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Global Energy & Materials Practice

The energy transition: Where are we, really?

Scaling up deployment of decarbonization technologies is crucial to achieve net zero, but there is a reality gap—the lack of firm EU and US project commitments could slow momentum.

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Almost nine years after the landmark Paris Agreement and nearly halfway through what has been called a "decisive decade" for climate change, the world stands at a critical juncture in their transition away from fossil fuels.

Translating into action the ambitious climate targets that have been put in place by governments and companies depends on accelerating the deployment and adoption of several interrelated technologies. These include renewable energy sources (RES), electrification technologies such as electric vehicles (EVs), and heat pumps—as well as comparatively less mature technologies, such as carbon capture, utilization, and storage (CCUS), green and blue hydrogen, and sustainable fuels.

These decarbonization technologies (alongside many others, such as nuclear, long-term duration energy storage, battery energy storage systems, and energy efficiency investments) are the cornerstone of efforts to reduce greenhouse gas (GHG) emissions in all McKinsey energy scenarios. The period until the end of this decade is a critical one to put in place a trajectory of accelerated adoption to meet 2030 and 2050 targets set by countries and companies.

While significant progress has been made in developing and deploying some of these technologies, notably solar and wind, for which installed capacity has risen sharply over the past 15 years, a significant gap has emerged between the actual results and the expected ones. The at-scale deployment of all these technologies is still not happening as fast as needed to reach 2030 targets (see sidebar "The technology gap"). Moreover, the technologies are at risk of facing raw material and labor shortages and long permitting procedures.

The technology gap

The gap between what is needed and what has been achieved in the deployment of low-emissions technology is large—to date, only about 10 percent of the deployment of low-emissions technologies globally by 2050 required for net zero has been achieved, mostly in less challenging use cases. Closing the gap would require building a new, high-performing energy system to match or exceed the current one, which would entail developing and deploying new low-emissions technologies, along with entirely new supply chains and infrastructure to support them.

Given the size and complexity of today's energy system, this is no easy task. The physical challenges that would need to be overcome to successfully transform the energy system are significant and would require concerted action to solve. McKinsey's recent report, "The Hard Stuff: Navigating the physical realities of the energy transition," identifies 25 physical challenges across seven domains of the energy system that would need to be addressed for the energy transition to succeed.[1]

Addressing these physical challenges would involve improving the performance of low-emissions technologies, addressing the interdependencies between multiple challenges, and achieving massive scale-ups, even in technologies where a strong track record has not yet been established. And, of course, this is only one side of the equation. To overcome these physical challenges, significant firm investment into low-emission technologies needs to be unlocked.

[1] *The hard stuff: Navigating the physical realities of the energy transition,* McKinsey Global Institute, August 14, 2024.

We have identified three major issues that threaten the necessary deployment of capital: first, the business case—that is, the economic returns and policy predictability for developers—often remains weak; second, many technologies are increasingly but not yet cost-competitive for consumers, given the lack of at-scale manufacturing capacity or learning rate driven by deployment; and third, several technologies have not been tested at scale and need multiyear product, project, and supply chain development, thereby creating uncertainty about their effectiveness and efficiency. Ultimately, technology-focused enablers have not yet managed to address the challenges posed by macroeconomic shocks, geopolitics, and what it takes to enable tech ecosystems.

Fresh McKinsey analysis of the energy transition landscape, including the uptake of key climate and decarbonization technologies and investment decisions that follow project announcements (see sidebar "Our analysis"), suggests that corporate, public, and private equity investors are hesitating about deploying capital for the reasons described above. Invested capital is behind where it needs to be to ensure deployment targets are met. As it stands, a significant proportion of announced projects have not yet reached the final investment decision (FID) stage at which projects are greenlit, meaning that there is a continuing risk of cancellation or leakage.[1] And projects with longer lead times (such as offshore wind) are quickly reaching the stage at which capacity that has reached FID will only come online after 2030.

Facing this hard truth, innovation and policy resets will be needed for the increasing number of country and company net-zero commitments to be achieved in practice and move projects to FID and quickly beyond to subsequent deployment.

Rigorous, fact-based assessment of real-world progress is key to ensuring that momentum is maintained, and the energy transition continues at the necessary pace. In this article—a prelude to our Global Energy Perspective 2024—we seek to provide a detailed, albeit partial, assessment of where the execution of projects stands for specific low-emissions technologies in Europe and the United States. The goal is to answer the critical question: where are we, really, in the energy transition?

While considerable progress in the energy transition has been made in many countries, this article focuses solely on Europe and the United States, both of which have set explicit 2030 targets.[2] It should be noted that we are neither modeling nor forecasting future outcomes, but rather seeking to bring to light the facts as best as can be defined to assess how big the gap is and what needs to be done to close it.

Commitments and enthusiasm are up

Recent years have seen a flurry of net-zero commitments and ever-growing enthusiasm for climate action from all parts of society.

On the policy side, all 195 countries that signed the historic 2015 Paris Agreement have put forward so-called Nationally Determined Contributions (NDCs)—climate action plans—and more than 70 countries today have net-zero targets enshrined in law or outlined as a goal in policy documents.[3] More than 155 countries have signed the Global Methane Pledge to reduce methane emissions by 30 percent below 2020 levels by 2030.[4]

Industrial policy in many OECD economies is now anchoring climate technologies as a core pillar and substantial public funds are being earmarked for their development. In both Europe and the United States, emerging industrial policy has centered on building up a competitive cleantech value chain.

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1 Final investment decision (FID) is the point at which formal approval from the project developer is given to proceed, marking the commitment to allocate capital resources to the execution of the project.

2 For the analysis in this article, Europe refers to the European Union plus Norway, Switzerland, and the United Kingdom. There may some gaps in the data based on data availability.

3 "Net Zero Tracker," accessed June 2024; "Nationally determined contributions under the Paris Agreement, synthesis report by the secretariat," United Nations Climate Change, November 14, 2023; *Net zero stocktake 2023,* a joint report by NewClimate Institute, Oxford Net Zero, Energy and Climate Intelligence Unit, and Data-Driven EnviroLab, June 2023.

4 "Global methane pledge," Climate and Clean Air Coalition, accessed June 2024.

