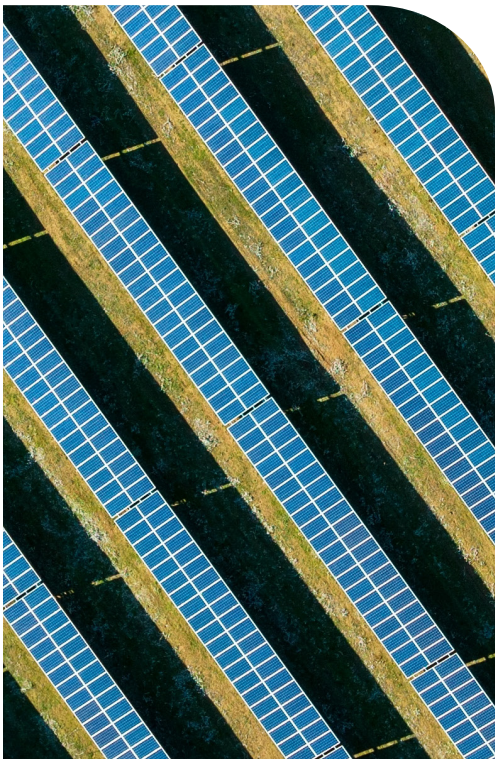

nuveen
A TIAA Company

Fourth Quarter 2025

The energy transition: 10 essential indicators for institutional investors

Evidence shows the energy transition continues to progress even as headwinds emerge in some regions

In the past year the pace of the progression of the energy transition, measured by the indicators we track, has been largely mixed, with acceleration in some areas such as global electric vehicle technology and infrastructure offset by decelerating factors such as U.S. federal policy changes. In the real economy global emissions continue to increase. We see investor's perception of the low-carbon transition growing overly negative relative to what the indicators and related data would suggest, creating a robust landscape of opportunities for institutional investors.

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The growing pessimism warrants concern: climate change mitigation and the speed at which the economy transitions to a low-carbon state are important to long-term economic growth due to the expected acute and chronic physical risks that come from higher global temperatures.

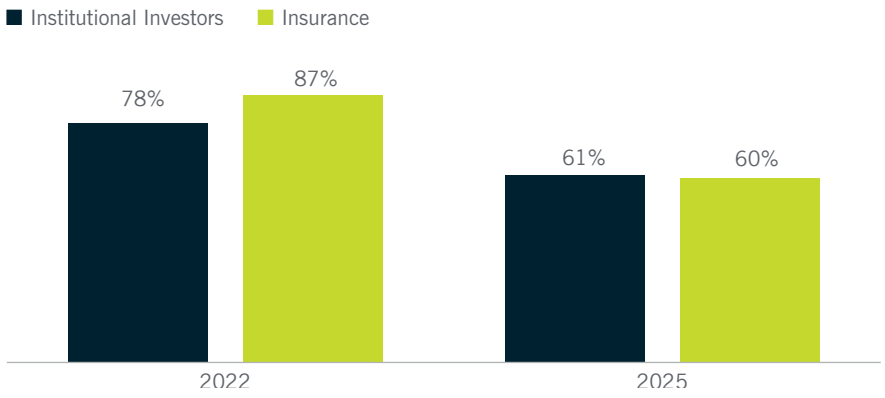
The Network for Greening the Financial System (NGFS), a group of central banks focused on the financial stability impacts of climate change, estimates that under current policies acute physical risks (droughts, heatwaves, floods, etc.) and chronic physical risks will reduce 2050 global GDP by 8% and 15%, respectively (relative to a counterfactual scenario with no climate change), these compare to estimated losses of 4% and 7% should the economy follow a net zero by 2050 pathway.

However, the extent of the economic damage is highly uncertain — if expressed in a distribution, there is arguably too much focus on the median or mean expected GDP shock, rather than the outcomes at the tail. Many scientists and Intergovernmental Panel on Climate Change (IPCC) authors argue that tipping points, which are extremely difficult to predict or model, could lead to drastically worse outcomes, and current economic interpretations are severely underestimating risks.

Keeping pace with the transition will require an adept ability to navigate short-term policy volatility and market cyclicality in a manner that takes advantage of dislocations. The negative sentiment is generally depressing valuations and growth assumptions in public and private markets, creating attractive opportunities for long-term investors to reposition portfolio exposures and increase capital allocation towards climate solutions.

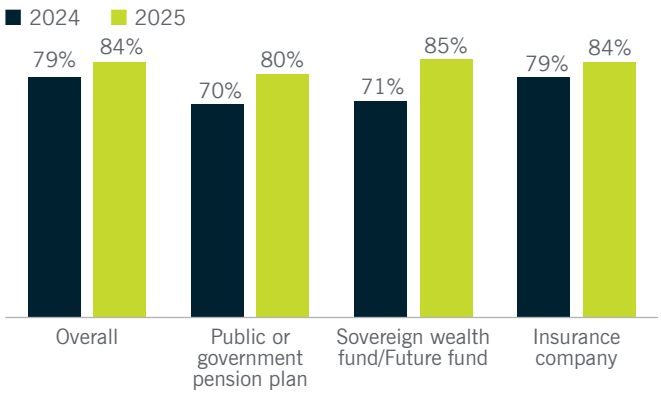
Nuveen's Equilibrium survey suggests institutional investors are increasingly considering environmental impact in their investment decision-making; opportunities to gain exposure to the structural theme of decarbonization while achieving market-rate or higher returns across asset classes are increasing in tandem with the need for higher clean-energy related global capital expenditures.

Figure 1: Investor beliefs: The transition to a low-carbon economy is inevitable (% agree)



Source: 2025 Nuveen Equilibrium Survey

Figure 2: Considers environmental impact in investment decision making or plans to over the next 12 months



Source: 2025 Nuveen Equilibrium Survey

Wildcard

Unanticipated surge in energy demand

Since OpenAI released ChatGPT in 2022 — gradually, then suddenly — the floodgates of artificial intelligence opened, and the technology and investment community have raced to expand upon the utility of large language models (LLMs) and Generative AI. These new models and technologies differ materially from prior AI functionality in the ability to create new content and respond to prompts at high levels of sophistication.

Speculation towards the transformative applications for consumers and businesses, and the related economic profits, have fueled more investment and innovation from venture capital and corporates, investing $131B and $252B in AI deals in 2024, respectively.[1] Expectations are high: PWC anticipates Generative AI will contribute up to ~$16T to the global economy by 2030, with $6.6T coming from increased productivity and ~$9.1T from consumer-related activity.[2]

The capital expenditures to realize these productivity gains are expected to range from $3.7T to $7.9T from 2025-2030, depending on the speed of adoption and use, requiring an incremental 78-205 gigawatts (GW) of electric power capacity.[3]

Energy is fundamental to economic growth. Notably, the provision of energy is typically subsidized globally due to both the natural monopolistic characteristics of utilities but also from the positive multiplier energy access provides for development. Nonetheless, about 666 million people still lack basic access to electricity, which roughly implies latent demand of an additional ~700 GW of capacity.[4]

The demand shock from AI, along with capital ready to pay up for power, is likely to have profound but mixed implications on the energy transition. On the one hand, the short-term reaction may cause relatively less substitution between sources and increase capacity utilization of fossil-based power generation.

However, we are also seeing the demand ignite and accelerate innovative, zero-carbon forms of power generation. Hyperscalers are directly or indirectly (through Power Purchase Agreements (PPAs) or other commitments) funding Enhanced Geothermal Systems (EGS) and nuclear small modular reactors (SMRs), accelerating the technology development, commercialization, and the scaling process of these nascent but important technologies. Pricing signals from this demand shock may further stimulate clean energy manufacturing economics and capacity growth.

