Charging *Forward*:

THE CASE FOR INVESTING IN POWER NOW

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- **Global demand for power has exploded since the mid-20th century**[1] and is set for more dramatic growth in the decades ahead.[2] Industrial development and an expanding middle class are driving demand for power infrastructure in emerging economies. AI-driven investment in data centers, EV adoption, and industrial electrification are stretching power networks in the developed world.

- **Countries, companies, and customers are demanding cleaner power.** Natural gas has been seen as a logical source of inexpensive, stable, clean***er*** power, but it is far from emissions-free and its pricing is volatile.[3] Renewable power's intermittent nature requires energy storage and resilience technology. Nuclear is emissions-free and provides stability, but waste, cost, and perception remain challenges.

- **Establishing the supply needed to meet demand requires new and better solutions.** Technological advances and policy changes both in the U.S. and other key countries and blocs support long-term growth for companies with sustainable competitive advantages in power markets.

- **Disruptions to the long-term growth trajectory for renewables remain a risk**, given geopolitical uncertainty and the imperative among developing nations to generate economic growth. The secular trend toward cost parity between renewables and fossil fuels should, however, continue to support expansion of emissions-free solutions.[4]

- **In this report, we highlight sectors that we believe are positioned to benefit** from this classic supply/demand imbalance over the long term.
  - Grid infrastructure and broad infrastructure
  - Energy generation operators (utilities)
  - Raw materials, metals, minerals
  - Storage, efficiency, resilience solutions
  - "Beaten-down" renewable energy OEMs
  - Natural gas products and services
  - Carbon capture storage

Introduction and Overview

As proponents of long-term investing, Pathstone seeks to identify and understand secular trends and disruptive forces that are likely to drive sustained and varied opportunities for investment. Along with many fund managers with whom we place capital on clients' behalf, we see long-term potential rooted in the imbalance of electricity supply with demand, which has seen a recent boost – a turbocharge, really – from the advent of generative artificial intelligence (AI).

The transition to renewable energy is well under way, but the interplay between power demand and supply also reflects near-term realities, risks and headwinds. In this report we attempt to provide a clear-eyed assessment of these demand and supply drivers in the context of the long-term global push to decarbonize the energy landscape. We also highlight segments of the electrification supply chain that we regard as holding long-term potential to benefit from these trends.

If you are a Pathstone client and would like more information about specific investment opportunities, please contact your client advisor.

Demand Drivers: Economic Development, AI, and the Push to Decarbonize in a Challenging Environment

Global demand for electrical power has increased significantly since the mid-20th century and is expected to grow even more in the coming decades. In the United States, the Energy Information Agency (EIA) reports that electricity consumption has quadrupled since the 1950s.[5] This trend is mirrored globally, with expectations for a 50-100% increase in electricity demand over the next 25 years.[6]

In emerging economies, industrial development and a growing middle class have been fueling growth in demand for electricity, while in developed countries, the adoption of electric vehicles (EVs) and the industrial shift toward renewable energy have been the key drivers.[7]

The mainstream launch of ChatGPT and other AI tools recently lit a match under demand expectations. A generative AI query such as one might make through ChatGPT uses as much as ten times the energy as a (pre-AI) Google search. Morgan Stanley estimates that global power needs for data centers will surge from 15 terawatt hours (TWh) in 2023 to 220 TWh in 2027.[8]

Efforts to decarbonize the economy globally support an increasing role for renewable energy sources in satisfying demand. There are significant forces at play that create tension and risk in this space, however:

- The all-in cost of renewables, including transmission and storage, remains higher than that of natural gas, the prevalent form of energy in use.[9]
- The initial cost of investment in low- or zero-carbon energy infrastructure can be prohibitive. Developing countries are unlikely to prioritize cleaner power systems at the expense of short-term economic growth and social mobility.
- Recent conflicts and trade tensions have heightened the focus on energy security, with countries striving to stabilize their energy infrastructure and reduce reliance on regions like Russia and the Middle East. This need for energy security often conflicts with long-term decarbonization goals, as seen in Germany's temporary return to coal-fired power amidst the natural gas crisis created by Russia's invasion of Ukraine.

Supply Dynamics: Renewables, Natural Gas, Nuclear…All of the Above?

Renewable energy prices have declined significantly over the past 25 years as a result of subsidies, industry maturation, and increased manufacturing capacity. National policies and incentives, such as the U.S. Inflation Reduction Act (IRA) and similar initiatives in Europe and Asia, have been crucial in driving clean energy investments, as have commitments from major tech companies. Google, for example, has pledged to source emissions-free electricity for its data centers, aiming for net-zero emissions by 2030.[10] However, challenges remain in delivering reliable energy using renewables alone given the challenges of storing and distributing the electricity.

Natural gas plays a transitional role in decarbonization efforts due to its lower carbon intensity compared to coal. Electricity from natural gas fired thermal generation plants is less carbon intensive than the incumbent electric fuel source, coal. Natural gas is also a dispatchable energy source. It can quickly fill supply gaps when intermittent sources like solar or wind are down. However, natural gas is not emissions-free, and it carries environmental risks. Also, natural gas prices have been volatile, influenced by factors like extreme weather and geopolitical events.

Nuclear power could also play a more significant role in future energy systems, especially with the development of small modular reactors (SMRs) and potential advancements in nuclear fusion. However, the majority of new emissions-free power generation capacity is expected to come from solar and wind.

Overall, an “all-of-the-above” approach, incorporating renewables, nuclear, backup batteries, and more sustainable hydrocarbons, is likely to shape the future power system.

Sectors Likely to Benefit

The transition to a cleaner energy system necessitates significant investment in renewable power, with BloombergNEF estimating that over 1,400 gigawatts of renewable power need to be installed annually through 2050. Despite record investments in 2023, the gap between current funding and the required investment remains substantial.[11]

Regardless of short-term disruptions from economic and geopolitical events, changes in government policy together with customer demand will continue to fuel long-term growth in key parts of the power generation and distribution supply chain, particularly those that play a role in the transition to clean energy. We highlight the market segments positioned to benefit in Figure 1.

Figure 1: Power and Related Sectors Likely to Benefit from Energy Transition

Grid infrastructure and broad infrastructure	▪ High voltage transmission lines, transformers, electrical components, other electronics hardware and software. ▪ Roads, trucks, boats, trains, other broad supporting infrastructure. ▪ Construction and engineering services.
Energy generation operators – electric utilities and independent power producers	▪ Utilities that can afford the capex necessary to connect existing power generation assets to new sources of demand, and/or to build new renewable power generation capacity.
Raw materials, metals, minerals	▪ Companies that can navigate the mining, processing, shipping, logistics, and fabrication of raw materials into useful base components.
Beaten down renewable energy OEMs (original equipment manufacturers)	▪ OEMs are descending into “value” territory despite projected longer-term growth as the energy transition unfolds. ▪ The rollout of tax credits and ongoing implementation of the Inflation Reduction Act could bolster sales. ▪ Beaten-down renewable OEMs could have the most to gain from a decline in interest rates.
Storage, efficiency, and resilience solutions	▪ In addition to lithium batteries, storage technologies just emerging from the R&D phase and working towards commercialization. ▪ Energy efficiency solutions such as electrification (e.g., vehicles and some residential building applications; energy management systems. ▪ Smart grid technology, virtual power plants, and other software and hardware products to enable renewable energy systems to reliably integrate with the end use of the power.
Natural gas products and services	▪ Utilities with generation turbines, natural gas services companies, decentralized/distributed generation backup power systems, and other avenues that acknowledge the continued role of natural gas in the power system.
Carbon capture storage	▪ Carbon capture storage – either at the point of use, or in wider atmosphere – is the process of using technology or natural solutions (e.g., living or geologic processes that ‘eat’ carbon dioxide) to remove carbon emitted from using fossil fuels and other sources of carbon emissions (e.g., agriculture).