In Europe, the European Green Deal, introduced in 2019, aims to make the European Union climate-neutral by 2050, with intermediate Fit for 55 targets to reduce GHGs by at least 55 percent by 2030 compared to 1990 levels.[5] In the United States, the Inflation Reduction Act (IRA) of 2022 is the largest climate investment in US history, with total climate-related spending of almost $370 billion over ten years, with the aim of cutting emissions by 40 percent by 2030 from 2005 levels.[6] In addition, the Infrastructure Investment and Jobs Act has allocated billions toward modernizing the energy grid, expanding EV infrastructure, and enhancing energy efficiency across sectors.[7]

Together with continued cost improvement, including through innovation, these and other policy initiatives are leading to progress. Globally, between 2010 and 2023, renewable energy installation capacity grew around 20 percent per year, while the adoption of EVs surged, with a compound annual growth rate of around 80 percent (Exhibit 1).[8]

[5] "European green deal," Council of the European Union, June 17, 2024.
[6] *Building a clean energy economy: A guidebook to the Inflation Reduction Act's investments in clean energy and climate action,* The White House, January 2023.
[7] "A guidebook to the bipartisan infrastructure law," The White House, January 2024.
[8] Renewable energy installation includes solar photovoltaic, solar thermal, onshore wind, and offshore wind.

Our analysis

To shed light on the current status of the energy transition and provide a rigorous, fact-based assessment, we conducted an extensive analysis involving several steps.

Scope: We identified the key singular technologies that together account for the bulk of decarbonization potential (onshore and offshore wind, solar PV, clean hydrogen, sustainable fuels, CCUS, electric vehicles, and heat pumps). This means we excluded several other decarbonization technologies, including energy storage and battery energy storage systems (BESS) because these technologies are already in vast supply, with very healthy pipelines, and numerous players not only announcing projects but committing to them. We also excluded energy efficiency, low-carbon thermal generation, and nuclear because these are very fragmented markets with limitations due to regulation.

Data collection: We gathered comprehensive data from various sources, including proprietary and commercial project-tracking databases. This allowed us to obtain up-to-date information on the status of numerous projects across different decarbonization technologies.

Policy and historical capacity review: We reviewed existing policies, historical capacity deployments, and growth trends to understand the broader context and the trajectory of different technologies. This helped us benchmark current progress against historical data and policy targets.

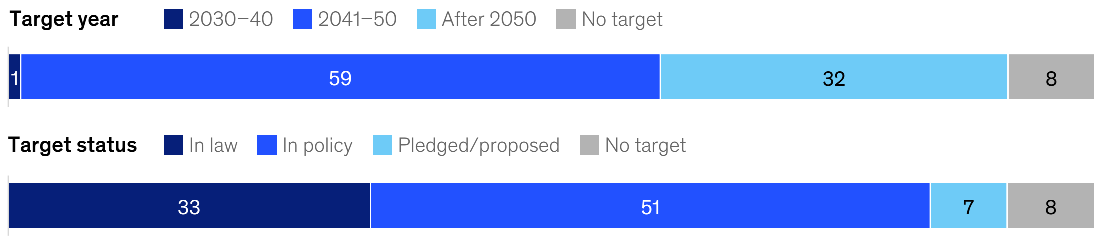
Comparative analysis: We compared stated targets with expected capacity deployments, including project status and historical sales levels for customer adoption-driven technologies, such as EVs and heat pumps. This enabled us to assess the alignment between ambitious climate targets and actual progress on the ground.

Gap assessment: By examining the project status, including those that have reached FID stage, we assessed the gap between target volumes, expected volumes (based on current trends), and volumes that have already reached FID. This analysis highlighted the discrepancies between announced projects and those that are likely to materialize.

Exhibit 1

Accelerated deployment of decarbonization technologies will be needed to meet the rising number of net-zero targets.

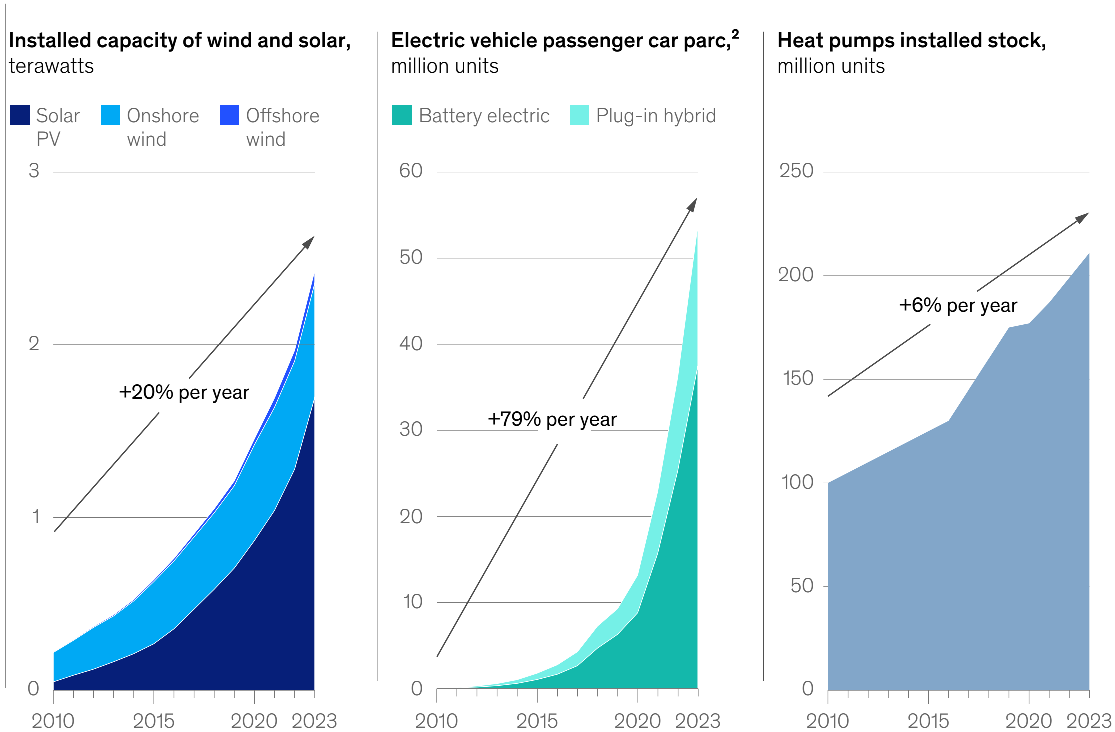
Net-zero goals by country target year and status, % of GDP



