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Three emerging forces influencing the Great Energy Transition:

Higher for Longer Interest Rates, Deglobalization, and Clean Technology Realism

John A. Cook, CIM
Senior Vice President, Portfolio Manager, Team Co-Lead
Mackenzie Greenchip Team

There are three developments that could both speed and slow the Great Energy Transition as we head into 2024:

1. A realization that inflation will be more persistent. That it was not solely related to COVID driven supply chain disruptions, or the result of profligate government spending, but something more structural – the supply demand imbalance caused when eight billion people clamor for declining resources on a finite planet. Central banks' rate response may actually have to be, "higher for longer", creating both headwinds and valuation opportunity for the great energy transition.
2. In a world of increasing geopolitical, energy, and supply chain *insecurity*, some level of deglobalization now seems certain.
3. The excessive hype surrounding economically uncompetitive clean technologies will start to wane.

Below is a condensed version of a speech that John Cook recently gave to a group of institutional investors in London, England on November 9th, 2023.

We are still in the early days of the energy transition

Any energy transition discussion will be more robust following a review of our existing global energy complex, starting with energy consumption, which is approaching 14 billion tons of oil equivalent energy each year. In dollar terms, at today's oil price this is about $8 trillion, or 7-8% of 2023 global GDP. Most of us struggle with orders of magnitude and I thought Vaclav Smil used a helpful analogy in his most recent book, "How the World Really Works". He described our use of energy like this, "it is as if 60 adults would be working day and night, for each average person (on the planet) …and for the inhabitants of affluent countries the equivalent of steadily laboring adults would be closer to 240" *…each day…365 days a year…times eight billion of us!*

It is not just scale it is also the complexity because the energy we consume comes from so many sources. Of total consumption, 82% of primary energy still comes from fossil fuels, about a third each from coal, oil and natural gas. The rest are biomass, hydro, nuclear, wind, solar, and geothermal, roughly in that order. From these sources, we turn about 18% into electricity. Of that, only 17% is truly renewable. Add nuclear generation, and we get to about one quarter of our *electricity* system that is "low carbon". As such, the vast majority of the energy we consume is neither renewable nor low carbon. And because so much primary energy is still combusted in highly inefficient ways – we are still decades away from a *sustainable* energy system.

Scale and complexity, however, doesn't mean the *transition* won't happen. If we want to maintain anything near our current way of life, we literally have no choice but to transition. First, we *will* run out of fossil fuels. To date we have discovered *only* 50 more years of oil and gas in the earths' crust based on todays' consumption levels. While we can probably find more, each barrel we do find will almost certainly cost more to extract than the last. And any investment in fossil production will need to compete with other *relatively* cheaper and cleaner energy sources.

Most believe our energy future will increasingly be electrified. Global electricity demand has already been growing at about 2.8% a year over the past decade. At this rate, demand for electrons will double in the next 25 years. Faster still as we increasingly connect EVs and install heat pumps, and so on. All the while, our existing electricity system continues to age. Few realize that our global nuclear reactors are now nearing 50 years old on average, a similar age to the grid level transformers in North America. The International Energy Agency recently estimated that 80 million kilometers of power lines will need to be replaced or added by 2040 to meet growing electricity demand.

To summarize, the global energy system is massive and complex. Despite the trillions invested to date, we're still in the early days of transition, yet the transition is facing an array of relatively new challenges today.

Higher for longer interest rates

Until Q1 2022, low interest rates, have mostly been a tailwind for the transition.

Annual clean energy investment has almost doubled in the past decade. According to Moody's Investor Services, global sustainable bond issuance is on track to hit $950 billion USD in 2023[1]. Global green bond issuance has now surpassed the entire US high yield market in scale. However, the appetite for green debt is starting to wane as rates increase.

There can be little doubt that low interest rates accelerated the installation of utility scale generation. At the consumer level, low-cost financing also drove rooftop solar installations, heat pump sales, and electric car leasing activity. Arguably, government programs like the US Infrastructure Act, The Inflation Reduction Act, and The European Green Deal, were born into a low-rate world, as were a cadre of "impact investment" strategies. Low rates have accelerated the transition.

Will higher rates do the opposite? So far, it seems they might.

For example, the list of write downs, penalties, and exits is growing for renewable developers. Last summer we saw Avangrid and Eversource Energy pay penalties to walk away from offshore wind developments. Avangrid's penalty alone was $48 million, an amount that seems like "dresser change" compared to the $5.6 billion write-down Orsted took last week on two New Jersey offshore wind developments. And the ongoing battle between Brookfield Asset Management and AustraliaSuper over the value of Australia's integrated energy company, Origin, shows how "higher for longer" in the very least, is creating asset price uncertainty.

A billion-dollar infrastructure project today faces about $50 million more in annual project financing costs than it did just two years ago. Investors adjust their models accordingly, which is partially why renewable energy benchmarks are down over 30% year-to-date.

Economists and environmentalists, however, might look at "higher for longer" through a different lens. Lower rates supercharged consumption. Over the past decade the world purchased more *stuff* than it really needed, particularly in the West. Profligate consumption exacerbates resource scarcity challenges, stresses the environment and our energy systems, and steals away from our ability to save.

