



accenture

Decarbonizing Energy: From A to Zero

Section 1
Resetting the destination



A practical guide to navigating the decarbonization process. Make the move towards a more affordable, sustainable and available future.

We call it positive energy.

Decarbonization of the energy system—from a hydrocarbon-based to a sustainable, low-carbon energy system—poses an existential threat to the oil and gas industry.

It also presents oil and gas companies with new portfolio opportunities to build adjacent businesses, shape and participate in new markets, and drive new sources of value from existing assets and capabilities. No company can afford to sit on the sideline.

The core climate-related target, agreed at the 2015 Paris Climate Change Conference, is to hold the global average temperature increase this century to within 2°C (3.6°F) of pre-industrial levels⁷. The Paris Agreement has formed the backdrop for much of today’s greenhouse gas narrative and also serves as the standard against which country and company sustainability commitments are judged. Nationally declared commitments (NDCs) are also used to describe sustainability goals, but they typically fall short of meeting the Paris target.

In recent years, as understanding of the climate change imperative¹ has accelerated, we’ve seen greater alignment and consensus across the scientific, political and business communities around the need to control

greenhouse gas emissions. Against this backdrop, there’s a strong business case for oil and gas companies to change what they do and how they do it.

At the beginning of 2020, Accenture analysis found that global energy-related CO₂ emissions totaled 40 GT². Nearly two-thirds of those emissions were related to oil and gas; coal was largely responsible for the remainder. Of the two-thirds emissions attributable to oil and gas, activities around extraction, processing, transportation and refining accounted for around 20 percent. The other 80 percent occurred when hydrocarbons were converted for other uses such as fuel for transportation or heat, or in the production of petrochemicals.

The imperative for oil and gas companies is to take actions that will limit not only the 20 percent of emissions that occur in their operations (Scope 1 and 2 emissions), but also the 80 percent of emissions that occur beyond their operations at points of conversion or consumption (Scope 3 emissions)².



The “scope” framework for classifying emissions*

The scope framework for emissions was introduced in 2001 by the World Resources Institute and World Business Council for Sustainable Development as part of their Greenhouse Gas Protocol Corporate Accounting and Reporting Standard. The three scopes allow companies to differentiate between the emissions they directly create and have control over, versus those they contribute to only indirectly.

Scope 1

Emissions are directly associated with a company’s operations. For oil and gas companies, these include emissions from methane leaks, gas flaring and refining processes, as well as those associated with transporting their products.

Scope 2

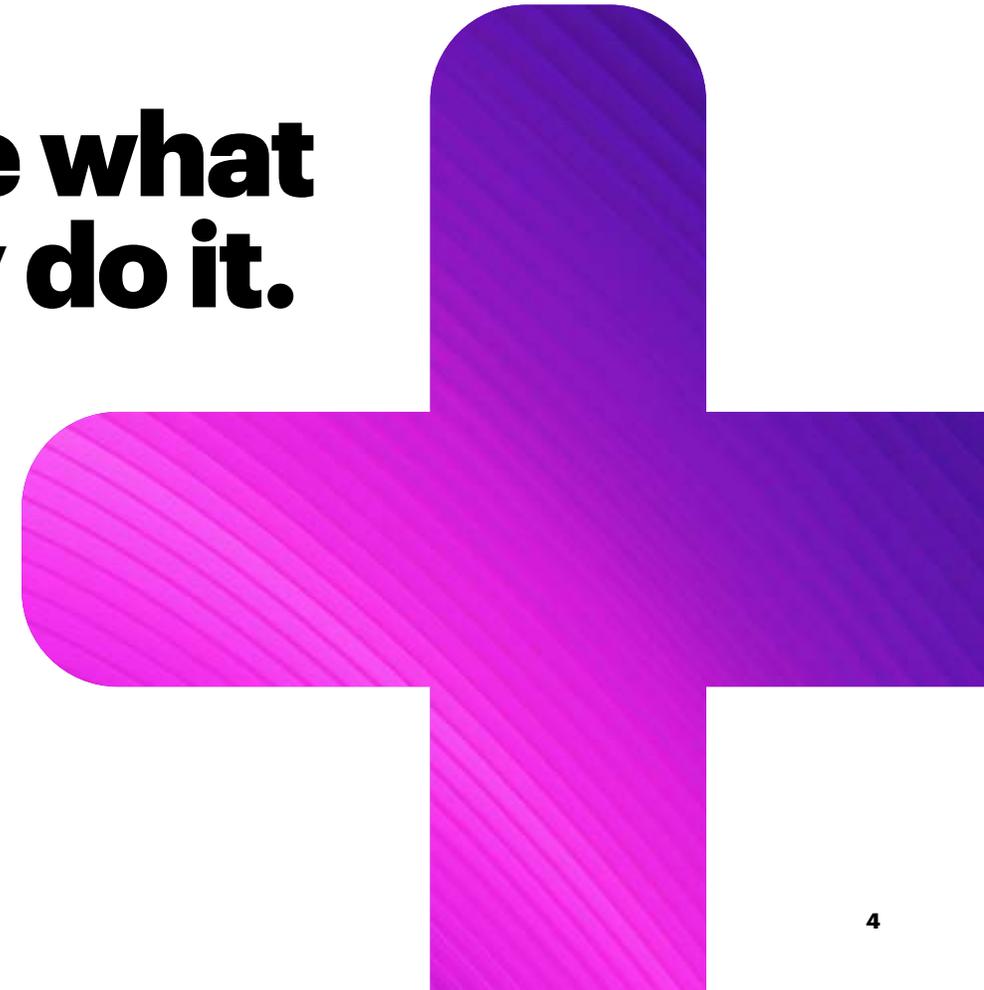
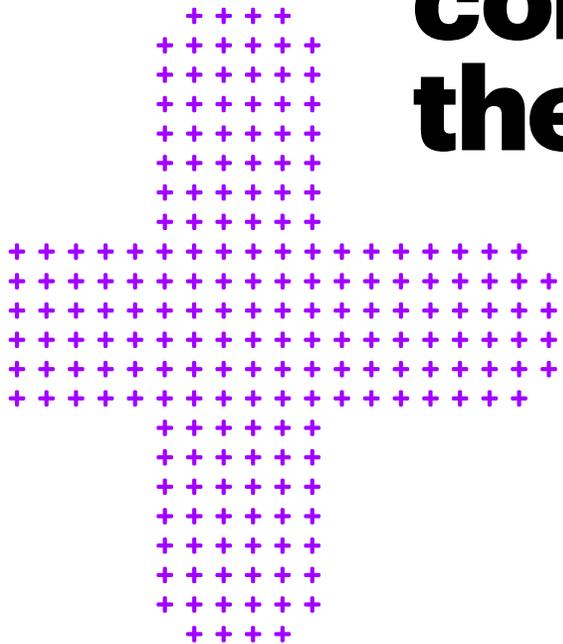
Emissions are just beyond a company’s immediate control and typically include emissions associated with the energy used to power operations. The emissions footprint of the electricity used depends on the carbon intensity of the generation. A company can reduce its Scope 2 emissions by: lowering its energy demand; sourcing electricity with renewable, onsite alternatives; replacing fossil energy sources with lower-emitting fossil fuels; or shifting to lower carbon-intensity electric power.

Scope 3

Emissions are associated with the consumption of the product. For oil and gas companies, these occur primarily within the transportation, industrial or power sectors and within their supply chains at the point of hydrocarbon combustion.

* Excluded from the scope of this paper are the contributions of natural sources—for example, peat bogs, forests and grasslands, the absorption of CO₂ by the oceans—as well as the role of agriculture. Although those factors are critical to our understanding and our ultimate outcomes, the relative inability of the energy industry to directly influence these components of the global CO₂ system led us to focus on the controllable aspects of the challenge directly ahead.

There's a strong business case for oil and gas companies to change what they do and how they do it.





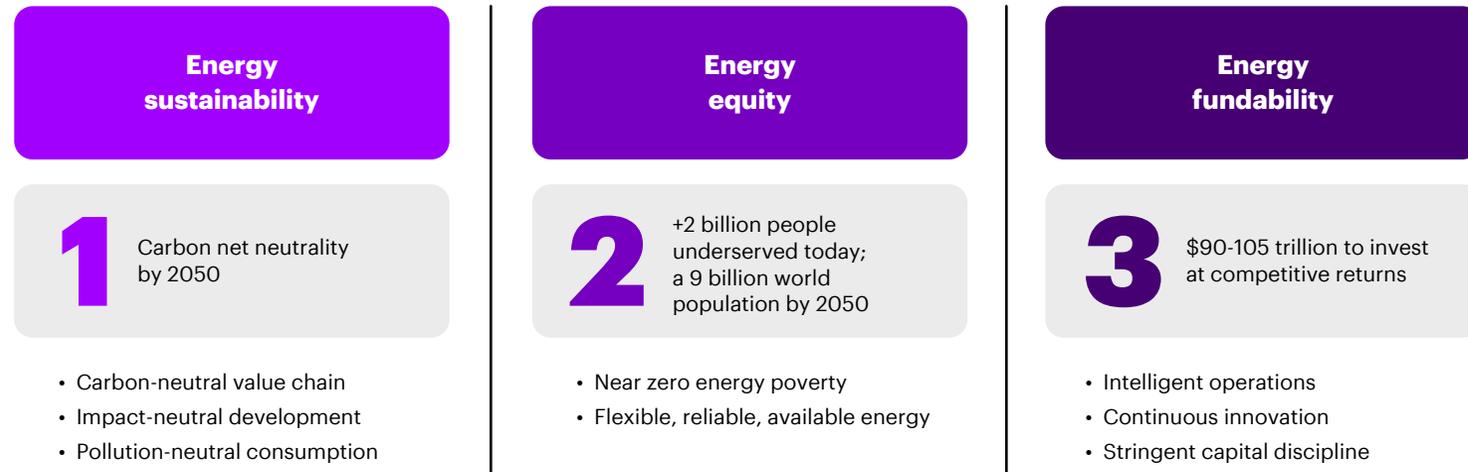
Balancing sustainability with equity and fundability

Successfully navigating the Decarbonization Transition is about more than achieving emissions-reduction targets and ensuring sustainability through carbon net neutrality, nitrogen oxide reductions and environmental stewardship. It's also about ensuring equity

in energy access to enable global growth and improve living standards. And it's about ensuring fundability of the transition. Companies will need to generate competitive returns to attract the infrastructure investments the transition will require.