>90% of countries by GDP have net zero commitments—including China and India

>10,000 companies are members of the “Race to Zero” campaign[1]

Global cleantech deployment



Note: Figures may not sum to 100%, because of rounding.
[1]Race to Zero is a global campaign to take immediate action to halve global emissions by 2030.
[2]Battery electric vehicles and plug-in hybrid vehicles.
Source: Carbon Brief; IEA; IRENA

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From the corporate side, 66 percent of Fortune 500 companies have made climate commitments (either carbon neutral, net-zero, or science-based).[9] Overall, more than 5,000 companies globally have joined the Science-Based Targets Initiative (SBTi)—widely considered the gold standard for voluntary climate targets—and have set approved targets compatible with a 1.5° pathway.[10] Public companies in the European Union and the United States increasingly report on their sustainability impact as part of their financial disclosure requirements.[11]

Such developments underscore a broader trend toward cleaner energy and reduced carbon emissions, but are now set against an increasingly complex and uncertain global energy space. Energy security, affordability, reliability, and industrial competitiveness can be challenging to achieve alongside sustainability, and investment is harder to secure.[12]

The challenge of maintaining momentum

The question remains whether the world's much-needed commitments can be translated to action. McKinsey's analysis of targets and announcements highlights a potential disconnect between climate ambitions and what is likely to be achieved in practice—at least at current course and speed. Regarding NDCs, for example, the United Nations acknowledges that "quality and ambition vary."[13] Where the SBTi is concerned, many of the companies that have signed up have made commitments but have not yet articulated a clear plan to achieve them.[14]

In the United States alone, more than 1,000 green or blue hydrogen projects have been announced since 2015. However, fewer than 15 percent had reached FID at the time of writing, indicating a high risk for project fall-through.[15] This discrepancy between announced projects and projects realized following FID does not only apply to hydrogen—it is true across most critical energy transition technologies (Exhibit 2).

Indeed, decarbonization technology projects have historically had a high fall-through rate, with only a small percentage of announced projects reaching FID, and an even smaller numbers of projects actually being realized. Our analysis shows that many planned projects for key decarbonization technologies in the European Union and the United States are falling short of announced targets, some significantly so.

The extent of this shortfall varies by technology and region—renewable energy generation technologies, especially solar, are the closest to meeting short-term goals, while electrification technologies have seen periods of rapid growth but are now losing momentum. Many innovative technologies that could be crucial for decarbonizing "hard-to-electrify" sectors have ambitious project pipelines but are not yet deployed at scale. These technologies need to be deployed as electrification is only a partial answer.

Here, we look at the progress of each of these technologies and where they are falling short of targets.

Solar PV and wind: Growth may lose momentum

In the European Union and the United States, renewable energy generation technologies, such as solar PV, onshore and offshore wind, and battery energy storage systems (BESS), have experienced rapid development, driven by supportive policies and increasing private sector investment.

BESS has seen significant technological advancement over the last decade and has scaled rapidly since 2015. In the United States, legislation

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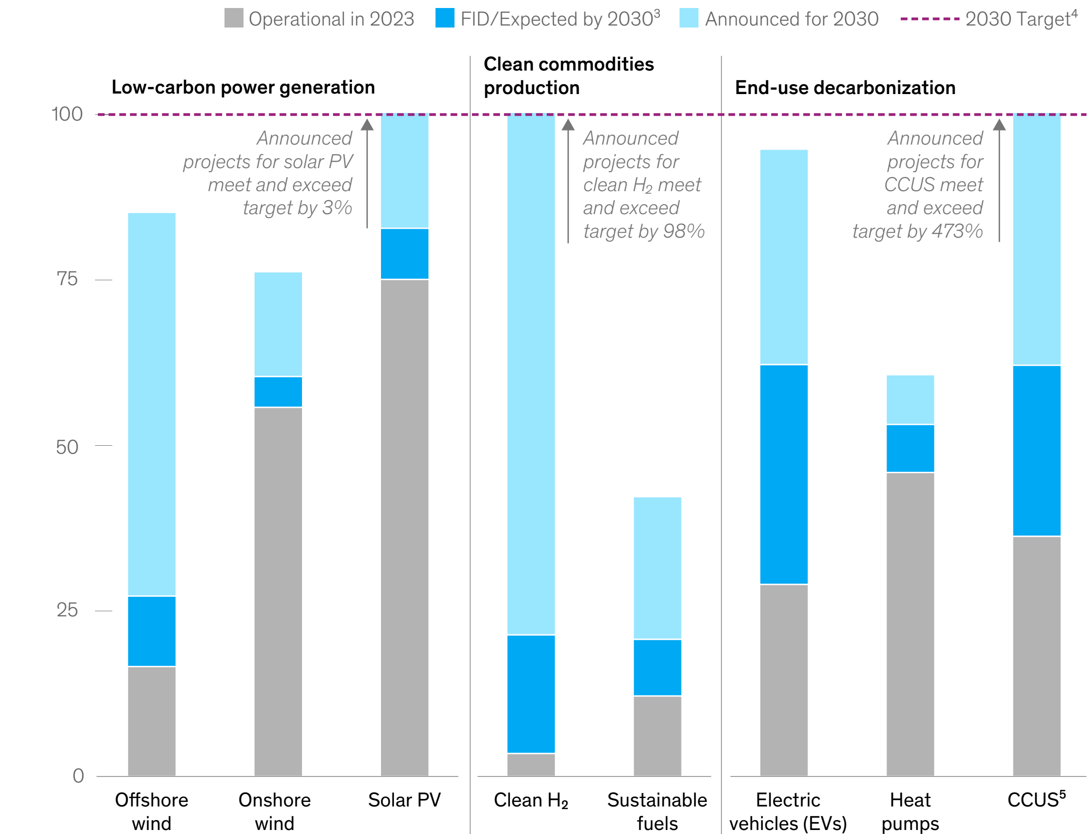
[9] "Commitment issues: Markers of real climate action in the Fortune Global 500," Climate Impact Partners.
[10] "Ambitious corporate climate action," Science Based Targets Initiative, July 2024.
[11] "Corporate sustainability reporting," European Commission, 2023.
[12] "An affordable, reliable, competitive path to net zero," McKinsey, November 30, 2023.
[13] "All about the NDCs," United Nations Climate Action, accessed July 2024.
[14] *SBTI monitoring report 2023,* Science Based Targets initiative, July 2023.
[15] Hydrogen Insights Project Tracker, McKinsey.