Looking forward, there will likely be more upside demand shocks to the power sector (mitigated to a degree by technology-driven gains in efficiency). Specifically, potential catalysts include the acceleration of electric vehicle adoption, hotter temperatures (cooling demand and HVAC penetration) — or further unforeseen technology developments such as artificial general intelligence and robotics. For reference to scale, the International Energy Agency expects global warming to double the penetration of air conditioning units between 2020 and 2040, which roughly implies ~200 GW+ of additional power capacity.[5]

Ultimately, these phenomena are a natural part of economic progress, and the low-carbon transition will need to accommodate cyclical and structural changes over time. AI, while significant, is only one source of additional energy demand anticipated over the short-to-medium term.

Decoding the transition with 10 key indicators

Leveraging our ongoing work with TIAA, we have identified 10 forward-looking indicators related to capital deployment, policy shifts and technological advancements. These indicators are highly interconnected and offer valuable insights into the pace of the energy transition over the near to medium term — helping investors calibrate scenario analysis and fundamental modelling assumptions.

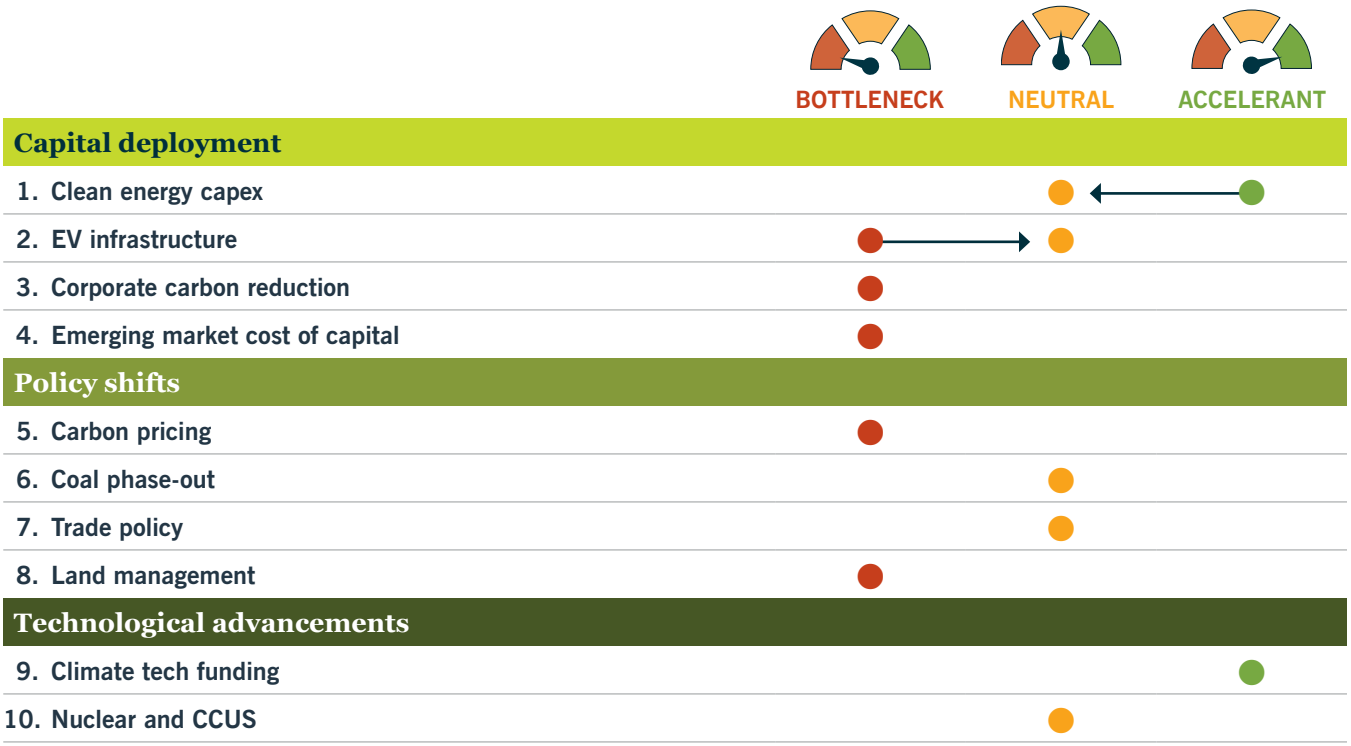
Each indicator is classified as an accelerant, bottleneck or neutral based on our assessment conducted in mid-2025. This determination reflects the indicators' current impact on the pace and progress of the energy transition but acknowledges that these classifications will evolve over time as market dynamics, policies and technologies change.

In this year's update, we are downgrading the status of the clean energy capex ratio[6] to neutral, as the growth in the ratio appears to be stagnating at ~2:1 (versus ramping to the 6:1 – 10:1 range which would be sufficient for an accelerated transition). Relative to the climate scenarios IEA has published forecasts for: the Stated Policies Scenario (STEPS), the Announced Pledges Scenario (APS) and the Net Zero by 2050 emissions scenario (NZE), the data suggests a pathway in-line with STEPS in the near term.

In contrast, we are upgrading the status of the EV infrastructure indicator, as we see robust growth in public charging points of over 30% in 2024, with additions equivalent to the total number of available charge points in 2020. Further, we see the uptick in innovative business models around battery swapping as a new form of charging network infrastructure gaining traction and providing an accelerant to EV penetration through enabling more affordable options for consumers.

In this report, we update each of the 10 indicators with the latest data available, and provide our key observations, outlook, and thoughts on investment implications relevant for both private and public markets.

Figure 3: 10 leading indicators of the energy transition: current status



Source: Nuveen

Capital deployment

1 Global capital expenditure

INDICATOR:
Clean energy to fossil fuel ratio 2:1 (2025)

Observations[7]

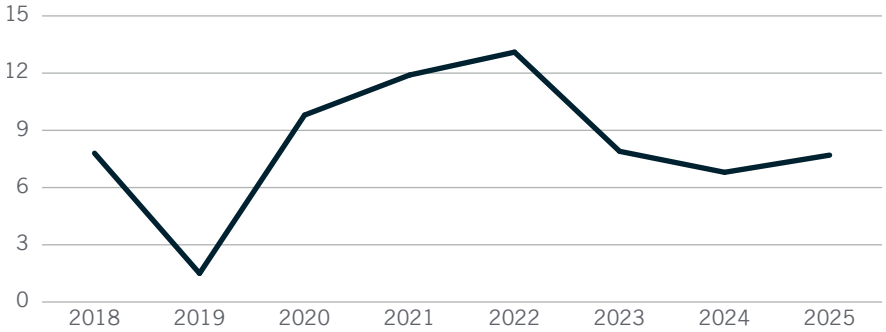
The ratio of clean energy to fossil fuel capital expenditure grew modestly in 2025 to 2:1. Several structural trends underpin the headline figure, with the most notable being China's overall investment in energy, nearing ~$900B or one-third of all global energy related spend.[8] China's clean energy industrial policy has led to production capacity outpacing demand with three important and related implications:

1. Structurally lowering prices across clean technologies (since 2022, solar modules prices are -67%, lithium-ion batteries are -31%, and wind turbines -21%);[9]
2. Tougher operating environment for western-based production, calling to question which countries can compete and grow capacity in the clean manufacturing space (and whether further protectionism is preferred, which in the short-term raises costs for deploying clean energy technologies); and
3. The increased affordability for emerging market countries has contributed to increasing adoption, with clean-tech imports rising from 22% to 43% from 2022 to 2024.[10]

From a fossil fuel perspective, there were modest declines in traditional upstream and refinery investment, while positive sentiment on gas and Liquified Natural Gas has fueled an investment cycle supportive of natural gas use for power generation. Oil majors continue to use cash on hand (>50%) to remunerate investors and have been pulling back low-emission/clean energy capex significantly.

Figure 4: From 2015 to 2025 the capex ratio grew from 1:1 to 2:1, but clean energy capex growth has moderated in recent years

Fossil fuel versus clean energy capital expenditure growth rate differential (3-year moving average)



Source: International Energy Agency.

In contrast, smaller Oil & Gas companies and some National Oil Companies (NOCs) have been increasing spending on low-emission technologies, doubling collective expenditure from ~$5B to ~$8B from 2022 to 2024. All-in, low-carbon investments (loosely defined) from the oil and gas sector remains minimal at $22B or 2.5% of total capital budgets (in 2024) and the narrative around these companies' low-carbon transformation has dramatically shifted, with many emphasizing exposures to natural gas and potential to ramp Carbon Capture Utilization and Storage investments as core to their transition strategies.