Figure 6

Three requirements for the Decarbonization Transition



Energy sustainability

Sustainability requires steady movement toward a carbon net-neutral energy system by mid-century, as well as the curtailment and elimination of processes that release emissions that negatively impact the environment. Our analysis finds that as much as 80 percent of the energy system's emissions can be eliminated by 2050².

There are three possible scenarios that energy-related supply and consumption sectors may find themselves in on their sustainability journeys between now and 2050.

In one scenario, no clear pathway emerges. Sectors such as aviation—which require energy-dense, yet transportable solutions—will likely not have developed fully scalable, zero-emission alternatives that can compete with hydrocarbons by 2050.

In the second scenario, a few pathways may emerge. In energy-intensive industries such as steel, mining and chemicals, net-zero solutions will be available. But they will co-exist with today's hydrocarbon-based energy system. Success will be based on a combination of technological advances, aligned regulations and policies, consumer preferences for low-carbon products, and the complementary deployment of carbon capture, utilization and storage (CCUS) solutions.

In the final scenario, multiple pathways emerge but full transition will require more time and investment. Sectors such as light vehicle transportation and buildings will have mature solutions beyond today's hydrocarbon-based approaches, for example, connected autonomous shared electric (CASE) battery-powered vehicles. While a complete

Decarbonization Transition is possible, the timing of the transition will depend on how quickly a sector can phase out existing capital stock. In the light vehicle transportation sector, for instance, existing internal combustion engines have a lifespan of about 10 to 20 years.

Sustainability is not cheap. The cumulative investment required through 2050 to meet nationally declared commitments is close to \$95 trillion. An incremental \$10-15 trillion investment is required to scale up renewable and clean energy solutions to achieve the 80 percent emissions-reduction target⁸. This figure, however, may be partially offset by lower fossil fuel subsidies assumed in the future energy mix.

Energy equity

Oil and gas companies need to ensure that a move to decarbonized solutions improves access to reliable, affordable energy. The global population is expected to grow from seven billion today to over nine billion by 2050⁹. That growth will occur primarily outside of today's developed economies, in nations where energy consumption is rising sharply. At the same time, up to two billion people are expected to move out of energy poverty and gain access to modern energy systems. Today, per capita energy consumption in the developed world is up to seven times higher than in developing countries¹⁰.

Meeting this growing need equitably and with low prices while maintaining progress on sustainability is fundamental to a successful energy transition. Pathways and speed of migration will differ from country to country, depending on their starting points and access to resources. The extent of international energy policy coordination, technology transfer, and alignment of energy transition agendas will affect their momentum.

Energy fundability

Our estimates place the operating expenditure (OPEX) and capital expenditure (CAPEX) required to support the Decarbonization Transition at between \$3 and \$3.5 trillion per year through 2050¹¹. A significant portion of this investment will be dedicated to building out the energy transmission infrastructure. Significant spending will need to occur across upstream, midstream, generation and energy management, spanning every type of energy supply, including hydrocarbons. But the sector will only be able to attract this investment if there can be an expectation of a competitive return.

Accenture analysis has shown that energy infrastructure investments have traditionally achieved payback within 10 and 15 years and positive cashflow within four to seven years⁵. However, over the past decade, few oil and

gas companies have generated sufficient cash from their operations to meet their annual CAPEX requirements and also return cash to shareholders. More recently, margin declines and the COVID-19 pandemic have further limited the industry's ability to fund long-cycle investments. Investments in oil and gas are expected to drop by over 30 percent in 2020, compared to 2019¹², whereas investments in the power sector are only estimated to drop by 10 percent¹³.

In short, the industry's struggle to attract capital will continue. In response to this challenge, industry leaders have started to explore shorter-cycle investments, asset-light business models and alternate funding structures. They are also focusing on delivering against holistic environmental, social and governance (ESG) commitments. More actions are needed.

The transition of all transitions



Previous transitions were characterized by supply shifting from one dominant source of energy to a newly abundant energy supply source—one offering clear advantages such as higher energy density, greater transportability, higher reliability, or lower extraction and processing costs. By contrast, the future energy mix after the current transition will be characterized by lower energy density, less transportability and, in some sectors, higher initial extraction and processing costs.

To date, policymakers, regulators, the scientific community and even consumers have had to step in to close the economic gap between the hydrocarbon energy system and the low-carbon system. This transition is an energy system transition, not a supply-centric one, and it is distinguished by placing decarbonization at the core.

Figure 7

This transition is different

Accenture’s analysis has confirmed the importance of collectively adopting a pragmatic, commercially investable, action-oriented approach to tackling emissions—all with a clear focus on executing the move at scale. Time is of the essence. Companies that act now will not only lead the decarbonization charge toward 2050, but also reposition for commercial success for many years after.

Further, we have identified four variables that will determine the success of the Decarbonization Transition: new infrastructures; new technologies and ecosystems; new markets and regulations; and new behaviors and customers.

	Previous energy transitions	The decarbonization transition
Goals	Supply-driven: discovery or creation of a better energy source	Demand-driven: need to decarbonize consumption ◀ Demand is harder to influence than supply
Proponents	Asset owner-driven: pursuit of value creation	Society- and stakeholder-driven: pursuit of environmental betterment ◀ Imperative for change goes beyond (near-term) financial results
Scope	Sector-driven: certain fuel sources and sectors in certain geographies	Globally-driven: required across all sectors and geographies ◀ Distributed responsibility for coordinated action
Timeframe and economics	Classical economics-driven: 50 years of innovation and 50 years of diffusion	External- and deadline-driven: race against 2050 emissions reduction goal ◀ Need for new markets and repricing

Source: Accenture Analysis

Variable 1: New infrastructures

The pace of the current Decarbonization Transition—like all transitions that came before—will be largely determined by how quickly a new infrastructure can be created to support the processing and distribution of the incoming energy supplies. The new infrastructure is needed to meet the changing needs of low or net-zero emissions oil and gas production; support future fleets of electric vehicles (EVs) and hydrogen-powered mobility; accommodate the addition of variable renewable power (VRE) through increased grid flexibility and dispatchability; and support production of new fuels such as biofuels.

To date, the majority of low-carbon investments have been either small (<\$100 million) or modular collections of individual assets complementing existing assets and infrastructures¹⁴. The model for larger clean energy projects, or those exceeding \$5 billion, has only recently started being tested and refined, with the progress made in solar power a relevant example.

The levelized cost of energy of utility-scale solar photovoltaic (PV) energy fell 13 percent in 2019 compared to 2018, taking the average cost down to \$0.068/kWh. Additionally, a fall in onshore and offshore wind over the same time period by around 9 percent resulted in average costs of \$0.053/kWh for onshore and \$0.115/kWh for offshore for newly commissioned projects. On a project level, records were set in Portugal for solar (\$16/Mwh) and in the UK for offshore wind (\$50/Mwh)¹⁵.

The “success” stories we’re seeing in solar and wind will have to be repeated across all major parts of the future energy system—with new infrastructures to support rapid build-out of hydrogen, electric vehicle (EV), CCUS, renewable and bio-based fuel solutions.

Overall, most of the \$90-105 trillion investment required in the energy system through 2050 will be related to infrastructure build¹⁶—and the ability to fund that will make or break the transition. Stimulus funding provided in the aftermath of COVID-19 may help.

Variable 2: New technologies and ecosystems

Technology and innovation have accelerated the Decarbonization Transition, and the predicted performance and cost-competitiveness of renewable and low-carbon energy resources have been repeatedly surpassed. Lower costs, in turn, have accelerated adoption. At the same time, advances in how the energy system operates, especially by leveraging digital applications, opens the door for lower-cost and more flexible solutions.

Today, we are looking to breakthrough innovations to help further the transition. Innovations that aren’t yet proven at scale or deliver the required returns are poised to Extend the Frontier of what is possible. As noted earlier, hydrogen, electricity-based fuels, biofuels, advanced industrial processes and select negative emission technologies are leading this pack.

The key difference going forward will be the ability to scale each of these technologies—and to take them toward their “theoretical maximum.” That will require extensive partnerships, or the creation of an expansive ecosystem. Neither the current energy sector, nor any adjacent sector alone, can fund the scaling of these technologies. The future technology landscape will be characterized by new types of ecosystem that include energy incumbents, technology companies and even non-traditional players such as private equity investors or cross-sector participants.

Variable 3: New markets and regulations

Our research suggests that regulations and subsidies serve as a catalyst for change and are, therefore, complementary to other efforts aimed at scaling and accelerating the transition. Regulatory and subsidy changes have focused on removing subsidies that artificially support hydrocarbon consumption. They are also leading to new clean-air policies that impact everything from fuel specifications to municipal and industrial emissions.

In some cases, policy decisions have unlocked large markets for low-carbon projects. These projects in turn drove supply economies and led to further advances in technology and performance.

Looking ahead, regulations must also be designed with an eye toward how revenue generated from carbon or emission policies will be reinvested back into the industry for the benefit of the consumer or to accelerate critical innovation in low-carbon solutions.

Variable 4: New behaviors and new customers

Individual and business energy consumers play a critical role in decarbonization programs. Accenture analysis suggests that as much as 25 percent of potential emissions reductions achievable through 2050 are dependent on collaboration between energy suppliers and their customers².

