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# The New Joule Order

**Security is now paramount.** The energy transformation is on the cusp of reaccelerating. Nuclear and renewable energy are likely to continue to expand rapidly in the years to come. Fossil fuels, however, will also expand—just more slowly—as natural gas replaces oil and coal fades. Climate concerns, however, will not be the main driver of *The New Joule Order*. It will be driven by the quest for security, with nations creating a diversified energy mix of joules across multiple sources to insulate themselves (and investment portfolios) from geopolitical, macro, and financial risks.

**Security drives higher returns and faster transition.** Fossil fuels are attractive as they can be traded. *If trade is under threat, then so are fossil fuels*. Non-fossil fuels are generally not traded and hence are local. These types of fuels thus become more demanded when security is paramount, which historically drives a more profitable, cleaner, and faster transition. The security-motivated transition (1973-1993) seen after the first oil crisis was about the same – if anything, 30 basis points per annum faster – than the Net Zero-motivated transition of 2010-2024.

**"Peak Oil" has already arrived as "Peak Trade."** Fossil fuels are not disappearing any time soon. However, we are now likely seeing "Peak Oil Trade," particularly from China. If consumers are able, they will try to reduce their imports of fossil fuels, which in most cases will mean increasing their supply of nuclear and renewable energy. The green premium has already faded and the market is in search of a security premium.

**The investment thesis is strong.** Investors have been overly fixated with how energy is produced at the expense of how it is consumed (i.e. levelized cost of energy (LCOE) over return on equity (ROE)). But all consumed energy is the same—it's a joule. Produced energies differ—a molecule of oil, an electron of electricity, a tonne of coal. The legacy of the Net Zero 2050 investment boom (arguably, 2010 through 2021) is that it made renewable energy cost competitive, but did not resolve system bottlenecks. Instead, malinvestment and grid congestion followed. As a result, forward demand expectations suggest that some energy sources for joules, particularly fossil fuels and nuclear energy all remain substantially underinvested relative to forward demand expectations.

## EXECUTIVE SUMMARY

→ **Time to focus on security**

Investors remain focused on two long-standing, interconnected themes: electrification and digitalization. AI represents the latest evolution of a technological shift that began with the internet over fifty years ago, while today's push for decarbonization is accelerating a century-long trend toward electrification. But a third theme—security—has emerged as both a constant concern and a newly urgent priority. This growing emphasis on security is reshaping the landscape of decarbonization and energy investing, driving a new era that promises to be more efficient, effective, and ultimately, more profitable.

→ **Bretton Woods defined the oil age**

The global framework established at the end of World War II—anchored by the Bretton Woods system—has been under mounting pressure for decades and is now fracturing. If the dollar was the heart of Bretton Woods and the US Navy its muscle, then oil was the lifeblood flowing through its veins. By shouldering the burden of global security, the United States enabled its allies—and eventually Russia and China—to structure their economies around a stable and predictable oil trade. Now, as that system unravels, the future of energy and geopolitics is entering uncharted territory.

→ **Oil dependency created security vulnerability**

As the largest producer of oil, the United States promoted global trade in oil at the end of World War II. The proliferation of the oil trade created a level of prosperity and energy dependence that had never been seen before.

→ **US energy independence helps end Bretton Woods**

Shortly after Bretton Woods, the United States become a net importer of oil and had an incentive to protect global supply lines. The shale revolution made the nation a net petroleum exporter, which has decreased US interest in protecting sea lanes. Because the United States is now energy independent, it is not safe for other countries to be energy dependent.

→ **Security first, economic efficiency second, environment third**

When nations' desires for energy security, economic efficiency, and environmental progress come into conflict, governments reveal their preferences with their actions. Germany, for example, was quick to return to lignite coal in 2022 when Russian natural gas imports were cut. However, it's also true that when these goals are mutually compatible, governments are quick to take advantage. For example, President Nixon used the oil crisis as an opportunity to reduce pollution in the United States in the 1970s.

→ **China prioritizes energy security**

China did not build its cutting edge nuclear and renewable power, energy storage, and electric vehicle industries in response to the Paris Agreement in 2015. Instead, China began its energy transition in 2000 by setting goals for energy security and economic freedom. As a result, Chinese fossil fuel imports peaked in 2019.

→ **Europe lags in prioritizing energy security**

Europe is more vulnerable than ever before. Due to domestic energy divestment policies, it now imports 54% of its energy—nearly all in fossil-fuel form—which is a record and higher than 20 years ago. Europe critically needs domestic energy production alongside defense.

→ **Tariffs speed the replacement of the green premium with the security premium**

Tariffs, including border adjustment taxes, are used to encourage local production, even if it leads to inefficiency. Local energy can command a premium as nations are willing to pay more to secure supply. Thus, a tariff and a security premium are analogous to a carbon tax and a green premium—and may be more effective at spurring transitions. France has one of the lowest carbon footprints in the world, but it didn't get there because its leaders wanted to save the climate—it got there because they wanted energy independence.

→ **Defend with an eco-system of diversified energy assets**

Neither fossil fuels nor renewables are going away. In the New Joule Order, every country will require a different optimal mix of energy sources which balance natural endowments with economic and security priorities. As this evolution occurs, investor portfolios will mirror national portfolios. And just as a diversified energy mix will insulate national markets from geopolitical as well as economic shocks, a well-diversified portfolio of energy assets will insulate investors from macroeconomic and financial volatility.

→ **There is no diversification without electrification**

Different fuels will compete to supply joules through an increasingly connected grid. The grid will connect markets that are geographically close, with batteries bridging short-term gaps. Natural gas will serve as the balancing joule, providing the marginal joule needed over longer periods. Electrification helps to further unlock the embedded optionality in energy assets, thus increasing their value.

→ **Capital and liquidity are becoming scarce**

It is no coincidence that the Net Zero 2050 narrative gained traction during a zero-interest-rate era that was largely predictable. With higher rates, investors must now make more deliberate allocations. Choices had little cost and duration was nearly infinite. Higher rates now mean harder choices.

→ **Actively managed private markets are necessary**

Policy-driven energy security initiatives will continue to create misallocated investments while market volatility increases due to geopolitical and climate-related shocks to supply and demand. With rates at zero, active management was compromised as market discipline eroded and malinvestment set in. However, in a normalized rate environment, the return of market discipline means active management is once again critical.

→ **Fossil fuels and renewables are counter cyclical**

Diversification to manage the cycle—combining fossil fuels, renewables, and nuclear energy in the form of joules allows investors to navigate market cycles more effectively. This diversification encourages strategic deployment and exits across sectors with negative correlations—helping mitigate one of the biggest obstacles to generating returns in energy.

→ **Less money will mean more credit**

Private credit will play a bigger role alongside private equity, as investors require assets to be self-liquidating in a world of higher rates, higher inflation, and greater uncertainty. The choice of credit or equity will be driven by the structure of the cash flows and the balance between fixed and variable costs. We believe investors will accordingly be more dynamic in their allocations to private capital and private equity.

# I. The New Joule Order

Investors have recently been focused on electrification and digitalization, two interlinked themes—there are no joules without bits—that have been around for decades. AI is the latest chapter in a story that began with the internet, while decarbonization is the most recent driver of the steady growth in electrification that began over a century ago.

There is a third theme, however—one that has been developing for decades but now come to the forefront: the shift in the postwar institutional order.

During the postwar era, two broad conditions characterized most of the developed world: the world was relatively safe, and capital was easy to access. This stability was largely supported by the institutional framework set in place by the United States amidst the ashes of World War II. That global framework has been under increasing pressure for decades and is now breaking down.

It's not a coincidence that the Net Zero 2050 narrative gained traction in a zero-interest-rate world that was largely predictable. Choices had little cost, and investment duration was nearly infinite. Large investments could be made in the present based on uncertain long-term outcomes.

Similarly, it is no coincidence that AI matured in the same environment. AI's roots can be traced back to the same American security complex that birthed the internet—AI being a logical extension of it—and was nourished by the same abundant liquidity. Investors could gamble with negative earnings in hopes of distant future growth, in the same way that they could herd into renewables in hopes of a decarbonized future.

