accenture

Decarbonizing Energy: From A to Zero

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

We call it positive energy.

Preface

The oil and gas industry is in the midst of a transformational change like no other. Unlike previous industry disruptions, the "Decarbonization Transition" will introduce an entirely new set of rules, challenges and opportunities.

Driven largely by consumer demands for a cleaner energy system and investor pressures for reliable financial, as well as environmental, social and governance (ESG) performance, the sprint to decarbonization is on. The industry has set ambitious emissions-related targets to retain its right to operate during and after the transition to a low-carbon/net-zero energy system. As well they should. A number of companies are already taking bold action. Unfortunately, it is highly unlikely that the industry will achieve its 2050 goals.

COVID-19 has given us a glimpse of what the future holds, in terms of cleaner skies and less congested cities. But we should consider it a cautionary tale. The pandemic's jolt to the energy system was extraordinarily painful. The oil and gas industry experienced 10 years of transition in just a matter of weeks. Oil demand collapsed and more than 20 percent of coal consumption in some large markets was rapidly displaced by net-zero, marginal-cost renewable power. Aftershocks are still playing out across the industry. The question now is, "How can the industry accelerate and lead an orderly Decarbonization Transition to 2050 and beyond?"

This report, based on deep analyses and insights, represents Accenture's attempt to answer that question. Our guidance is meant to be pragmatic. It is about more than saving the core business of oil and gas. It's about orchestrating the transition across sectors and beyond the limits of its value chain. It's about redefining the role of oil and gas in the future energy system to 2050 and well beyond.

At Accenture, we have the privilege of working with super-majors, national oil companies, integrated oil companies and oilfield and equipment services providers around the world. We know the challenges they face. And the steps they can take to overcome them. We also know what is realistic. And we have a unique vision of what is possible for oil and gas companies that take bold decisions and make even bolder moves today.

In this report, we've attempted to lay out our perspective. In section one, we describe the context of change and present a practical case for what is achievable by the middle of the century. In section two, we explore the impact of the transition on the sectors that rely most on oil and gas. Oil and gas companies will need to not only reimagine their relationships with their customers, but also architect a united response to the seismic change that will affect all. In section three, we outline what we consider to be the only three viable options for oil and gas companies moving forward. We consider them archetypes, rather than cast-in-stone business models. But their general boundaries are set. Companies can choose only one path to follow.

Clearly, aggressive decarbonization actions must be taken. But they must be coupled with a clear understanding of the role each company can play in a new energy system. Action + Ambition will set the next generation of leaders apart.

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 reposition for commercial success for many years after.

In closing, I would like to thank: Jean-Marc Ollagnier, Accenture's Europe CEO, for inspiring us to set the direction for the industry through this flagship report; my colleagues David Rabley, Tom Beswetherick, Sylvain Vaquer, Leanne Rutherford, Simone Ponticelli, Boris Leshchinskiy, and Anshu Agrawal for leading this effort and without whose commitment, analytical fortitude and passion for the industry they serve this report would not have been possible; and our various industry experts, in particular Vicky Parker, Andrew Smart, David Elizondo and Mauricio Bermudez. I am grateful for their contributions.

Muqsit Ashraf
Senior Managing Director
Global Energy Industry Sector Lead

Contents

Storm clouds have been gathering over the oil and gas industry for years. It's now time to heed the warning signs.

The advances in renewable energy technologies that threaten the industry's relevance. The world's growing demand for climate action and a low-carbon future. An abundance of supply that may never be used.

The tempest is upon us.

And lightning flashes (like the COVID-19 pandemic) illuminate in blinding relief the fragility of an industry that is at risk of being washed away.

Or is it?

For oil and gas companies looking for safe harbors during the Decarbonization Transition, there are few. Investors and customers, alike, are turning their backs on traditional hydrocarbon companies.

As oil and gas companies are realizing, storms can be scary and destructive events, destabilizing the foundations of the most solid structures. But they also bring with them new life. New hope. And a fertile ground upon which to rebuild.

Accenture has identified three distinct roles—or archetypes—that today's oil and gas companies can assume during the transition and beyond. They can only choose one path forward that they can dominate and that will provide the shelter they seek.

In the eye of the storm

Transforming the fossil fuel-based energy system to one that is sustainable and decarbonized is one of humanity's greatest challenges. It also represents one of the greatest opportunities to make global energy supplies more available and affordable than ever before.

The 2015 Paris Agreement, which set the goal of keeping global average temperature increases less than 2°C (3.6˚F) above pre-industrial levels by 2050, has provided a roadmap for countries and industries looking to combat climate change and adapt to its effects. At the heart of the response lie ambitious programs to quickly curtail emissions of greenhouse gases—particularly carbon dioxide (CO_2)—into the atmosphere. To date, more than 800 companies have committed to science-based targets to align strategies with the Paris Agreement.

All eyes are on the global "carbon budget," or the amount of CO_2 countries can emit before the world is guaranteed to warm at least 2°C (3.6°F). The outlook isn't encouraging. At the current emissions trajectory, the world will exhaust its remaining carbon budget between 2030 and 2035[1]. Based on Accenture's analyses, we are on course to overshoot our carbon limit by as much as 200 percent by 2050[2]. This would create significant climate effects, including sea level rise, extreme weather, and temperatures routinely exceeding 50°C (122°F) in large, densely populated cities.

A number of stakeholders are placing oil and gas companies at the center of efforts to curb the emissions trajectory and shift it toward net zero by 2050. Environmental activists and concerned consumers alike, have long been pressuring the industry to rein in its emissions. Regulators, also subject to public scrutiny over their handling of environmental issues, are taking more aggressive action. Providers of renewable energy sources have jumped into the fray, adding their voices to criticize the oil and gas industry's environmental record while also touting their low-carbon—and increasingly flexible—energy alternatives.

Then there are those holding the purse strings. Investors are demanding that industry players not only take bold actions to lessen their reliance on hydrocarbons, but also define and execute long-term strategies to compete in a cleaner energy future. They're increasingly walking away from companies that don't have what it takes to manage the transition. Today, a range of greenhouse gas emissions (GHG) are modeled by banks and investors to assess cashflow and risk metrics in investment and credit decisions. Governments are focusing portions of their COVID-19 recovery and stimulus packages on clean energy. Recipient industries, including airlines, are required to meet environmental standards in exchange for funds. And consumers are incentivized to spend their stimulus payments on more energy-efficient solutions.

Some of the loudest calls for oil and gas companies to change course come from the industry itself. Operators recognize their responsibility to deliver energy assets sustainably. Their license to operate depends on the trust that consumers, employees and shareholders place in them. Rebuilding that trust must start today.

About our findings

Accenture is committed to helping oil and gas companies navigate short-term uncertainties and achieve sustainable, long-term growth and relevance. In addition to working directly with clients across the value chain, we continually analyze corporate, trend and climate data and refine scenario models to bring new insights—and new solutions—to the industry. This report and the scenarios we envision are based on our recent analyses and findings.

It won't be easy

Accenture believes that achieving net-zero emissions by 2050 is unlikely, if not impossible. Our stretch scenario outlines a pathway and pragmatic set of actions to get to 80 percent of that goal. Negative emissions will potentially close a portion of the gap that remains and the momentum from concerted action will likely bring about additional gains post-2050. Of course, that's not what the public or industry leaders want to hear. But an honest assessment of the decarbonization trajectory is more valuable than rosier forecasts that will only need to be adjusted down the road.

By knowing what they are up against now, industry leaders can correct course. They can reconsider the trusted role they will play in the global energy future. And they can take the decisive actions that are needed to achieve their net-zero ambitions—even if those ambitions won't be fulfilled until after 2050.

We know what those actions are. We also know the ambitions that are within reach. It is this combination—Action + Ambition—that will set the leaders apart.

Then came COVID-19

As we completed our analysis in mid-2020, COVID-19 was having a deep impact on global emissions. Restricted travel and less industrial and commercial activity have driven a 10 percent reduction in global CO_2 emissions. Importantly, the energy system is responding by reducing higher-cost sources of supply and relying, instead, on lower-cost renewables for a greater share of electricity generation.

Learnings from previous downturns suggest that current reductions in emissions will be short lived. Without deep structural change, the pandemic is expected to affect the emissions trajectory by less than 2 percent through 2050. However, this downturn is different. And so is the response to it. If authorities and industries seize the moment and use stimulus funding and incentives wisely, they can architect and execute holistic structural change in the emissions trajectory.

Action

Ambition

We know what those actions are. We also know the ambitions that are within reach. Combining these two will set leaders apart.

Glimmers of sunlight amid the rain

The good news is that the oil and gas industry has accepted that financial returns are increasingly aligned to environmental, social and governance (ESG) outcomes. There's now a correlation emerging between strong corporate performance on ESG factors and a company's stock performance. Over the past few years, the stocks of companies with high ESG ratings have tended to outperform, and this has also been the case during the COVID-19 crisis[3].

The shift to a sustainability mindset is accelerating. In the 2018-19 period, investments in ESG-focused passive funds rose by approximately 12 percent. Equally telling, 99 percent of CEOs of the world's largest corporations now believe sustainability is important to the future success of their business[4]. Consumers are on board too, with 62 percent wanting businesses to take a stand on issues like sustainability[5].

Like the shift in thinking about environmental stewardship, the transition to decarbonized energy has unstoppable momentum. Several oil and gas companies have already taken a bold stance and have defined their strategic roadmaps (with some reinforcing their commitment during the COVID-19 crisis). The shift is due, in part, to a greater understanding of the role the energy system—and CO_2 emissions, in particular—plays in climate change, as well as evolving consumer demands for lower- or no-carbon energy options. Finally, new innovations in areas such as storage, renewable-grid integration and electricity-based fuels have emerged up to 10 years ahead of their anticipated arrival[5], levelizing the cost of renewable generation.

Amid growing interest in decarbonization, oil and gas companies find themselves awash with hydrocarbons. Supply abundance, coupled with the demand slowdown expected in the next 20 years, has made investors skittish and driven the cost of capital up. A lack of discipline among many operators to focus on margins and cash has added fuel to the hydrocarbon fire. It's therefore no surprise that returns from traditional hydrocarbon extraction and processing projects have dipped into single digits from previous highs well above 10 percent[1]. The need for oil and gas companies to accelerate their transition to the decarbonized energy future has never been greater.