Outlook

Our indicator status downgrade stems from the lack of a material step-up in clean energy expenditures commensurate with the ~$3T+[11] per annum required to accelerated climate mitigation at pace aligned with the goals of the Paris Agreement.

Investors should consider where optimal spending might be, on a geography and technology basis, to close the gap. We see room for investors to increase infrastructure allocations focused both on grids and on emerging and developing countries where attractive yields and returns persist.

Headline renewable power investment at ~$1.3T is primarily going to advanced economies and China, with only 20% going to emerging market and developing economies — with the clean energy to fossil fuel capex ratio 12:1, 6:1, and 2:1, respectively. On a technology basis, grid investment, although expected to surpass $400B in 2025, is not keeping up with generation — globally 60 cents of grid investment for every dollar of generation in 2016 has declined to 40 cents per dollar today.[12]

The Mission Possible Partnership tracks the build of commercial-scale clean industrial plants, particularly relevant for decarbonizing hard-to-abate sectors such as chemicals, aviation, steel, aluminium, and cement. As of June 2025, they've identified 69 operational plants, 65 plant with secured final investment decisions (FIDs), and 692 announced plants in need of financing. These opportunities are material and would benefit from supportive industrial policy and incentives such as carbon pricing.

The operational or secured FIDs represent ~$250B in capital investment, while the announced projects reflect a ~$1.6T investment opportunity, with nearly half of that pipeline in emerging market and developing countries. Institutional investors and governments may look to partner on these investments to ensure both funding but also to enable policy support to de-risk project economics.

Despite the downgrade, the breadth of project opportunities gives us a positive orientation on the outlook and potential for this indicator to re-accelerate in coming years.

Investment implications

Many asset owners are considering climate solution targets. We encourage the consideration of incremental capital flowing to the real economy and would recommend incorporating principles from the Global Impact Investment Network's (GIIN) Climate Solutions framework. This framework helps investors think strategically about deploying capital in a manner that directly increases the deployment of clean technologies.

Private markets

In the U.S., federal policy changes have created pockets of opportunity for institutional investors to support projects where prior funding sources have been withdrawn. Given the capital intensity of the transition, asset owners should consider increasing allocations to sustainable infrastructure where compelling characteristics like structural growth and higher yields are present.

Public markets

Following recent shareholder proposals, some banks are now disclosing what is termed the 'energy supply financing ratio' (ESFR), which is analogous to this indicator with the scope of a bank's balance sheet. Bloomberg New Energy Finance (BNEF) has begun tracking ESFR for public market funds, finding that funds tracking the S&P 500 bias towards a lower ESFR between 0.5 – 1.0.[13] Public market investors should monitor this ratio versus their benchmark and consider constructing portfolios with higher ratios to proactively manage transition risk and capture transition opportunities.

2
EV infrastructure

INDICATOR:
5.2m public connectors in 2024 globally

Observations

Despite slower growth in the U.S., momentum in the electric vehicle market is accelerating. In 2024, new electric vehicle sales grew by 25% (to 17 million units) and public charging points grew by ~33%. Globally, fast chargers grew 42% and now represent ~38% of public chargers.[14] We view the infrastructure build as a necessary precursor to adoption. McKinsey survey data suggests skeptical EV buyers would only begin to consider an electric vehicle purchase when the availability of chargers is equivalent to that of gas stations.[15]

On a regional basis, public charging station growth in the U.S. (+21%), China (+30%), and Europe (+36%) was robust; however, in all other markets charging infrastructure grew +131%, with fast chargers growing +318%.[16] Alongside the rise in publicly available fast chargers, there are also innovations increasing the ultimate speed of fast charging. In March 2025, BYD set a new benchmark utilizing next-gen battery technology able to deliver ~400km of range in five minutes.

In China, and some emerging markets, battery swapping is gaining traction as an innovative form of charging infrastructure 'as a service'. Benefits include materially lower costs for the electric vehicle, improved battery longevity, superior integration within power grids, and better ability to coordinate battery recycling and reuse.

Importantly, the more affordable EVs enable access to large markets are particularly useful for 2- and 3-wheel vehicles popular in many emerging markets. Companies like Sun Mobility, Spiro, SWAP Ampersand, Arc Ride, Roam, and others are scaling swap station in markets in East Asia and East Africa. Beyond 2- and 3-wheelers, the battery as a service model is also useful for fleets of trucks and may emerge as the popular model for electrifying heavy-duty vehicles. In developed markets, further interoperability of Tesla charging stations with other vehicle types effectively increases charging capacity.

Outlook

The projection for this indicator provided by the International Energy Agency (IEA) in the stated policy scenario, which is closest to its base case, has been raised by 6% relative to last year's forecast, driven by the expectation of more rapid deployment of fast chargers. The public stock of charging stations is now estimated to reach ~17.1 million by 2030.[17]

On the electric vehicle side, the fast-growing Chinese market is enabling greater emerging market EV adoption via exports. Meanwhile, geopolitical considerations support further technology diffusion, as Chinese manufacturers set up JVs and plants oversees with certain IP sharing requirements. This force acts like a flywheel incenting more charging infrastructure investment — suggesting potential upside to IEA estimates.

The extent to which this momentum continues will have material implications for the speed of oil demand destruction and related impacts for fossil-fuel assets, reserves, and geopolitics. By 2030, on the aforementioned IEA estimates, an incremental ~3.8 million barrels per day of oil demand will shift to ~605,000 GWh of electricity demand.

The rapid progress over the last year has driven our upgrade and positive outlook on the indicator.

Investment Implications

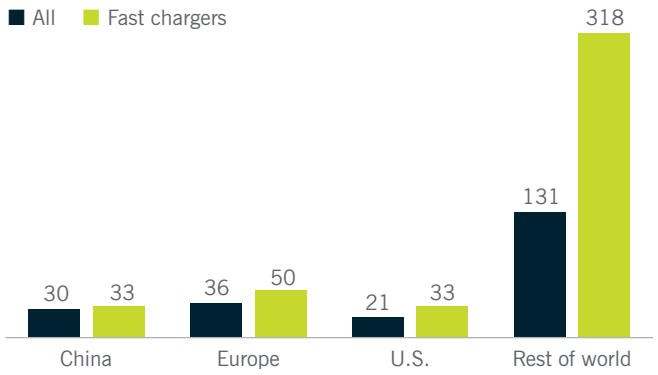
Private markets

The economic and logistical benefits of battery swapping are demonstrating success in several markets — the provision of financing to compete with, scale, or introduce this model to new markets is a compelling opportunity for both private equity and debt.

Public markets

The direct relationship to oil demand destruction is important to monitor and of EV adoption for public market investors looking at long-term oil and gas corporate debt issuances. Particular attention on long-term sovereign issuance from countries reliant on fossil-fuel exports may also be warranted.

Figure 5: 2024 Public charging station growth rates (%)



Source: Global EV Outlook 2025. IEA.

3 Corporate carbon reduction

BOTTLENECK

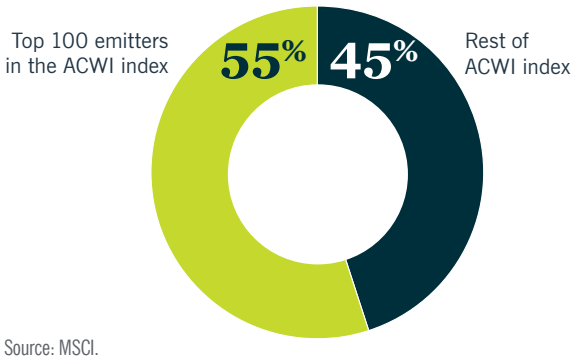
INDICATOR:
-0.06% projected annual decline of GHG emissions forecast from 2025 – 2030 for the top 100 corporate emitters in the MSCI ACWI

Observations

We continue to rate this indicator as a bottleneck because projected corporate carbon reductions through 2030 are far below levels required to align with a Net Zero scenario carbon budget. On the positive, through a time of U.S. policy volatility, corporate commitments to carbon reduction persist and are increasingly being adopted by smaller companies. The latest PwC State of Decarbonization report highlights a couple of noteworthy trends amongst the 4,000 corporates that report through CDP:[18]

1. 37% of companies are increasing ambition versus 16% that are getting less aggressive
2. Smaller companies are making commitments in reaction to supplier engagements, with median revenue of companies making new corporate reduction targets in 2024 $1.3B, versus $3.6B in 2020
3. Companies are maintaining commitments through CEO/leadership transitions, suggesting strong board oversight and stewardship

Figure 6: Absolute emissions (Scope 1 – 3) from companies in the MSCI ACWI Index



Source: MSCI.

