FRANKLIN TEMPLETON | Institute

October 2023

Energy transition: Accelerating investment opportunities

Disclaimer

About Franklin Templeton Institute

Our mission is to provide our clients with research that meets their needs and concerns. We do this by listening, understanding, and then harnessing the resources of our firm to answer the challenge. We organize around areas of exploration to develop distinct insights and their practical applications.

Foreword

Anne Simpson
Global Head of Sustainability
Franklin Templeton

As you read this, be it on screen or old-fashioned paper, sitting down with a cup of tea, hot from the kettle, with perhaps a slice of cake or piece of fruit, you are in the midst of the global energy transformation. Energy powers everything in the room in which you sit and is critical to the production of most of the things that fill that room.

The source of energy—its reliability, affordability and impact on climate change—puts us at the heart of complex and urgent challenges. The first industrial revolution brought prosperity to many as we drew upon an ancient store of carbon laid below ground over 300 million years ago. The trees and other plants that covered the earth for eons were buried under rock at great pressure to form coal, oil and gas. Happily, in the evolutionary arc of change, this was before microbes came along, so this precious store of organic material did not decompose. It was transformed under pressure, and we stumbled across it in an extraordinarily recent stage in human history.

We started tapping into those sources of energy just 300 years ago, and now around 80% of our world energy supply is taken from that extraordinary Carboniferous Period, well named for the familiar carbon element.

Although this may be an ancient source, we've transformed our world in a short time through its use. Now there is a mighty task ahead. Many scientists tell us, and world governments agree, that we need to shift to low and net-zero carbon in a little less than 30 years.

Arguably, this is currently humanity's greatest challenge. Meeting this will likely require all sides to pull together. The invisible hand of the market can play its part clasped with the visible hand of policy. Both are informed by, and reliant upon,

This new collection of papers from our Franklin Templeton Institute will help us navigate this transition in the global financial markets that is transforming our understanding of how we ensure those risk-adjusted returns are generated. It's important to point out this piece represents a cross section of our specialist investment teams, all of which have autonomous investment processes and decision-making—this breadth of investment perspectives is one of the strengths of Franklin Templeton.

innovation to bring forward the technology we need. Civil societies will buttress both the policy measures of their governments and also provide the bulk of the finance needed as they channel their savings to pay for vitally important financial goals.

It is a complex, global partnership at work, in which investors have a critical role given the capital needed to fund this transition. It also provides us with a tremendous opportunity. This opportunity is financial, as meeting the demands of the energy transition brings new potential for generating the risk-adjusted returns that sustainable investment demands. As a fiduciary, we must make decisions that have a foundation in economics and that seek to ensure the best outcomes for our clients.

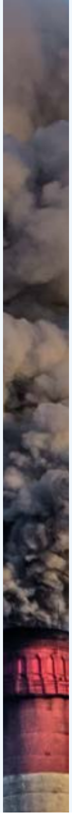
This new collection of papers from our Franklin Templeton Institute will help us navigate this transition in the global financial markets that is transforming our understanding of how we ensure those risk-adjusted returns are generated. It's important to point out this piece represents a cross section of our specialist investment teams, all of which have autonomous investment processes and decision-making—this breadth of investment perspectives is one of the strengths of Franklin Templeton. We write this with humility, as we all are navigating quickly changing environments. As such, we can't cover every aspect of energy transition, or even cover each technology or proposed solution at stake fully. Without hesitation, we face headwinds, but we cannot turn around—we choose to tack into the wind.

We know this requires stewardship of not only financial but also natural and human capital. In simple terms, it reflects the potential for reframing our strategies around people, planet and prosperity. This approach is set out with clarity in the preamble to the 2015 Paris Agreement, which provides the Climate Action framework and action plans of the United Nations' Sustainable Development Goals, agreed to the following spring by 196 governments. Those signatures to the treaty—and it important to note the Paris Agreement is an international treaty—provide the licence to operate.

I hope your tea has not gone cold as you read this. Put the kettle back on and settle in to reading how finance is working to be part of the solution across asset classes in our global portfolios.

We look forward to discussing these pieces with you, and welcome your feedback.

Anne Simpson



Framing the energy transition: Market opportunities and challenges

Seth Cothrun
Director, Thought Leadership
Franklin Templeton

The last few years, we've focused our sustainability thought leadership on the energy-water-food nexus—where the interdependencies and complexities of the global economy peak—and where we see the most potential for risk, price disruption and overall market impacts as we move into the next years and decades. This third paper focuses on the opportunities of energy transition—moving from fossil fuel to renewables—and how our investment teams, across asset classes, are approaching this historic opportunity and challenge. It's clear we must transition—the main questions hover around "how." How do we finance transition? How fast a transition is realistic? How do we ensure a just transition? How do we ensure clients' assets are protected through this transition? And transition is not just limited to countries and companies focused on sustainability. Energy transition impacts sectors, companies and geographies dependent on fossil fuel, and their attempts to diversify business models and economies.

Before we get to the how, let's start with the why…

Why transition?

Net zero is the set of collective actions required to limit global temperature increases well below 2°C (3.6°F), with a target of 1.5°C (2.7°F)—mainly via the reduction of greenhouse gas (GHG) and its removal from the atmosphere. At 1.5°C, we (read: all inhabitants of Earth) face severe climate change impacts on people and planet. We are already, and increasingly, experiencing many of these impacts, such as: extreme weather and heat; climate-related health impacts; malnutrition due to climate-related impacts on the food system; accelerating species extinction and biodiversity loss; etc. Above 2°C, we face catastrophic collapse of most global ecosystems.

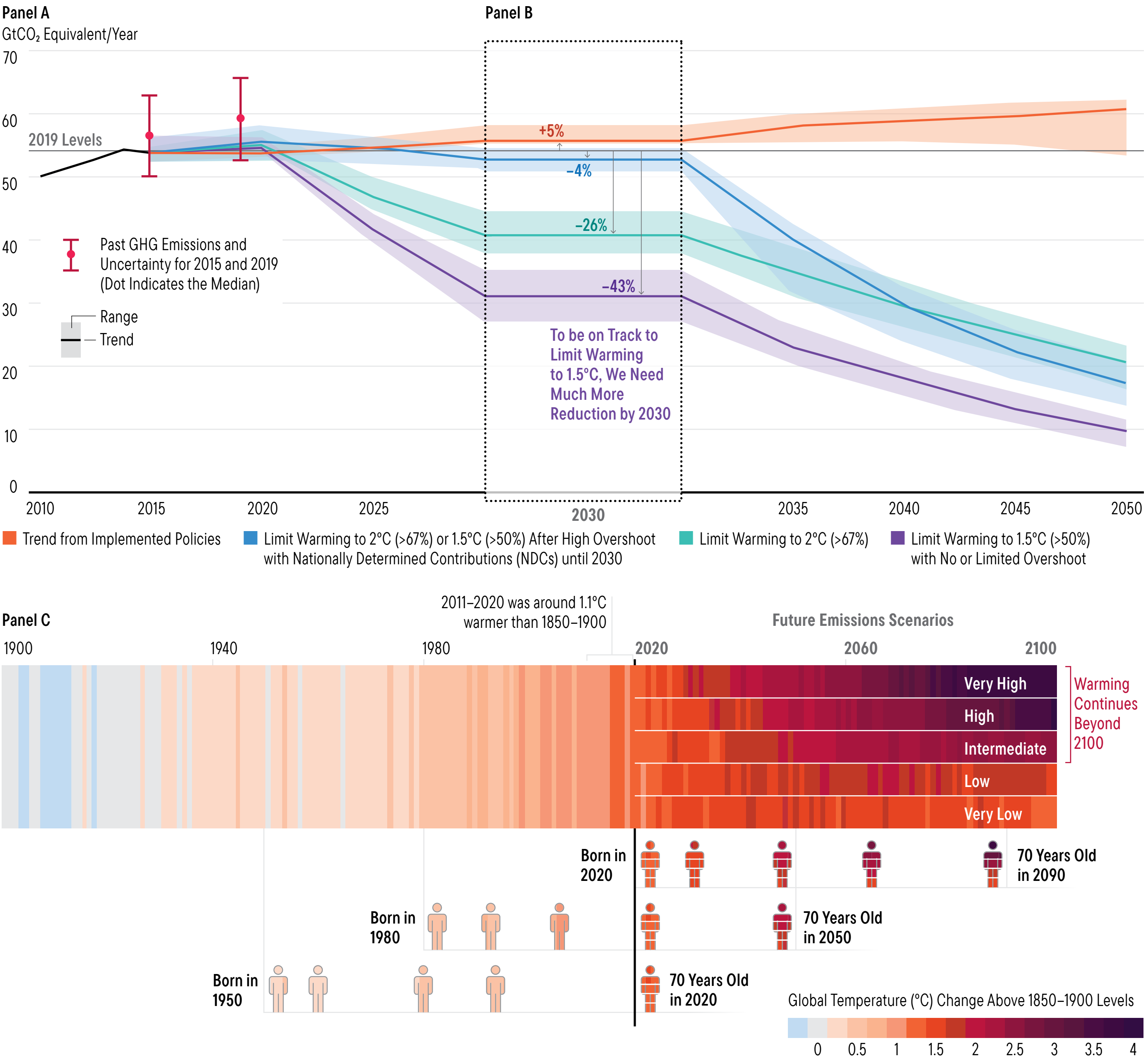
We're currently off track to achieve net zero by 2050, the target date set out in the United Nations' (UN) 2015 Paris Agreement.[1] As of mid-2023, we stand at 1.1°C (1.98°F) and on a trajectory to 2.4°C (4.3°F)…

We're currently off track to achieve net zero by 2050, the target date set out in the United Nations' (UN) 2015 Paris Agreement. As of mid-2023, we stand at 1.1°C (1.98°F) and on a trajectory to 2.4°C (4.3°F), as seen in Exhibit 1 on the next page. Despite the 2020 dip in emissions due to the global COVID-19 pandemic, 2021 emissions quickly rebounded, and 2022 emissions hit an all-time high. To date, 2023 is on track to be the highest emissions level year on record, but scientists hope 2023 will mark the beginning of an emissions plateau due to increasing investments in renewable energy and slowing global growth.[2] However, a plateau is not sufficient; massive and rapid reductions are necessary, as seen in panel B of Exhibit 1. Otherwise, global citizens can expect to experience rising temperatures throughout this century. For example, babies born over recent years could easily see 1.5°C as adolescents, 2°C as young adults, 3°C by middle age, and 4°C by retirement—as seen in panel C of Exhibit 1.

Today's Decisions Matter—The Good? The Bad? Or the Ugly?

Exhibit 1: Global GHG Emissions of Modelled Pathways (Funnels in Panel A); Projected Emission Outcomes from Near-Term Policy Assessments for 2030 (Panel B); The Extent to which the Future Will Experience a Hotter and Different World Based on Future Emissions Scenarios (Panel C).

2023



Sources: Core Writing Team, H. Lee and J. Romero (eds.). 2023. Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC: Geneva. (in press). Notes: **Panel A** shows global GHG emissions over 2015–2050 for four types of assessed modelled global pathways, which all are explained in detail in IPCC report: Top (orange) Trend from implemented policies: Pathways with projected near-term GHG emissions in line with policies implemented until the end of 2020 and extended with comparable ambition levels beyond 2030; Second (blue) Limit to 2°C (>67%) or return warming to 1.5°C (>50%) after a high overshoot until 2030 associated with the implementation of NDCs announced prior to COP26, followed by accelerated emissions reductions *likely* to limit warming to 2°C or to return warming to 1.5°C with a probability of 50% or greater after high overshoot. Third (green) Limit to 2°C (>67%) with immediate action after 2020; Bottom (purple) Limit to 1.5°C (>50%) with no or limited overshoot. **Panel B** shows a snapshot of the GHG emission ranges of the modelled pathways in 2030 and projected emissions outcomes from near-term policy assessments in 2030 from WGIII Chapter 4.2 (Tables 4.2 and 4.3; median and full range). GHG emissions are CO_2-equivalent using GWP100 from AR6 WGI. **Panel C** shows observed (1900–2020) and projected (2021–2100) changes in global surface temperature (relative to 1850–1900), which are linked to changes in climate conditions and impacts, illustrate how the climate has already changed and will change along the lifespan of three representative generations (born in 1950, 1980 and 2020). Future projections (2021–2100) of changes in global surface temperature are shown for very low (SSP1-1.9), low (SSP1-2.6), intermediate (SSP2-4.5), high (SSP3-7.0) and very high (SSP5-8.5) GHG emissions scenarios. Changes in annual global surface temperatures are presented as "climate stripes", with future projections showing the human-caused long-term trends and continuing modulation by natural variability (represented here using observed levels of past natural variability). Colors on the generational icons correspond to the global surface temperature stripes for each year, with segments on future icons differentiating possible future experiences. There is no assurance any forecast, projection or estimate will be realized.

Where to cut?

This may be the simplest question to answer and the easiest data to digest because the answer is not based on future models or scenarios. As seen in Exhibit 2, most carbon dioxide (CO_2) emissions come from the production of energy, in its many forms—generating electricity, powering industrial processes, moving us around, lighting our homes and businesses, growing our food. All critical needs. And as you read the chapters from my colleagues from across our investment teams and specialist investment managers, these industries and sectors are major foci in investment and engagement strategies.

It is important to note, CO_2 is not the only GHG we must reduce—methane (CH_4) and nitrous oxide (N_2O) are also contributing to warming, as seen in Exhibit 2. In many ways, methane is even worse than CO_2 as it has a 25× impact on warming.[3] However, it typically drops out of the atmosphere much faster than CO_2.[4] Agriculture is a major source of both gases, and we encourage you to read our previous piece in this series, *Food innovation: Investing to feed our future*, where we cover the food system's investment opportunities and challenges in detail.

Finally, this is not just about cutting emissions; it is about decarbonizing these sectors, and the economy as a whole. This will require wholesale changes to public policy, restructuring economies and funneling trillions of dollars into new technologies and infrastructures.

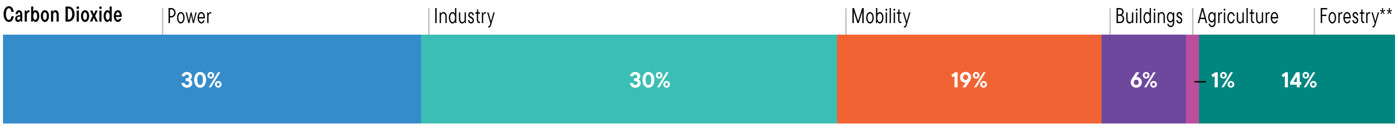
How much capital is needed?

The Network of Central Banks and Supervisors for Greening the Financial System (NGFS), a consortium of 125 central banks and 19 financial observers, have estimated that transition investments under their Net Zero 2050 scenario must total around US$275 trillion over the next 30 years. This may seem like an astounding figure but on average works out to around 6%–9% of annual global gross domestic product (GDP) most years.[5] And it is only about US$25 trillion more than implementing current policies.

Emissions Sources

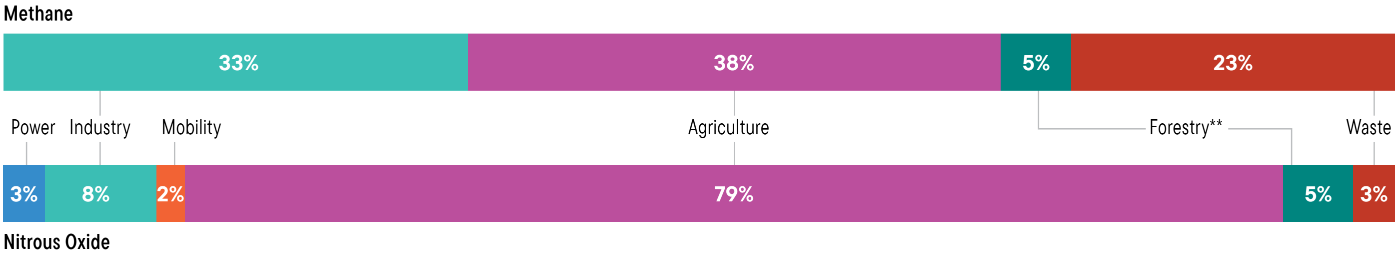
Exhibit 2: Percentage Shares of Emissions* Per Energy and Land-Systems

2019



Subsectors' Share of System Emissions, %

Electricity	97	Steel	26	Road	75	Residential	70	Farming	96	Forestry	100
Heat	3	Cement	20	Aviation	13	Commercial	30	Fishing	4		
		Oil & Gas Extraction	15	Maritime	11						
		Chemicals	12	Rail	1						
		Coal Mining	6	Other	<1						
		Other	20								



Sources: EMIT database by McKinsey Sustainability Insights (September 2021, data for 2019); McKinsey Global Institute analysis. McKinsey EMIT database draws on a variety of bottom-up sources. Depending on the emissions database used, data per system and the economy as a whole may vary. Figures may not sum to 100% because of rounding. Chart notes: *Includes all fossil fuel CO_2 sources as well as short-cycle emissions (e.g., large-scale biomass burning, forest fires). Power includes emissions from electricity and heat generation (i.e., from combined heat and power plants); Industry includes various industrial processes, including production of steel, cement, and chemicals, and extraction and refining of oil, gas, and coal; Mobility includes emissions from road, aviation, rail, maritime, and other forms of transportation; Buildings includes emissions from heating, cooking, and lighting of commercial and residential buildings; Agriculture includes emissions from direct on-farm energy use and fishing; Forestry includes net flux of CO_2 from land use and land cover change but not the opportunity cost of lost carbon capture; Waste includes emissions from solid waste disposal and treatment, incineration, and wastewater treatment. The global CO_2 emissions in this exhibit represent the total emissions of the full sectors, not of the subsectors considered in this report. Based on 2019 emissions. **Forestry and other land use.

The challenge is ramping up investment and doing so immediately. In 2022, energy transition investment flows hit a record high of US$1.6 trillion, as seen in Exhibit 3 on the next page. According to the International Energy Agency (IEA), 2022 marked the first time transition investment matched fossil fuel investment.[6] This, however, is not enough. Investments must triple in 2023 to over US$4.5 trillion, and continue to grow, also seen in Exhibit 3. NGFS's models project these numbers slightly higher, capping at around US$10 trillion a year in the 2030s, and then dropping off to around US$8 trillion a year in the late 2040s.[7]

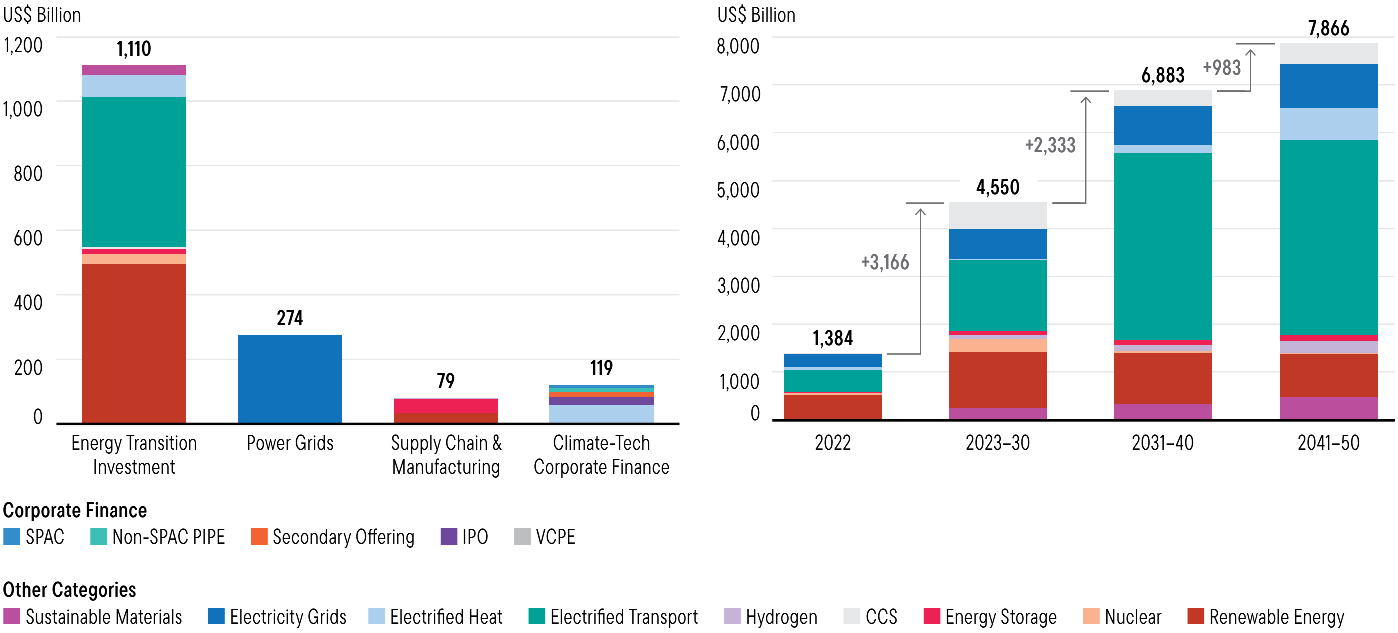
No matter which scenario you use, the investment need is significant. But, again, fulfilling the need is doable in the context of global GDP. That said, and as you will read in some chapters from my colleagues, the speed of this transition and redeployment of capital may not be practical. As we saw with the dual shocks of COVID-19 and the 2022 Russian invasion of Ukraine—and the subsequent energy shock[8]—the best-laid plans can quickly fall apart. So it is important to note that lower-emission bridge fuels, such as natural gas, will play an important role in the transition. That said, though some believe transition may not be practical, it is possible. And, given that fossil fuels are finite, the transition will happen—the only question is one of timing. Do we transition prior to having more substantial climate change problems, and the associated costs of negative externalities, and prior to running out of appropriate levels of fossil fuels?

Where are the investment opportunities?

The US$4.5 trillion required for the rest of the 2020s will come from many sources, including government finance and incentives—as we are seeing in the US Inflation Reduction Act, China's Belt and Road, and Europe's Green Deal Industrial Plan—international finance and concessional capital via the World Bank and International Monetary Fund, and private and public market investments. The Glasgow Financial Alliance for Net Zero (GFANZ), which Franklin Templeton participates in through Climate Action 100+ and which several of our special investment managers are members of via the Net Zero Asset Managers Initiative,[9] pledged to commit over US$130 trillion to moving the economy toward net zero, including US$32 trillion between 2021 and 2030.[10] This investment includes a wide range of investors, from individuals to institutions and corporate actors to commercial lenders. To date, the financing has not hit funding targets despite the record high investments, which GFANZ has pointed out in their most recent progress report.[11]

Record-Setting Investments...Are Not Enough

Exhibit 3: Total 2022 Investments Across Categories (left); Comparison: 2022 Energy Transition and Grid Investment Versus Required Annual Investment in 2023–30, 2031–40, and 2041–50 in New Energy Outlook 2022 Net-Zero Scenario (right)



Source: BloombergNEF. Note: Future values are from the New Energy Outlook 2022, except electrified transport, which is from the Electric Vehicle Outlook 2021 Net-Zero Scenario. The Net-Zero Scenario targets global net zero by 2050 in line with 1.77°C of warming. Investment includes electricity grids. There is no assurance any forecast, projection or estimate will be realized.

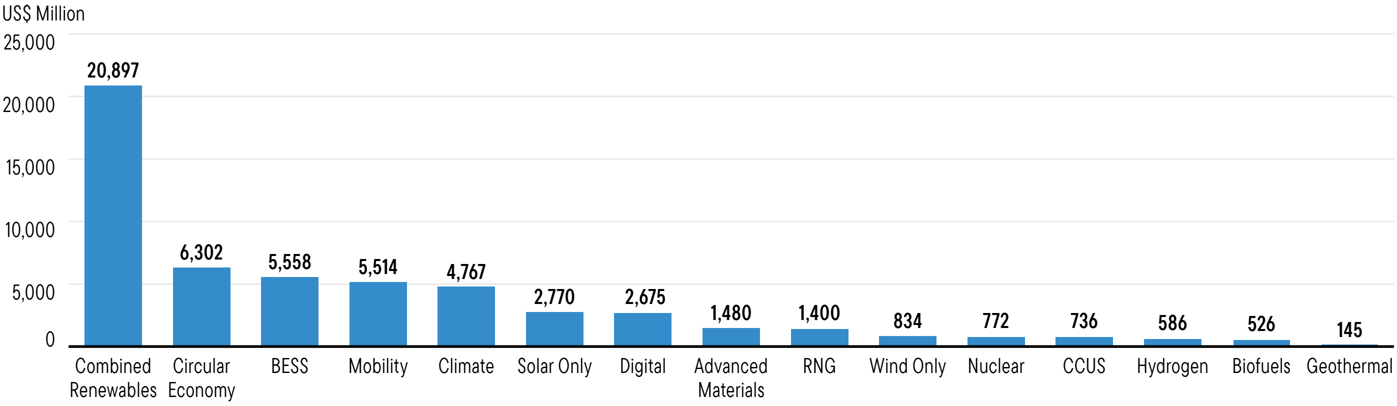
In the following chapters, you'll find views from a cross section of our investment teams on the role equity, fixed income, real assets, private markets, shareholders and carbon markets will play in transitioning major industries and sectors towards net zero. The common theme is opportunity and the belief we'll see substantial growth in markets, technologies and innovations required to transition the economy.

This is especially true in private equity (PE) and venture capital (VC), where we've seen growing funding and increased deals in the last couple years, with a major focus on combined renewables, storage, circular economy and mobility, as seen in Exhibits 4 and 5. We believe private markets offer great potential in the energy transition space due to the long lockup periods and governance control.

Private Capital Goes Green

Exhibit 4: Private Capital Energy Investment by Technology

August 2022–February 2023

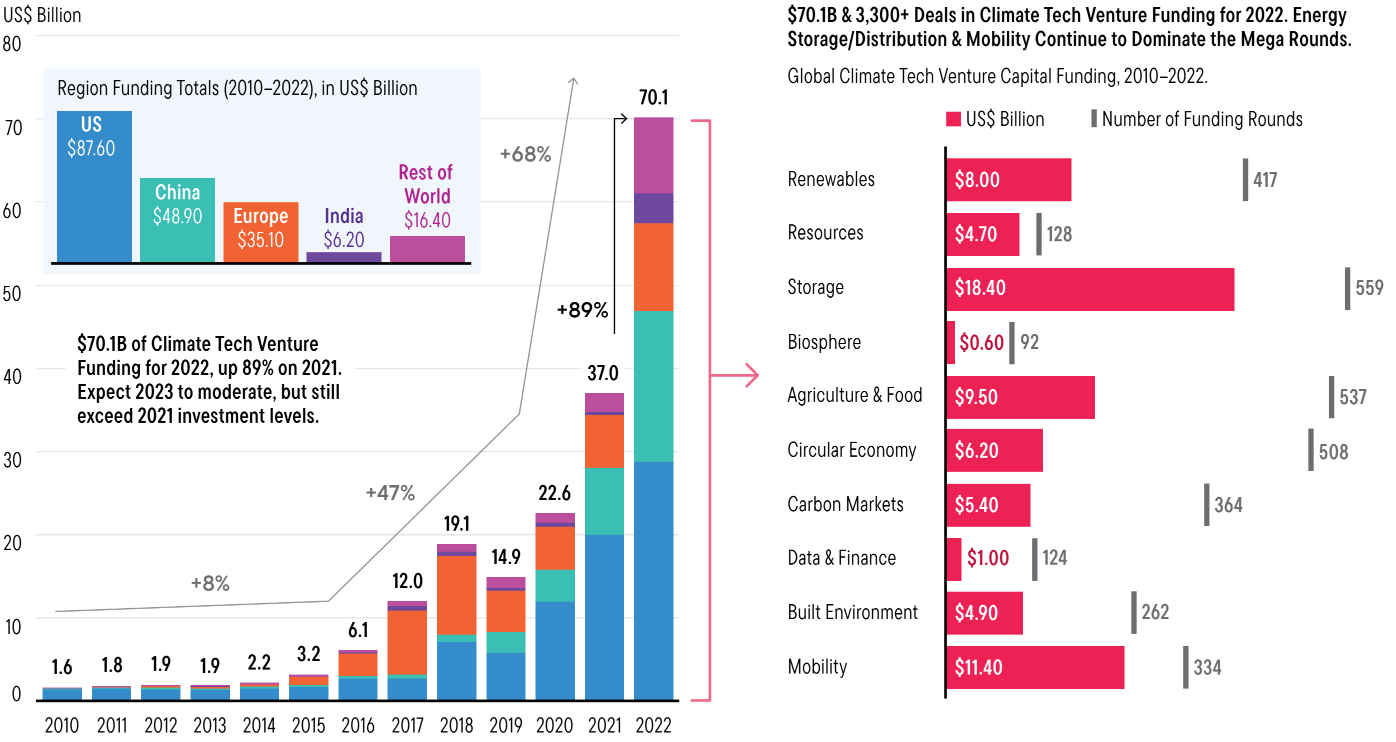


Source: S&P Global Commodity Insights. As of March 30, 2023.
Note: BESS = Battery Energy Storage System; RNG = Renewable Natural Gas; CCUS = Carbon Capture, Utilization, and Sequestration

Venture Capital's Global New Green Deals

Exhibit 5: Global Climate Tech Venture Capital Funding with Spotlight on 2022 Deals

2010–2022



Source: HolonIQ. As of January 2, 2023. Note: All numbers rounded and may not sum exactly due to rounding. Excludes private equity transactions. All years calculated at historic FX (spot rate of funding date).

The risk of delay or not transitioning

Focusing on the staggering cost of transition is myopic. Quite frankly, the cost of not transitioning far outweighs the investments and costs of transition, as seen by modeled impacts on global GDP in Exhibit 6. That's not to say transition does not come without risk—transition risk costs are represented by the teal green bars in the graph—and will impact GDP but can be minimized through rapid transition and mostly eliminated after transition. To better understand transition risk, please see the **Transition risk basics** sidebar.

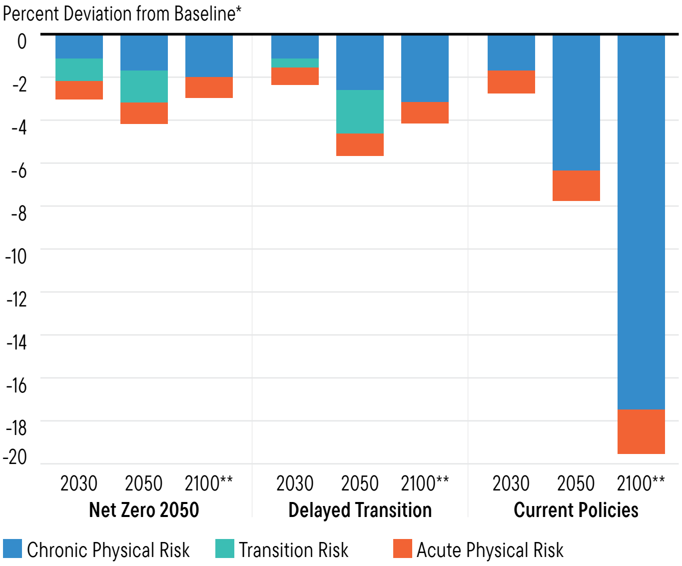
Also, transition investments are just that: investments. They come with returns! In 2018, the World Bank estimated a US$4 return on every US$1 invested on just infrastructure investments through 2030.[12] Not transitioning is pure loss—loss of capital, loss of assets, loss of property, loss of food systems, loss of species and life. For example, real estate losses in The Hague, Amsterdam, and London at 1.5°C are estimated at nearly €1.1 trillion. At 4°C, reached in the top three emission scenarios in Exhibit 1, that number exceeds €1.6 trillion.[13] These figures are based on 2020 values and the value of the euro; with current inflation, those numbers jump to €1.3 trillion and €1.9 trillion in less than three years.

We are already seeing growing gaps in the ability to insure these losses. Of the US$275 billion natural catastrophe losses in 2022—driven by extreme weather events—US$150 billion were uncovered. Losses are projected to grow 5% to 7% annually.[14] Two factors driving the growing loss gap are (1) the increasing frequency of "generational" events—events occurring historically once every 25 or 50 or 100 years are happening annually and (2) hard-to-assess or

Catastrophic GDP Impacts

Exhibit 6: Forecast GDP Deviation Due to Transition, Chronic and Acute Loss Based on Net Zero, Delayed Transition and Current Policy Scenarios

2030 vs. 2050 vs. 2100



Source: IIASA NGFS Climate Scenarios Database, NiGEM model (REMIND inputs). There is no assurance any forecast, projection or estimate will be realized. Additional chart notes: Net Zero 2050 limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050. Some jurisdictions such as the US, EU, UK, Canada, Australia and Japan reach net zero for all GHGs. Delayed transition assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. Negative emissions are limited. Current Policies assumes that only currently implemented policies are preserved, leading to high physical risks. *The NiGEM baseline is a hypothetical scenario with no transition nor physical risk. **Economic impacts are modelled out to 2050. To obtain an estimate of impacts in 2100, we took the estimate of chronic physical risk impacts based on the damage function, extrapolated acute physical risk increase (based on the period 2022–2050) up to 2100, and assumed no transition risk impacts at this point (i.e., the GDP loss is solely due to physical risk).

Transition risk basics

The Task Force for Climate-Related Financial Disclosure (TCFD), developed by The ClimateWise Transition Risk Framework to help investors:

1. Assess the breadth of asset types exposed to transition risk and opportunity across an investor's portfolio (across different subsectors, regions and time frames).
2. Define the potential financial impact from the low-carbon transition down to an asset level.
3. Incorporate transition impacts into their asset financial models.