Exhibit 2

Investment announcements have been significant but many have failed to reach final investment decision.

Technology deployment pipeline in EU27+3[1] and US vs targets,[2] % of target, normalized



	Offshore wind	Onshore wind	Solar PV	Clean H_2	Sustainable fuels	Electric vehicles (EVs)	Heat pumps	CCUS[5]
2030 target[4]	205 GW[6]	695 GW	705 GW	15 mtpa[7]	136 mtpa	56 million	156 million	75 mtpa
Additions needed	30 GW	165 GW	On trajectory	11.8 mtpa	136 mtpa	On trajectory	61 million	28 mtpa

[1]EU27 + Norway, Switzerland, and the United Kingdom. [2]Technology deployment is a measurement to understand the gap between actual vs needed deployment.
[3]Final investment decision (FID) except for EVs and heat pumps (expected sales based on average sales over the last few years). [4]Target as defined for 2030 for both EU27+3 and the US; for solar, sustainable fuels, and heat pumps, no target exists, and the McKinsey Sustainable Transformation scenario was used.
[5]Carbon capture, utilization, and storage. [6]Gigawatts. [7]Metric tons per annum.
Source: EHPA; EIA; Eurostat; IEA; Rystad; Wind 4C; McKinsey Energy Solutions; McKinsey Hydrogen Insights

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has supported a robust pipeline and project conversion, especially in states like California and Texas. In Europe, we expect the solar PV project pipeline will in turn attract BESS projects, especially in places like Germany and Spain where colocation is favorable. All in all, battery production capacity appears healthy, leading us to believe there is less risk of a supply gap (and therefore why we excluded BESS from this analysis).

However, our analysis of offshore wind and solar PV shows that not all renewable pipelines are on track to meet 2030 targets and short-term deceleration is threatening the existing pipeline further (Exhibit 3). System bottlenecks need to be resolved faster to ensure deployment scales at the required rate.

Solar PV

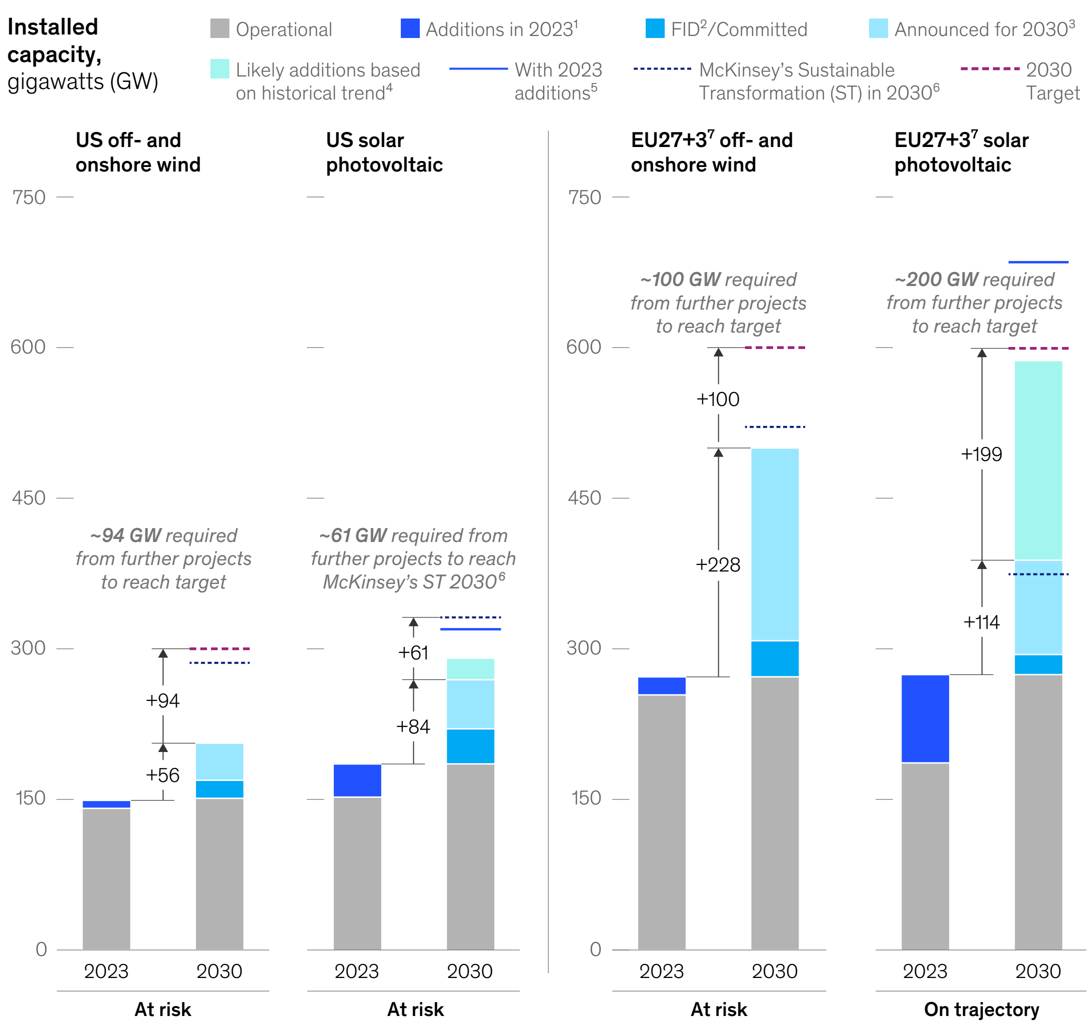
Solar PV has experienced significant growth in both Europe and the United States, with around 180 gigawatts (GW) and 120 GW of solar PV capacity added since 2015, respectively.[16]

Despite this growth, Europe's solar pipeline is not on track to meet 2030 capacity targets of 600 GW: less than 390 GW of capacity is planned to be online by end of the decade, leaving a

[16] "Renewable capacity statistics 2023," International Renewable Energy Agency, March 2023.

Exhibit 3

Clean generation pipelines are largely falling below targets.