A break in the clouds

As noted, Accenture estimates that by 2050, an 80 percent reduction of system-wide emissions (and even more thereafter) is achievable if decarbonization actions are complemented with negative emission technologies. Achieving this goal is dependent on the actions oil and gas companies take today, the strategic postures they want to hold tomorrow, and their ability to orchestrate and influence hydrocarbon-burning sectors to join them in the cause along the way.

Forecasting the long-term future of the energy system and the roles different companies play is a complex undertaking. As a first step, it requires an understanding of the themes and influences that will shape the transition to a decarbonized energy system—not only for oil and gas companies, but also the sectors that depend on them most, and the other industries adjacent to them.

To this end, Accenture has envisioned two "states of the world" through to 2050. One state is the by-product of business-as-usual (BAU) practices and mindsets. The other depicts what we've termed the "stretch case." It represents what we believe is possible, realistic and within reach.

Players across the energy system have three types of action at their disposal along the journey to decarbonization. They can Clean the Core to minimize emissions and maximize efficiency from current operations, infrastructure and value chains. They can Accelerate the Transition to replace existing sources of energy and demand with available and competitive cleaner and zero-emission alternatives. And they can Extend the Frontier to adopt and scale new sources of energy, processes and technologies that are beyond what is commercially and technically possible today. Success requires all three sets of actions to be activated. De-risking the journey depends on getting the balance right over time.

Accenture's 2050 stretch case assesses the potential impact of over 300 technology and process levers on the energy system. The combined impact of these levers can exceed 40 gigatons of CO_2 emission reduction by 2050.

Figure 1

Source: Accenture Analysis

Global CO_2 emissions by sector (gigaton CO_2 equivalent)

	2019 emissions	2050 business-as-usual	Priority levers	2050 stretch
Hydrocarbon extraction	5.4	6.7	• Renewable sources of fuel • Grid flexibility and energy storage • Gas as a transition fuel	0.5
Power	13.2	15.4	• Renewable sources of fuel • Grid flexibility and energy storage • Gas as a transition fuel	2.2
Light vehicles	3.7	5.8	• EV adoption and mobility evolution • ICE efficiency gains • Hydrogen and synthetic fuels	1.7
Aviation	1.1	1.8	• Aircraft design and efficiency • Fleet optimization and operations • Biofuels and hydrogen	0.7
Heavy road transport	2.6	4.6	• EV for heavy-duty transportation • LPG, hydrogen, biodiesel fuels • ICE efficiency, supply management	1.0
Shipping	1.0	1.7	• Vessel design and operations • Electricity-based fuels (synfuels, ammonia, hydrogen, battery)	0.5
Industry	8.8	12.6	• Process improvement and efficiency • Circular solutions and energy demand • Hydrogen and decarbonized fuels	2.6
Buildings	3.5	3.8	• High-efficiency and electric appliances • Energy-efficient design and operations	1.1

Clean the Core

These actions reduce or eliminate emissions inherent in current assets using existing energy sources, and collectively represent an opportunity to lower global emissions by almost 20 GT.

Currently, processes directly associated with extracting, transporting and processing hydrocarbons emit over 5 GT of CO_2 each year. That could rise to close to 7 GT by 2050[2]. Reducing direct emissions of CO_2 and also methane (which is smaller in absolute volumes, but 30 times as polluting as CO_2)[6] will determine whether the industry retains the right to operate in the future. The technology and processes required to achieve near net-zero emissions exist and have been proven.

To achieve this, oil and gas companies have a number of options. They can maximize the efficiency of existing assets across the energy system. They can capture vented, flared and fugitive gas emissions. And they can deploy circular solutions that reduce energy intensity and waste from operations. Together, such actions can reduce an oil and gas company's direct emissions by 80 percent[2].

Natural gas plays a critical role. Heralded as a "transition fuel" due to the fact that it burns cleaner than other fossil fuels, natural gas has the potential to be more than a source of feedstock for power generation and chemicals. It can, for example, support the hydrogen economy and enable cleaning of industrial processes in sectors like heavy-duty transportation. But gas will only reach its potential as a transition fuel (and more) if its emissions liability can be materially lowered. If it can't, we can expect to see an accelerated pull back from the commodity and a far more disruptive transition as a result.

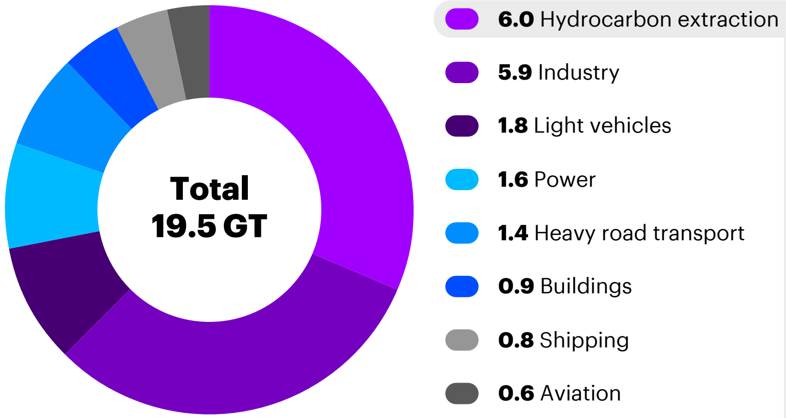
Sectors adjacent to or dependent on oil and gas, such as power and heavy industries, can similarly reduce emissions by improving energy and materials efficiency and capturing greenhouse gases to clean their core operations. Their actions will not only help to achieve their own decarbonization targets, but also have a direct bearing on the oil and gas industry's Scope 3 emissions, which occur at the point of combustion and within their customers' supply chains.

The full oil and gas value chain emits an additional 20 GT once Scope 3 emissions are factored in. The remainder of emissions derived from the energy system lies with coal, which adds close to 15 GT[2]. Effectively addressing the Scope 3 emissions requires new models of partnership, innovation and collaboration across the energy system. Oil and gas companies will not succeed without putting skin in the game and actively working with the companies that consume their products to actively lower emissions in their downstream operations, processes and activities.

Figure 2

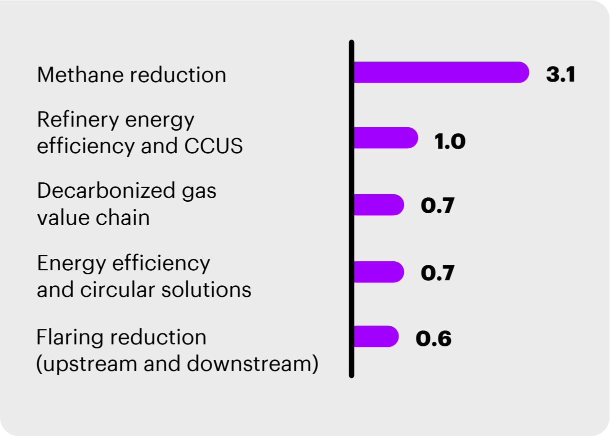
Clean the Core GT CO_2 reduction

Sector opportunity to reduce emissions from 2050 business-as-usual to 2050 stretch



Oil and Gas Clean The Core GT CO_2 opportunity types

Theme opportunity to reduce emissions from 2050 business-as-usual to 2050 stretch



*Total might not equal sum of individual rows owing to rounding

Source: Accenture Analysis

Accelerate the Transition

These actions reduce or eliminate emissions by shifting to commercially and technically scalable, lower emission-intensity energy supply sources, and collectively represent an opportunity to lower global emissions by 21 GT.

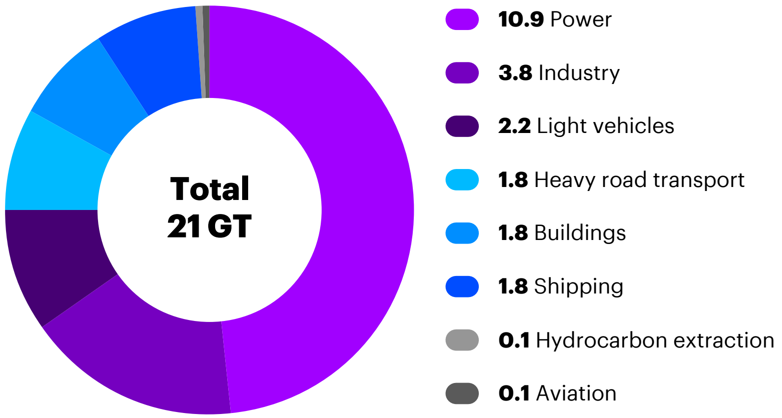
While transitioning toward lower- or zero-emitting fuels, oil and gas companies must also look beyond the impact of the transition within their own operations. They need to consider how their scope of engagement across the energy sector and actions might influence or support their customers and help to architect changes in adjacent sectors. This broader thinking is a must for oil and gas companies that are committed to tackling Scope 3 emissions—or the emissions associated with consumption of their products.

Helping to mitigate Scope 3 emissions is notoriously challenging, given that they occur after the point of sale for oil and gas companies. Oil and gas companies, therefore, need to position themselves as partners to their customers, jointly committed to supporting their emissions-reduction strategies and harmonizing emissions reporting. Offering new fuel blends or energy sources, demand management expertise or even infrastructure services will be critical since the inclusion of Scope 3 multiplies the oil and gas industry's CO_2 emissions targets by up to 500 percent. The good news is that as energy shifts from being a pure commodity to a source of tangible customer value, new partnership models will take shape to drive the transition.

Figure 3

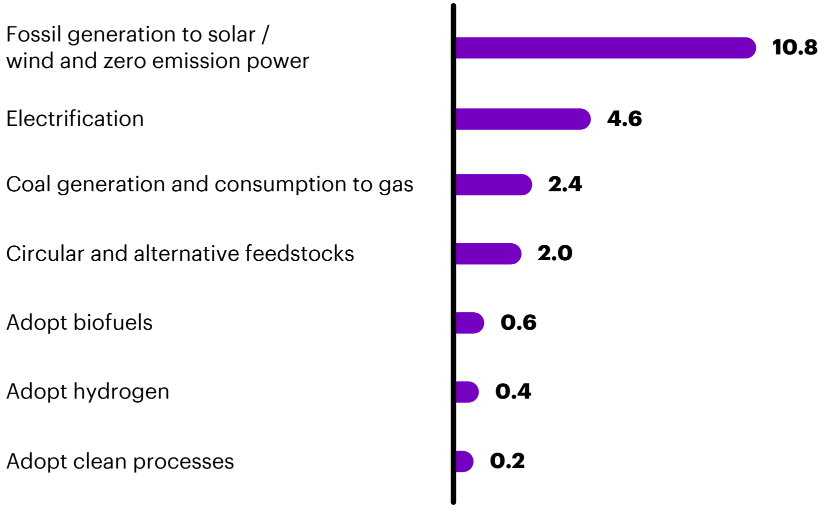
Accelerate the Transition GT CO_2 reduction

Sector opportunity to reduce emissions
from 2050 business-as-usual to 2050 stretch



Accelerate the Transition opportunity types

Theme opportunity to reduce emissions
from 2050 business-as-usual to 2050 stretch



Source: Accenture Analysis

Extend the Frontier

These actions reduce or eliminate emissions by deploying processes and energy supply sources that are not yet currently commercially and technically scalable, but will be by 2050. Extend the Frontier actions collectively represent an opportunity to reduce stretch case emissions by an additional 17 percent in 2050, or over 2 GT.