Source: Pathstone, using information from multiple sources cited throughout this report.

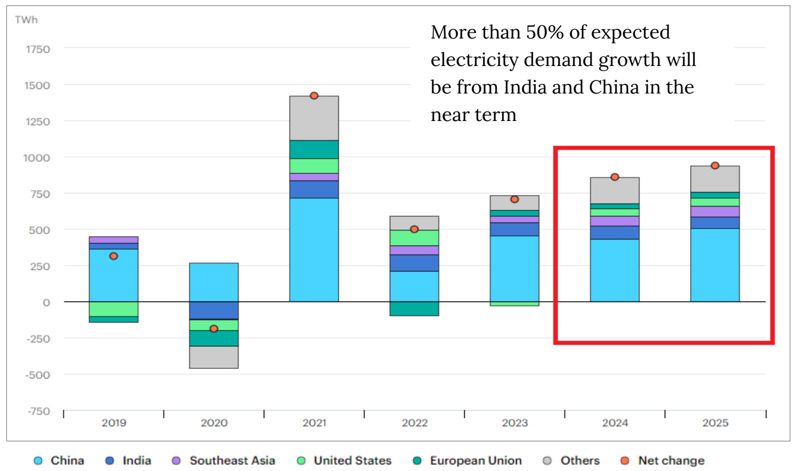
Forces Driving Global Power Demand

Global demand for electrical power has risen dramatically since the mid-20th century and is set for more explosive growth in the decades ahead. Industrial development and an expanding middle class are driving demand for power infrastructure in emerging economies, creating difficult trade-offs between near-term growth goals and sustainable long-term planning (Figure 2). In the developed world, demand is being driven by EV adoption, industrial electrification, and – in a fairly recent surge – data center expansion from the emergence of generative AI (see next section). [12]

According to the U.S. Energy Information Agency (EIA), U.S. electricity consumption has quadrupled since the 1950s and global growth has followed a similar trajectory over the past 40 years.[13] The EIA expects another 50-100% jump in demand for electricity over the next 25 years, despite efforts to improve energy efficiency.[14]

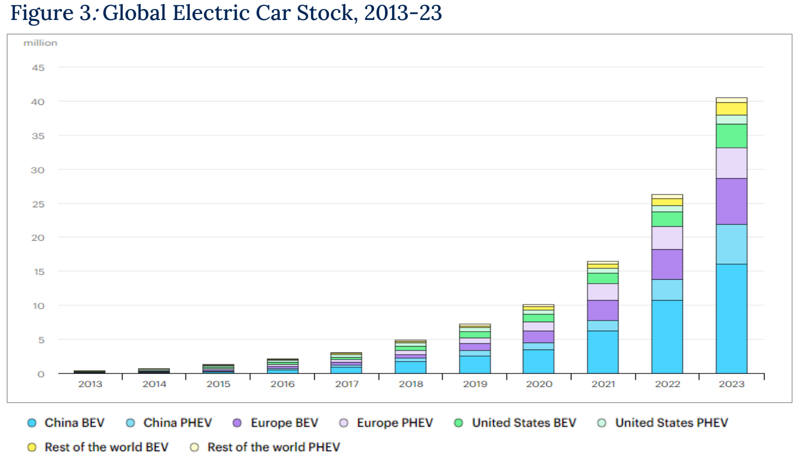
The growing market for autos in emerging economies illustrates the massive potential for electricity demand growth, with signs of bypassing internal combustion engine technology and going straight to electric powertrains. China, in particular, is a demand center for battery electric vehicle (BEVs) and plug-in hybrid electric vehicle (PHEVs), accounting for more than 50% of all EVs added to the market globally in 2023 (Figure 3). India and Southeast Asian car markets may be starting from a low base of EVs, but demand growth is skyrocketing – India saw 70% growth in new registrations last year; Thailand a fourfold increase. [15]

Figure 2: Forecast Electricity Demand Growth by Country/Region



Source: EIA.

Figure 3: Global Electric Car Stock, 2013-23



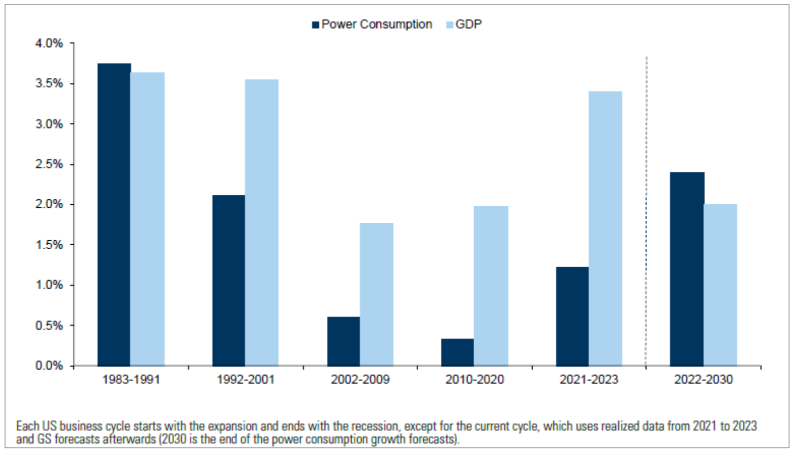
Source: EIA.

As we discuss in the following section on supply considerations, national ambitions to decarbonize the economy entail perceived trade-offs between growth and fossil fuel usage. Over longer time periods, this may be an illusion due to lower unit costs of cleaner power. In the shorter term, however, the higher up-front cost of low or zero carbon energy equipment leaves less funding to invest in other necessary infrastructure. Developing countries likely will not develop a cleaner power system at the expense of short-term economic growth and social mobility for citizens.

The Role of Generative AI

Goldman Sachs recently concluded that energy demand growth will soon outpace economic growth for the first time in 30 years (Figure 4).[16] This analysis was borne out of new forecasted figures regarding data center expansion, which we discuss below, and the understanding that data center development is constrained by access to power.