Annual carbon reduction rate 2025-2035 for top 100 corporate emitters:

-0.06% MSCI forecasts based on credibility of company targets

-10.61% Required to align with Net Zero scenario carbon budget

Corporate commitments help accelerate the transition in two distinct ways: 1) create demand for low-carbon solutions (either directly from purchases or indirectly through supply chain influence); 2) create new supply of low carbon solutions. Different business models will be more or less able to contribute to these levers.

From a theory of change perspective, we do not believe corporate commitments are a silver bullet. The idea, once prevalent in the sustainability community, that each corporate will decarbonize to the point of net zero is unrealistic.

This indicator focuses on the forecasts of the top 100 emitters of the MSCI ACWI and suggests little change over the next decade.[19] Voluntary corporate commitments are especially poor drivers of Scope 3 carbon reduction. Of the companies voluntarily reporting carbon emissions to CDP, Scope 3 represents four times more emissions than Scope 1 and 2, ~50% of Scope 3 emissions are covered by reduction targets, and just ~54% of companies are on track to meet their Scope 3 targets.[20]

In short, the corporate lever can be extremely useful in expanding supply/demand for climate solutions on the margin, but will not be the primary catalyst for the low-carbon transition due to legal, practical, and economic limitations.

Outlook

Decarbonization efforts of some industries where enough margin exists to underwrite or provide offtake certainty for nascent or subscale climate solutions can be particularly helpful. We are seeing this dynamic in the tech industry, where energy intensity is increasing yet corporate efforts to commercialize new forms of power generation and innovative carbon removal technologies are notable — Microsoft is a poster child for these initiatives.

The relevancy of corporate decarbonization is primarily in hard-to-abate sectors in heavy industry, materials, energy, and where carbon intensity is highest. For these companies, the potential future costs, liabilities, and conversely opportunities from lower carbon solutions are financially material — and managing cash flow and capital to navigate these challenges requires adept management teams and governance.

There is still a lack of long-termism amongst corporate management teams, where incentives and compensation structures bias towards shorter time periods. This creates an environment that makes it difficult to underwrite investments or IRRs factoring in material carbon prices or policy changes. Public equity markets generally reinforce and exacerbate this short term bias.

These factors lead us to a negative outlook on the potential for a significant acceleration of corporate carbon reduction efforts.

Investment Implications

Private markets

There is an opportunity for investors in private markets to learn and lead in the financing of carbon removal and carbon credit projects. Many of these are backed by offtake agreements with public corporates, but do not have sufficient collateral or risk-profile for banks and are not in the traditional wheelhouse of private equity and debt firms.

Public markets

With the large amount of passive assets tracking indices, there is merit for investors with climate commitments to continue with aggressive stewardship efforts amongst the largest emitters, focusing on financially attractive decarbonization strategies. Actively managed portfolios should seek companies with evidence of decarbonizing business models and low carbon innovation, such as green patents, that help position for growth in a low carbon future.

4
Emerging markets cost of capital[21]

BOTTLENECK

INDICATOR:
~5.2%+ emerging market sovereign risk premium implied by 10-year government bonds (for select EM countries)[22]

Observations

Many clean energy technologies, and certainly renewables, are capital intensive. Intuitively, financing costs are a clear bottleneck to deployment, even as the technologies become cheaper. There is an ongoing debate as to whether the factors that influence country risk premia and credit ratings — income, currency, government stewardship and institutions, debt levels, growth potential, etc. — are systematically biased towards higher income.

A report from the Columbia Center on Sustainable Investment suggests that "the high cost of capital in EMDEs is driven by the perception that default risk is very high for these countries". Their research suggests eight distinct points for improvement to the credit rating agency methodologies that would further enable capital flows.[23] These include using a longer 30 to 40 year time horizon for growth trajectory and assuming higher GDP growth potential over this horizon. Other financial sector stakeholders, including development banks and private sector financial institutions, may have similar opportunities to shift practices and structure to mobilize more capital into emerging markets.

Outlook

The IEA estimates just $420B of clean energy will be deployed in emerging market and developing countries (ex-China) in 2025, growing at just +3.5% per annum in the past decade. Countries in Africa are receiving just 2% of all clean energy investment despite representing 20% of the population. The insufficiency of robust weighted average cost of capital (WACC) data is further afflicting strategic planning, resource allocation, competitiveness and infrastructure development.[24]

While 'blended' financing mechanisms aim to solve these structural issues, the market for these securities remains relatively small and sub-scale. In 2024, both the deal count and financing flows were down year on year, from 129 to 123 and from $23.1B to $18.9B, respectively.[25] Of the 123 deals in 2024, half of them were climate-focused and represented nearly two-thirds of the total financing.

Due to the structural nature of these cost of capital challenges, our outlook remains negative on this indicator improving demonstrably over the near-term.

There is an ongoing debate as to whether the factors that influence country risk premia and credit ratings — income, currency, government stewardship and institutions, debt levels, growth potential, etc. — are systematically biased towards higher income.

Investment Implications

Private markets

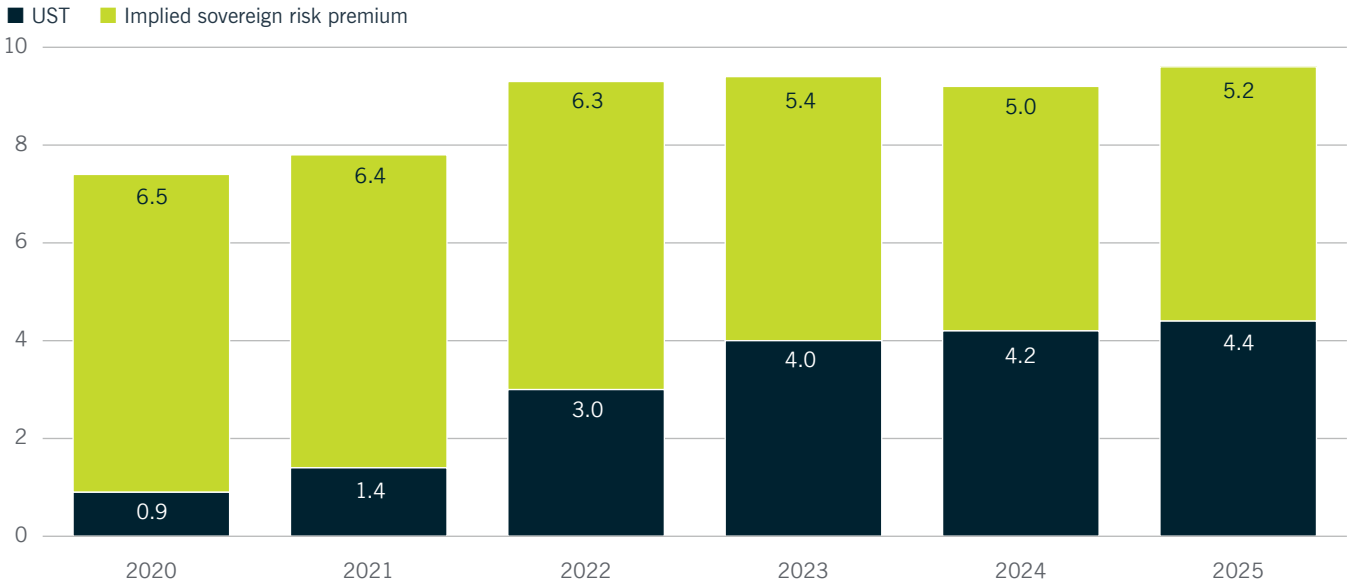
Investors should focus on opportunities in emerging markets where fundamentals and economic growth prospects are sound but country-risk perception and capital availability induce higher yields and return potential. From a valuation perspective, investors should be wary of adding an additional country risk premium to cost of capital, as McKinsey, the global consultancy, suggests: "adding an extra country risk premium to the cost of capital doesn't add insight; it obscures it."[26]

Public markets

For institutional investors with climate commitments, asset allocation increases in emerging market debt could allow for greater impact of the portfolio, while improving overall risk-adjusted returns by favoring safer and/or more stable assets within those markets — such as green bonds from utilities and renewable energy developers.