Examples include blue hydrogen that oil and gas companies can derive from steam-methane reforming at an increasingly competitive cost. This opens up new possibilities in transportation and energy storage, where it can enable a greater share of intermittent renewables, as well as in hard-to-abate industries such as metals and mining. Biofuels offer a potential alternative to jet fuel, which oil and gas companies can process in repurposed refineries. Oil and gas companies can also further leverage the current supply infrastructure and customer relationships that have enabled their industry to date. Advanced industrial processes that avoid emissions from the process itself will further Extend the Frontier as technology and economics overcome the existing challenges in scale and cost. A case in point is Portland cement manufacturing, where more than 50 percent of emissions arise from the current requirement to super-heat ground limestone to produce calcium oxide; future advanced processes using alkali-activated cements can replace this step with a low-emission alternative.

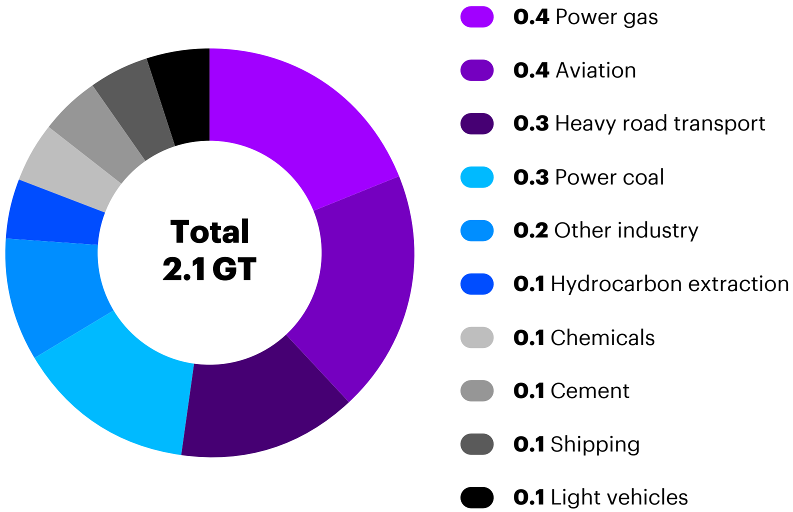
In addition, negative emissions actions, including direct air capture (atmospheric carbon dioxide reduction) and bioenergy with carbon capture and sequestration (BECCS) are worth pursuing—even though they may not yet be proven at scale or at the required level of economic viability. Truly "breakthrough" solutions such as nuclear fusion, which could transform energy permanently, are also advancing. Yet their contribution within the upcoming 30 years is still uncertain.

It is our view that technology leaders with deep R&D and energy sector experience will be in a position to emerge at the forefront of this expanded energy system. Few should bet against oil and gas playing a key role. With clear leadership capabilities and unparalleled record in maturing complex energy solutions, the oil and gas industry might have found its next growth frontier.

Figure 4

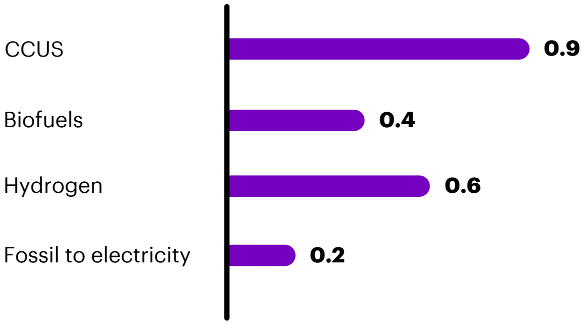
Extend the Frontier GT CO_2 reduction

Sector opportunity to reduce emissions
from 2050 business-as-usual to 2050 stretch

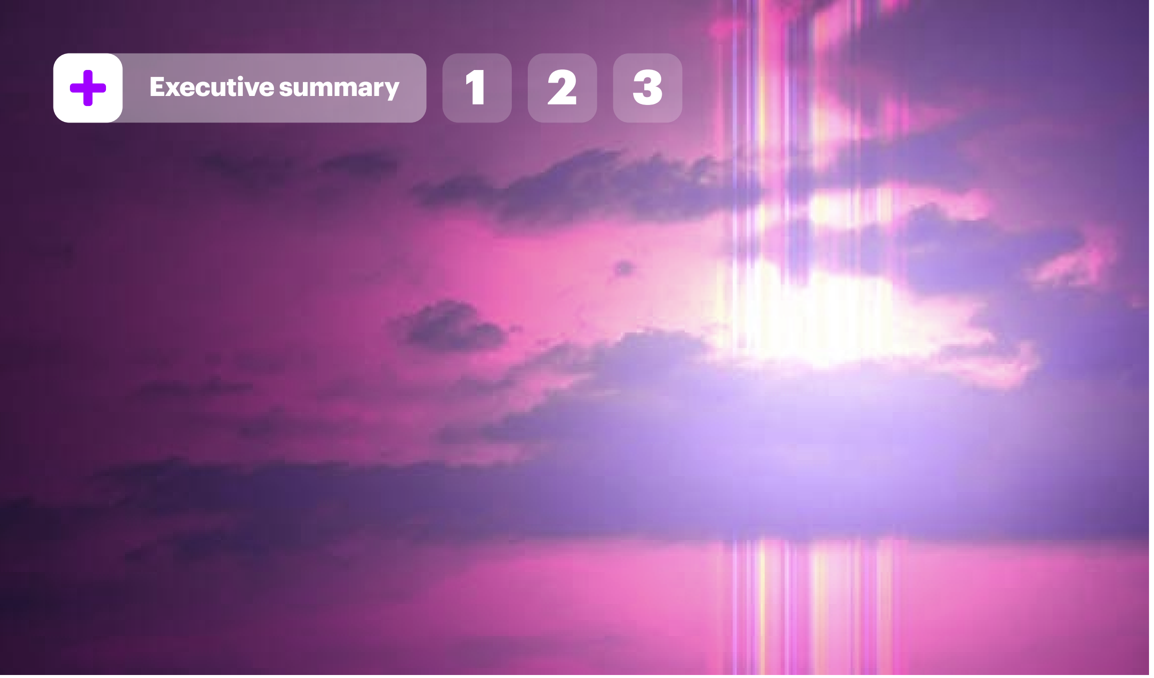


Extend the Frontier opportunity types

Theme opportunity to reduce emissions
from 2050 business-as-usual to 2050 stretch



Source: Accenture Analysis



Forecast: Partly cloudy

The 2050 end game is not an energy system without fossil fuels. Rather, the objective for oil and gas companies is to play a central role in the decarbonization of the energy system. A new focus on process efficiency and demand management, together with an expansion into decarbonized and electricity-based energy solutions, can extend the license of oil and gas to create value for years to come.

There are compelling opportunities for oil and gas companies during the transition to a decarbonized energy system. However, balancing shareholder returns, emissions mitigation, consumer needs, and new business value will challenge the industry to reinvent itself.

Through the 2020s, value and investment are poised to migrate away from oil and gas companies' core business, toward electricity-linked energy. Near-term priorities will be focused on transforming today's core portfolio, while also creating optionality to win in adjacent sectors. The Decarbonization Transition won't be as effective—or may not happen at all—if oil and gas companies don't play an active role in developing solutions for their customers in those sectors.

That means more than investing. It means innovating and collaborating with partners to make the transition to a low- or no-emission future a reality. Cross-sector R&D teams can, for example, work together to identify potential uses for hydrogen with biofuels in the aviation industry. Or oil and gas companies might join up with utilities to extend the traditional value chain to cross-sector offerings like mobility-as-a-service solutions. In these and countless other ways, oil and gas companies will be actively architecting and creating the low-carbon opportunities in which they can invest—and through which they can grow.

Importantly, they will also be actively creating something else: stronger customer relationships. To take optimal advantage of these new opportunities, oil and gas companies need to appreciate that the end-customer journey and demand patterns will continue to change. The target end consumers for oil and gas companies (and other sectors where they play an important role) are shifting from primarily large businesses to also include small businesses, B2B2C operators, and even individual consumers such as households or neighborhoods (for power services, for example). Reaching and engaging these customers during and after the Decarbonization Transition will be key.

Furthermore, digital technologies that promote collaboration and transparency, sustainable supply chains, new customer touchpoints, integrated carbon and emissions visibility and tracking, and compelling, differentiated customer experiences all have a big part to play in the direct-to-consumer world, and are a core element of the sector's digital transformation.

Technology and existing infrastructures play to the oil and gas industry's strengths, both as it pursues new opportunities and in the delivery of electricity-based fuels, biofuels, geothermal, offshore wind and carbon capture, utilization and storage (CCUS) solutions. However, the competitiveness, returns and cash profile of these businesses (with the exception of offshore wind and large-scale solar photovoltaics) are challenged in the near term. To date, they have been reliant on subsidies or capital structures that are inaccessible to oil and gas companies. What's more, oil and gas operating models are not yet aligned to manage portfolios that have one foot in today and one in tomorrow.

But this is all set to change. After several false starts, there's an unstoppable momentum toward a low-cost, available, reliable, decarbonized energy system that drives growth and enhances living standards. While it's certainly too early to claim victory, the emergence of clear pathways for success across most of the largest energy system sectors is cause for new optimism. And positive support, inputs and incentives from many quarters—policy, innovation, society and business—will accelerate that momentum. Especially for oil and gas.