Climate-related risk is broken into four categories

1. Market and Technology Risks: Includes impacts on supply and demand, as well as the role new technologies will play on creating winners (adoption) and losers (obsolescence).
2. Policy and Legal Risks: Includes the financial impact of policy change, as well as the risk of litigation.
3. Reputational Risks: Includes customer and community perceptions based on a company's contribution to or detraction from transition.
4. Physical Risk: Includes direct and indirect damage to physical assets and/or the supply chain, including impacts to resource availability. Chronic risk (e.g., temperature, precipitation, agricultural productivity, sea levels) and acute risk (e.g., heatwaves, floods, cyclones and wildfires) must be factored in.

For a detailed analysis and description of these concepts, please refer to: Cambridge Institute for Sustainability Leadership (CISL). 2019. *Transition risk framework: Managing the impacts of the low carbon transition on infrastructure investments.* UK: Cambridge Institute for Sustainability Leadership.

underestimated risks are more frequent, with first-time or never-seen events occurring in regions with no record of such events. Both factors make it difficult, and increasingly impossible, to model risk and insure losses.

Finally, we can't just look at this from an investment and GDP standpoint. The failure to transition will have devastating and irreversible impacts on people, ecosystems and species. None of us want to experience a 3°C or 4°C planet—devaluation of assets will be the least of concerns for the shrinking population.[15]

The importance of a just transition

Developed economies can afford transition and have multiple paths to cut emissions. On the other hand, many developing economies still lack basic energy infrastructure and services. Lack of energy access is a barrier to achieving UN Sustainable Development Goals (SDGs) that include ensuring access to safe water and sanitation, eradicating poverty, achieving food security and ending hunger and ensuring healthy lives and well-being for all at all ages. Affordable and Clean Energy (SDG 7) is a key to addressing, and unlocking, many of these challenges.

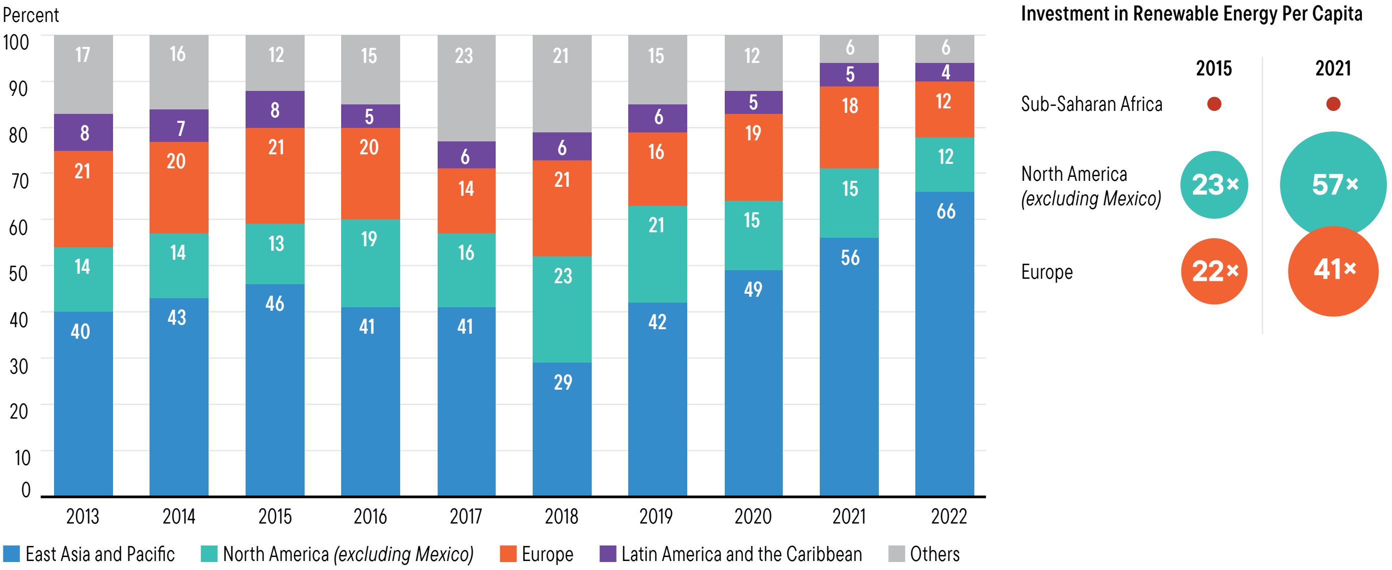
Access and cost of capital currently stands as one of the largest barriers to SDG 7 in developing countries. The three main factors, perceived or real, preventing investment are:[16]

1. Perceived credit risk and foreign exchange (FX) rate risk
2. Persistent home-country bias in high-income markets
3. Procyclical volatility—large inflows in good market conditions and fast outflows in downturns—that exacerbate economic uncertainty, defaults and FX volatility

According to the UN Environment Programme, developing countries have essential need gaps ranging from 4–8×, in Latin America, to 14–28×, in the Middle East. Essentially, countries least responsible for climate change are most impacted by climate change and lack the resources to address impacts and transition. As a result of these factors, investment versus need are out of alignment, and we're seeing little progress, as seen in Exhibit 7. If anything, the gap has grown. Focusing on sub-Saharan Africa, for every US$1 invested in renewable energy in 2015, US$23 dollars were invested in Europe and 24 in North America (excluding Mexico). In 2021, those numbers were 41:1 in Europe and 57:1 in North America (excluding Mexico).

Widening Disparity

Exhibit 7: Investment in Renewable Energy by Region of Destination, 2013–2022 (left); Growing Disparities in Per Capita Investment Between Sub-Saharan Africa, Europe and North America, 2015 vs. 2021 (right)



Sources: Naran, B. et. al. 2022. *Global Landscape of Climate Finance database.* Climate Policy Initiative (CPI); International Renewable Energy Agency and CPI. 2023 (revised). *Global landscape of renewable energy finance, 2023.* IRENA : Abu Dhabi.

Note: "North America (excluding Mexico)" includes Bermuda, Canada and the United States. "Others" include the Middle East and North Africa, Other Oceania, Transregional, Other Asia and Unknown.

Transition is possible. But it must happen now. Scaling financing from US$1 trillion to the necessary US$4 trillion requires innovation. Carbon markets, green bonds, blockchain and tokenized carbon assets and low-cost financing ("slow capital") must immediately be scaled up and rapidly deployed. Even if private markets can redeploy assets, major policy changes are required to de-risk the wholesale transition of the economy.

Investors, financial institutions, international debt institutions and governments must rapidly innovate to create financial instruments and funding mechanisms to bridge the gap to affordable, long-term and secure financing. Because many frontier and developing economies lack basic infrastructure, it is possible to leapfrog dirty fossil fuel energy solutions and go straight to renewable programs.

Innovation required

Transition is possible. But it must happen now. Scaling financing from US$1 trillion to the necessary US$4 trillion requires innovation. Carbon markets, green bonds, blockchain and tokenized carbon assets and low-cost financing ("slow capital") must immediately be scaled up and rapidly deployed. Even if private markets can redeploy assets, major policy changes are required to de-risk the wholesale transition of the economy. Concepts like carbon-based quantitative easing[17] must move off the drawing board and into the conversation in boardrooms of central banks. Public-private-nongovernment organization partnerships like we saw with Belize's debt-for-nature swap must be further explored and expanded.[18]

In the following chapters, you'll read perspectives from a cross section of our investment teams, but it was impossible to cover all sectors and concepts. It is also important to point out that some views may differ due to the autonomous investment processes and breadth of perspectives of our specialist investment managers. The speed and complexity of taking hydrogen to scale is one example where you'll read different perspectives. Just as these technologies are debated and discussed in the marketplace, we're having those same debates internally. Finally, this is a jumping off point to a discussion, which we encourage and welcome!

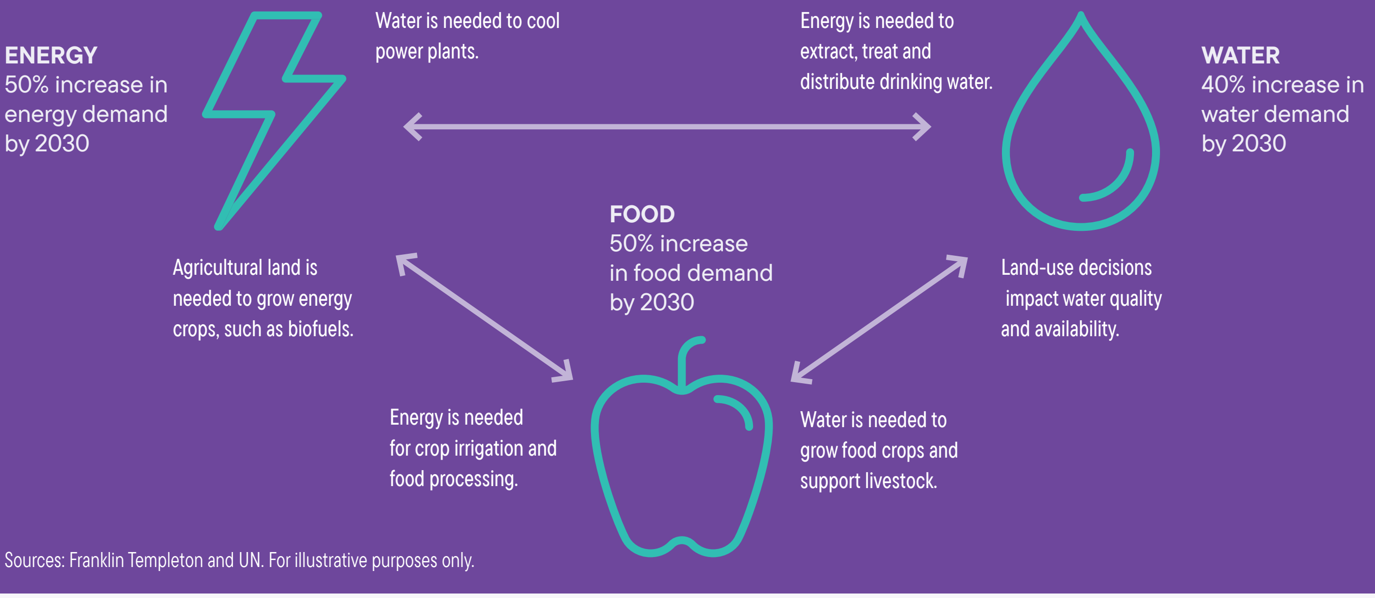
Energy-water-food nexus

As discussed, energy drives the global economy. It is the intersection of energy, water, and food—commonly referred to as the “nexus”—where the interdependencies and complexities peak. These interactions rank among the most complex global challenges today and will only grow over the coming decades. Over 25% of global energy production is consumed by food production and supply.[19] And, global energy production accounted for roughly 10% of global freshwater withdrawal[20]—a quickly shrinking resource that is putting energy generation in many regions at risk. As investors, our goal is to seek to understand the effects of these complex interactions on companies and industries.

The nexus highlights our challenges but also is the key to solutions. Energy transition and a net-zero emissions pathway are critical to reversing the global water crisis. As we recently highlighted, addressing the water crisis is a catalyst to addressing all 17 UN Sustainable Development Goals (SDGs), which sum our biggest global challenges.[21] Those challenges include food security and hunger. The food system is one of the biggest contributors to GHG emissions—and therefore climate change—and under increasing threat as temperatures increase. Energy transition is key to achieving food security and ending hunger in our world.

Can’t Have One Without the Others

Exhibit 8: Energy-Water-Food Nexus



Sources: Franklin Templeton and UN. For illustrative purposes only.

We encourage you to delve deeper into the energy-water-food nexus series through our first two pieces in this series, *Water disruption: Investment risk from multiple angles*, focused on water, and our views on food, *Food innovation: Investing to feed our future*. It is this trifecta where we see the most potential for risk, price disruption and overall market impacts as we move into the next years and decades.

Finding alpha at the energy-water-food nexus

Stephen Dover, CFA
Chief Market Strategist, Head of the
Franklin Templeton Institute

The energy-water-food "nexus" is widely recognized as a critical element of the efforts to combat climate change, as well as a key source of themes guiding investment management in the coming decades. The energy-water-food nexus is vast in scope and importance, so the number of potential investment themes emerging from it is practically without limit. The best way to characterize such a broad field is by example, so we present some vignettes that suggest possible investment opportunities at the intersection of energy, water and food over the medium to long run.

Energy, water and food

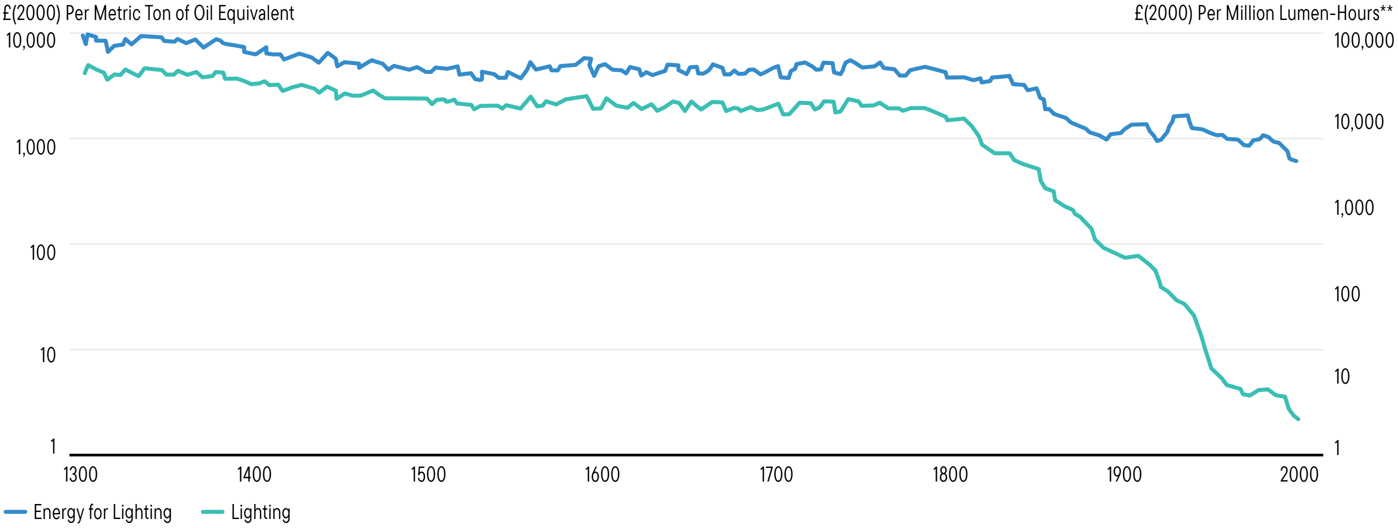
Energy is the ultimate resource, the physicist Alvin Weinberg wrote three generations ago, because it is the resource that allows all other resources to be produced or used.[22] Thus the progress of civilizations has been, and will continue to be, tightly linked to the availability and abundance of energy.

To trace the progress of energy availability and cost over the centuries, a useful barometer is lighting—where the necessary data exist. Exhibit 9 shows the declining cost of lighting from 1,300 to the present. The upper line shows how

Let There Be (Cheaper) Light

Exhibit 9: Price of Unit of Energy for Lighting and of a Unit of Lighting* (in year 2000 £ equiv.)

1300–2000



Source: Fouquet, R. and P. Pearson. 2012. *The long run demand for lighting: elasticities and rebound effects in different phases of economic development.* Economics of Energy and Environmental Policy, vol. 1 (1). Revised October 20, 2021. *Note: Based on five-year averages.

the price (in constant £) of a unit of *energy* fell; because lighting devices also became radically more energy-efficient, the lower line, showing the price of a unit of *lighting*, fell much more. When the price decline became a cascade around 1800, the Industrial Revolution flourished and many countries' standards of living began their climb from just above subsistence to where they are now.

Human beings, like every living thing, run on energy, but we can only get energy from food. In a very real sense, food *is* energy. We also need water, both to produce food and to lubricate the human organism. (Other uses of water, such as industrial uses, are also important, but first we have to stay alive.)

As a result, the oldest and most important uses of energy are to collect, store and distribute water and to find, cultivate and deliver food. The mix of energy sources is always changing, but each era of human history is associated with a particular energy source—the current one with oil. We are nearing the end of the Oil Age. We do not know what to call the next age because the current energy transition is exploring many possible ways of producing energy—but we do know that changes on this scale offer a myriad of opportunities to investors.

The economics and logistics of water and food, too, are changing, again offering opportunities to investors. Some of the changes arise from the need to use energy more efficiently in producing food and making water available. Others are due to water scarcity. Still others reflect the need to feed our world's population. This paper describes some investment themes related to the changes just described.

Irrigation: from flooding to smart water delivery

The problem: Traditional irrigation methods are inefficient and energy intensive.

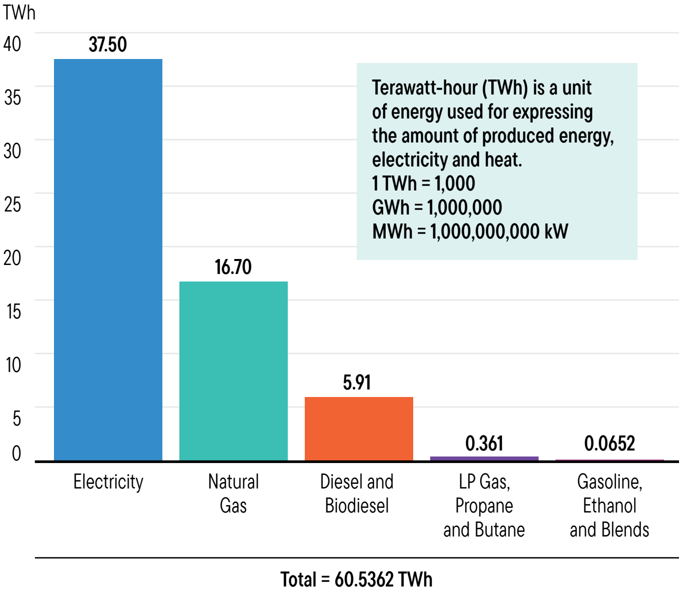
The Earth has plenty of water, but most of it is salty, and what little fresh water exists is often located far from where it is needed. Almost everywhere in the world, the infrastructure for collecting, storing and delivering water needs to be rebuilt or built from scratch, an undertaking that will involve trillions of dollars in infrastructure investments over time. We're still mostly using ancient technology—dams and aqueducts—so the improvement from just upgrading to 20th century technology would be significant, but 21st century technology is radically more advanced and efficient. It will also involve a massive expenditure of energy, because water is heavy and, having already flowed to the lowest elevation it can find, has to be pumped uphill.

Focusing on an area that is vital to maintaining and increasing the world's food supply, let's take a deeper dive into irrigation. Agriculture accounts for 70% of the world's water use, and irrigation is the key to making much of the world's land arable. But this irrigation is also energy intensive. In the United States alone, an estimated 60.6 terrawatt-hours (TWh) of energy—or nearly 20% of US energy consumption—in 2018 was used to deliver irrigation water, as seen in Exhibit 10.[23] Irrigation can be made much more efficient and effective.

Irrigation's Energy Footprint

Exhibit 10: Estimated US Energy Consumption for Irrigation Pumping

2018



Source: Sowby R., and E Dicataldo. 2022. *The energy footprint of U.S. irrigation: A first estimate from open data.* Energy Nexus (vol. 6), June 16, 2022.

Improving traditional irrigation practices

The US Geological Survey reports that variations on flood irrigation are still the most common form of irrigation in the United States, just barely beating out spray irrigation.[24] Yet flood irrigation, done naïvely, is incredibly wasteful: most of the water never reaches the plant roots and simply flows back to the water source, having picked up fertilizer pollution and other impurities along the way.

In addition, flood irrigation often involves energy-intensive pumping of water over long distances and potentially uphill. Flood irrigation can be made more efficient by leveling the fields, a process that used to be done by eyesight but that now uses laser beams. Capturing and reusing the runoff is another efficiency-enhancing innovation, made possible with chemicals and membranes that purify the water enough to be useful. Because flood irrigation is so cheap and easy, it will continue to be used where water is abundant, and these techniques for improving its efficiency represent an opportunity for investors.

Spray (sprinkler) irrigation is familiar to everyone with a garden hose, but most spray irrigation is done at large scale using a device called a center-pivot system, which traverses a very large (typically 130-acre) circle in the fields. Pivots typically run on powerful diesel generators; for example, a pivot used for large-scale cotton farming in Arizona pumps 10,000 gallons a minute. The first solar-powered pivot in North America was installed in Nebraska only as recently as July 2022[25]; with 150,000 pivots in operation in the United States alone, there's an opportunity in substituting solar for fossil-fuel power in many of these. Several companies are already positioned for this build-out.

Center-pivot irrigation also wastes water (in this case due to evaporation) but again it is cheap and easy and thus destined to survive, albeit with improvements. One such improvement is drip irrigation, which is just sprinkler irrigation at low water pressure. With drip irrigation, more water reaches the plant roots and less evaporates or runs off. Again, replacing less efficient with more efficient machinery involves spending and generates profits for the manufacturer and installer. The low water pressure also means less energy use.

Smart irrigation

But the most exciting and potentially most profitable changes in irrigation technology involve "artificial intelligence, analytics [and] connected sensors," according to a McKinsey report, which notes that "if connectivity is implemented successfully in agriculture, the industry could [add] $500 billion…to the global gross domestic product by 2030."[26] This is a 7% to 9% improvement in agricultural output over what would otherwise be expected and, the McKinsey report asserts, "also has the potential to reduce energy consumption…[through internet-based] monitoring [of] conditions and usage of buildings and equipment."

This improvement involves the use of robotics, an obvious productivity enhancement opportunity. Even today, farming in most places is backbreaking work, better done by human-supervised intelligent machines.

To get started on this path, fast internet connections would have to be made available in rural locations, including—or especially—in developing countries. This involves a large investment in satellites and on-the-ground devices, including autonomous farming machinery.

Smart agriculture overall

How does all this connectivity help? McKinsey detailed five categories of benefits (a partial list):

- smart-crop monitoring,
- drone farming,
- smart building-and-equipment management,
- autonomous-farming machinery, much of which runs on electric—thus potentially clean— power[27] and
- smart livestock monitoring.

We've already discussed smart farming of plants. How about animals? McKinsey describes smart-livestock monitoring as:

> [i]ndividualized feeding-and-care plans based on connected-body-sensor data and movement tracking, aimed at detecting illnesses early and providing each animal with its optimal feed and medicine mix to maximize growth.

With the next steak or leather goods purchase, think about that. The individual cow was on the internet, being "optimized" by a complex algorithm created by engineers and agronomists. We might want to invest in the companies that do this work.

"Green" fertilizer production

The problem: Fertilizer manufacture uses a lot of energy and produces undesirable emissions.

For these reasons, we expect changes in the way that fertilizer for crops (including crops used to feed animals) is produced. These changes will occur for natural economic reasons—that is, in response to rising energy costs—and because of regulations and incentives. If investors can get ahead of these changes, they can potentially earn exceptional returns.

Deirdre Lockwood (2018), writing for Chemical Engineering News, reports that:

> The [more than a century old] Haber-Bosch process, which combines nitrogen and hydrogen to make ammonia [for fertilizer], consumes about 2% of the world's energy supply, and its hydrogen feedstock is made by steam reforming methane at high temperature and pressure, producing significant CO_2 [and methane] emissions.[28]

Toward a solution

Crops are going to continue to need fertilizer—it's part of their biology. As a result, chemists have long attempted to find and implement a more energy-efficient, water-efficient and environmentally sound fertilizer production process. In the Haber-Bosch process, both water and electricity are key components in electrolysis.

So far, success at replacing Haber-Bosch with other processes has been modest. A thorough review of sustainable ammonia production processes is described in a 2021 *Frontiers in Energy Research* article.[29] Lockwood notes that "some researchers have surmounted this hurdle by eschewing the iron-based catalyst used in Haber-Bosch in favor of a catalyst [consisting of] gold nanorods." This may or may not be scalable; obtaining a large amount of gold in a hurry seems unlikely.

But, as Lockwood reports, a chemist at Monash University in Australia named Douglas MacFarlane is "tackling the problem by swapping the aqueous electrolyte for an ionic liquid—a salt that cannot crystallize at ambient conditions and so exists in liquid form." This innovation has multiplied the energy efficiency of the process sixfold. But—bad news—"the rate of the reaction itself—the amount of ammonia produced per unit time—was about a tenth that of other systems." We have to do better.

Tricky engineering problems like this one tend to be solved by competition among venture-backed companies (or, occasionally, by large existing corporations with research and development facilities) that expect large profits if they succeed. For this model to work, farmers need to be able to pay more for fertilizer during the transition period, either out of their own money or through subsidies; while there's some slack in developed-country farm budgets, most developing countries are still trying to maximize food production per dollar spent. As a result, we see innovation in fertilizer manufacture getting uptake first in the developed economies, then more gradually spreading to the rest of the world (as is the case with all expensive innovations). We also envision transfers from developed to developing economies to speed this process.

Fertilizer as pollutant

Because fertilizers are water-soluble, pollution from fertilizer runoff creates algae blooms that can impact water sources and economies that are highly dependent on fresh water (e.g., dead zones in major river deltas). Also, ammonia production uses a lot of water—nine tons of water are required to produce one ton of hydrogen via electrolysis—resulting in a lot of greenhouse gases. Even if we cannot find a substitute for Haber-Bosch as described above, moving Haber-Bosch to using renewable energy would be a large investment opportunity, although it would not solve the direct-emissions problem that Haber-Bosch creates.[30]

To limit the damage from fertilizer runoff, at least two technologies are in play. Fertilizers are being developed that are less toxic or that do not remain in the natural environment as long.[31] Pinpointed fertilizer distribution, along the same lines as the automated and artificial intelligence (AI) enabled pinpoint water distribution described above, greatly reduces the amount of fertilizer lost to runoff.

Increased calorie consumption in developing economies

Extreme poverty is still with us. About 1.3 billion people experienced food insecurity in 2022, an increase of 10% from 2021.[32] As noted in my piece on the future of food, COVID-related supply and logistical challenges affected food production and distribution.[33] Parts used to repair farm equipment don't arrive, ships can't unload, trucks lack truck drivers (or truck drivers lack trucks). We don't realize how important our system of logistics is until it's impaired.

The recent rise in energy prices also harmed food production and affordability. Fossil fuels still supply about 80% of the world's energy,[34] including the energy used to produce and distribute food. As a result, food prices have risen sharply.

We expect the relatively short-term problems caused by COVID and the energy price spike to mostly resolve. But the fact that the problems became as serious as they did, and persist to some extent several years later, shows our vulnerability to natural occurrences and remind us that progress is never guaranteed.

Toward a solution

Economic growth and the adoption of 21st-century water and agritech/farming practices, including genetically modified organism (GMO) crops and livestock, will enable per-capita caloric intake to grow in the next 20 years. The need to increase the absolute amount of food grown to address food insecurity will also present many opportunities to investors—as will the tendency of people to consume higher-quality food as per-capita gross domestic product (GDP) rises.

This will take a lot of energy and a lot of water. In sub-Saharan Africa, introducing infrastructure—such as reservoirs, aqueducts and wastewater removal—will be an improvement on the rain-based agriculture that now predominates. According to a World Bank report:

> Farmer-led smallholder irrigation (FLSI) in [Asia] may offer Sub-Saharan Africa better guidance than state-led centralized large irrigation projects…[M]otor pump–driven FLSI…made famines history and countries food-secure in Asia in a short span of a decade or two. With its ample shallow groundwater resources and sparse farming areas, Sub-Saharan Africa has immense potential to grow pump-driven FLSI quickly…[and] cost-effectively…Finally, Sub-Saharan Africa can and needs to leapfrog and build its FLSI economy around solar irrigation pumps…[35]

Leapfrogging to 21st century water technology in sub-Saharan Africa could produce the same leapfrog effect we've seen with cellular phones, where most cell phone infrastructures did not have to compete with landline infrastructure.[36]

There's a lot of opportunity, in several different industrial sectors. For example, any type of irrigation will use a lot of concrete or concrete substitutes. As currently manufactured, most concrete is environmentally problematic—the production of cement (the key ingredient in concrete) is now responsible for emitting 8% of total CO_2 emissions and is also a heavy energy consumer.

Emissions reduction mandates in California, New York and other locales, however, are forcing engineers to rethink the cement manufacturing process. Low-carbon concrete technologies are still limited, and cutting emissions now involves many small steps rather than a "magic bullet."[37] One such step is carbon infusion into the concrete itself:

> Producers…inject captured CO_2 into fresh concrete during mixing. Once injected, the CO_2 reacts with the concrete mix and becomes a mineral that is permanently embedded…The CO_2 mineralization also increases the concrete's strength.[38]

GMO foods

GMO foods are important enough to deserve separate mention. They not only increase food yields and enable crops and livestock to be grown in a broader range of environments; they also provide some surprising benefits. While the development and use of GMO foods is an established strategy, such foods are still an investment opportunity—we're not finished modifying the genomes of the organisms we consume and we're probably just starting. Thus, biotech investments are a promising alpha source over the long run.[39] However, GMOs still face restrictions in many European and other countries globally, and an increasing number of people around the world choose to eat organic and non-GMO products.

Conclusion

Most investment in most of the history of the world has been directed at obtaining energy, water and food. As we've become more prosperous, the market share of these kinds of basic investments has declined. But energy, water and food are still the most important economic goods because of our basic biology. As such, the amount of investment related to them will remain large. Global economic growth, efforts to combat climate change and climate change itself will intensify this tendency.

This expected investment in the real economy will correspond to high returns in the capital markets that support real investment. By carefully analyzing the thematic opportunities that we've identified and purchasing stocks and other securities that will benefit from these trends, we believe that substantial alpha can be generated over the medium to long term.

Government incentives accelerating the shift to green energy

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Many government policies—both carrots and sticks—are driving the global transition to greener energy systems. In this piece, we compare regulatory sticks, like carbon pricing, with carrots, like feed-in tariffs that subsidized solar renewables in countries like Germany.[40]

First, we review carbon pricing across the globe. Higher prices remain challenging to implement politically. We explain why some economists fixate on the efficiencies of carbon taxes and dismiss government subsidies as wasteful. We explore China's new carbon market, which aims to lower emissions from China's coal-fired power plants.

Second, we explain how governments like Germany helped kick-start a boom in solar-power innovations by deploying subsidized carrots. One of the biggest catalysts driving down today's solar prices comes from economies of scale in Chinese manufacturing. We review an emerging consensus among economists that subsidies are accelerating a "green vortex" in places like Texas in the United States.

We conclude with an optimistic outlook of the US government's new industrial policy and note a new record in global investments in low-carbon technologies. That said, governments in China, the European Union and the United States are deploying carrots and sticks at markedly different speeds and intensity. Looking ahead, global security analysts seeking to generate alpha will need to integrate top-down subsidies into bottom-up security analysis to uncover risks and opportunities.

Carbon sticks

For many years, the primary climate policy recommended by many economists was carbon pricing. Compared to government subsidies, carbon price signals offered a more elegant response to the complex problem of CO_2 emissions. Why? In their view, subsidies are often inflexible and inherently prone to wasteful overcapacity. With more countries racing to subsidize home-grown green industries, *The Economist* warns vast amounts of public money may go to waste.[41] Instead of picking winners via government handouts—a "destructive new logic" that forsakes the invisible hand of free-market capitalism for the visible hand of "aggressive industrial policy"[42]—carbon pricing offers a more efficient approach. Unlike subsidies, carbon pricing gives companies the freedom to reduce emissions by whatever means they see fit.

Looking ahead, global security analysts seeking to generate alpha will need to integrate top-down subsidies into bottom-up security analysis to uncover risks and opportunities.