All of this was predicated on a security and financial order underwritten by the United States—an order that may now be ending. It's no coincidence that this shift is occuring at the same time the macro trend is reversing towards structurally

*Figure 1.*
**Reducing imported fossil fuels enhances security**

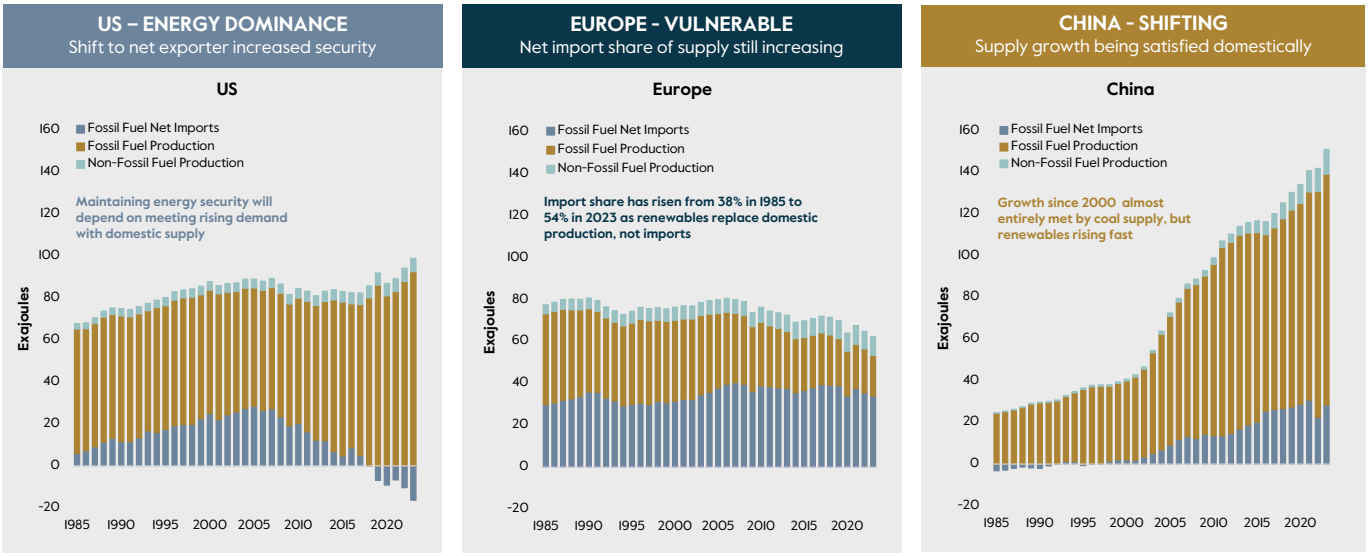



Figure I. Source: Carlyle Analysis; Energy Institute. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

higher interest rates which increases the financial burden of maintaining the old world order—which defined the Oil Age. Electrification and digitalisation will remain key investment themes in the New Joule Order, but both the motivations and mechanisms are changing rapidly—reshaping the investment environment in the process.

To understand the importance of energy security and how Peak Oil—now defined as Peak Oil Trade—can drive an energy transition, it is instructive to examine how energy security in the United States, China, and Europe has evolved over the past 40 years.

The critical assumption now shifting the old-world order that made oil trade secure and encouraged energy dependence. As the United States transitioned to a net oil exporter post-Covid, its incentive to protect global shipping lanes waned. It is no coincidence that this also coincided with peak fossil fuel imports into China, as the country shifted towards domestic fossil fuels, locally-sourced renewables, and nuclear energy.

In fact, China is transitioning faster even faster than Europe. In contrast, Europe's energy vulnerability has increased, with fossil fuel imports rising to 54% of its energy supply—making energy independence and defense spending a priority in the New Joule Order.

Not only does The New Joule Order put an emphasis on security as a key driver, but it also emphasizes delivered energy to consumers in the form of joules. Delivered energy holds greater value than produced energy, which emphasizes return on equity (ROE) as opposed to achieving the lowest levelized cost of energy (LCOE).

Prosperity depends on having energy available where and when it's needed—not merely on the ability to produce it. For a country to thrive, energy must be reliable and accessible, rather than intermittent and dependent on factors such as when the wind blows or the sun shines.

Conversely, energy scarcity leads to economic decline. In the New Joule Order, the quest for energy security will drive investors toward:

1. **An ecosystem of diversified energy assets**—fossil fuels, renewables, and nuclear—that leverages embedded optionality. For example, a natural gas peaker next to a solar farm drives greater portfolio diversification, higher long-term returns, and substantially lower volatility.

2. **Diversification to manage the cycle**—combining fossil fuels, renewables, and nuclear energy in the form of joules allows investors to navigate market cycles more effectively. This diversification encourages strategic deployment and exits across sectors with negative correlations—helping mitigate one of the biggest obstacles to generating returns in energy.

3. **An energy security premium that is already replacing the green premium**, as the focus shifts from producing electrons at the lowest cost (LCOE) to delivering joules at a return (ROE). Tariffs and border adjustment taxes can incentivize secure, localized energy production. Without a carbon tax, the financial motivation for green energy fades at higher interest rates, analogous to the impact rising tariffs have on security premiums.

4. **A fixed-return/variable-return asset divide to replace the green/brown asset divide.** With industrial policy firmly entrenched, current environmental classifications are now being replaced with a divide based upon cash flow profiles. There are "tolling" assets like nuclear and renewables that require fixed-returns to attract capital, and "trading" assets like storage and upstream that are variable-return assets.

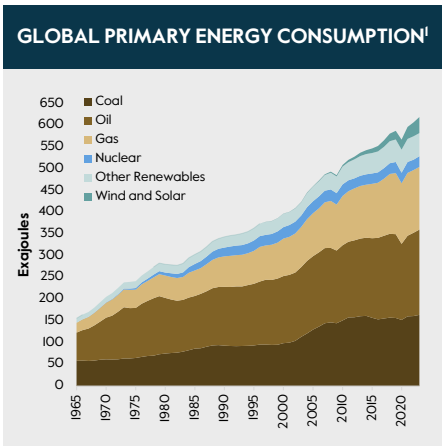
5. **A greater role for active management and credit allocation.** All of this requires more active management, and a shift in allocations to include more credit alongside equity as the New Joule Order takes hold.

The investment thesis is stronger today than before. Following the 2022 rate hikes and the 2023 decline in energy prices, investment in all energy sectors declined from levels that were already inadequate for long-term growth. Importantly, companies that pursued a diversified energy ecosystem, such as the large integrated US IPPs, stand out for having risen in value since 2023.

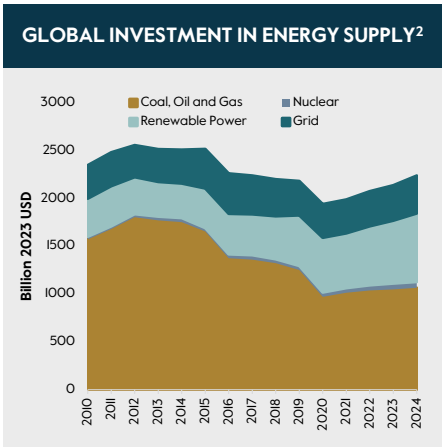
The bottom line is the investment evidence for this approach is solid. To understand why security will motivate the New Joule Order and why a diversified ecosystem of energy assets is an optimal way forward, it is critical to review its evolution.

*Figure 2.*
## Growth in demand for joules is steady while investment in supply of joules is inadequate

**Global joules consumption has grown at a steady 2.5% annual pace over the past sixty years**




**Real joules investment has yet to recover from EM crisis of 2015...**




**Order books show coming surge in capex tied to demand but not supply**


Figure 2. Source: Carlyle Analysis; Energy Institute.. 2) Source: Carlyle Analysis; Goldman Sachs, January 2025. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

# II. The Evolution of the New Joule Order

**SECURITY DRIVES A FASTER—AND POTENTIALLY GREENER—TRANSITION**

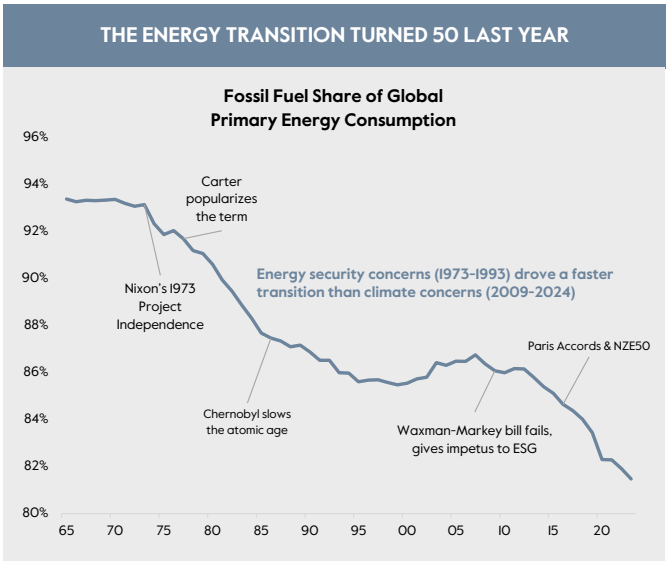
The energy transition as we define it today—a shift away from fossil fuels—did not begin with the Paris Accords in 2015. It started in 1973 with the first oil crisis, which prompted a global focus on energy independence, particularly in the United States.

The reason we use fossil fuels is because they are storable, portable, energy dense, and easy to use. This means they can be moved from where they are abundant to where they are needed—thus facilitating industrialization and economic growth.

It is crucial to note that, at least for the moment, there is still no energy trade without fossil fuels. Accordingly, one of the most attractive characteristics of fossil fuels is that they can be traded. For better or worse, economic prosperity has come to depend on the seaborne oil trade. So *if trade is under threat, then so are fossil fuels.*

In contrast, non-fossil fuels are not traded and grow in demand when energy security is paramount. This can be seen in the 1970s and early 1980s, prior to Chernobyl, when nuclear energy rapidly replaced oil consumption and renewables become a viable alternative.