¹Operational GW capacity added in 2023. ²Announced projects that have reached the final investment decision. ³Includes announced projects and prefinal investment decision. ⁴Trajectory of capacity if GW addition average of past 3 years would be added every year. ⁵Trajectory of capacity of 3-year average plus the additions from 2023. ⁶Continued momentum scenario. ⁷EU27 + Norway, Switzerland, and the United Kingdom.
Source: Rystad; WindEurope

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gap of approximately 200 GW. Moreover, of the approximate 114 GW of additional solar capacity expected to come online over the next five years, less than 20 percent has reached FID. A catch-up is still possible: in contrast to wind, additional solar capacity could be delivered rapidly, within 18 months, and the pipeline between now and 2030 could increase and become firmer.

In the United States, according to our analysis, annual solar PV capacity additions will slow down after 2028, at about 220 GW of capacity (operational and FID), because of a lack of firm longer-term commitments. Of the announced capacity to come online before 2030, around 60 percent is still pending FID, putting a significant proportion of planned solar at risk. However, again, here we would acknowledge that the nature of solar installation is such that the pipelines could indeed materialize in time.

Offshore and onshore wind

In wind, power projections vary significantly by geography and technology. Wind projects typically have longer lead times, too, which can make project pipelines less secure. In Europe, the wind energy pipeline is broadly on track to meet 2030 targets, while in the United States, the pipeline appears to be less secure.

Europe currently has approximately 240 GW of onshore wind capacity in operation, with an additional 106 GW in the pipeline. If fully realized, this would exceed the target of 314 GW of onshore wind capacity. However, this pipeline is not yet committed, with only 17 GW (16 percent) of planned capacity having reached FID. The United States faces a more challenging situation, with only 39 GW of onshore wind capacity expected to come online after 2025, and just 16 GW (41 percent of the total pipeline) having secured FID.

Offshore wind development in Europe has a gap of only 18 GW remaining to meet its overall 2030 target of 176 GW. But, again, of the announced 124 GW of offshore wind capacity in the European pipeline, approximately 65 percent is still pending FID.

The United States currently has about 1 GW of installed offshore wind capacity—far off its national targets, which aim for 30 GW by 2030. The 17 GW of offshore wind capacity that has been announced to come online by 2030 still only represents 60 percent of this goal—of which, 90 percent are still in the pre-FID phase.

Electric vehicles and heat pumps: Momentum has slowed when it most needs to pick up

Of course, RES and BESS do not alone hold the answer to the energy transition. Decarbonization also involves replacing fossil fuel-powered processes with electric alternatives in areas such as transportation and residential and commercial heating.[17]

Historically, EVs and heat pumps have seen strong growth. Since the Paris Agreement, the adoption of EVs and heat pumps has surged in both the European Union and United States; however, particularly for EVs, this momentum has slowed precisely at the time when acceleration is needed, requiring action to put EVs back on track to meet targets (Exhibit 4).

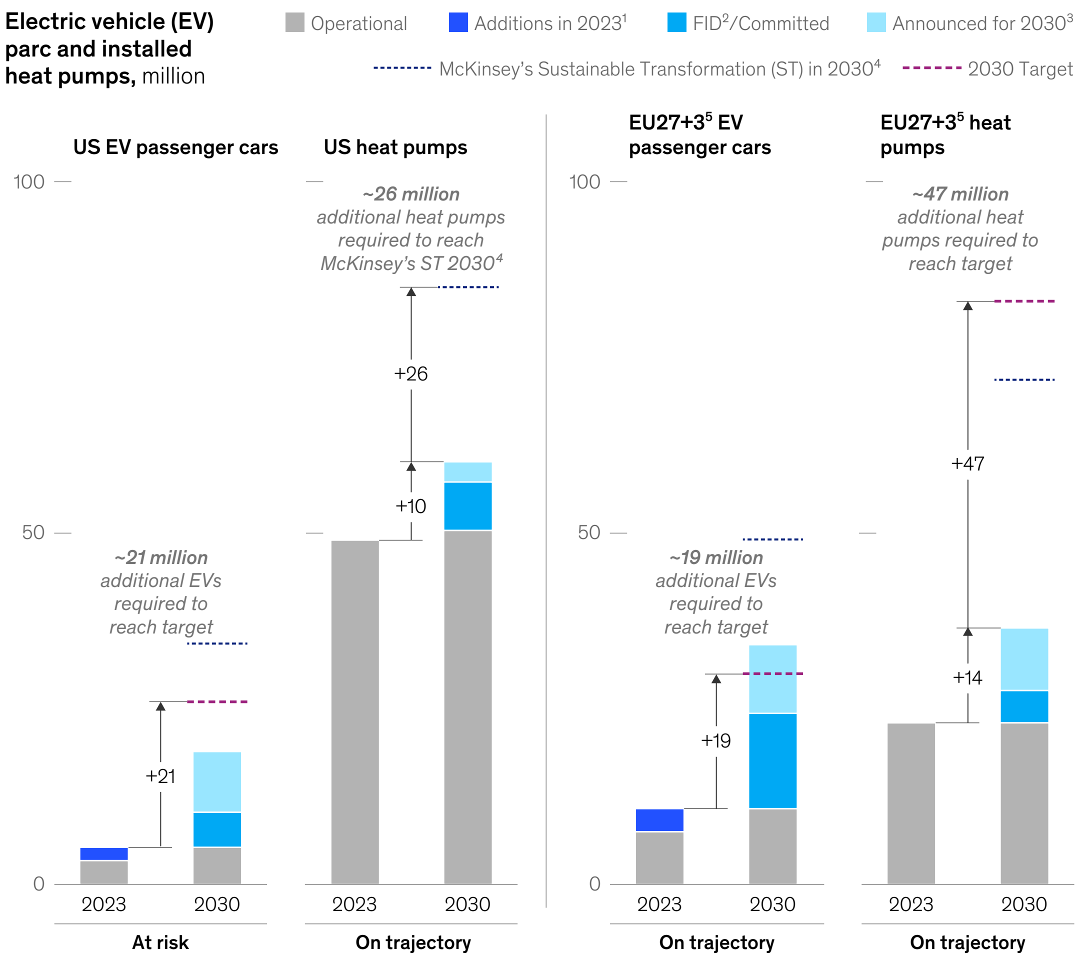
Electric vehicles

For the European Union to meet its target of 30 million EVs by 2030, it would need to add almost twice as many EVs as it currently has on the road (around 11 million) over the next five years.[18] A similar scale-up rate is required in the United States, which is targeting 26 million EVs by 2030, but has only 5 million EVs on the road today. Even with the ground still to be made up, based on FID commitments, the

[17] To achieve true zero-carbon status, these electric alternatives must be powered by green electricity—putting even more pressure on the European Union and United States to meet their targets.
[18] IEA Global EV Data Explorer.