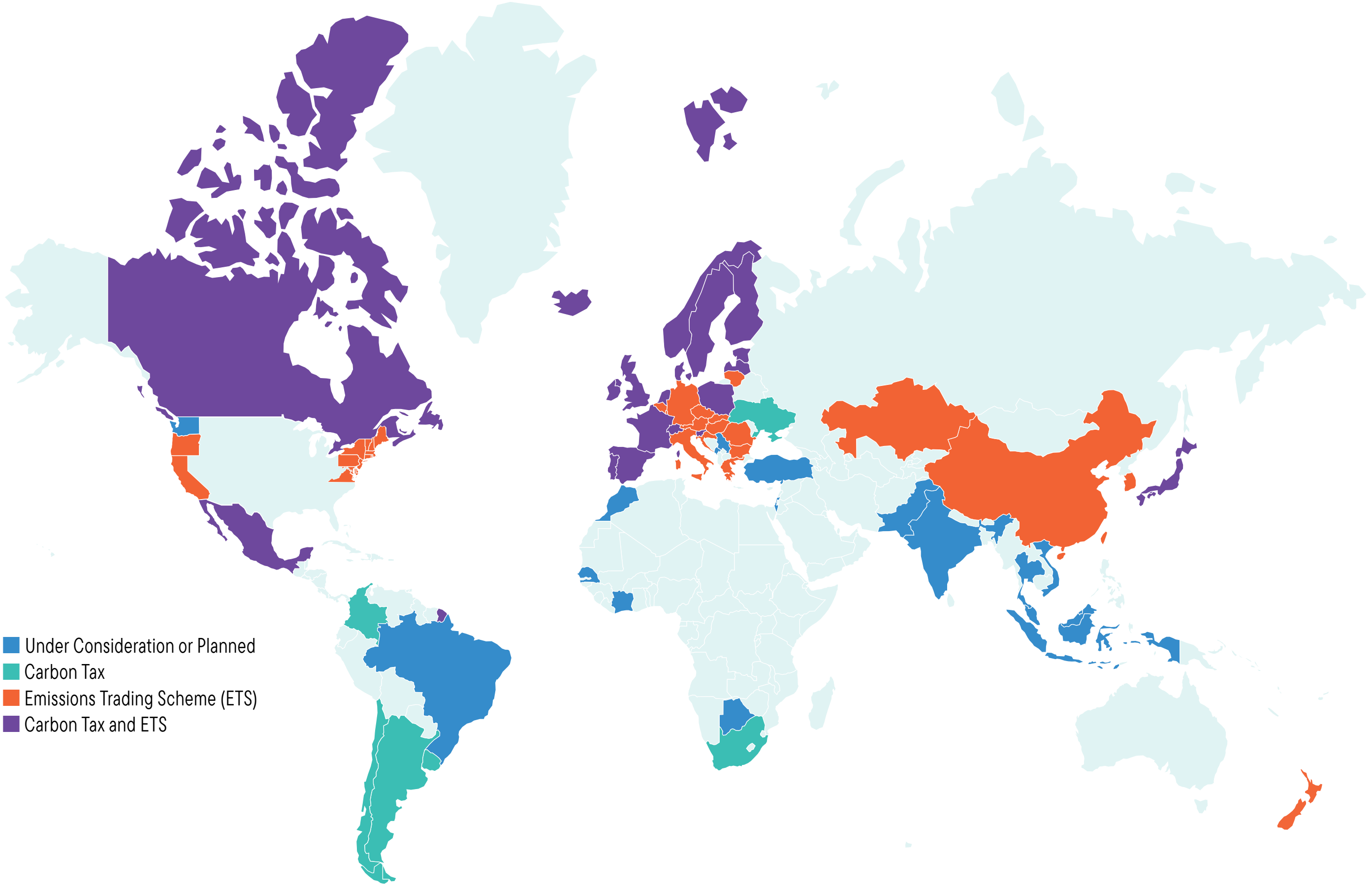
If carbon pricing offers a more efficient road to our zero-carbon future, there's progress to celebrate. Over 46 countries price greenhouse gases—either through carbon taxes, emissions trading systems (ETS) or both—and they together cover 30% of global CO_2 emissions, as seen in Exhibit 11.[43] One notable participant, China, launched the world's largest carbon markets in 2021, covering one-seventh of global CO_2 emissions, and three times larger than the European Union's ETS.[44] Currently, China's nation-wide ETS regulates roughly 2,162 companies from the country's power generation sector, which emit 4.5 billion tons of CO_2 annually.[45] Given China is the world's largest carbon emitter, we think this is a critical step in that country's drive to reach zero carbon by 2060.

At this early stage, China's ETS is mainly structured to incentivize improvements at its coal-fired power plants by squeezing out inefficiencies and reducing carbon intensity.[46] China's government initially planned to also include other high-carbon industrial sectors such as cement and aluminum in 2022 but saw delays due to data quality. China's Ministry of Ecology and Environment, for example, found compliance verification issues with most of the power sector company data, according to Refinitiv.[47] By 2025, China aims to include even more carbon-emitting sectors, such as oil refining, chemicals, building materials and non-ferrous metals.

Carbon Price Signals Go Global

Exhibit 11: Countries Choose Different Approaches to Pricing Carbon

As of August 2023



Carbon pricing via carbon taxes, emissions trading systems or both

Carbon taxes have a practical appeal by providing certainty over future emission prices that encourage green investments. These taxes also generate revenues that governments can use to tackle debt, ensure a more "just transition" by redirecting revenue to the poor and make green investments.

Emissions trading systems directly target emission levels by issuing carbon allowances that companies are required to obtain. By trading these allowances, the free market establishes carbon prices. It's not a fixed tax. Countries like France deploy fixed carbon taxes alongside the EU's ETS.

Sources: World Bank Group (WGB), International Monetary Fund (IMF), and national sources. Note: The boundaries and other information shown on any maps do not imply on the part of IMF any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

Looking ahead, India plans to launch its own national carbon market in 2026. Like China, India's stakeholders will target high-carbon sectors such as power generation alongside a range of industrials like steel and cement.[48] Details of this cap-and-trade market—similar to the European Union's (EU's) ETS—are still being worked out. For example, it's unclear how India's existing voluntary carbon market will fit into the new trading scheme. That said, many of India's stakeholders understand that carbon price signals need to be high enough that cutting emissions will be rewarded. To that end, India's government plans to deploy a price stabilization mechanism to better incentivize low-carbon solutions.[49]

The framework for India's pricing mechanism comes from the EU, which added a carbon "market stability reserve" to its ETS in 2019. Just months after launching, EU carbon prices reached levels not seen in a decade.[50] Why? The supply of allowances had outstripped demand, causing a surplus. That meant carbon price signals were too low to incentivize economic changes. By tapping its reserve portfolio to buy carbon allowances, the EU has boosted carbon pricing to over US$100 per metric ton in 2022. As we discuss below, in the absence of stronger price signals, free markets can have difficulty reshaping economic activities.

No pain, no gain

Since 2013, California's ETS has had a clear mission. By setting limits for 85 percent of California's CO_2 emissions, state authorities have established "a price signal needed to drive long-term investment in cleaner fuels and more efficient use of energy."[51] In retrospect, however, a growing cohort of economists now admit these prices haven't been tough enough to force much change on their own.

To be clear, California's electric utilities have slashed emissions by 36% from 2013 through 2019—but that was mainly due to state laws forcing utilities to incorporate more renewable power.[52] This critique isn't unique to California. Back in 2012, economists reached the same conclusion when assessing Europe's ETS. They found the program had quite limited effects on the rate and direction of corporate clean-energy innovations.[53] Thanks to the new price stability mechanism, however, the EU's carbon price signals are exponentially higher today, as shown in Exhibit 12.

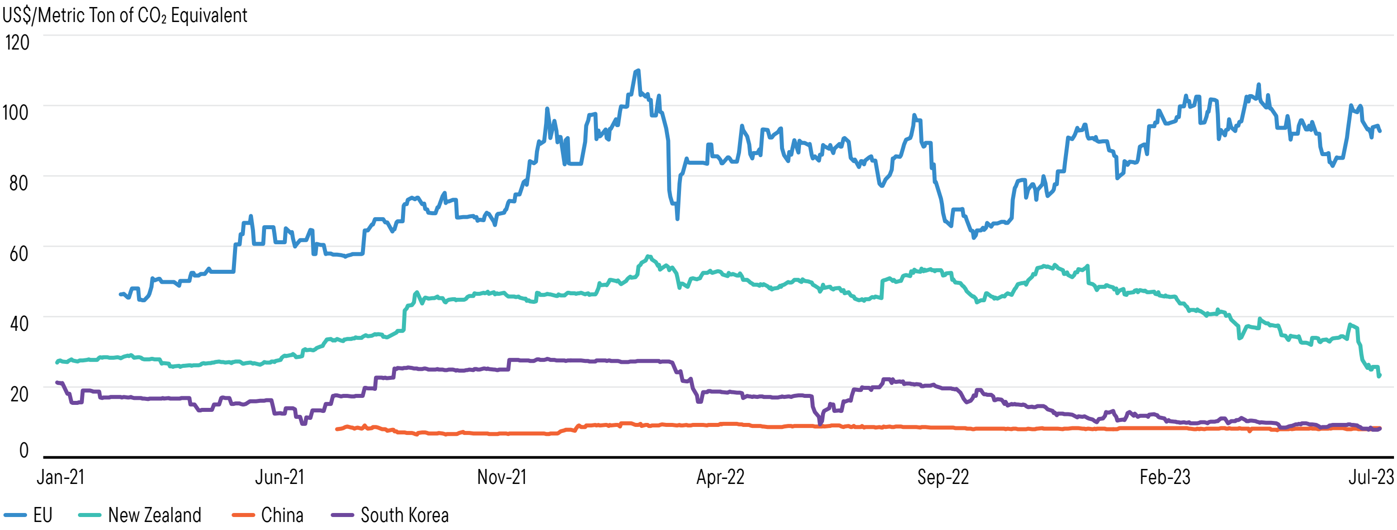
This begs two questions when looking at the global carbon-pricing map in Exhibit 11. First, how high are carbon prices today? Globally, the IMF estimates US$20 per ton on average across regions with price signals. Across all CO_2 emissions globally, however, it drops to US$5 per ton.[54] In regions with price signals, only 10% have carbon prices at US$65 per ton or higher, according to the Organisation for Economic Co-operation and Development (OECD).[55]

Second, how high should carbon price signals be? This depends on specific future goals: such as reaching net zero by 2050, calculating future carbon sequestration costs or measuring the social costs of carbon (SCC) that each ton of carbon inflicts on humans. In 2013, an interagency working group within the US government estimated the SCC were

Carbon Pricing—Not So Taxing

Exhibit 12: Emissions Trading Systems EU, New Zealand, South Korea and China

January 4, 2021–July 5, 2023 (Daily)



Source: Bloomberg. As of July 6, 2023. Note: Index currencies converted to US$. Korean Allowance Unit 2022: Listing on January 4, 2021 and delisting on August 11, 2023.

US$36 per ton.[56] Nine years later, new climate analysis by the US Environmental Protection Agency raised the SCC to US$190 per ton.[57] This dovetails with 2022 economic research by Resources for the Future—a climate and energy think tank—that finds each additional ton of carbon emissions costs society US$185.[58]

It's worth noting here that the United States doesn't have a national ETS, nor do many other countries. Indeed, less than 30% of global CO_2 emissions are covered by carbon pricing schemes.[59] Out of this slice, the vast majority of today's CO_2 trading volume comes from just two carbon markets in the EU and China. Recent efforts to convince US corporate CEOs and US lawmakers to launch a similar ETS has come from the Commodity Futures Trading Commission (CFTC).[60] In testimony before the United States Senate in 2021, CFTC Climate-Related Market Risk Subcommittee of the Market Risk Advisory Committee chairman Bob Litterman explained that without a national ETS, all manner of US financial instruments—stocks, bonds, futures, bank loans—face painful and disorderly adjustments down the road.[61]

The CFTC's core message reflects the growing certainty that, outside the EU, average carbon prices are simply too low to redirect capital at the scale and speed we need. Case in point, China's price is just US$8 per ton of CO_2, far below the EU, as shown above in Exhibit 12. That said, we're less concerned for two reasons.

First, China's carbon pricing will reduce the carbon intensity of its coal-fired plants in the near term, before scaling up in the future. Second, the EU plans to implement a carbon border tax that will have positive ripple effects across the globe. Countries that trade regularly with the EU can either forfeit money at the border when selling high-carbon products or invest more at home in clean-energy systems to avoid the tax. We think the EU's carbon stick will help incentivize trading partners to transition their economies quickly.

Indeed, in his Senate testimony, Litterman noted the US economy is 300% more carbon-efficient than competitors like China, Russia and India. A carbon border adjustment would raise new revenues for the US government. From Litterman's vantage, he said it was remarkable that leaders from both Republican and Democratic administrations have come together in support of a market mechanism that asks non-domestic manufacturers to compete based on carbon efficiency. "But given the win-win outcomes, it should not be surprising," he said.[62]

From now through the end of 2025, there will be no carbon tax at the EU's borders. Instead, the focus will be ironing out the methodology for accurately measuring the "Scope 1 emissions" embedded in these industrial goods. Scope 1 refers to direct CO_2 emissions during the production process.

Measuring carbon leakage

It's important to note that the EU's carbon border adjustment mechanism (CBAM) remains a work in progress. For starters, the EU is initially targeting sectors it believes have the most significant risk of carbon leakage.[63] That means high-carbon industrials, like iron and steel, aluminum, cement, fertilizers, as well as electricity and hydrogen. Many of these sectors, like cement, pose significant engineering and technology challenges, as we discussed in 2021.[64] Europe is deploying billions of capital in early-stage demonstration projects, testing green hydrogen and carbon capture solutions at steel and cement factories across Europe.

From now through the end of 2025, there will be no carbon tax at the EU's borders. Instead, the focus will be ironing out the methodology for accurately measuring the "Scope 1 emissions" embedded in these industrial goods. Scope 1 refers to direct CO_2 emissions during the production process. If nothing else, establishing the right methodologies to measure carbon, that's also verifiable globally, will be an enormous step forward.

These new methods are necessary to measure carbon leakage, which can happen in two ways. First, EU businesses could relocate industrial production to countries outside the EU with lower or no carbon prices. Second, carbon leakage can occur if products made in the EU like steel or cement are replaced by equivalent imports with higher CO_2 intensity at cheaper prices.

For security analysts, it's clear that EU carbon pricing brings headwinds to Europe's industrial companies. The costs of retrofitting plants with carbon capture, for example, are eating into profits and may boost prices higher than most non-EU competitors. Indeed, the “buy or sell” recommendations of Europe’s largest cement makers were downgraded in 2020 for this exact reason.[65] Analysts rightly argued that higher cement prices would expose EU companies to carbon leakage via cheaper imports from India’s cement industry.[66] At the time, we noted a carbon border tax would likely resolve this issue. We stand by our analysis and think the macroeconomic impact on emerging economies will be modest—see our sidebar on “spillover effects.” We think Europe’s border tax will lead the way to a faster energy transition across developed and emerging economies alike.

The green vortex

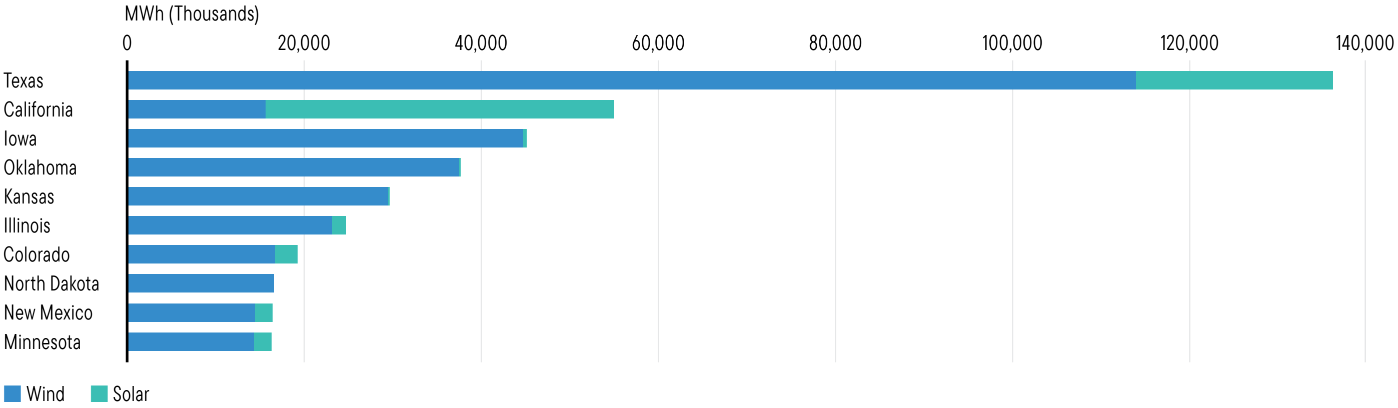
As we’ve discussed, carbon pricing has dominated conversations around climate policy for decades. Today, it still features prominently in academic circles and publications like *The Economist*. A growing number of scientists, however, now recognize carbon sticks aren’t the only option. And they have clear evidence to prove it. Consider California’s carbon market, which some climate analysts consider to be one of the best-designed carbon programs in the world.[67] If that’s true, how do we explain power generation in the state of Texas?

In the first quarter of 2022, Texas led the United States in renewable energy, accounting for over 14% of US green-energy production.[68] Many Texans bristle at government taxes—the state doesn’t levy a state income tax—and are proud of its fossil-fuel industries. And yet, Texas now produces nearly twice as much electricity from renewables as from coal, as shown in Exhibit 13.

Texas’ Green Vortex

Exhibit 13A: Top 10 US State Wind & Solar Leaders (Annual)

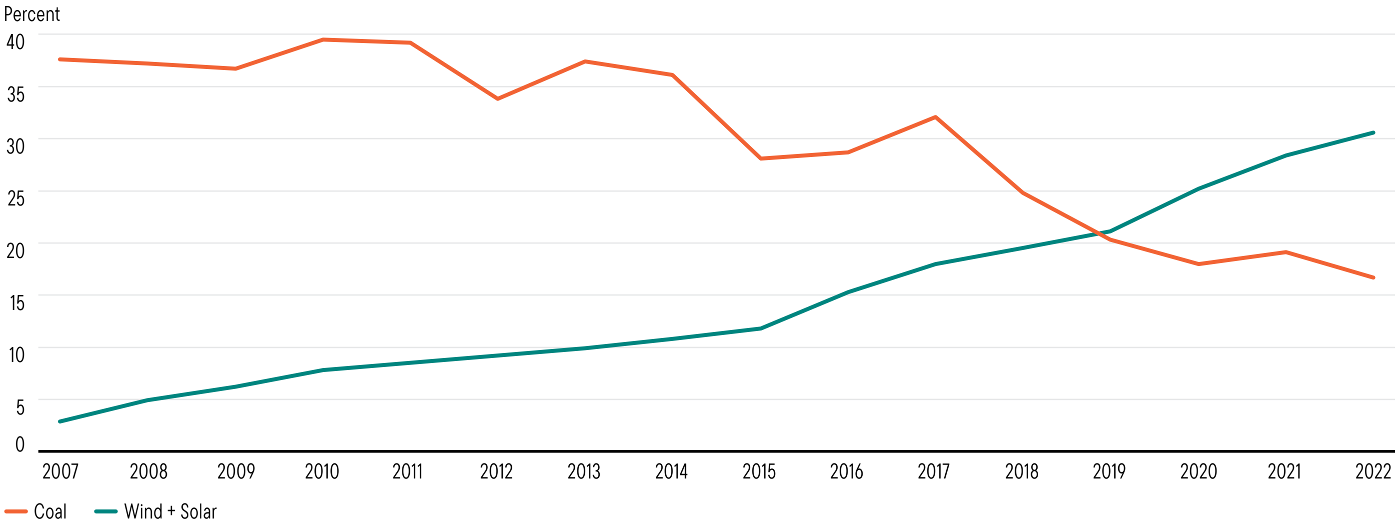
2022



Source: U.S. Energy Information Agency (EIA)

Exhibit 13B: Texas Wind + Solar and Coal Generation

2007–2022



Source: Electric Reliability Council of Texas (ERCOT).

Texas is clearly decarbonizing. But why? Some climate analysts call this process a "green vortex."[69] The phrase describes the accelerating combo of technological advances and the appeal of green profits that were kickstarted by—wait for it—government subsidies. Today, we're seeing a newfound appreciation for industrial policy among economists, though certainly not all.[70] This represents a qualitative shift away from classic climate policy that mainly focused on carbon pricing.

In our view, today's green vortex represents a handshake between the visible hand of government policies—which kick-start innovation with early funding—and the invisible hand of free-market capitalism, which efficiently directs capital to climate solutions. All combined, the return premium from green climate solutions—a return "greenium"—is something we discuss in an upcoming paper in the *Journal of Investment Management*.

To unpack this worldview, we turn next to advancements in solar photovoltaic (PV) production in recent decades, which benefited from a wide range of government carrots such as loan guarantees and feed-in tariffs. Rather than imposing upfront costs on existing fossil-fuel assets, some policy analysts now argue clean-energy subsidies should *precede* phased-in taxes, to better redirect "private investment away from polluting capital and toward clean capital."[71]

Spillover effects of a carbon border tax

By design, carbon border taxes are meant to have a global impact. But what about the spillover effects on emerging economies? Because many countries have either quite low or no carbon prices, some security analysts think companies outside the EU will simply shift their exports, like steel and fertilizer, to other non-EU countries and not bother decarbonizing.[72] One think tank has modeled the cost increases that future EU carbon tariffs will have on iron and steel imported into the EU from China, Brazil, Russia and India. Prices for India's steel could rise 15% in the EU; prices for steel from China, Brazil and Russia could rise 3%–4%.[73] The authors, however, note the macroeconomic impact of the border tax on these countries looks modest. For example, the effect on China's GDP is negligible—these exports into the EU are just 0.4% of China's overall exports—while Russia's GDP could drop 0.2% by 2030. Bear in mind, this economic analysis was published mere weeks after Russia's invasion of Ukraine.

Subsidized carrots

Last October at the opening of the Chinese Communist Party's 20th National Congress, President Xi Jinping spoke at considerable length about safeguarding the environment by accelerating China's clean-energy revolution. To reach carbon neutrality by 2060, Xi reiterated the principle of "establishing the new before destroying the old."[74] This phrase means building a reliable, renewables-centered economy *first* through government subsidies, before eliminating the use of fossil fuels like coal.

Xi's philosophy isn't unique to China. Researchers at the think tank MacroPolo remind us that advanced economies, chiefly Japan and Germany, deployed government loans and capital in the 1990s to help jump-start their fledgling solar industries. For example, Japan launched a solar rooftop subsidy program in 1994, helping drive down costs of solar installations by more than 65% over the following decade.[75]

Across Europe, but particularly in Germany, government feed-in tariffs were deployed as either a primary or exclusive policy mechanism to drive solar energy deployment through the 1990s and 2000s. Feed-in tariffs are government incentives that guarantee a certain level of financial benefit for each unit of electricity produced by renewables, like solar panels. These fixed-price contracts—which typically last 10 to 20 years—sent a clear price signal to developers and utilities across Europe that installing solar panels would be profitable.[76] By substantially increasing these solar subsidies in 2000 and 2004, Germany saw an explosion of solar installations through the 2000s, as shown in Exhibit 14 on the next page.

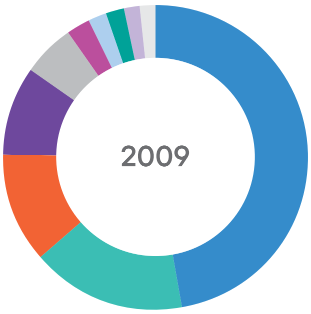
Green industrial policies

Around this same time, China was busy incentivizing solar panel manufacturing in rapidly urbanizing cities like Wuxi. China's manufacturers received access to subsidized land and modern manufacturing infrastructure, along with special financing and tax cuts. The goal was to accelerate growth in polysilicon manufacturing and wafer production, creating vertically integrated supply chains. The economist Paul Krugman calls this phenomenon, in which supplies of key materials, like polysilicon, are situated near the production of solar PV cells, modules and panels, "agglomeration."

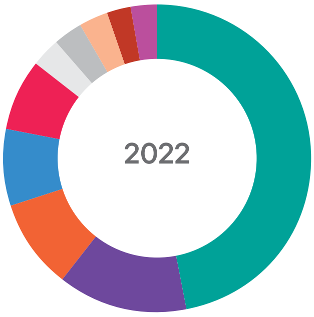
Green Carrot Evolution

Exhibit 14: Top 10 Countries by Share of Installed Solar Capacity

2009 and 2022



Installed Capacity in Mw	% of Total World Capacity
● Germany	44.8
● Spain	15.7
● Japan	11.1
● United States	8.8
● Italy	5.4
● Republic of Korea	2.2
● Czechia	2.0
● China	1.8
● Belgium	1.6
● Australia	1.4



Installed Capacity in Mw	% of Total World Capacity
● China	37.3
● United States	10.7
● Japan	7.5
● Germany	6.3
● India	6.0
● Australia	2.5
● Italy	2.4
● Brazil	2.3
● Netherlands	2.1
● Republic of Korea	2.0

Source: International Renewable Energy Agency (IRENA).

All combined, China's industrial carrots helped scale up solar PV production 500 times from 2000 to 2016.[77] Why is scale important? Economists studying the mechanics of technological innovations find economies of scale and learning-by-doing play an outsize role in lowering costs and improving quality across clean-energy technologies.[78] This economic theory—known as Moore's Law and, in a slightly modified version, called Wright's Law—was recently tested against historical data and held up quite well.[79]

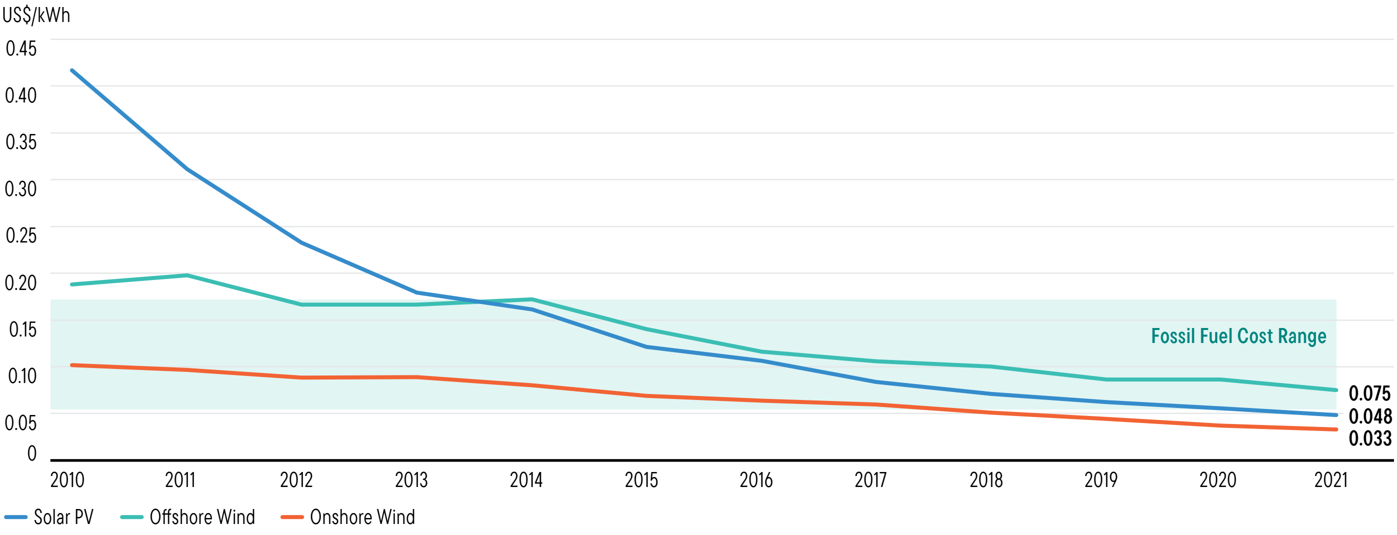
It's these economic laws—and the government incentives that drove them—that help to explain a seismic shift in competitiveness of renewable electricity over fossil fuel options. From 2010 to 2021, the costs of solar PV electricity dropped 88%, which is now below the costs of fossil fuel electricity, as indicated in Exhibit 15.[80] At these prices, solar PV is now more profitable for power plants than coal- or gas-fired electricity.

This breakthrough in clean-energy pricing brings us back to the concept of the "green vortex" that we discussed earlier. In India, the outlines of a national carbon market are just emerging. And yet, it's with an eye toward green profits that India's largest power company is now committed to building 60 gigawatts of solar PV electricity by 2032.[81] Why? The power from newly built solar capacity in India is now cheaper than the power from existing Indian gas- and coal-fired power plants. It's really that simple. Indeed, India's government now plans to stop building new coal-fired power plants by

Renewable Costs Falling Sharply

Exhibit 15: World's Levelized Cost of Renewable Electricity

2010–2021



Sources: Our World in Data, IRENA.

removing a key clause from the final draft of its National Electricity Policy.[82] Cheaper renewables means India doesn't need new coal additions, apart from what's already in the near-term pipeline.

Leading with carrots

For investors worried that industrial policies may usher in the demise of free-market principles championed by Adam Smith, we highly recommend a new economic paper from the *Boston Review*.[83] The authors have assembled a wide array of new research from economists who suggest government incentives—both industrial policy carrots *and* carbon pricing sticks—are indispensable to reaching our clean-energy future.

As for green-energy carrots overturning free-market orthodoxy, BloombergNEF notes that G20 governments handed out US$3.3 trillion of direct fossil-fuel subsidies from 2015 through 2019.[84] These *direct* subsidies, however, don't include the mountain of *implicit* subsidies from governments that don't currently impose national carbon prices. The International Monetary Fund recently calculated that governments showered companies with US$5.9 trillion of *implicit* fossil fuel subsidies in 2020 alone.[85] If governments can hand out "carbon carrots" to oil and gas companies by avoiding an EU-style ETS, then subsidizing green-energy innovations shouldn't scramble free markets, in our view.

As for solely focusing on carbon sticks to incentivize the energy transition, that approach can deliver short-term pain, like higher energy bills, while concealing longer-term gains for the environment, public health and most economies. In our view, it's better to lead with government carrots that accelerate the arrival of cheaper green energy and well-paying jobs before phasing in higher carbon prices. In other words, we should build the new before destroying the old. This carrot approach has finally arrived in the United States, first with infrastructure legislation in 2021, earmarking billions for a clean-energy grid and charging stations for electric vehicles (EVs),[86] and then with the Inflation Reduction Act (IRA) of 2022. The IRA offers US$369 billion in subsidies to jump-start clean-energy innovations while on-shoring green manufacturing.[87]

These subsidies might be jarring to some security analysts. Some will point to Solyndra, a solar PV start-up that received a US$535 million loan guarantee from the US government in 2009. In their view, Solyndra's bankruptcy in 2011 is proof that government carrots are inherently wasteful. We note that Tesla received a similar loan for US$465 million in 2010—part of the same program to accelerate US clean-energy technologies—allowing Tesla to expand its production facility.[88] Was that loan also wasteful?

To understand how our security analysts scrutinize the impact of government carrots on capital markets and individual companies, we suggest reading an interview with our Shanghai-based investment team. They explain how integrating policies like "Made in China 2025" into equity and credit analysis helps uncover risks and opportunities that many investors might otherwise miss.[89]

The path forward

If there's some handwringing over US President Joe Biden's new industrial policies, *The Economist* notes that history offers some reasons for optimism. For example, in the aftermath of the second world war, scores of governments unleashed industrial carrots to supercharge industrialization, with great success in places like Japan and South Korea.[90] Today, the Biden administration is deploying similar incentives, like green-energy procurement contracts that will accelerate demand for 100 gigawatts of solar power systems over the next decade. That's nearly as much as the US's installed solar-power capacity today. It's an economic approach that harkens back to policies the United States deployed to land astronauts on the moon.

Responding to the United States, the EU unveiled its own green industrial strategy in March 2023. While it doesn't offer new funding, the plan aims to simplify the thicket of EU regulatory hurdles, streamlining the approval of national green-finance tools already available in Brussels.[91] A major goal of building green industries inside the EU is reducing dependence on energy imports, a security lesson learned from Russia's war in Ukraine. The EU recognizes that China dominates global manufacturing across key net-zero technologies—including EV batteries, solar panels and wind turbines.[92]

So what impact will these EU and US industrial policies have? Over the long term, we see these programs expediting the push of green technologies forward, with competition between the world's three largest economies—the United States, China and the EU—reducing the costs of green technologies even faster.[93] Looking ahead, we believe the ability of investment analysts to produce alpha will increasingly hinge on analyzing how government carrots and sticks are accelerating both opportunities and risks across private and public investments.

Electrification—infrastructure's staggering task ahead

Andrew Chambers
Portfolio Manager, Real Assets
Martin Currie Australia

As the clean energy and electrification revolution continues to gather speed, we take another look at this important theme. The investment required to deliver energy transformation at a global level has a very wide range of forecasts; however, what is clear is that the capital expenditure numbers are quite staggering.

According to the International Renewable Energy Agency (IRENA), 2022 investments in energy transition technologies reached a new record of US$1.3 trillion. By 2050, cumulative investments must amount to US$150 trillion, averaging US$5 trillion a year to get anywhere near the 1.5°C warming pathway for 2050, as seen in Exhibit 16.[94] Alongside investments in renewable generation, electrification and grid expansion will have an important role in enabling efficient and flexible transition technologies.

These investments will also help completely remake the mix of energy sources, while also nearly tripling the generating capacity, seen in Exhibit 17. Both of those are critical

The Challenge: Triple Capacity While Reducing Emissions

Exhibit 16: Annual Investment Needs to Achieve the 1.5°C Scenario

Current vs. 2030F vs. 2050F

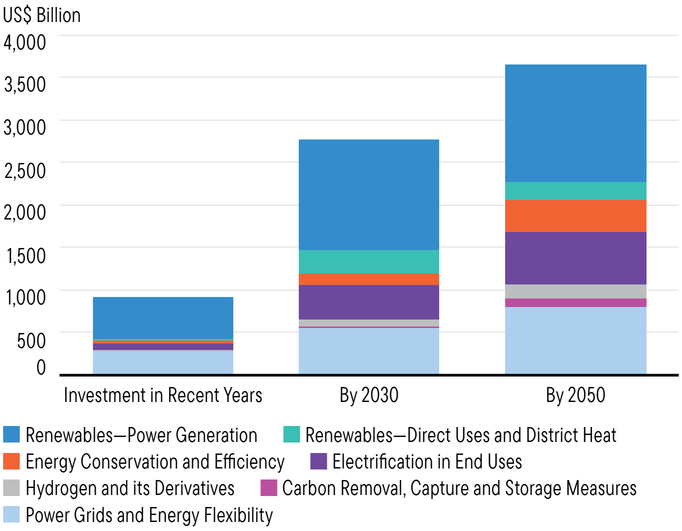
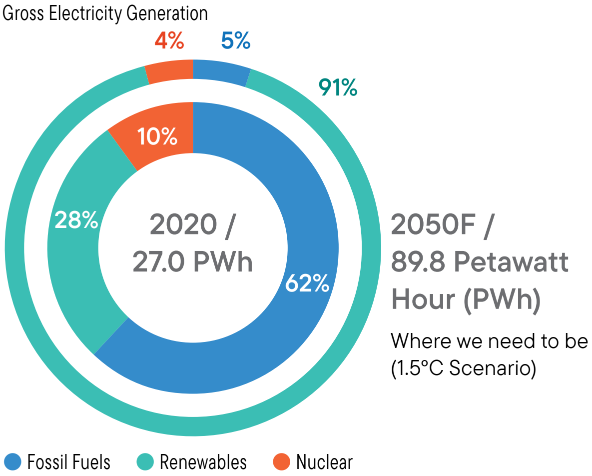


Exhibit 17: Power Generation Capacity and Sources Required to Achieve 1.5°C Scenario

2020 vs. 2050F



Source (for both charts above): IRENA. 2023. *World Energy Transitions Outlook 2023: 1.5°C Pathway; Preview*. IRENA : Abu Dhabi. Note: A petawatt is equivalent to a quadrillion watts. F = forecast. There is no assurance any forecast, projection or estimate will be realized.

for supporting a growing global population. And in some emerging-market countries, such as India or the Philippines, the electrification revolution also involves connecting entire communities to electricity for the first time.