*Figure 3.*
Security has driven the transition fast than environment



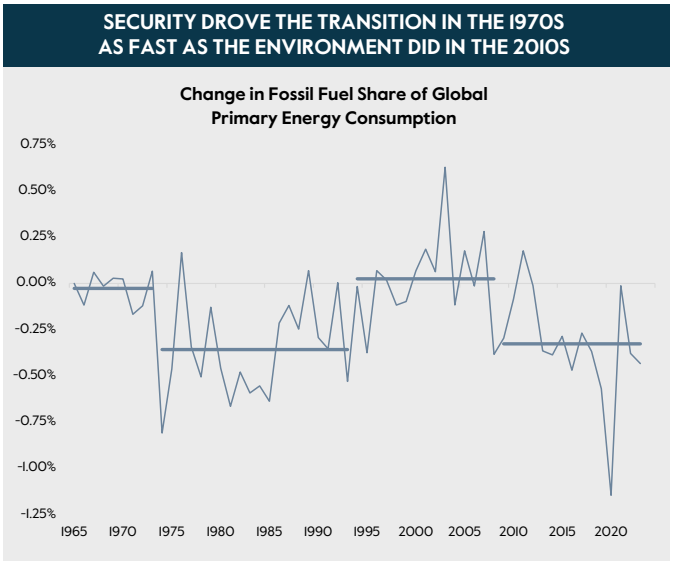




Figure 3. Source: Carlyle Analysis; Energy Institute. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

Energy independence can accelerate transition faster than environmental concerns or even economic efficiency. Empirically, the energy security era (1973-1993) produced an energy transition that added nuclear and renewables the same pace, if not marginally faster by 30bps, than the Net Zero 2050 era (2014 to 2024). The energy security transition reduced fossil fuels from 94% to 85% of total joule consumption, whereas the Net Zero 2050 transition took it from 85% to 81%.

In an era where "how we get our energy" is more concerning than "if we will get our energy," a carbon tax is most efficient way to discourage fossil fuel consumption, even if organizing a global carbon tax is a daunting challenge. At the same time, green energy can command a premium as consumers are willing to pay more in order to reduce pollution. However, when access to energy itself becomes uncertain and interest rates rise structurally, the green premium disappears, particularly in the absence of permanent carbon taxes.

Tariffs are frequently used to encourage local production, even if it leads to inefficiency. At the same time, locally produced energy can command a premium as nations are willing to pay more to secure supply. Thus, a tariff and an energy security premium are analogous to a carbon tax and a green premium—and may be more effective at spurring energy transitions. After all, France has one of the lowest carbon footprints in the world, but it didn't get there because its leaders wanted to save the climate—it got there because they wanted energy independence.

*Figure 4.*
## Security and profit motives can reduce emissions

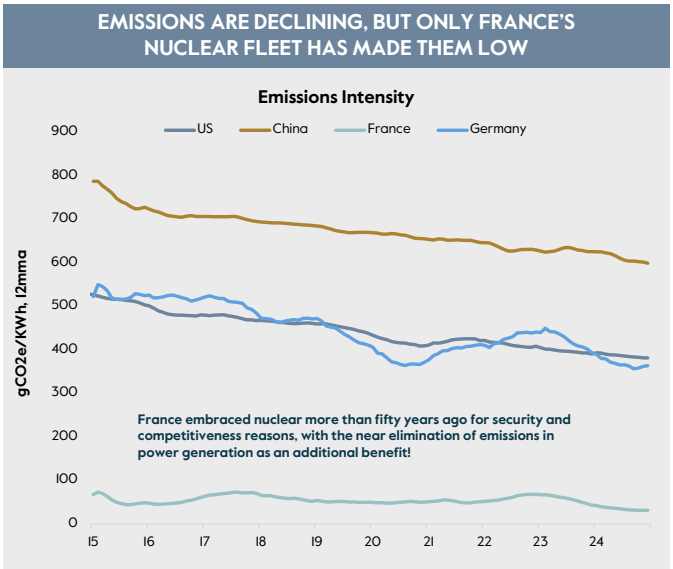



Figure 4. Source: Carlyle Analysis; Ember. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

**SECURITY FIRST, ECONOMIC EFFICIENCY SECOND, ENVIRONMENT THIRD**

France turned to nuclear energy as a way of creating energy independence after losing access to hydrocarbons from Algeria. The primary goal of a state is sovereignty, which is another way of saying survival. It does this by keeping borders secure, industry strong, and citizens supportive. Since nothing can happen without energy, the first goal of a state must be keeping the lights on. Its second priority is doing so efficiently, and its third is doing so cleanly.

When these goals come into conflict, governments reveal their priorities through their actions. Germany, for example, quickly reverted to lignite coal when security concerns triggered a supply shortage that impacted the economy. However, when these goals are mutually compatible, governments are also quick to take advantage. The Nixon administration, for example, used the push to reduce the United States' reliance on imported oil in the early 1970s as an opportunity to also reduce pollution.

In extreme scenarios, energy insecurity can lead to geopolitical conflict. For example, France and Germany wrestled over the coal fields of Alsace-Lorraine and the Saarland for seventy years, engaging in three wars until the European Coal and Steel Community finally set the issue to rest (and laid the foundations for the European Union). Similarly, Japan's attack on Pearl Harbor and simultaneous lunge for oil-rich European colonies in Asia was—at least from Japan's perspective—a necessary and defensive reaction to the energy insecurity stemming from American energy dominance. And when Iraq invaded Kuwait in 1991, it was no surprise that the then-oil-dependent United States would go to war to liberate Kuwait and protect Saudi Arabia.

**BRETTON WOODS DEFINED THE OIL AGE**

Before World War II, economies were mostly energy independent as coal was extremely difficult to ship by sea, and oil accounted for less than 5% of global energy consumption, with the United States and USSR dominating usage. It's no coincidence that these two countries also dominated postwar-era geopolitics. Since energy poverty was not an option, countries could either fight over existing energy resources, increase their own production, or get comfortable with the assumption that energy can be brought in from somewhere else—a physically complex task at the time.

In 1944, at Bretton Woods, NH, the United States changed the narrative. Unlike previous victors, it did not impose an imperial or colonial regime on the defeated nations. Instead, the United States chose not to occupy key nodes in the global economy, nor did it tax global trade of income.

Instead, the United States offered its naval power to protect all maritime trade—even if that trade had nothing directly to do with the nation. This security architecture, exemplified by NATO, allowed allies to focus on growth and trade while the United States carried most of the security burden. To support this system, the United States also provided credit for trade partners to use the dollar, now backed by gold, to facilitate free trade and manage capital flows. New York became the financial center of this new global network.

Although fixed exchange rates and convertibility came to an end in 1971 (Bretton Woods I), the institutions and the petrodollar recycling carried on (Bretton Woods II). Most countries redesigned their economies around safe trade, prioritizing exports of goods and imports of raw materials, primarily crude oil. Crucially, both Russia and China ultimately adapted to rely on this system when they finally began to open up in the early 1990s.

If the US dollar was considered the heart of the Bretton Woods system, and the US Navy its muscle, then oil was the blood in its veins. Bretton Woods defined the oil age, and Bretton Woods was made possible by oil. This made the world richer, but also more dependent on the United States.

The risks to other nations relying on this American led system, however, were realized for Russia in 2022 when its central bank assets were seized in response to the Ukrainian invasion. While Russia had long recognized this risk, the greater surprise has only come recently, when the United States signaled a willingness to weaken its security commitments to allies and trading partners while imposing tariffs.

**US ENERGY DOMINANCE HELPS DRIVE THE END OF BRETTON WOODS**

As the largest producer of oil, the United States promoted the global oil trade. However, when it became the largest importer of oil, its interests to protect global supply lines were now aligned with the rest of the world. The world benefited from the economic growth fueled by cheap imported oil, and so did the United States.

The nation remained a net oil importer until 2022, when the shale revolution that had begun a decade prior finally pushed the United States into being a sustainable net oil exporter. As an energy independent nation today, it has less direct interest in protecting global shipping lanes.

While the strategic benefits of protecting global trade have diminished for the United States, the financial costs have not. The Bretton Woods system established the US dollar as the global reserve currency, facilitating international trade and investment, and this gave the United States both a strong dollar and the means of financing the enormous debts that come with maintaining its military—often referred to as the "exorbitant privilege." The relationship is mutually reinforcing – remove one part, and the other parts collapse.

Russia, China and India have all expressed wariness about being too reliant on the US-led system. Now, even the United States itself, and key allies such as Germany, are showing that they too are interested in going their separate ways. As a result, the risks of dependence on traded oil and gas have risen sharply.

# III. From Peak Oil Supply to Peak Oil Trade

Ironically, the energy transition was initially driven by the fear of running out of oil. Although this was never plausible, the concept was simple and easy to understand, and the notion of Peak Oil Supply took hold. At the same time, consensus in the scientific community around anthropogenic climate change was becoming well established. It was clear that the world was rapidly warming—largely due to human activity, primarily greenhouse gas emissions—and the consequences of these environmental changes will likely be dramatic. However, there was also a strong consensus that Peak Oil Supply would resolve climate change long before it mattered.

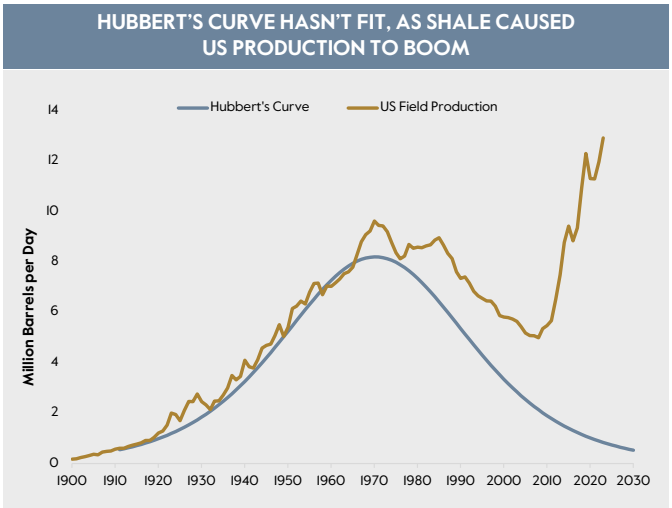
**THE FEAR OF RUNNING OUT OF OIL: "PEAK OIL" INITIALLY MEANT "PEAK SUPPLY"**

Throughout the Oil Age, fear of peak oil has been a constant. Anxiety around "Peak Oil Supply" began in the 1930s, leading US President Franklin D. Roosevelt to gain access to and promote the development of Middle Eastern oil reserves. The Oil Shock of 1973 seemed to validate these concerns, reinforcing Hubbert's Peak Oil Theory, which projected a peak in global oil supply based on declining production rates in US oil fields.