Extended forecast: Sunny at times

In many markets, the power utility sector has added intermittent renewables to the generation mix at a pace few forecasters anticipated. The oil and gas industry must now embark on a similar journey across the energy system and within its core assets. How will oil and gas players thrive and lead during the period of transition and beyond? Nothing short of a comprehensive rebuild will cut it, transforming today's oil and gas leaders into energy-solution-focused, customer-centric, low-carbon companies that drive new value in new ways. The ultimate destination for oil and gas companies could take several forms. Through our analysis, we have identified three archetypal choices for tomorrow's oil and gas leaders: the Decarbonization Specialist; the Energy Major; and the Low-Carbon Solutions Leader. Each is distinct in its requirements, sources of value, and the extent of shift that will be required to move beyond today's business.

Archetype 1: Decarbonization Specialist

Some will rightly select to be the Decarbonization Specialists in the traditional oil and gas value chain. These companies will double down on operating the cleanest, highest-margin portfolio of oil and gas assets upstream, midstream and/or downstream. With the most efficient production and emissions management capabilities, they will create value through a low-emissions operating model and high-performing ecosystem that other players can't readily emulate. Circularity—characterized in this instance by the reduction, reuse and recycling of equipment and waste—will feature prominently in their business models. So will cleaner energy sources to power operations and assets. But today's oil and gas businesses will not automatically become Decarbonization Specialists. It is a role that only the highest-performing asset and infrastructure operators can seek to play.

Archetype 2: Energy Major

Integrated oil companies and selected national oil companies have the potential to extend their business and operating models into the wider energy system. These Energy Majors of the future will carve out a role in both oil and gas and an electricity-dominated energy system. In that capacity, they may build or add a winning and scaled clean electricity business to their integrated portfolio of assets, using their advantaged supply position, brand and retail networks, and trading and project-development capabilities, to build out competitive positions in power and other energy sources.

Expansion into the wider energy space will create optionality that enables them to reduce their emissions intensity. While continuing to hold strong positions in the oil and gas value chain, they will likely branch out into other areas such as storage, mobility or infrastructure. They will be well placed, for example, to lower the carbon intensity or help boost the proportion of intermittent renewables in the energy mix. Or they may stake their claims in alternative sources of energy that can be scaled. Biofuels and hydrogen hold great potential. Regardless of the specific moves they make, tomorrow's Energy Majors will need to become customer-centric organizations. That will likely require them to build enhanced retail capabilities or new service-oriented business models. As with Decarbonization Specialists, the pathway for becoming an Energy Major is not open to all. Those that succeed will place significant investments in their new area of focus, be it electricity, alternative fuels, or energy-related services.

Archetype 3: Low-Carbon Solutions Leader

The Low-Carbon Solutions Leader will undertake a profound strategic departure from its current business model. Companies choosing this path will exit their current roles, monetize their core assets, and leverage their capabilities and expertise to win in new areas of the emerging clean energy sector such as offshore wind, biofuels or hydrogen. They will build a new portfolio of solutions supplying clean power, developing biofuels or green hydrogen solutions, storing energy or even providing technical and technological solutions to other players. This strategy can enable oil and gas companies to reinvent as clean energy companies relatively quickly—and without the burden of existing assets, portfolios and constraints. But success on this path requires more than cash. It requires developing or acquiring a unique set of capabilities and a vision to re-emerge as a very different type of energy company to the one that they were.

Figure 5

Source: Accenture Analysis

Strategic archetypes of the future

Strategic archetypes	Upstream independent	Integrated and national oil company	Downstream refining, retail and chemicals	Oilfield equipment and services
The Decarbonization Specialist	Deliver clean upstream at lowest cost	Operate competitive, lowest-carbon assets across value chain	Operate lowest-carbon refining and processing assets	Technology, data and services partner to upstream lowest-carbon players
The Energy Major	Low strategic fit	Unlock value at intersection of hydrocarbons and power, plus lead in new energy solutions	Low strategic fit	No strategic fit
The Low-Carbon Solutions Leader	Leverage technical capabilities to strategically pivot into decarbonized fuels	Refocus portfolio to solutions across full energy value chain	Leverage capabilities across hydrogen, synfuels and customer	Build new businesses and services across new energy solutions and decarbonization

Low opportunity to win, little fit with capabilities and assets

High opportunity to win, strong fit with capabilities and assets

Oil and gas company leaders are already assessing their alternatives. The strategic archetypes outlined above define the general boundaries and stark alternatives over the coming decades.

There are, of course, some in the industry that will not survive during the transition to decarbonization. And few, if any, will emerge with the same models they have today. The vast majority will have to transform. While the specifics of any transformation will differ from company to company, there are certain things all companies must get right. They need, for example, to move forward with three sets of actions to Clean the Core, Accelerate the Transition and Extend the Frontier of possibilities. They also need to identify opportunities to partner with customers to accelerate new and valuable solutions. And they need to set an intentional course to enter and win in new business areas with revamped operating models, technologies and ecosystem partners across the energy value chain.

With the right ambition, the right preparation, a commitment to purposeful change, and an approach that balances opportunity and risk, oil and gas companies can take the lead in creating a net-zero future.

The path to achieving their future ambitions is open now. It's time for the industry leaders to make their moves.

Section 1

Resetting the destination

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 levels[7]. 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 imperative[1] 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 CO_2 emissions totaled 40 GT[2]. 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 CO_2 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 CO_2 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

1 Carbon net neutrality by 2050

- Carbon-neutral value chain
- Impact-neutral development
- Pollution-neutral consumption

Energy equity

2 +2 billion people underserved today; a 9 billion world population by 2050

- Near zero energy poverty
- Flexible, reliable, available energy

Energy fundability

3 $90-105 trillion to invest at competitive returns

- Intelligent operations
- Continuous innovation
- Stringent capital discipline

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 2050[2].

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 target[8]. 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 2050[9]. 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 countries[10].

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 2050[11]. 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 years[5]. 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 2019[12], whereas investments in the power sector are only estimated to drop by 10 percent[13].

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.

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.

Figure 7

This transition is different

	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 infrastructures[14]. 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 build[16]—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 customers[2].

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 increasing 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.