Our team is very excited by the growth prospects of listed utilities. When we combine our urban population growth thematic investment screens with the electrification opportunity, we believe that once "boring" or stable listed utilities may have some additional spark in the years ahead. We explore this through two case studies later in the piece, one from a developed market and one from an emerging market.

The current electricity grid environment

Electricity transmission networks traditionally connected large power generators, such as coal, gas or nuclear, generally located a long distance from where people live and work, to the lower-voltage distribution networks in our cities and towns.

In many countries, the system evolved to connect networks between countries or states. For example, the UK National Grid now connects to various other European counties, and Australia's east coast now has the longest interconnected electricity system in the world. The expanding electrical grids help diversify the sources of energy, which improves reliability as well as access to and transport of the lowest-cost generation.

While the private sector traditionally owned the electricity grids in the United States, in many parts of the world, grid ownership and development were managed by the public sector. However, over the last few decades, we've seen governments in many countries sell down, privatize and publicly list electricity grids—providing much needed funds for other expenditure items. Today, the private sector is a key stakeholder in distribution utilities, with around 29% of them privately owned. However, in high-income countries, there is a much larger proportion; around 40% to 45% are privately owned.[95]

After a utility has been privatized, governments often continue to play a major role in the privately owned grids via regulation of the sector. Private or listed ownership of electricity grids is facilitating private capital investment into the ongoing capital expenditure of electricity grids, and we believe this will help facilitate the energy transition and grow the rate/asset bases of the electricity grids.

Electrifying a lower-carbon economy

As aging, coal-fired, gas-fired or nuclear generation assets are retired, they are increasingly replaced by renewables such as wind, solar, geothermal or hydro. Unlike traditional fossil fuel generation, where a large amount of capacity is in one location (i.e., the "power plant"), the new mix of renewable sources are often in many different locations, requiring a lengthening and expansion of transmission networks into new areas.

We are believers in electrification's role as a key pillar in a lower-carbon economy. Advantages of electrification include sourcing low emissions electricity generation from renewable sources and facilitating improved efficiency through electric technologies (such as EVs and heat pumps) compared to fossil fuel-based alternatives.

Electrification demand

Some key areas where we see electrification demand:

- Transport and electric vehicle (EV) charging
- Heat pump efficiency gains and a growth in electrical heating (versus gas) and new air-conditioning installations
- Digital device purchases and strong growth in data centers, Bitcoin mining
- Automation or robotic labor for activities such as cleaning and manufacturing

As electrification of industry and transport ramps up, we expect to see significant growth in the total amount of electricity consumed, which will necessitate an increase in the capacity of the whole system. Expansion likely requires significant network capital expenditure as well as additional storage, smart grids and energy efficiency.

While electrification may be the long-term solution to a lower carbon economy, the massive growth in electricity demand may potentially also require some of the older generation sources, such as coal, gas or aging nuclear plants, to delay mothballing and continue running for the medium term to meet peak-demand-period requirements. We believe reliability of the electricity grid is an important part of the sector, maintaining a strong social license to operate and the political support for transition.

Developing energy storage systems

Renewable energy intermittency will also require a mix of fast-start thermal generation and/or a large increase in energy storage solutions, such as: batteries, pumped hydro or potentially newer technologies such as hydrogen. Many of these will need to be incorporated into existing grids.

At times, new generation creates bottlenecks within electricity networks; therefore, the location of energy storage will be far from universal. For example, if the bottleneck is between a remote solar or wind generation source and a major load center, then locating the storage near the generation source may make sense. However, if the bottleneck forms within an existing city due to peak load growth, then more-localized energy storage makes sense. Urban planning is also now considering and incorporating the energy transition, through better building designs and smarter cities that harness and store energy.

Hydrogen (or ammonia) is an interesting technology but comes with various challenges around production, energy losses, water use, current high costs, and difficulty with storage and transport. For many applications, battery storage appears to be a much better solution any may prevent or slow widespread global use of hydrogen. However, in some countries with high demand and limited land mass to generate renewable electricity, offshore hydrogen may well be part of the solution. For example, Australia is utilizing its large land mass to produce green hydrogen for export to Japan or Korea.

Funding of energy storage systems will come from multiple sources, and investors appear keen to deploy capital into energy transition. Traditional utilities integrating storage into management of their existing supply and demand are employing a wide mix of different methods such as traditional equity and corporate debt, as well as traditional project finance for these critical investments. We are also seeing non-traditional stakeholders such as mining companies, IT billionaires, family offices and mutual funds enter the energy storage space using a wide range of traditional structured financing methods. Many are based on long-term offtake contracts to the traditional utilities, and some are even taking on more risk via developing projects without price or revenue certainty. This is based on a view that the transition will accelerate increasing energy price volatility and hence potentially increase returns on storage investments.

Smart grids basically use real time information to adjust electricity demand and flows. This ensures better energy efficiency and distributed energy resources. This improves the overall electricity supply system across the power grid, ultimately improving the efficiency of flows, smoothing supply and demand and lowering costs for all participants.

Smart grids and energy efficiency

Given that existing energy systems were not originally designed with such massive change in mind, we also believe that smart grids and energy efficiency will feature prominently into the future. In particular, they will help alleviate the challenges associated with the intermittency of many forms of renewable energy and also help manage the costs of bottlenecks arising within the networks.

Smart grids basically use real time information to adjust electricity demand and flows. This ensures better energy efficiency and distributed energy resources and improves the overall electricity supply system across the power grid, ultimately improving the efficiency of flows, smoothing supply and demand and lowering costs for all participants.

Growing policy support

Strong policy support for the energy transition is occurring around the world via a mix of direct incentives or emission reduction policies, such as Australia's Safeguard Mechanism, the European Emissions Trading System and the US's Inflation Reduction Act (IRA).

- While clearly stimulating capital investment into the listed utility sector, these incentives will also catalyze significant investment by industry. For example, New Zealand dairy processor Fonterra is investing directly in heat pumps and biomass to exit the use of coal-fired boilers.[96]
- In the United States, the IRA is expected to incentivize significant investments into clean energy initiatives, including renewable energy projects and battery storage. Duke Energy describes it as "game-changer" and "a once-in-a-generation legislation that funnels nearly US$400 billion of federal funding into clean energy initiatives."[97]

Developed-market case study: Australia

The Australian National Electricity Market (NEM), which is managed by the Australian Energy Market Operator (AEMO), is one of the largest interconnected electricity systems in the world. It covers around 40,000 km of transmission lines and cables, supplying around nine million customers for Australia's east coast and southern states—approximately 80% of Australia's electricity consumption.[98] AEMO was established in 2009 by the Council of Australian Governments (COAG) to manage the NEM, and is made up of members representing federal and state governments, in addition to industry, to manage generation, production, and distribution of energy, as well as the wholesale and retail energy markets.

The NEM is currently undergoing significant change to accommodate and respond to changes in emissions, integrate new and emerging technologies in generation and storage and meet changes in consumer energy needs and preferences.

AEMO has published an Integrated System Plan (ISP), which is basically a whole system plan for supplying affordable and reliable electricity to homes and businesses in the eastern and southeastern states, while supporting Australia's net-zero ambitions.[99]

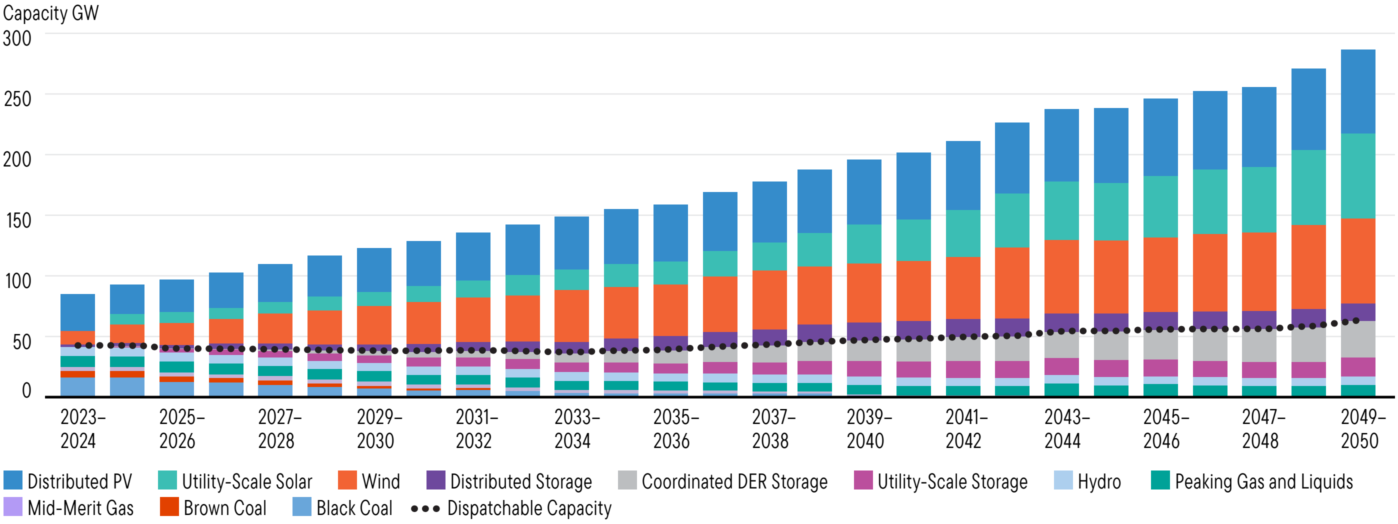
Exhibit 18 highlights the forecast changes in NEM capacity to 2050 under the step change scenario, which is the scenario that most closely resembles our team's views around significant growth in new energy sources. Martin Currie Australia also believes there will be a closure of aging thermal generation, particularly on the coal side but perhaps with slower shutdown schedules given the massive task of building and connecting all the renewable energy.

Australia's population continues to increase, as seen in Exhibit 19, due to its immigration program and its lifting of COVID-19 travel restrictions. At Martin Currie, we expect that this population growth will also drive strong electricity

Electrification and Population Growth = Supercharged Opportunities

Exhibit 18: Forecast NEM Capacity to 2050, Step Change Scenario

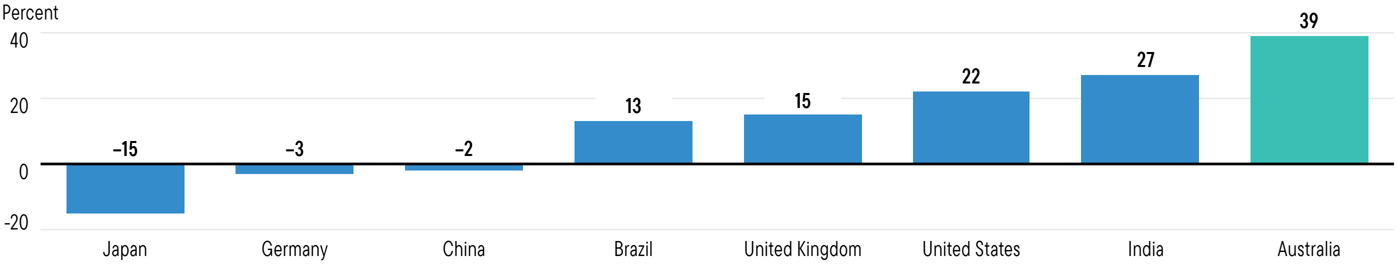
2023–2050F



Source: Australian Energy Market Operator Limited (AEMO). 2022. *2022 Integrated System Plan.* Sydney: AMEO. F=forecast. There is no assurance any forecast, projection or estimate will be realized.

Exhibit 19: Population Growth Estimates of Select G20 Countries

2015–2050F



Sources: UN Population Division; United Nations, Department of Economic and Social Affairs, Population Division (2018). *World Urbanization Prospects: The 2018 Revision.* New York: United Nations. F=forecast. There is no assurance that any estimate, forecast or projection will be realized.

demand growth. When combined with a transformation of the electricity network, we expect to see a significant growth in the electricity network, and opportunities for listed utilities to benefit financially from this growth.

Emerging-market case study: India

India is the world's third-largest electricity consumer with installed power capacity of over 400 gigawatts (GW) in March 2022, as seen in Exhibit 20.[100] India's strong urban population growth, combined with a rapidly growing middle class and electrification of energy use, is expected to result in installed capacity of almost 600 GW by March 2028[101] and to greater than 800 GW by March 2030 to meet national net-zero targets.[102] This is a whopping 9.5% per year growth rate.

India's Transformation

Exhibit 20: India's Installed and Projected Capacity

2022–2030F

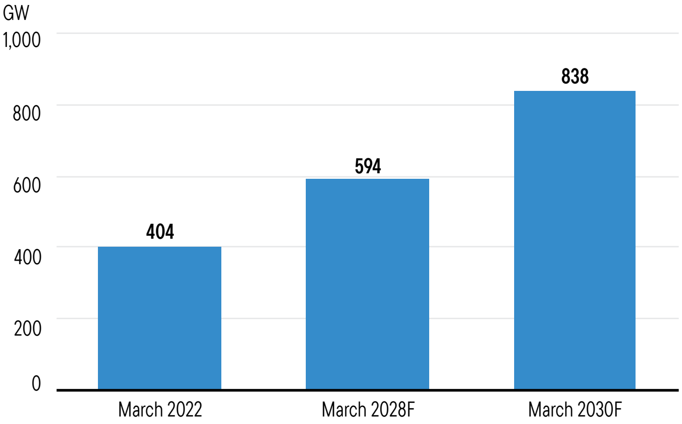
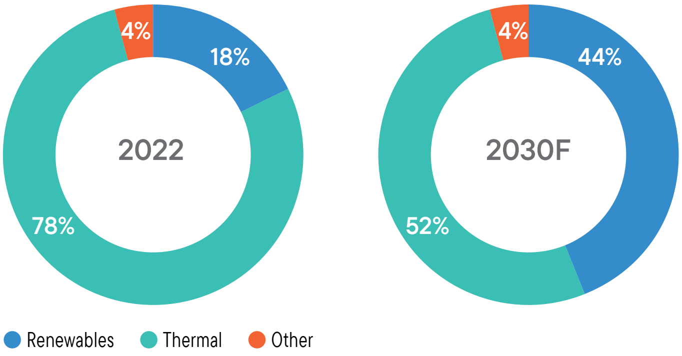


Exhibit 21: India's Current and Forecasted Sources of Energy Generation

2022 vs. 2030F



Sources (for both charts above): Powergrid India, CTUIL Rolling Plan, CEA. F=forecast. There is no assurance that any estimate, forecast or projection will be realized.

We expect the Indian electricity sector to undergo a massive transformation in the years ahead to deal with this demand growth, and we also expect to see significant changes in the energy mix, as shown in Exhibit 21, with an acceleration in clean energy investment. This means that the electricity transmission and distribution networks will require significant expansion by the listed utilities to connect new demand to new supply and storage sources.

However, given the demand growth is so strong, we do expect to see growth in not only renewable energy but also traditional thermal energy generation. We highlight that the Central Electricity Authority (CEA) estimates that the share of renewable energy generation would increase from 18% to 44%, while that of thermal energy is expected to reduce from 78% to 52% by 2030.[103]

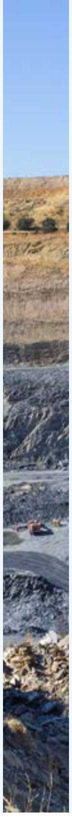
The path forward

Transition investments will increase materially in coming years to many trillions of dollars per year, with a massive increase in investments from listed real assets, unlisted infrastructure, industrial companies (including supply chains) and governments.

However, there remain considerable challenges to meet annual investments to IRENA's suggested requirement, which amounts to over US$5 trillion per year to stay on the 1.5°C pathway.[104] Some of the key challenges include planning and permits, supply chain bottlenecks and labor shortages in some parts of the world.

There is also the circular reference challenge that many of the supply chains that need expanding require traditional fossil fuels during the manufacture/processing and transport, hence in some regions—particularly some emerging market economies—the energy transition may result in an increase in short-term emissions for the global transition to accelerate and bring down longer-term emissions.

At Martin Currie, we're strong believers and supporters of electrification. However, given the size of the task ahead, a lot more needs to be done and the process may well take many decades. Despite the ongoing debate around pathways, time frames and annual spend amounts, what is very clear to us is that the once "boring" or stable listed utilities may have some additional spark in the years ahead.



Will high yield fund the energy transition?

Bryant Dieffenbacher, CFA
Portfolio Manager, Research Analyst
Franklin Templeton Fixed Income

The US high-yield (HY) bond market was a key enabler of the shale oil and gas boom, with far-reaching implications ranging from geopolitics to US industrial competitiveness. Robust US oil production growth flipped the United States from a net importer to a net exporter of crude oil, while cheap natural gas aided a shift away from emissions-heavy coal-fired electricity generation. Despite the positive implications of the shale boom, debt and equity investors endured two sharp energy default cycles over the past decade that incinerated a tremendous amount of capital. The aftermath of these default cycles, as well as growing environmental, social and governance (ESG) and regulatory influences, have changed the financing market for below-investment-grade oil and gas companies. These changes, as well as new, more-disciplined capital allocation and governance frameworks, can present attractive opportunities to invest in the HY oil and gas industry. ESG considerations remain top of mind for issuers in the industry, and some of the more interesting investment opportunities could come from ESG leaders. While there are some energy transition investment opportunities at the periphery of traditional HY energy businesses, it remains to be seen whether the HY bond market will fund a boom in energy transition capital investment as it did with the shale oil and gas boom.

> **While there are some energy transition investment opportunities at the periphery of traditional HY energy businesses, it remains to be seen whether the HY bond market will fund a boom in energy transition capital investment as it did with the shale oil and gas boom.**

Financing the shale boom

Prior to the global financial crisis (GFC), US oil production experienced a decades-long secular decline, while US natural gas production growth was relatively stagnant. The adoption of hydraulic fracturing ("fracking") and horizontal drilling techniques in the 2000–2010 decade laid a foundation for the post-GFC boom in US oil and gas production.

These technologies helped exploration and production companies (E&Ps) unlock known oil and gas reserves found in shale rock previously viewed as uneconomic to extract. Relatively high oil and gas prices coming out of the GFC (WTI crude oil averaged US$95 per barrel from 2011 to 2014[105]) provided an umbrella for E&Ps to optimize fracking and horizontal drilling techniques.

These improved production techniques contributed to US oil production more than doubling from less than six million barrels per day (mm bbls/d) in late 2011 to a peak of over 13 mm bbls/d in late 2019, just before the COVID-induced

Unlocking a Boom

Exhibit 22: Long-term US Oil Production

January 1960–February 2023

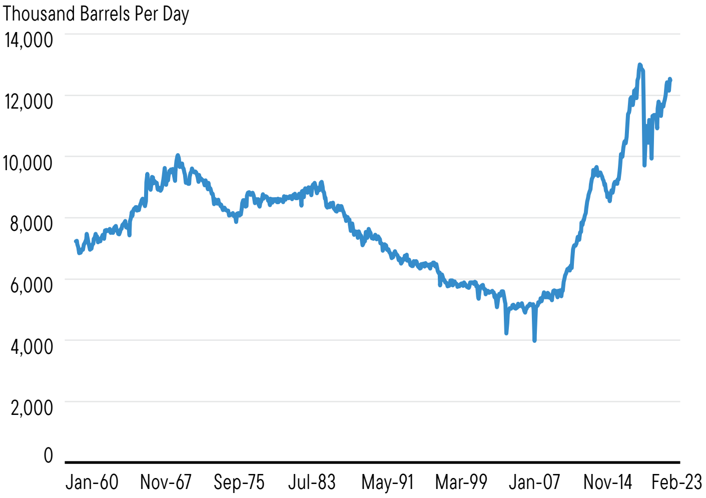
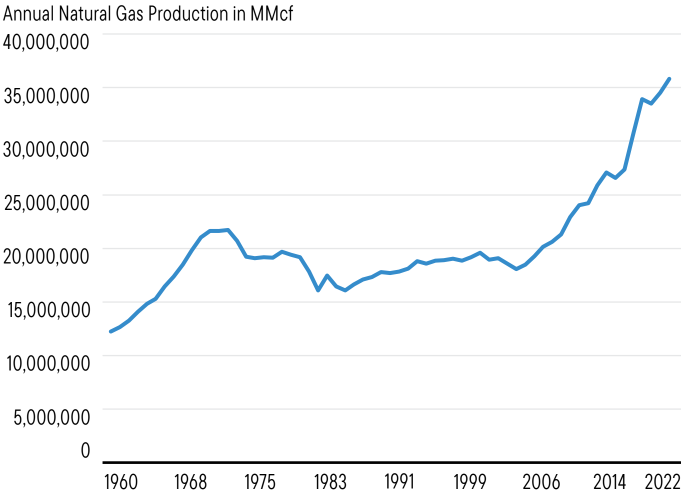


Exhibit 23: Long-term US Natural Gas Production

1960–2022



Source: U.S. Energy Information Administration.

negative demand shock, as shown in Exhibit 22. For context, current global oil and liquids production today is around 100 mm bbls/d.[106] A similar boom was seen on the natural gas side, also shown in Exhibit 23.

The oil and gas industry did not achieve this impressive production growth on its own. The typical business model for many of the early shale-focused E&Ps required frequent access to external financing—both debt and equity—but especially debt. In the early 2010s, the equity market and acquirers favored production growth and net asset value accretion and rewarded companies delivering on these parameters with premium valuations. This provided an incentive for shale E&Ps to spend heavily on drilling new oil wells and acquiring acreage leases to accelerate production growth and capture undeveloped resources. These capital investments often required considerably more cash than the businesses were generating from existing producing wells.

Conveniently, the revolution in shale drilling techniques coincided with a relatively low interest-rate environment. With the HY bond market starved for yield and keen to invest in growth, shale E&Ps enjoyed easy access to the HY market to fund outspending. In addition to the HY bond market, commercial and investment banks provided cheap asset-backed debt via reserve-based lending (RBL) revolving credit facilities. RBL facilities generally offer greater borrowing capacity as oil and gas production increases. This feature provided yet another incentive for E&P management teams to prioritize production growth.

While E&Ps did access equity capital from public and private equity (PE) markets, the magnitude of HY debt E&Ps incurred to plug the funding gap was enormous. From the end of 2008 to the end of 2015, the face amount of HY E&P bonds outstanding nearly quintupled, from US$22 billion to US$107 billion, shown in Exhibit 24[107] on the next page. Moreover, the E&P financing boom made its mark on the industry composition of the US HY market. E&P bonds outstanding accounted for about 4.5% of the HY market at year-end 2008 but nearly doubled their share to just under 9% by late 2014. Energy overall accounted for about 16% of outstanding HY bonds by then, up from less than 10% at year-end 2008.[108]

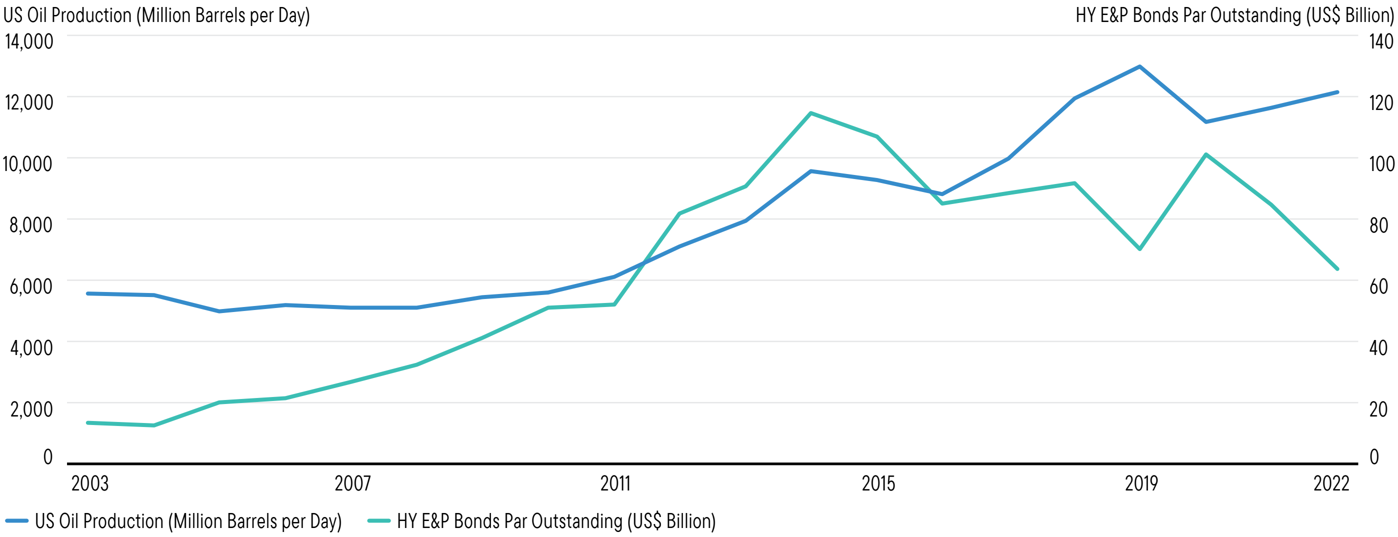
Hangover from the shale boom: Two HY energy default cycles

The boom in HY bond issuance from E&Ps—perhaps inevitably—led to a bust. The first HY energy default cycle kicked off in late 2014. WTI crude oil ended September 2014 at over US$90 per barrel but by Thanksgiving had fallen to less than US$75.[109] Market sentiment then soured considerably following the fateful Thanksgiving Day meeting of the Organization of Petroleum Exporting Countries (OPEC). OPEC refused to cut production despite growing concerns about oversupply. Without OPEC's support, WTI dropped into the mid-US$40s by the end of January 2015. After averaging US$49 per barrel in 2015, WTI oil ultimately bottomed in the mid-US$20s in February 2016.[110]

Plugging the Funding Gap

Exhibit 24: US Oil Production vs. HY E&P Bonds Outstanding

December 31, 2003–December 31, 2022

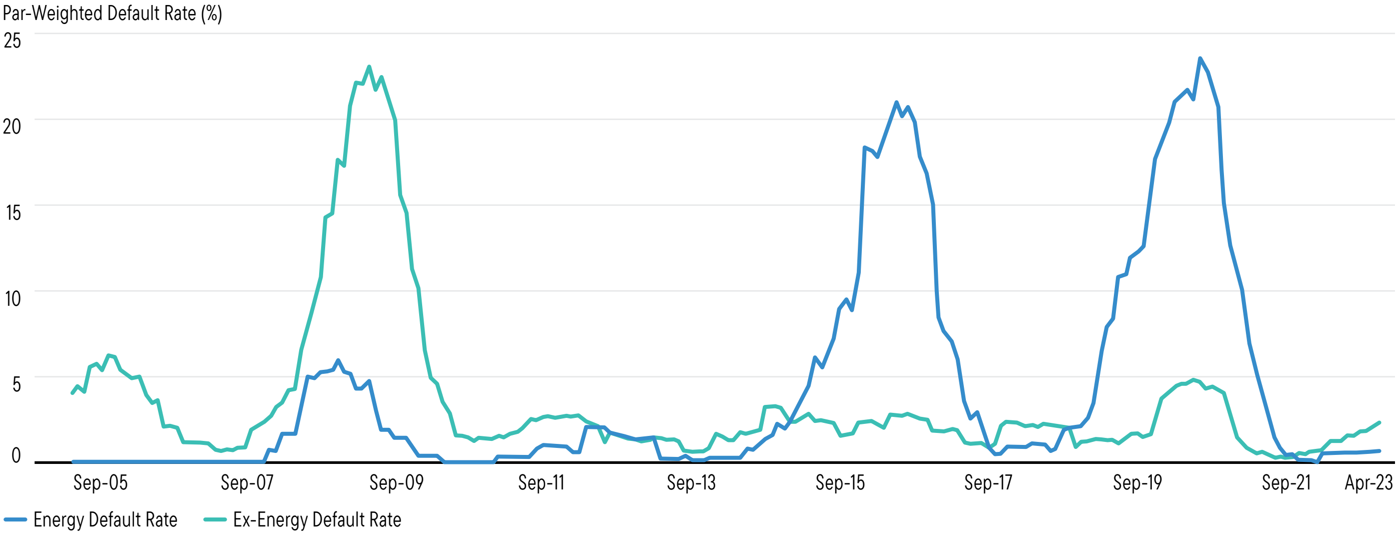


Sources: ICE BofA US High Yield Index; U.S. Energy Information Administration. The ICE BofA US High Yield Index tracks the performance of USD-denominated below investment-grade corporate debt publicly issued in the major domestic markets. Indexes are unmanaged and one cannot directly invest in them. They do not include fees, expenses or sales charges. **Past performance is not an indicator or a guarantee of future results.**

Energy-Driven Defaults

Exhibit 25: HY Energy and HY Ex-energy Default Rates

September 30, 2005–April 30, 2023



Source: BofA.

Many HY E&Ps were not equipped to deal with the new oil price regime, leading to the first of two HY energy default waves, with over 7% of HY energy bonds by face amount defaulting in 2015, as seen in Exhibit 25. The following year, 2016, was even worse, with the default rate reaching 21% by year-end.[111]

Following the first default wave, E&Ps once again largely prioritized production growth over free cash flow. By year end 2019, US oil production surged to 13 mm bbls/d, up from under nine mm bbls/d at the end of 2016.[112] The shale industry's second spurt of production growth was interrupted by the COVID-19-related oil demand crash that ultimately pushed oil to a negative price in April 2020. This wreaked havoc on the HY energy industry, sparking another bankruptcy cycle. The default rate for the HY energy sector default rate again pushed past 20% by the end of 2020, again shown in Exhibit 25.

Scared straight: Real changes in E&P corporate strategy and governance after COVID-19 demand shock

Based on our team's research, observations and deep experience in the energy sector, we've seen the following general trends and changes due to the COVID demand shock:

Before	**After**
High rate of production growth drives higher equity valuation	Free cash flow generation drives equity valuation
Capital allocation: Outspend cash flow to "grow" into capital structures	Capital allocation: Pay down debt to low levels, then pay dividends and buy back shares
Mergers and acquisitions (M&A): Accelerate growth via acquiring smaller E&Ps and undeveloped acreage using debt	M&A: Equity-funded mergers-of-equals to build scale and reduce balance sheet risk
Target moderate debt leverage and use revolvers to fund acquisitions and drilling	Target low leverage and use revolvers sparingly
Management incentives centered around production growth	Management incentives often increasingly based on free cash flow generation and capital return to shareholders

Poor returns + ESG = a changing financing model for oil & gas?

The US oil and gas industry's track record of capital destruction during the two oil and gas default cycles over the past decade, coupled with the increasing influence of ESG considerations, put the industry out of favor with many debt and equity investors and sparked some changes in how the industry may be financed in the future. Consistent with recent trends, we expect utilization of RBL credit facilities and equity raises—both public and private—to remain less-utilized financing sources compared to prior shale E&P industry practice. We anticipate that with longer maturities, fixed coupons and terms that allow for reasonable operational and financial flexibility, HY bonds will continue to be viewed as a cornerstone financing source by independent E&Ps—though the industry trend towards lower debt levels could ultimately lead to further declines in HY E&P bonds outstanding.

Some traditional RBL banks have either exited or reduced lending exposure to the oil and gas industry. Not only did the two recent energy default cycles suggest RBL facilities have greater credit risk than previously believed, but also some bank stakeholders have pushed for a retreat from the RBL market due to ESG considerations. In our conversations with E&P management teams, many concede they see risks of lower availability of and less favorable terms for RBL financing. As a consequence, many E&Ps are managing their capital structure more conservatively, relying less on RBLs and also operating the business with generally lower levels of debt.

Equity funding—both private and public—for the E&P industry has declined considerably in recent years. The decline in public equity funding is highlighted in Exhibit 26 on the next page. The PE industry has also stepped back from funding E&Ps, with some PE firms de-emphasizing or outright avoiding investments in oil and gas and others shifting focus towards opportunities in renewable energy and energy transition investments. Similar to trends in the RBL market, we believe both the industry's track record of volatile returns and the ESG preferences of ultimate end investors are driving this trend.