At the time, localizing energy supply was seen as the pathway to energy security. Oil and gas imports can be disrupted, but the wind and the sun cannot.

As a result, President Richard Nixon became the environmental president when he rolled out "Project Independence" in 1973. The policy emphasized elements of conservation as well, such as lowering the national speed limit to 55 miles per hour, and introducing crucial environmental initiatives (albeit many before the oil crisis—it was Nixon who created the Environmental Protection Agency, and the Clean Air Act was expanded under his administration.

*Figure 5.*
Peak oil supply didn't happen, because shale did



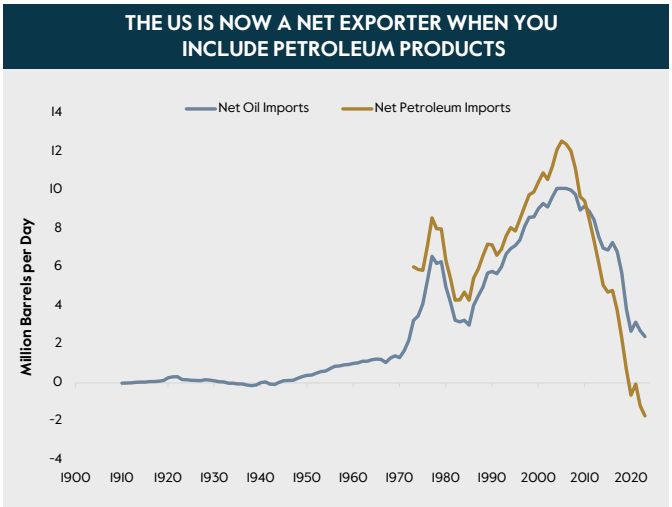




Figure 5. Source: Carlyle Analysis, EIA, IEA. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

Except oil didn't peak. The theory of Peak Oil ignored innovation and adaptation. In fact, proven oil reserves have only grown over time, and US petroleum production has surged by more than 250% since 2008. Oil consumption in the United States has held steady, meaning imports have fallen and exports have risen. Fifty years later, Nixon's Project Independence had achieved success—just not in the way anyone anticipated at the time.

**THE FEAR OF TOO MUCH OIL:**
**"PEAK OIL" BECOMES "PEAK DEMAND"**

Increasing concern over global warming resulted in another Peak Oil—this time, peak demand. Abundant and inexpensive oil and gas flowing through a global trade and financial system shifted the focus from energy insecurity and economic competitiveness to global warming. This culminated in the Paris Agreement in 2015, a treaty committing signatories to dramatically reduce net carbon emissions to zero by 2050. Given the role played by fossil fuels in carbon emissions, this was tantamount to committing to slash fossil fuel consumption—in other words, *Peak Oil Demand.*

But once again, the peak hasn't quite arrived. In the case of Peak Oil Supply, we consistently failed to appreciate the role of innovation and our ability to expand oil production. In the case of Peak Oil Demand, we are failing to appreciate the role of incentives and our reluctance to forgo oil and gas consumption.

The Net Zero 2050 roadmap from the International Energy Agency (IEA) assumes that energy consumption globally will fall over the coming decades. This is unprecedented, but also implausible—AI represents a huge increase in power demand, and even this is less than the hunger in the Global South to grow their economies—and thus their energy consumption. We have never abandoned an energy source yet—even the use of traditional biomass and animal power only peaked in the late 1980s. If anything, powerful historical trends will continue and global energy consumption will grow.

*Figure 6.*
Peak energy consumption is integral to NZE2050

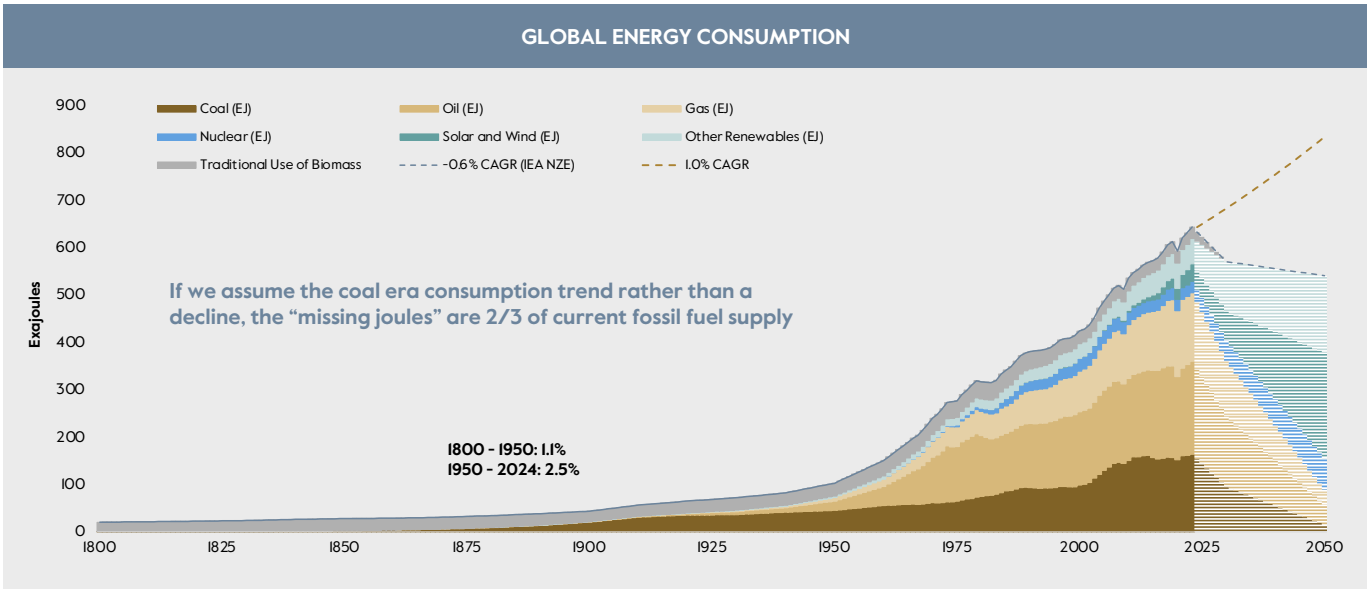


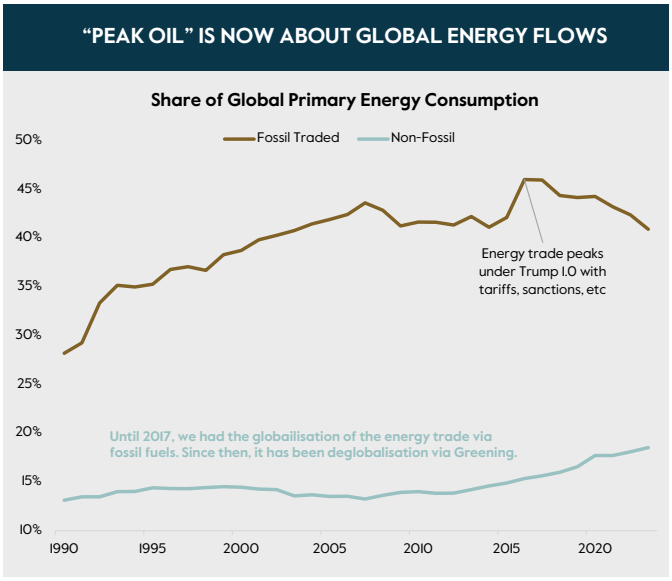

Figure 6. Source: Carlyle Analysis; IEA; Energy Institute; Our World In Data; Vaclav Smil (2017). There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

The Peak Oil Demand narrative also underestimated consumers' willingness to adopt green energy technologies that failed to replicate the convenience that portable, storable, high-density fossil fuels can provide. It has always been extremely difficult to imagine a scenario where nuclear and renewables could grow fast enough to replace nearly all of the oil and gas currently being consumed. These things don't just take time and money, they require coordination and a profit. To assume that investment in non-fossil fuels could also satisfy future demand growth as well seems implausible.

**THE FEAR OF SOURCING OIL:**
**"PEAK OIL" HAS NOW BECOME "PEAK TRADE"**

Fossil fuels are not going away any time soon. However, we do believe that we are now seeing Peak Oil Trade. Oil and gas are very convenient, but they are also increasingly vulnerable to interdiction. If consumers are able, they will try to reduce their imports of fossil fuels, which in many cases will mean increasing their supply of nuclear and renewable energy.

*Figure 7.*
Peak Oil: The decline in fossil fuel trade has accelerated post-Covid




And now they are able to do so. Non-fossil fuels provide a path to reducing energy dependence, which also reduces emissions and to restoring the order of energy security, affordability, and environmental efficacy. The cross-border trade in electricity is less than 1% of total global energy consumption, and this is overwhelmingly with near neighbors. Apart from uranium, and in the absence of a green hydrogen trade, there is no other way for energy to travel long distances. Thus, virtually the entire cross-border energy trade is portable and storable fossil fuels—solid coal, liquid oil, or (liquified) gas. The share of global energy consumption that came from fossil fuels that crossed borders peaked in 2017, and has since declined by 5%. This is partly due to the increased extraction of localized fossil fuels, and to increased renewables, which is by its very nature localized.

