4th Quarter Commentary

January 2023

Prefatory Remarks

There is more clarity gained from thinking about investing than talking about investments, and in discussing context before talking corporate earnings. Part of today's *economic* context is that investors now face questions they haven't had to consider for 40 years, such as how to protect purchasing power in a chronic inflationary environment. Part of the *investment* context is the dawning realization that the indexation and asset allocation models that came to dominate the past 20 years can no longer be relied upon as having predictive value.

One reason those models are now in disarray is because they depended on a presumption that the prior 20 or 40 years of daily price data represented normality, whereas it actually described an anomalous period that won't be reproduced 'in the next cycle.' Such a model can't contemplate a deviation from their statistical presumptions – like driving a car smoothly down a ruler-straight Interstate without occasion to realize, during the first 50 or 100 miles, that the steering wheel doesn't turn more than 5° on a side.

We've already much discussed the two forces for anticipating an extended inflationary environment: the government's structural debt and budget deficits, which lead to excess money supply; and the structural commodity supply deficit. But that doesn't mean the discussion is done. It will have to continue, because those two forces will continue and gather force; they are not in an equilibrium state. It's not that we're enamored with the inflation thesis or wedded to it, but it's the best judgment we've come up with. We could be wrong as to the evaluation of what we see in the moment. Or, we could be correct in the moment, but wrong in the end, because the world is complex and conditions change, in which case so will our viewpoint. Based on the facts and information we see, though, it is far more reasonable to assume an extended inflationary environment than not, and to invest accordingly.

However, the discussion will never be mere repetition, because circumstances and new information continue to evolve. New opportunities emerge, as they have already been doing, because the securities markets are not a zero-sum game. When 'the market' is down, not all of it is, and that's not always a random phenomenon. Excesses in one area, whether of fear or avid interest, inevitably beget deficits and opportunities in others. So, on to some new observations about familiar ideas, and one or two new ideas.

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The Approaching Reckoning with the Federal Debt Leverage: Closer and Closer

In last quarter's Commentary, the informed estimation approach was used to suggest how rapidly the past year's interest rate increases would filter through to enough of the Federal government's treasury securities to drastically impact the national deficit and push the central bank into a more dramatic money-printing cycle. This time, no estimation is necessary. The numbers are a bit startling.

The Treasury Dept. provides a line-by-line listing of all outstanding marketable securities, from short-term Treasury Bills through 30-year Bonds and TIPS—434 in all, by my count. As to when they each come due, 30% mature in the next year, by January 2024. A cumulative 52% come due within 3 years, and 66% within 5 years. Even at the 10-year mark, which encompasses over 80% of all outstanding public debt, it is so front-loaded that the weighted average maturity is only 2.8 years. The entirety of the Federal debt has an average maturity of only 7 years.

Maturity	Yrs to Maturity	Running % Maturities of All Outstanding	Weighted Avg Maturity Cumulative
Jan-24	1	30.0%	0.3
Jan-25	2	42.5%	0.5
Jan-26	3	51.7%	0.8
Jan-27	4	59.0%	1.1
Jan-28	5	65.9%	1.5
Jan-29	6	71.3%	1.8
Jan-30	7	75.3%	2.1
Jan-31	8	80.5%	2.3
Jan-32	9	80.7%	2.5
Jan-33	10	82.9%	2.8
Feb-43	20	87.5%	4.1
Nov-52	30	100.0%	7.2
Total Amount Outstanding at 12/31/22:		**23,800,119**	**7.2**

That's terribly short, leaving the government's finances very vulnerable to higher rates. That term structure is perhaps not by design so much as a reflection of bond investors' unwillingness to purchase long-term debt, probably because they fear the same risk.

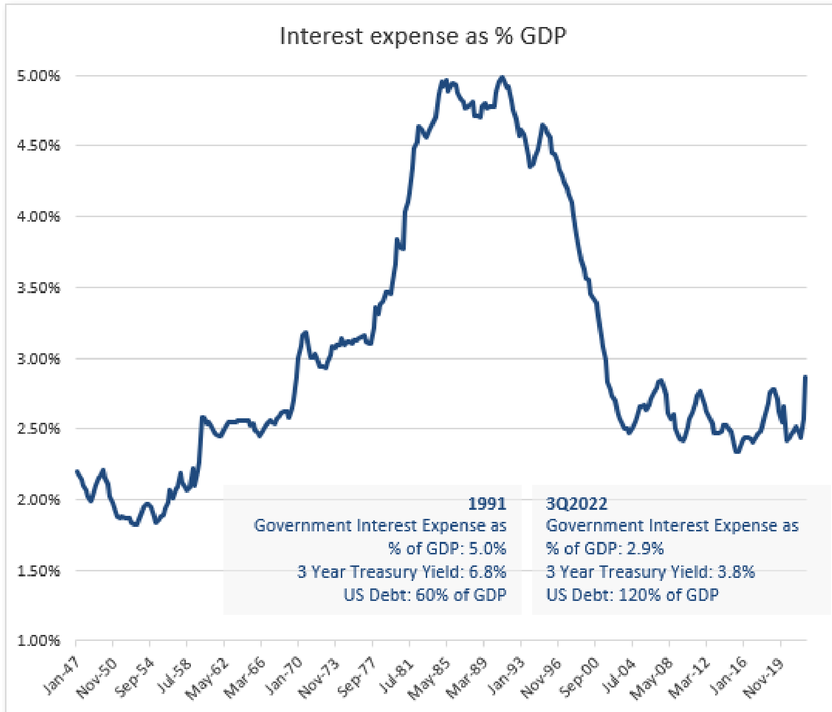
That exceedingly short average maturity means that the interest rate increases of the past year will infiltrate much of the Federal debt structure in fairly short order.

The run-rate interest expense on the total Federal debt is reported as $736.7 billion[1]. Before we get to 'what happens next,' let's pause to notice that the 'what happens next' part has already started. The average interest rate on all $30.929 trillion of Federal debt[1] is already up to 2.38%. Last year at this time, it was only 1.79%[2]. What could it be three years from now?

In three years, over one-half of the total Federal debt will have matured and been refinanced at market rates, whatever they might be. Today, the market rates on maturities from 3 months through 3 years averages about 4.4%. That means, absent the impact of any other factors, that the yield on half the Federal debt will rise by another 2% in just 3 years.

At 1/20/2023	
3-month Treasury Bill	4.63%
6-month Treasury Bill	4.80%
12-month Treasury Bill	4.44%
2-year Treasury Note	4.25%
3-year Treasury Note	3.83%
Simple Average:	*4.39%*

[1] As of September 2022
[2] Run-rate interest expense was $528.8 million

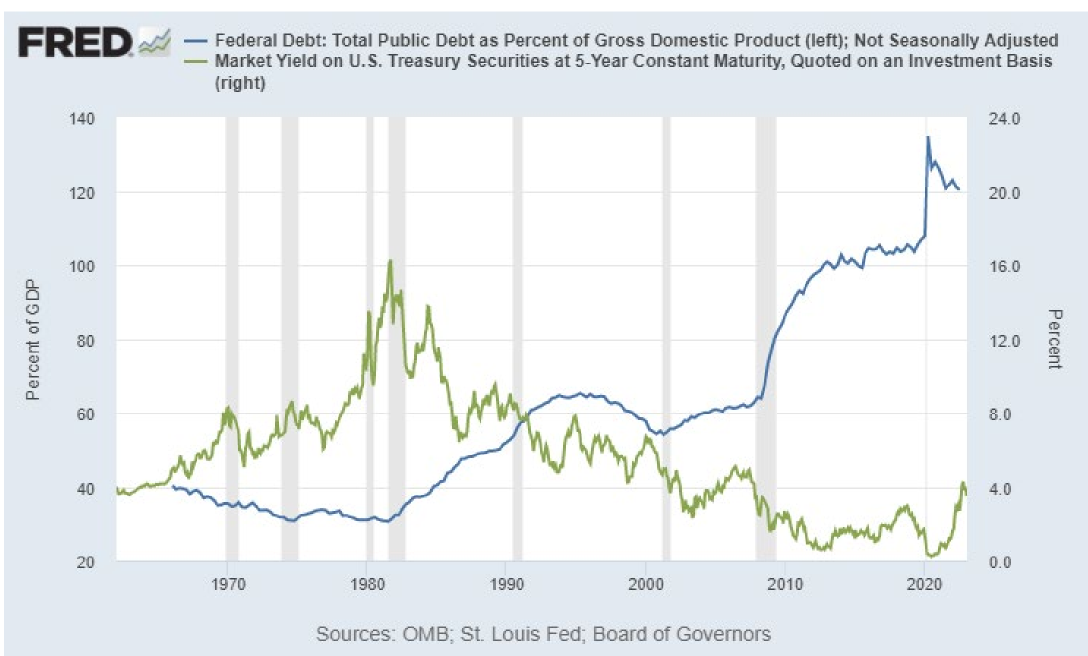


Source: fred.stlouisfed.org data series, Quarterly, Seasonally Adjusted Annual Rate: Federal government current expenditures: Interest payments, Gross Domestic Product

What are the practical implications? The government's interest expense of $736.7 billion consumes 2.85% of GNP[3]. It seems a small figure, and well below the post-World War II high of 5%, but a couple of pictures will show how dire the current structural pathway is relative to that prior historical extreme.