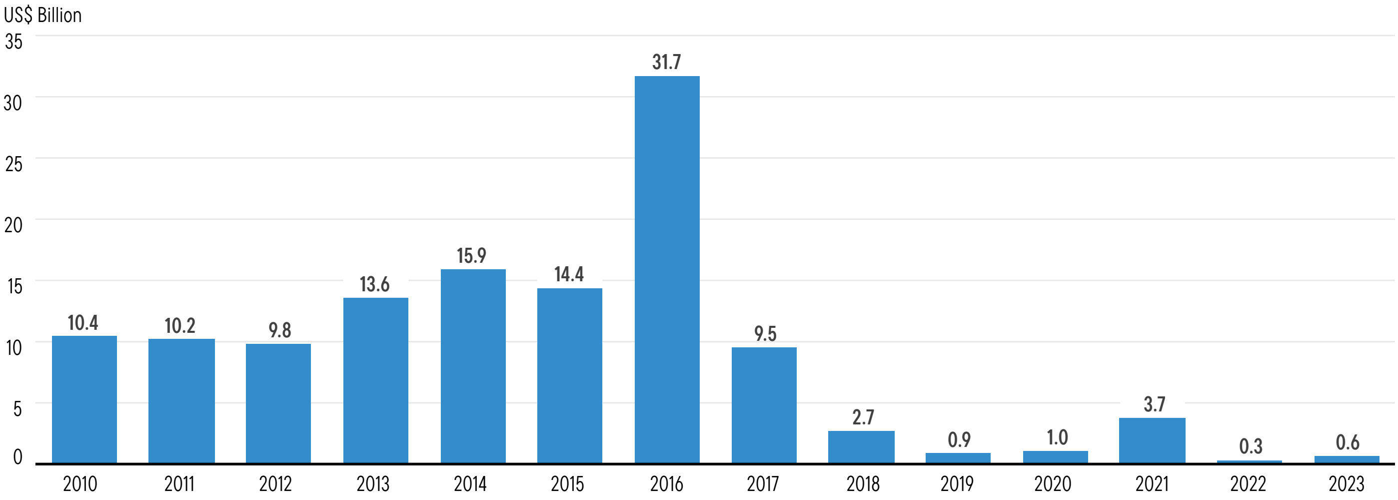
While the oil and gas industry has a history of developing creative financing structures, such as the market for asset-backed securitizations backed by oil and gas wells, we expect the tightening financing market for E&Ps will lead to a continued focus on financing growth with internally generated cash flow. We believe this should lead to lower production growth and, with capital spending kept in check, overall more favorable credit profiles for HY E&P issuers.

A consequence of ESG and regulatory trends is a focus on greenhouse gas (GHG) emissions metrics for E&Ps. In some cases, E&Ps seek to drive emissions lower in hopes of attracting equity and debt investors, potentially lowering cost of capital. In other cases, lowering emissions can be a corporate strategy to get ahead of regulatory trends related to carbon taxes or other carbon pricing mechanisms—ultimately setting the company up for a lower overall cost structure in the future.

E&P's Equity Problem

Exhibit 26: US E&P Public Equity Issuance

January 2010–April 2023



Source: Bloomberg.

A popular view of some market participants is cost of capital for fossil fuel businesses will disproportionately increase over time. Focusing on the HY bond market, a dominant factor in relative valuation of E&Ps is the strong credit quality improvement of E&Ps in the 2021–2022 time frame. Given the influence of this factor, we think it is too early to definitively endorse this view. However, we are paying close attention to valuation of issuers that are perceived to have inferior emissions and environmental attributes.

Exhibit 27 on the next page demonstrates the higher yield of a BB rated E&P that we believe is perceived to possess more negative headline ESG considerations relative to the overall cohort of BB rated E&Ps. While there are some fundamental differences across companies within this cohort, the yield premium the market requires for this E&P could be an early indication of incrementally higher cost of capital for issuers with ESG and regulatory concerns.

To lower emissions intensity, some companies are divesting high emissions assets rather than investing capital to lower emissions. While the seller could present an improved environmental profile to the public, if the assets are sold to a private operator that does not prioritize emissions performance, overall net emissions could actually *increase*.

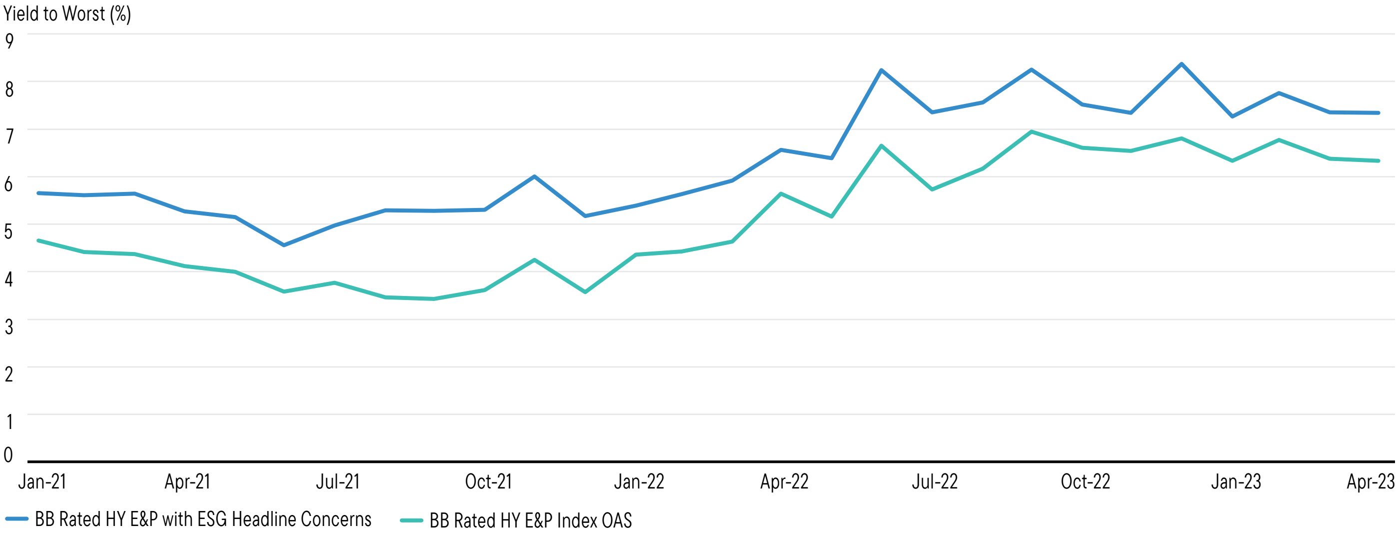
To lower emissions intensity, some companies are divesting high emissions assets rather than investing capital to lower emissions. While the seller could present an improved environmental profile to the public, if the assets are sold to a private operator that does not prioritize emissions performance, overall net emissions could actually *increase*. We expect divestitures of higher-emissions assets to private companies could result in additional bond issuance from privately owned HY E&P companies. In cases where the private E&P firm has expertise in managing mature assets and a credible plan to reduce emissions, these HY bonds could present attractive investment opportunities that ultimately help incrementally lower overall emissions.

An important trend to watch is ESG-related exclusionary investment policies. These are most prevalent in markets with increasingly ESG-focused investors, such as in Europe. For example, in late 2021, giant Dutch pension fund ABP, which manages nearly €500 billion, decided to divest its investments in producers of fossil fuels.[113] On the one hand, excluding oil and gas producers from equity and fixed-income portfolios could encourage investors to allocate capital instead to developing cleaner sources of energy. However, on the other hand, limited capital availability could result in more

ESG Headline Impact

Exhibit 27: Yield for a BB Rated E&P with ESG Concerns vs. Overall BB Rated E&P Cohort

January 31, 2021–April 30, 2023



Source: ICE BofA HY Index data. The ICE BofA US High Yield Index tracks the performance of USD-denominated below investment-grade corporate debt publicly issued in the major domestic markets. Indexes are unmanaged and one cannot directly invest in them. They do not include fees, expenses or sales charges. **Past performance is not an indicator or a guarantee of future results.**

restrained capital investment and, all else equal, tighter supply and demand balances and higher prices for fossil fuels. Rather than blanket exclude oil and gas producers from portfolios, our investment team prefers to engage with management teams to encourage them to set and execute ambitious and realistic goals for the reduction of emissions and overall environmental impacts.

Funding transition

In recent years, some oil and gas companies started investing more earnestly in businesses featuring renewable energy or carbon reduction, ostensibly adjacencies to their traditional business lines. Examples of this include oil refiners investing in renewable diesel production and a subset of E&Ps pioneering business models to capture and sequester carbon emissions. In the United States, 2022's Inflation Reduction Act (IRA)—which in some cases enhances the economics of these emerging business models with tax credits—has helped accelerate interest in these new business opportunities for oil and gas companies. Thus far, in many cases, the capital required for these types of projects has either been fairly modest during earlier stages in the investment cycle or fulfilled by internal cash generation or project finance. As such, these companies have not yet accessed the HY bond markets in a meaningful way to source capital for investment in these new businesses, but this will be a key area to watch in the future and could provide attractive returns for HY bond investors while also improving the environmental profile of portfolios.

While we are in the early stages of traditional HY energy companies funding nascent energy transition assets and businesses, we have yet to see a boom in energy transition funding from the HY market. Perhaps the bad memories of the shale boom and busts are too fresh in investors' memories. That said, we think HY has the potential to play an important role in funding an energy transition. The HY market has a history of funding industries and businesses that have strong growth potential but that are not mature enough to access the investment-grade markets or that have already tapped out the equity, project finance or bank lending markets. Looking ahead, history could very well rhyme, with the HY market providing an impactful portion of the capital needed to fund an energy transition.

Clearing the air

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Atmospheric reduction of greenhouse gases (GHGs) is essential for reaching global climate change mitigation goals. Within transportation, light vehicles have successfully developed a pathway to reduce their emissions by curbing dependence on fossil fuels as a power source. Aviation, however, has lagged the decarbonization trend. Given air travel's expected future growth rate, the need to reduce emissions produced by planes is urgent. Emission reduction solutions utilized by trains, trucks and automobiles, such as electricity and hydrogen power, are not yet feasible for most commercial aircraft. However, many stakeholders in the aviation industry are dedicated to solving the issues preventing decarbonization and are leaning on sustainable aviation fuel (SAF) as the likely widespread solution.

The European Commission is working to legislate that jet fuel must be 70% SAF blend by 2050.[114] United States agencies instituted the "SAF Grand Challenge," calling for a 50% reduction in life cycle GHGs for jet fuel by 2030 and net-zero emissions by 2050.[115] Experts agree these are ambitious although feasible goals if backed with the right kind of governmental action and private investment. The effect on certain areas of the economy and corporate activity as organizations strive to decarbonize aviation could be significant. We think investment opportunities may materialize as companies move to make high-blend SAF a reality, particularly within industries impacted by feedstock production, power-to-liquids (PtL) technology development and SAF production and blending infrastructure.

The plane facts

As of 2022, there were estimated to be about 25,500 aircraft in service worldwide.[116] These aircraft are essential to travel and trade, carrying roughly 3.8 billion passengers and 218 million ton-kilometers of cargo each year. This activity currently produces about 2% of all human-generated carbon dioxide (CO_2)[117] and could continue to grow if additional measures are not taken to mitigate GHG emissions. Today's planes are much more fuel-efficient and produce fewer GHGs than planes in service decades ago. Engineering advances for engines and aircraft design have led to an 85% improvement in fuel efficiency since the first planes in the 1950s, according to the Air Transport Action Group (ATAG).

It's expected that ongoing advancements in aircraft design technology will continue to have positive effects on reducing GHG emissions. However, according to traffic forecasts, it's estimated that seven billion passengers will travel a total of nearly 20 trillion kilometers each year by 2035.[118] This travel, without any substantial additional mitigation of GHG emissions, is still expected to generate nearly 1,800 megatons of CO_2 per annum.[119] As air travel becomes an increasingly common and essential form of transportation, solutions are needed to reduce environmental impact. The three most viable emission reduction solutions are electrical power, hydrogen power and SAF. Battery and hydrogen technologies are limited in their applications, making SAF the go-to technology for decarbonizing short-, medium- and long-haul commercial passenger and cargo flights.

Fueling improvement

Currently, there are about 30 electric aircraft concepts in development for commercial-scale operation.[120] However, experts predict that battery power will not be readily available for most flights before 2050. The biggest obstacle is the energy-density-to-weight ratio of batteries. The size of battery required for a long, high-occupancy flight would be too heavy without significant developments in battery technology. Next, the fire safety of lithium batteries remains questionable. Lastly, while an electrically powered flight emits no GHGs, the environmental impact of mining the materials needed to produce batteries is significant, making the life-cycle impact of this power source more negative than that of SAF. As such, we think the potential for electrically powered aircraft technology to outpace SAF investment and development pre-2050 is unlikely, making for fewer investment opportunities when compared to SAF.

Hydrogen is another potential source of propulsion for planes. It can be used in two ways: hydrogen fuel cell construction and direct burning. There are challenges associated with both. First, liquid hydrogen requires very low storage temperatures. In addition, due to different weight-to-energy ratios versus traditional jet fuel, it would take a hydrogen tank about four times the size of a traditional jet fuel tank to produce the same power.[121] Next, planes would need to be fitted with hydrogen combustion engines and adjusted with a longer fuselage as the fuel tank would need to be moved from the wings to the center of the plane due to the increased size.[122] These variances from the current system mean the industry would have to install significant amounts of new equipment to make this option feasible. We think hydrogen power is a less favorable option than SAF for widespread decarbonization of aviation by 2050 due to these additional complications associated with implementation. Therefore, adaptations to power aircraft via hydrogen are less likely to produce large-scale investment opportunities in the coming decades, in our opinion.

Due to the difficulties in cultivating electrical and hydrogen power for long-haul flights, the industry is scaling up its capacity to generate and deploy SAF. Over 250,000 commercial flights have flown using SAF as a partial fuel source since it was first approved in 2011.[123] SAF refers to any aviation fuel that is not fossil-derived. It can come from discarded plant matter, waste oils, municipal waste or even out of thin air using carbon capture technology. A main requirement of the fuel is that it is sustainably produced,[124] meaning:

One of the biggest benefits of SAF is that it requires no adjustments to the airplane or engine. It is considered “drop-in” fuel, meaning it is seamlessly integrated with the existing fueling systems. In fact, SAF is already blended into most airline fuel. Depending on the technology type and base materials, current blending standards dictate the jet fuel may be up to 50% SAF.

1. Its production, transportation and combustion must reduce global net carbon emissions versus fossil fuel. This includes production of the feedstock, the transition to fuel, transportation of the fuel and burning the fuel.
2. It cannot compete with or displace food production, cause deforestation or otherwise negatively impact biodiversity.
3. It must be certified sustainable over its entire lifecycle with respect to land, water and energy use.

One of the biggest benefits of SAF is that it requires no adjustments to the airplane or engine. It is considered “drop-in” fuel, meaning it is seamlessly integrated with the existing fueling systems. In fact, SAF is already blended into most airline fuel. Depending on the technology type and base materials, current blending standards dictate the jet fuel may be up to 50% SAF, as shown in Exhibit 28 on the next page.

However, due to production constraints, the global average blend percentage is about 1% of the 278 billion liters (73.5 billion gallons) of jet fuel currently consumed annually.[125] Incrementally increasing the global SAF blend to 2% is expected to reduce CO_2 emissions by 14.2 megatons per year.[126] Stakeholders in the European Union (EU) and United States have some of the most ambitious plans to produce and support demand for SAF, which could be very impactful since these regions host many of the 180 global airport fuel depots that handle 90% of the world’s airline passengers.[127] With governmental and industry powers working together to increase production and blending rates, there may be opportunities for investment as aviation evolves. Plans for the integration of higher blending levels of SAF needed to reach the 2050 goal require significant infrastructure upgrades and improvements to SAF generation technologies.

What's in a Name?

Exhibit 28: Approved Methods of Creating SAF

As of May 2023

Technology Type	Base Materials	How it's Made	Current Maximum Blend %	Organic/ Synthetic
Fischer Tropsch Synthesized Isoparaffinic Kerosene (FT-SPK)	Municipal Solid Waste, Coal, Gas, Sawdust	Base materials are gasified into hydrogen and CO. The syngas is converted to a liquid hydrocarbon fuel blending component.	50%	Organic
Synthesized Iso-Paraffins (SIP)	Sugarcane, Sugar Beet	Sugar product is fermented into a hydrocrabon molecule that is blended into conventional fuel.	10%	Organic
Hydroprocessed Hydrocarbons-Synthesized Isoparaffinic Kerosene (HH-SPK)	Oils Produced from Algae	Bio-derived hydrocarbons taken from base materials are hydroprocessed into blendable material.	10%	Organic
Hydroprocessed Fatty Acid Esters and Fatty Acids (HEFA)	Lipids: Tallow, Waste Oils, Plant or Algae Oils	Lipid base materials are deogynated then hydroprocessed. Produces a pure hydrocrabon fuel blending component.	50%	Organic
Alcohol to Jet (ATJ)	Sugar Beet, Sawdust, Lignocellulosic Residues	Base materials are fermented. Dehydration, oligomerization and hydro processing convert the mix to hycrocarbon fuel.	50%	Organic
Catalytic Hydrothermolysis Jet Fuel (CHJ)	Waste Oils or Energy Oils	Base materials are processed with preheated liquid in a reactor under high temperature and pressure.	50%	Organic
Power-to-Liquids (PtL)	Renewable Electricity, Carbon Captured from the Air	Hydrogen split from water via electrolysis is combined with carbon taken from the air or industrial gasses.	50%	Synthetic

Source: International Air Transport Association (IATA). Note: These fuels are currently they only "drop-in" replacements that meet technical certification ASTM D7566. This certification evaluates which technologies, under specific circumstances and characteristics, can be used for producing on specification neat SAF.

Reduce, reuse, ReFuelEU

In July 2021, the European Commission presented the ReFuelEU Aviation initiative as part of a package to reduce GHG emissions. On April 26, 2023, the European Parliament reached an agreement with member states, creating a binding set of SAF blending standards for all flights leaving the bloc. The new standards begin in 2025, with a 2% requirement. Blend requirements then increase periodically through 2050, as shown in Exhibit 29.

Right on Target

Exhibit 29: ReFuelEU SAF Blend Requirements

As of April 2023

Year	% of Total Fuel	% Requiring Synthetic Origin
2025	2	0
2030	6	1.2
2040	20	1.2
2050	70	35

Source: Abnett, Kate, Kar-Gupta, Sudip and Plucinska, Joanna. "EU agrees binding green fuel targets for aviation." Reuters. April 26, 2023.

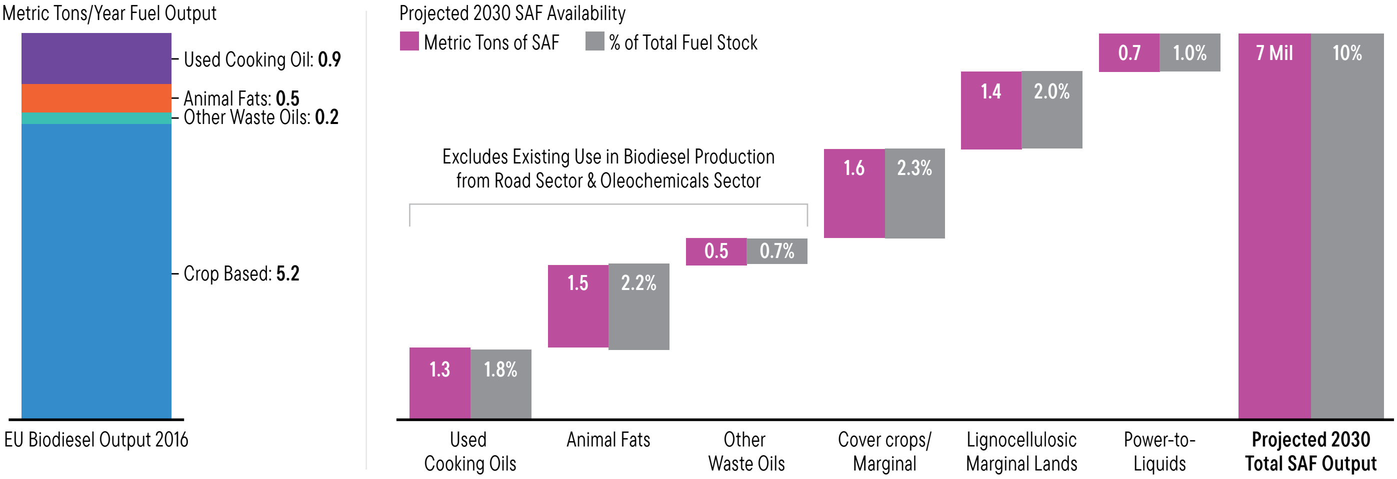
EU member countries must each independently approve the deal before it can become law. As part of the proposal, EU-based airlines could receive up to €2 billion (US$2.2 billion) to help them facilitate the switch to SAF.[128] Parliament has also proposed a Sustainable Aviation Fund to be funded in part by fees charged to airlines that fail to comply with the new standards. The proceeds will be used to further SAF feedstock development, PtL technology and blending infrastructure enhancements.

The European Energy Transition Commission (ETC) conducted an SAF ramp-up feasibility assessment in 2021. This assessment analyzed the possibilities for SAF production in the EU, including the likelihood of SAF satisfying 10% of jet fuel demand by 2030, as seen in Exhibit 30.[129] It found that 10% satisfaction is possible if efforts start immediately. First, existing fat and oil hydroprocessed fatty acid esters and fatty acids (HEFA) capability should be utilized to its full potential. Next, investment should be made in alcohol to jet (ATJ) and synthesized isoparaffinic kerosene (SPK) methods to bring them to scale, converting plant and biomass materials to SAF. Lastly, PtL technology should be built out, as this will supply the synthetic component required by

One Person's Trash Is Another Person's Jet Fuel

Exhibit 30: Eurozone SAF Production Potential by Feedstock in 2030

As of September 2020



Source: Analysis based on World Economic Forum (2020), Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation and ECOFYS (2019), Technical Assistance in Realisation of the 2018 Report on Biofuels Sustainability.

the ReFuelEU standards and has the highest long-term capacity for SAF production beyond 2030. Plant and biomass feedstock and PtL technology offer some of the biggest opportunities for investment as they become more prominent.

A grand challenge

United States agencies developed the Sustainable Aviation Fuel Grand Challenge aimed at reducing the cost of SAF and ramping up production. The goal of the SAF Grand Challenge is to domestically produce and support demand for three billion gallons (11.4 billion liters) of SAF each year by 2030 and 35 billion gallons (132.5 billion liters) per year by 2050.[130] To make these goals feasible, the initiative aims to focus on feedstock and conversion technology innovation, supply chain fortification, policy changes and supporting demand by airlines. According to the US Department of Energy, about one billion tons of plant-based and other biomass can be sustainably grown or collected every year, allowing for the creation of 50–60 billion gallons of SAF without impacting trade, agriculture or other current uses.[131]

Like the European plan, the US' SAF Grand Challenge intends to focus on lipid-based pathways leading up to 2030, then incorporate ATJ and SPK technologies in higher amounts as they become more viable. Unlike Europe, there is less of a governmental push to focus on developing PtL capabilities for large-scale use beyond 2030. The SAF Grand Challenge plan is to focus primarily on utilizing lipids and feedstocks through various conversion methods to meet output goals. This means investment in high-volume development, harvesting, transport and conversion of these materials will likely be the focus of SAF efforts until PtL technology is proven viable elsewhere and can be adopted in the United States at a large enough scale.

(Head and tail) winds of change

The biggest challenges in meeting the net-zero 2050 goals involve the development and production of appropriate feedstocks, a build-out of the fuel-blending and delivery infrastructure and the viability of PtL technology. While these three items provide headwinds to reaching higher levels of SAF blending in jet fuel, they also provide opportunities for investment as the breadth and depth of the technologies increase.

In the United States and Europe, the most immediately viable feedstock gathering and production technology is HEFA conversion, which uses waste lipids to generate SAF. This waste is already widely available, so the headwind and resulting improvement opportunity lies in transporting it to newly built conversion facilities. In Europe alone, it is estimated 30 new production facilities, in addition to the conversion of existing refineries, will be needed to reach 2030 goals.[132] To reach the 2050 benchmark, 250 plants will be needed, many of which are expected to be ATJ and PtL oriented as the technology matures.[133] The lead time for construction of an SAF production plant is three to six years once the designated conversion technology becomes

What a Fantastic Waste

Exhibit 31: Biomass Feedstock Production Potential

As of September 2022

	Feedstock	Potential (Million Dry Tons/Year)
Biomass Based on 2021 Ethanol and Biodiesel Production Capacity[a]	Seed Oils	9
	Corn Grain	148
Biomass Based on 2016 Billion-Ton Report[b]	Forestry Resources and Woody Wastes	133
	Woody Energy Crops	71
	Municipal Solid Waste	55
	Agricultural Residues	176
	Herbaceous Energy Crops	340
Algae Input Based on 2017 Algae Harmonization Study[c]	Algae	235
Biomass Based on 2017 Biofuels and Bioproducts from Wet and Gaseous Wastes[d]	Fats, Oils and Greases (Fog)	9
	Wet Wastes (Animal Waste, Food Waste, Wastewater Solids)	148
TOTAL		1,252

a. Feedstock input based on existing production capacity dividend by yield. 2019 biodiesel production capacity of 2.54 billion gal/yr with assumed biodiesel yield of 281 gallons of gasoline equivalent per ton seed oil. Ethanol production capacity of 17.44 billion gal/yr with yield of 118 gal ethanol/dry ton.

b. Feedstock inputs are from the 2016 Billion-Ton Report. All pathways assume reference case 2040 projections at US$60/ton.

c. Algae feedstock is based on 2017 Algae Harmonization Study. Total 235 million tons/yr based on the cumulative volume from the saline scenario.

d. Wet waste volume is from Biofuels and Bioproducts from Wet and Gaseous Waste Stream; includes wastewater residuals, animal wastes, and food waste. Total volume is scaled up by 9% for assumed population growth between 2017 and 2030.

Source: US Department of Energy.

commercially viable. Plants will need to be constructed at a consistent pace to meet yearly SAF production ramp-up goals. As plants are constructed, materials such as concrete, rebar, heavy machinery, copper, cement and others will be needed for their construction.

Like the SAF production plants, blending facilities will need to be constructed to properly mix the sustainable fuel with traditional fuel. Due to the "drop-in" nature of SAF, once it is properly blended, existing methods of transport to airports, on-site storage and aircraft fueling mechanisms can be utilized.

Since PtL is anticipated to be the most sustainable and easily scaled-up technology once it is ready, investment in its capability will be paramount for regions that plan to lean on it to meet their carbon reduction goals. The PtL SAF manufacturing process, as shown in Exhibit 32, requires large-scale carbon capture capability, which in itself is a global climate change mitigation initiative many companies are working on implementing. It is not expected the technology will be ready for widespread use to meet 2030 benchmarks, but many regions and companies are investing heavily in its development with a view to its contribution toward longer-dated production targets.

The cost to airlines is another potential hurdle. It is estimated that SAF currently costs about twice the amount of traditional jet fuel for waste-based production and up to six times as much for carbon capture–based synthetic production.[134] This is due mostly to production constraints. SAF adoption rates by airlines are currently low, potentially due to high cost and limited availability. However, it is anticipated that the cost will come down after feedstock development, conversion and blending technology improves. In addition, several regions' green energy initiatives plan to subsidize part of the cost of SAF to take some pressure off airlines' margins. Increasing carbon costs in the form of carbon taxes or other fees imposed by governing bodies for not implementing higher SAF blends may also work to level the playing field from a cost comparison perspective.

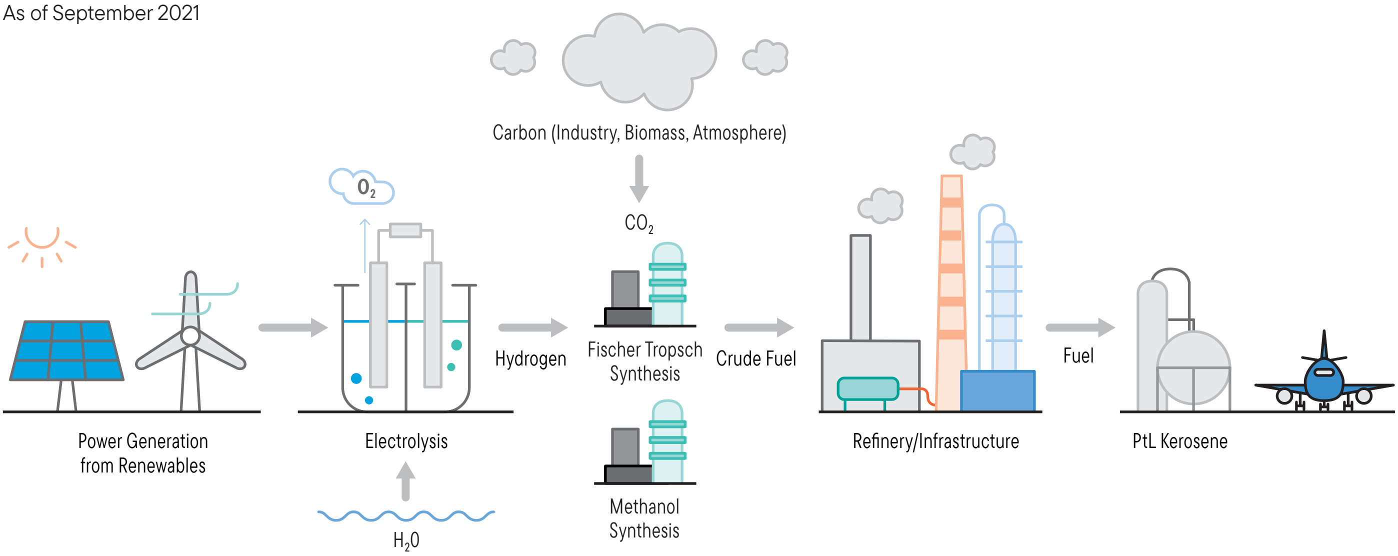
Despite the headwinds facing higher levels of SAF production and adoption, several companies are moving forward with their own initiatives to develop aviation decarbonization technologies. In December 2022, Rolls-Royce, one of the world's largest airline engine manufactures, was the first producer to conduct a long-distance flight with 100% SAF—a HEFA based

As the airline industry continues to grow, so will its impact on the planet. The dedication to net-zero emissions by 2050 is key to helping meet global climate change mitigation initiatives. The development of SAF is an important part of that goal.

Got the Power

Exhibit 32: How the PtL Process Works

As of September 2021



Source: Evalueserve Insights; based on NOW GmbH. For illustrative purposes only.

fuel with the potential to reduce carbon emissions by nearly 80%.[135] To push past the 50% blend limit, Rolls-Royce participated in the Federal Aviation Administration's Continuous Lower Energy, Emissions and Noise II (CLEEN II) program, developing a safe and viable 100% ATJ-generated SAF with added aromatics.[136] A European airline manufacturer is partnering with the SAF+ Consortium to develop large-scale PtL capabilities within Canada, with the eventual goal of sharing the technology with the rest of North America.[137] It was one of the first partnerships of its kind. Within the last year, several other airlines have formed partnerships with energy companies to promote the manufacture and more widespread utilization of SAF. Lastly, one of the world largest air carriers, United Airlines, made the largest investment in SAF to date through a joint venture partnership with a US-based sustainable fuel producer, and a leading energy company focused on decarbonization. The joint venture will manufacture SAF from non-petroleum ethanol feedstock—with a target of 135 million gallons annually.[138]

As the airline industry continues to grow, so will its impact on the planet. The dedication to net-zero emissions by 2050 is key to helping meet global climate change mitigation initiatives. The development of SAF is an important part of that goal. Stakeholders in the United States and in Europe are moving forward with plans to develop technology which will meet production and blending goals by 2030 and 2050 and bring the industry across the net-zero emission threshold. Along with these initiatives, there will be challenges. However, these challenges can be overcome and in doing so could bring global benefits and opportunities for investment.

Green steel— the industry's path to net zero?

Andrew Ness
Portfolio Manager
Franklin Templeton
Emerging Markets Equity

The steel industry is one of the largest contributors to global carbon emissions, accounting for 7% of total emissions in 2019.[139] Left unchecked, emissions are forecast to rise by 44% by 2050.[140] However, there is another option wherein emissions could fall by 54% by 2050: green steel from zero-emissions hydrogen. The challenge for investors and the industry is cost. Producing green steel from zero-emissions hydrogen is estimated to require an investment of US$2.8 trillion.[141] In this chapter, we focus on green steel's production process, breaking down costs and technologies in each step of the process.

Zero-emissions, or "green" hydrogen, can act as catalyst for accelerating the decarbonization of other industries, including fertilizer, transportation and glassmaking. Using hydrogen as an energy source is not new—what has changed is the dramatic decline in cost of renewable energy and expectations that economies of scale will drive down the cost of the electrolyzers needed to produce green hydrogen.

Steel demand is forecast to grow to 2.5–2.8 b/t by 2050 based on assumptions for steel consumption per capita as economies develop and mature.[143] Per-capita stock of steel is estimated at 12 tons in the United States, 7.5 tons in China and 4.5 tons in the rest of the world.[144]

We acknowledge that steel is a highly polluting industry. Our team believes divesting is not the right approach to addressing the challenges the industry faces. Our focus is on engaging with companies that recognize the impact steelmaking has on the environment and working with them as they embark on the journey toward net zero. We acknowledge that companies we engage with are at different stages of the decarbonization journey, ranging from acknowledgment, to planning, to testing new technologies.

The global steel market

Global steel demand in 2022 was estimated to be 1.8 billion tons (b/t), broken down as 1.35 b/t from new steel and 0.45 b/t from scrap.[142] Steel demand is forecast to grow to 2.5–2.8 b/t by 2050 based on assumptions for steel consumption per capita as economies develop and mature.[143] Per-capita stock of steel is estimated at 12 tons in the United States, 7.5 tons in China and 4.5 tons in the rest of the world.[144] Given the industrialization needs of India and the Middle East and North Africa region, the demand assumptions are unlikely to disappoint, in our view.