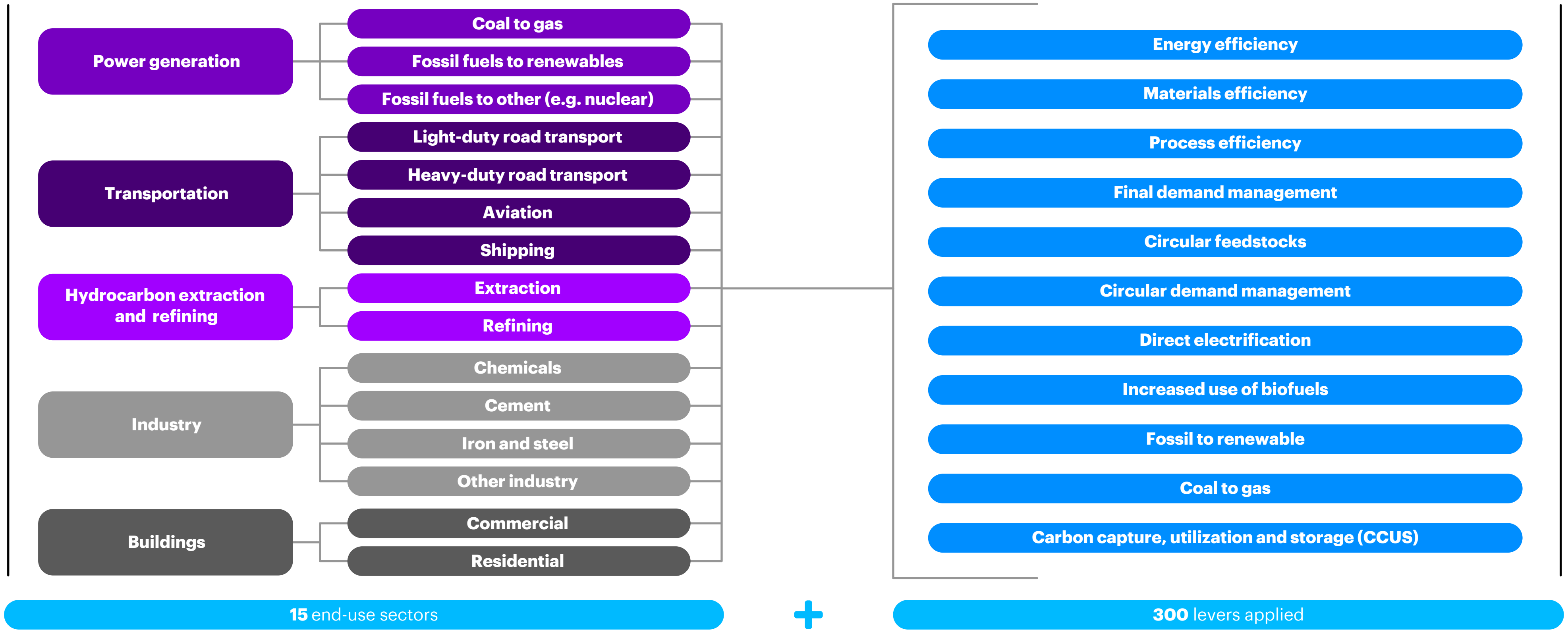
Figure 8

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

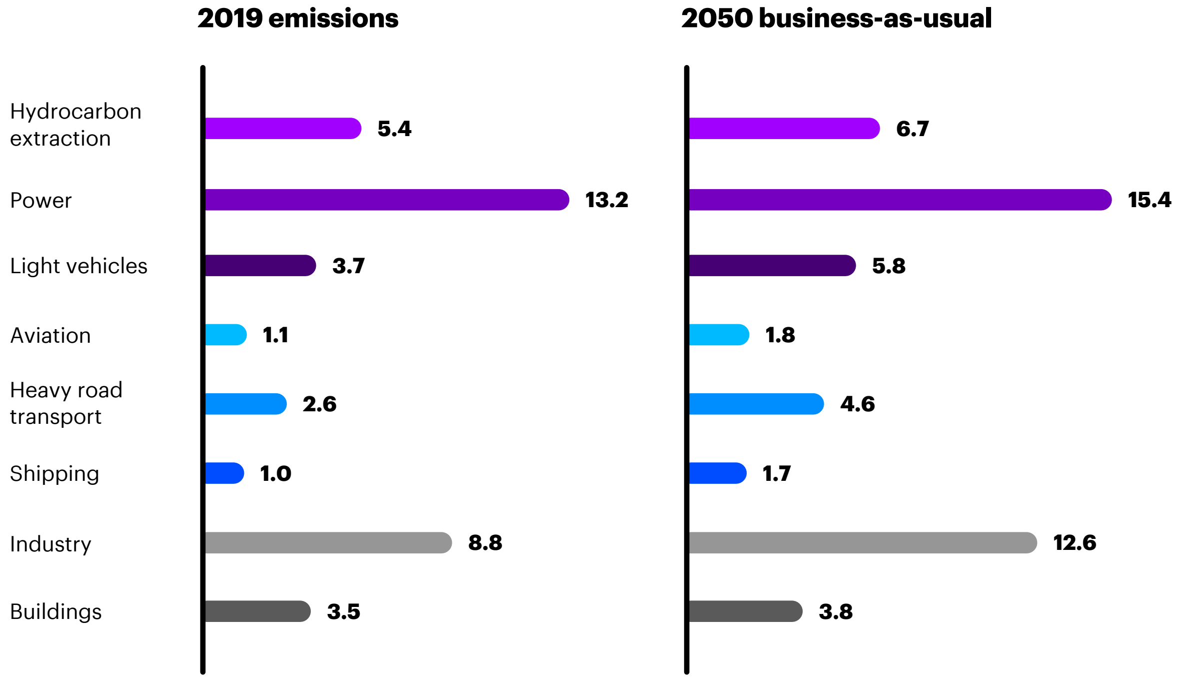
Scenario one
Business-as-usual

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 CO_2 emissions will rise by 35 percent, to as much as 54 GT by 2050[2]. This case does not paint a very rosy future. Global CO_2 emissions increase by about 1 percent annually from 2020 through 2050[17]. This would rapidly overwhelm the remaining global CO_2 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 generation[18]. 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 improvement[2]. 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 CO_2 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.

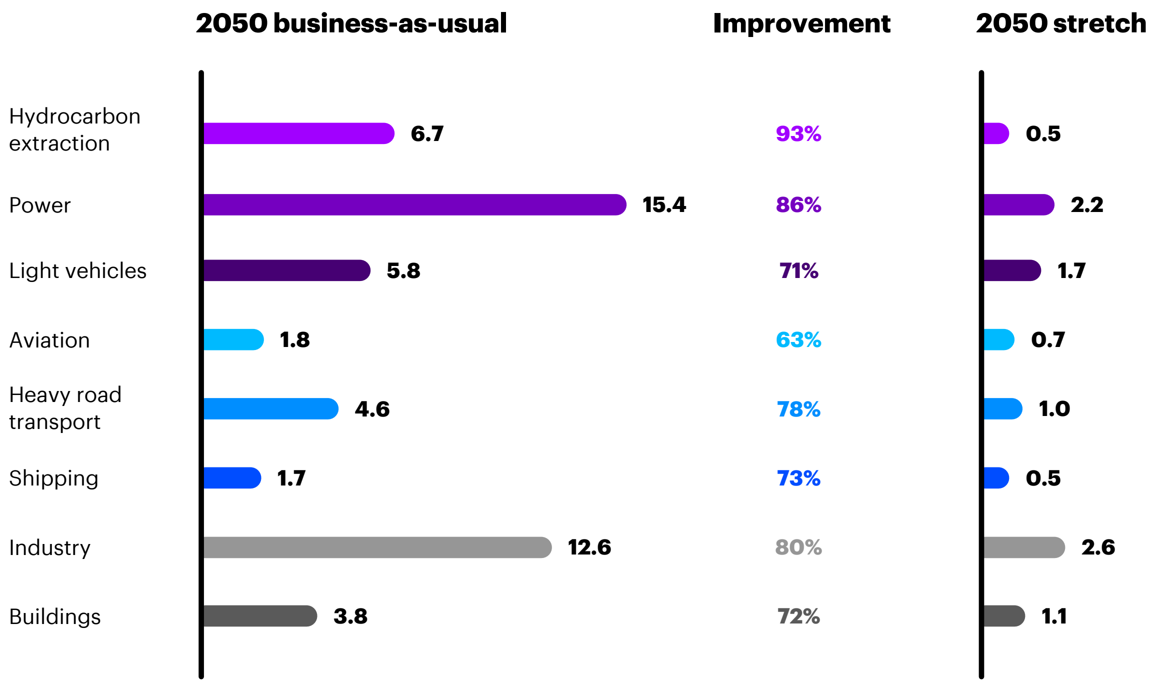
The stretch case: A “living” analysis

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 CO_2 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

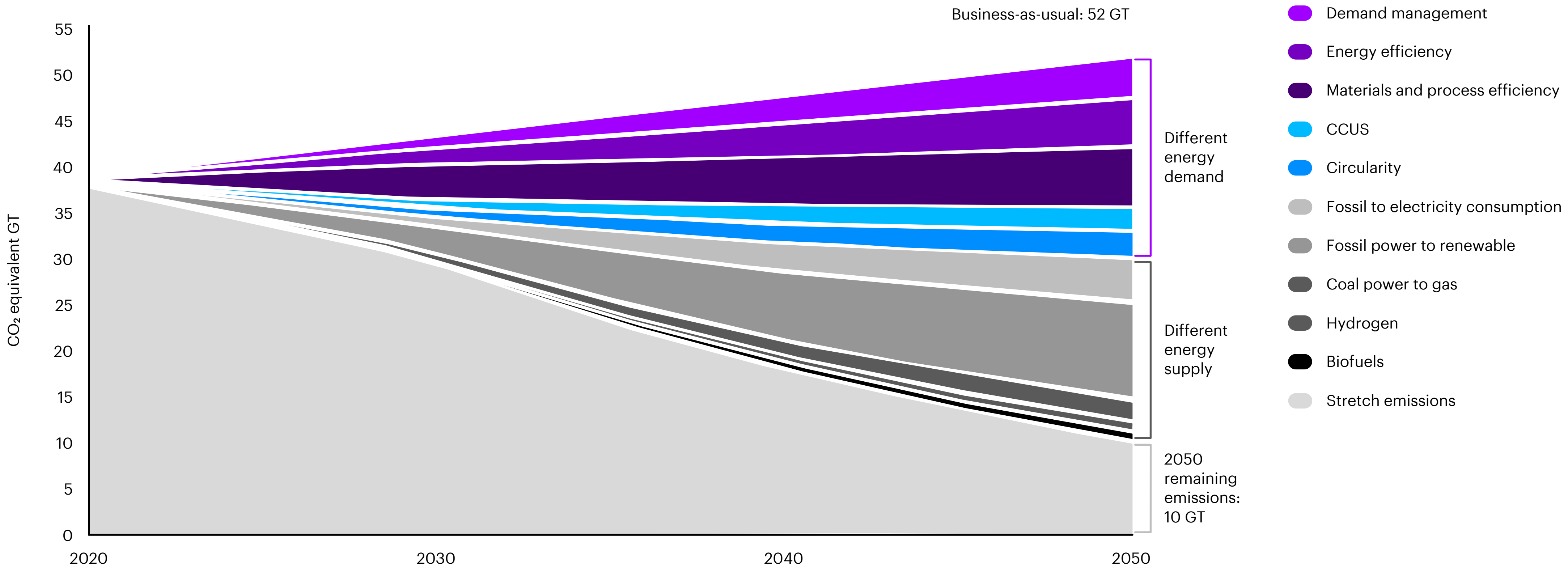
The emissions profile of the hydrocarbons used in power generation is also critical. Our stretch case identifies the near total elimination of coal in the power mix as a critical driver of emissions reduction.

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 CO_2 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 CO_2 being eliminated by 2050 through efficiency and demand-centric shifts.

Energy efficiency (-7 GT CO_2)

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 CO_2 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 CO_2)

Primary industries like cement, iron, steel and chemicals, are significant emitters. Advances in manufacturing techniques and replacement of high CO_2 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 CO_2)

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 CO_2)

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 CO_2)

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 CO_2 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 CO_2)

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 CO_2 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 CO_2)

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 CO_2)

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 CO_2)

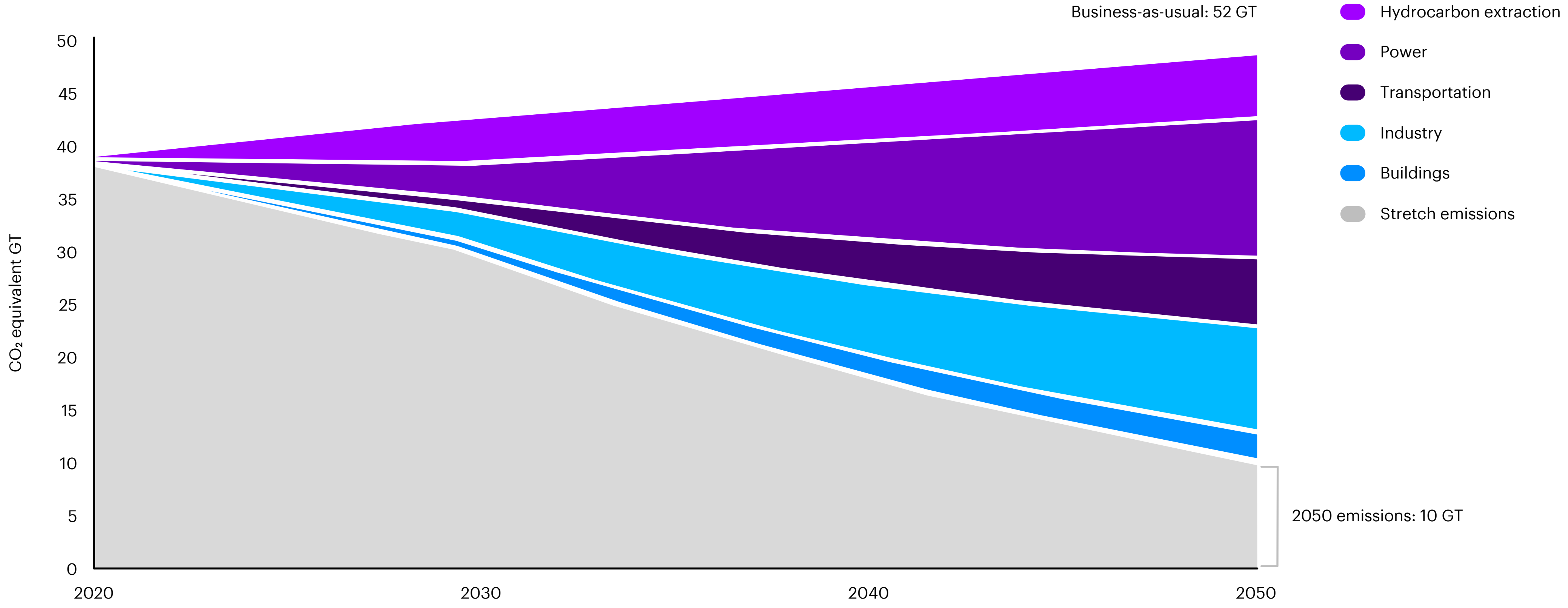
An energy carrier, hydrogen offers exciting clean energy opportunities such as supporting storage or providing intense heat for industrial processes. Green hydrogen, which is formed using energy from clean renewable sources, and blue hydrogen, which is formed using the steam methane reforming process, 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 CO_2)

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 CO_2 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.