Figure 4: Projected U.S. Power Consumption Growth vs Real GDP, by Business Cycle



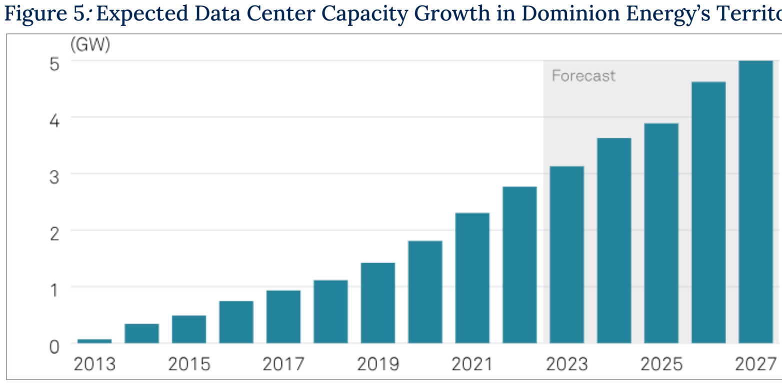
Source: EIA, Haver Analytics, Goldman Sachs Global Investment Research

For generative AI alone, Morgan Stanley estimates that power needs for data centers globally will go from 15 terawatt hours (TWh) in 2023 to 220 TWh in 2027.[17] One TWh is enough to fully power 70,000 U.S. homes for a year – that's a *lot* of energy. This is not surprising given the power demand of an AI-based query in a datacenter is 10 times that of a standard search (e.g., Google).[18]

The International Energy Agency (IEA) is a global consortium of agencies, including the U.S. EIA, that forecasts global energy trends. At the start of 2023, before the AI boom, it projected a 15% *reduction* in energy demand by approximately 2050 as industries move towards more efficient electrical processes and as other electrically driven systems improve efficiencies. [19] However, AI's rapid rise in 2023 was a black swan event that created tremendous new electricity demand seemingly out of thin air. The advances in AI – and the computing power needed to serve it – changed assumptions about how the electrical grid can keep pace, let alone the nature of net zero transition pathways.

Expected capacity growth at Dominion Energy – a crucial utility serving northern Virginia, a region with one of the highest concentrations of data centers globally – illustrates this trend, as shown in Figure 5.

Figure 5: Expected Data Center Capacity Growth in Dominion Energy's Territory



Source: Dominion Energy

Concurrently, mega-cap tech players have pledged to source emissions-free electricity to run their data centers. Google made such a pledge to do so by 2030.[20] If renewables get more expensive, meeting this goal might come at a massive cost and be abandoned, but for now, most tech companies have committed to power operations with renewable energy and are working to source that energy from utilities, independent energy operators, or by using their own renewable energy equipment on premise.

Geopolitics and Energy Security

Energy security has become a hot-button topic in the developed world considering recent escalations in regional and global tensions. Wars, shadow-wars, and international trade tensions have countries focused in the short term on “keeping the lights on” at a reasonable price.

This could be a boon for energy firms with a competitive advantage as countries look to stabilize their energy infrastructure and dislocate fuel supplies from conflict regions like Russia and the Middle East. The Israel-Hamas war presents the most current threat given its growing regionalization, with Iran and Iranian proxies (via Hezbollah in Jordan and Lebanon, and the Houthis in Yemen) threatening fuel sources (oil and gas wells and infrastructure) and critical shipping lanes.

These short-term drivers sometimes conflict with long-term decarbonization goals; Germany’s need to revert to coal-fired power from Russian natural gas in 2022 despite ambitions in the longer term to move to zero carbon energy is an example of this. While switching from one carbon intense fuel to another could be an option in the short term, over longer periods, energy security and a clean transition are natural partners Especially as renewable energy sources (sun, wind, water) are not practically bound to international counterparties’ fuel supplies. However, renewable technologies do, technically speaking, entail supply chain risks and trade-offs, as we explore in Supply.

Rising Temperatures and AC Demand Feedback Loop

Rising temperatures could be a feedback loop driving demand ever higher. Air conditioning already has a strong penetration in the developed world (where cultural norms/preferences or needs exist) but is a new luxury for much of the developed world as incomes rise. AC unit sales growth annually in these markets is exploding.[21] As incomes and temperatures continue to rise, so too will the number of AC units sold and the frequency with which they’re used, driving demand for the electricity that powers them.

The feedback loop unique to this trend is twofold. First, electricity in the developing world is primarily generated with unabated fossil fuel sources, as we explore later, which will increase atmosphere warming emissions and drive temperatures higher, fueling further demand for AC. Second, the chemical coolants at the core of the AC technologies themselves are climate-warming compounds, the worst of which having warming effects 1,000 times greater than carbon dioxide.[22]

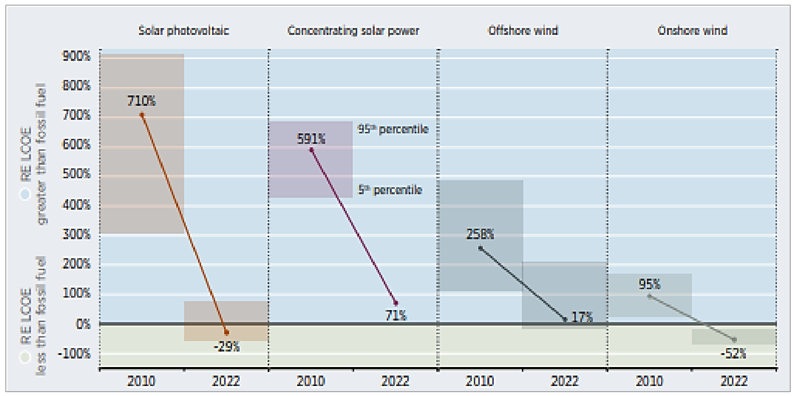
Complex Supply Considerations

Meeting the seemingly insatiable global demand for electricity involves considerations of national and consumer preferences, technology advances and gaps, and structural industry challenges and opportunities. Many of these factors are closely interwoven, making energy markets among the most complex sectors to analyze. Some of the most significant supply trends are highlighted in this section.

Renewable Energy Pricing in Secular Decline

If we only look at renewable energy's recent (1-3 year) challenges (see Near-term Headwinds for detail), we ignore a more meaningful trend: Renewable electricity prices have drastically declined compared with traditional energy prices over the past 25 years. Subsidies to incentivize technology have played a role, but the reductions also reflect industry maturation and increasing manufacturing capacity as well as demand for renewable energy reducing the financing costs of projects - the so-called greenium.

Figure 6: Change in competitiveness of solar and wind by country based on global weighted average LCOE, 2010-22 (RE = Renewable Energy)



Source: U.S. EIA.

The industry terminology for comparing power of different fuel sources is known as the levelized cost of electricity (LCOE). Figure 6 shows that the LCOE for renewables has been on the decline for many years; both solar photovoltaic and onshore wind were cheaper in many instances than the lowest-cost traditional source of energy (in 2022, combined cycle natural gas.)[23]

Figure 7: Estimated capacity-weighted LCOE and LCOS for new resources entering service in 2027 (2021 dollars per MW/hr)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[b]	Levelized variable cost	Levelized transmis-sion cost	Total system LCOE or LCOS	Levelized tax credit[c]	Total LCOE or LCOS including tax credit
Dispatchable technologies								
Ultra-supercritical coal	NB	NB	NB	NB	NB	NB	NB	NB
Combined cycle	87%	$8.56	$1.68	$25.80	$1.01	$37.05	NA	$37.05
Advanced nuclear	NB	NB	NB	NB	NB	NB	NB	NB
Geothermal	90%	$21.80	$15.20	$1.21	$1.40	$39.61	-$2.18	$37.43
Biomass	NB	NB	NB	NB	NB	NB	NB	NB
Resource-constrained technologies								
Wind, onshore	43%	$27.45	$7.44	$0.00	$2.91	$37.80	NA	$37.80
Wind, offshore	NB	NB	NB	NB	NB	NB	NB	NB
Solar, standalone[d]	29%	$26.35	$6.34	$0.00	$3.41	$36.09	-$2.64	$33.46
Solar, hybrid[d,e]	26%	$39.12	$15.00	$0.00	$4.51	$58.62	-$3.91	$54.71
Hydroelectric[e]	NB	NB	NB	NB	NB	NB	NB	NB
Capacity resource technologies								
Combustion turbine	10%	$55.55	$8.37	$49.93	$10.00	$123.84	NA	$123.84
Battery storage	10%	$64.74	$29.64	$18.92	$11.54	$124.84	$0.00	$124.84