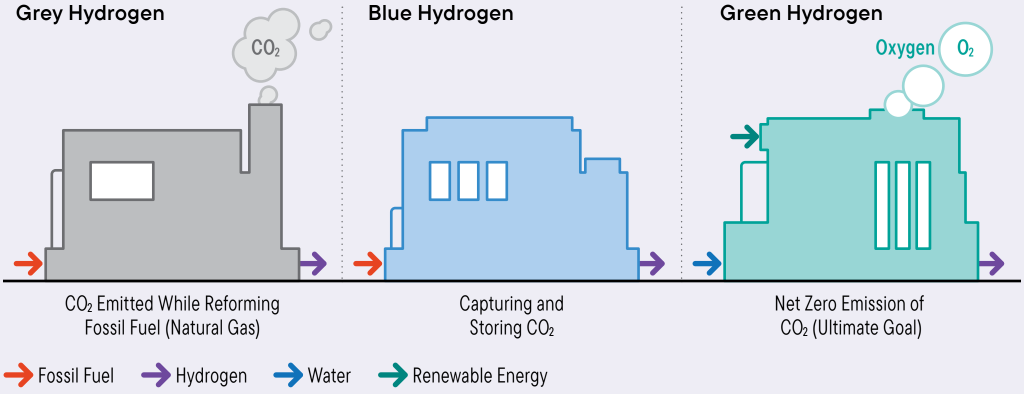
Forecasts for an additional one billion tons of steel demand globally by 2050 are plausible once the global economy continues to expand and more economies industrialize. As such, the primary lever for the steel industry to decarbonize

Not all hydrogen is created equal

Scientists have prefixed hydrogen with color labels to denote the different methods of production, as hydrogen can be a clean or dirty source of power. Hydrogen is a clean source of power when it is created using renewable energy, which is labeled green hydrogen. It is a dirty source of power when it is created using coal or natural gas, labeled blue or grey hydrogen, as shown in Exhibit 33.

Hydrogen Color Chart

Exhibit 33: Grey, Blue and Green Hydrogen Inputs, Outputs, Emissions



Source: Frackcheck. For illustrative purposes only.

is unlikely to come from lower demand; rather, the industry will have to adopt new production processes, including producing steel from zero-emissions hydrogen. This is of global relevance as without the decarbonization of the steel industry (along with transport and energy), countries will fail to achieve their net-zero commitments.

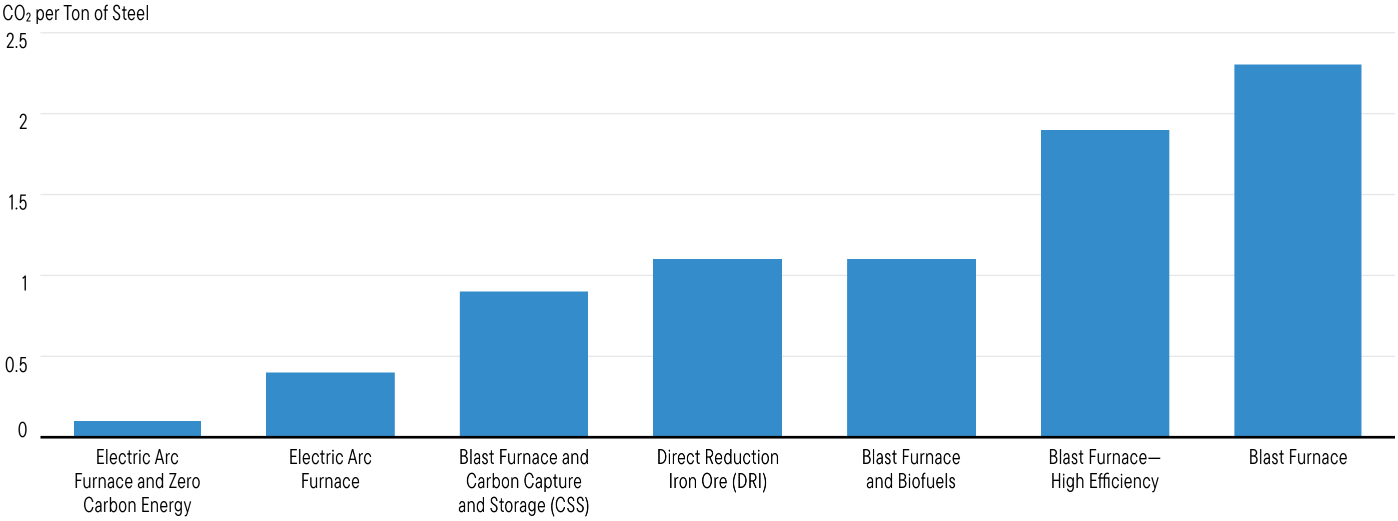
Steel's carbon emissions and sources

For every ton of steel produced, the global average of carbon emissions is 1.85 tons.[145] As economies mature, the raw material used in production of steel changes, and with it, the carbon intensity. In developed markets, where the steel capital stock is high, scrap steel is the primary raw material for steel production in an electric arc furnace (EAF). As seen in Exhibit 34, the carbon intensity of steel produced via EAF is 0.4 ton of carbon dioxide (CO_2) per ton of steel. In emerging markets, where the capital stock of steel is low and there is a greater reliance on using iron ore and coal in a blast furnace, the emission intensity is 2.3 tons of CO_2 per ton of steel produced. This contrasts with steel produced from direct reduction iron ore (DRI) using green hydrogen, which emits a mere 0.1 ton of CO_2 emissions.[146]

Carbon Intensity

Exhibit 34: Carbon Emission Per Ton of Steel Based on Production Process

2022



Source: Energy Transition Commission.

Coal is the primary source of carbon emissions in the "traditional" steelmaking process—divided between direct and indirect emissions. The direct release of emissions happens when coal is added to iron ore in a blast furnace and heated to 3,000°F, as seen in Exhibit 35. Heating coal releases carbon monoxide gas, the reductant agent, which then triggers a chemical reaction separating or reducing the oxygen in the iron ore. Molten iron is produced with the released oxygen combining with carbon to create carbon dioxide. The indirect source of emissions is the process of burning fossil fuels to create the necessary heat for the chemical reaction to occur in the blast furnace. This can be coal, gas or other fossil fuels.

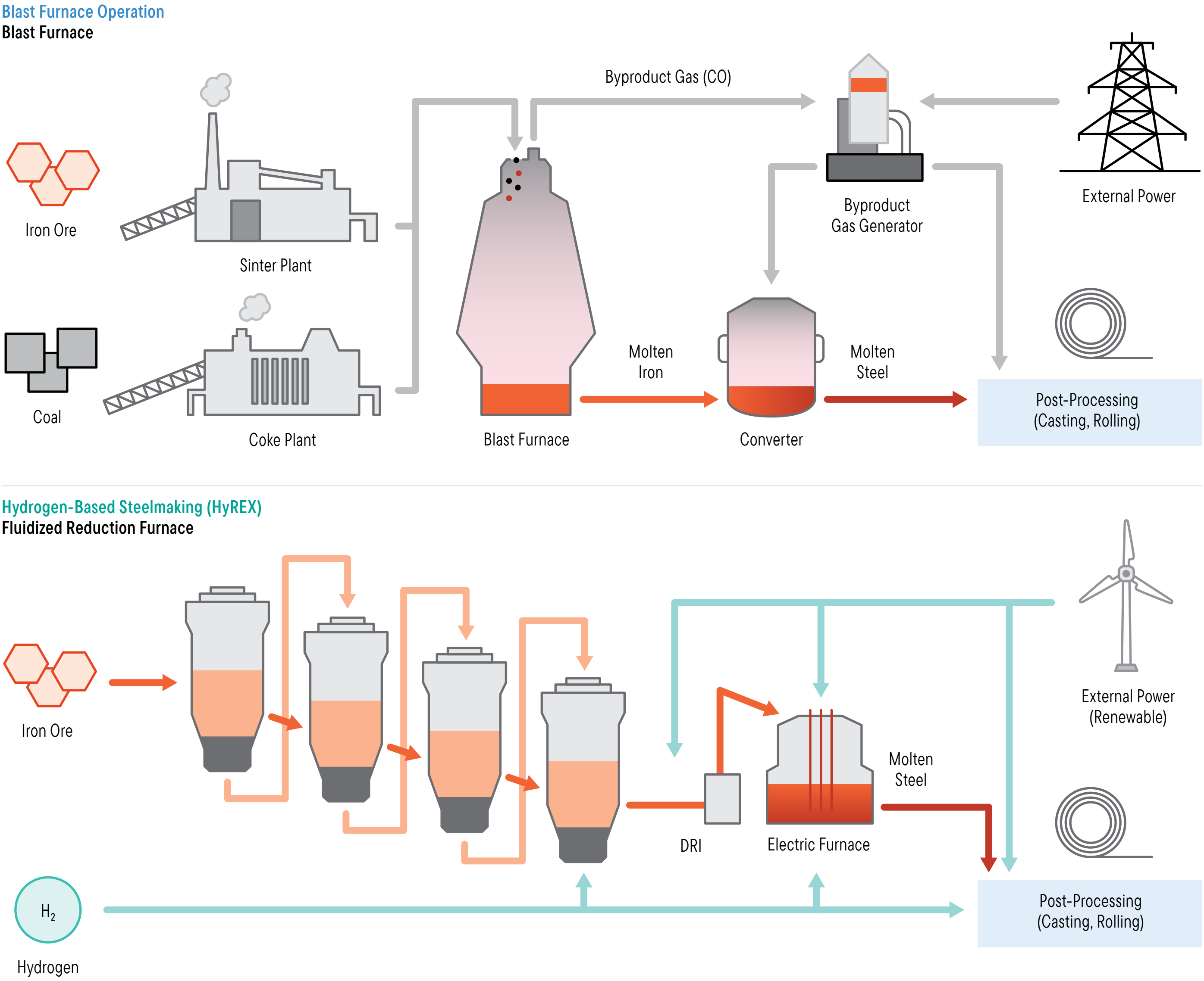
Switching to hydrogen-based steelmaking, or "green steel," removes an estimated 90% of the carbon released compared to traditional blast furnace and blast oxygen blast furnace operation.[147] When producing steel from green hydrogen, the blast furnace is replaced with a fluidized reduction furnace. Hydrogen acts as the reducing agent when it is added to the iron ore and triggers a chemical reaction separating or reducing the oxygen in the iron ore, producing DRI.

There are no direct sources of carbon produced in this process as the hydrogen is carbon-free. In the fluidized reduction furnace, the iron ore and hydrogen mix does not melt; rather, it is formed into DRI. When the DRI is added with

Traditional vs. Green Steel

Exhibit 35: Blast Furnace Steelmaking Process vs. Hydrogen-Based Steelmaking (HyREX)

2018



Source: POSCO. For illustrative purposes only.

scrap metal in the EAF, there are no indirect sources of emissions when using electricity from renewable sources. If the electricity used to power the electric arc furnace is renewable, emissions can be further reduced but not eliminated as some carbon is still required in the steelmaking process.

Green steel's obstacles

Green steel plants are under construction or at the advanced planning stage in many countries. However, there are several obstacles to be overcome before the technology can be widely adopted. We go into more detail on each below, but they include:

- Hydrogen supply
- Renewable energy access
- Electrolyzer capacity
- High-grade iron ore supply
- Sunk costs of blast furnaces

Hydrogen supply

Global hydrogen supply must increase dramatically if it is to be a practical fuel source in steel production. Currently, green hydrogen is only produced in demonstration quantities of a few million tons per year. Nevertheless, we view current output as a snapshot before major investment in the sector begins. As the cost of inputs to generate renewable energy continues to decline, we expect investment plans for green hydrogen to accelerate.

The International Energy Administration (IEA) estimates total global production in 2022 was 94 million tons (m/t) and forecasts this needs to rise to 530 m/t by 2050 based on the needs of industry, including steel, transportation and power.[148] Given the assumption that a ton of green steel requires 90 kilograms of hydrogen, if the industry switched to hydrogen-based green steel today, it would require 122 m/t of hydrogen. This is equivalent to 130% of the current supply of hydrogen used by all industries.

The technology to create hydrogen from water is well-established. Nevertheless, there are two practical challenges to increasing green hydrogen supply to the IEA's 530 m/t forecast. The first is the supply of renewable power, used as the energy source, and the second is the supply of electrolyzers, which is the system that uses electricity to convert water into hydrogen and oxygen.

Renewable energy access

Access to renewable energy is a key factor for steel producers to consider when establishing new steel plants based on fluidized reduction furnaces. Some steel regions, such as Scandinavia, benefit from abundant renewable energy from hydro and wind sources. This is reflected in Europe's first DRI plant and first large-scale battery plant locating in Sweden. Southern Europe benefits from solar electricity, with DRI and battery plants also planned for the region.

The United States has access to renewable energy, but the low cost of shale gas implies that this is the preferred energy source for producing hydrogen used in producing steel. Australia and the Middle East region also benefit from abundant sources of renewable energy and are likely to be sources of green hydrogen. Asia stands out as having limited surplus renewable energy and may be an importer of hydrogen used in producing green steel.

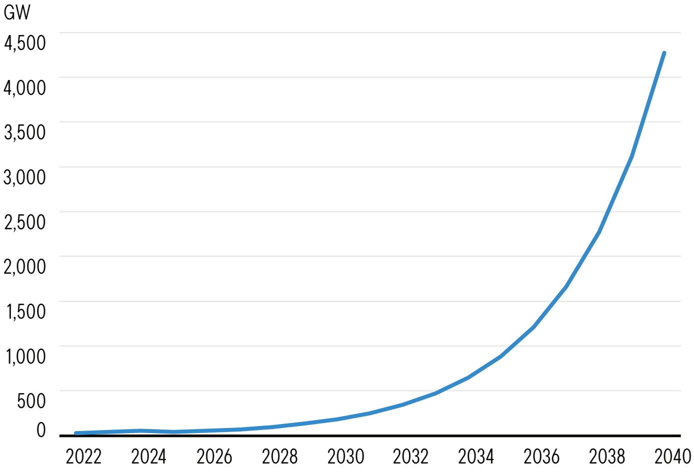
Electrolyzer capacity

Electrolyzer capacity is clearly a constraint on hydrogen production. Current global electrolyzer capacity is estimated to be 5 gigawatts (GW),[149] which is forecast to rise to 38 GW in 2025, and to 4,000 GW if forecast demand of 530 m/t of green hydrogen per year by 2040 is to be achieved, as shown in Exhibit 36. This implies a compound annual growth rate of 37% from the estimate installed capacity of electrolyzers in 2025.

Electolyzers' Compound Growth Requirement

Exhibit 36: Current and Estimated Installed Base of Electrolyzers

2022



Source: Carbon Commentary. There is no assurance any forecast, projection or estimate will be realized.

While this pace of growth in electrolyzer capacity is dramatic, companies such as NEL of Norway are looking to ramp up production capacity to deliver on the needs of the industry. The IEA forecasts electrolyzer capacity will accelerate dramatically in the coming years as new production in Australia, Europe and the United States comes on stream.[150] Supporting the production of this equipment is the premium that users of green steel have indicated they're prepared to pay to access the supply.

High-grade iron ore availability

The production of DRI in a fluidized reduction furnace requires higher-grade iron ore, or 72% magnetite, produced mostly in Brazil, Canada and South Australia. Blast furnaces use 67% hematite, which is produced mostly in Western Australia, China and Brazil. In 2021, global production of 67% hematite was 2.5 billion tons[151]; higher-grade production is estimated to be 115 m/t.[152]

Planned fluidized reduction furnaces imply demand for higher-grade iron ore will increase to 150 m/t by 2030.[153] As higher-purity iron ore grades trade at an average 20% premium to lower grade,[154] there is an incentive for producers to invest in production. In Brazil, one of the large iron ore mining companies has announced plans for 72 m/t of agglomerates, which includes higher-grade iron ore by 2030. Brazil is expected to be the largest supplier of high-grade iron ore globally.

Sunk costs

The current installed capacity of blast furnaces, which can cost billions of dollars to build and have a life span of 30–50 years, represents a constraint on the transformation of the steel industry. Current estimates hover around US$2.8 trillion to decarbonize the steel industry, globally.[155] Given the age profile of blast furnaces globally, it appears that the switch to fluidized reduction furnaces will occur

Global Iron Ore Exporters

Exhibit 37: World's Largest Iron Ore Exporting Countries

As of 2020

Source: BHP.

first in Europe and South Korea. Emerging markets including China will make the switch at a later date, but they still intend to build demonstration plants in the near term to master the technology.

Alternative sources of decarbonization

There are other options for the decarbonization of the steel industry, including carbon capture and storage (CCS), bioenergy and direct electrification. The technology readiness level (TRL) is one approach to assess the feasibility of each of these processes, seen in Exhibit 38.[156] Zero-emissions hydrogen is classed as demonstration on the TRL, CCS is proof of concept, bioenergy is early adoption and direct electrification is prototype.

Carbon capture and storage (CCS)

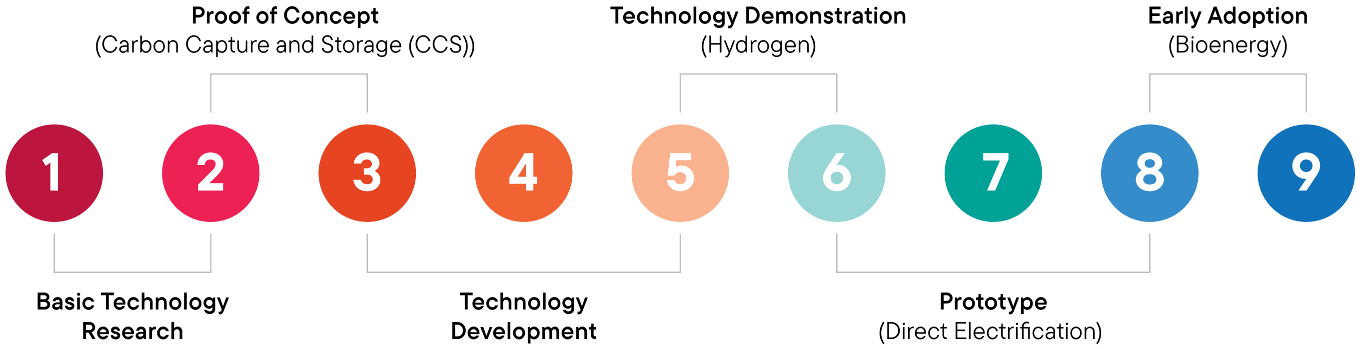
CCS is an alternative method to reduce emissions in steel production. Steel companies propose combining CCS with hydrogen produced from coal gasification or the steam methane reforming process.

As highlighted in Exhibit 39, the primary difference between these two processes and zero-emission hydrogen is the former use coal or natural gas, or grey hydrogen, as the energy source to separate water into hydrogen and oxygen, whereas the latter uses renewable energy—green hydrogen.

Capturing the carbon released in coal gasification or steam methane reforming process is in principle an effective way to reduce emissions. It has been widely researched as a valid

From Concept to Launch

Exhibit 38: Technology Readiness Level

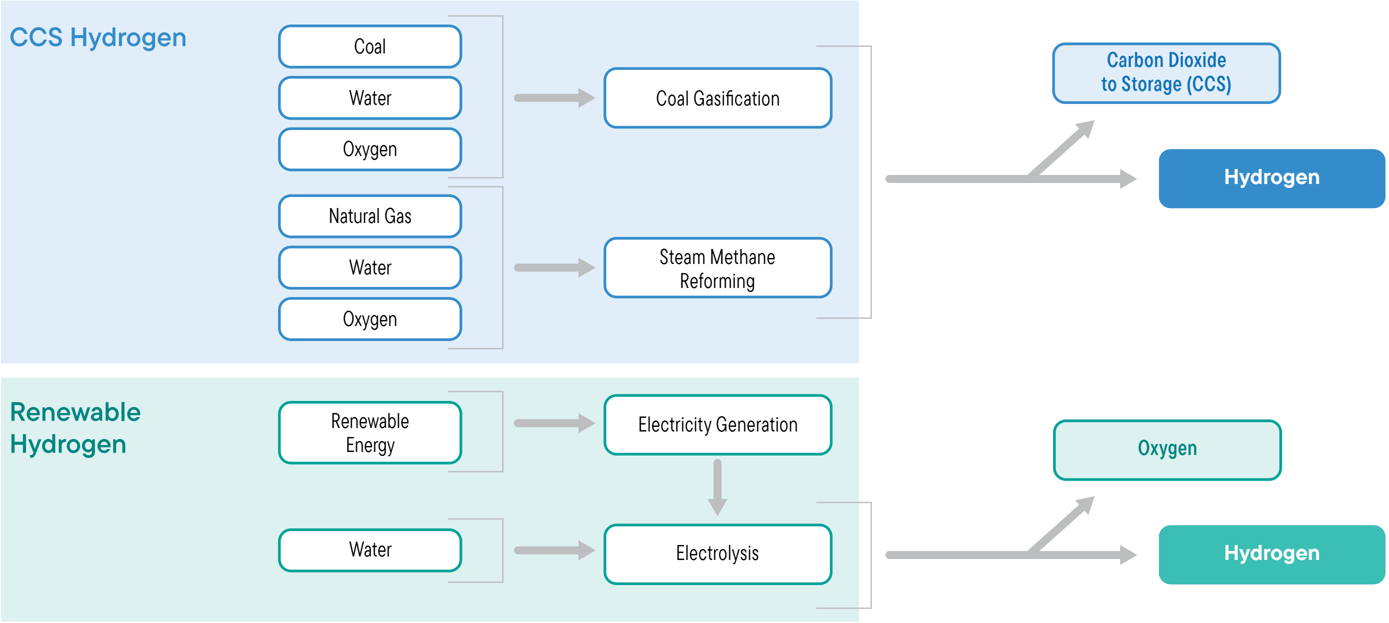


Source: Based on John C. Mankins/NASA. For illustrative purposes only.

Grey vs. Green Hydrogen

Exhibit 39: CCS Hydrogen vs. Renewable Hydrogen Production Processes

2018



Source: Hydrogen for Australia's future, Commonwealth of Australia. For illustrative purposes only.

technology to contribute to the achievement of net-zero emissions. As the name suggests, carbon is captured—or more specifically the flue gas—from the burning of fossil fuels as opposed to being vented into the air.

There are a number of challenges with CCS; the most significant is the absence of a large-scale plant. The largest proof of concept is in Iceland, but its capacity is a mere 4,000 tons of carbon dioxide per annum, the equivalent annual emissions for 250 people.[157]

Regional and country green steel plans

Europe is currently at the forefront of producing green steel, thanks to low renewable energy costs in selected countries and supportive government policies. Its carbon emissions from steel are already below the global average, at 1.1 tons of CO_2 per ton of steel.[158] This is due to its large stock of steel per capita and high use of scrap (50%) in steel production. To demonstrate Europe's readiness, we've prepared a case study, please see the *Combining expertise—the HYBRIT project* sidebar.

The US Inflation Reduction Act has incentives for companies to produce hydrogen; however, given the low cost of shale gas, the focus is likely to be on blue hydrogen.

India plans to reach its net-zero commitment by 2070, 20 years later than that required to limit the pace of global warming to below 1.5°–2°C. In our view, the decarbonization of India's steel industry will require technology transfer, potentially aided by a future acceleration in its net-zero commitments. POSCO, a South Korean-based producer ranked seventh in global steel production in 2022 and the largest emerging market steel produce ex-China,[159] has already indicated it will build an advanced steel plant in India based on its HyREX green steel technology—once again, please see Exhibit 35. However, the extent of technology transfer remains uncertain.

Combining expertise—the HYBRIT project

Producing ultra-low-emissions DRI in a fluidized reduction furnace is classed as a demonstration technology on the technology readiness scale. A consortium of companies with expertise in renewable energy, steel and iron ore mining are currently testing the most advanced prototype in Sweden. The country is uniquely well-positioned to produce ultra-low-emission DRI and green steel, as it has high-quality iron ore required for producing DRI and ample renewable energy available to power the electrolyzers to produce green hydrogen.

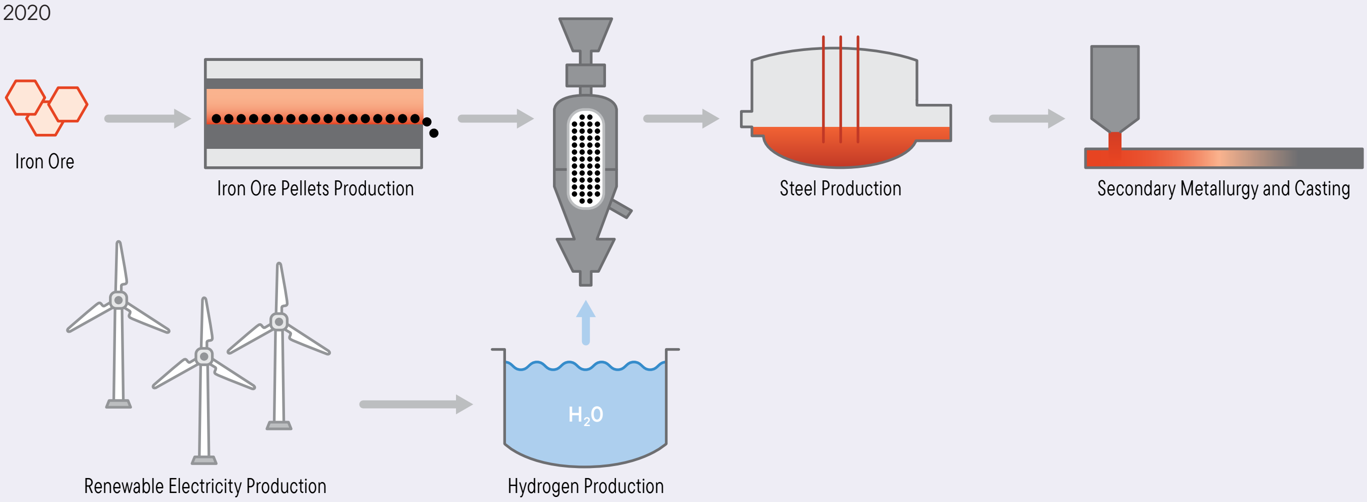
Fossil-fuel-free steel

Three Swedish companies—steel manufacturer SSAB, mining company LKAB and energy company Vattenfall—aim to create the world's first zero-carbon steelmaking process from mine to finished product. Its location in Sweden reflects the availability of low-cost renewable energy and high-grade iron ore. The consortium calls their process Hydrogen Breakthrough Ironmaking Technology (HYBRIT), as shown in Exhibit 40.

Zero-Carbon Steel

Exhibit 40: SSAB's HYBRIT Process

2020



Source: SSAB. For illustrative purposes only.

Combining expertise—the HYBRIT project (continued)

Abundant natural resources

Sweden has a long history in steelmaking based on its abundant renewable energy resources and high-grade iron ore mines. In the 18th century, Sweden dominated global steel production, accounting for an estimated 35% of production.[160] That began to change when lower-cost coal replaced charcoal as the reductant in the steelmaking process. However, its reserves of high-grade iron ore remain, and an abundance of renewable power has once again placed it at the center of the global steel industry, albeit not by volume.

Green steel timeline

The process of creating fossil-fuel-free steel in Sweden started in 2016, when the Swedish energy agency funded a feasibility study on the process. This led to a joint venture between SSAB, LKAB and Vattenfall. Fossil-fuel-free DRI was produced in 2018 at a demonstration plant. The next phase of development, for which the European Commission has been granted US$100 million in funding, is a plant expected to produce 1.3 m/t of DRI by 2026 and 2.7 m/t by 2030.[16]

The Swedish cost advantage

The cost difference per ton of steel produced in a blast furnace using natural gas and in an electric arc furnace using renewable energy and DRI produced from hydrogen is estimated to be 17% for green steel.[162] However, this is highly dependent on fossil fuel, power and iron ore costs. One of the reasons why the HYBRIT project was launched in Sweden is the ability of the three firms, SSAB, LKAB and Vattenfall, which each specialize in individual parts of the steelmaking process, to come together and agree on long-term investments and long-term input prices to reduce the financial risks of the project. Companies in other countries can secure similar long-term supply agreements to unlock the investment required for projects with a life span of 30–50 years.

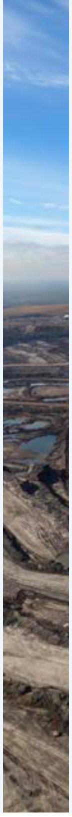
Note: SSAB/LKAB/Vattenfall is used as an example in this paper because it is the only consortium developing integrated DRI, steel and using renewable power. Franklin Templeton does not recommend or endorse SSAB/LKAB/Vattenfall.

Chinese steel companies also have decarbonization plans, but they are not as advanced as those in other Asian or developed markets and rely on blue hydrogen as a transition fuel. We remain in discussion with these companies as to whether investing in unproven technology such as carbon capture and storage (CCS) to produce blue hydrogen is the best use of scarce capital.

China's plan to reach net zero by 2060 will require significant investment in renewable energy and in carbon-intensive industries, including steel. Companies we have engaged with have highlighted detailed plans, but we acknowledge that without government support and technology transfer, progress may be slower than plans suggest.

Conclusion

We are optimistic that the switch to green steel using hydrogen as the reductant and heat source will occur in developed markets. However, as the drivers of the forecast one billion-ton increase in steel demand by 2050 will be concentrated in emerging markets, these countries will need support and technology transfer if the challenge of decarbonization in the global steel industry is to be successful.

Large-scale carbon capture: Theory to reality in the oil sands

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Collectively, the oil sands are one of Canada's largest industrial emitters and in aggregate are believed to account for roughly 13% of Canada's greenhouse gas (GHG) emissions.[163] The oil sands also account for nearly three-quarters of Western Canada's total crude oil production, with the associated crown royalties, corporate taxes and other economic spin-offs making them a significant contributor to Canada's economic growth—contributing nearly 3% to annual gross domestic product (GDP).[164]

Oil sands producers, more than other fossil fuel producers, seemingly face an uphill battle for investment dollars from sustainability- or environmental, social and governance–themed portfolios. Some of this reluctance is historical: early oil sands development was via surface mining, which necessitated tailings ponds and visually unappealing surface disruption. But as sustainability has taken shape, and especially as GHG emissions have become a focal point, the oil sands have received increased scrutiny.

Oil sands mining, like most industrially intensive operations, generates GHG emissions. The more environmentally taxing open-pit mining technologies, however, apply to roughly just 20% of oil sands reserves, according to Natural Resources Canada.[165] Resource depths below 75 meters require too much overburden removal to be economically viable, leading to the development of *"in situ"* production methods, most notably steam-assisted gravity drainage (SAGD). (See our sidebar on oil sands production methods.)

And while carbon sequestration will play a significant role in reducing emissions going forward, electrical cogeneration and R&D across many facets of the production and upgrading process will remain key contributors.

Although significant growth in oil sands production volumes has contributed to rising absolute emissions, the industry has been successful in reducing the emissions intensity of a barrel of crude oil. Reduction in intensity to date has largely come from improved operational processes, not carbon sequestration. And while carbon sequestration will play a significant role in reducing emissions going forward, electrical cogeneration and research and development (R&D) across many facets of the production and upgrading process will remain key contributors.

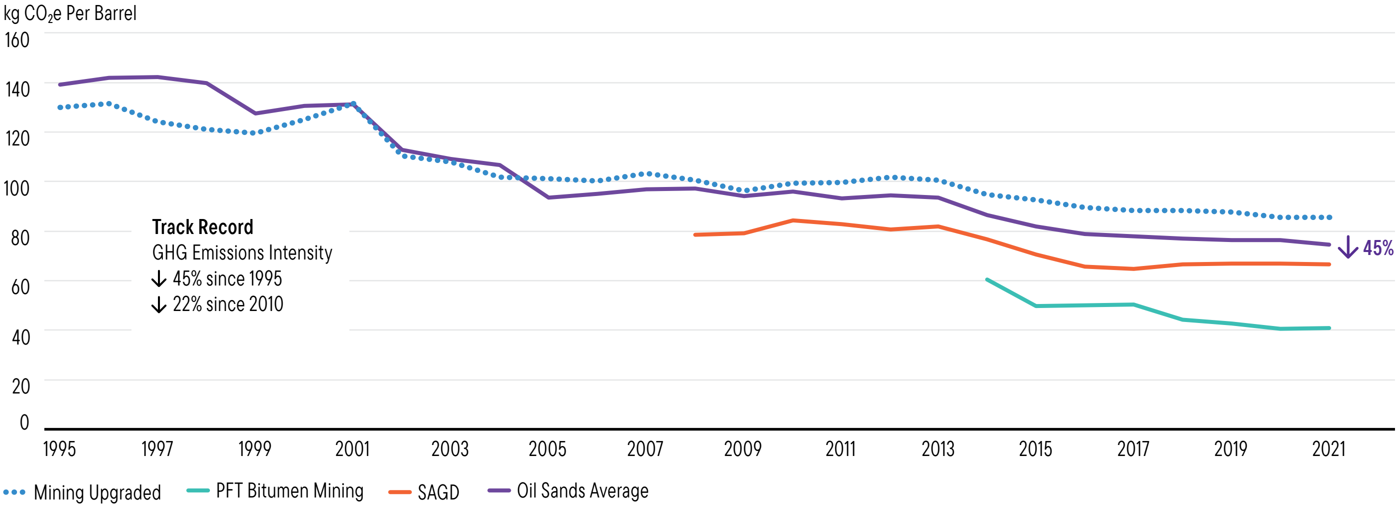
Regulation and carbon tax: Challenges and opportunities

Beginning in 2020, oil sands companies were subjected to Alberta's Technology, Innovation and Emissions Reduction Regulation (TIER) system, a form of carbon tax levy specific to the province replacing a prior carbon pricing mechanism. Contrary to what many would believe, Alberta was the first Canadian province to put a price on carbon. The original levy on GHG emissions began in 2007 under a program called the

Oil Sands Carbon Intensity Steady Decline

Exhibit 41: Oil Sands GHG Intensity Trend

1995–2021



Source: BMO Capital Markets. As of December 31, 2021. Note: PFT stands for paraffinic froth treatment, a production process in which parts of the oil sands barrel that are most energy intensive to treat are removed prior to further processing, reducing CO_2 emissions.