In 1991, the 3-year Treasury yield averaged 6.82%, almost 3x times higher than the 2.38% now being paid. In 1991, the U.S. debt was 60% of GDP; it is now 120%, exactly twice as high. The reason the danger of today's record debt leverage has yet to truly impact the economy and alarm investors is only because the cost of that debt is still only a third of what it was in 1991. But only for a while, because the deterioration in this interest coverage trend has only just started.

What could a model for 3 years from now look like? First, account must be taken of the constant increase of the federal debt. That's because the U.S. operates with a budget deficit. Revenue shortfalls are made up with more borrowing.



[3] GNP, at Sept. 2022, of $25.885 trillion; run-rate interest expense was $736.7 billion.

The most recent Congressional Budget Office analysis of the President's budget[4] projects a $1 trillion deficit in 2023, a $1.1 trillion deficit in 2024, and a $1.3 trillion deficit in 2005. Is that reliable? Here are three of the many, many assumptions behind these projections.

- The CBO's baseline forecast[5] presumes real GDP growth in 2023 and 2024 of 2.2% and 1.5%.
- Its baseline inflation forecast for each year is 2.3% and 2.1%.
- Its forecast for the 3-month Treasury Bill rate for this year and next is 2.0% and 2.5%, within a range of 1.7% to 4.8% for next year.

In other words, these $1+ trillion budget deficit projections assume no recession, inflation that is about one-third the current rate, and a short-term interest rate that is one-half the current rate.

In contrast, the Treasury Dept.'s Monthly Treasury Statement shows that the 2022 deficit was $1.375 trillion. Let's go with that one and, for the sake of conservatism, skip the assumption (which shouldn't be skipped) that this figure will increase annually.

In $ billions	Current Year		Annual Increase	2025(e)
Total Public Debt	30,928	$1.375 trillion/year (= 2022 budget deficit)	4,125	35,053
Annual Int. Expense	737	The half of the Fed debt maturing in the next 3 years is re-priced at 4.4%, the current market rate, and the other half remains at roughly 2.4%,	455	1,192
GDP	25,724	2% annual growth	1,575	27,299

Federal Expenditures Budget USD Billions	Actual	Actual	Projected	
Total Outlays:	**2019**	**2021**	**2022**	**2025**
Mandatory Expenditures	2,735	4,834	3,751	3,834
Defense Spending	676	742	760	842
Interest Expense	376	352	737	1,192
Sub-total	3,787	5,928	5,248	5,868
Discretionary Spending (ex. Defense):	660	894	962	1,020
Total	4,447	6,822	6,210	6,530

With $1.375 trillion of annual deficits, the total federal debt[6] in 3 years will be $35.053 trillion. If half of it—the half that matures in the next three years—will be re-priced at 4.4%, and the other half remains at roughly 2.4%, then annual interest expense would be $1.2 trillion, more than 60% higher than today, under the most benign assumptions. If the federal government must pay $1.2 trillion annually in interest expense, this would amount to 25% of the entirety of current federal spending. Nothing in the American historical record that matches that.

Returning to the interest expense/ GDP metric, if GDP expands by 2% each year[7], it will be $27.298 trillion, so $1.2 trillion of debt service burden would be 4.36% of GDP, close to the historical precedent of 5%. It is not difficult to calculate scenarios with a much higher figure; however, there can be no doubt about the general trend.

[4] Published in September 2022

[5] As of May, so it will be revised shortly

[6] Somewhat larger, at $30.929 trillion, than the publicly traded debt cited earlier

[7] From the recent $25.724 trillion

In this scenario, based simply on the repricing of the next 3 years' debt maturities, the U.S. government must pay an extra $450 billion in annual interest expense. This does not include the possibility of: higher interest rates; any recession impact; or emergency spending impacts, as for disaster aid or war. (One might note, as to how official budget projections work, that annual weather disaster relief costs are now in the $200 billion per year range[8], which far exceeds annual appropriations and supplemental appropriations of about $65 billion[9]. The appropriations are based in part on 5-and 10-year historical average costs. Yes, in the 2000s, annual disaster relief costs did average, $60 billion, though they approached $100 billion in the 2010s.)

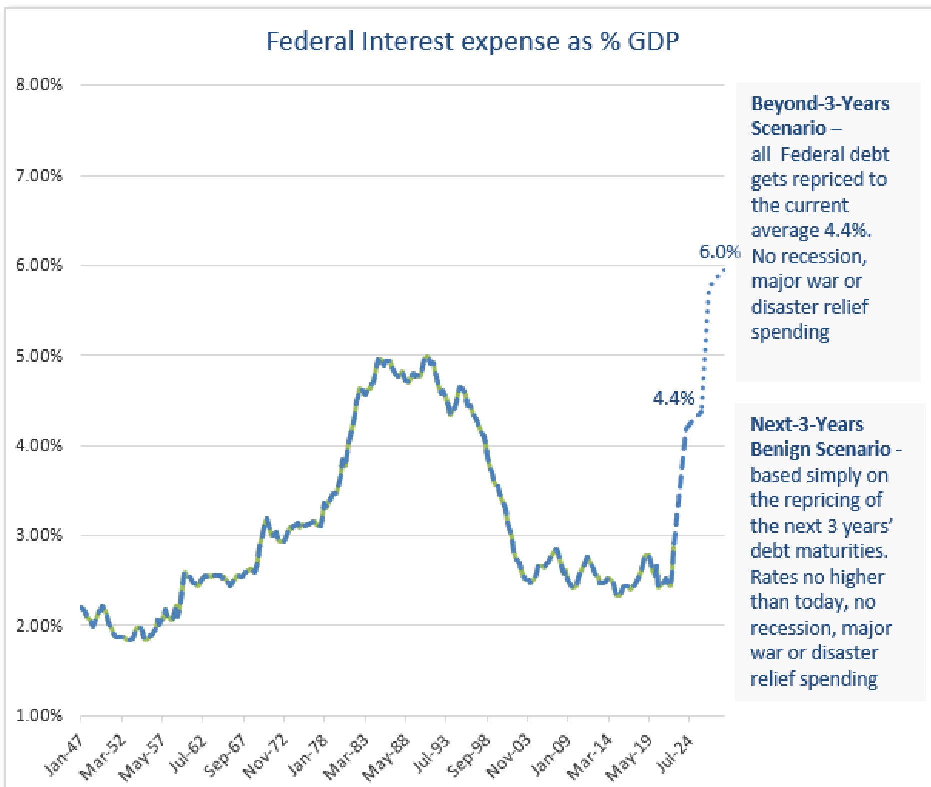
Weather and climate statistics

Select Time Period Comparisons of United States Billion-Dollar Disaster Statistics (CPI-Adjusted)

Time Period	Events/Year	Cost/Year‡
1980s (1980-1989)	3.1	$20.5B
1990s (1990-1999)	5.5	$31.4B
2000s (2000-2009)	6.7	$58.7B
2010s (2010-2019)	12.8	$93.6B
Last 5 Years (2018-2022)	17.8	$119.1B‡
Last 3 Years (2020-2022)	20	$144.9B‡
Last Year (2022)	18	$165.0B‡

*‡Cost statistics **not included** for December 2022 Central and Eastern Winter Storm and Cold Wave*

The additional interest expense could easily be $1 trillion. Whatever the figure, $450 billion can reasonably be considered a lower bound. The government must find some way to raise that revenue each year or reduce annual spending by that amount. That *incremental* interest expense is about exactly one-third the size of last year's budget deficit. It would be extremely difficult to accomplish even a half-trillion dollars' worth of increased tax revenue or reduced spending. Is it even practically possible?