Exhibit 4

Growth in electric vehicles and heat pumps is slowing after several years of rapid development.



[1]Operational gigawatts (GW) capacity added in 2023. [2]Announced projects that have reached the final investment decision. [3]Includes announced projects and prefinal investment decision. [4]Continued momentum scenario. [5]EU27 + Norway, Switzerland, and the United Kingdom.
Source: IEA EV data explorer; *Global Energy Perspective 2023*, McKinsey, October 2023; McKinsey analysis

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momentum in Europe is stronger than that in the United States.

Despite optimistic forecasts for EV deployment, lackluster sales figures over the past two years suggest a continued US slowdown in EV growth to 2030.[19] A lack of charging infrastructure is one of the challenges that will still need to be overcome, to increase consumer confidence in EVs.

Heat pumps

Heat pumps are seeing a similar mixed picture, creating a challenge to the successful decarbonization of residential heat in both regions.

[19] Ibid.

Heat pumps have seen continued growth since 2016 due in part to policy action such as the EU Green Deal, which targets a 55 percent reduction in natural gas imports by 2030, and financial incentives in the United States to lower the upfront costs of heat pump installation.[20]

While European heat pump sales are still on a positive trajectory, the high cost of capital, among other factors, may impact this progress. In the United States, heat pump sales declined in 2023, and, if this trend continues, the United States could see a marked slowdown in heat pump additions before 2030.[21]

CCUS, hydrogen, and sustainable fuels: Interdependencies put progress at risk

Some sectors are, by their nature, hard to decarbonize. Their successful decarbonization relies on the deployment of electrification technologies, combined with renewable technologies and newer technologies, such as CCUS and hydrogen.

For the most part, these technologies remain largely untested at scale and have the lowest levels of FID among all decarbonization levers. Project delays or cancellations here could hinder the development of sustainable fuels and other critical components of the energy transition, with knock-on effects for energy transition targets. Further, the challenge with some of these value chains is that they require the development not just of a singular technology (for example, capture trains) but an entire value chain that coincides with the deployment of projects—further complicating the issue.

Carbon capture, utilization, and storage

CCUS has emerged as a key decarbonization lever across Europe and the United States. Project pipelines are full and ambitious, with around 60 times and nine times the amount of current CCUS capacity in Europe and the United States to be available, respectively, over the next six years. However, while announced capacity is high, the vast majority of projects are still lacking FID and hence are at high risk of not materializing (Exhibit 5). Regulatory approvals can also be lengthy. Approximately 15 percent of the announced projects are in more conventional segments (for example, gas processing) while the rest is in new(er) segments, such as cement and hydrogen.

Hydrogen

Clean hydrogen has also attracted significant attention as a critical energy source, with both Europe and the United States setting ambitious targets for clean hydrogen production.[22] The European Union aims for 20 megatons (Mt) of clean hydrogen supply by 2030, with 10 Mt produced domestically and 10 Mt imported.[23] The United States is targeting 10 Mt of clean hydrogen production by the same year.

The data suggest that there is a long way to go in both regions. To meet 2030 targets, clean hydrogen production needs to increase approximately 25-fold in Europe and 20-fold in the United States over the next five years. Current project pipelines are projected to meet about 90 percent of European and 70 percent of US targets, but only around 11 percent of Europe's and 15 percent of US announced project pipelines have reached FID. And, while Europe's clean hydrogen project pipeline anticipates steady capacity addition until 2030, the US project pipeline already shows a sharp decline after 2028 (Exhibit 6).