Figure 7: Developing countries classified as lower and upper middle income by the World Bank face significant financing costs, structurally raising the cost of the energy transition even as clean energy technologies grow cheaper

10-year government bond – select EM countries (average yield %)



Source: Bloomberg; Countries include India, Brazil, Indonesia, and South Africa

Policy shifts

5 Carbon pricing

BOTTLENECK

INDICATOR:
Global weighted average carbon price ~$23/ton CO2 equivalent (CO2e) covering ~15 gigatons CO2e[27]

Observations[28]

In the compliance market — which includes carbon taxes and trading schemes, but not voluntary carbon credits — there has been little movement in pricing while coverage expansion from ~23% of global emissions to ~28% was driven by China's emissions trading scheme (ETS) expanding to additional industrial sectors (cement, steel, and aluminum). If pricing is extrapolated to include all global emissions not directly subject to a carbon price, the resulting ~$5 per ton is insufficient to induce significant changes in corporate and market behavior and investment.

There has been notable recent progress in emerging markets. Brazil has approved a law to formally establish an ETS, India's government adopted a rate-based ETS scheme covering energy-intensive industrial sectors, Indonesia expanded its ETS to additional coal-fired power plants, and Turkey is establishing a legal and governance framework for an ETS it is expected to pilot in 2026. Japan is also expected to commence a national ETS in 2026 covering corporates emitting over 100,000 tCO2e per year. The prospect of the EU's Carbon Border Adjustment Mechanism (CBAM) provides additional impetus for countries — particularly those with high levels of exports into the EU — to further develop carbon tax or trading schemes that would allow them to retain revenue generated from the tax.

The revenue generated from compliance markets once again totaled ~$100B in 2024, and the use of proceeds continue to be spread across a mix of investments with a variety of goals. Roughly half of the funds over the past seven years, nearly ~$300B, have been earmarked towards environmental, infrastructure, and development projects. The use of funds towards mitigating the social impact of the transition went from less than 10% in 2018 to ~25% in 2024, through direct transfers to impacted households or tax cuts elsewhere.[29]

Compliance markets are beginning to integrate with the voluntary carbon credit market, which is generally a positive in enhancing the overall carbon credit market structure, liquidity, and development. For example, compliance markets of California, Chile, Colombia, and South Africa are a source of demand for certain carbon credits and as well as industry compliance frameworks such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). At COP29, the final rules for Article 6.2 and 6.4, addressing technical details covering the operational components of international carbon markets, were agreed to, representing a positive milestone for further integration.

Outlook

Two industries in the transport sector, aviation and marine transportation, are on the precipice of operationalizing carbon pricing schemes. The International Maritime Organization (IMO), have put forth a program whereby large vessels over 5,000 gross tonnage that emit beyond set limits will pay a fee, beginning at $100 per excess ton and rising to a maximum of $380 . The vote to adopt this regulation, initially planned for October of 2025, has recently been delayed for political reasons to October 2026, bringing some uncertainty to implementation timing which had been envisioned to take effect in 2027. Once implemented, the rule would add ~3% or ~1.5 Gt CO2e to the total global GHG emissions covered by carbon pricing [30]

CORSIA is in its first phase which is not mandatory; however, beginning in 2027 the second phase which is mandatory will commence, applicable to international flights only, and generally requires airlines to purchase offsets to any increase in their emissions above a 2019 baseline. These offsets are called CORSIA Eligible Emissions Units (CEEUs) and follow a standards set by carbon offset verification standards, with some activity exclusions. The expected demand from this program is material, projected to cumulatively reach ~100 – 150 MtCO2e for Phase 1 (2024 – 2026) and between ~500 – 1,300 MtCO2e for Phase 2 (2027-2035), relative to total voluntary carbon credit issuance of ~290M tCO2e in 2024 (987 million credits from 2021-2024 remain unretired).[31]

These developments, alongside the potential spillover impacts of emerging carbon border adjustment mechanisms leads us to a positive outlook on the indicator, despite its current status as a bottleneck.

Investment Implications

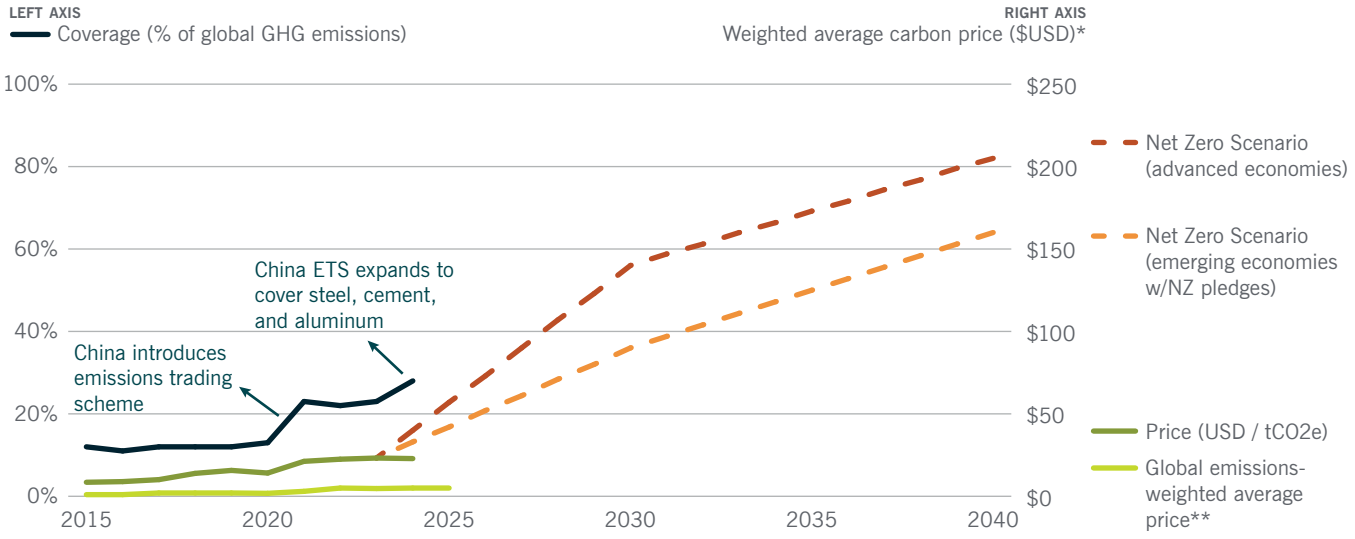
Private markets

The opportunity set to provide capital to the developers and/or suppliers of carbon credits is growing. In the voluntary market, carbon removals have the most value and it is worth considering gaining exposure through 1) natural capital strategies where carbon credits can enhance the return profile; or 2) private credit — financing for developers with offtake agreements from trusted corporate counterparties that have trouble accessing traditional bank financing.

Public markets

For exposures in industries imminently impacted by new carbon pricing schemes (e.g. shipping and airlines), investors might consider both which corporates are better positioned but also the opportunities from indirect implications, such as the demand and supply dynamics for sustainable aviation fuel or green ammonia.