This localization of renewable energy output was initially a flaw but is rapidly becoming a feature. While the oil and gas trade is not going away, fossil fuel imports are a lot easier to block then wind and solar. Because of this, we believe that

Figure 7. Source: Carlyle Analysis; Energy Institute. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

the benefits of a diversified and localized energy supply system will lead to a reduction in trade and thus slower oil and gas demand.

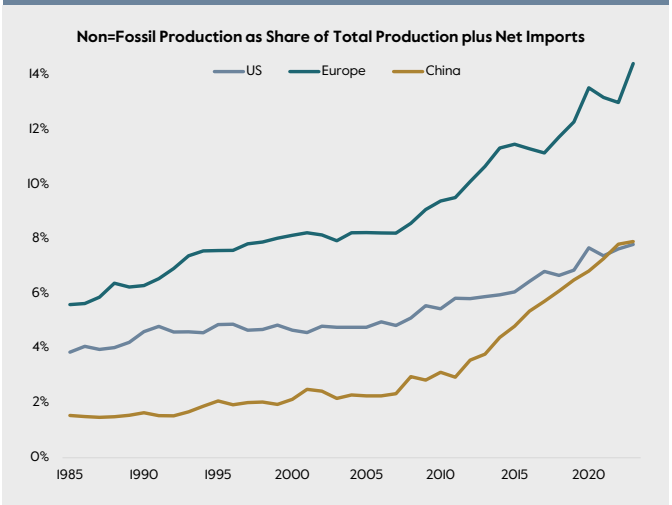
Zero-carbon energy sources like nuclear, hydropower, geothermal, wind, and solar are likely to continue to expand, and do so rapidly. Attached to the grid and in the presence of battery storage, they are able to compete with fossil fuels. But as long as people want to move energy across long distances or long timespans, fossil fuels will continue to be competitive.

**EUROPE LAGS IN PRIORITIZING ENERGY SECURITY**

China has pursued an energy independence strategy that is not dissimilar to the United States, but reflects China's different endowments. China's calculus a quarter century ago was to make investments to avoid importing seaborne fossil fuels. China's fossil fuel imports likely peaked in 2019 and it appears they have no intention of ever letting their imports exceed 25% of the global seaborne market of crude oil, underscoring the risks of being dependent upon one energy source.

*Figure 8.*
## Europe and China are transitioning faster than the US

**CHINA HAS SURPASSED THE US IN NON-FOSSIL FUELS AS A SHARE OF CONSUMPTION...**




**...WHILE RELATIVE TO PRODUCTION, THE US HAS ACTUALLY PRODUCED MORE FOSSIL FUELS THAN NON-FOSSIL FUELS**

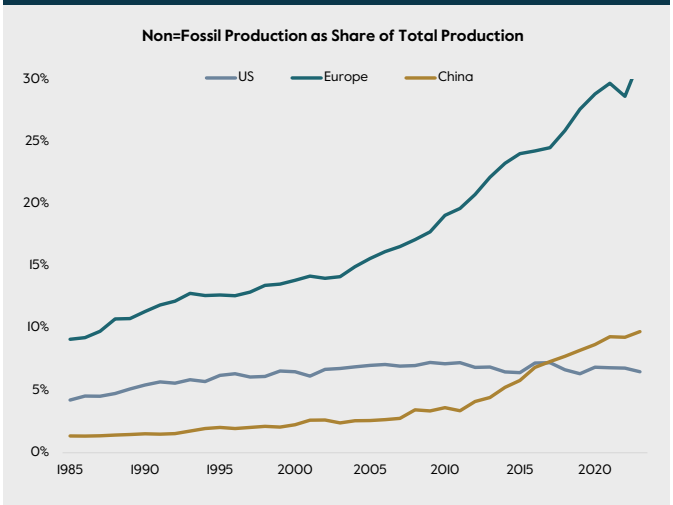
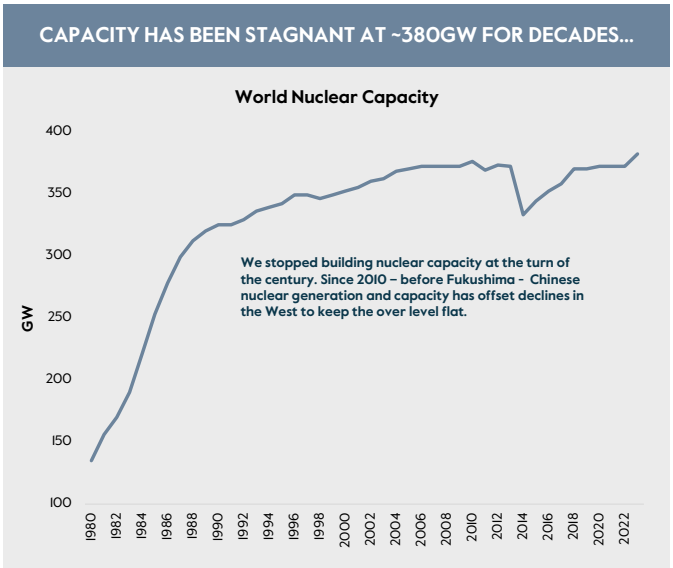
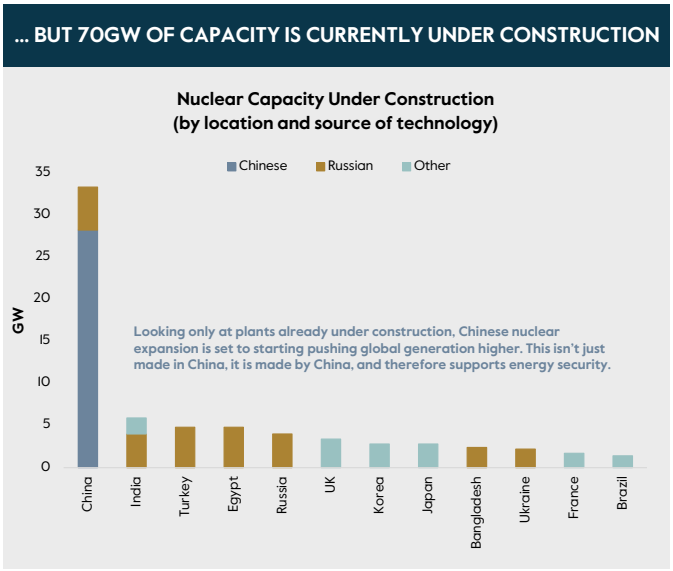



Figure 8. Source: Carlyle Analysis; Energy Institute. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

*Figure 9.*
## China, not the West, is building nuclear now




The immediate solution for China as it began to rapidly industrialize was to ramp up domestic fossil fuel production, primarily coal. China doesn't have the fossil fuel reserves that the United States has, so the Chinese also focused on building out a domestic non-fossil fuel supply base. Thus, China's dominance in green capex goods including EV's, solar panels and batteries, and nuclear technology was not motivated by environmental concerns but rather by security concerns.

In comparison, Europe stands out for its vulnerability. It's import dependence has only grown over time, as local fossil fuel production shrunk while non-fossil supply growth hasn't grown nearly fast enough. The example of Germany over the past few years demonstrates what happens when a country gets the rank ordering of energy security, competitiveness, and environment out of order. While recent elections in Germany validate the required ordering, it is critical to understand what happened to understand investment risks.

The Germans have pursued three energy objectives over the past fifteen years:

- Eliminating nuclear power in the wake of the Fukushima accident
- Eliminating net carbon emissions by 2045 to combat climate change
- Eliminating oil and gas imports from Russia in the wake of the invasion of Ukraine

However, Germany had virtually no fossil fuel resources upon which it could rely and is heavily dependent on energy to support its manufacturing sector. In other words, national security and competitiveness were vulnerable to energy supply disruptions, which would be exacerbated by the three "eliminations."

Figure 9. Source: Carlyle Analysis, EIA, IEA. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

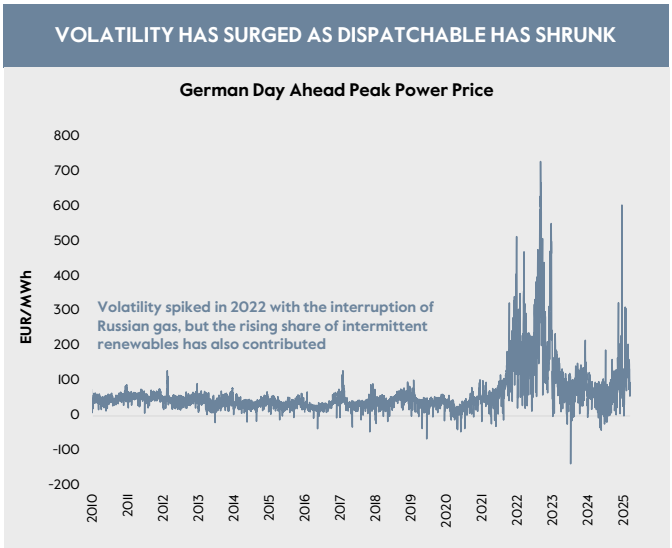
The German solution has been focused on rapidly expanding its wind and solar capacity. This is not a priori a bad idea; while Germany may not be as naturally endowed as breezy and sunny Spain, the sun does in fact shine in Germany, and the wind does blow. However, the Germans went too far, too fast. In 2000, 6% of German electricity came from renewable sources—less than a third of the global share. In 2023, more than half of German power was from renewables—two-thirds more than the global share.