Source: U.S. EIA, Annual Energy Outlook 2022

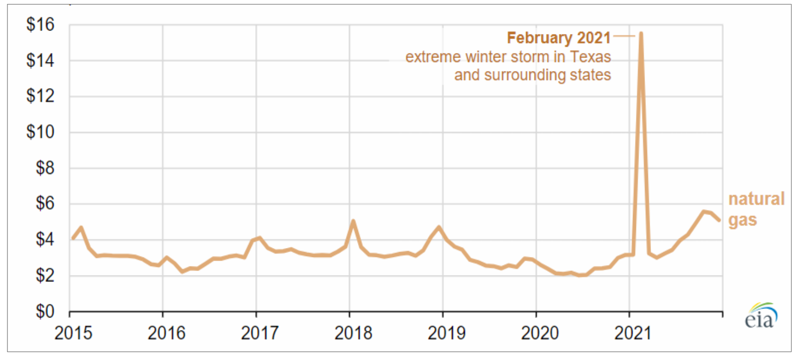
That study purely assessed power *generation*. However, it is important to consider the costs of power *storage* for renewables to account for the intermittent availability of wind and solar. Figure 7 shows that hybrid systems (e.g., solar plus backup batteries) are still more expensive than combined cycle natural gas.

The energy market is complex and price changes in different areas of supply chains can affect prices at a given time. For instance, the aluminum, copper, cobalt, lithium, and silicon commodities that are key to renewable products, or natural gas on the traditional energy generation side, are core elements which can be volatile. Nonetheless, the trend is obvious: Electricity from renewables has come down in cost considerably and in many cases is the most economic source of power today.

Volatile Natural Gas Pricing

On the traditional energy side, the main driver of electricity costs is the pricing of the commodity serving as fuel source. Most commodity prices have been volatile, historically. As shown in Figure 8, the price of natural gas, the most prevalent traditional energy source in the U.S., generally ranged from $2 per million British thermal units (MMBTU) to $5/MMBTU between 2015 and 2020, then spiked during an extreme weather episode in early 2021.

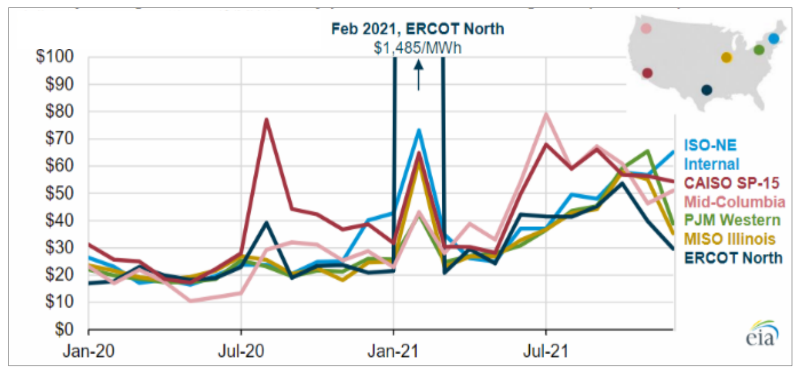
Figure 8: Average U.S. cost of natural gas delivered to electric generators, 1/15 – 12/21 ($ per million BTU)



Source: U.S. EIA

Another jolt in prices came in 2022, as Russia invaded Ukraine and countries boycotted Russian gas, triggering a spike to $16/MMBTU in the early months of the war. This volatility resulted in power prices rising 100%-plus for some customers in the U.S. as seen in Figure 9.[24]

Figure 9: Monthly Avge Wholesale Electricity Prices at Selected Trading Hubs, 2020-21 ($/MWh)



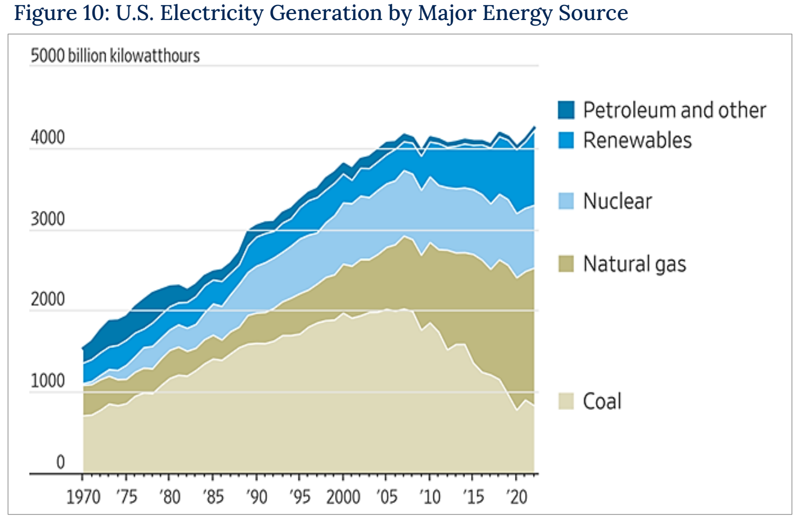
Source: U.S. EIA, S&P Global Market Intelligence

While natural gas's role in creating electricity supply to meet the rising demand will be critical in coming years, volatility in the commodity poses a risk. Over the longer term, the technology will continue to be at odds with declining prices of renewable energy and ever growing regulatory risk as countries, industries, and consumers look to address climate change, as we see next.

Decarbonization Ambitions

Currently, 88% of global emissions are covered by some form of national pledge to move to net zero by 2050-70.[25] Executing on these pledges entails creating massive new electricity supply from emissions-free sources. According to BloombergNEF, which tracks the energy outlook annually, more than 1,400 gigawatts (1 GW = 1 billion watts) of renewable power needs to be installed annually through 2050 to meet energy demand and transition fully off fossil fuels.[26] Referring back to the discussion above, which cited data center demand in terms of terawatt *hours*, 1 GW of installed solar ends up creating about one TWh of energy throughout a year if you use US installed capacity and output numbers. [27] [28]

Figure 10: U.S. Electricity Generation by Major Energy Source



Source: U.S. EIA

To put this BloombergNEF estimate in context: In 2023, about 440GW of renewable energy capacity was installed globally – a dramatic uptick from the 300GW-plus added in 2022 but far below what's needed for full transition by mid-century. Putting the funding gap in dollar figures, investment in 2023 hit a record $1.8 trillion, up 17% from 2022, but still well short of the $4.8 trillion in annual investment needed.[29]

Meanwhile, national fiscal policies and tax incentives (as well as regional or local incentives) are helping spark investment. In the U.S., the 2022 Inflation Reduction Act (IRA) included more than $300 billion in tax incentives for clean energy development. Similar laws or actions have been introduced in Europe and Asia (EU Green Deal, or China's $800 Billion+ 2023 green spending.) [30] [31]

However, many of the national decarbonization pledges are without teeth. As time goes on, we could witness a divergence between what countries have pledged and what they do. [32] Progress will be most easily measured by the global power generation mix - or the percent of each fuel source – over the years (Figure 10).