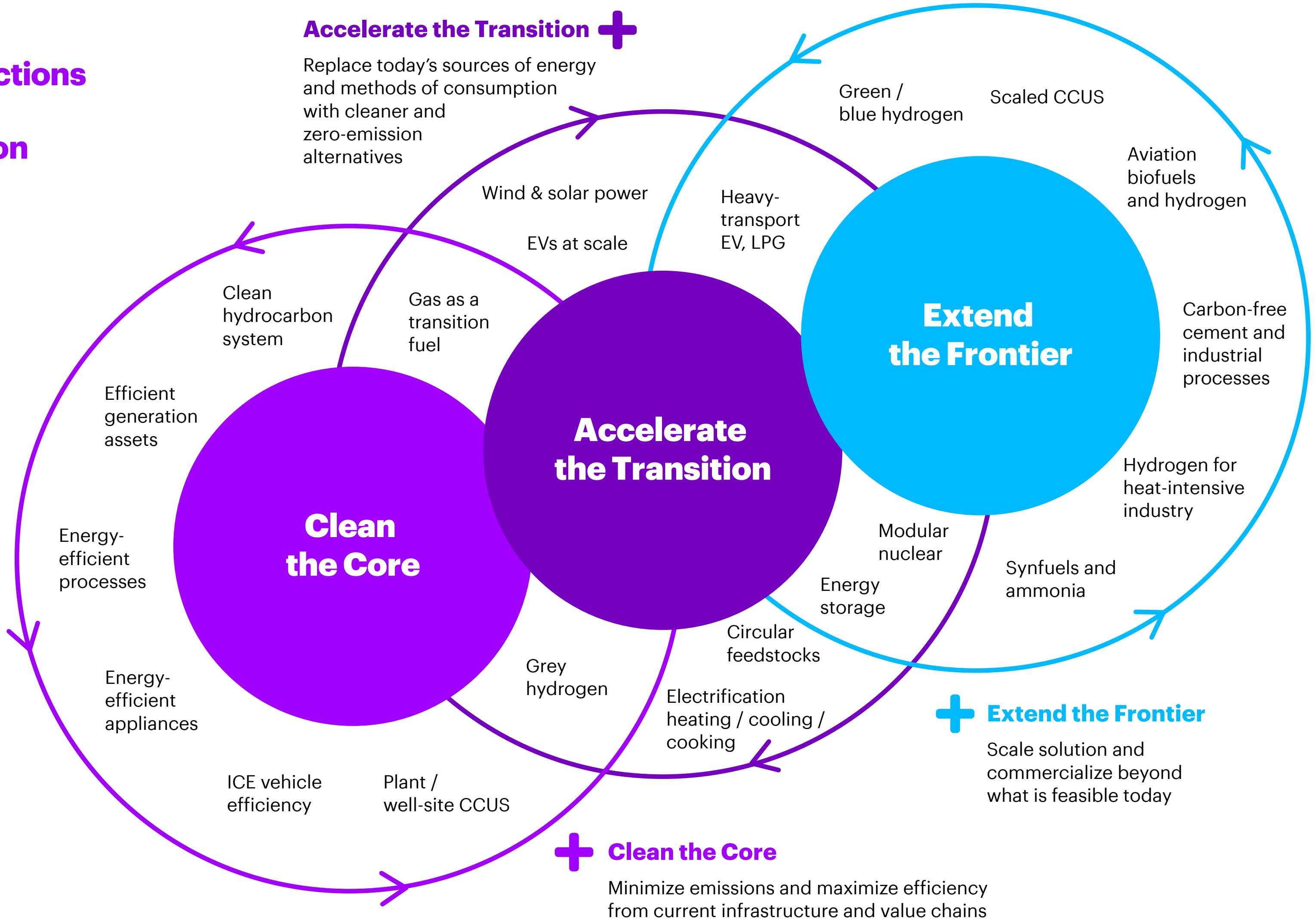
Beyond Cleaning the Core, there are other proven and commercially viable actions that will usher in lower-cost, higher-performing and cleaner energy consumption solutions. These actions Accelerate the Transition. Companies that accelerate and scale their adoption will accelerate their decarbonization 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 snyfuels; 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 assets[2]. 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 CO_2 emissions[2] 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 sectors[2].

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 dispatchability[2]. 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 CO_2, 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 CO_2 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 solutions[2]. The absolute amount of CO_2 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 CO_2 by 2050. Extend the Frontier actions could further lower that by at least 2–3 GT by 2050, getting total emissions below 9 GT[2].

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.

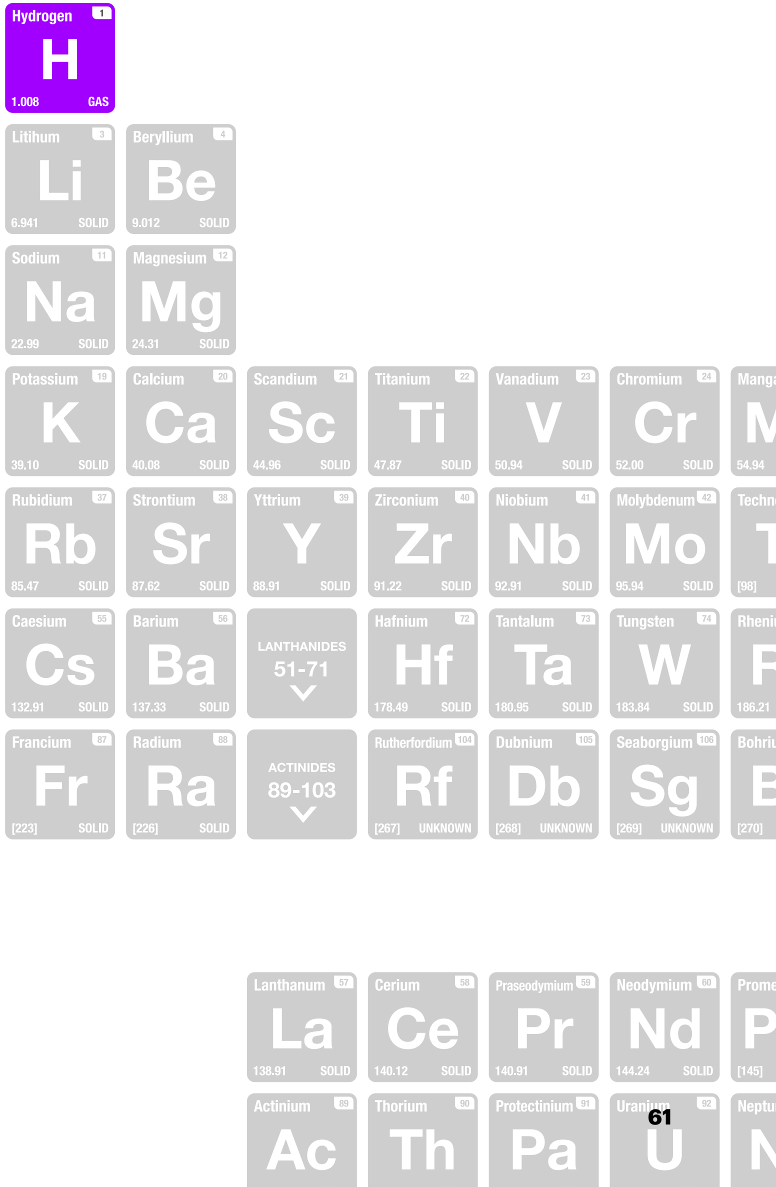
Biofuels provide another reason for optimism. They have emerged as the leading alternative to jet fuel for aviation. Because they can leverage existing infrastructure and be used in engines with minimal change, biofuels are attractive to an aviation sector looking to change the narrative on the carbon 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 CO_2[2]. They can be applied to other heat-intensive and CO_2-generating processes across industries. To date, the efficacy of CCUS solutions for lower concentrations of CO_2 streams, their cost points, and limited commercial market opportunities for the captured CO_2 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 CO_2.

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.

+ Section 2

Navigating the new route

Oil and gas companies looking to establish winning positions in the Decarbonization Transition and beyond can’t achieve that goal by themselves.

They will need the help of their customers, particularly those that are heavily dependent on hydrocarbons, and adjacent sectors. Only by participating in, and architecting, cross-sectoral actions can oil and gas companies hope to mitigate emissions across the energy system. This will be a new and valuable role for the industry to play.

In this section, we analyze and describe actions to be taken within the six critical sectors that are not only most impacted by the Decarbonization Transition, but also critical in making it a reality.

For each sector, we have identified three key levers for emissions abatement and the corresponding implications and actions for the oil and gas industry. Greater emphasis has been placed on analyzing trends in the hydrocarbon extraction and refining, power and transportation sectors. Our focus on the hydrocarbon industry relates very directly to the near-term actions that oil and gas companies will have to take. Our focus on power and transportation highlights why and how these sectors will have the greatest impact on gas and oil demand, respectively.