For segments such as light transportation and residential buildings, energy demand is driven by the individual behaviors of billions of people. The ability to reach these individuals with messages that explain the benefits of energy efficiency will either underscore or undermine any infrastructure, technology or regulation-based action.

The investor has emerged as a new “customer” in this Decarbonization Transition. Leading institutional funds have become increasingly vocal in their expectations that the companies in which they invest are well positioned for the transition and are leaders in delivering on ESG. Given the importance of attracting capital, boards across the energy sector are doubling down on their transition strategies and building internal mechanisms, such as linking executive and managerial pay to emissions performance.



Looking ahead: Two states of the 2050 world

Forecasting the long-term future of the energy system is a complex undertaking. But it's necessary in order to understand the actions that are required today. Accenture doesn't have a crystal ball. But we do have an objective point of view, from which we can deconstruct and understand the themes, actions and roles that will shape the Decarbonization Transition.

Based on our findings, we have developed two possible "states of the world" for 2050. One is the consequence of business-as-usual (BAU) practices and mindsets. The other depicts what we've termed the "stretch case." It represents a world derived from changes that we believe are possible, realistic and within reach. In modeling these states, we analyzed five core energy sectors, 15 industry sub-sectors, and 11 cross-sector themes.



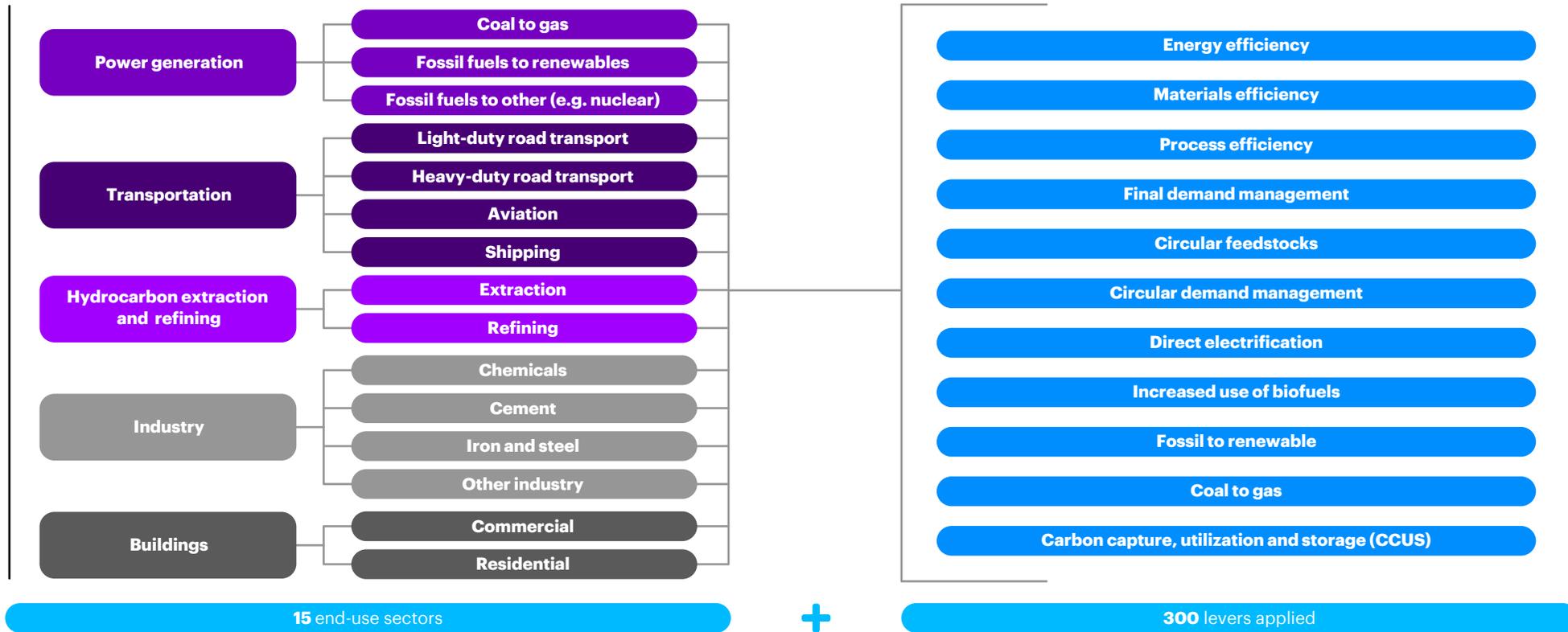
Figure 8

Source: Accenture Analysis

Accenture decarbonization scenarios

15 end-use sectors modeled for our 2050 business-as-usual emissions scenario

Emissions-reduction themes applied to each sector in our 2050 stretch case scenario



State of the 2050 world

Scenario one Business-as-usual

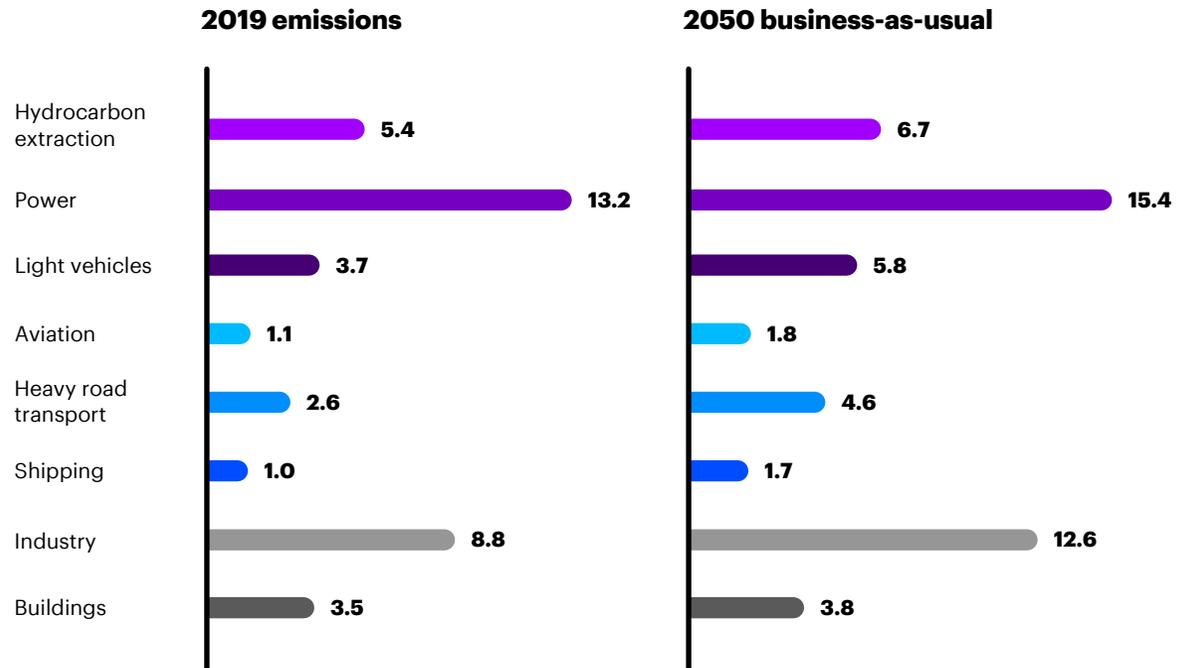


Our business-as-usual case describes the outcomes that would be achieved if the shifts already underway continue, but do not accelerate dramatically or change direction.

In this scenario, we project that global CO₂ emissions will rise by 35 percent, to as much as 54 GT by 2050². This case does not paint a very rosy future. Global CO₂ emissions increase by about 1 percent annually from 2020 through 2050¹⁷. This would rapidly overwhelm the remaining global CO₂ budget of approximately 500 GT before the middle of the next decade and, by 2050, lead to a deficit equal to twice today's remaining budget.

Figure 9

Projected emissions in 2050 business-as-usual scenario



Source: Accenture Analysis

Four sectors will drive most of the projected rise in emissions

Power

In our business-as-usual case, global electricity consumption will increase from 20 to nearly 35 percent of final consumption by 2050. Renewables will account for 59 percent of electricity generation¹⁸. Both are significant increases over today. Coal will remain a significant source of power globally and

the fuel of choice for many developing nations. While we do not project an increase in coal power consumption in the business-as-usual case, the decline will be only marginal. Gas power, on the other hand, is set to increase significantly as an abundance of cheap gas will enable electrification in emerging markets.



Transportation

Demand for transportation will continue to grow with significant increases in the aviation and light vehicle sectors (from 1.3 billion to three billion vehicles on the road). Efficiency gains in internal combustion engines (ICE) would increase from the current 0.7 percent annual improvement to about 1 percent annual improvement². Plus, significant increases in demand would occur in both shipping and heavy-duty road transportation.

Buildings

Buildings will experience modest increases in emissions. That's because the growth in demand for buildings will be offset by the increased efficiency of appliances, the switch to electricity-based consumption from gas and coal, and the improved design of buildings with more energy-efficient heating and cooling systems.



Heavy industry

The outlook for heavy industry is nuanced and sector specific. The steel industry, for example, is influenced by high demand from developing nations for primary steel. Demand from OECD nations (and, over the next decade, China) will shift to recycled steel, which, in turn, will enable cleaner electricity-powered furnaces to reprocess primary steel. Also, continued urbanization will drive continued demand for cement, with availability of alternative building materials remaining limited.

State of the 2050 world

Scenario two The Accenture "stretch case"



Our stretch case analysis prioritizes solutions that promote decarbonization, but also reduce energy demand, increase efficiency, reduce cost or control risk.

With this approach, our assessment is less dependent on yet-to-be-proven solutions and focused, instead, on addressable opportunities. In our stretch case, we assume that companies will pursue solutions that offer the highest return, require the shortest time to cash, and are most easily scalable. We have also made assumptions about energy consumption (especially electricity) and the role of renewables, coal and gas in the future.