Source: fred.stlouisfed.org data series, Quarterly, Seasonally Adjusted Annual Rate Federal government current expenditures: Interest payments, Gross Domestic Product

[8] https://www.ncei.noaa.gov/access/billions/summary-stats/US/2021-2022

[9] Congressional Research Service, The Disaster Relief Fund, Jan 20, 2022

Consequently, a moment of reckoning is approaching. It is difficult to determine precisely when that moment will arrive, but it is no longer possible to credibly deny that it is pending. A government that has difficulty raising adequate revenue is always a government in crisis. A 660-basis-point fed funds rate increase between 1976 and 1978, from 4.2% to 10.8% did not halt inflation. The CPI rose from 5% to 9% in that period. Given the debt levels today, it is unimaginable that the Fed could raise rates that much. In order to stop inflation, which topped out at 14.6% in March 1980, the central bank found it necessary to increase the fed funds rate to 21%.

	1976	1978	1980
Fed Funds Rate	4.2%	10.8%	21%
CPI	5%	9%	14.6%

Source: www.macrotrends.net

The magnitude of today's debt levels must greatly reduce the central bank monetary policy options. This is the central difference between the prior inflationary period and the current one. If the inflation cannot be controlled by interest rate increases, perhaps it cannot be controlled.

- One policy solution is to control inflation via money supply, meaning actually reducing the money supply. The last time that was tried was during the Great Depression. It did not work out as well as the theoreticians might have hoped. That idea has since become anathema to the point of taboo.
- The usual choice in such circumstances is to do the opposite of the Great Depression approach, namely to tolerate or even encourage inflation, using time as tool. Over time monetary inflation diminishes the relative value of the debt liabilities (more dollar bills in the economy per unit of bonds). That is the mechanism at the government's disposal. The central bank might already be trapped into a long-term strategy of inflationary money printing.

Structural Inflation Factor #3: The Energy Transition

Preface and Recap

To forestall any 'oh, no, not more of this' feeling about these ongoing energy-related discussions: if we at Horizon Kinetics never again belabor the topics of energy insufficiency and inflation, the regular news, political and policy worlds will eventually end up putting it before you anyway. The stresses will eventually become unavoidably visible.

To briefly recap what we've covered of this topic previously, the arithmetic reality is that global population and economic growth, combined with improving standards of living in less-developed nations, will require inexorably more global energy production. The lurking supply insufficiencies that will intersect with that expanding demand have been a decade or even decades in the making, the result of underinvestment in the necessary reserves and infrastructure replacement and development.

Readers are now familiar with the chronic underspending on reserves replacement for oil, gold, and copper. This table, updated from our 4th Quarter 2021 Commentary, shows that Freeport-McMoran's[10] capital expenditures are now one-third lower than 10 years ago, and three-quarters lower than in 2014, on an inflation-adjusted basis. There's been no alarm about copper supplies simply because the company has continued producing the same volume every year. The trade-off: reserves have been in continual decline for a decade.

Freeport-McMoRan Inc.

	Reserves (bill lbs.)	Production (bill. Lbs.)	Capital Expenditures (mill.)	CPI-Adjusted Expenditures (mill.)
Dec-21	107.2	(3.8)	$ 2,115	$ 1,706
Dec-20	113.2	(3.2)	1,961	1,704
Dec-19	116.0	(3.2)	2,652	2,333
Dec-18 [1]	119.6	(3.8)	1,971	1,765
Dec-17	86.7	(3.8)	1,410	1,294
Dec-16 [2]	86.8	(4.2)	2,813	2,636
Dec-15	99.5	(4.0)	6,353	6,029
Dec-14	103.5	(4.0)	7,215	6,855
Dec-13	111.2	(3.9)	5,286	5,102
Dec-12	116.5	(3.7)	3,494	3,422
Dec-11	119.7	(3.7)	2,534	2,534

[1] Reserve increase due to $3.5 billion acquisition of Indonesia reserves; purchase price ~ 10% of Freeport's market cap at the time.

[2] Disposed of interest in Democratic Republic of Congo reserves (~7 mill lbs)

Source: Horizon Kinetics; company reports

The same underlying erosion of capacity sufficiency applies to the electricity grid and oil refineries. But there are many more facets of this emerging reality to understand, related directly to the broad move to electrification, away from fossil fuels, and we will begin to explore those, too. First, though, for today's news…

Recent Inflation Data: Weather shouldn't be confused with Climate, nor News with Information

One can hear notes of relief in many recent news reports about inflation. The year-over-year Consumer Price Index figures have declined for months, from 9.1% in June to 6.5% in December. It is acknowledged that 6.5% is still too high, but the sharp edge of worry appears to have been blunted. Comfort was gained from data showing that the 6.5% increase was heavily influenced by rising energy prices, plus energy's indirect impact on the index, such as through food prices. Excluding food and energy, the CPI was up only

[10] Freeport-McMoRan is the world's 2nd largest publicly traded copper producer, and 3rd largest overall.

5.7%, which is thought to show that inflation was even lower. Though some might wonder if, without food and energy, there would be anyone left to calculate the CPI. But the thought seems to relieve many people.

Better yet, on a month-to-month basis, the CPI dropped by -0.1% in December. In this case, unlike the annual figures, it is not considered worrisome that the only reason for the decline was that energy prices dropped by -4.5%. In this one-month case, excluding the impact of food and energy, the CPI rose by 0.3%.

Let's call these figures news; there isn't sufficient data or context to call it information. It's like an unusually cold week that is described in great detail by the local weather service—there's data on wind, cloud cover, humidity, storm fronts—but it doesn't tell you anything about whether the climate is colder or not.

A few extra data points might provide additional context for the recent and near-term oil prices.

- In late March 2022, to reverse the politically fraught spike in gasoline prices associated with the loss of Russian oil imports, that being related to the Ukraine war, Pres. Biden announced that a record 180 million barrels of oil would be released from the Strategic Petroleum Reserve. Ordinarily, the SPR holds about 640 to 700 million barrels. As planned, by mid-December, 186 million barrels were drawn down, to a level of 380 million barrels, the lowest it has been almost 40 years, since December 1983. Funny how that 40-year figure keeps coming up in our change-of-era discussions. That level of market intervention can't be repeated. For the national security, one doesn't want to draw it down to zero. In any case, there's a regulatory lower bound; it can't be drawn down below 252 million barrels.

  By mid-year gasoline prices did begin to decline dramatically, and oil prices declined as well. That was then. The sales program is over, and in December, the Energy Dept. announced that it will begin buying back oil that it sold. The first purchase will be in February, next month, and contracts with oil companies have already been awarded.

- The next data point is that as of February 5, 2022, Europeans, under their version of the sanctions, will no longer buy Russian refined oil products, such as diesel fuel, of which Russia is one of the major global exporters. The EU nations will have to find other sources. This kind of scrounging for supply of a demand-inelastic resource tends to raise prices.

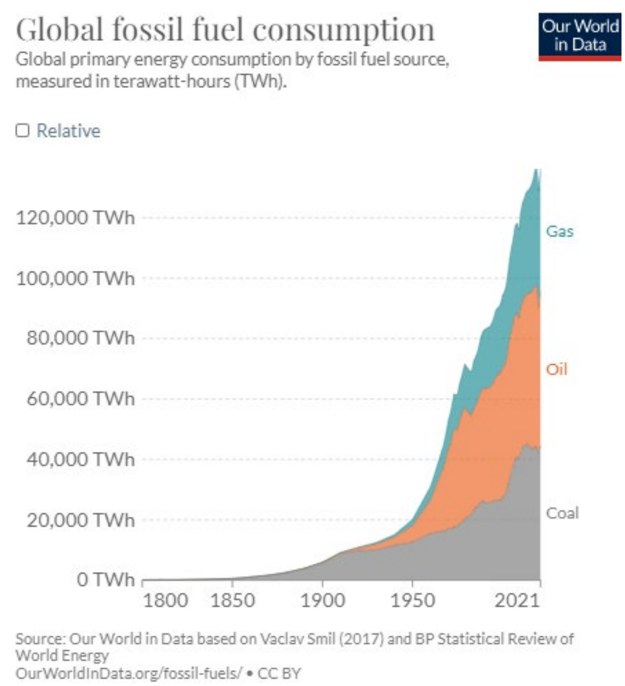
- Another data point is that China's zero-Covid lock-down policy has come to an end. Presumably economic activity within China and to and from China will recover, as will their demand for oil. China is the largest oil importer in the world and rather poor in reserves. It imports more oil than the entirety of Europe.

All those data points are coming up. Yet, they're not what the long-term thesis about energy inflation rests upon. This discussion was more like the weather than the climate.