The Transitional Role of Natural Gas

While natural gas is certainly not decarbon***ized***, it plays a role in most national policies on decarbon***ization***, or reducing carbon footprint. Electricity from natural gas fired thermal generation plants is less carbon intensive than the incumbent electric fuel source, coal. Natural gas is also a dispatchable energy source. It can quickly fill supply gaps when intermittent sources like solar or wind are down. Backup power (like batteries charged by wind/solar) could play a role, but require capital investment, and generally are only good for 4-6 hours maximum of power.[33]

There are a couple major challenges with relying too heavily on natural gas for a decarbonized economy. First, natural gas is not emissions-free. It produces less carbon dioxide than coal, but that's a low bar to beat. Further, the primary molecule in natural gas, methane, results in 50-70x more warming in the atmosphere than carbon dioxide, although it dissipates sooner. [34]

Another challenge is the risk of leakage. If things are working correctly in the supply chain, natural gas should not generate more than 1% leakage.[35] However, studies have documented 2-5% leakage of the total product from source to electricity generation, in practice - enough to completely offset any gains towards decarbonization relative to using coal. [36] [37] [38] [39]

There are, of course, ancillary benefits to moving to a gas-based power system from coal – pollution, particulates, mining safety issues, and more. This is not an argument against moving from coal to natural gas as part of the energy transition, but we do highlight the goal of fully decarbonizing the energy system could be hamstrung by even small margins of leaks in the natural gas-fueled supply of electricity.

Rethinking Nuclear?

Aside from renewables, it's possible that emissions-free electricity could be supplied in greater numbers by nuclear-powered generation. The use of nuclear-powered electricity has largely remained flat in the US for the past 20 years, with only one utility-scale nuclear plant commissioned in the U.S. in that time. Concerns about safety from local communities, wider regulatory hurdles, and challenges with waste disposal are still factors preventing deeper nuclear development in the U.S. and in many other developed countries. Outside the U.S. and many OECD countries, however, new, large-scale reactors are under construction (60) or proposed (90) throughout Asia and select Eurozone countries,[40] which could prove crucial for meeting these countries' electrical demands and emissions reduction plans.

Perhaps as next-generation small modular reactors (SMRs) for nuclear energy become commercialized – and assuming waste issues subside or are solved – nuclear could become a larger part of the solution. Nuclear fusion energy could be a black swan on the supply side too, especially as AI and quantum computing solve more complex problems. For now, though, there is a common saying about nuclear fusion power: Commercial nuclear fusion energy is always 30 years away. The majority of new emissions-free power generation capacity will come from solar and wind, with limited exceptions.

Near-term Headwinds

In the United States, despite the small share of the power system overall from renewable energy sources, recent years' data makes investing in this segment of the power transition more promising. In 2022, 85% of new electricity generation was from renewables, with solar the single largest source (56%). [41]

As discussed, the scale of solar and wind growth could be constrained by intermittency of wind/sun. As such, battery storage and grid connectivity from energy supply (wind, sunshine) to energy demand (cities, data centers, etc.) are critically important considerations when new solar and wind turbine farms are developed.

Outside of the structural and technological hurdles, in 2022-23, elevated interest rates were the primary challenge for renewable energy firms as customers struggled to finance the high upfront cost of capital intensive projects.

Other real economy pressures included supply chain friction and demand *growth*, both of which inflated prices to customers. This started following COVID-19 in 2020 (as in most industries) but continued through 2022 for renewable equipment manufacturers as China – which dominates this market and its supply chain – remained on relative lockdown. The constrained supply boosted global prices of manufactured equipment dramatically in the second half of 2022. This pressure was exacerbated by higher interest rates, which saw renewable energy firms struggle to finance the high upfront cost of capital-intensive projects.

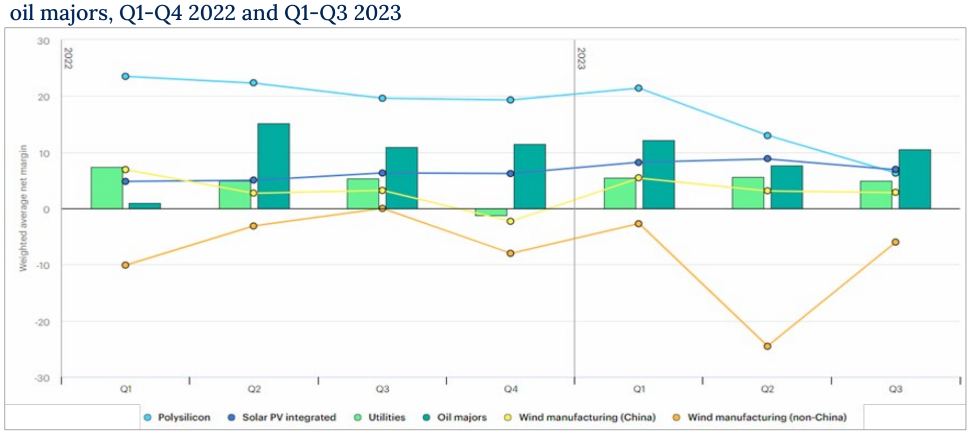
The effects on financial statements and stock prices were commensurate with this downswing. Revenue on the income statements of certain companies decreased as developers (such as offshore wind companies and homeowners looking to install solar) found financing prohibitively expensive. At the same time, forward prices for raw materials and other critical components in supply chains skyrocketed, thus leading companies to lower estimates for sales and earnings.

In an industry where equipment costs are depreciated over many years, limiting financing and principal costs (total financed cost) is crucial. On net, from cost of goods inflation and elevated rates, we saw financed solar module prices move 30% higher in 2022. [42]

These cost increases were largely due to inflationary and responsive interest rate pressures, but also reflected unforeseen geopolitical issues. Demand for equipment in Europe and other countries reliant on Russian gas at the start of the Ukraine war triggered enormous spikes for wind and solar specifically. [43] In addition, while there was a 35% increase in new solar deployment in 2022, this reflected equipment sales from years before. [44]

The margin pressure on renewables created by the convergence of demand growth, cost of goods sold/supply chain inflation, and financing costs played out across renewables in 2022 and 2023. This can be seen in Figure 8, which shows offshore wind net margins falling steeply negative in 2022 and 2023. Solar saw manufacturing prices increase steadily in 2022, cost pressures eased in 2023, but margins have yet to recover fully.

Figure 8: Weighted average net margins of renewable energy companies, large utilities and oil majors, Q1-Q4 2022 and Q1-Q3 2023



Source: IEA.

With these firms hitting serious headwinds and stock prices falling precipitously in 2023 and flat or down in 2024, it feels like the last exciting development for renewable energy investors was the Inflation Reduction Act (IRA), signed into law in mid-2022. The benefits from this legislation have still not yet hit company balance sheets. Investors expect 2024-25 to be a better year for firms able to navigate the complexities of the program/subsidies; if interest rates fall, inflation cools, and China continues on its path increasing industrial capacity, we believe these companies should see revenues rise as customers can finance long-term projects at a lower cost – or at least not at higher prices from previous years.