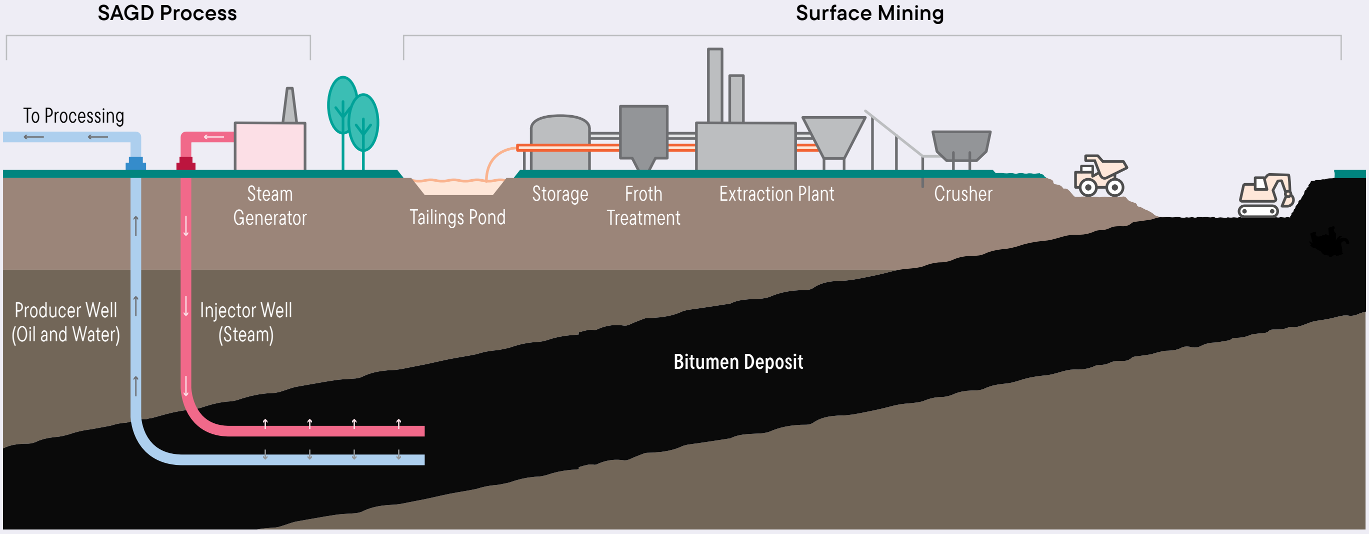
Oil sands production: Surface mining vs. steam-assisted gravity drainage (SAGD)

Surface mining

Surface material is removed, then oil-saturated sands are collected by large shovels and transported by truck to crushers that process the ore. Hot water is added, creating a slurry which is fed into an extraction plant, where a separation vessel causes the components (bitumen, sand, clay, water) to separate. The bitumen is then removed and upgraded before being refined into various products. Waste products include fine tailings, which include a mixture of water, sands, fine silts, clay, residual hydrocarbons and water-soluble material. The tailings are stored in basins called tailings ponds, where over time the solids settle. Ultimately, the water is processed and recovered (or evaporates) and the area is reclaimed, though this process can take many years. Energy is used and CO_2 is emitted in all parts of the mining and upgrading process, creating the potential to both use less energy (through technical process improvement) and capture associated CO_2 emissions.

SAGD process

SAGD development involves drilling a pair of horizontal wells, one on top of the other. The top well is used to inject steam into the reservoir; the steam reduces the viscosity of the bitumen and allows crude oil to flow to the surface via the bottom well.



For illustrative purposes only.

Specifed Gas Emitters Regulation (SGER). As of 2022, the TIER system charges a levy of C$50/metric ton (mt) of CO_2 equivalent (up from C$40/mt previously in 2021).[166] As Alberta's TIER system is deemed to be aligned with the federal government's Greenhouse Gas Pollution Pricing Act (GGPPA), we assume the levy will increase over time commensurate with the GGPPA, which is planned to reach C$170/mt by 2030.[167] The TIER system also provides for annual GHG reduction obligations.

In addition to the potential financial impact of rising carbon taxes, the oil sands industry recognizes that emissions are an obstacle for investment and that reductions are critical for Canada to reach its national GHG reduction targets. In 2016, the industry committed to a regulated cap on total emissions. Since then, the Pathways Alliance member companies have set a target of net-zero emissions from oil sands operations by 2050. The Canadian federal government is proposing an intermediate target for the oil and gas sector of a 42% reduction in emissions from 2019 levels by 2030. This is a more aggressive target than the 30% overall emissions reduction for all emitting sectors over the same time period. The oil and gas industry was originally assessed at the 30% level and opposes being singled out for a more aggressive target; various industry representatives have said it is unachievable due to permitting and construction timelines for required projects. Nevertheless, there is a clear focus by both parties to not only arrest the increase in emissions but also to reduce absolute emissions by 2030.

Pathways Alliance

The Oil Sands Pathways to Net Zero Alliance was formed in 2021 by six oil sands producers that collectively represent more than 95% of Canada's oil sands production: Canadian Natural Resources, Cenovus, ConocoPhillips, Imperial Oil, MEG Energy and Suncor.

In June 2022, the Pathways oil sands group combined with two other industry organizations focused on innovation and responsible development, Canada's Oil Sands Innovation Alliance (COSIA) and the Oil Sands Community Alliance (OSCA) to form a single organization called Pathways Alliance.

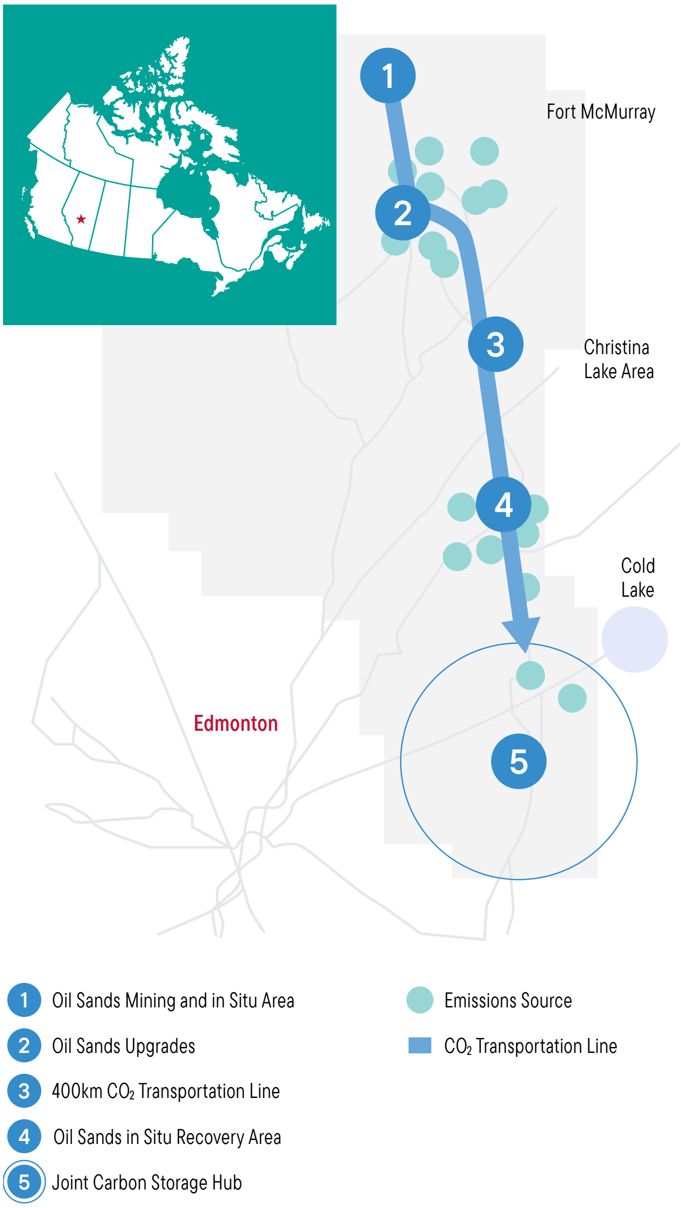
Foundational project: Carbon capture system

The partners in Pathways Alliance are committed to sharing best practices and technological knowledge to facilitate emissions reductions and to fund joint projects of interest. The group's foundational project involves the construction of a carbon capture, utilization and sequestration system (CCUS) and an associated transportation pipeline. This line would connect the oil sands facilities to a sequestration hub near Cold Lake, Alberta (see Exhibit 42 below). Approximately 95% of the proposed pipeline route follows existing rights-of-way, according to Pathways Alliance.

Pathways Prototype

Exhibit 42: Illustrative Map of Pathways Alliance Project

As of October 2022



Source: Pathways Alliance.

The overall project goal of the Pathways Alliance is to enable partner oil sands emissions to reach net zero by 2050 in three phases. The first phase, which relies heavily on carbon capture and storage but also other technological improvements, envisions a reduction of 22 million metric tons (mmt) of CO_2e by 2030 (see Exhibit 43), with about 10–12 mmt/year of CO_2e reductions from the Phase 1 carbon capture and sequestration project and the rest from process efficiencies, electrification, and other initiatvies. A reduction of 45 mmt of CO_2e annually is targeted by 2040, with additional contribution from CCS and other initiatives.[168]

Carbon capture and transport is already in use in Alberta. For example, the North West Redwater Sturgeon Refinery captures and supplies CO_2 to the Alberta Carbon Trunk Line (ACTL). ACTL is an integrated system that transports and stores CO_2 for enhanced oil recovery projects, with a system capacity of 14.6 mmt CO_2/year.[169]

Combined effort: Other technologies to decarbonize oil production

The plan to reduce oil sands GHG emissions involves a variety of technologies, both in operation and under various stages of development. Within the upstream business, mining and in situ operations have different opportunities and challenges. Innovations within oil sands mining operations include the use of autonomous haul trucks that optimize ore transport, reducing fuel usage. The In-Pit Extraction Process (IPEP), currently in the pilot stage, involves a relocatable, modular extraction plant that processes and separates bitumen in the mine pit. It reduces materials transportation distance and energy usage and produces dry, stackable tailings that would potentially elimate the need for future tailings ponds.

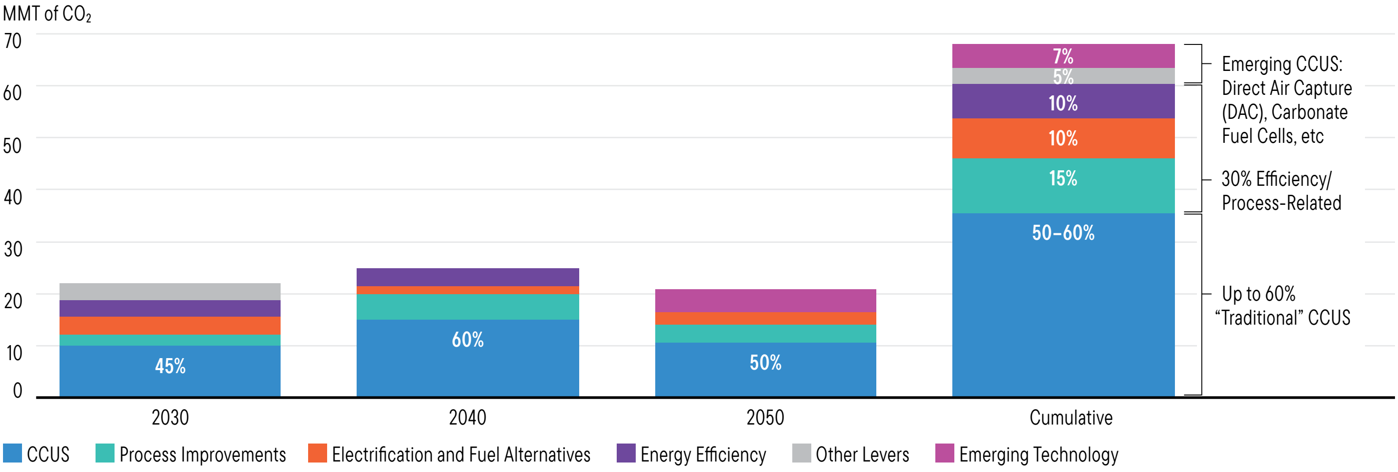
Within in situ, the use of solvent-enhanced oil recovery is one of the most promising methods for further reducing the amount of steam used in the oil recovery process.The use of solvents is expected to achieve up to a 50% lower GHG emissions intensity per in situ barrel. A 2022 pilot project by one of the Pathways Alliance members demonstrated reductions of 45% in GHG intensity and a solvent recovery rate of 85%, suggesting potential for significant improvement in project economics along with the GHG reduction benefit (about C$1/barrel in operating cost savings and potentially lower capital costs due to less steam generation being required).[170]

Some technological innovations have benefits that go beyond GHG emission reduction. For instance, one member has reduced its freshwater usage intensity by 48% in its mining operations since 2017, with an 86% water recycling rate, while in situ operations have reduced freshwater usage by 57%, with 85% of produced water being recycled.[171] At the Horizon Oil Sands Mine, site of a current carbon capture project, 0.4 mmt/year of CO_2 is captured from the associated hydrogren plant and injected into tailings to accelerate tailings readiness for pond closure and reclamation.[172]

Multiple Paths to Oil Sands Emissions Reduction

Exhibit 43: Projected Pathways Alliance Cumulative Emissions Reduction Sources

As of March 2023



Sources: Pathways Alliance, BMO Capital Markets. There is no assurance any forecast, projection or estimate will be realized.

Crucially, the Pathways project carbon transportation line would be open to other industries seeking to capture and sequester CO_2. Perhaps the biggest obstacle to a successful project is the cost. As this involves emerging technologies, estimates vary, but project proponents currently believe it will cost C$75 billion to achieve net zero in oil sands, with the amounts spent over three decades (C$2.5 bn/yr on average). Industry groups are seeking financial support from both federal and provincial levels of government.

Pathways Alliance members announced plans to spend C$24.1 billion before 2030 in the first phase of the plan, with C$16.5 billion spent on the carbon capture and storage network, and the remaining C$7.6 billion spent on major emissions reduction projects and technologies. Collectively, the individual Pathways members spent more than C$10 billion on R&D on various technologies from 2012 to 2021. According to S&P Global, some of these technologies helped to reduce per barrel emissions by about 20% between 2009 and 2020.

Emissions reduction potential in other sectors

Although it is too early to assess the project return impact from third-party carbon volumes on the transportation line, presumably a tolling arrangement or cost of service–based fee structure would be created. This would distribute the cost of transportation among project proponents, the government (to the extent there is direct public financing) and other enterprises seeking CO_2 transport solutions.

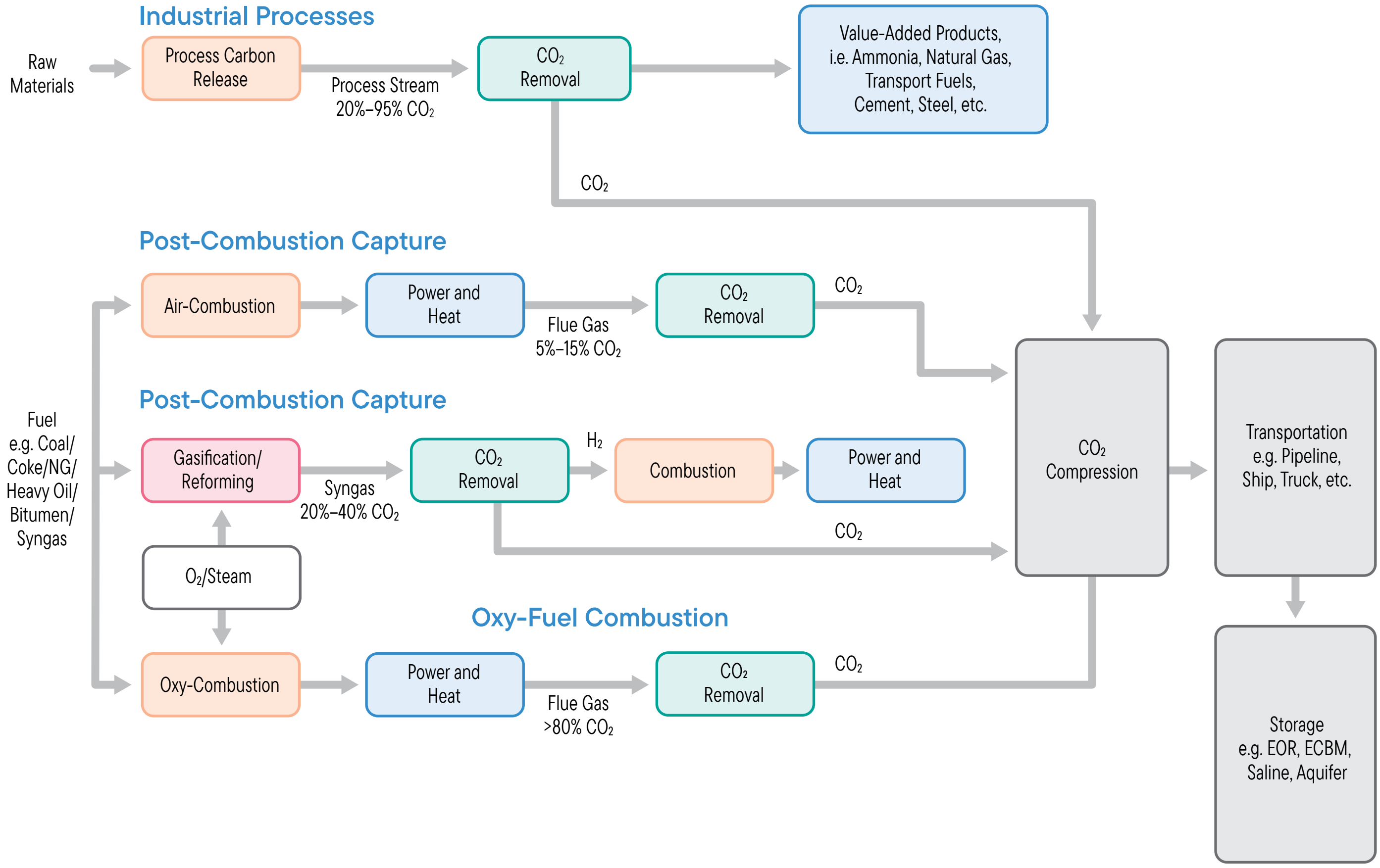
Canadian investment tax credit helps, but is it enough?

The Pathways Alliance proponents point to two international projects as examples of public-private cooperation in CCUS projects: 1) the Porthos carbon storage project in the Netherlands and 2) the Northern Lights project in Norway.

In April 2022, the Canadian government announced the creation of an investment tax credit (ITC) for CCUS projects in Canada. Although we believe the ITC does improve the

Means of Carbon Capture Will Vary by Process

Exhibit 44: Carbon Capture Processes



Sources: Mezt, B., Ogunlande, D., de Conick, H., Loos, M. and L. Meyer (eds.) 2005. *IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate. Intergovernmental Panel on Climate Change.* IPCC: Cambridge University Press.; and Stellae Energy for Pathways Alliance Project specific process modifications. For illustrative purposes only.

While we remain very much aware of 2030—the year when substantial progress is expected to be made to reduce industry GHG emissions—we are encouraged that it appears the Pathways member companies, as well as the Canadian federal and Alberta provincial governments, are beginning to work together with the same sense of urgency.

feasibility of CCUS investment in Canada, we make two key observations. One, the ITC credit is not available for enhanced oil recovery projects for conventional oil and gas production, which makes its use somewhat less widespread for industry (although able to be used in projects such as the Pathways project). Secondly, and perhaps more importantly, the benefit of the ITC pales in comparison to the "45Q" tax credit offered in the United States. Simply described, the US 45Q is a performance-based credit, which creates a tax liability offset equivalent to US$85/ton for carbon capture and geologic storage (CCS) and US$60/ton CO_2 for carbon capture and storage via utilization (CCUS) including enhanced oil recovery (EOR). By contrast, the Canadian ITC is a refundable tax credit that applies to upfront capital investment for eligible expenditures (50% for capture equipment, 37.5% for transportation and storage) but does not apply to front-end engineering and design costs, and only applies in full for projects sanctioned before 2030 (after which the ITC falls by half). It is our understanding that industry stakeholders are in active discussions with the Canadian and Alberta governments to improve the cost-sharing basis, perhaps by augmenting the ITC (federal) or allowing royalty deductions (provincial). While we believe some progress will be made on this front, and that the Pathways companies are actively working on engineering and design work for capture and transportation, the timing of project sanctioning and permitting is critical, given significant construction timelines, if companies are to show progress by 2030.

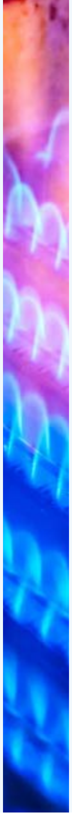
Pathways project gathering steam

Engagement is important to this process, and our team has met with the management of several Pathway Alliance members on a number of occasions over the past few years and continue to actively follow project developments. Given the substantial portion of the Canadian economy and Canadian equity market represented by the energy sector, success by some of the largest stakeholders in reducing emissions while enabling the continued production of energy to meet global demand is not just important for the economic health of the country but also represents an opportunity for continued investor returns.

The pace of project announcements has certainly sped up since we started following this project. In January 2023, Pathways reached another milestone as it entered into a Carbon Sequestration Evaluation Agreement with the government of Alberta, enabling Pathways to conduct a detailed evaluation of the proposed geological storage hub to safely inject and permanently store CO_2. In February 2023, Pathways Alliance awarded a C$10 million contract to a global engineering and consulting company to develop detailed plans for the 400 km CO_2 transportation line that will link the oil sands facilities to the permanent storage hub near Cold Lake, Alberta.[173] Also in February, the government of Alberta announced its 2023 budget, which included support for CCUS projects and coordination with federal CCUS initiatives. Engineering and field work is progressing to support an anticipated regulatory application for the CCS network in the fourth quarter of 2023. Early engagement with more than 20 Indigenous communities along the proposed CO_2 transportation and storage network corridor is underway, and formal engagement is expected to begin in the second quarter.

In April 2023, we met with representatives of Pathways Alliance. Pathways Alliance continues to advocate on behalf of the project to various levels of government and also plays a role in educating the public about carbon sequestration and the potential for this technology to be deployed across industries.

While we remain very much aware of 2030—the year when substantial progress is expected to be made to reduce industry GHG emissions—we are encouraged that it appears the Pathways member companies, as well as the Canadian federal and Alberta provincial governments, are beginning to work together with the same sense of urgency. ⚡



Net-zero’s bridge fuel: Natural gas’s critical role in transition

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Portfolio Manager and Research Analyst
Franklin Equity Group

To address challenges of energy-linked environmental degradation and climate change, we must start by understanding how energy is produced, used and required. Today, the fossil fuel system is the predominant source of energy, and fossil fuel producers face pressure from the “green revolution.” Institutional investors have leaned on energy sector executives to devote less money to expanding fossil fuel production and focus instead on returning capital to shareholders. This is due, in part, to the lower returns companies generated during the prolonged downturn that began in late 2014 and also to risks created by opposition to fossil fuel consumption.

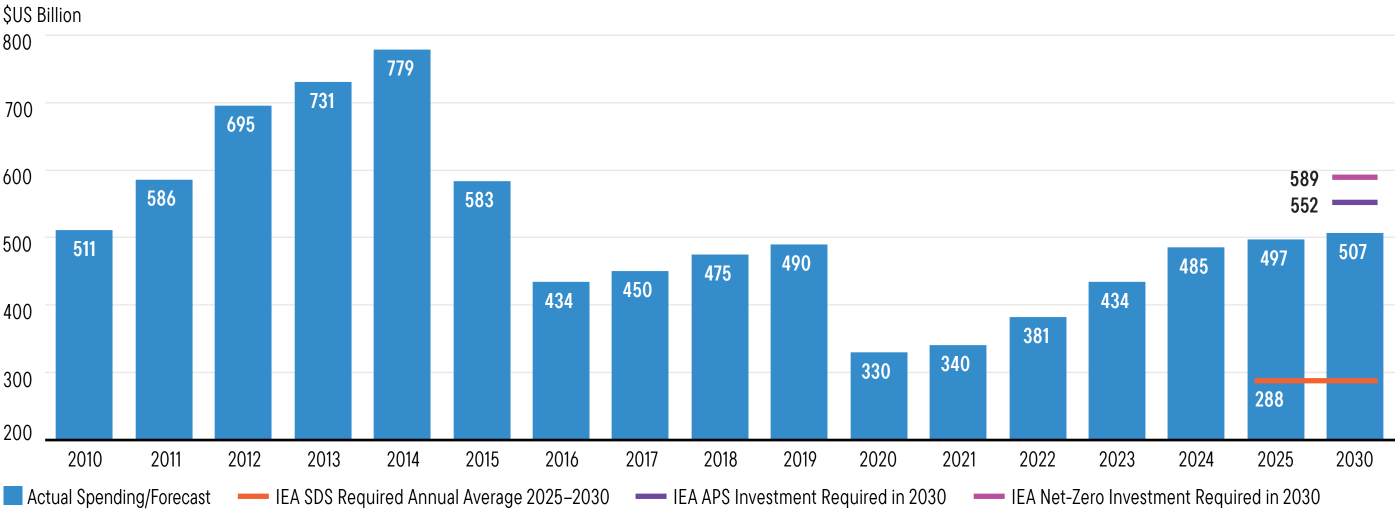
These dynamics create a potential gap in meeting production needs in the intermediate future. As Exhibit 45 on the next page suggests, even under the International Energy Agency’s (IEA’s) Sustainable Development Scenario (SDS),[174] producers must spend about 50% more each year through 2030 to meet global oil demand despite electricity generated by cleaner sources moving closer to becoming the core of our energy system.[175] With the energy transition underway, integrated energy companies aren’t sure how much natural gas, petroleum and coal the world will need to ensure reliable supplies vis-à-vis huge increases in renewable energy capacity and storage systems (batteries, fuel cells, etc.), particularly with many governments trying to phase out carbon-emitting fuels. In such a fluid environment, reliable and more environmentally friendly baseload power[176] (lower-carbon fossil fuels, use of carbon capture technology etc.) will be required so power can ramp up and down when renewables are unable to meet demand. Bridge fuels—with an emphasis on those that are plentiful and burn cleaner, such as natural gas—will put less strain on communities and renewable supply chains as they ramp up, which will allow for a smoother transition.

We believe a responsible energy transition approach includes examining all tiers of policy scenarios—STEPS, APS and NZE[177]—to inform the required level of future investment. This includes natural gas production and distribution, which can displace coal- and petroleum-fired power generation in the near future. Such substitutions can provide immediate environmental benefits without putting undue strain on supply chains since much of the technology has been around for decades and is readily available. In a world where energy consumption is expected to swell, particularly in non-Organisation for Economic Co-operation and Development (OECD) countries (see Exhibit 46 on the next page), further investment is required with greater emphasis on natural gas to help reduce dependence on fuels with a bigger carbon footprint. Existing infrastructure can eventually play the role of backup capacity to help solve for obstacles such as renewables’ intermittency and grid-complexity issues, along with scarcities of source materials we’ll likely encounter during an expansive, multidecade transition. This is a much more flexible, cost-effective and expedient approach to achieving decarbonization goals, with global natural gas markets expected to evolve as market dynamics point to a structural change. Many integrated energy producers already shifted in this direction, with as much as 50% of their upstream production, on a BTU equivalent basis,[178] now coming from natural gas.[179]

Impact of Spending Shortfall Awaits Traditional Energy Producers...

Exhibit 45: Global Energy Sector Upstream Spending, Including Forward Estimates

2010–2030F

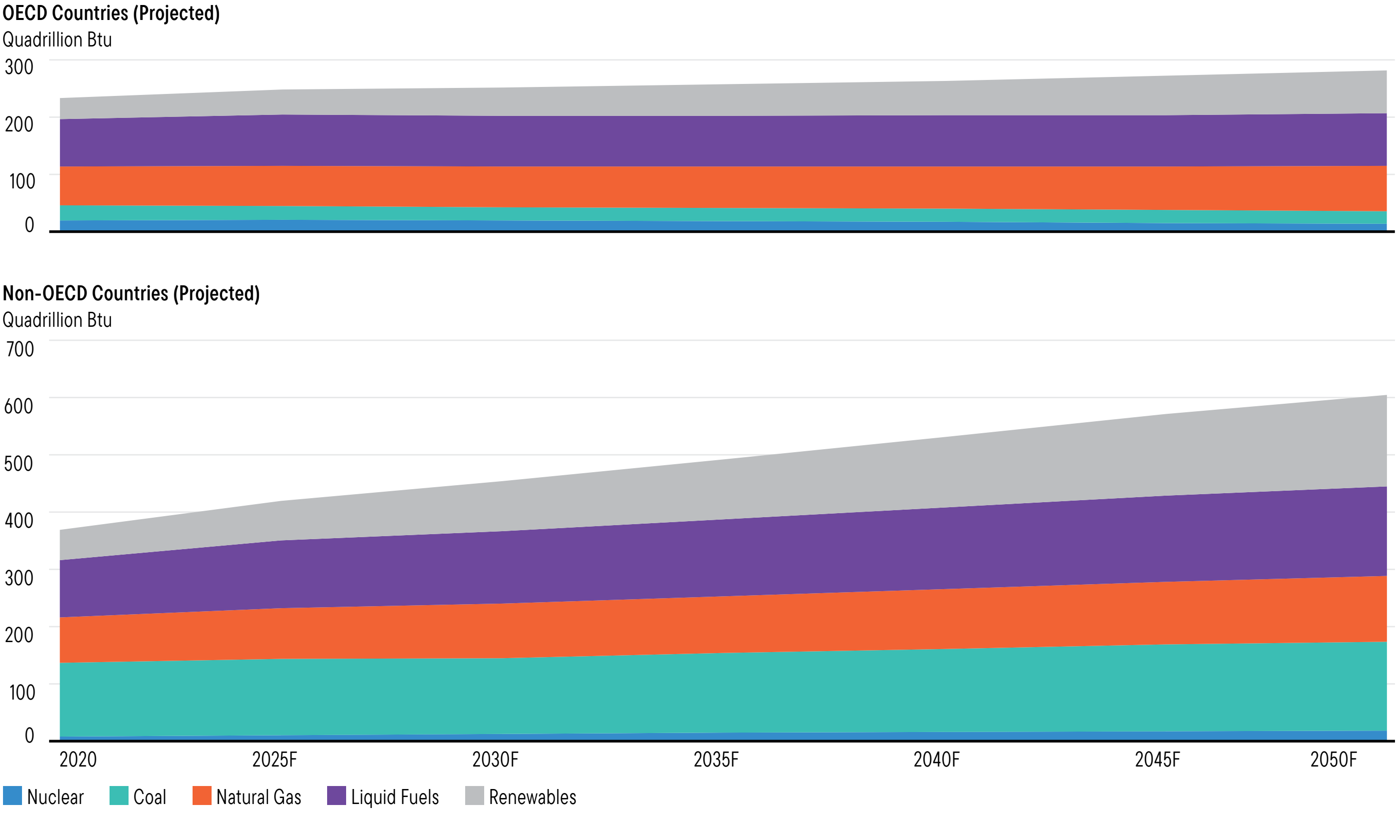


Sources: Baker Hughes, IEA and Goldman Sachs & Co. Note: IEA estimates based on three primary scenarios: Sustainable Development Scenario (SDS) describes a pathway for the global energy sector (through to 2040) that keeps the world on track to meet the long-term mitigation goals of the Paris Agreement, while also achieving universal access to modern energy and substantially reducing air pollution; Announced Pledges Scenario (APS) assumes all aspirational targets announced by governments are met on time and in full, including their net-zero and energy access goals; the Net Zero Emissions by 2050 (NZE) scenario maps out a way to achieve a 1.5°C stabilization in the rise in global average temperatures, alongside universal access to modern energy by 2030. F=forecast. There is no assurance that any forecast, estimate or projection will be realized.

While Markets Test Their Adaptive Momentum...

Exhibit 46: Projected Energy Consumption by Source, OECD (top) and Non-OECD Countries (bottom)

2020–2050F



Source: US Energy Information Administration, International Energy Outlook 2021 (IEO2021). F=forecast. There is no assurance that any forecast, estimate or projection will be realized.

Tough to quit

Despite the environmental impact, fossil fuels are tough to quit. The average US consumer uses over 20 barrels of oil per year, while most other highly populated countries are seeing a rise from the low single digits amid robust consumption growth trends.[180] Per-capita energy consumption growth is forecast to continue expanding at a rapid pace, particularly in Asian countries such as India, while those with smaller populations in sub-Saharan Africa—like Mozambique and Tanzania—are also experiencing improvements in living standards and the higher energy consumption that goes along with it. Energy use in these countries remains far below that in developed economies, as depicted in Exhibit 47. These are regions where natural gas power plants are currently being built as energy demand scales up and security of supply becomes a priority. Small incremental standard-of-living gains can translate into massive upshifts in electricity demand and fossil fuel consumption, particularly when spread across billions of people.