Next Big Thought: The Inflationary Impact of the Energy Transition.
Moving from a Fuel-Intensive to a Mineral-Intensive Economy

Not only is chronic underinvestment in conventional energy sources—oil and gas reserves—not yet recognized for its pending inflationary impact, neither are the inflationary implications of electrification of the economy. To be reckoned with is the mismatch between the vast scale of demand developing for the necessary raw materials and today's supply capability. Raw materials for solar and wind installations, electric vehicles, vehicle batteries, and utility-scale storage batteries.

The enormity of the mismatch is not much appreciated, but is easily conveyed: pretty much all of the global technological and quality of life progress that's taken place in the past two and a half centuries, with the start of the industrial revolution, rests on a single resource. And, today, a staggering amount of it. The accompanying chart sums it up.



As of about 200 years ago, humanity began making dramatic use of fossil fuels, for the simple reasons that they were plentiful and extraordinarily effective power sources. In 1850, coal accounted for only 7% of all fuel energy in North America and Europe; almost all the balance of applied kinetic energy came from direct human labor and draft animals. By 1900, coal and oil accounted for half of all global primary energy[11]; and that was only 1900. From 1850 onward, the entire edifice of global technological advances and population growth, in food sufficiency, medical care, and transportation, has depended on the use and improvements in the use of fossil fuels.

Even our daily bread could not be supplied to more than a small fraction of the population without them. Since 1800, progressing from human and oxen muscle power, through the introduction of horse-drawn mechanical harvesters, to natural gas based nitrogen fertilizers and 400-horsepower tractors, the amount of human labor required to produce a kilogram of wheat has been reduced by 99.7%. In the inverse, efficiency has improved 29,900%[7]. Before those energy-facilitated improvements, the U.S. required 83% of the population to farm, in order to support the remaining 17%. Today farmers are 1.4% of total employment.

If, after two centuries of fossil fuel use, if we wish to change to different energy sources, alternative substances are required. This is the practical, physical science challenge in the transition to solar, wind and battery power: the enabling elements, such as lithium, silver, cobalt and neodymium, are neither as plentiful nor accessible. The energy transition will be far more complex and challenging than presumed.

[11] Smil, Vaclav. How the World Really Works. Penguin Random House UK, 2022.

It is nothing less than prudent to learn about this topic, still invisible to the broader investment community. Consider: even conventional energy is still 'below the radar' as far as mainstream investment wisdom goes, the proof being that even after having doubled last year, the energy sector is only 5% of the S&P 500. The energy transition cannot be successful without substantially greater volumes of the necessary electrification metals, the procurement of which will cost more, which means the transition from fuels to minerals will cost more.

To ask a Socratic question: can one change from one comprehensively integrated global physical, process and energy infrastructure to another without cost? Really? It will require, not coincidentally, much usage of fossil fuels in the interim, however long that period might be.

Demand: Some Energy Transition Figures

Two years ago, the Q1 2021 Commentary referenced the best study we found of the critical metals requirements to achieve climate-neutral status from wind and solar power and electric vehicles. It was commissioned by the Netherlands. The 2018 study suggested that there might be insufficient *global* supply of some metals even if demand were limited to the Netherlands, which has a population of only 17 million.

Today, there is far broader interest in these demand/supply questions. This year, the International Energy Agency released perhaps the most comprehensive review to date. It references some sources and studies not in the free public domain. This small sampling of facts and figures draws considerably from that report[12].

One of 30 pages of references:

The Role of Critical Minerals in Clean Energy Transitions

Annexes

Technology	Sources
Electricity networks	BloombergNEF (2020), *Copper and Aluminum Compete to Build the Future Power Grid.*
	Private communication with companies
EV batteries	Argonne National Laboratory (2020), BatPaC Model Software Version 4.0, https://www.anl.gov/cse/batpac-model-softwareBatPac 2020
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	Private communication with researchers of early-stage technologies
EV motors	Argonne National Laboratory (2020), GREET 2020, https://greet.es.anl.gov/
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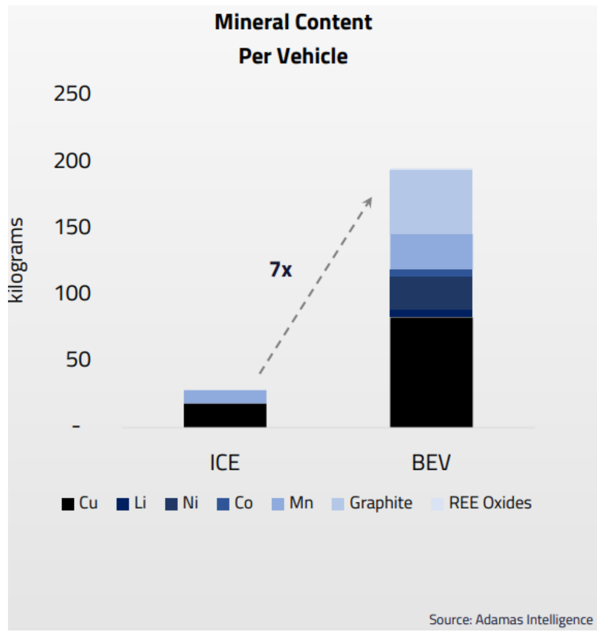
	Bushveld Minerals, (2018), *Energy Storage & Vanadium Redox Flow Batteries 101*, http://www.bushveldminerals.com/wp-content/uploads/2018/11/Energy-Storage-Vanadium-Redox-Flow-Batteries-101.pdf.
	Fernandez-Marchante, C. M. et al. (2020), Environmental and preliminary cost assessments of redox flow batteries for renewable energy storage, *Energy Technology*, *8*(11), 1900914, https://doi.org/10.1002/ente.201900914
	Le Varlet, T. et al. (2020), Comparative life cycle assessment of lithium-ion battery chemistries for residential storage, *Journal of Energy Storage*, *28*, 101230, https://doi.org/10.1016/j.est.2020.101230
	Zhang, X. et al. (2016), Optimal sizing of vanadium redox flow battery systems for residential applications based on battery electrochemical characteristics, *Energies*, *9*(10), 857, https://doi.org/10.3390/en9100857

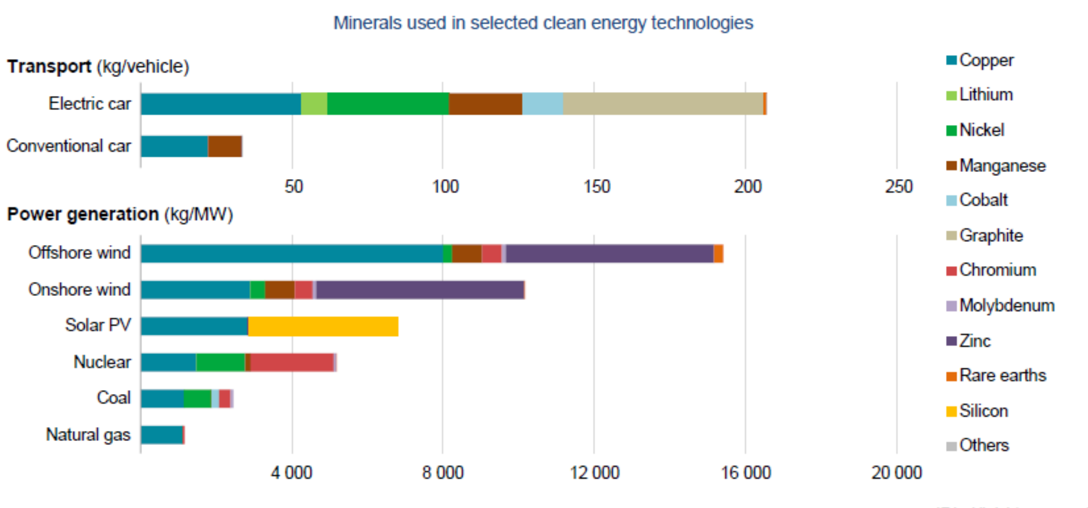
12 www.IEA.org IEA World Energy Outlook Special Report: The Role of Critical Minerals in Clean Energy Transitions

- **Electric cars** typically require 6x the mineral inputs of an internal combustion engine car[8]. A different study, by Adamas Intelligence, calculates the number as 7x. Why can the estimates differ so much? Judgments; many, many subjective judgments.
  - Permanent-magnet motors generate the most power per unit of weight. However, they rely on rare earth metals (REEs) like neodymium, which are more expensive.
  - Induction-motor EVs are less expensive, but have poorer performance. They use about 4x more copper: 24-53 lbs/car vs. 6 ½ -13 lbs.