In terms of energy consumption, the Accenture stretch case assumes that total energy consumption will peak between 2020 and 2030 and then fall to a level of around 85 percent of the 2019 level by 2050. This implies a declining energy intensity, increased efficiency in final energy consumption, and scaling up of circularity—reducing the amount of energy demanded by primary industry.

The share of final energy consumption in the stretch case would shift significantly toward electricity, increasing from 20 percent in 2019 to 45 percent by 2050. Such a transition would require electrification of multiple sectors such as transportation and buildings. The combination of growth in electricity and increasing efficiency would translate to a 40 percent reduction in the amount of energy provided by hydrocarbons through 2050. Without decarbonizing the electricity sector, electrification will fail to achieve the objectives of the transition.

A critical metric in the stretch case will be the share of renewables used in power generation. We project this to grow to as much as 91 percent by 2050. In combination with a shift away from coal and improvements in process efficiencies, we also project a 90 percent improvement in the intensity of CO₂ emissions from power generation. While the use of hydro and nuclear power will increase in absolute terms through 2050, wind and solar will contribute most to the changing electricity supply mix.

**The stretch case:
A “living” analysis**

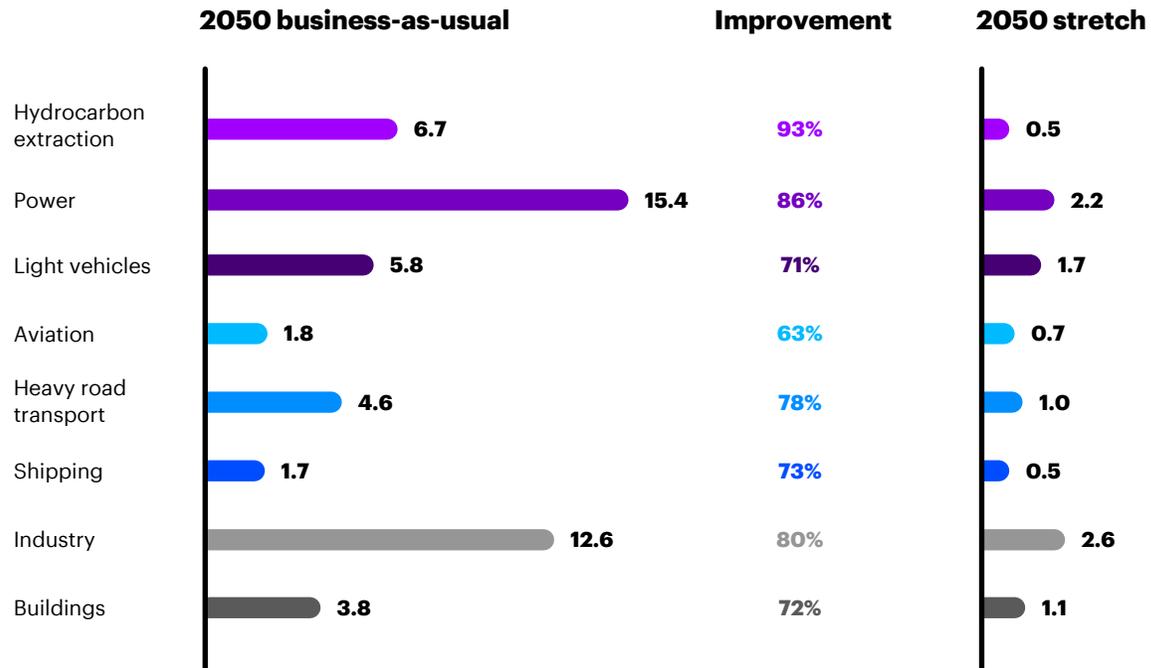
Accenture’s stretch case—which adopts an action-oriented, bottom-up approach—will be revised over time to reflect the progress made, or not made, as the transition unfolds.

For example, as we assessed the impact of COVID-19 on aviation, light transportation and industrial demand on 2020 CO₂ emissions, we found an 8-20 percent impact on emissions in 2020. This corresponds to a <1 percent impact on emissions through 2050. The destination, therefore, is unaffected, although the journey might take a different course. Our calculations will change if structural changes recently enacted become permanent and the stimulus investments made into the economy are effectively directed toward low-carbon sectors.



Figure 10

Shifts to reduce emissions from 2050 business-as-usual to 2050 stretch



Source: Accenture Analysis

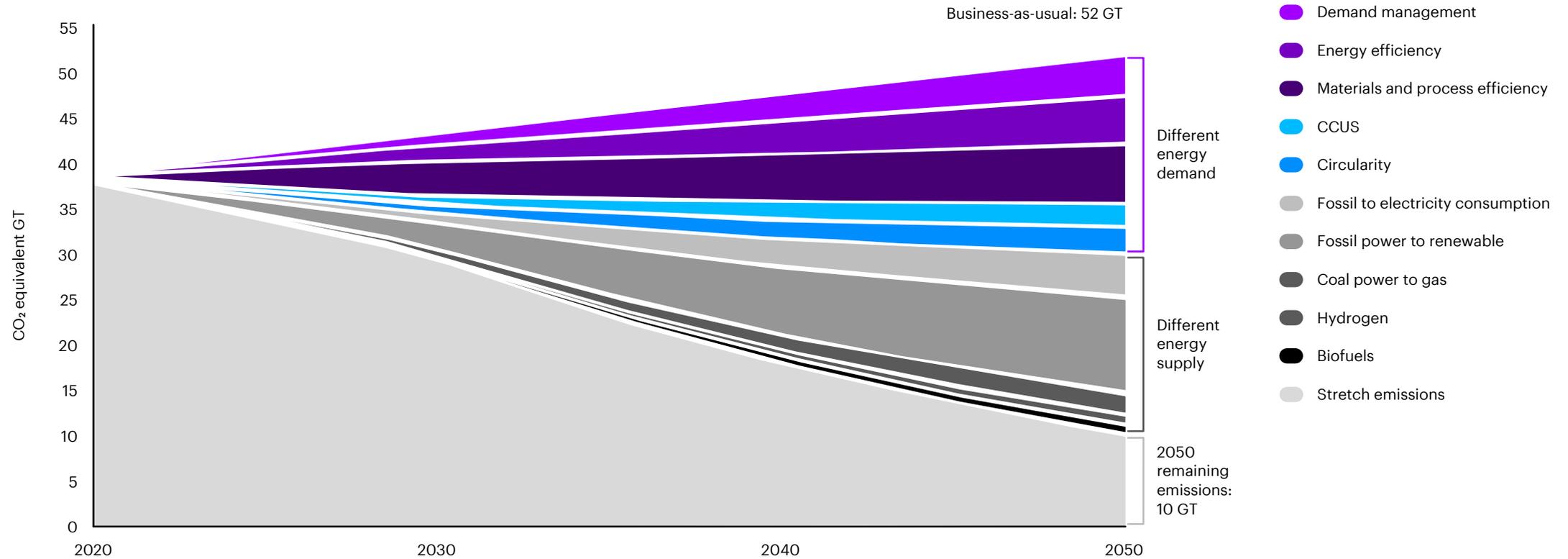
The emissions profile of the hydrocarbons used in power generation is also critical. Our stretch case identifies the near total elimination of coal in the power mix as a critical driver of emissions reduction.

The aggregated outcome of emissions scenarios is often shaped by the role of gas within the power mix. Our stretch case recognizes the importance of gas as a transition fuel and the key role it will play in providing baseload generation. Gas will be challenged, however. The economics of gas generally already lag behind coal and increasingly behind integrated renewables when used in combination with energy management solutions.

The future of gas as a destination fuel is, therefore, not assured unless it becomes significantly cleaner and more competitive. Underpinning our stretch case analyses are 10 shifts that, together, are poised to eliminate an annual 45 GT CO₂ versus the 2050 business-as-usual case. We have identified two types of shifts occurring across sectors—those that impact final energy demand and those that impact energy supply.

Figure 11

Global energy emissions shifts



Source: Accenture Analysis

Impact of stretch case shifts on final energy demand

In our stretch case, we envision 22 GT of CO₂ being eliminated by 2050 through efficiency and demand-centric shifts.

Energy efficiency (-7 GT CO₂)

Improvements in how energy is used will reduce the need for energy supply and, consequently, the emissions generated. Internal combustion engines will continue to deliver efficiency improvements in both CO₂ emissions and fuel consumption. Advances in ship hull design, aircraft design and jet engine performance will enhance energy efficiency in other transportation sectors.

Process and material efficiency (-7 GT CO₂)

Primary industries like cement, iron, steel and chemicals, are significant emitters. Advances in manufacturing techniques and replacement of high CO₂ emitting processes will lower emissions and contribute to greater process stability, predictive solutions, and continued application of lean practices. The hydrocarbon extraction sector can reduce vented, flared and fugitive emissions by improving process controls.

Final demand management (-5.4 GT CO₂)

There are opportunities to lower demand for hydrocarbons in many sectors by, for example, shortening global supply chains and reducing reliance on single-use plastics. There are also opportunities to shift demand to lower-emission solutions such as shared vehicles or using timber rather than cement in construction. Logistics efficiency, demand smoothing and more efficient design processes can also play key roles.

Carbon capture, utilization and storage (CCUS) (-2.8 GT CO₂)

While not yet widely installed, CCUS solutions have potential to scale significantly across industrial sectors and along the hydrocarbon value chain. Once an effective carbon price is introduced, gas processing, refining, LNG and petrochemicals offer the greatest opportunities across the oil and gas sector. Furnace-related opportunities in steel manufacturing may also grow.

Circularity solutions (-2.4 GT CO₂)

Reusing already processed material, reducing the demand for primary industrial processing cuts energy use and processes emissions. Primary industrial processing can require up to ten times the amount of energy used in secondary processing.