Developing Economies as Disruptors

Perhaps the most important region/country for the energy transition in the long term is China. Not only is China a massive demand driver of electricity generation, as we demonstrated in our section on Demand, it also dominates the supply chain. From raw minerals to mineral processing, core component manufacturing and all the way up to renewable energy generating modules, it cannot be understated how important China is to the global energy sector – and even more so for renewable systems. For instance:

- Production of polysilicon, a key material for solar panels, is > 70% Chinese
- Lithium and cobalt processing are 60% and 70% Chinese-dominated, respectively
- Battery manufacturing is more than 50% Chinese[45]
- Solar module production capacity is dominated by China, accounting for 80% of the market[46]

Fractures in global relationships with countries or companies reliant on these materials is a huge risk. Direct or indirect conflict, elevated tariffs, or embargos all raise prices of goods across the economy and especially so in power markets.

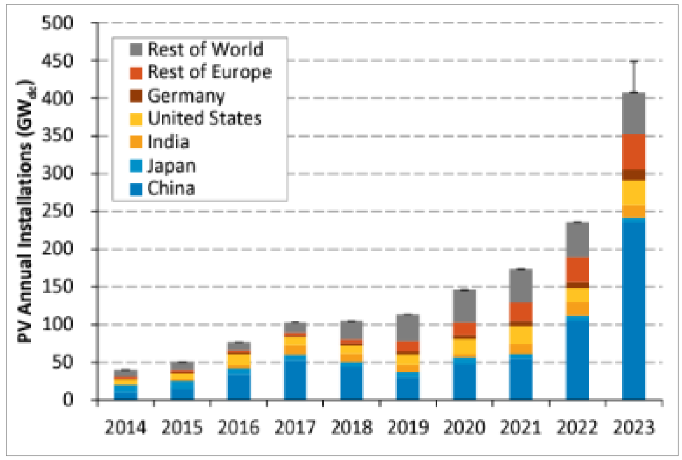
Countries may try to decouple from Chinese supply chains and develop their own by “reshoring” – another goal of the Inflation Reduction Act. Moving more renewable energy related production back onshore theoretically could lower costs or at least enable more stable power supply in the future. That outcome is far from certain though, and supply chains were established in China for a reason: It was less costly to do so.

As for sales of completed products – not just supply chain components, but PV solar panels, lithium battery systems, EVs, etc. – China is a massive player in this space. Currently, Chinese solar panels cannot be sold in the U.S., which supports prices for U.S. manufacturers but has kept equipment prices higher for end customers. It will be interesting how this dynamic plays out in coming years; as recently as April 2024, the U.S. was still signaling China to not oversupply markets with their products during Treasury Secretary Janet Yellen's visit to Beijing.

As a purchaser of energy capital, China deploys more renewable technologies than most of the world. As shown in Figure 9, in 2022 it installed about as much solar PV capacity as the rest of the world combined, then almost doubled that achievement in 2023.[47] [48]

Meanwhile, China simultaneously commissioned new coal burning power plants as the rest of the developed (and even much of the developing) world moves away from the carbon-intense energy source. As in other developing nations, this reflects a tension between the goal of developing a cleaner power system and supporting economic growth, social mobility, and improved standards of living for the country's citizens.

Figure 9: Global Annual PV Capacity Additions by Country



Source: National Renewable Energy Laboratory

On a net basis though, China is leaning more towards renewables: it installed over 215 GW of solar alone[49], while adding 48 GW of coal fired energy capacity in 2022.[50]

Looking at the other economic powerhouse in Asia as a comparison, India has rapidly deployed renewable power across the country, including 10GW of solar added in 2023, though it also installed 4GW of new coal fired power capacity in the same year. [51] India has been a leader in renewable output until recently, as a result of output from new coal plants exceeding renewable energy in the country for the first time since 2019. This story reflects the country's ambitions for growth and supporting a massive population eager for an improved standard of living. Providing access to energy enables this. Indeed, while most developed nations are targeting a country-wide net zero target date of 2050, India recently announced 2070 is the target for its net zero pledge. While the cost of generating electricity from renewables vs gas or coal may be comparable, other factors are taken for granted, like developed economies already having a relatively established power grid nationally for transmitting the power to users compared to developing nation peers.

"All-Weather" Sectors We Are Watching

The dynamics outlined in previous sections illustrate the tremendous need for investment to satisfy our demand for electrical power. Regardless of short-term disruptions from economic and geopolitical events, changes in government policy together with customer demand will continue to fuel long-term growth in key parts of the power generation and distribution supply chain. We view the market segments outlined in this section as likely beneficiaries.

Grid infrastructure and broad infrastructure

The transition to renewables requires a huge investment in the transmission and distribution of energy from new, distant solar and wind farms to end users in population centers. This means high voltage transmission lines, transformers, electrical components, and other electronics hardware and software. Installing this grid infrastructure means new roads, trucks, boats, trains and other broad infrastructure, not to mention the services of construction and engineering experts.

In advanced economies, electricity demand growth from data centers, electric vehicles, and industry is spurring the need for grid infrastructure upgrades and expansion. Charging stations, backup power for data center servers, and the high voltage needs for industrial firms and manufacturers will require new distribution interconnection to the grid.

The last piece – industrial electrification – is another cross-cutting theme: Reshoring/nearshoring and supply chain hardening. The Inflation Reduction Act ties these themes together because there is a requirement for the products to be domestically produced to qualify for certain additional tax credits.

Energy generation operators – electric utilities and independent power producers

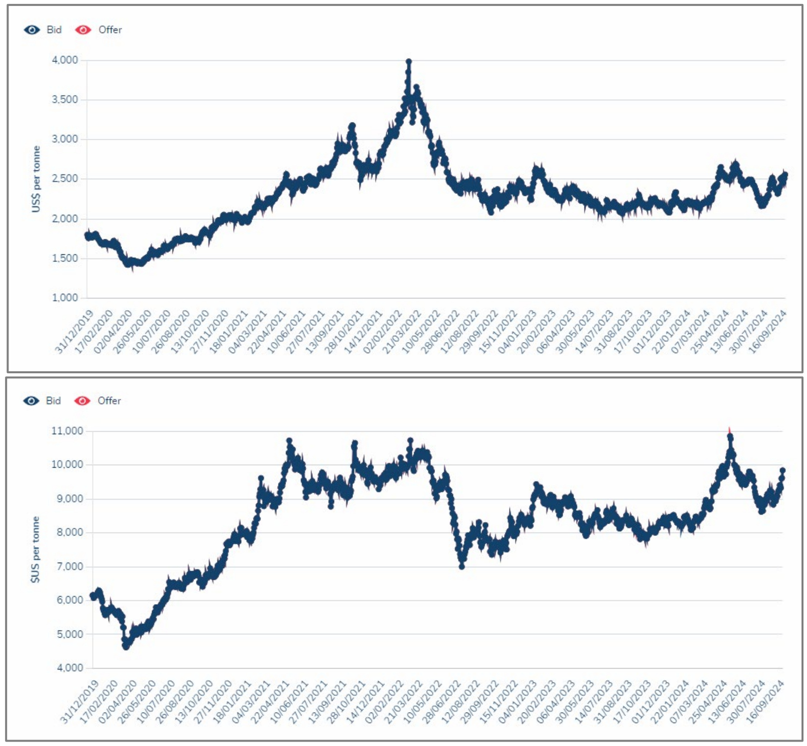
The case for electric utilities is a simple one: As power demand surges, the suppliers of that power see a boost in revenues. Not all utilities offer the same investment potential, however. Attractive candidates are well capitalized and can afford the capex necessary to connect existing power generation assets to new sources of demand, and/or to build new renewable power generation capacity. Critically for utilities that have cash on hand or the ability to take on more debt, the tax incentives provided by the IRA benefit buyers and operators of renewable energy equipment by lowering the total capex costs for new investment, which have risen due to aforementioned transitory inflation and now sticky interest rates. The IRA may benefit electricity generators the most with a lower cost of installing new generation assets that customers require for new datacenters and electrification – and that they would prefer was renewably sourced.