Figure 8: While coverage improved modestly, carbon pricing remains off-track relative to an accelerated transition scenario



*Represents weighted average of all emissions covered by carbon pricing; **Weighted average includes uncovered emissions

Source: World Bank, Statista, IEA Net Zero Roadmap

6
Coal phase-out

NEUTRAL

INDICATOR:
300 gigawatts of coal capacity planned for retirement between 2023 and 2040[32]

Observations[33]

From 2022-2024 electricity generation output and GHG emissions from coal continued to rise by ~1.4%/1.3% per annum, respectively, and coal plant retirements in 2024 (25 GW) were more than offset by new capacity additions (44 GW). From a regional standpoint, China and India comprised the majority (92%) of capacity additions.

Outside of these two countries, coal power development has declined materially over the past decade, with just 80 GW of capacity either in the construction, permitted, pre-permit, or announced stage in 2024 versus 445 GW in 2015. However, there remains ~690 GW of coal capacity under development globally.

A development worth noting is the push to mobilize finance and compensation for early retirement of coal plants, with some ideas proposing carbon credit mechanisms to acknowledge the 'avoided emissions' of such initiatives.

The Rockefeller Foundation launched the Coal to Clean Credit Initiative (CCCI) centered on 'transition credits.' The credits are created when a coal plant shuts down early, which could be sold to companies or organizations where the funds raised from selling the credits would contribute to replacing the energy generation with renewable sources.[34] Verra, a certifier of carbon credits, has already approved the methodology for these types of credits and there is currently a pilot in the Philippines with ACEN Corporation which is looking to retire a 246 MW coal plant by 2030 (it was originally slated to retire in 2040).

Outlook

As mentioned in the Wildcard section, the recent data center-driven power demand surge will likely raise existing coal plant capacity utilization in the near-term, elevating emissions from coal and potentially delaying imminent retirements. Nonetheless, given the levelized cost of energy in most markets (LCOEs) in most markets, increasing demand in the medium to long-term will unlikely be met by coal, and most countries with large existing fleets understand the health and climate costs of the generation source.

In the U.S., however, policy has drifted towards a direction more supportive of coal. Despite over half of U.S. capacity is planned to retire before 2035, we have recently seen a flurry of announced delays or withdrawing of planned retirements as corporates are embolden by government support and are concerned for grid stability. Despite this, the merit order and marginal costs of operating these plants here will likely drive continued retirements which may even accelerate towards the latter end of the decade depending on the extent to which solar and battery costs continue to decline.

From a global perspective, the growing output of natural gas and liquified natural gas (LNG) will further contribute to coal-to-gas substitution which on balance should be net positive for retirements and emission declines. LNG supply is expected to increase by ~42% from by 2030, from 440 Mtpa to 626 Mtpa.[35] Although there are debates about the impact of growing gas consumption, and particularly concerns around methane emissions and leakage, the emergence of gas power generation in the U.S. was arguably the largest factor in reducing the carbon intensity of the power sector over the past several decades.

Given that new coal capacity under development currently stands more than double the capacity projected to be retired between 2025 – 2040, our outlook on the status of this indicator is negative.

Investment Implications

Private markets

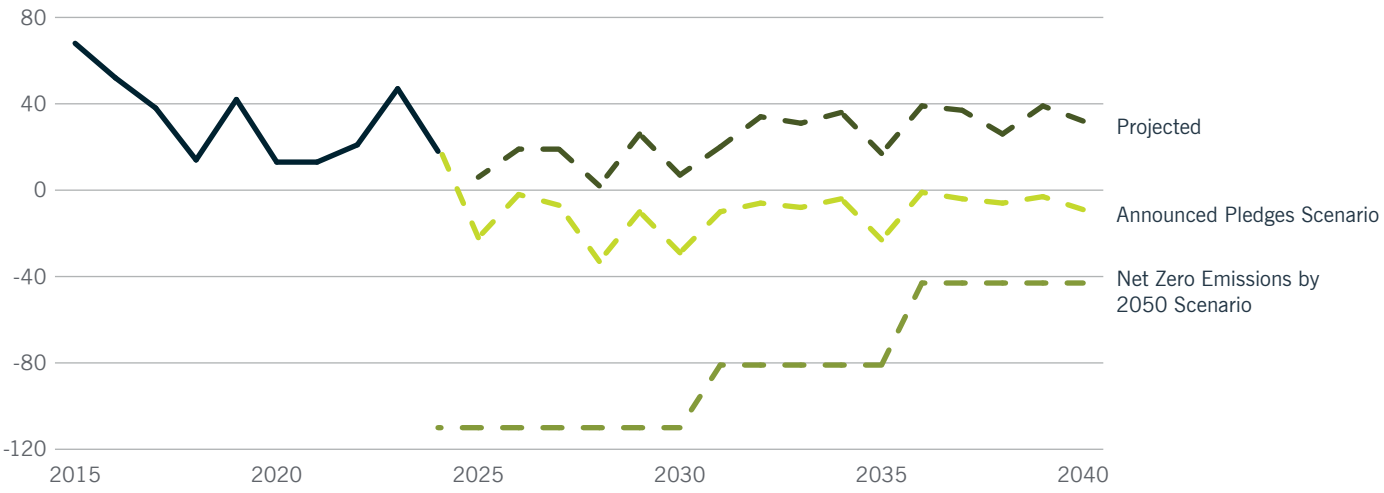
Opportunities to finance first-of-a-kind (FOAK) projects and scale emerging carbon free baseload technologies, such as Enhanced Geothermal Systems (EGS) and Small Modular Reactors (SMR) persist and the technologies' maturation and cost decline would represent a material pathway towards accelerated coal retirements.

Public markets

From a stewardship perspective, there is an opportunity to engage and raise awareness to corporate buyers of carbon credits of the emerging CCCI 'transition credits'. If accepted as an attractive type of credit on par with removals, the mechanism may unlock a faster path towards coal phaseout.

Figure 9: On a net basis, new coal capacity under development (690 GW) is more than double the capacity projected to be retired over the next 15 years (300 GW)

Net GW (additions - retirements)



Source: Global Energy Monitor, IEA Net Zero Roadmap

"The recent data center-driven power demand surge will likely raise existing coal plant capacity utilization in the near-term, elevating emissions from coal and potentially delaying imminent retirements."

7 Trade policy

NEUTRAL

INDICATOR:
One major climate policy in motion (Japan), one on the horizon (Korea) while another largely rescinded (U.S.)

Observations

Excessive focus on federal U.S. policy changes from investors and stakeholders alike might be misplaced given that U.S. GHG emissions comprise just 12% of the global total. As a positive for the transition, the new administration's prioritization of gas production and LNG exports may hasten coal retirement in APAC and policy support for carbon-free baseload technologies like nuclear has been retained.

Nonetheless, there are negative climate implications from various components of the recently passed One Big Beautiful Bill, and estimates suggest U.S. emission reductions through 2035 will be ~7-9% less than the reductions anticipated during the prior administration — mainly driven from the effects to the power sector.[36] This impact may underestimate the power of market forces, however, as corporate management teams continue to cite renewable sources as the quickest and most compelling technology to meet surging energy demand.

Elements of Japan's (Green Transformation) GX policy — a comprehensive industrial policy initiative aiming to mobilize ~$1T USD of capital investment over 10 years — are beginning to take form. There are both carrots and sticks included in Japan's transition strategy, as it will look to provide investment, credit, and risk-reduction capital while simultaneously standing up a carbon trading scheme that grows more aggressive in a predictable manner. The country plans to raise ~$135B through sovereign bonds over this time frame to support upfront transition investments.

Elsewhere, South Korea's newly elected President Lee Jae Myung has quickly signaled robust ambition for decarbonization, establishing a new Ministry of Climate and Energy and targeting structural reforms. Although it's early days, investors might expect elements of new industrial climate policy to emerge in South Koreain coming years.

Outlook

Geopolitics have reached a moment of heightened angst, and a change in the U.S. administration has catalyzed a rethink of normative trade parameters and relationships. Notably, a shift towards protectionism — aside from the economic implications suggested by basic theory — usher in a new frame with which to view the transition, one coined by Carlyle as the New Joule Order,[37] which places a premium on independent energy sourcing.