Greg Payne, the *other* lead portfolio manager at Greenchip, who also happens to be an economist, has been reminding me for years that capital formation can only truly come through *savings*. He often repeats, "Central bankers can print money, but they cannot print *capital*". Higher rates should incentivize saving, in time, this should lead to greater capital formation, and capital investment. It is a *theoretical* argument, however, that takes time to play out. As such, the debate over the effect of "higher for longer", is somewhat related to time horizon.

In the very least, I think we can all agree that rates near zero created economic distortions. Investors fixated on low capital business models, ones that don't make physical things: technology platforms, entertainment content, financial services, and most recently artificial intelligence. At the same time, investors showed little interest in financing new mines or manufacturing capacity. Greg and I still recall a mobility conference in Boston several years ago. We were there hoping to hear about battery chemistry advances and EV manufacturing techniques. Instead, the organizer started the conference with this announcement, "folks, capital investment is dead, the future is all about digital platforms", and went on to discuss the value of data collected by an electric scooter business he was hyping. This is partly what zero interest rates have done.

Sadly, most executives running "low capital businesses" don't even know what to do with the capital we do send their way. They buy back shares, dividend out free cash or hide it in tax havens. They overpay for acquisitions, they overpay *themselves*, and invent products most of us don't even need. Did we really need a 15th generation iPhone… albeit encased this time in *titanium*? Worse still, Apple's Reality Pro goggles that enable you to watch the kids and Netflix at the same time? Sadly, this is what gets investors excited these days, at a time when capital investment is so obviously needed just to keep our lights on or, ironically, to charge those virtual headsets!

My view is that "higher for longer" is likely a long-term blessing that will create a near term bump for the energy transition.

Deglobalization

Offshoring manufacturing to emerging markets long predates the founding of Greenchip in 2007. On reflection, however, I believe manufacturing leadership positions in many of the most important environmental technologies were still available to the West at that time. For example, the United States and Germany battled with Japanese manufacturers like Toshiba and Panasonic for solar module manufacturing leadership. The West processed enough polysilicon, the key ingredient in most solar cells, to support growing domestic manufacturing. Today, however, China produces over 80% of the world's solar modules and the top ten producers are all Chinese. Only Wacker Chemie based in Germany produces solar grade poly at scale, yet there is not nearly enough of it to support the US, let alone German demand. It seems like a massive failure of industrial policy that the West let such an important industry slip away.

Electric vehicle manufacturing has a more *nuanced* story. GM famously "killed the electric car" in 1999, however by 2008, Tesla had released its first "Roadster", and Tesla has arguably gone on to become the premier *global* EV brand. But Mr. Musk might want to tone the hubris, *significant* competition is coming.

What I witnessed on a recent EV and battery tour in China was, frankly, gobsmacking. It is not just their manufacturing *scale*, but the level of *automation* that challenged my preconceived belief that their advantage was cheap labour and government support. The risk taking and capitalistic culture was surprisingly impressive.

China now manufactures 66% of all batteries sold in the world but it is their complete dominance over the components that is most alarming. According to The New York Times, China now controls: 77% of cathodes, 74% of separators, 82% of electrolytes, and 92% of anodes. Perhaps more challenging for the West is that China also controls between 60% and 95% of manganese, cobalt, graphite, lithium, and nickel - all the key materials for battery production. China also seems to be hedging its bets on emerging battery chemistries. CATL, the largest battery manufacturer in the world for example, manufactures NCM, LFP, and sodium batteries. They are experimenting with combinations of different cells in battery packs, including their new LF…M…P chemistry. Their combinations of cells to maximize different performance attributes is bringing costs down and performance up. It seemed a more pragmatic approach than the *all-in* single chemistry bets that the Koreans, or even US cleantech darlings like QuantumScape have made. And while billions for battery manufacturing plants have been announced in the past year in countries like Canada and the US, there has been unconvincing discussion related to battery materials supplies. We are years behind!

To give time and assistance to sectors like solar, batteries and EVs, Western governments have been slapping significant tariffs on Asian imports.

One thought is that deglobalization, might help us rebuild more *resilient* supply chains, and in time, create a more even transition.

There will, however, be interim pain – deglobalization is incredibly inflationary. Consider that the average solar panel installed in most parts of the world now costs about 14 cents per watt. In the United States, however, the price is about 35 cents…after the various tariffs are added. Interestingly, solar modules are only about 25% of overall installation cost, as such, the tariffs have *slowed,* but not killed solar installation.

The cost difference between Chinese and Western EVs, however, is more meaningful to adoption rates. Chinese OEM BYD saw its sales go from zero to 13% of the German EV market – in only one year[2]. Why? Their Model 3 type car was almost half the price of Tesla's. I listened to a former German Finance Minister discuss this conundrum in Copenhagen in September. He warned, "If Germany slaps anti-dumping tariffs on BYD, China will reciprocate with tariffs on BMWs and Mercedes". I can tell you that I saw *a lot* of German luxury cars in China last month.