  Projecting demand for metals ten, 20 and 30 years forward requires judgments about differing demand for one type of technology over another. Modelling has to take into account the possibility of prohibitive cost increases for neodymium and a subsequent shift in demand to copper.

  - Batteries also have competing technologies. Nickel-manganese-cobalt oxide (NMC) batteries contain 8x more cobalt than nickel-cobalt-aluminum oxide batteries. If cobalt becomes prohibitively expensive, then the other battery might become dominant. Alternatively, nickel-manganese-cobalt batteries require half the nickel. Then there are lithium-ion phosphate batteries, which don't use nickel or cobalt, but use 50% more copper than NMC batteries.



It is only by looking at the underlying data oneself, when hearing an estimate about future demand for EVs or their physical resource content, that one can make one's own informed judgment.

The EIA projections assume that permanent-magnet motors remain the dominant technology, and the report does therefore discuss the prospect and implications of higher rare earth metal prices.

- **Wind turbines** likewise have competing technologies and two classes of required metals. There are base metals like copper, nickel and zinc, and rare earth metals. Wind power plants uses on the order of 7x to 10x the minerals content of natural gas power plants. The preceding chart of the minerals used in wind power doesn't include the startlingly large quantities of cement for anchoring the towers, or of the steel for structural support.

- **Electricity grids**. You can generate all the solar and wind power you desire, but the only way to access it is through the grid. No electrification of the economy without it. It has been underinvested in for 50 years. Aside from upgrading simply to carry greater quantities of power and accommodate more rapid fluctuations in supply from wind and solar sources, the grid has to be extended to accommodate the more geographically distributed sources of power—from the few central fossil fuel plants around which the network was originally constructed, to the many peripheral sources. There are 200,000 miles of high-voltage transmission lines in the U.S. There are over 700,000 miles of distribution lines.

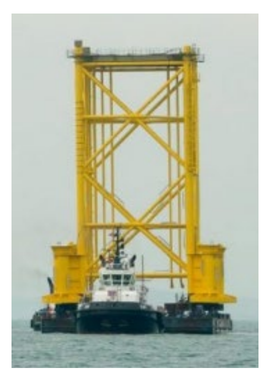
  That will require a great deal more copper, up to a doubling by 2040, according to the EIA study.

  There's also steel. When thinking about supply, that really means iron ore, since iron comprises 97% of steel. Actually, more steel means much more iron ore, since about 1.6 tons of ore are required to produce 1 ton of steel.

- **Steel** is rarely mentioned in discussions of the energy transition. The focus of those inquiries is different than ours. We are interested in understanding the long-term risks to portfolios and the long-term opportunities. As it turns out, steel (which for our investment purposes means iron ore) is one of the most comprehensively necessary physical inputs in the energy transition. Its structural strength characteristics contain or support most of the other components of which we speak.

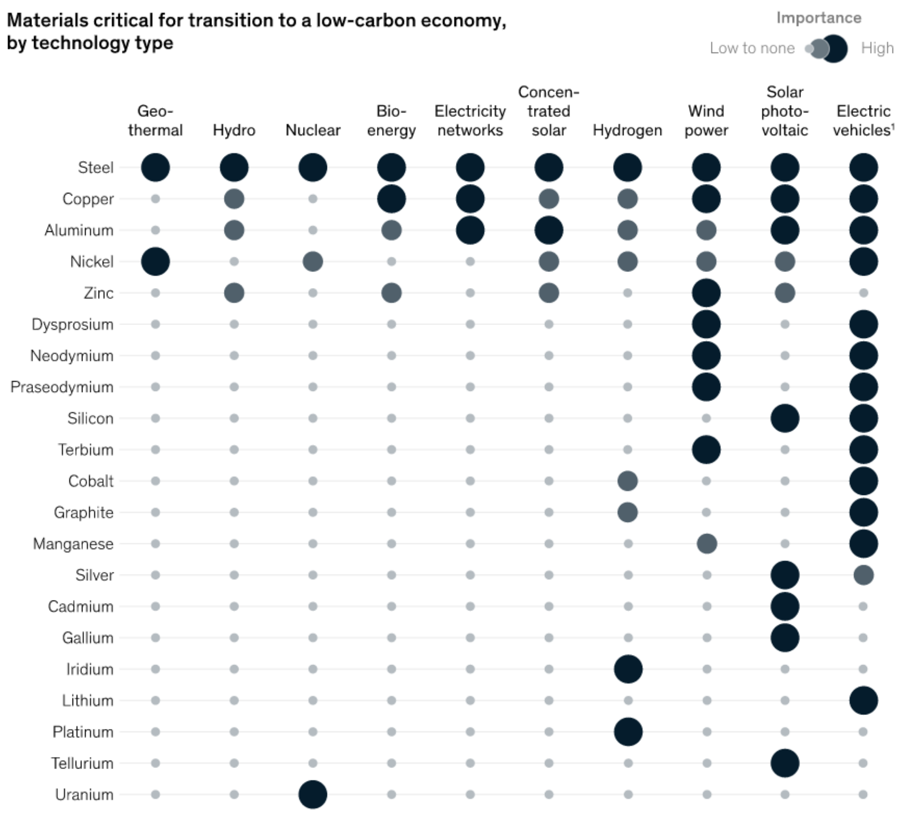
  

  For example, the steel foundation for a 3.45-megawatt turbine (the above-surface and sub-surface structures shown in the accompanying photos) weigh up to 915 tons (1.83 million pounds) and reach 280 feet[13]. Separately, the turbines include a 210-foot tower that weighs 167 tons, and a 23-foot-tall housing weighing 163 tons. Photovoltaic project panels are framed in steel and each panel array is also framed and supported by steel.

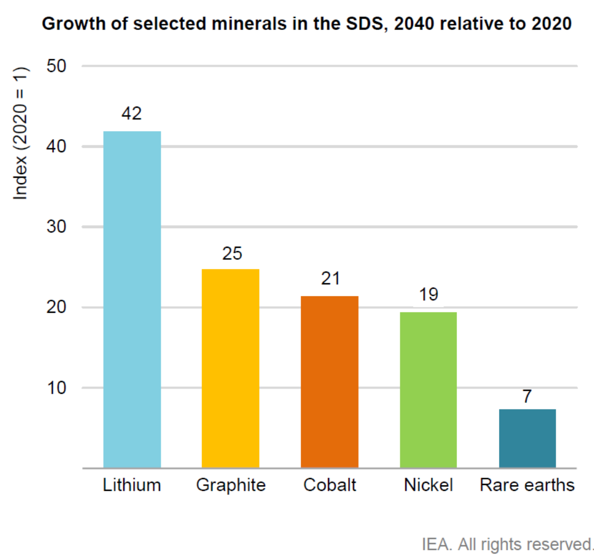
  The following analysis by McKinsey details the ubiquitous and substantial use of steel in every large-scale power source[14].

[13] https://www.rampionoffshore.com/wind-farm/components/foundations/
[14] https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-raw-materials-challenge-how-the-metals-and-mining-sector-will-be-at-the-core-of-enabling-the-energy-transition



[1]Includes energy storage.
Source: *Critical raw materials for strategic technologies and sectors in the EU*, A foresight study, European Commission, Mar 9, 2020; *The role of critical minerals in clean energy transitions*, IEA, May 2021; McKinsey analysis

- **The final word on demand** in the EIA study is encapsulated in this chart of the most dramatic supply increase requirements, based on an electrification transition trajectory that would meet the Paris Agreement goals for the year 2040. The estimated demand for rare earth metals, above what is already being consumed and mined, is 7x greater. That is simply an enormous increase. The needs for cobalt and nickel are presumed to be about 10x greater, and for lithium the figure is 42x



Some Supply Limitation Figures

The demand message: the greatest natural resource extraction phase in human history might be about to take place. It must, if minerals-based energy is to replace a meaningful portion of global energy now provided by two centuries of the first greatest mineral extraction phase of human history—of fossil fuels.

An investor has to question what the deleterious inflationary impact of rising energy costs could be upon saved wealth. In which case one has to inquire about what forms of profitable participation are available without undue risk. Ultimately, it is the counterpoise of demand and supply that determine price. In this instance, the *time factor* of future supply availability might become the dominant factor determining how long the transition will take. That is, with what rapidity it is even feasible to produce the necessary volumes of raw materials (locate, permit, fund, buy, and develop new mines) and build out accessory infrastructure like the electric grid.