Impact of stretch case shifts on final energy supply

On the energy supply side, the largest single impact will be due to the transition away from a hydrocarbon-based electricity supply system. In combination with the shift toward electricity-based consumption, the power sector can eliminate 20 GT CO₂ emissions. The impact of hydrogen—including synthetic fuels and ammonia—and biofuels is smaller, but critical to the decarbonization of both the heavy industry and commercial transportation sectors.

Coal to solar and wind (-11 GT CO₂)

Replacing coal generation with clean wind and solar is critical to the sustainability objective of the transition. The sharp reduction in coal consumption that occurred as COVID-19 reduced global electricity demand illuminated the opportunity to replace coal with zero marginal cost and zero marginal emissions power once wind and solar alternatives are installed. Large, low-cost domestic reserves of coal will likely remain attractive and dependable energy supply sources for some nations. But it will be increasingly challenged by lower-cost renewable sources. The CO₂ intensity of electricity production is a critical global metric for the energy transition and falls by 90 percent in our stretch case scenario.

Fossil fuel to electricity consumption (-5.2 GT CO₂)

The increase in electricity consumption significantly reduces emissions and the direct combustion of hydrocarbons. The transportation sector will be a key

driver of this ongoing shift as electric vehicles are adopted at scale and the heavy transportation industry starts using batteries. Additionally, buildings will accelerate their move from gas to electricity for cooking and heating. Industry will also switch to more electricity-based solutions.

Coal to gas (-2.1 GT CO₂)

Gas, long heralded as the “transition fuel” will play a critical role. As the cleanest of the hydrocarbons, it releases approximately half the emissions of coal. Gas is poised for near-term growth. However, it is increasingly likely that gas will remain a transition, not a destination, fuel. In our stretch case scenario, it’s imperative for owners of gas assets—reserves and infrastructure—to monetize their positions quickly.

Hydrogen (-1 GT CO₂)

An energy carrier, hydrogen offers exciting clean energy opportunities such as supporting storage or providing intense heat for industrial processes. Green hydrogen,

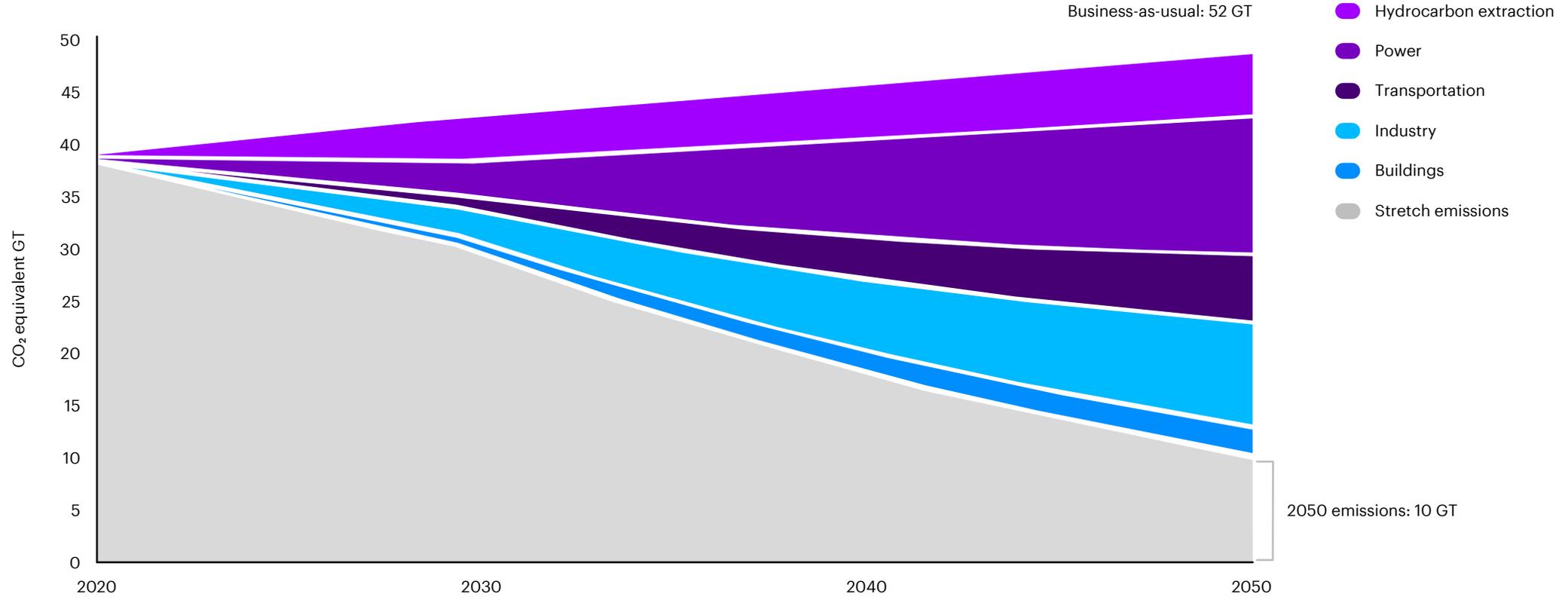
which is formed using energy from clean renewable sources, and blue hydrogen, which is formed using the steam methane reforming process, will hold more appeal. However, green hydrogen currently represents less than 0.1 percent of hydrogen currently produced and blue hydrogen 0.6 percent of today’s hydrogen supply. A six-fold improvement in efficiency is required before green or blue hydrogen can be commercially viable.

Biofuels (-0.9 GT CO₂)

Biofuels are already part of the energy mix and offer the most viable options to replace jet fuel in aviation. Although biofuel technologies are maturing, the low energy intensity of the feed places significant stress on the supply chain, thereby limiting their scope. Biofuels will be increasingly blended into transportation fuels. But because they emit more than existing electric vehicle alternatives, it is likely that the aviation sector will be prioritized.

Figure 12

Global energy emissions stretch opportunity by sector



Source: Accenture Analysis

Avoiding emissions of more than 40 GT of energy industry-related CO₂ is a complex undertaking. Accenture believes there are three approaches industry leaders and policymakers can consider when setting targets and assessing progress.

The perfect landing

This scenario is based on reducing global emissions perfectly each year to reach absolute zero carbon emissions from the energy sector by 2050. Simple in concept, but nearly impossible in practice, this pathway is unrealistic given the trajectory of emissions. A dramatic acceleration in emission reductions would be needed from 2030 to 2050.

The overshoot

While the 2050 target may not be achievable, there's the possibility of building a sustainable pathway by 2100 or so. The "overshoot" scenario defers action on the Decarbonization Transition further into the future. The nearer-term effect of climate change, and whether the impact is reversible, and the true cost of extending the transition by decades are not yet clear.

The net-zero solution

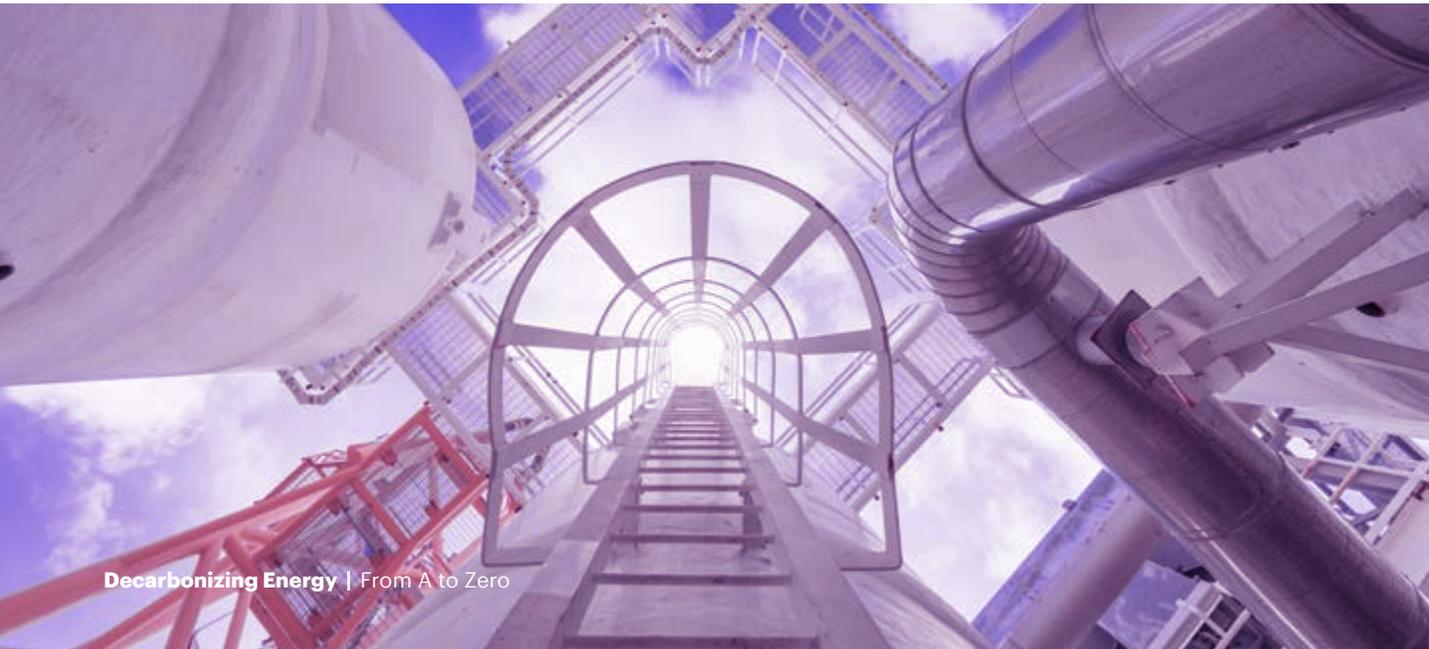
Net-zero targets do not call for an absolute zero carbon outcome. In this scenario, carbon "offsets" co-exist with carbon emissions so, in aggregate, the overall target is attained. Accenture believes this is the only approach with a realistic chance of success. It is imperative, however, that offsets are not seen as a license to emit in the near term.