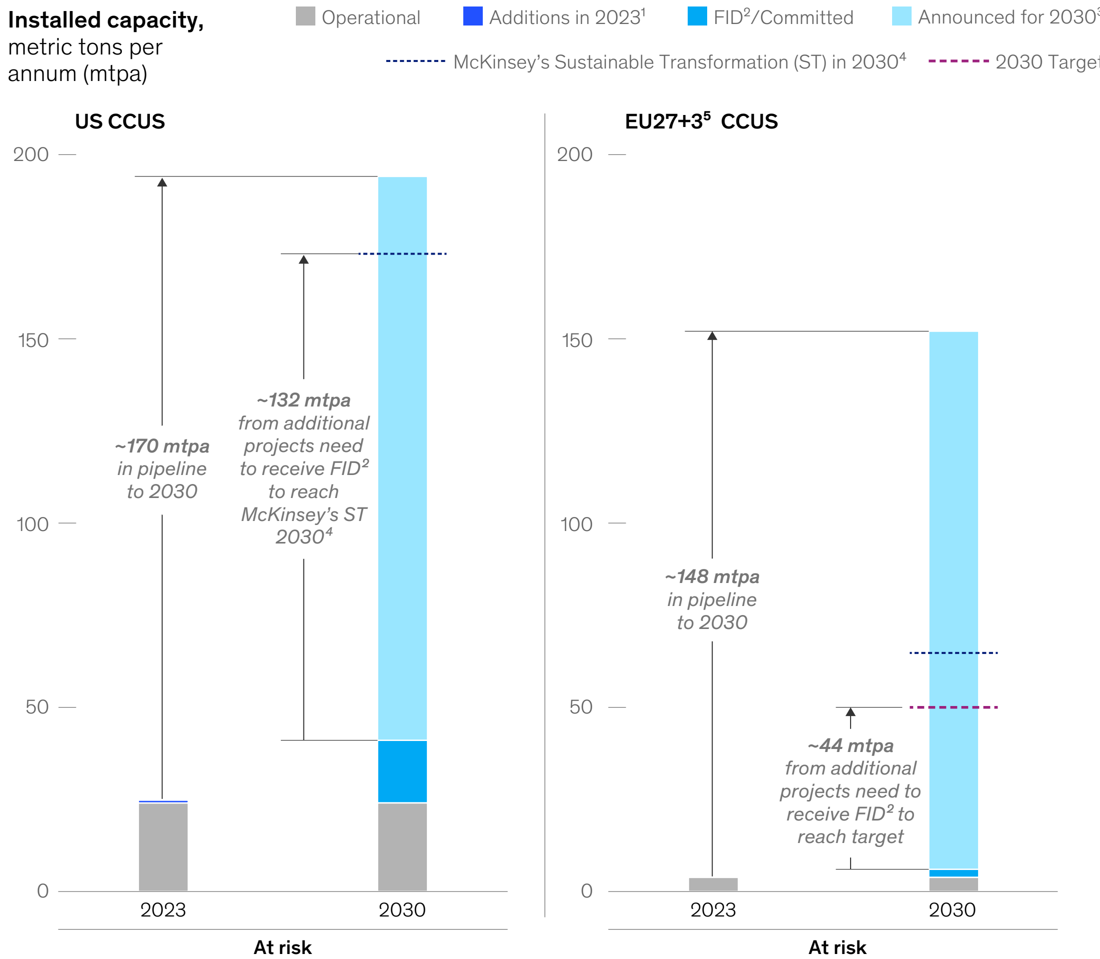
Sustainable fuels

Biobased sustainable fuels are also uncertain, largely due to the unsettled hydrogen project pipeline, given hydrogen's role as a critical input for sustainable fuels production. This may

[20] "European green deal," Council of the European Union, June 17, 2024; "Inflation reduction act overview," US Environmental Protection Agency, January 2023.
[21] "AHRI releases December 2023 US heating and cooling equipment shipment data," AHRI, February 9, 2024.
[22] Clean hydrogen includes both green hydrogen (hydrogen produced from the electrolysis of water using renewable energy sources) and blue hydrogen (produced using steam methane reforming or gasification with CCUS).
[23] "Hydrogen," European Commission.

Exhibit 5

Carbon capture, utilization, and storage is on a trajectory of exponential growth, but only small volumes are committed to date.



[1]Operational GW capacity added in 2023. [2]Announced projects that have reached the final investment decision. [3]Includes announced projects and prefinal investment decision. [4]Continued momentum scenario. [5]EU27 + Norway, Switzerland, and the United Kingdom.
Source: CCUS project tracker

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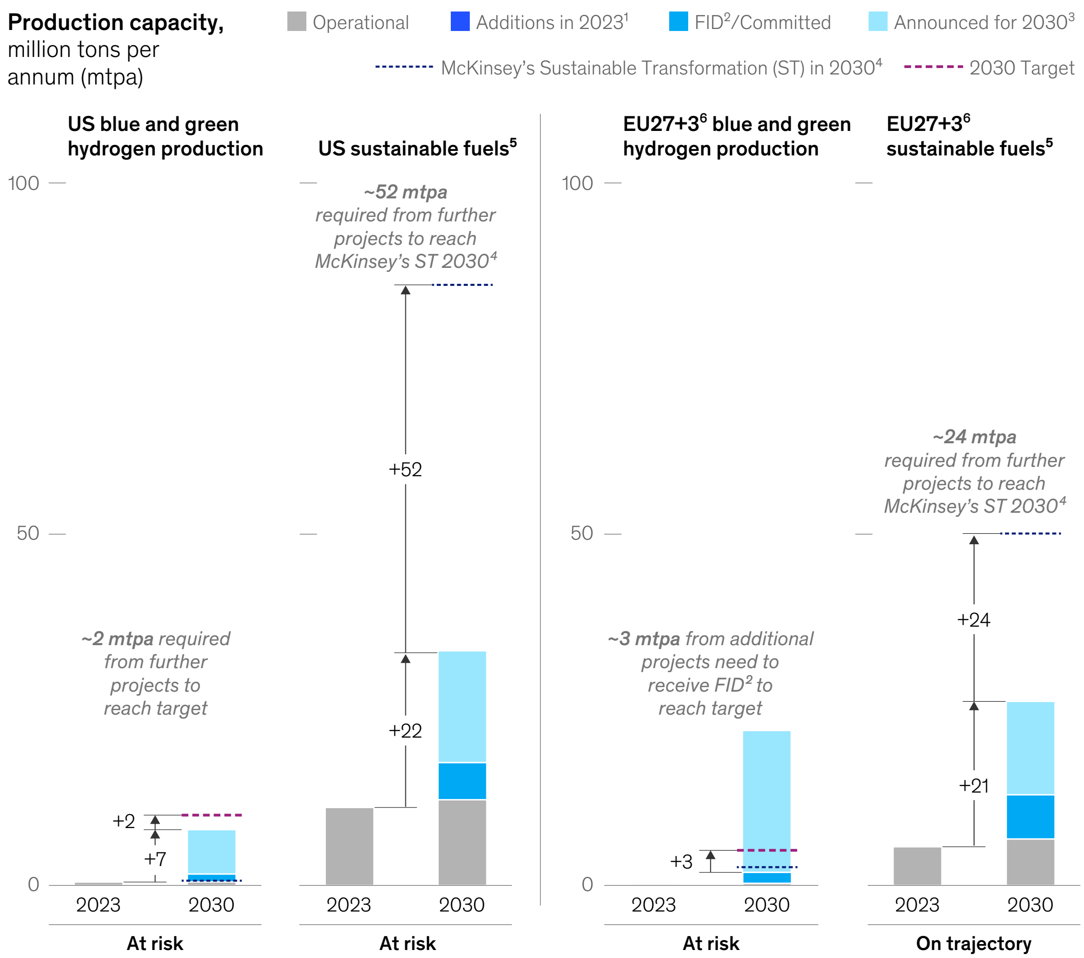
slow the impetus for sustainable fuels following policy developments, including ReFuelEU and the US sustainable aviation fuels (SAF) "Grand Challenge."[24]

The current European and US announced pipelines include around 21 million tons per annum (mtpa) and 33 mtpa of sustainable fuel capacity, respectively, with the vast majority of this being in hydrotreated vegetable oils (HVO) and hydroprocessed esters and fatty acids (HEFA).[25] Although the production of HVO and HEFA is largely on track, achieving these goals would entail more than quadrupling current European

[24]Grand Challenge refers to the combined work of US DOE, DOT, USDA, and other federal government agencies working to scale up the Sustainable Aviation Fuel value chain.
[25]HVO/HEFA, advanced middle distillate and methanol.

Exhibit 6

Many hydrogen projects may not materialize, putting non-biobased sustainable fuels at risk.