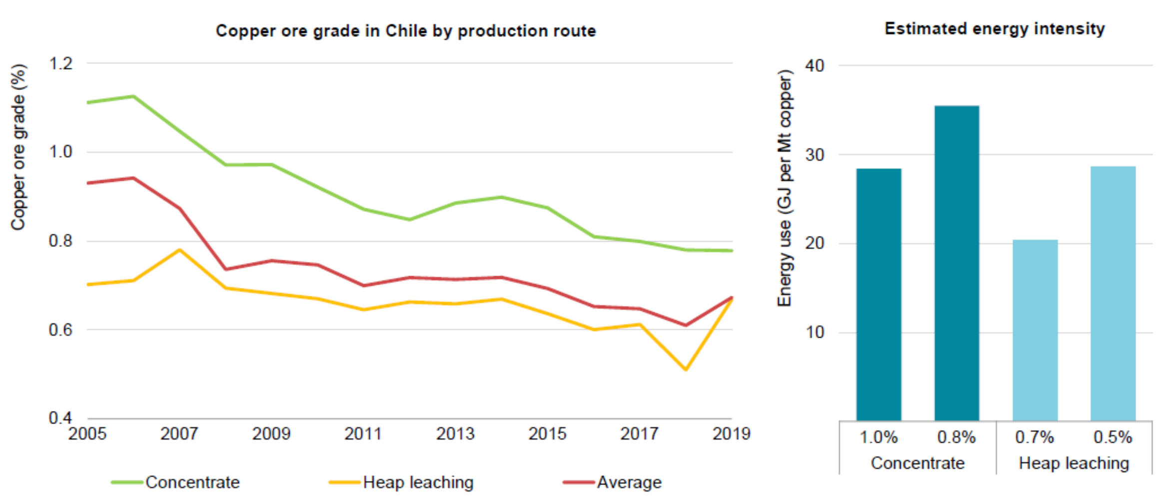
One thing is certain: informed knowledge will be important. Here's a sample reason why science and 'slow knowledge', as opposed to quick answers, matter. Someone tells you about rapid, scalable growth of hydrogen as an energy carrier. That it's actually happening.

- Do you buy into hydrogen production plants, into IPOs for the technology leaders, or maybe an index of hydrogen-related investments?
- Or do you look to benefit from the demand growth for nickel and the platinum-group metals that are required for the hydrogen fuel cells? During the California Gold Rush, most participants invested in mining; a relative few sold them the picks and shovels. Then there's Levi Strauss. He invested in serge de Nimes fabric and sold sturdy riveted work pants.

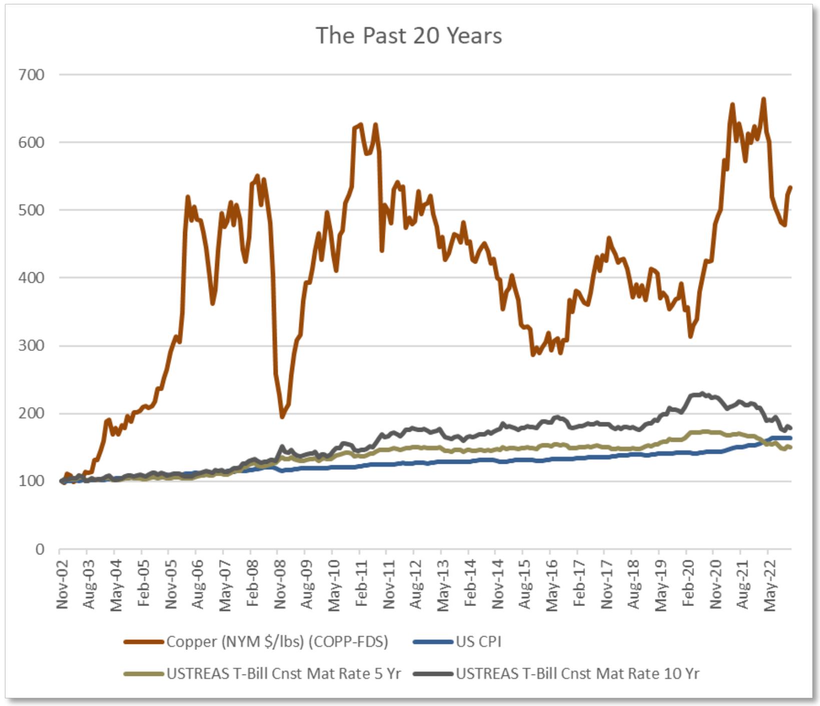
Minerals production costs There is a great deal of historical data about minerals production.

- When Freeport-McMoRan spent a decade producing the same quantity of copper every year, but less and less on replacing its reserves, it mined the highest-grade, most profitable ore bodies first. If the remaining ores contain less copper, the extraction cost per pound produced must rise. The same trend occurred in Chile, which is the largest global copper producer. Over 15 years, the percentage of copper in the ore declined by roughly 30%, while the energy required to extract it has risen significantly.

Average ore grade in Chile and estimated energy intensity by quality



Notes: Energy use for concentrate covers mine, concentrating plant, smelter, refinery and services. For heap leaching, energy use covers mine, leaching, solvent extraction, electro-winning processes and services. GJ = gigajoule.
Source: IEA analysis based on COCHILCO (2019) and Rötzer and Schmidt (2020).



Exactly 50 years ago, on Jan 29, 1973, copper was $0.55/lb. At the most recent price of $4.26, the price has risen at a 4.2% annualized rate. In the past 20 years, it's risen at an 8.8% rate, and in the last 5 years at 5.9%/yr. That is 1.6x to 3.5x the rate of inflation as measured by Bureau of Economic Statistics in the CPI figures. Few observers would suggest that this was a supply constrained or otherwise inflationary period for base metals mining. Rather, extraction technology and efficiency were improving.

The 20-year rates of return from 5-year and 10-year Treasuries were 2.0% and 2.8%. A *non-inflationary* copper return was superior to bonds.

In an economically rational way, Freeport-McMoRan's unit cost of production over the past decade has risen by over 5% annually, not so different than the market selling price. Freeport-McMoRan is not special; it merely serves as a handy example.

Freeport-McMoRan Inc.

	Reserves (bill lbs.)	Net Cash Operating Costs/lb 3-Yr Average
Dec-21	107.2	1.52
Dec-20	113.2	1.43
Dec-19	116.0	1.34
Dec-18 [1]	119.6	1.18
Dec-17	86.7	1.33
Dec-16 [2]	86.8	1.43
Dec-15	99.5	1.51
Dec-14	103.5	1.41
Dec-13	111.2	0.94
Dec-12	116.5	0.71
Dec-11	119.7	0.48
Dec-10	120.5	0.83

[1] Reserve increase due to $3.5 billion acquisition of Indonesia reserves; purchase price ~ 10% of Freeport's market cap at the time.
[2] Disposed of interest in Democratic Republic of Congo reserves (~7 mill lbs)
Source: Horizon Kinetics; company reports

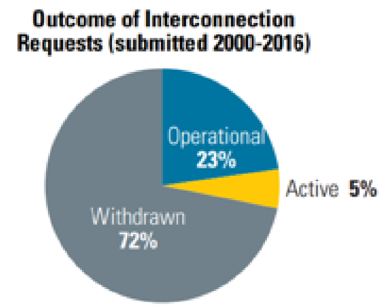
Also over the last decade, for instance, Wheaton Precious Metals, the 2nd largest precious metals royalty company, experienced, on a look-through basis to the various operators that do the actual mining, a 3.3% annualized increase in the per-ounce cash costs of silver produced. For gold, the annual cost of production rose by 4.0%/oz.

ESG-driven production costs

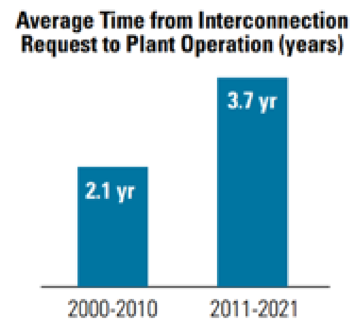
A different form of production cost inflation for energy transition metals might, paradoxically, come from ESG compliance pressures to improve environmental performance, because mining and processing is energy intensive. That's another indicator of how complex, with overlapping and recursive aspects, the energy transition process will be. For instance, energy accounts for nearly 20% of the total cash cost of copper mining, and electricity for about 25% of refining and smelting costs. Therefore, a rise in energy or electricity prices directly raises the cost of copper (or of nickel or zinc, and so forth), which raises the cost of the energy transition building blocks, whether batteries, cars, or the electricity grid.

The Electricity Grid: Transition-Limiting Factor and Inflation Vector

There were over 8,100 electric generation projects seeking grid interconnection at the end of 2021. They represented over 1,400 GW of generation and storage capacity. Over 90% was from the zero-carbon category, like solar, wind, and battery storage. Hopeful news? Less than one-quarter of them will be built.