Successfully navigating the Decarbonization Transition requires oil and gas companies to maintain their commitment and momentum, a sense of urgency, and realistic—yet "stretch"—expectations. Working toward a net-zero solution, but with an understanding that an overshoot may happen, creates the optimal conditions for success.

Achieving the Decarbonization Transition

Achieving the global net-zero goal requires both aspiration and action. But which actions will be the most impactful, investable and executable? In other words, which actions are most likely to happen?

The short answer is those that offer attractive returns, leverage existing infrastructure and value chains, and can be funded. We have identified these as Clean the Core actions, or the ready-to-go actions that eliminate or mitigate emissions from today's energy system. And because they tackle cumulative emissions, rather than annual emissions, they are highly relevant.



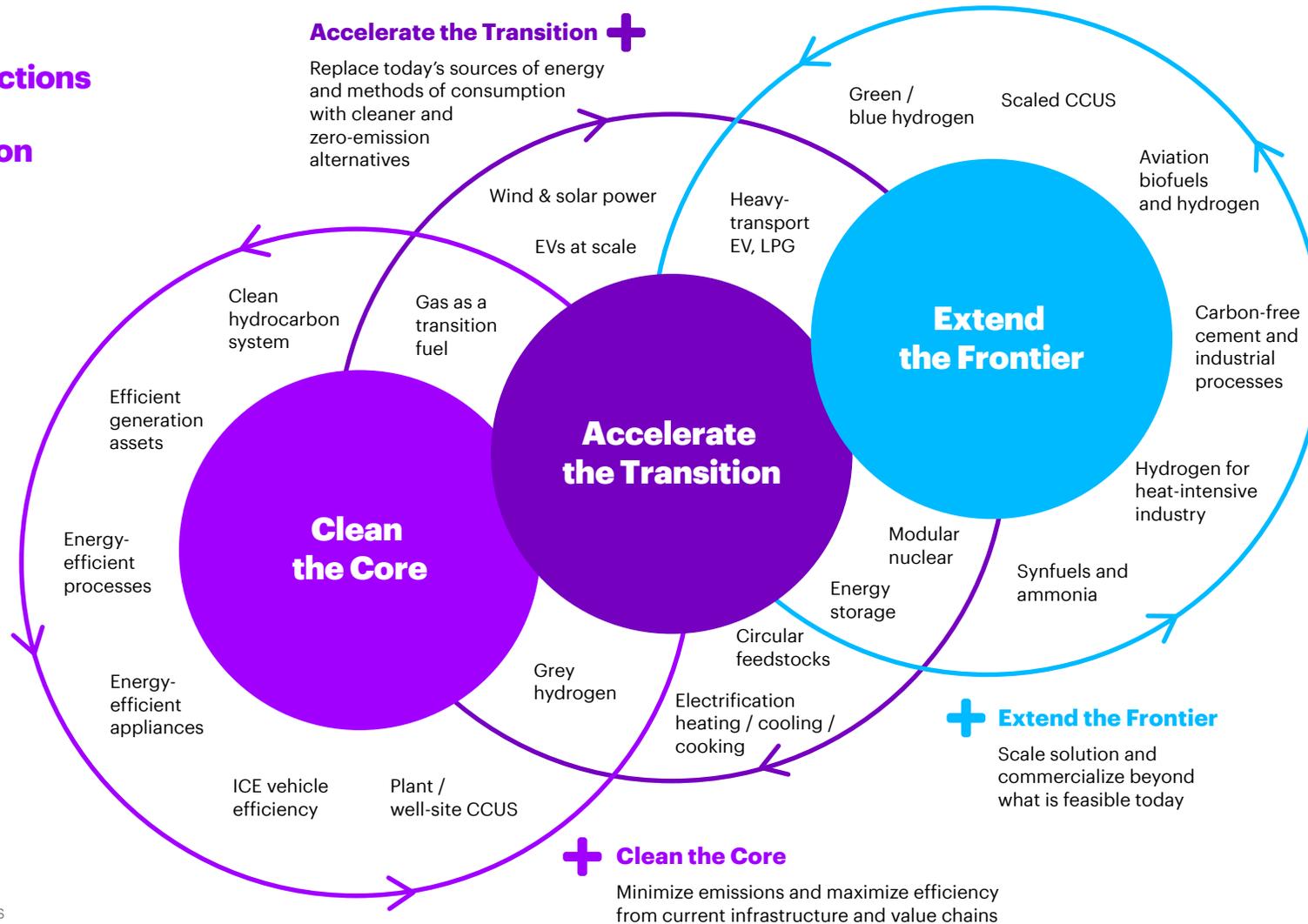
Beyond Cleaning the Core, there are other proven and commercially viable actions that will usher in lower-cost, higher-performing and cleaner energy consumption solutions. These actions Accelerate the Transition. Companies that accelerate and scale their adoption will accelerate their decarbonization transitions. Accelerate the Transition actions include: switching supplies from coal to cleaner gas and renewable electricity; replacing today's internal combustion engine vehicles with battery-powered and low-carbon solutions in transportation; and replacing existing feedstocks with recycled alternatives that require less processing energy or release fewer in-process emissions.

The other set of actions will Extend the Frontier by providing solutions that overcome otherwise unabatable energy emissions challenges or that satisfy demands that currently can only be met through fossil-based energy supplies. Such solutions will materialize over time and contribute significantly to the transition as they achieve viability at scale. These actions include: the development and commercialization of green and blue hydrogen; biofuels for aviation and shipping; electricity-based fuels such as ammonia and synthetic fuels; advanced clean industrial processes; and in-situ CCUS solutions beyond what is technically and economically feasible today.

Because they depend on yet-to-be-proven solutions, Extend the Frontier actions are naturally less certain and riskier—both in terms of their economic returns and scalability. We believe they hold tremendous potential to close the gap to net zero. But they will require significant investments and will play a limited role in reducing emissions through at least 2035. This does not imply they should be dropped from consideration—it simply suggests that they are likely to be applied to, or only complement, an energy system that has already acted to Clean the Core and Accelerate the Transition. After 2035, however, Extend the Frontier actions will start to multiply and their relevance will only grow to 2050—and beyond.

Figure 13

Three sets of actions to achieve the Decarbonization Transition



Source: Accenture Analysis



Actions to Clean the Core

The Decarbonization Transition has sometimes been perceived as dependent on future technologies and aggressive market interventions. Our assessment takes the opposite view.

The largest share of the potential emissions improvement between now and 2050 will be due to actions that improve the performance of today's core energy supply and demand assets². This underlines the pivotal roles that today's oil and gas industry and energy consumption sector play in leading the transition.

Our stretch case analysis identified that certain actions—maximizing efficiency, managing demand and enhancing operating practices—can help leaders achieve as much as a 21 GT improvement in CO₂ emissions² by 2050. Remarkably, this is roughly equivalent to half today's total emissions.

But Clean the Core actions do not need to be justified solely on their emissions benefits. They can typically reduce operating and maintenance

costs and also support development of new markets. That, in our view, increases the likelihood that they will be successfully adopted and scaled.

Clean the Core actions offer the greatest potential impact in asset-intensive industries such as hydrocarbon extraction and processing, for example, to reduce vented, flared and fugitive emissions. Additionally, improvements in energy demand efficiency along the oil and gas supply chain will lower energy costs, while driving out emissions. As the oil and gas industry evolves to internalize the cost of carbon, it will reorient toward those resources and opportunities that offer the best combination of margin, cashflow and carbon—creating a naturally self-reinforcing dynamic toward a lower carbon footprint.

Heavy transportation—including the shipping, commercial road and aviation sectors—will benefit significantly from cleaning their core as portions of their vehicle stock switch to lower-emission at-the-wheel solutions. From a global emissions perspective, the potential impact of actions to improve engine and fuel efficiency, manage transportation demand, and increase the shared utilization of transport outweighs the impact that the transition to electric vehicles will have.

Demand sectors such as aviation or cement, which have not yet identified a plausible pathway to decarbonize, will see most of their improvements come from Clean the Core actions.

Actions to Accelerate the Transition

These actions pivot their organizations toward low-carbon, renewable energy sources, both for supply and demand.

In our stretch case, Accelerate the Transition opportunities represent over 45 percent of the potential improvement in emissions through 2050. These are evenly split with an approximately 10 GT reduction from the power sector and another 10 GT from direct consumption sectors².

The rising share of energy consumed as electricity is one of the core pillars of the Decarbonization Transition. How that energy is produced is fundamental to the success of the transition, with a failure to decarbonize electricity putting the entire transition at risk, if not rendering it impossible. There are two transition opportunities. The first involves replacing coal, especially as baseload, with cleaner gas. The second involves increasing the proportion of intermittent, variable renewable power in the generation mix.

Gas deserves a special mention. It has become a global fuel, available to faraway markets through international pipelines and liquid natural gas (LNG). Gas is the only fossil energy source for which there is a clear consensus

that it will exit this decade with higher volumes than when it started. Gas offers half the emissions intensity of coal when used in power, yet all of the benefits of dispatchability². Future opportunities for gas will depend on further improvements to its emissions profile.

Identified as the “transition fuel,” gas has become a central part of the decarbonization narrative for oil and gas companies. However, its security as a destination fuel for the future is much less certain. The discord around its clean credentials (due to its methane emissions, extensive flaring and venting) is reaching a crescendo. A case can now be made that the growing emissions from extracting and processing gas are outweighing its advantages at the point of combustion. Compared to CO₂, methane emissions are 30 times more potent as a heat-trapping gas over 100 years. Also, a level of release intensity greater than 2 percent can render gas less clean than coal. Furthermore, flaring has grown at a dangerous pace. In fact, the amount of flared gas in Texas alone can

supply the power needs of the entire state. Additionally, renewable sources are emerging with more attractive economics, zero marginal cost of operations, and greater opportunities for employment.