Raw materials, metals, minerals

The building blocks of the energy transition include a range of metals and raw materials, each of which is critical to making a transition to net zero happen. Companies that can navigate the mining, processing, shipping, logistics, and fabrication of raw materials into useful base components could benefit from the uptick in the supply/demand imbalances in raw materials markets.

In 2022 and 2023, the focus may have been on lithium as battery manufacturers tried to keep up with EV demand. Meanwhile, copper and aluminum, key building blocks of many electrical components, including equipment for renewables like solar and wind, have steadily risen in value the last two years, copper peaking in May 2024 and aluminum earlier in 2022, although retracing more recently (Figure 10).[52]

Figure 10: London Metal Exchange Prices, Aluminum and Copper, March 2019 - mid-September 2024



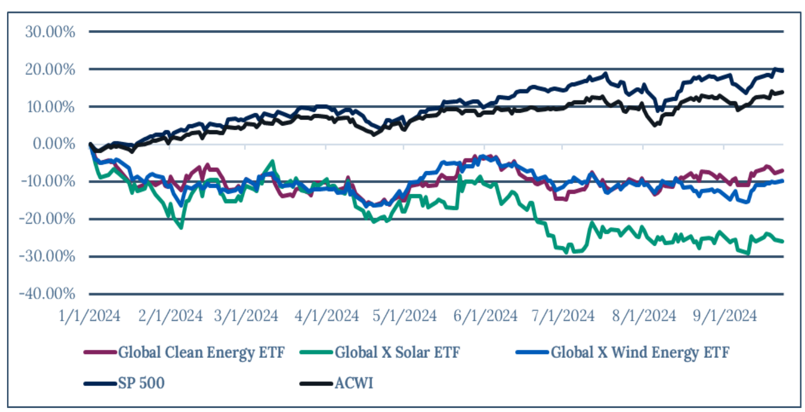
Source: London Metal Exchange

Other key building blocks like polysilicon, graphite, nickel, cobalt, and a range of rare earths are also interesting, though more difficult to invest directly as a handful of companies and countries (primarily China) have cornered markets. Innovative disruptors in this space should be monitored.

Beaten down renewable energy OEMs

2023 was a rough year for original equipment manufacturing (OEM) companies making solar panels, wind turbines, inverters, equipment racks, hydrogen electrolyzers, and more. The start of 2024 for renewable energy stocks has also been rough, with solar and wind companies down more than 20% and 10%, respectively, vs roughly 20% and 15% gains in the S&P 500 and ACWI as of mid-September (Figure 11.)

Figure 11: Performance Broad Market vs Renewable Energy Stocks, 2024



Source: Morningstar, Pathstone September 2024

Nonetheless, energy transition investors are optimistic for several reasons:

- Valuations of OEMs are descending into "value" territory despite projected longer-term growth as the energy transition unfolds.
- The rollout of tax credits and ongoing implementation of the Inflation Reduction Act could bolster renewable energy and other clean energy adjacent companies' sales as developers become bullish again – particularly if interest rates begin to decline as expected. (The market and Fed are still signaling further rate cuts by year-end 2024.)
- Declining interest rates would soften the headwinds that have worked against renewable project development finance, which has high upfront costs. Beaten-down renewable OEMs could have the most to gain from a monetary policy shift.

Storage, efficiency, and resilience solutions

Storage. Wind and solar get the lion's share of attention in the energy transition and rightly so, but energy storage is also essential. Currently, lithium-based batteries are the main component in EVs, at-home backup electric, and consumer electronics like laptops and phones. Other battery chemistries and novel physical approaches that are earlier in development aim to overcome the many shortcomings of lithium (such as cost, temperature sensitivity, fire risk, and limited lifespan).[53] There are storage technologies just emerging from the R&D phase and working towards commercialization that we believe are worth watching: flow batteries, solid state lithium ion batteries, non-lithium ion chemistries, hydrogen and ammonia, advanced fuel cells, and larger scale projects focused on kinetic (pumped hydro) and thermal storage.

Efficiency. *How* we use electricity can drastically improve the energy system and allow the world to transition without as much installed generation capacity.[54] An example of this is electrifying tasks that were previously handled by internal combustion engines (i.e., fossil fuel powered), which can boost energy efficiency in some instances. Examples include passenger vehicles, light commercial trucks traveling short distances, and some residential building applications. [55]

Other investable energy efficiency ideas include energy management systems for building as well as the energy efficiency gains that chip manufacturers are accomplishing in the semiconductor industry. The latter is particularly important, as reducing the energy footprint from data centers will be critical to preventing exponential power demands as AI ramps.

Resiliency. Reliable, secure delivery of essential energy where and when it is needed is key to a successful transition, as is redundancy (backup). This is mission-critical to the functioning of hospitals and emergency services, but also for business owners and governments that need to keep things running for their stakeholders and citizens. This need should drive growth in smart grid technology, virtual power plants, and other software and hardware products to enable renewable energy systems to seamlessly integrate with the end use of the power. Resiliency and redundancy are also relevant to the wider implementation of renewables and energy storage, which will enable energy security and independence from foreign countries' fossil fuel.

Natural gas products and services

Natural gas has a role in the power system for the foreseeable future. Renewable sources of energy still have shortcomings relative to traditional, fossil-fuel powered generation. Over time, technology will evolve to the point where traditional natural gas can be phased out, but most realistic estimates see natural gas having a large role to play in the power system for the next 10-20 years.

Bearing this in mind, investment opportunities related to natural gas may remain attractive: utilities with generation turbines, natural gas services companies, decentralized/distributed generation backup power systems, and other avenues that acknowledge the continued role of natural gas in the power system.

Regarding natural gas producers, Pathstone does not take a stance on any single commodity, and while natural gas producers might benefit from increased demand, that is uncertain. The U.S. is already the world's leading producer of the commodity, and signs suggest that additional sources of supply (natural gas deposits) may have reached their peak.

The role of major oils

Many traditional oil and gas companies have stated commitments to the energy transition. How they see that transition taking place may not align with the leading research on climate change, energy, and geoscience. Most oil and gas firms operate under the assumption that long term, fossil fuel emissions will be abated through technology or nature-based solutions. Science has shown that we need immediate, *unabated decreases* in fossil fuel use across sectors.[56] Abatement technology is still in its earliest form, and the ability to leverage natural solutions like forestry, soil, ocean, and other earth-bound sinks for carbon are limited by land use patterns as much as economics.