When the renewable share of the power stack reaches this level, intermittency can drive massive price swings. On sunny and windy days, Germany had a surplus of available electricity, and on dim and still days they had a shortage. When the renewable power producers had electricity to sell, the price was effectively zero, and when the price was high, this was because they had no power to sell. This ends up being bad for the renewable power producer and the consumer (although the owners of dispatchable power capacity probably didn't mind).

The result in Germany has been higher energy prices, a return to coal as a backstop, and now a new vulnerability with liquified natural gas imports dependent on the United States. On all three counts the German situation has deteriorated. Furthermore, Germany's emissions intensity is the same as the United States, who depends upon mostly natural gas and far less on renewables.

If Germany were to prioritize national energy security, it would restore its nuclear output, maintain natural gas supplies, and sequence the introduction of wind and solar with the development of long duration storage and the expansion of the grid. None of these energy sources is perfect, but in combination they can give Germany diversification and thus stability. These may be politically unpalatable, but that is a national conversation that Germany is in the process of having.

*Figure 10.*
## German electricity price volatility has increased



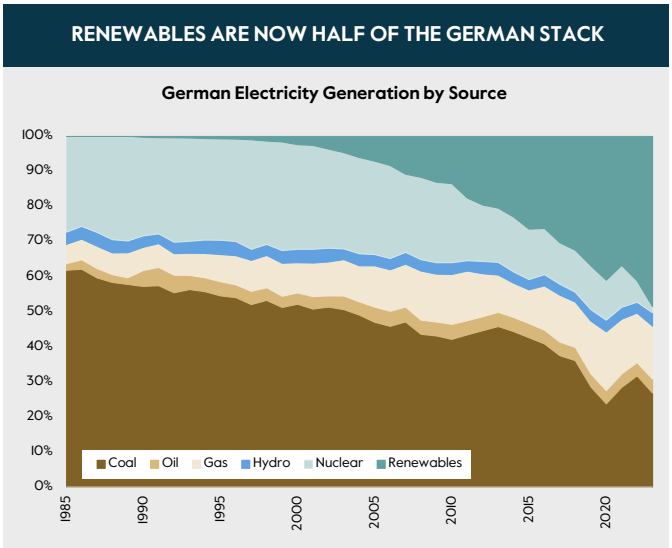




Figure 10. Source: Carlyle Analysis; Ember, Energy Institute, Our World in Data, Bloomberg, EEX. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

# IV. Investing in the New Joule Order

**A DIVERSIFIED ECOSYSTEM OF ENERGY ASSETS**

In the same way that fossil fuels are not going away, renewables are not going away. Both of them solve a critical problem. In the case of fossil fuels, the storable and portable energy can be moved across time and space from where it is cheapest to produce to where it is most valuable to consume. In the case of nuclear and renewables, production is localized and thus strategically secure.

Until recently, we've seen nuclear and renewables trading with a "green premium", which reflected a world where oil and gas imports could be taken for granted and environmental concerns were prioritized. Looking ahead, we believe those technologies will enjoy a "security premium" as a result of the changing world, which will likely prove a stronger motivation than the environmental concerns that preceded it.

Achieving this ecosystem will require different regions and countries to implement different strategies and actions. Clearly, each country is going to have a different optimal mix of energy sources, with a tradeoff between endowments, costs, and perceived insecurity. The United States, for example, is blessed with abundant domestic oil and gas, as well as areas with plenty of wind and sunshine. There is less need for a security premium, so the American portfolio of energy assets will likely remain skewed towards fossil fuels, with nuclear and renewables contributing in those parts of the country where they are competitive.

In Europe, the portfolio will likely include more of a skew towards nuclear and renewables where possible, and oil and gas where necessary. The French made a strategic commitment to nuclear fifty years ago, and their fleet is likely to be joined by SMR (small modular reactors) around Europe in the coming decades. Everywhere in Europe will use renewables like wind and solar, but areas that aren't a well endowed as Spain or Norway will have to invest more heavily in long duration energy storage and a more expansive grid. In the short term, fossil fuels will be necessary to stabilize European markets, but over time, consumption of imported fossil fuels will likely decline even if it is cheaper—because it is imported.

Strategies across Asia may be mixed, as well. China will likely continue on the same trajectory it has been on. Like the United States, it will rely on its domestic fossil fuel resources to feed its economy while limiting imports. And like Europe, it will continue to grow its nuclear and renewables. India, which is relatively fossil-fuel poor, will likely continue to pursue renewables and increasingly nuclear power while growing coal production as it can. Japan, with the misfortune of having neither fossil fuels nor easy access to solar power, but a troubled history with nuclear, is going to have to find a way to return to nuclear power and engineer ways to access what renewable power they can as best they can, all the while recognizing that its dependence on some form of imported chemical storage of energy is not going to go away.

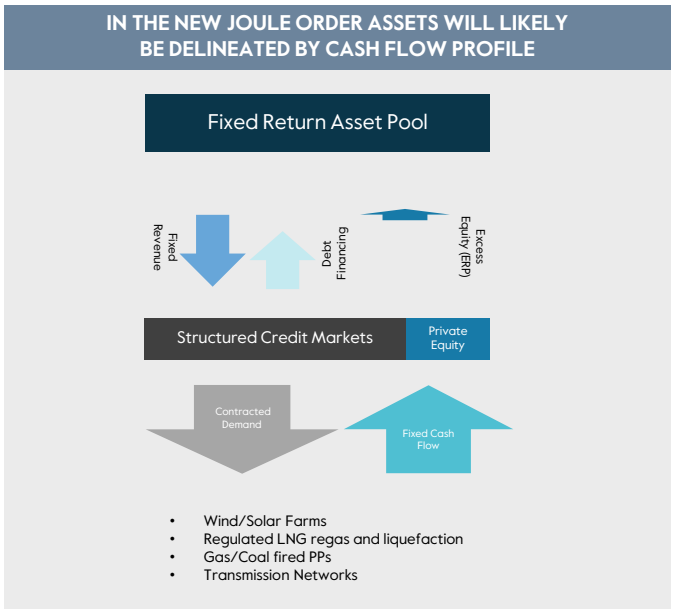
As this takes shape, investor portfolios will likely tend to mirror national portfolios. The same assets that supply the energy consumer will be owned by the energy investor. And just as a diversified energy mix will insulate national markets from geopolitical as well as economic shocks, a similarly diversified energy portfolio will help insulate investors from macro as well as financial volatility.

**COMBINING TOLLING WITH TRADING ASSETS HELPS CREATE DIVERSIFICATION**

This diversification is achieved by the fact that different capital structures have different risk profiles. The more stable the earnings, the more debt that is used. For example, nuclear power and renewable assets require power purchase agreements (PPAs) and more of a fixed-return structure to attract long-term capital. These are more "tolling" types of assets which stand in contrast to more "trading" types of assets like storage, upstream, and transportation. The trading type of assets are more variable return. Given that there is now unlikely to be a global carbon tax that can sustain a green premium, the green versus brown divide no longer makes economic sense. Instead dividing the assets based upon their cash flows and how this creates diversification will be critical in The New Joule Order.

To see how this creates diversification, it is important to understand that tolling assets typically carry far more debt, which makes them proxy for investment grade credit. And since the trading assets are variable return and driven primarily by oil prices, their returns are a proxy for inflation. As oil prices and inflation go up, the more credit-driven instruments go down and vice versa. This negative correlation between assets creates two cycles that are countercyclical, which gives the investor a wide range of new opportunities to invest in both types of assets. We believe this division of assets will likely be the best way to think about asset types in The New Joule Order.

*Figure 11.*
Tolling versus Trading Asset Pool



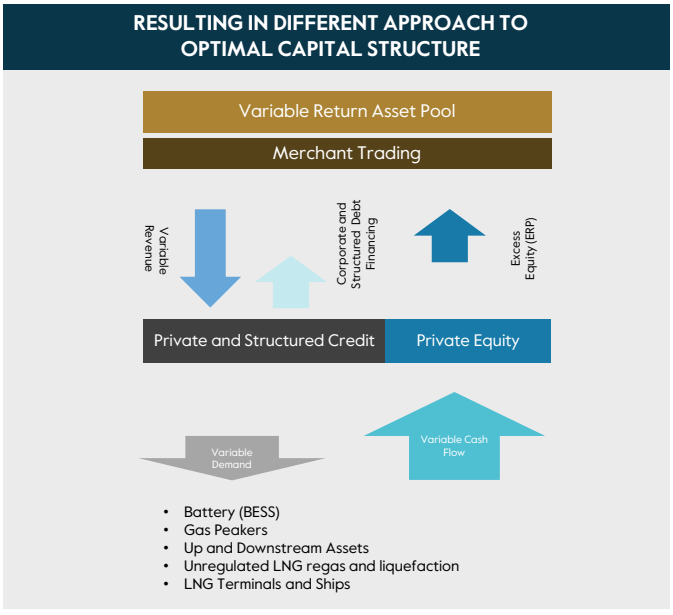




Figure II. Source: Carlyle.