Solar, wind, and battery storage technologies are continuing to grow cheaper and more ubiquitous. Meanwhile, fossil fuel purchase agreements are being used as a bargaining chip against punitive tariffs in other sectors. Against this backdrop, the value of energy security becomes obvious. Fossil fuel importing countries have a particular motivation to shift toward clean energy. Indeed, from 2020 – 2025, ~70% of the increase in clean energy expenditures came from fossil-fuel importers.

With industrial trade policies such as Europe's CBAM on the horizon and China's increasing export of clean energy technologies at affordable prices we are positive on the outlook for this indicator.

Investment Implications

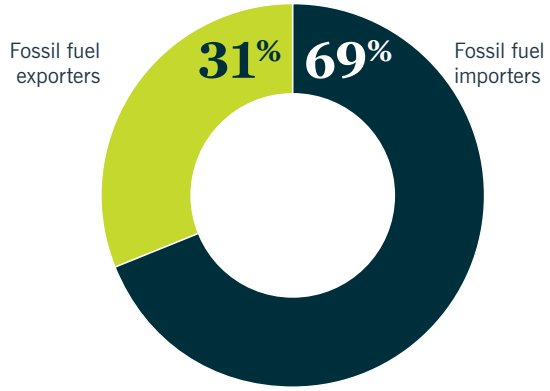
Private markets

Investors in markets where the governments just beginning to pursue aggressive decarbonization policies should seek to gain exposure and experience investing in clean energy technologies in other, more mature markets.

Public markets

While there has been a lot of focus on corporate transition plans, other factors such as country transition plans, risk exposures, and capital spending have been relatively overlooked. Sovereign credit strategies that are transition-aware may be worth exploring going forward.

Figure 10: From 2020 to 2025, ~70% of the increase in clean energy expenditures came from fossil-fuel importers



Source: IEA

"A shift towards protectionism — aside from the economic implications suggested by basic theory — usher in a new frame in which to view the transition."

8
Land management

BOTTLENECK

INDICATOR:
Tropical primary forest cover loss of 6.73 million hectares in 2024[38]

Observations

In this update, we've narrowed the indicator to focus on tropical primary forest cover, which has significant carbon sequestration capacity and generally stores more carbon than other types of forests. In 2024, the hottest year on record, tropical forest loss jumped 80%, driven by a 371% YoY increase in loss due to fires.[39] Outside of the tropics, regions with boreal forests like Canada and Russia also experienced extreme fires.

Nearly half of the primary forest cover loss in 2024 occurred the Brazilian Amazon, driven largely by fires. Concerns around tipping points for the region that would catalyze a full transition from lush forest to degraded savanna are growing. A study published in Nature examining the Amazon forests system estimates that "by 2050, 10% to 47% of Amazonian forests will be exposed to compounding disturbances that may trigger unexpected ecosystem transitions and potentially exacerbate regional climate change."[40] Bolivia also stands out with a 200% increase in forest loss relative to 2023, comprising ~20% of the global tropical primary forest loss in 2024.[41]

Increasing wildfires are associated with global warming and seemingly are poised to increase as temperatures rise faster than scientists have modelled.

From an awareness standpoint, the investment community continues to elevate nature issues and frameworks like the Taskforce for Nature-related Financial Disclosures continue to see adoption. The Kunming-Montreal Global Biodiversity Framework, a global treaty analogous to the Paris Agreement, includes a set of 23 specific 2030 targets, a few of which tangentially cover the preservation and expansion of forest cover and key carbon sinks. However, we note that these are high level goals that aren't yet specifically integrated into broad economic decision making or market structures.

Outlook

Investor attention and capital allocation towards nature has been increasing. In 2024, $102B of private finance went to nature-based solutions, up from just ~$9B in 2020.[42] Carbon markets have reflected higher priority and demand for nature-based carbon removals. Meanwhile, forestry and land use-related avoided emissions, such as those facilitated by REDD+, have been out of favor due to greenwashing concerns. Accordingly, from 2022-2024 prices of removal-based credits have remained resilient at ~$15/tCO2e while avoided deforestation-related credits have fallen from ~$15/tCO2e to ~$5/tCO2e.[43]

This positive momentum in markets is noteworthy but marginal relative to the impact the changing climate and hotter temperatures are having on carbon sinks and ecosystem health. Consider that the average contribution to tree cover loss from wildfires has risen from ~20% in the early 2000s to ~35%+ since 2020 and the incidence of extreme wildfires are expected to rise by ~14% by 2030.[44]

With tropical forest loss from wildfire on the rise and poised to increase further,our outlook on the status of this indicator is negative.

Investment Implications

Private markets

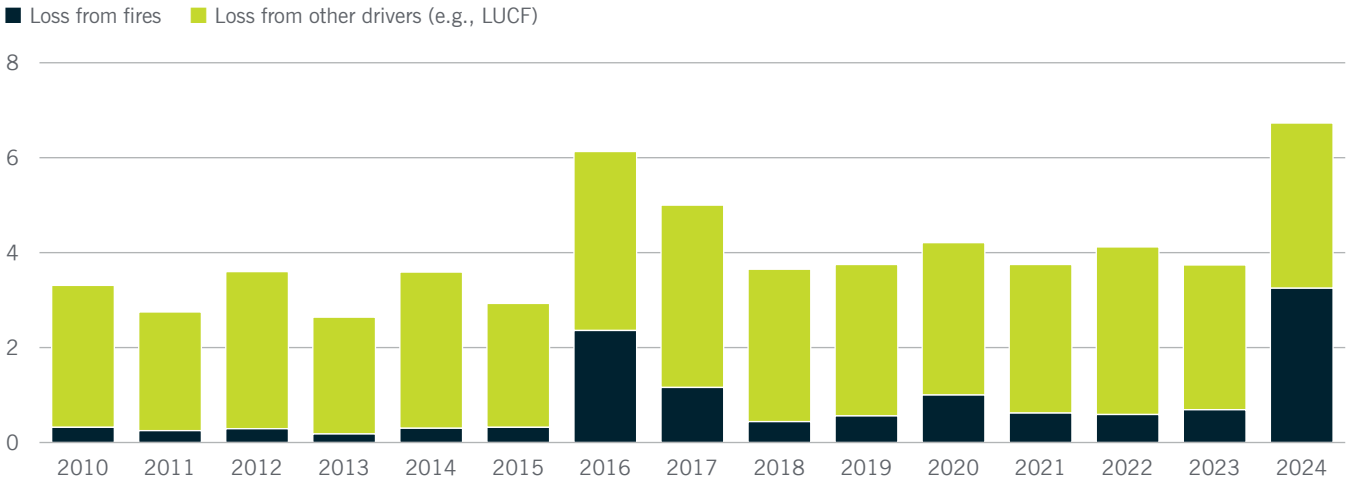
Investors should look for innovative investment opportunities including nature-based solutions, that aim to increase asset resiliency. Carbon removal credits can add new revenue streams to nature-based assets, like timberland and farmland, while also generating positive environmental benefits.

Public markets

Issuance in the bond market for use-of-proceeds instruments targeting nature-based solutions are increasing and investors can help catalyze impact by contributing to the design and committing to anchoring such securities.

Figure 11: In 2024, the hottest year on record, tropical forest lost jumped 80%, driven by a 371% YoY increase in loss due to fires.

Tropical primary forest cover (million hectares)



Source: World Resources Institute. Global Forest Review

"Increasing wildfires are associated with global warming and seemingly are poised to increase as temperatures rise faster than scientists have modeled."

Technological advancements

9 Climate tech funding

ACCELERANT

INDICATOR:
~8.3% of all VC and PE investment[45]

Observations

Unsurprisingly, AI is both crowding out climate tech investments and taking a share of climate-focused ventures. Meanwhile, the capital moving towards adaptation and resilience solutions is also on the rise, comprising over a quarter of deals in 2024. The relatively higher interest rate environment and uncertain policy landscape present challenges, but the resilience in climate tech deal count (4,427) and total funding ($92.1B) is encouraging.[46] In a sign of maturity and potential commercialization, the proportion of debt financing increased to make up half of all funding.