For those that see EVs as an energy transition technology, the West could arguably transition faster by importing less expensive Chinese cars. The EV adoption rates back this up: EV sales will be less than 8% of total US car sales in 2023 vs. 18% globally, and currently over 35% in China.

In summary, Chinese solar, battery, and EV manufacturing capacity could help speed the energy transition, at least in the near term with less deglobalization. I will be interested to hear your thoughts.

The realities…and limitations…of energy technologies

For years, technologists have argued that humans have a history of invention, and that *disruptive* technology would solve both our energy predicament and save us from the worst of climate change. The most vocal of these often had made fortunes in the digital revolution. The energy transition, however, is less about moving electrons and digital packages, and more about heating, cooling, and reorganizing molecules – a world where the laws of physics matter. For this reason, many hopeful energy solutions have eventually been laid bare as fanciful "perpetual motion machines".

I believe cleantech investors are finally becoming more cynical about several clean technologies – and that is a good thing. Here are a few examples: Functional *nuclear fusion* is increasingly seen as a scientific crapshoot that remains at least two generations away. The stock prices of hydrogen electrolyzer and hydrogen fuel cell manufacturers, suggest investors are questioning the economic competitiveness and/or narrowness of application – their enlightenment is well founded in my opinion. Most biofuels, green ammonia, hybrid steel, gasoline electrolyzed from seawater, also come to mind. Many early-stage green energy technologies have ended up using more energy than they produced. Others required significant electricity cost declines to become competitive. Over the past decade, the cost for wind and solar electricity generation declined significantly, however, these learning curves may now have bottomed. As such, our team believes some of these technologies will never close their greenium cost gaps.

There is a flip side to this emerging technological pragmatism. The faster we acknowledge a technology cannot work; the more capital that can be allocated to solutions that do. Our experience is that clean technological advances are more likely to be *incremental than transformational*. A useful mindset that keeps capital away from long-shot science projects.

I am not suggesting governments and universities abandon their basic research programs or that venture investment be curtailed. I am suggesting, however, that investors embrace a higher level of diligence and skepticism than we've exhibited in the past few decades. At the same time, they should carry the optimism that *incremental* technological advances have value. Consider the following:

1. In the past ten years, we have likely replaced 80 *billion* incandescent lightbulbs around the world with LED luminaires. This would have cut the energy consumption related to lighting by about 80% – Stunning! And yet, LEDs were a 1960s invention. It wasn't until the discovery of *blue light* LEDs by a trio of Japanese scientists thirty years later that the adoption of LEDs for general purpose lighting became possible…blue light was the *incremental* breakthrough.

2. Consider modern solar photovoltaics, they were a 1950s invention. Originally costing a small fortune with energy transfer efficiencies less than 10%. Sixty years later when Greenchip was founded, solar *still* required massive subsidies to compete. However, in the past decade we have seen photovoltaic costs decline from $5 per watt to 14 cents – Let me repeat, *five dollars* to 14 cents[3]! While part of this was related to scaled manufacturing, the list of incremental advances in efficiencies has been mindboggling: Polysilicon to mono, to bi-facial, to PERC and p-type doping, to the latest TOPCon n-type doping. Today, modules are widely available with 26%+ efficiency[4]. Incrementalism can be totally disruptive. Today, annual investment in clean energy exceeds fossil CAPEX by over $400 billion[5]!

3. The same story is playing out with high energy density batteries. Incremental breakthroughs in chemistry, form factor, materials reduction, and so on, have driven prices down 80% in a decade. They are closing in on the economic inflection point with gasoline powered cars. I believe we'll get there.

Every time I think *existing* technologies reach performance and/or cost maturity, incremental advances seem to lower costs and improve performance. Allocating more to *existing* clean technologies, and less to *disruptive* ones, will in my opinion speed the transition. Again, I will be interested to hear your thoughts.

Final thoughts – what it all means for Energy Transition investors

Despite a strong rally in the past few weeks, 2023 has been a very challenging year for Energy Transition investing. Year-to-date, in USD, most clean *energy* Indexes are down more than 30% and The Cleantech Index, a good proxy for broader environmental sectors, is down 17% (as of November, 2023). Benchmarks and strategies doing better almost always include some members of the "magnificent seven" that in my opinion have nothing to do with the energy transition.

If you ask me what the outlook is from here, well I believe some stocks have over corrected. That said, I think it partially depends on how you see: **Higher for Longer Interest Rates, Deglobalization, and Clean Technology Realism playing out.**

1. Source: Bloomberg, July 2023 Sustainable Bond Issuance to Hit $950 Billion in 2023: Moody's – Bloomberg
2. Source: InsideEvs, September 2023Germany: All-Electric Car Sales More Than Doubled In August 2023 (insideevs.com)
3. Source: IEA, 2023 Overview and key findings – World Energy Investment 2023 – Analysis – IEA
4. Source: PV Tech, July 2023 Astronergy leading TOPCon cells toward 26% average conversion efficiency era – PV Tech (pv-tech.org)
5. Source: IEA, 2023 Overview and key findings – World Energy Investment 2023 – Analysis – IEA