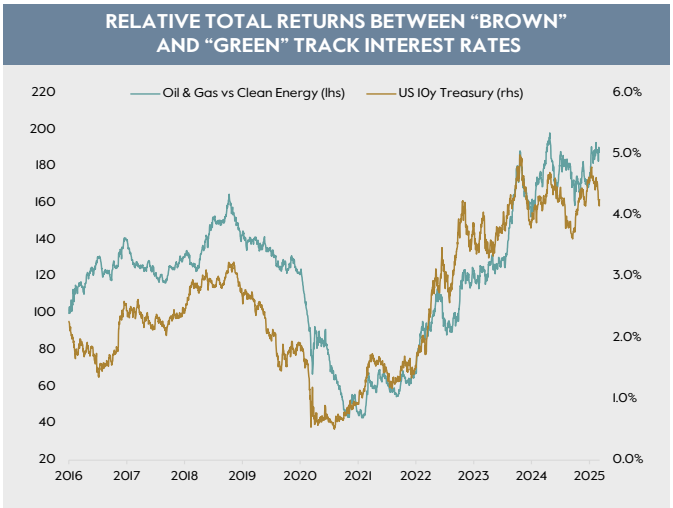
Given that variable cost assets are essentially inflation and fixed-return assets are credit, the ratio of the two is essentially the rate cycle. What this tells you is that the market is agnostic to everything except borrowing costs, cash flows, and rate of return. Despite all of the noise, politics simply don't matter. The relative value of investing in green versus brown since 2016 (prior to which green wasn't a categorization) is entirely explained by the US yield. The relative merits of producing energy one way or the other are irrelevant; the market simply recognizes that one type of energy asset requires a significant amount of borrowed capital and the other doesn't. The product—energy or joules—is the same. The meaningful difference is capex dynamics.

**THERE IS NO DIVERSIFICATION WITHOUT ELECTRIFICATION**

Different fuels will compete to provide the same joules over the rapidly expanding grid, thus creating a convergence of delivered joules. The optimal mix depends not just on what is available to a country, but also on what it can provide. Nuclear power has a high upfront capital cost and long lead times, but provides stable and inexpensive power. Renewables like wind and solar plus storage also have a high upfront capital cost, but are relatively quick to deploy. Once established, the marginal cost of the power provided by renewables is low, but intermittent. Fossil fuels like natural gas have relatively modest initial capital costs and lead times, but a higher marginal cost, and are vulnerable to trade disruptions. However, this is a dispatchable power source, which can therefore ensure price and grid stability.

Diversified national energy systems will also lead to diversified investor energy portfolios. As renewables with storage, nuclear, and gas all compete via an expanding grid to provide energy to consumers, fluctuations due to pockets of scarcity and surplus in individual markets will help offset each other and thereby help stabilize portfolio returns. The ability to arbitrage between increasingly interconnected markets in time, space, and form will increase opportunities to enhance returns via active management of price risk. This portfolio approach to energy assets can then create a stream of returns to fit the needs of an investor, whether that be steady coupons or dividends, inflation or macro hedges, or capital appreciation driven by market growth.

*Figure 12.*
## Green is a long duration asset compared to brown



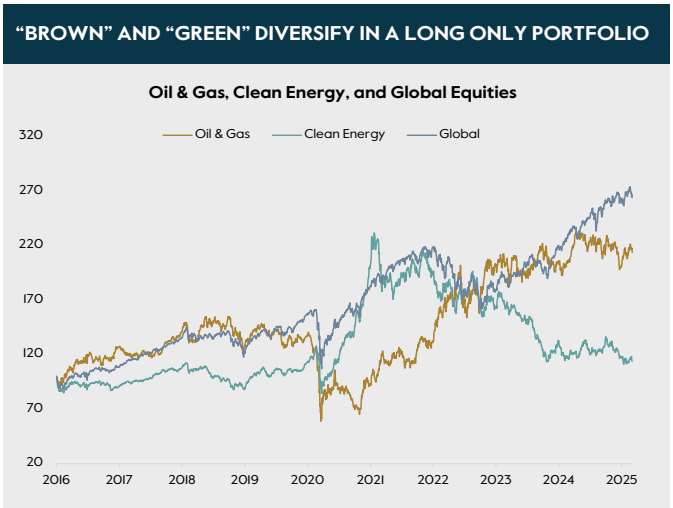
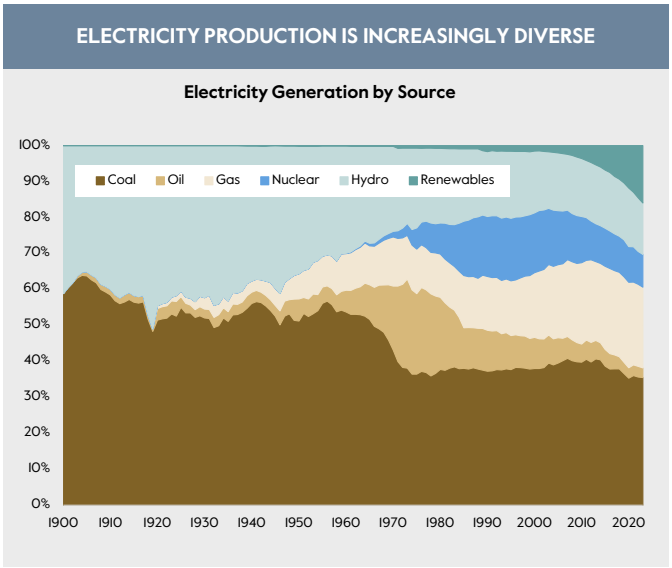
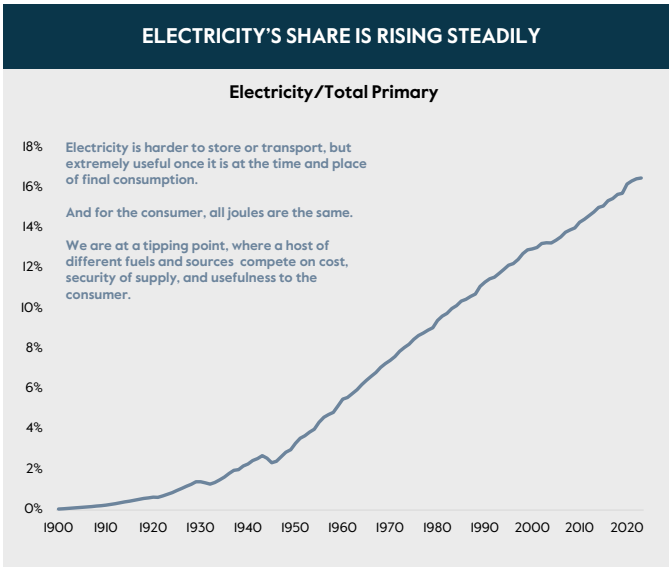




Figure 12. Source: Carlyle Analysis; Bloomberg, Goldman Sachs, S&P. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

*Figure 13.*
## Electrification remains on a steady trend




**FROM THE SEARCH FOR YIELD TO THE SEARCH FOR STABILITY**

The policy-driven push for energy security will continue to create instances of malinvestment, and thus episodes of scarcity and surplus. We believe volatilities will be higher because of the increased frequency of geopolitical and weather-related shocks to both supply and demand, while correlations will increase as these shocks propagate between markets that had hitherto been segmented by time, space, and form.

The energy market is distinct in having a well developed and liquid futures and options market for many inputs and most outputs. Most of what a cellphone manufacturer buys, and none of what it sells, has a financial market, but the opposite is true for an oil refiner.

Because of the skew in commodity price distributions, the returns from being long volatility are non-linear. As long as storage constraints do not bind, there is a floor to prices in a surplus market, but there is theoretically no limit to prices in a deficit market. If you are long volatility—which energy producers are by their very nature—once in a while you have the capacity to take the opportunity. Thus, most of the time an energy asset makes a reasonable return, but on occasion they make a bumper return by monetizing a portion of the upside risk that is retained for just this purpose.

With structurally higher volatility, the value of the real options embedded in energy assets goes up. In a world with higher rates, both real and nominal, investors have more choices, and thus the opportunity cost of ignoring the embedded real options go up. The firms and funds that can monetize that optionality will get a lower cost of capital and will build assets; those who cannot, will not.

Figure 13. Source: Carlyle Analysis; IEA, Energy Institute,, Our World In Data. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

**LESS MONEY WILL MEAN MORE CREDIT**

The energy assets that will diversify national and investor energy portfolios—nuclear and renewables—are characterized by high up front capital costs and low marginal costs, with no real exposure to commodity input prices.

The obvious solution for the high fixed-cost project developer is to sell forward, thus locking in margins and thereby allowing coupons to be paid on bonds. Thus, access to hedging markets allows asset developers to get capital today by locking in sales tomorrow. The high up-front production profile for shale, which is another way of saying steep decline rates, meant that producers were able aggressively monetize their future production and thus finance their investment. In essence, the US shale revolution that led to America's energy independence was the result of financial as well as engineering innovation.

In a similar vein, the renewables boom in the early 2020s has been heavily dependent on PPAs. Consumers who needed to lock in clean power could do so, and the developers would therefore get be able to pledge the revenues and obtain the bond.

This can be great for a society in pursuit of energy independence or decarbonization, but can ultimately prove costly for the energy sector itself. Instead of adjusting output and prices in response to scarcity or surplus, producers with a PPA or hedge can end up exacerbating surpluses and thus scarcity. Indeed, the biggest beneficiaries of this herding behavior can often be the providers of dispatchable power—that is, fossil fuels.