This is a worsening situation, not an improving one. In the past decade, queue times (while projects seeking to connect to the grid await approval) have expanded from 2 years, to 3.7 years. In California, solar projects built in the last 5 years have required 3 ½ to 5 ½ years to reach commercial operation *after* getting interconnection approval.[15]



https://emp.lbl.gov/queues

The number of projects withdrawn has been rising sharply, too. Among the many obstacles are conflicting regulatory mandates between states, states and local governments, challenges in securing locations, uneconomic cost allocation by system operators to the project promoters, and applicants' uncertainty over the approval process.

This topic can't be done justice here; it could easily absorb a number of hours. The intention is to provide a sense of how entrenched and institutionalized the challenges are:

- The greatest wind and solar energy resources are remote from the population centers that they will serve. That requires new transmission lines.
- But the siting and permitting process can exceed a decade. A review of over 30 transmission projects initiated after the 2005 Energy Policy Act found that a new transmission line takes an average of over 10 years to complete[16].
- Crossing state lines further complicates the process. The 732-mile TransWest Express high voltage transmission line, from Wyoming through Colorado and Utah to Las Vegas, filed its first permit application in 2007, received its final approval in 2020, operations to start in 2026, 19 years later.

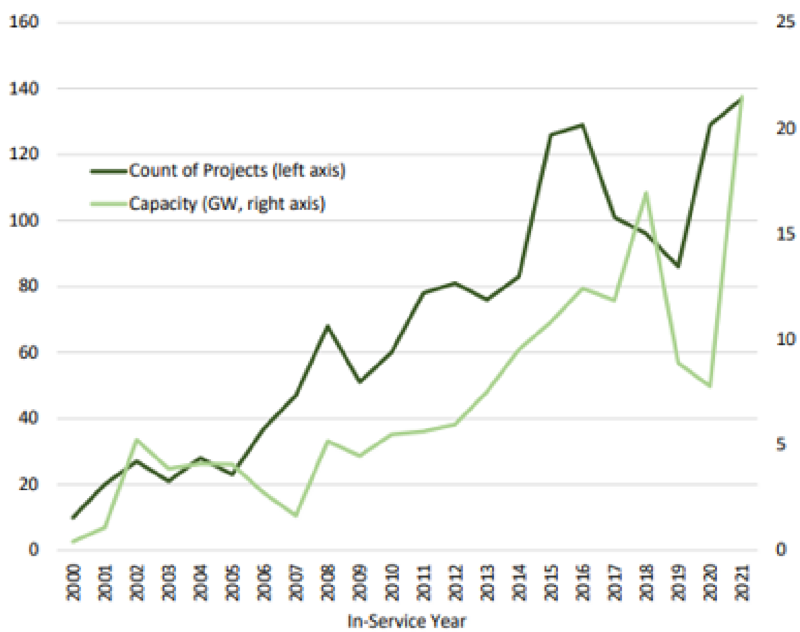
It's as important to understand the magnitude of required grid investments. A detailed scenario analysis study by the Andlinger Center for Energy and the Environment at Princeton University concluded that transmission line capacity would need to at least double by 2050[17]. There are 200,000 miles of high-voltage transmission lines in the U.S. The cost, however it was estimated, is in the trillion-dollar-plus range.

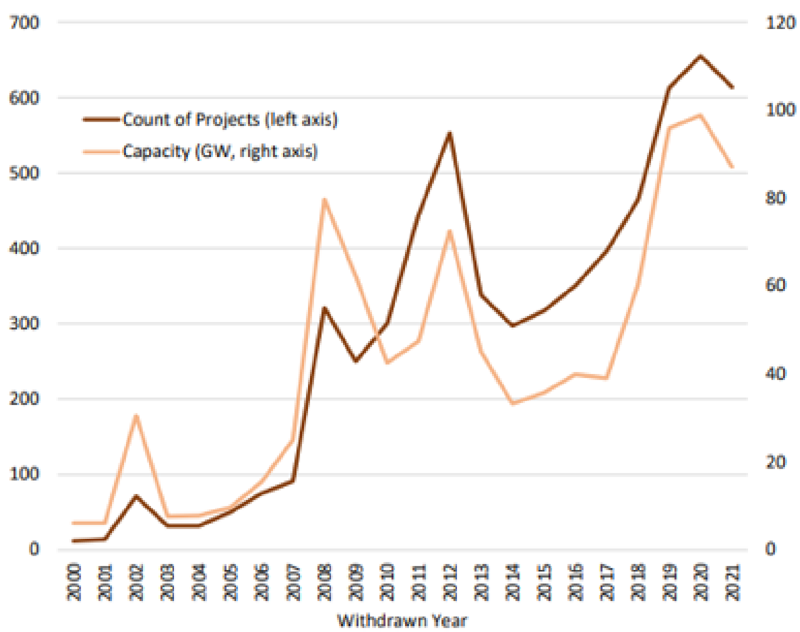
[15] https://emp.lbl.gov/queues

[16] Moch, Jonathan M. and Henry Lee. "The Challenges of Decarbonizing the U.S. Electric Grid by 2035." Policy Brief, February 2022

[17] https://netzeroameica.princeton.edu

There's more that could be covered, or covered in more detail, but which is not necessary to make the point. The point of this section is simply to suggest that among the major changes under way in our world, which seem to be pointing to an extended period of greater inflation, the transition from direct fossil fuel energy sources to solar and wind power is a new and impactful addition. It should inform investment inquiries and choices.





Lawrence Berkley National Laboratory, April 2022

Whatever noise (as opposed to signals) emanates from news briefings (root word: brief) of Fed meeting notes, CPI changes or gasoline prices, until such time that the data just described—or new data, for that matter—suggest otherwise, this is the data we find most informing.

News alert:
From the Bangor Daily News, Dec. 23, 2022

Maine utilities have been denying customer applications to connect rooftop solar panels to the electric grid. Said a representative, "We feel for these customers. Without the expensive upgrades needed to maintain system safety, we're running out of capacity." One customer's application was denied because the level of generation would cause high voltage in the system. Former MPUC commissioner David Lintell, said he dealt with the issue last year when a voltage variation led to a power surge that fried his electric car charger.

Investment Comments

A Short Word on Valuations

Much talk lately about the historically extraordinary declines in the financial markets last year. Much debate about whether the market is cheap enough to now be rewarding, or just fairly priced, or maybe not. Here, too, context can make decision-making much easier. This is an updated simple—but not simplistic—tool that brings much clarity.

Source: Federal Reserve Bank of St. Louis, U.S. Bureau of Economic Analysis; Wilshire Associates.

The comprehensive version of the P/E ratio of the S&P 500 is to compare the market value of all publicly traded stocks to GDP. It dispenses with all the underlying judgments and complexities about whether and how to make adjustments for companies that might have negative earnings, what to do about non-cash write-downs, etc., etc. It simply relates the market value that investors have jointly assigned to the entirety of public corporate earnings and/or book value and/or intangibles to the economy in which they operate. That valuation multiple remains at the highest level in 50 years, other than last year, of course.

Newer Holdings

Much as we wrote last year at this time, portfolios have been positioned in companies with business models we believe to be uniquely structured to benefit from an extended inflation, whether commodity-scarcity based or monetary-debasement based. In the past year, land companies were added to some strategies.

Land is the ultimate perpetuity and its per-capita scarcity value increases over time. Yet there are no land companies in the major stock indexes. That is both a deficit or 'negative exposure' for the indexes, and engenders a valuation discount benefit for independent investors. REITs which are the index version of real estate, because they can be packaged in large, liquid form, are an entirely different economic proposition. Contrary to popular belief, they are generally not good inflation beneficiaries. They also tend to be overpriced during periods of low interest rates, because they are sought by income-oriented funds for their dividend yields. They must pay out most of their earnings as dividends, so can't accumulate capital for reinvestment to compound their value internally. Expansion requires external funding, via share issuance or borrowing. The first choice is dilutive to per-share values; the second, if excessive, can expose the REIT to rising debt costs at a time when operating costs might rise or exceed the revenue growth from rent escalation clauses or longer-dated lease expirations.

The value of land can increase without any further investment. In the right location (the three Ls of real estate) the value can be enhanced manyfold over time through sequential levels of development. In the case of Saint Joe Company, with vast property along 80 miles of the Panama City section of Florida's west coast, diversified real estate development is ongoing. Tejon Ranch, has almost 300,000 acres strategically located by and across one of the nation's busiest intersections on the I-5 corridor one hour north of (overly congested and priced) Los Angeles. It is earlier in its development phase, having only just received approvals for a number of master planned communities, after many long years of effort, in addition to its commercial and industrial real estate.