Yet, gas still has its advocates. One of the reasons gas features prominently in Accelerate the Transition actions is related to the intermittency and dispatchability challenges that renewables face. Electricity can't be generated when the sun is not shining or the wind is not blowing. And solar and wind electricity needs to be stored in order to be available during high-demand periods. In many geographies, renewables are insufficient alternatives to fossil fuels—especially for the replacement of baseload. But improvements in grid flexibility, operations and energy storage are now converging to resolve intermittency and dispatchability issues. We anticipate further progress. These solutions will not only allow significantly greater proportions of intermittent wind and solar energy in the electricity supply, but also lead to deeper cuts in emissions generated by gas.

The role of gas can be extended by decarbonizing along the gas processing value chain. Leading LNG liquefaction plants have installed advanced CCUS equipment to capture the CO₂ stripped out from the gas. And the Oil and Gas Climate Initiative has rightly established methane reduction as its primary goal and focus. Is the window for gas already starting to close?

In addition to the transition to electricity, there will be a transition to circularity. The circular economy gathers, aggregates and provides used products, feedstocks and alternatives to primary producers. This dynamic lowers both the emissions that would have been generated when these products end their life and the energy intensity required to create new products. Circularity also enables a number of other environmental benefits. For example, the steel industry is at the tipping point of a transition—moving from primary ore-based steel manufacturing in China to meeting its steel demand with recycled products that have already been used once. Recycled steel can be produced in electric arc furnaces, which opens up the possibility for low-carbon production and more energy-efficient processes.

Then there are actions around mobility. Currently the dominant source of energy demand for oil, the transportation sector will transition toward new fuels and battery solutions for both light vehicles and heavy transportation. That transition will offer up to zero emissions at the wheel and lower end-to-end lifetime emissions. The light vehicle transition from the internal combustion engine to electric vehicles is a core opportunity to Accelerate the Transition. The trajectory will depend on battery technology, charging infrastructure and platforms, and how mobility services will be consumed in the future. For heavy vehicles, the transition will likely involve integrated actions related to the use of batteries, LPG and biodiesel. But given current fuel cell availability and pricing, we consider the advent of hydrogen vehicles to still be many years off.



Actions to Extend the Frontier

Actions that Extend the Frontier are breakthrough moves that transform the cost or effectiveness of an energy solution, unlocking potential to achieve new levels of efficiency.

Importantly, these solutions can decarbonize parts of the energy system that otherwise can't get close to zero or net-zero emissions due to their reliance on hydrocarbons for energy-dense, transportable fuel.

In the coming decades, Extend the Frontier actions will be critical to the Decarbonization Transition. While delivering a smaller contribution as they ramp up over the next 10 to 20 years, they will then have the potential to make the leap from subsidized or one-off proofs of concept to at-scale businesses.

Accenture analysis found that up to 20 percent of global emissions not decarbonized by Clean the Core or Accelerate the Transition solutions can be addressed by 2050 through Extend the Frontier solutions². The absolute amount of CO₂ reduction Extend the Frontier actions will deliver, therefore, depends on whether the prior ready-to-go actions have been executed. Accenture's stretch case shows that total emissions could be lowered by Clean the Core and Accelerate the Transition actions to 11-12 GT CO₂ by 2050.

Extend the Frontier actions could further lower that by at least 2-3 GT by 2050, getting total emissions below 9 GT².

Although 9 GT is not zero, it is increasingly realistic to think that net zero will be achievable, thanks to negative emission actions that may be able to close the gap. Our analysis did not consider negative emission technologies such as direct air capture, bioenergy with carbon sequestration, or natural climate solutions within the Extend the Frontier actions set. However, we will reconsider assessing these types of technologies should they start to play a more direct role in shaping the energy system.

Biofuels provide another reason for optimism. They have emerged as the leading alternative to jet fuel for aviation. Because they can leverage existing infrastructure and be used in engines with minimal change, biofuels are attractive to an aviation sector looking to change the narrative on the carbon footprint of flying. The challenges associated with

biofuels lie in the supply chain—namely, the volume of material and amount of land required to produce the refined product. Large-scale biofuel refineries will be necessary to drive the cost to commercially viable levels. And, while those refineries come with solvable technical challenges, they will require a greater level of investment than we've seen to date.

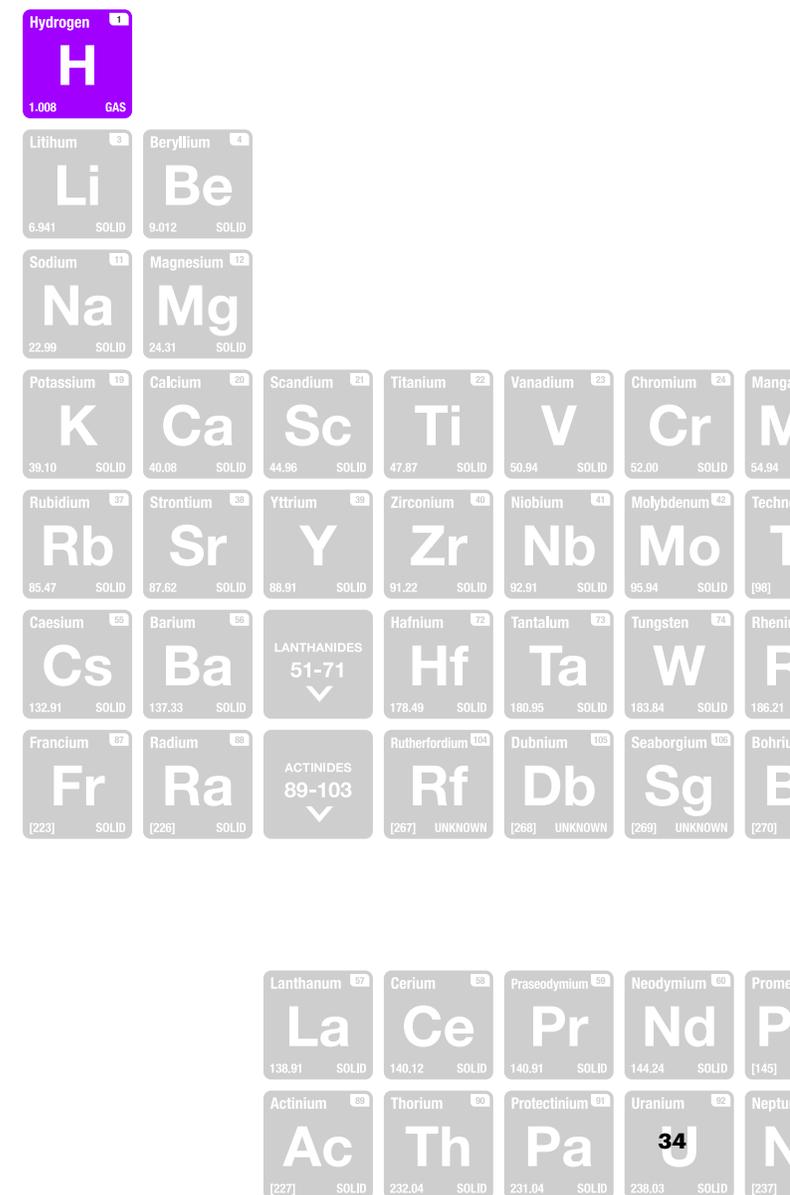
Then there are CCUS technologies, which are maturing and now responsible for capturing between 70 and 80 percent of the oil and gas industry's CO₂². They can be applied to other heat-intensive and CO₂-generating processes across industries. To date, the efficacy of CCUS solutions for lower concentrations of CO₂ streams, their cost points, and limited commercial market opportunities for the captured CO₂ have prevented CCUS actions from really taking hold. The opportunity ahead is for CCUS leaders to scale beyond the oil and gas sector as their technologies mature and support demand for uses of CO₂.

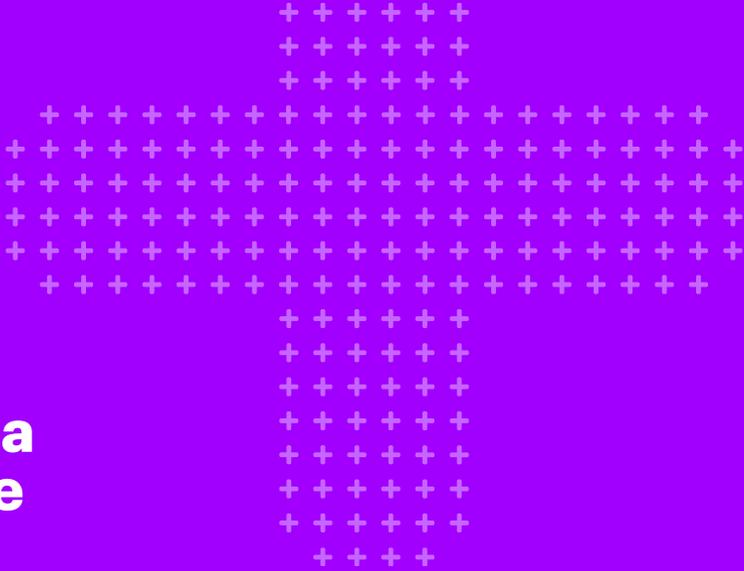
Hydrogen, too, has rightly become the focus of much investment and research. Green hydrogen—produced from water using electrolyzers powered with electricity generated from renewable sources—has the potential to be a fully zero-carbon energy carrier. While not a fuel in itself, hydrogen can be zero emission at the point of combustion. It is becoming a technologically viable form of energy storage and can deliver dispatchability for wind and solar generation when built into integrated energy projects. Green hydrogen’s challenge is cost. And while that cost has fallen, it continues to lag other competing energy sources by a factor of five or six. Currently, green hydrogen represents a very small percentage of hydrogen produced by volume. Reducing cost will be key to scaling the technology.