Outside of the private sector, it is worth noting that publicly funded R&D in the clean energy sector, including energy efficiency, renewables, nuclear, hydrogen fuel cells, storage, and other related technologies totaled ~$24B in 2024 and over ~$100B cumulatively since 2019.[47] Governments should consider spending more here, as a review of 40 years of US energy R&D programs found that the net annual ROI of that spend was +27% with a cumulative cost to benefit ratio of 33:1.[48]

Outlook

It's a challenge to predict how transformational current and future innovations will be. This is one of the largest variables when considering the global emissions pathway. Currently there's ~$86B of investable dry powder available amongst VC, Growth, and PE/Infra funds, suggesting a positive orientation towards near-term funding.

The IEA's *State of Energy Innovation* report highlights 28 distinct milestones across emerging technologies which provides a steer on what technologies may require financing to scale in the near term. There were a few notable areas for investors to monitor, including;

- Progress on geothermal energy,
- Battery and storage advances,
- Cement production processes.

Our outlook remains positive on this indicator as an accelerant of the low-carbon transition.

Investment Implications

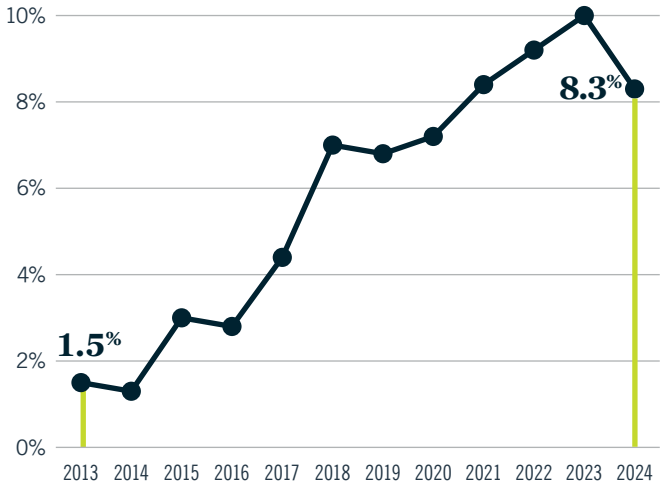
Private markets

There are still funding gaps, particularly within what is known as the 'missing middle', where FOAK or technologies with successful pilots are looking to commercialize and scale, but the uncertainty around demand and execution makes capital prohibitively expensive or unavailable. For these situations, flexible capital and corporate offtake agreements (de-risking) can unlock high impact, high return opportunities.

Public markets

Large corporates with decarbonization commitments can provide more visibility into achieving carbon reduction targets, as well as catalyze the scaling of low-carbon solutions, by committing to future demand in a manner that enables financing. The technology sector, and hyperscalers specifically, are demonstrating the positive impact this can have in the context of their energy supply chain.

Figure 12: Climate technology investment as a percent of all VC and PE investment



Source: Pitchbook, PwC Analysis

"Flexible capital and corporate offtake agreements (de-risking) can unlock high impact, high return opportunities."

10
Nuclear & Carbon Capture Utilization and Storage

INDICATOR:
~50m tCO2e avoided from CCUS in 2024, ~420 GW of nuclear generation capacity in 2024[49]

Observations[50]

For carbon capture, 2024 saw a few milestones including a final investment decision for natural gas power plant with carbon capture storage in the UK, an operational cement plant in China outfitted with carbon capture technology and a total of eight new smaller scale CCUS projects commencing operations. The voluntary carbon market has provided support with advance offtake agreements for ~6m tC02e being signed with project developers in 2024.

For nuclear, sentiment continues to be positive and capacity increase is supported by a wave of useful life extensions of existing reactors. Globally, There are 63 nuclear reactors under construction currently with ~70 GW of capacity, with annual investment exceeding ~$60B.[51] Half of the projects currently under construction are located in China. There is continued optimism for small modular reactors (SMRs), but material deployment of this technology remains a 2030 and beyond story.

Outlook

For CCUS, carbon pricing remains the largest catalyst for accelerated development and deployment Currently we see little likelihood of a meaningful step-up in the carbon pricing environment in the near term. When the market is ready to scale, there may be supply chain issues to watch for as some of the bespoke components to CCUS systems could take time to scale production.

Recent announcements, commitments, and general interest from technology sector corporates in SMR power generation has helped accelerate development. This phase of execution, demonstration, and cost control will be critical to the scaling and deployment of this technology, as early success will be needed to inspire a strong wave of investment and increased demand.

Given recent milestones, we are modestly positive on the outlook for both CCUS and nuclear — although neither technology theme is at the stage of materially reducing real-world emissions in the near term.

"There is continued optimism for small modular reactors (SMRs), but material deployment of this technology remains a 2030 and beyond story."

Investment Implications

Private markets

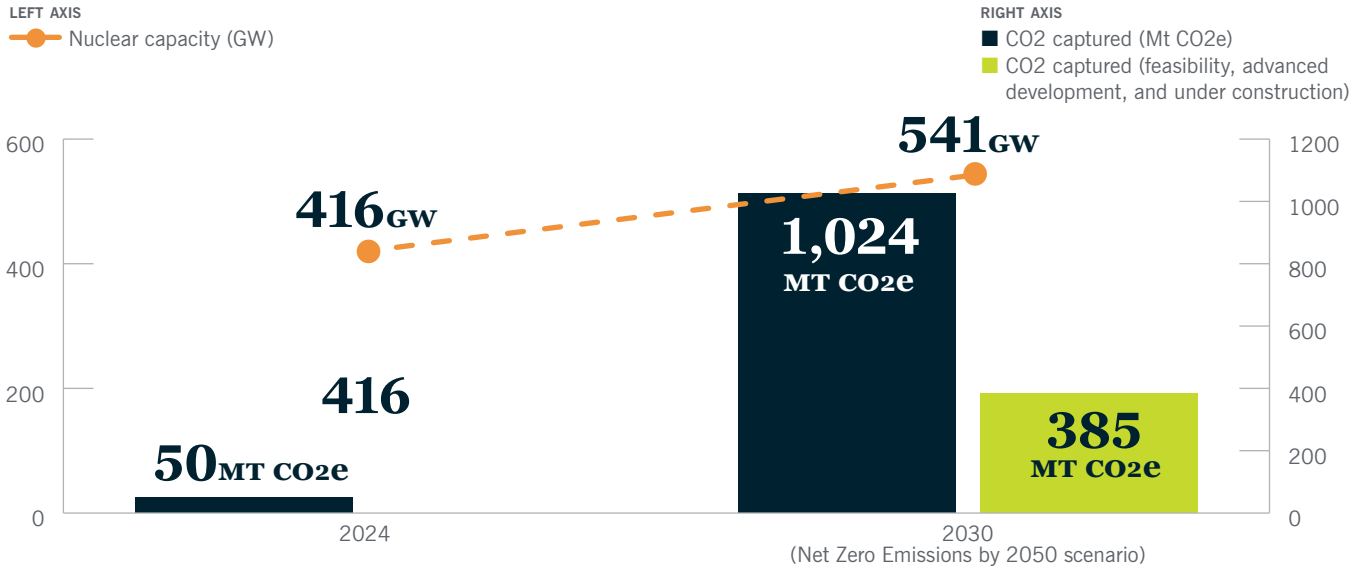
Opportunities to invest in both SMR and nuclear fusion are growing and while risky, could lead to transformative impacts and tremendous returns on capital.

Public markets

Oil and gas majors that have strategically embraced CCUS are likely to be better positioned versus peers through the energy transition and potentially advantaged versus peers that have diversified into areas outside of their core competencies.

Figure 13: New Nuclear and CCUS technology are potentially transformative for the energy transition but remain in early stages of development

Progress on nuclear and CCUS



Source: IEA. Nuclear data as of March 2024, CCUS data as of April 2024

For more information, please visit nuveen.com.

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