Additional royalty companies were also added this year, bringing exposure to iron ore, copper, a range of electrification and battery metals, and even fertilizer, and even wind and solar power projects. Why, do this, aside from diversifying into a broader array of inflation vectors? Because they're too cheap. Why too cheap? Because, A) investors generally remain unaware of the true inflation risks, so they don't yet value such companies appropriately, and B) most such companies are decidedly not to be found in the world of indexed securities – call them index-unavailable.

As to volume growth possibilities, rare earth metals—praseodymium, neodymium, terbium, dysprosium—are required for the strong permanent magnets in wind turbines and electric vehicle motors. Copper is needed for everything electrical, iron ore for steel for any utility-scale construction of anything, and potash for fertilizer. As to the prices of commodities, it will not be a matter of whether Wall Street is bullish or bearish on them, or what analysts' consensus opinion is. Commodities valuations are not determined like IT growth company valuations. Ultimately, the bottom limit of pricing is the cost of production. Want some wheat? If it costs 20% more to produce, the farmer can't *not* charge 20% more, otherwise no more farmer and no more wheat. That will be the price.

Permian Basin Royalty Trust

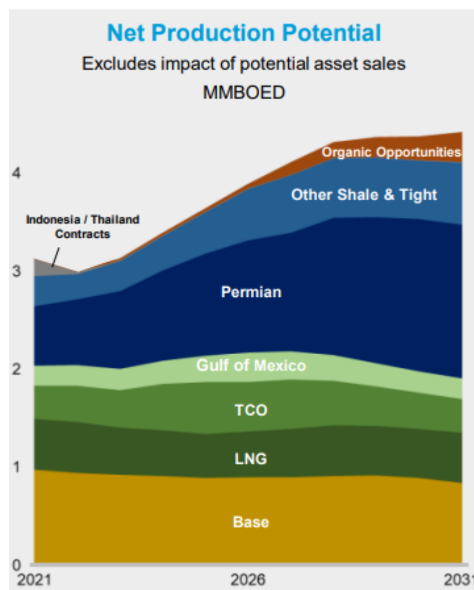
A client asked, before this call, whether Permian Basin Royalty Trust is still a compelling investment after the extreme price increase over the last year. Sometimes, information itself answers the question.

A year ago, on January 24th, the PBT shares traded at $12.75 per share, and it's now $25, so it's up 2x. Absent any context, I suppose prudence suggests cashing in the bingo ticket.

- A year ago, the run-rate monthly distribution was $0.30 per year, which was a yield of about 2.3%. The December 2022 distribution, on a run-rate basis was $0.45, for a yield of 1.8%. In September, though, it was $0.22 for the month, which would have been $2.68 on an annualized basis. That's up 9x, and would be over a 10% dividend yield. So, which is it, a $0.45 annual dividend or $2.68?
- PBT is an unusual royalty company in that it gets exceedingly high royalty rates, between 37.5% and 50% of the operator's revenues on its Waddell Ranch property. It also, unusually, is indirectly responsible for a share of the operator's expenditures. The operator has been making significant capital expenditures, the purpose of which is to increase output. A share of those expenditures has been withheld from PBT's royalties until they are effectively paid.
- That capital expenditure program, which is uneven from month to month, is subsiding. At a much lower estimated 'maintenance' level of spending, the annual PBT distribution this past September could have been about $3.36 per year, a yield of 13% and 11x the distribution rate of a year ago.
- In addition, those expenditures should result in significantly higher production volumes, which would further increase PBT's royalty revenues. In the company's December distribution announcement, it stated that production was over 60% higher than a year earlier, so that will give some indication of the productivity of the capital investment program.

Crane County, where the Waddell Ranch is located, is one or two counties east of where most of Texas Pacific Land Corp.'s royalty interests are located, and hasn't been much developed by the large oil companies. Nevertheless, an indication of the direction of activity in that region is provided by the capital expenditure plans of the significant drillers there.

- In December, Chevron announced that its 2023 capital expenditure budget would be 25% higher. In the U.S. its oil exploration and production budget will be $8 billion, and half of that is allocated to the Permian Basin. The company expects to get a greater and greater share of its total global production from the Permian. This is where it's at for Chevron.
- ExxonMobil is generally less specific than Chevron. It announced that more than 70% of its capital investments in oil and gas production would be deployed in the Permian Basin, Guyana, Brazil, and LNG projects.



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Income

Another, almost unavoidable, opportunity on the horizon is a disruption in the bond market. Yes, another disruption not yet in evidence. In the past 12 months, the marginal cost of corporate borrowing has doubled. There hasn't been time for these interest cost increases to filter into companies' income statements. But, they will. And it doesn't take much to tip many a BBB-credit into the BB non-investment grade category. Meanwhile, during the zero-interest rate years, investment grade bond funds came to rely heavily on that lowest rung of corporate credits, the BBBs, for extra yield. When those downgrades ultimately occur, those index funds will be, at one and the same time, both price-insensitive and time-sensitive sellers. If history is a guide, there may be many interesting opportunities, both for income-oriented and, possibly, equity accounts.

Horizon Kinetics is also developing a new fund, with an entirely different mode of generating a traditional bond-level of interest income plus substantial equity optionality that does not entail any equity level risk. It is also structured to avoid the always real risk of a further rise in interest rates, since the effective maturity profile is very short. It has some very interesting characteristics. There should be more to say about this by the time of our next Commentary.

New Asset Class

Among the interesting new funds we introduced this year—the hope is that any investments we bring to your attention can only be called interesting—is one that helps address the pressing need for true return diversification. This one is the Diamond Standard Fund, launched in partnership with Diamond Standard Ltd. Enabled by patented computer technology, Diamond Standard transforms algorithmically selected packets of diamonds into a tradeable, fungible commodity, each of precisely the same value, 500x more value-dense than gold bars. That was previously impossible, each single diamond being unique. But, with such transparency, there is now trading a new, global scale and well-known asset class, uncorrelated or negatively correlated with gold and other asset classes, and accessible to individuals and institutions. As to price development, as in all human economic endeavors, supply relative to demand is the determining factor.

The addressable demand for portfolio-allocable commoditized diamond 'coins' and 'bars' (initially denominated, respectively, as $5,000 and $50,000) is immense, and, moreover, for an asset manifesting declining long-term production supply.

Cryptocurrencies

We would be remiss to not mention our exposure to fixed-supply cryptocurrencies (bitcoin, which we introduced in 2016, as a then-border-of-de minimis holding, in a variety of strategies). Though currently (and maladroitly) maligned, it remains a strategic allocation for the looming stretch of structurally high inflation. The prospects for such technologies and assets are abundantly clear to most who dedicate the proper time and attention to objective analysis. However, the worst actors in a nascent industry can temporarily obscure its value proposition.

Just two current observations relevant to many of you, but by no means anywhere near a proper discussion:

Relative to the FTX episode, it is clear that people still don't distinguish between what was simply a case of fraud, which could as easily have happened with dollars, and cryptocurrency. That they don't is evidenced in the 50% discount to net asset value at which the Grayscale Bitcoin Trust trades. It's important to first understand that FTX was not a securities exchange. Rather, it was a brokerage firm that just called itself an exchange, which under U.S. law is not even legal. Therefore, the collapse was of a broker and had no direct relevance to the operation or legitimacy of blockchain technology or the business of mining.

This has created an interesting valuation discrepancy in a number of the Grayscale Trusts, including the one for bitcoin. It is clear that people don't yet distinguish that these assets are on the blockchain, because the Grayscale Bitcoin Investment Trust now trades at a 50% discount to its net asset value. The Trust is audited, meaning it has full transparency, with unrelated parties looking at the statements and checking all the figures. [18] It is in no manner even remotely close to the FTX circumstance. For the moment, that is not yet understood by those who read or hear uninformed assessments.

As to the discount, the mere return of the Trust's share price to the market value of the holdings means a total return of 100%. If that were to take a year, that would be a 100% annualized return; three years, a 25% annualized return, even if the price of bitcoin never rises. Eventually, whenever 'eventually' occurs, the Trust is likely to become an ETF, in which case it's going to trade at net asset value at that time.

[18] https://grayscale.com/safety-security-and-transparency/?sfclid=003f400000nPHVVAA4

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The charts in this material are for illustrative purposes only and are not indicative of what will occur in the future. In general, they are intended to show how investors view performance over differing time periods.

Past performance is not indicative of future results. The information contained herein is subject to explanation during a presentation.

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