1. Hydrocarbon extraction and refining

2. Power generation

3. Light-duty passenger vehicles

4. Heavy-duty and commercial transportation

4.1 Heavy-duty road transportation

4.2 Aviation

4.3 Shipping

5. Heavy industry

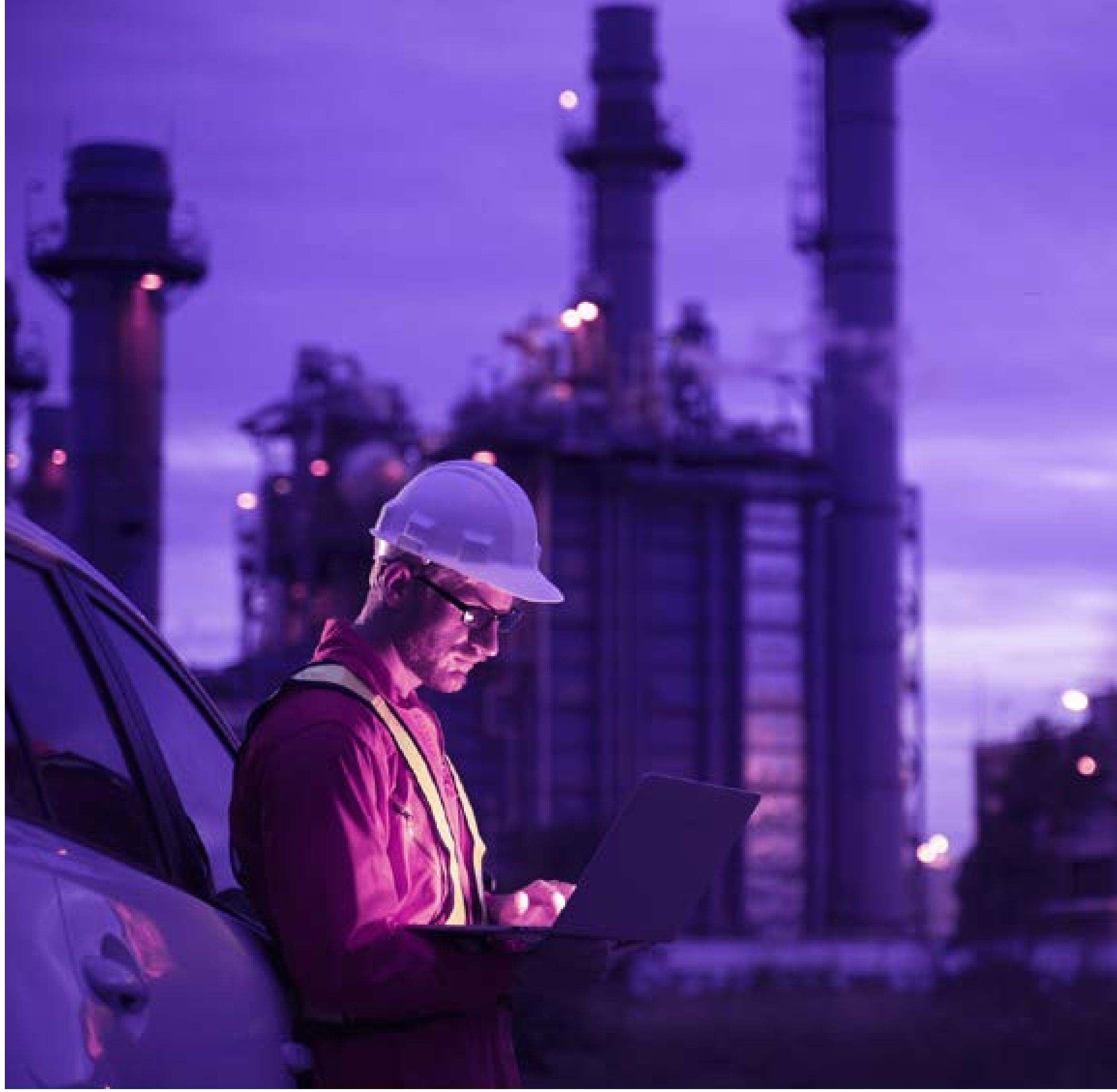
5.1 Cement

5.2 Iron and steel

5.3 Chemicals

6. Commercial and residential buildings

Hydrocarbon extraction and refining



Accenture 2050 stretch goal

93 percent reduction from 2050 business-as-usual emissions through near elimination of Scope 1 and 2 emissions.

The brief

Our top levers to reduce emissions from operations in the hydrocarbon extraction and refining sector.

1. Construct a low-cost, low-emission portfolio to ensure continued capital investment (Clean the Core).
2. Reduce Scope 1 and 2 emissions by managing methane leaks, venting and flaring (Clean the Core).
3. Reduce energy intensity with operational efficiency and low-carbon operations (Clean the Core).
4. Scale up CCUS deployment in enhanced oil recovery (EOR) with a view to monetizing the technology in other industries (Extend the Frontier).

The production, transport, processing and consumption of oil and gas products accounts for 60 percent of all global greenhouse gas emissions, with a quarter of those (15 percent) directly attributable to the oil and gas industry[2] (Scope 1 and 2 emissions).

Emissions from oil and gas operators' existing portfolios are equivalent to 5.2 MtCO2e per year (more than five times the emissions from the aviation sector)[19].

Even with recent acceleration in the electrification of light-duty and heavy-duty road transport, oil demand is expected to increase by 5 to 10 percent by 2030 before flatlining to 2040. Gas demand, on the other hand, is expected to grow by more than 30 percent to 2040[20]. These increases will raise industry emissions even further unless oil and gas operators take strong action to tackle both upstream and downstream emissions. For operators that have set net-zero targets—which include Scope 3 emissions—this presents a huge challenge[21].

Regulators (through carbon pricing and reporting and activity bans), activist investors (through fossil-fuel divestment) and consumers (through preference for cleaner energy supply) are all coming together to increase the pressure on the industry to decarbonize. It is estimated that the most emissions-intensive 50 percent of existing oil reserves and 48 percent of existing gas reserves are incompatible with achieving the Paris Agreement and might never get produced[22]. These numbers will only increase if coal is not rapidly phased out.

Gas decarbonization is particularly important given its demand outlook. Despite more than 100 emission-reduction initiatives announced over the last three years, the level of emissions per barrel of oil equivalent per day (BOEPD) has decreased by less than 1 percent per year over the last decade. That trend appears likely to continue through 2030 unless immediate actions are taken[5].

Moving to a structurally lower emissions intensity portfolio will make it easier for first-mover operators to achieve cleaner core oil and gas operations and reduce the risk of stranded assets.

Poor returns, environmentally driven fund divestment, and growing alternative investments are squeezing access to capital in the oil and gas sector. In addition to these malaises, future hydrocarbon projects are increasingly factoring in shareholder-driven shadow carbon pricing, which at $50/ton would add on average an additional $6/BOE to global production costs.

Therefore, as oil and gas companies look ahead to the next decade, a competitive portfolio will no longer solely be determined by its breakeven price, but also by its environmental impact from Scope 1 and 2 emissions. These two concerns will converge as higher carbon pricing is factored into project-level economics.

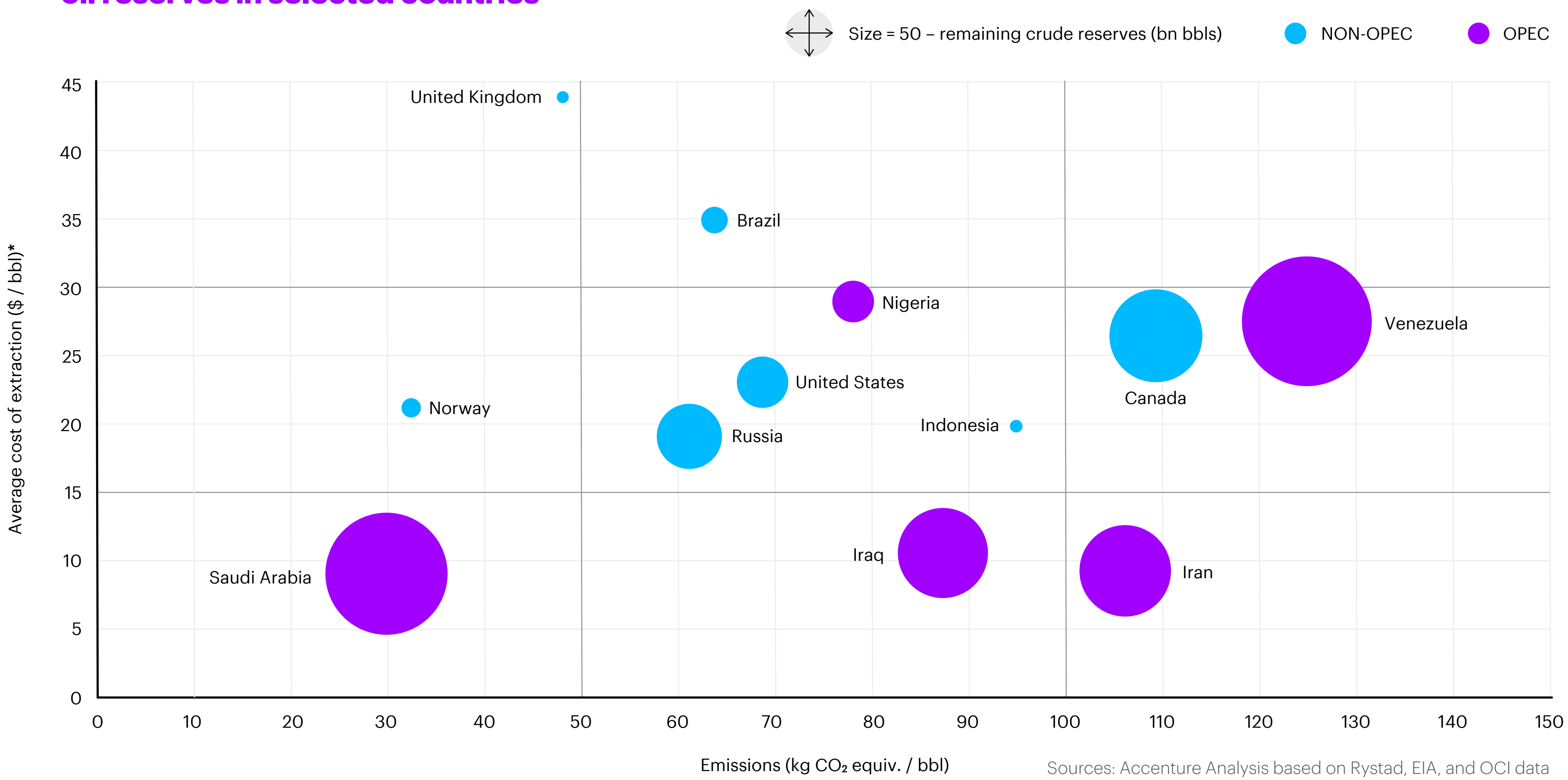
Emissions intensity is, therefore, becoming an increasingly important metric in portfolio strategy. And, as with the breakeven metric, not all oil and gas reserves are equal in terms of emissions intensity. Oil from Canada and Venezuela, for example, creates emissions four to five times greater than that of Saudi Arabian oil, in addition to having a breakeven price more than twice as high.