Some pilot and even commercialized projects should be taken seriously and are advancing the transition to a more emissions-free power system. Also, the industry is investing in the energy transition perhaps more than any other sector of the economy in dollar terms. For example:

- Chevron recently announced a $500M fund to invest in low carbon technology.
- BP has set ambitious internal carbon reduction goals for the company. Among other things, bp is investing in an EV charging network and has stated it will invest up to $1b in EV charging across the U.S. by 2030. Simultaneously, bp is planning to invest $8b in oil and gas over the same time period.
- Most large oil and gas companies are developing fuels like blue ammonia and hydrogen, but Shell and Exxon may be leading in this effort. The end user of the fuels creates zero greenhouse gases and will open the market for other firms to create fuels without fossil fuels (green hydrogen & ammonia). But the inputs are natural gas, which carries the risk of methane leakage and still emits carbon.

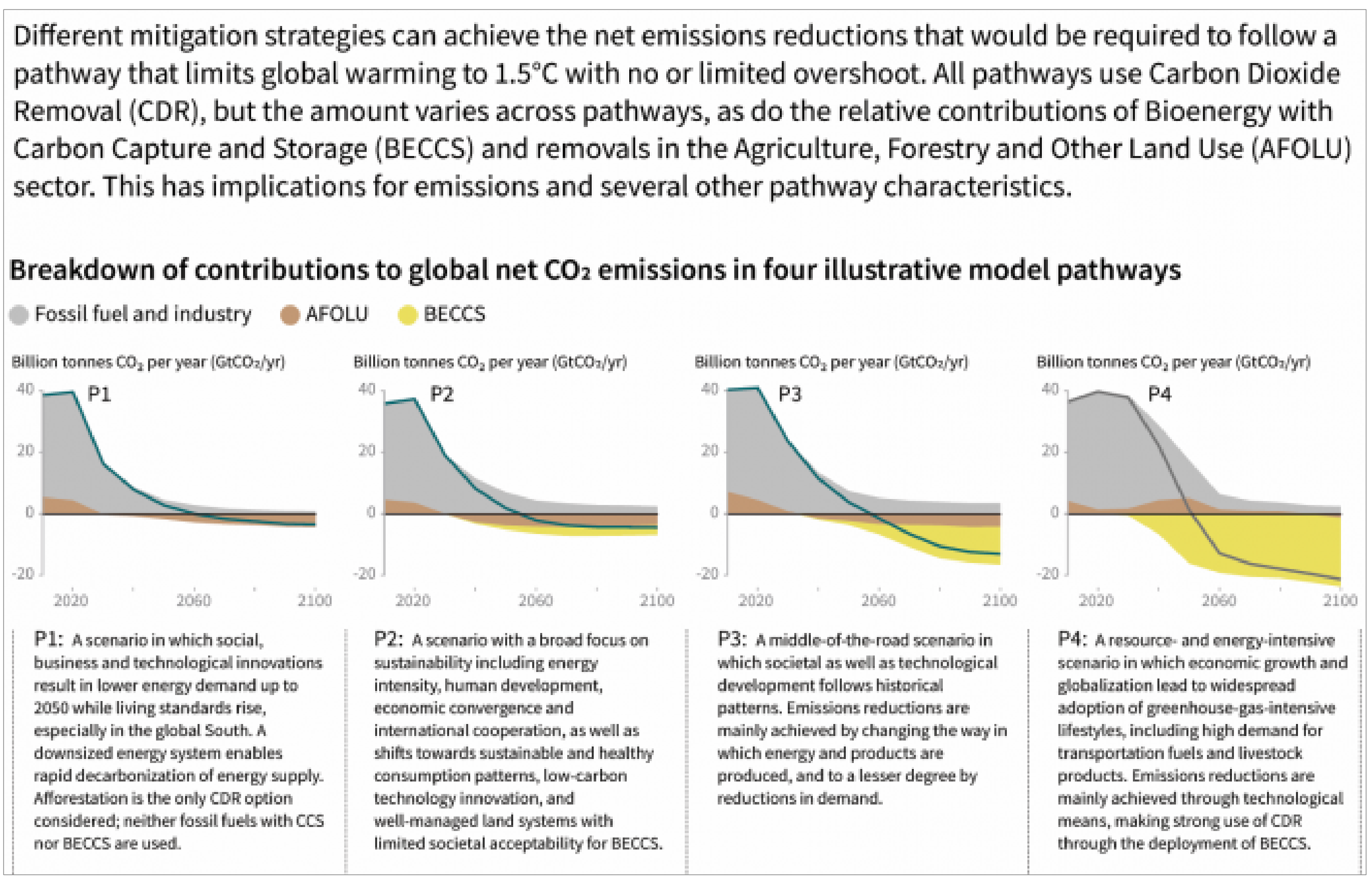
However, as a percentage of total investment, oil and gas companies are still putting most of their free cash flow into traditional energy capex, new exploration, and dividends or buybacks. These companies do not appear to be planning to scale down oil and gas based products in line with science-based targets. In our view, the opportunity for investing in natural gas – whether in the commodity itself, producers, or in the larger opportunities for its use in power generation – does not lie in technology or business models that merely wade into the renewables space.

Carbon Capture Storage. One area where the traditional oil and gas players may have the most positive effect on the energy transition is carbon capture storage: the process of using technology or natural solutions (e.g., living or geologic processes that 'eat' carbon dioxide) to remove carbon emitted from using fossil fuels and other sources of carbon emissions, such as agriculture.

In any energy transition strategy using science-based targets, fossil fuels play a role in industries and businesses where the technological barriers to electrification (and therefore the ability to power via renewables) are too high. In other words, we will need fossil fuels for at least another 80 years in some capacity. And because we need to keep using fossil fuels, we need technology and changes in our forestry and land use to capture these carbon emissions if we want to address climate change.

As Figure 12 shows, the Intergovernmental Protocol on Climate Change (IPCC) calculates there is no science-based carbon reduction target scenario) scenario in which we transition to net zero without some carbon removal solutions. While some have expressed concern that such solutions could be used as a crutch to stay on fossil fuels longer, we will need them. Oil and gas companies are leaders in hardware technology and distribution networks to address emissions. In one such effort, Occidental Petroleum formed a joint venture with Blackrock to launch Stratos, the world's largest direct-air carbon capture system (DACCS).

Figure 12: Characteristics of four illustrative model pathways



Source: IPCC.

Conclusion

Power demand growth is creating challenges for a smooth transition to the renewables-based power system required by science-based targets to prevent the worst impacts from climate change. The growth of renewables delivered to the grids worldwide over the past few years is promising, but there is a gap in what is being delivered versus what is required for a timely transition to renewables. Technological barriers are falling, policy/fiscal incentives are rolling out, and continued investor demand for these solutions are all trends coalescing right now to support investors in the short, medium, and long term.

To this end, opportunities for investors may coincide with the greatest needs: electrical infrastructure equipment and service providers, electricity generators like utilities, renewable energy manufacturers, technologies that fill the gaps of renewable energy in terms of storage, efficiency, and resilience; and the companies and technologies that will solve the challenges traditional fossil fuel companies face, especially carbon capture and storage.

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