Blue hydrogen is produced from decarbonized natural gas using the steam methane reforming (SMR) process. Blue hydrogen is not a carbon net-zero product. However, as long as the emissions produced through the SMR process are fully captured through CCUS solutions, blue hydrogen

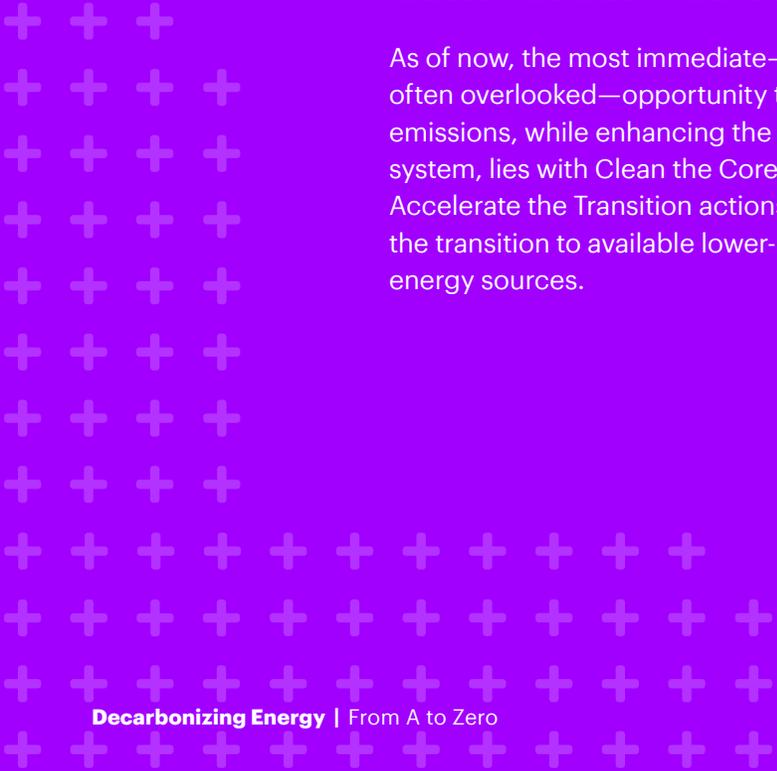
offers the advantages of an energy-dense, transportable fuel with a fraction of the emissions footprint of industrially produced grey hydrogen but at a disadvantaged cost driven by the carbon-capture process. Currently, it represents a very small percentage of hydrogen produced. But as CCUS technologies mature and potentially rising gas prices close the economic gap, blue hydrogen may scale in growth and relevance.

Extend the Frontier actions can also include pursuing specific innovations in industrial processes, such as cement production, that enable a product or its equivalent to be produced at significantly lower emissions. Electricity-based fuels, which are synthetically produced using generated electricity, can be complementary solutions to meet demand in the heavy transportation sector, typically replacing diesel or heavy fuel oil products. Although nuclear fusion can also be considered an Extend the Frontier action, we have not included it in this analysis given the uncertainty of its contribution to the energy system before 2030.



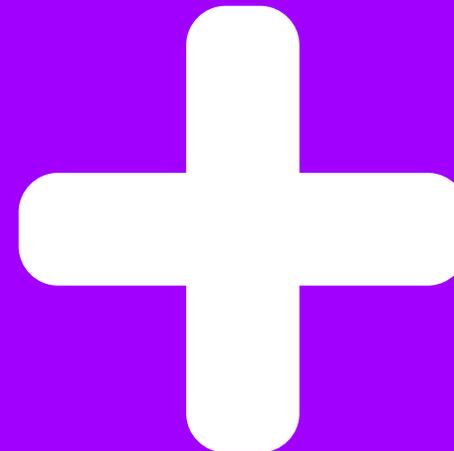


In short, the energy system requires a balance of all three action types to be on a firm trajectory toward net-zero emissions or full decarbonization.



As of now, the most immediate—yet often overlooked—opportunity to impact emissions, while enhancing the energy system, lies with Clean the Core actions. Accelerate the Transition actions will scale the transition to available lower-emission energy sources.

Extend the Frontier solutions won't be developed in time to have as significant an impact by 2050 as the other types of action. This analysis, therefore, points to the importance of collectively adopting a pragmatic, commercially investable, action-oriented approach to tackling emissions with a clear focus on execution at scale.



Accenture Decarbonization Scenarios

The Accenture global decarbonization model was constructed using a four-step approach.

- 1.** We first established the emissions base case (emissions today) for each demand sector using accredited governmental and NGO sources.
- 2.** We then projected BAU emissions to 2050 by combining the expected increase in sector demand with the expected emissions abatement on current trajectories.
- 3.** As a next step, we identified, by demand sector, the emissions reduction levers and their potential if fully implemented.
- 4.** Finally we projected a percentage reduction achieved by lever according to the remaining business-as-usual emissions it would impact (near-term levers will have a larger percentage impact than those that come later and have a reduced base to impact) and the extent to which we will be successful in fully implementing each lever by 2050.

Glossary

Term	Definition
2DC guideline	One of the key guidelines formulated during the Paris Agreement, which called for an assessment of the impact on a company's portfolio and business strategy of policies and restrictions consistent with achieving the globally agreed upon target to limit global average temperature rise to no more than 2°C above preindustrial levels.
5G	Refers to the 5th generation mobile network. It is a new global wireless standard that is designed to connect everyone and everything, including machines, objects and devices. Advantages of 5G include higher peak data speeds, ultra low latency, massive network capacity and increased availability.
Asset-light business model	A business model where the company owns relatively fewer capital assets than is required to run its operations. This is achieved by outsourcing the capital requirements by way of operating leases or other pay-per-use service models.
BAU	Business-as-usual
Bio-energy with carbon capture & sequestration (BECCS)	A carbon removal technique that includes two technologies. First, biomass is converted into heat, electricity or liquid / gas fuel and, subsequently, the carbon emissions from this conversion are captured and stored or utilized in other long-lasting products. BECCS can thus serve to reduce the overall CO ₂ concentration in the atmosphere.

Term	Definition
Biodiesel	Biodiesel is a form of diesel fuel derived from plants or animals and consists of long-chain fatty acid esters. It is a renewable, biodegradable fuel produced from vegetable oils, animal fats, etc.
Biofuel	A type of renewable energy source derived from microbial, plant or animal materials. Examples include ethanol (derived from corn or sugarcane), biodiesel (derived from vegetable oils, animal fats, etc.), green diesel (derived from algae, etc.) and biogas (methane derived from animal excretions, etc.).
Biomethane	Also known as "renewable natural gas," it refers to methane produced either by "upgrading" biogas (a process that removes any CO ₂ and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation.
Biomethanol	Biomethanol is typically generated through a thermochemical reaction. The feedstocks for the process can be any type of concentrated carbonaceous materials (i.e. biomass, solid waste, coal, etc.). The process entails converting feedstock into biogas through gasification and the synthesis of methanol.
Black start service applications	Black start is the procedure used to restore power in the event of a total or partial shutdown of the electricity transmission system without relying on any external electric power source.
Blue hydrogen	Hydrogen produced by steam methane reformation, where the emissions are curtailed using carbon capture and storage.
Carbon budget	The overall quantity of CO ₂ and other greenhouse gases that the world, country or company can emit without risking an average global temperature increase beyond 2°C. It can also refer to the quantity of CO ₂ or greenhouse gases that a country, company or organization has agreed is the maximum it will produce in a given time period.

Term	Definition
Carbon net neutrality	Carbon neutrality means every ton of CO ₂ that is emitted is compensated with an equivalent amount of CO ₂ which is removed.
Carbon offsets	A reduction in emissions of CO ₂ or other greenhouse gases made in order to compensate for emissions made elsewhere.
CCUS	Carbon capture, utilization and storage (or CCUS) is a critical emissions reduction technology that can be applied across the value chain. CCUS systems capture CO ₂ from power plants or industrial processes and either use it as a raw material in the production of other fuels or permanently store it in deep underground geological formations.
Circular economy	An industrial system that hinges on a shift towards renewable energy, eliminates the usage of toxic chemicals, and eliminates waste through enhanced design of materials, products, systems and processes.
CNG	Compressed natural gas (or CNG) is gas compressed to a pressure of 200+ bars. It is used in cars and other light commercial vehicles as a fuel and produces lower emissions compared to diesel- or petrol-fired internal combustion engines.
Connected Autonomous Shared Electric (CASE)	CASE refers to new areas of "connected" cars, "autonomous / automated" driving, "shared" and "electric." Technological advances in these areas are disrupting the automotive industry.
Crowd shipping	A novel shipping concept where logistics operations are carried out by crowd sourcing and existing resources such as vehicle capacity and drivers, thereby offering potential for economic, social and environmental benefits.

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References

- 2** Accenture decarbonization scenarios – for an explanation see P36
- 5** Accenture Analysis
- 7** UNFCCC Paris Agreement – <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>
- 8** “Global Energy Transformation”; 2019; IRENA © 2011-2020 IRENA - International Renewable Energy Agency
- 9** “World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100”; June 21st 2020; United Nations © UNITED NATIONS
- 10** “Energy in Developing Countries”; Oxford Energy © Oxford University 2020
- 11** “World Energy Investment 2020”; May 2020; IEA (c) IEA 2020 - Key findings
- 12** “The Covid-19 crisis is causing the biggest fall in global energy investment in history”; May 27th 2020; IEA © IEA 2020
- 13** “World Energy Investment 2020”; May 2020; IEA © IEA 20210 - Power sector
- 14** Consolidated from various company annual reports
- 15** “Renewable Power Generation Costs in 2019”; June 2020; IRENA © 2011-2020 IRENA - International Renewable Energy Agency
- 16** “Transforming the Energy System”; 2019; IRENA © 2011-2020 IRENA - International Renewable Energy Agency
- 17** “Global Energy Transformation”; 2018; IRENA © 2011-2020 IRENA - International Renewable Energy Agency
- 18** “EIA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia”; September 24th 2019; U.S. Energy Information Administration © 2020

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