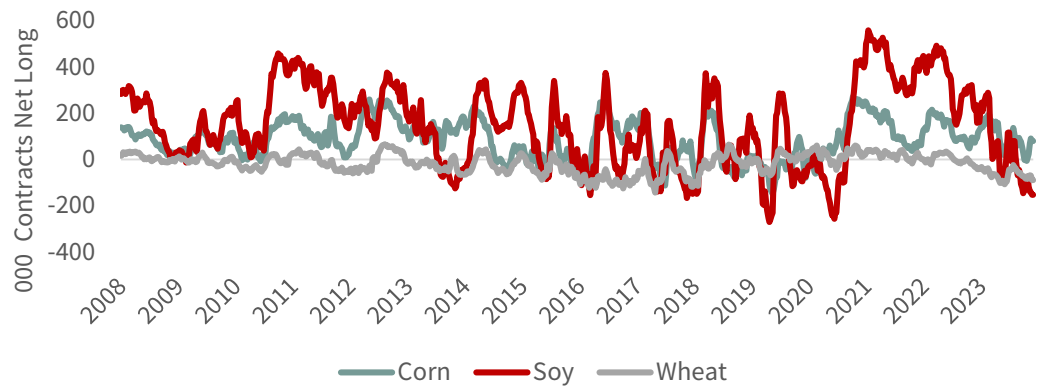
Another trend will likely emerge this decade, further destabilizing global agricultural markets: the emergence of speculators. In a Financial Times opinion piece, “Big Companies have become even bigger,” from October 23, 2023, the author states:

“Financialization plays a key role in this (surging agricultural prices). The growing importance of financial activities as part of companies’ business model has become an amplifier of their power,” says Richard Kozul-Wright, Director of the Globalisation and Development Strategies Division in the United Nations Conference of Trade and Development. In his report, he states: “Unregulated activity within the commodities sector contributes to speculative price increases and market and market instability that has exacerbated the global food crisis.” His report further states that corporate price gouging is to blame for many high food prices: “Profiteering from financial activities now drives profits in the global food trading sector.”

Thus far, we have seen little in the way of agriculture financial speculation. We believe this could change materially in the next several years. Since the financial crisis 2008, total open interest in the Chicago Board of Trade corn, soybean, and wheat futures markets have been

relatively stable with open interest today only marginally higher than before the financial crisis began.

FIGURE 16 Crop Open Interest CFTC



Source: Bloomberg.

In contrast, financial reserves on the Fed's balance sheet have ballooned. Since the GFC, the Fed's monetary base has surged five-fold.

Almost all of this excess liquidity has encouraged speculative activity in other financial markets: big-cap tech stocks, crypto, and bonds. Very little speculative activity has occurred because of the enormous bear market in most commodities since 2010, including in agricultural markets. If we are right and commodity prices go from significantly undervalued to extremely overvalued by the decade's end, speculative activity will surely accelerate.

Investors could redirect the same liquidity that produced numerous trillion-dollar tech stock market capitalizations toward general commodity and grain markets. These markets are tiny relative to stocks and bonds and, combined with the frequent disruptive weather pattern now emerging, could wind up pushing prices to miserable levels for consumers.

The agricultural crisis has already started, and the second leg is about to commence. Weather trends will be increasingly disruptive next year, while "food nationalism" sentiment is growing. For example, unforeseen supply disruptions such as war may push prices much higher in the coming years.

A persistent bull market and ample volatility would present speculators with tremendous short-term profit opportunities, drawing torrents of speculative capital. Excess liquidity always ends up destroying and distorting markets. Speculative bubbles in crypto-currencies are one thing. Speculative bubbles in agricultural markets—something people need to survive--are completely different.

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