In both the shale and renewables cases, a dramatic decline in costs made the hedging and investment math work. However, a second order effect on prices was disregarded. When shale producers don't have to worry about low prices, their continued production will keep pushing prices lower. For renewables, a similar logic applies. With inelastic production, they tend to have a lot of power to sell when it is cheap or free, and very little to sell when it is expensive. That may be tolerable during the period of the PPA, but the value of the asset also depends on what it is expected to earn once the hedge rolls off. With interest rates up, the higher discount factor on a reduced future earnings stream has been a double blow for producers.

This is also an expensive way to pay for credit. As discussed above, the value of the embedded optionality is significant, and is foregone when it is hedged away. Both developer and investor would prefer to retain and monetize this upside, but the former needs the capital and the latter needs the coupons.

A diversified portfolio of assets with a more active management of risks can square this circle, and thus provide a steadier stream of coupons while mitigating the need to sacrifice return through hedging. Reserve-based lending could be enhanced with payment-in-kind structures to further enhance returns yet appeal to credit investors.

Private credit is expected to play a bigger role alongside private equity, as investors require assets to be self-liquidating in a world of higher rates, higher inflation, and greater uncertainty. The choice of credit or equity will be driven by the structure of cash flows and balance between fixed and variable costs. Energy assets have embedded real options that are easily monetized through the liquid futures market, and this is a distinction that sets them apart from all other asset types.

**RISING JOULES DEMAND CREATES A BUBBLING CAULDRON OF BOOM AND BUST CYCLES**

There is no reason to expect peak joule demand in energy as the IEA had modeled in its Net Zero 2050 scenario. Energy demand will continue to be driven by the 3D's: demographics, digitalization, and decarbonization.

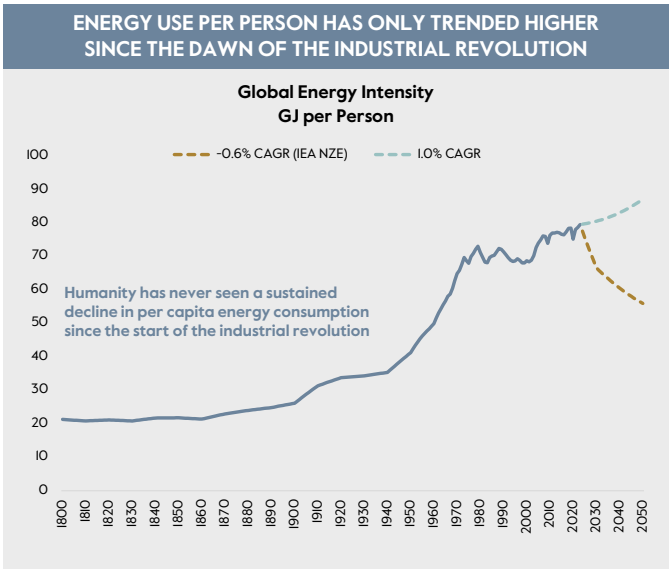
Global energy consumption has grown at a steady 2.5% annual pace over the past sixty years, with consumption per capita rising by 66% as more people left poverty. This occurred with consumption per dollar of real GDP declining by 45% as energy use became more efficient, which is Jevon's Paradox. There is every reason to believe that the number of people in the world, particularly those who are not impoverished, will be higher in the decades to come, and that the world will be richer. If history is any guide, we should be prepared for global energy consumption to be higher, not lower, in the decades to come.

Economic development as a driver of commodity demand is an old story. What will make this new cycle particularly unique is the local nature and the breadth of the demand growth. Globalization from 1985 to 2018 boosted demand growth in China as it became the manufacturer to the world. As manufacturing becomes more local again demand growth will be more dispersed, and it is important to emphasize that if much of that demand in China is lost via a trade war and tariffs, it will be replaced in the West.

Deglobalization is something that the world hasn't experienced since the 1930s, particularly tariffs and trade wars that drive reshoring of manufacturing, both of which create inefficiencies and redundancies. Deglobalization also drives energy and commodity demand through defense spending, which is already on the rise.

Digitization began to take hold in the 1990s, but expansion of the cloud and data centers only became significant in the past two decades, with AI now pushing further acceleration. Digitization also reduces the role of emerging markets since most data centers will be located in developed nations.

*Figure 14.*
## Energy demand isn't likely to fall



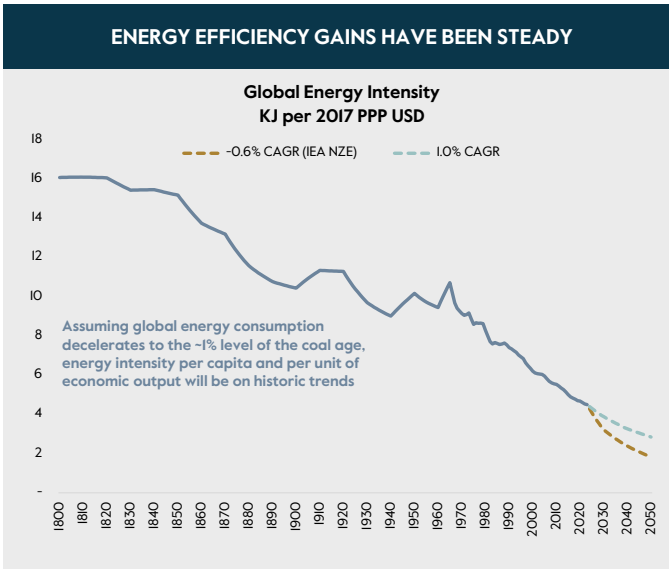




Figure 14. Source: Carlyle Analysis; IEA, World Bank, United Nations, Vaclav Smil (2017), Our World In Data. There is no guarantee that any projections will be achieved or that any historical trends will continue. Certain statements made on this slide are opinions and beliefs of Carlyle and should not be relied upon as a promise or representation as to past or future performance.

What do all of these demand drivers have in common? They depend on large scale physical investment, particularly in energy infrastructure. These capex cycles have an inherent cyclicality that inexorably drives booms and busts. When physical capacity is plentiful, inflation is low and stable, which allows for the lower interest rates. Eventually, however, demand catches up to physical capacity constraints, creating potential for better returns in the physical economy than the financial economy, motivating the redirection of capital back into the physical economy, as we saw in the 1970s (1968-1980) and the BRICs super-cycle (2002-2014). The higher cost of capital simply reflects better returns in the physical economy and the need to attract capex to expand production capacity, which is where we believe we are nearing today. As a result, a commodity super-cycle is nothing other than a capex cycle. In real terms, overall investment in energy today is actually lower than fifteen years ago, when the focus on renewables really took off. Oil and gas have been modestly crowded out by renewables, nuclear has grown from a very low base, and grid investment has been flat.

Malinvestment is suboptimal investment that can be the result of uncoordinated investment across a supply chain, often due to excessively low interest rates or subsidies, and it results in de facto stranded assets. In the past, we invested in production to get barrels of energy dense, storable, and transportable oil that were sent to whichever consumer needed it and put into the existing infrastructure to refine and further distribute. This meant the industry could over or underinvest, but malinvestment was less likely (baring gross incompetency) as supply chains were relatively simple and flexible. Today, supply chains are far more complex not only due to deglobalization, but also more recently due to trade wars, sanctions, and rerouting which increase the odds of malinvestment.

With electrons, it is easier to malinvest because supply is intermittent and difficult to store or ship. For example, if wind or solar capacity doesn't have storage or grid capacity also arriving at the right time and place, then it is de facto stranded. This results in having electrons we don't need in certain times and places because of malinvestment, while not having electrons we do need in a different time or place because of underinvestment.

Malinvestment isn't fatal—it is an opportunity. Continuing on the example above, if one can provide the storage and the grid then electrons are no longer stranded. The power producer earns more, the consumer pays less, and the provider of the storage gets paid as well. Moreover, there is less demand for fossil fuel. The key, of course, is to be the investor that solves the problem rather than the one who has the problem.

Post the Russian invasion of Ukraine, the new buzz words in energy policy became reliability and resiliency. It isn't enough to simply invest to meet additional needs and transition from fossil fuels, or to minimize malinvestment. There also needs to be a capacity buffer, just in case Mother Nature or your neighbor doesn't behave as planned.

The good news is this expands the opportunity set for investors. The good old fashioned super cycle is likely being replaced by a bubbling cauldron of boom and bust cycles, each of which creates fresh opportunities to solve problems, make a profit, and support the energy transition.

# Jeff Currie

## CHIEF STRATEGY OFFICER OF ENERGY PATHWAYS AT CARLYLE

Mr. Currie focuses on conducting analysis of commodity market trends and the evaluation of new investment opportunities across energy markets and the commodity supply chain central to the energy transition.

Mr. Currie is the former Global Head of Commodities Research at Goldman Sachs, where he helped to build their commodities business. During his nearly three decades at the firm, he became one of the leading commodity market strategists on Wall Street, known for advising clients through the commodity "super cycle" of the 2000s, the shale supply shock of the 2010s, and most recently the twin shocks of the pandemic and the Russia-Ukraine war.

Mr. Currie is a graduate of Pepperdine University and holds a Master of Arts Economics and a PhD in Economics from the University of Chicago.

# James Gutman

## STRATEGIST

Mr. Gutman focuses on analyzing the economics of energy and related commodity markets. He is a graduate of Tulane University and holds Masters Degrees in Political Science and in Economics, and a PhD in Political Science from the University of Michigan.