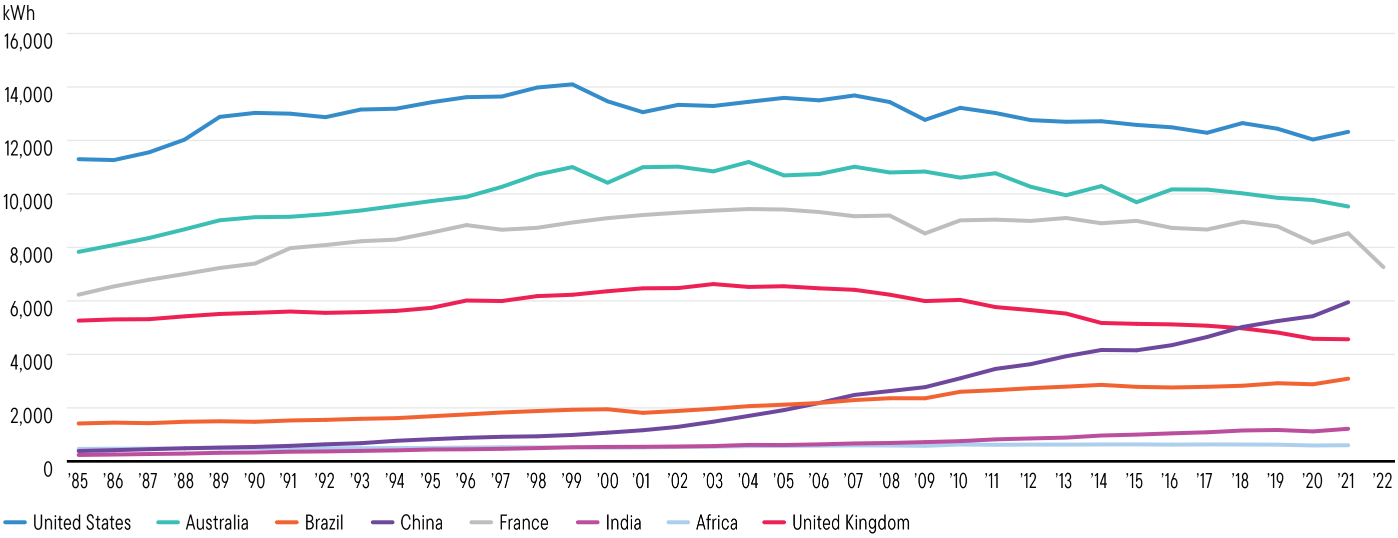
Energy security, a critical factor in prosperity, is not just an emerging or frontier market dilemma. Germany experienced shortages in natural gas with Russian imports curtailed in 2022, forcing domestic lignite coal use to spike. Even after Germany curbed energy use, hard-won environmental benefits tied to its energy transition were erased. Simultaneously, Europe paid record-high prices in a rush to secure enough liquefied natural gas (LNG) for the winter, much of it from the United States, as part of a larger goal to attain independence from Russian gas supplies. Europe is fast-tracking construction of LNG regasification[181] terminals amid the market's abrupt shift—a turning point underscored by the German Bundestag passing the LNG Acceleration Act in May of 2022.[182]

Europe's move to future-proof its energy infrastructure occurred as a result of a dependence on renewables and non-European supplies becoming unreliable. Renewable energy generation is subject to the inconsistency of nature and requires storage systems or alternate generation capacity. Energy storage systems (ESS), such as batteries, offer a short-term solution but cannot provide adequate supplies during periods of prolonged outages. This was the case in 2021 when windless doldrums enveloped the North Sea, leading to idle wind farms and natural gas storage depletion—and likely emboldening Russia given Europe's dependency on Russian natural gas. And, though it seems a strange contradiction, wind turbines are designed to stop in *too much* wind to prevent damage. Novel methods of energy storage are under development—including compressed air and gravity-based systems—but are not yet economically viable, while others like pumped hydro are in use today but are limited by the availability and topography of land and, in some cases, water.

Converging Demand

Exhibit 47: Average Annual Per-Capita Electricity Generation in Key Developed and Emerging Markets

1985–2022



Source: Our World in Data based on BP Statistical Review of World Energy (2022); Our World in Data based on Ember's Yearly Electricity Data (2023); Our World in Data based on Ember's European Electricity Review (2022); Per-capita electricity generation (ourworldindata.org).

Bridge fuel

Among the traditional energy inputs, we see natural gas as a critical bridge fuel that will likely continue to play a role in baseload electricity generation. Natural gas is the cleanest-burning fossil fuel—one that can be made cleaner through carbon capture technology.[183] Technology advancements have also made the development of unconventional natural gas resources economically viable, vastly expanding resource availability. When we analyze various nations' climate targets and policies compared to the Paris Agreement's ambitious goal to hold Earth's average temperature to within 1.5°C (2.7°F) above pre-industrial levels, natural gas surfaces as the most compelling bridge fuel—moving us toward decarbonization in an affordable way while ensuring security of supply.

To progress these global climate objectives, ongoing investment in natural gas drilling and transportation to areas where local supplies are inadequate—particularly in countries heavily reliant on coal and diesel power generation—is essential. As seen in Exhibit 48, US emissions dropped sharply when natural gas-generated electricity displaced electricity produced from coal. It was also a fairly painless process that didn't result in significant cost increases for consumers or any degradation of energy security; in some cases, it led to a reduction in power prices. While other countries lack natural gas resources, they can still benefit from ample supplies shipped from other regions.

Above all else, natural gas can cover energy demand lost to shuttered coal-fired plants, while powering numerous industrial and transportation applications that cannot yet be electrified. Due to technological limitations or other factors, sectors currently beyond the scope of electrified power include: heavy-duty and long-haul trucks, railways, large marine vessels and high-heat factory processes such as metal smelting and glassmaking. It will become an integral part of a hybrid system where natural gas and eventually hydrogen can be dispatched into combined-cycle gas *or* hydrogen turbines to produce electricity as needed—which can help avoid capacity shortfalls. See our sidebar, *"'Clean' Hydrogen Conundrum,"* on the next page for our current views on hydrogen development.

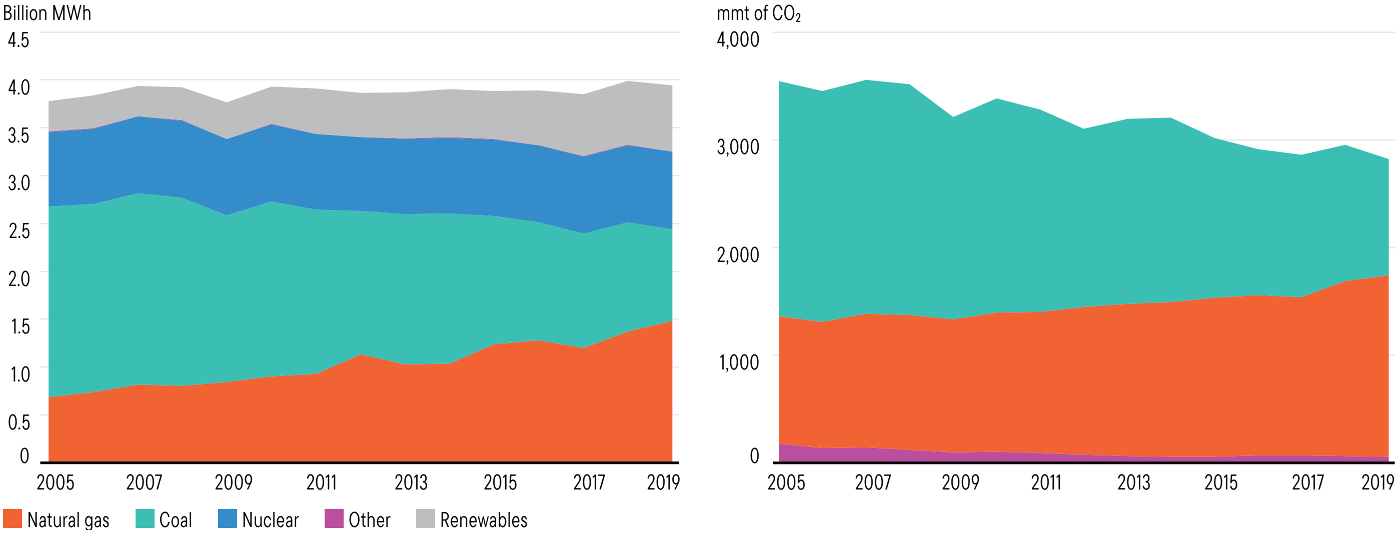
Geographic consideration and energy shocks

Other emissions-eliminating strategies are striving for efficiency improvements and the levelizing of costs (see Exhibit 49) to shrink the relative utility-cost gap between legacy fuel inputs versus wind and solar, but this will take time. Although renewables in some instances are comparable to or even less expensive than natural gas generation, this is not always the case depending on weather-related factors.

Emissions Drop: Shifting from Coal to Natural Gas

Exhibit 48: US Electric Power Sector Electricity Generation and CO_2 Emissions by Source

2005–2019



Source: US Energy Information Administration, *Power Plant Operations Report*.

“Clean” hydrogen conundrum

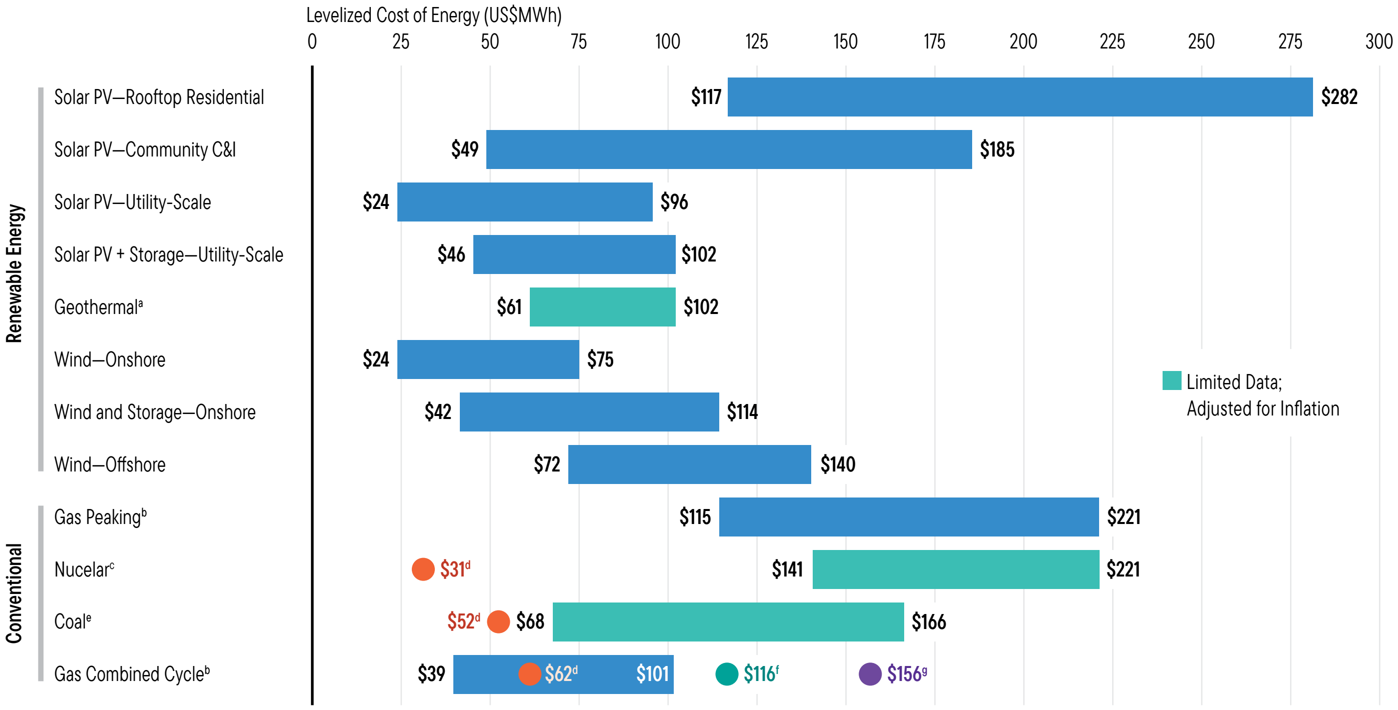
Many scientists believe the use of hydrogen is the most sensible path toward decarbonization, though the cost of production remains too high today. Hydrogen currently leaves a carbon footprint, as isolating it requires energy, lots of it. Hydrogen production—the majority of which is currently reliant on carbon-omitting fuels (“grey hydrogen”)—may also play a role in fossil-fuel displacement longer term. Some companies are already blending small amounts of hydrogen into their natural gas streams, but hydrogen is a smaller molecule that requires specialized equipment that takes time to build out. Hydrogen is fundamentally another method of “energy conveyance” but one that is emissions- free if it can be made cost-competitive using renewable power (“green hydrogen”).

In transportation, hydrogen-drive systems have been undergoing research for at least 25 years and advances continue today, though large-scale adoption remains elusive. In addition, methodically creating a global system to produce, transport and store hydrogen without exacerbating climate impact requires new infrastructure that may take decades to build, in our view.

Competing on Cost: Renewable vs. Conventional

Exhibit 49: Levelized Cost of Energy Comparison—Unsubsidized Analysis

As of April 2023



Source: Lazard and Roland Berger estimates (and publicly available information). There is no assurance that any forecast, estimate or projection will be realized.

Note: The analysis assumes 60% debt at an 8% interest rate and 40% equity at a 12% cost. See page titled “Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital” for cost of capital sensitivities.

a. Given the limited data set available for new-build geothermal projects, the LCOE presented herein represents Lazard’s LCOE v15.0 results adjusted for inflation.

b. The fuel cost assumption for Lazard’s unsubsidized analysis for gas-fired generation resources is US$3.45/MMBTU for year-over-year comparison purposes. See page titled “Levelized Cost of Energy Comparison—Sensitivity to Fuel Prices” for fuel price sensitivities.

c. Given the limited public and/or observable data set available for new-build nuclear projects and the emerging range of new nuclear generation strategies, the LCOE presented herein represents Lazard’s LCOE v15.0 results adjusted for inflation (results are based on then-estimated costs of the Vogtle Plant and are US-focused).

d. Represents the midpoint of the unsubsidized marginal cost of operating fully depreciated gas combined cycle, coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned gas combined cycle or coal asset is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating gas combined cycle, coal and nuclear assets across the US Capacity factors, fuel, variable and fixed operating expenses are based on upper-and lower-quartile estimates derived from Lazard’s research. See page titled “Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation Technologies” for additional details.

e. Given the limited public and/or observable data set available for new-build coal projects, the LCOE presented herein represents Lazard’s LCOE v15.0 results adjusted for inflation. High end incorporates 90% carbon capture and storage (“CCS”). Does not include cost of transportation and storage.

f. Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of “Blue” hydrogen, (i.e., hydrogen produced from a steam-methane reformer, using natural gas as a feedstock, and sequestering the resulting CO_2 in a nearby saline aquifer). No plant modifications are assumed beyond a 2% adjustment to the plant’s heat rate. The corresponding fuel cost is $5.20/MMBTU, assuming ~US$1.40/kg for Blue hydrogen.

g. Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of “Green” hydrogen, (i.e., hydrogen produced from an electrolyzer powered by a mix of wind and solar.

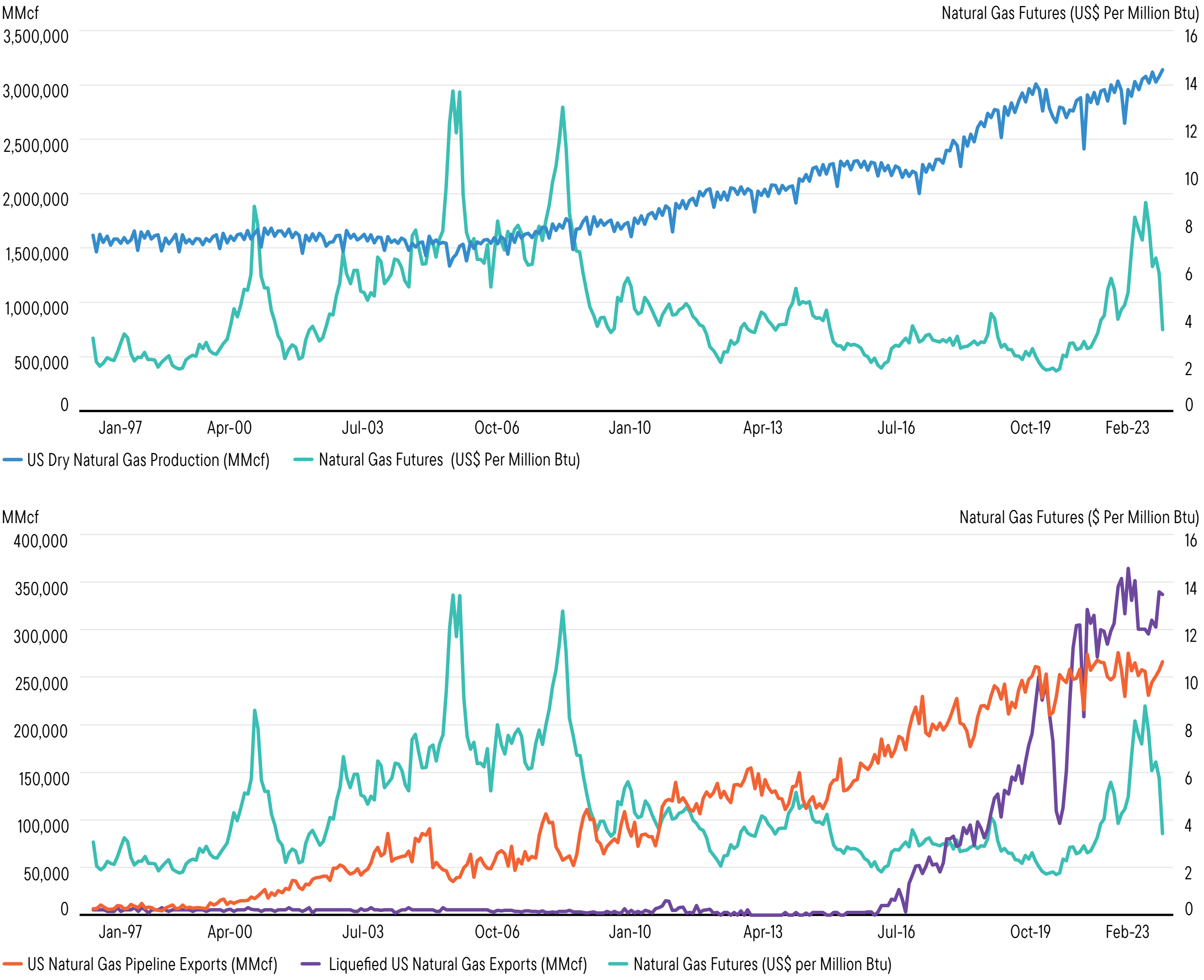
It is also not currently practical to send renewable electricity around the world; it tends to stay local due to infrastructure constraints and attrition over longer distances. We believe the world will require additional natural gas sourcing, and related logistics management, to meet incremental consumer demand during the transition period. This view contrasts sharply with some IEA analyst scenarios in which no new natural gas fields need to be developed.

LNG capacity expanded briskly over the past 20 years, with primary development in Qatar, Australia, Russia and, more recently, the United States, Canada and offshore Israel. This supply primarily fed demand in Asia, which helped reduce the region's coal consumption. In the United States, the hydraulic fracturing (fracking) revolution and production boom that started in 2010,[184] as reflected in Exhibit 50, led to a reduction in greenhouse gas emissions as domestic coal plants were decommissioned. In total, current proposed and approved LNG plant projects are set to boost global LNG supplies by 67% from 2021 levels—to 636 million metric tons (mt) per annum—by 2030.[185] That's enough to displace about 26.5 million mt of coal and reduce CO_2 emissions by 683.3 million mt—roughly the same amount emitted by 152 million US passenger vehicles each year, on average.[186]

A Deflationary Shale Gas Boom

Exhibit 50: US Natural Gas Prices vs. Production Growth (top) and Exports (bottom)

January 1997–February 2023



Source: US Energy Information Administration.

The world will require fossil fuels for years to come, though investment in the field lags as governments and investors turn their attention to renewable energy projects and away from fossil fuels. In examining the size and scope of the problem, our analysis implies the transition is likely to take longer than expected and rely more heavily on natural gas production and utilization than many might otherwise surmise.

One example is the Coastal GasLink Project in British Columbia, Canada: once complete, it will be Canada's first direct link for LNG deliveries, mostly to Asia. The pipeline will serve as a conduit for natural gas supplies to feed LNG projects on Canada's west coast. The project is estimated to further support displacing 60 to 90 million mt of CO_2 emissions annually, primarily from coal—an important step for carbon reduction efforts.

In Qatar, the major integrated energy companies are partnering to nearly double the country's production capacity with the development of two new regions called the North Field East (NFE) and North Field South (NFS). And in Africa, countries such as Mozambique, Nigeria, Tanzania, Equatorial Guinea and Mauritania/Senegal are offering multiple extraction opportunities. Mozambique, for instance, has significant natural gas reserves in its Rovuma Basin. The country has been attracting attention from international energy companies, and several major LNG projects are under development. These projects aim to extract natural gas onshore and offshore and establish LNG export facilities. Not to be left out, the United States is advancing several projects, primarily in the Gulf of Mexico, that stand to increase capacity by as much as 70% by 2027 and perhaps much more by the end of the decade if all proposed projects come to fruition.[187]

Future supply: Modular LNG and fast LNG

These LNG developments around the world aren't simple enterprises. Logistical challenges arise wherever natural gas is not concentrated in commercially viable amounts, which makes extraction feasible only in a limited number of deposits and regions. Inefficient or "stranded" gas covers parts of the planet where it is too difficult, expensive and/or unsafe to discover and exploit. Transporting the fuel from viable natural gas deposits requires a global infrastructure of liquefaction plants, tanks, tankers, regasification facilities and pipelines.

Modular LNG, a more recent development, employs flexible integrated technologies in the construction of smaller scale LNG plants, which can address the logistical challenges related to extraction. These plants differ from typical LNG facilities in several key aspects tied to capacity, lower cost, shorter construction timelines, scalability and accessibility. A private contractor has been developing modular LNG facilities on the Gulf of Mexico coast using technology provided by a prominent US oilfield services and equipment company and recently commissioned its Calcasieu Pass plant (Louisiana) following the briefest construction phase for any American LNG export project to date—and has three more in the planning stages.[188]

In a similar vein, one LNG logistics and delivery specialist emerged as a leader in converting portions of several Caribbean and Latin American nations' electricity generation to natural gas from diesel. This was achieved by funding plant conversion projects and signing long-term LNG supply contracts. These power plants may be able to blend in or switch to green hydrogen if economically viable, as technology improves, and as production costs come down. This company also plans to deploy modular LNG technology in their Gulf of Mexico "Fast LNG" plants.

Conclusion

The world will require fossil fuels for years to come, though investment in the field lags as governments and investors turn their attention to renewable energy projects and away from fossil fuels. In examining the size and scope of the problem, our analysis implies the transition is likely to take longer than expected and rely more heavily on natural gas production and utilization than many might otherwise surmise. Natural gas offers myriad benefits as a bridge fuel, and key development projects and supporting logistics are being rolled out across the world. As energy investors, we see opportunity here in natural gas production, infrastructure and transportation as global stakeholders partner to meet consumer demand while working toward societies' climate change goals.

Investment synthesis: New energy drives economies and investment portfolios globally

Stephen Dover, CFA
Chief Market Strategist, Head of the
Franklin Templeton Institute

Energy pricing, production and transportation significantly drive the global economy, with energy spending estimated at 13% of global gross domestic product in 2022—a significant jump of 1.3× spending levels in 2018 and almost threefold the average from 1900 to 2020.[189] Low-cost energy is a growth engine for many economies, with low-cost renewables emerging as a primary new growth catalyst. As costs of renewables approach and continue to drop below traditional fossil fuel costs, numerous investment opportunities emerge.

New technologies are accelerating the renewable energy transition while reducing environmental impacts. The renewable energy sources of today and the future require new and smarter technologies as well as the rapid creation of new infrastructure. These challenges create investment opportunities throughout development and deployment cycles.

Energy as a keystone

Energy will be a key source of investment themes in coming decades because of its integral role in all functions of the global economy. Investment themes within energy will cover all aspects of its use, including production and storage.

This is a time of innovation in the sector—more than many investors realize. For investors, many fertile ideas can produce attractive investment results. The investments themselves will come in a variety of investment vehicles and capital structures. Investors need to be prepared to utilize both public and private instruments across asset classes. These types of investment opportunities require robust research to identify the best ideas and business plans.

As traditional energy sources shift toward newer technologies and options, an investor's approach needs to adjust to identify the best opportunities across the industry given the potential risk and reward. In reviewing the exciting developments in the energy field within this piece, some key themes stand out as particularly strong, including innovations driving growth in the energy sector.

Nearer-term opportunity in bridge solutions

There are opportunities in both bridge solutions that temporarily fill in for traditional energy approaches as well as in long-term solutions for new, replacement energy technology and renewables. We see both contributing to the changing investable landscape of energy sources. Some of the bridge solutions that look attractive include natural gas, sustainable airplane fuels and increased energy efficiency from the use of artificial intelligence and battery storage.

Sustainable airplane fuels

As an example, aircraft are essential to economic trade, transportation and travel. Aircraft today are increasingly efficient, even as they account for 2% of human-generated carbon dioxide.[190] As the aviation industry seeks more efficient energy solutions, the use of sustainable aviation fuel (SAF) seems to be a widespread bridge solution. As standards become more stringent, companies may move to the use of high-blend (ratio of SAF in jet fuel) SAF, contributing to growth in industries supporting SAF, such as power-to-liquids (PtL) technology development and SAF production and blending infrastructure.

Natural gas

There is a need for bridge options between traditional fossil fuels and renewable fuels to fill a projected interim gap, as more stringent standards on the use of fossil fuels are combined with the lead time needed for renewable fuels to become available for general use. Natural gas is plentiful and burns the cleanest of traditional fossil fuels.[191] It is likely to play a larger interim role in the transition to renewable energy sources as a result.

Artificial intelligence's (AI's) role in energy efficiency and cost-effectiveness

Irrigation challenges in agriculture

Agriculture accounts for 70% of the world's freshwater use[192]—much of which must be moved from source to fields. In many cases, we still depend on *ancient technology*, such as dams and aqueducts, to move and store water. Getting water to the right place is challenging with such old "technology"—not to mention that water is heavy. As a result, moving water for agriculture accounts for nearly 20% of US energy consumption.[193] Clearly, this is an area where gains can be made in the application of smart irrigation technology. Applying AI in irrigation technology could not only potentially increase crop yields by 7% to 9%; it could do so while also reducing energy consumption.[194]

Energy grids may bring new life to "boring" listed utilities

As an increasing percentage of the energy production mix comes from renewable sources such as wind, solar, geothermal or offshore hydro, these new sources need to be integrated into existing energy distribution grid systems. Additionally, these new renewable "farms" are often distributed across widely dispersed geographies, rather than centralized locations (read: power plants), like we have seen in most traditional fossil fuel–dependent sources. Moving energy to end users will therefore require expansion of power transmission networks. An increased demand for electricity in transportation and industry accompanies this growth. These combined forces require electrical network investment in areas such as additional storage, transportation and smart grids to optimize energy efficiency in real time. Smart grids can help manage the intermittent nature of many forms of renewable energy sources as well as manage the costs of bottlenecks within the networks.

Across the globe, many countries are implementing various approaches to energy transition ranging from sticks (regulatory taxes and fees) to carrots (as incentives). They are introducing these incentives at notably different speeds and subsidy levels.

Carrots, not sticks, create higher growth

Across the globe, many countries are implementing various approaches to energy transition ranging from sticks (regulatory taxes and fees) to carrots (as incentives). They are introducing these incentives at notably different speeds and subsidy levels. To fully understand a security's valuation and earnings potential, analysts will need to understand and value the regulatory environment and the impact of either carrots or sticks on each firm's projected earnings.

Subsidies create outpaced solar growth in Japan and Germany

Incentives (carrots) have spawned growth in new industries at a pace significantly faster than without them. For example, governments in both Japan and Germany offered loans and capital in the 1990s to incentivize solar development. Japan's solar rooftop subsidy program, introduced in 1994, is credited with driving down costs of solar installations by more than 65% in the following decade.[195] Germany implemented government feed-in tariffs to drive solar energy deployment in the 1990s through 2000s. These tariffs guarantee a certain level of financial benefit for each unit of electricity that renewable sources, such as solar panels, produce. Germany's solar installations exploded, ranking it first globally among countries' share of installed solar capacity.[196]

The "green vortex" is...Texas! Surprised?

The most well-known "stick" is carbon pricing, which has been implemented for decades, but rarely at scale. However, we are forced to examine the effectiveness of carrots when reviewing the impact of renewable energy growth in the US state of Texas. The phrase the "green vortex" describes the accelerating combination of technology advances based on the appeal of green profits that government subsidies kick-started.[197] Following an initial subsidy, these green-vortex businesses rely on classic incentives to direct capital to the best opportunities.

An investor may find opportunities across the globe in public or private markets, across equity, debt and credit instruments. These plentiful opportunities represent unique approaches to reducing carbon use and increasing renewable energy supplies, storage and transportation. With careful research, we believe investors can identify good potential opportunities in the expanding energy industry.

Why such interest in the impact of the green vortex? For the first quarter of 2022, Texas led the United States in renewable energy production, accounting for over 14% of the US total.[198] Surprisingly, Texas, while still tied to its fossil-fuel industrial history, is producing almost twice the electricity from renewable sources as from coal.

Agglomeration accelerates a new scale in renewable industries

Agglomeration is a condition of vertically integrated supply chains with materials and steps of production designed to take place near to each other. China's government employed agglomeration to incentivize solar panel manufacturing. Manufacturers were granted access to subsidized land and modern manufacturing infrastructure, which were partially financed with tax cuts and additional special financing. And key raw materials are located near production sites. This all aided in the achievement of scale, which lowers costs and improves quality.[199] The efforts in China, using incentives with agglomeration, led solar photovoltaic production to increase 500 times in 16 years.[200] As the renewable industries develop, watching for opportunities with agglomeration (in materials, supply chains and incentives/subsidies) should produce scale and payouts more quickly.

Many roads lead with hydrogen

Hydrogen is cited in a broad number of electric applications as a possible technology of the future. As with all new technologies, it is not clear how quickly challenges of production—high current cost, water use, storage and transportation needs—will be overcome. But the broad number of industries looking to hydrogen bears some research.

Hydrogen may fuel green steel as well as other industries

Currently, the steel industry accounts for 7% of global carbon emissions, but it could rise to 44% by 2050 if the industry's traditional technology is not transitioned to cleaner fuels.[201] Using green hydrogen—produced with renewable energy sources—in the manufacturing process could produce so-called "green steel," and emissions could fall by 54% over this period. The challenge with this solution is the cost, which requires an investment of an estimated US$2.8 trillion to decarbonize the steel industry, globally.[202]

Emerging markets have the highest emission levels associated with steel production. The raw materials used to produce steel vary depending on a particular country's stage of industrial development. In developed markets, steel production generally relies on scrap steel. But in emerging markets, where scrap steel is not as readily available, there is a greater reliance on iron ore and coal fired in a blast furnace to produce steel.

There are a number of industries with particularly high emissions that may also look to hydrogen for decarbonization. Some of them include fertilizer production, mining, cement, transportation and glassmaking.

Investing in renewables for a more energetic portfolio

The global economy's shift toward more renewable energy is well underway, with a myriad of different approaches and technologies. There will be potential investment opportunities in bridge solutions and emerging technologies, as well as new and larger-scale renewable energy approaches. As companies grow or change, they will seek investment in various ways depending on their capital structure needed for growth. The scale of change is global and impacts not just energy but all business. Such a thematic shift creates many investment opportunities. An investor may find opportunities across the globe in public or private markets, across equity, debt and credit instruments. These plentiful opportunities represent unique approaches to reducing carbon use and increasing renewable energy supplies, storage and transportation. With careful research, we believe investors can identify good potential opportunities in the expanding energy industry.

Endnotes

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WHAT ARE THE RISKS?

All investments involve risks, including possible loss of principal.

The views expressed are those of the investment manager and the comments, opinions and analyses are rendered as at publication date and may change without notice.

Fixed income securities involve interest rate, credit, inflation and reinvestment risks, and possible loss of principal. As interest rates rise, the value of fixed income securities falls.

Equity securities are subject to price fluctuation and possible loss of principal.

Investing in the **natural resources sector** involves special risks, including increased susceptibility to adverse economic and regulatory developments affecting the sector—prices of such securities can be volatile, particularly over the short term.

Small- and mid-cap stocks involve greater risks and volatility than large-cap stocks.

International investments are subject to special risks, including currency fluctuations and social, economic and political uncertainties, which could increase volatility. These risks are magnified in emerging markets.

Sovereign debt securities are subject to various risks in addition to those relating to debt securities and foreign securities generally, including, but not limited to, the risk that a governmental entity may be unwilling or unable to pay interest and repay principal on its sovereign debt.

Investments in **fast-growing industries** like the technology and health care sectors (which have historically been volatile) could result in increased price fluctuation, especially over the short term, due to the rapid pace of product change and development and changes in government regulation of companies emphasizing scientific or technological advancement.

Real estate securities involve special risks, such as declines in the value of real estate and increased susceptibility to adverse economic or regulatory developments affecting the sector.

Any companies and/or case studies referenced herein are used solely for illustrative purposes; any investment may or may not be currently held by any portfolio advised by Franklin Templeton. The information provided is not a recommendation or individual investment advice for any particular security, strategy, or investment product and is not an indication of the trading intent of any Franklin Templeton managed portfolio.

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