[1]Operational GW capacity added in 2023. [2]Announced projects that have reached the final investment decision. [3]Includes announced projects and prefinal investment decision. [4]Continued momentum scenario. [5]Hydrotreated vegetable oil (HVO)/hydroprocessed esters and fatty acids (HEFA), advanced middle distillate, methanol. [6]EU27 + Norway, Switzerland, and the United Kingdom.
Source: Hydrogen Insights Project tracker, McKinsey's Sustainable Fuels Project database

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SAF production and tripling that of the United States over the next five years.

The SAF project pipeline—while ambitious—is largely not yet firm, with only around 25 percent and 30 percent of capacity until 2030 having achieved FID in Europe and the United States, respectively.

Factors affecting market performance

The evolving policy environment has done much to accelerate the energy transition up till now, but more will be needed to help achieve key climate goals as existing policies may be too narrow and not long-dated enough. And, policy alone may not be enough to overcome the converging factors now affecting progress. Many of these factors and potential solutions have been discussed in previous McKinsey articles (see sidebar "Further reading").

In brief, they include the following factors.

Challenging macroeconomic environment: Economic uncertainties and fluctuating investment climates impact both the financing and prioritization of green projects. Even with initiatives like the IRA in the United States, rising inflation and interest rates have made capital expenditure-intensive projects even more expensive, likely contributing to project cancellations and continued lack of FID due to the changing financial environment.

Technology and business case maturity: CCUS, clean hydrogen, and some sustainable fuels are fundamental to the decarbonization pathways of many geographies and corporations alike, yet many new technologies have not yet been tested at scale, creating uncertainty about their effectiveness and reliability—and making them less attractive to investors.

Lack of reference projects: In contrast to "incumbent" energy technologies such as refining or upstream oil and gas, many of the emerging technology business cases lack reference cases to show investors that industry-leading companies are actually underwriting the projects. Moving forward requires pioneering thinking given the uncertainties and investor pressures on returns.

Long permitting procedures: Reported lengthy and complex permitting processes are delaying the approval and deployment of new projects. Across technologies, we have observed a high percentage of projects stuck in permitting phases, which is not helped by the heterogeneous nature of permitting processes across geographies.

Specialized labor shortages: A lack of skilled workers in green technologies is slowing the installation and maintenance of new systems across different supply chain stages, geographies, and technology maturity levels. For newer technologies such as sustainable fuels, there is a shortage of engineering, procurement,

Further reading

In the coming weeks, McKinsey will publish its annual Global Energy Perspective, outlining various projected scenarios for the energy transition in the years to 2050, alongside the new Global Materials Perspective 2024.

For further reading on the energy transition and what it will take to overcome bottlenecks and challenges, see:

"*What would it take to scale critical climate technologies?*," McKinsey, December 1, 2023.

"*The hard stuff: Navigating the physical realities of the energy transition*," McKinsey Global Institute, August 14, 2024.

"*A radical approach to cost reduction at climate tech companies*," McKinsey, June 18, 2024.

and construction (EPC) contractors with the experience needed to develop the technology. More mature technologies such as heat pumps, grids, and solar do not have enough downstream installers to keep up with installation demand.

Raw material shortages: The supply chains for critical components such as batteries, solar panels, and wind turbines are affected by raw materials' availability. The production of lithium-ion batteries, essential for EVs and BESS, is particularly vulnerable due to high demand for lithium, cobalt, and nickel. Potential shortages not only drive up costs but also cause delays in manufacturing, potentially stalling the expansion of EVs and BESS. Similarly, the supply chain of rare earth elements such as neodymium and dysprosium, crucial for wind turbine magnets, is critical for the growth of wind energy projects.

Geopolitical uncertainty: Strained supply chains and limited availability of critical technologies and raw materials are affected by factors such as international supply chain tensions and trade disruptions. This is especially relevant for technologies where raw materials or production capacity are heavily concentrated in one specific region.

Accelerating action to meet climate goals

Make no mistake—a lot of progress has been made since the 2015 Paris Agreement. New policy initiatives combined with progressive corporate attitudes (spurred on by ever-increasing public pressure) mean the world is moving in the right direction where climate action is concerned.

At the current pace, however, Europe and the United States risk missing important 2030 climate targets across critical technologies. The interdependent nature of these technologies means that delays could have cascading effects, hindering the development and successful deployment of subsequent innovations and putting 2050 net-zero goals at risk.

Nevertheless, there is still a window of opportunity for governments and companies to deliver the growth needed to meet net-zero ambitions. To do so, reevaluating existing strategies in the light of changing global conditions may be necessary. Many current decarbonization strategies assumed a different economic and policy landscape than the one that exists today.

With this clear view of current progress in hand, now is the time for stakeholders across the energy value chain to revisit decarbonization plans and assess if these plans are still sufficient to achieve their climate goals.

Companies will need to adjust portfolio focus, given the rapid evolution of policies and government targets. Those with more experience in specific technologies could hold a significant advantage. But, they will also need to avoid getting too far ahead in regions and markets with low pipeline firmness or small pipelines.

Relevant government stakeholders could prioritize project- and market-enabling policies to improve project economics and to drive demand from the market for new products and solutions. For the former, options include financing schemes (for example, tax credits such as the 45Q in the United States). For the latter, policymakers may want to consider carbon pricing, product mandates, or other demand drivers.

After revising their portfolio strategy, stakeholders could actively derisk critical developments integral to the company's strategy, for instance, by:

- **Forming partnerships:** industrial OEMs and engineering, procurement, and construction (EPC) players face the challenge of delivering increasingly complex technologies at lower costs. Forming industrial partnerships could provide better visibility into product development and help maintain a network of trusted EPCs and partners.

- **Engaging actively:** with policies and subsidies becoming more complex, stakeholders could actively engage in discussions and highlight the challenges, bottlenecks, and enablers that are needed to advance the net-zero transition. This engagement could help ensure that policies provide strong signals for investors and enable positive returns.

- **Addressing offtakes and infrastructure needs:** given that the possible reduced availability of specific technologies may affect the demand/supply balance, stakeholders could proactively seek offtake agreements, understand green premiums, and address infrastructure needs.

- **Staying on top of developments:** as the changing market landscape impacts the attractiveness of merchant strategies, stakeholders can adjust these strategies based on the latest market intelligence and sector developments.

By revising their portfolio strategies and actively derisking critical developments, stakeholders may be better able to navigate the uncertainties of the evolving market landscape, ensuring sustained growth to reach their climate goals.

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