Over the next decade, the competitiveness of an oil and gas company's portfolio will no longer solely be determined by its breakeven price, but also by its environmental impact.

Figure 14

Emissions versus extraction costs for oil reserves in selected countries

*Average cost of extraction includes CAPEX, production, transportation and taxes



Sources: Accenture Analysis based on Rystad, EIA, and OCI data

Even within a single country, the emissions intensity disparity between different fields can be large. In Nigeria, for example, there is a 500 percent difference between the OML 118 and OML 58 fields, driven largely by flaring and venting.

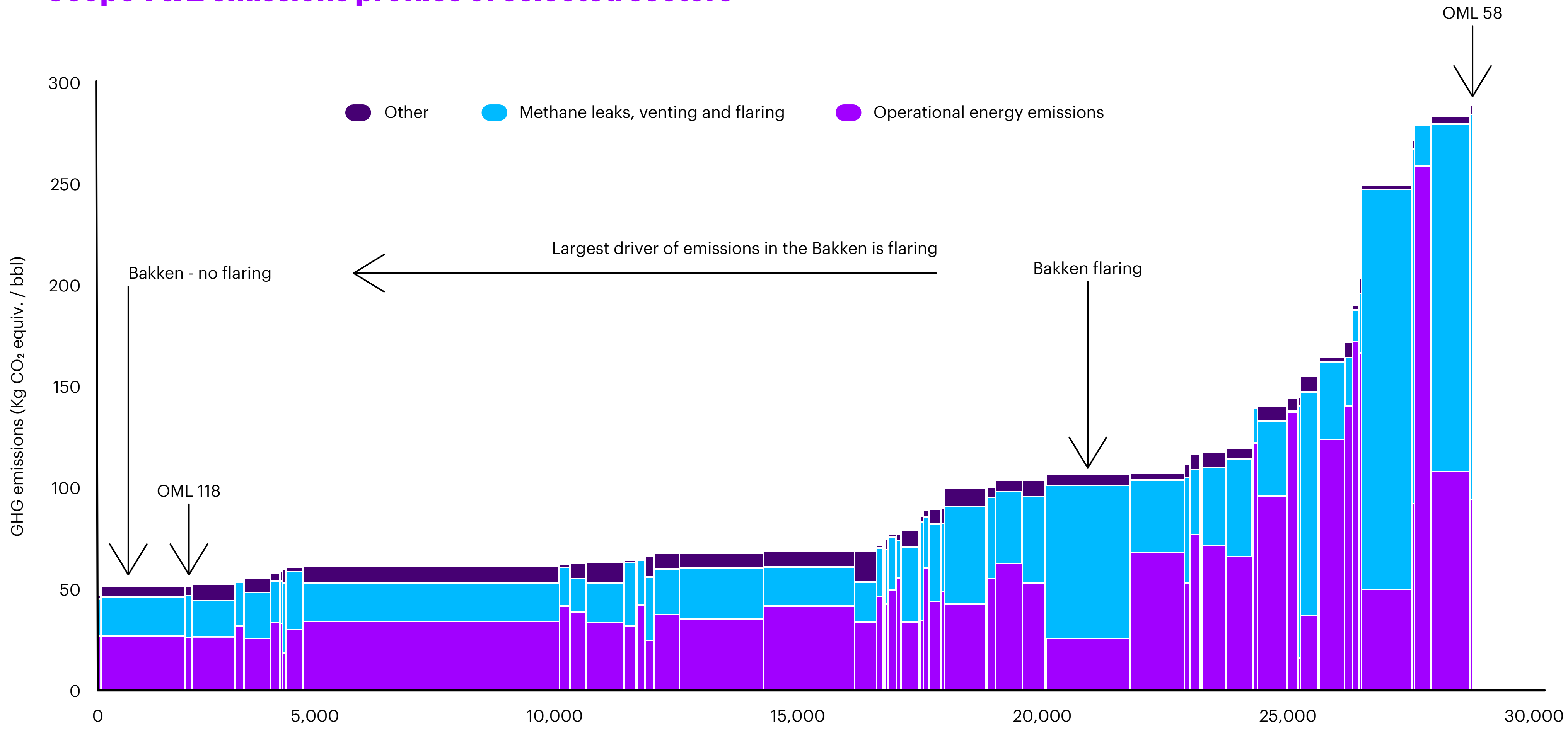
Having granular visibility into the emissions intensity of an oil and gas field, along with an understanding of the drivers of those emissions and the operator's ability to reduce them, is evolving to be another branch—and competitive advantage of—portfolio strategy. For example, fields where methane represents a high percentage of intensity today could eventually become lower-intensity fields if the industry acts quickly and strongly to prevent methane leakage. For example, eliminating all flaring in the US Bakken shale play would reduce its emissions by around 50 percent. Operators specializing in reducing particular emission sources could create a business model focused on fields with higher emissions in that particular category.

Although outside the scope of the hydrocarbon sector's direct emissions, an important step in reducing Scope 3 emissions is choosing barrels with products like lighter oils, natural gas and natural gas liquids that are less emitting. While the emissions intensity differences between fields for Scope 3 emissions are not as great on a relative basis when compared to Scope 1 and 2 emissions, on an absolute emissions-per-barrel basis, field differences have a similar impact in determining a barrel's overall impact across Scope 1, 2 and 3 emissions.

Figure 15

Sources: Accenture Analysis based on global data and OCI data

Scope 1 & 2 emissions profiles of selected sectors



For current assets, tackling methane leaks and reducing venting and flaring could decrease sector emissions by up to 50 percent.

Methane leaks alone (often known as fugitive emissions) account for approximately 2.2 billion tons CO_2e of emissions from upstream and midstream activities.

We believe that there is a significant opportunity for existing players to generate positive net present value (NPV), while reducing up to 45 percent of methane emissions (approximately one billion tons of CO_2e) by leveraging proven technologies and solutions. For example, leak detection and repair systems, together with predictive maintenance and intelligent asset management capabilities, have demonstrated the ability to lower methane emissions by about 25 percent. Additional carbon pricing and technological advances such as tracking methane emissions through satellite data will make the reduction of the remaining 55 percent of methane emissions increasingly economical.

Another source of emissions, and lost value, is deliberate venting and flaring. In 2018, oil and gas operators flared 145 billion cubic meters of gas[23]. That equals the total annual gas consumption of Central and South America combined. It also translates into $20 billion of wasted revenue annually and accounts for roughly 0.3 billion tons CO_2[2].

Venting and flaring are practiced when the costs of capturing, storing and transporting associated gas to market outweighs the market value of the gas. However, in response to strict regulatory policies focused on reducing flaring, oil and gas companies are now investing in infrastructures to alleviate storage and takeaway constraints and deploying onsite technologies to monetize the gas produced. Thirty-six oil and gas companies have already endorsed the World Bank's "Zero Routine Flaring by 2030" Initiative.

However, despite these developments and a commitment "to do the right thing," global flaring has only been reduced by 10 percent over the last decade[23].

We have determined that solving for infrastructure constraints and deploying onsite monetization technologies such as gas-to-power (for example with microturbines and gas-to-product as in the case of gas-to-fertilizers) could reduce flaring by 25 percent, while generating positive returns.

To reduce the remaining flared volumes, economic incentives can be used to push the gas to market rather than flare it. Nigeria, for example, has introduced a fee of $2 per thousand cubic feet of flared gas, driving a reduction in flaring by 50 percent over the last decade[24].

The energy used in the process of extracting and refining hydrocarbons accounts for almost 40 percent of sectoral emissions and has potential for NPV positive reduction.

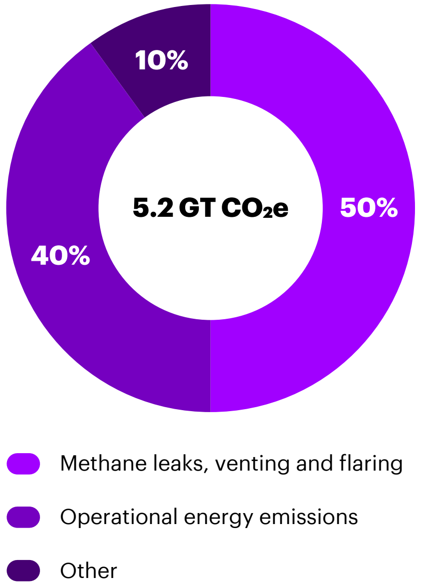
Direct emissions from energy required for upstream, midstream and downstream activities make up 39 percent of the total direct CO_2e emissions that are released by this sector[25]. Direct emissions are expected to increase as production volumes continue to grow and as resources that are easier to extract are replaced by more energy-intensive ones.

Some upstream operators have achieved 15 to 20 percent energy efficiency gains, equivalent to a 5 to 7 percent reduction in total sector emissions, by deploying only those initiatives that are proven NPV-positive before factoring in a carbon price[2]. Energy efficiency improvement gains downstream, on the other hand, are likely to be more limited. That's because energy usage in this part of the value chain has a greater impact on margins and is, therefore, more optimized today. Enhancing performance and predictability of current operations can also bring energy intensity down. This involves ensuring that equipment is operating within its envelope and reducing frequency of events.

Operators can further reduce energy intensity during extraction by shifting to power generation from low-carbon sources and replacing existing fleets with electrified equipment. Recent deployments of "power-from-shore" and "floating wind/solar farm" solutions for platforms have the potential to deliver up to 20 percent of the offshore energy requirement by 2030. This is equivalent to a 2 to 3 percent total emissions reduction, while increasing sales revenue from produced gas by up to 2 percent[2].

Figure 16

Global greenhouse gas emissions from hydrocarbon extraction and refining



Source: IEA; The Oil and Gas Industry in Energy Transitions; Accenture Analysis

Increased deployment of CCUS technologies could reduce sector emissions by up to 80 MTCO2e per year by 2030.

Despite only having limited potential for an impact on the sector's emissions, increased CCUS deployment would open opportunities for monetization in other sectors, such as heavy industry, which are likely to rely on it heavily for decarbonization.

The oil and gas industry is the world leader in deploying CCUS solutions, particularly through enhanced oil recovery (EOR). Oil and gas companies are rapidly scaling their use of CCUS technologies as a crucial means to meet emission-reduction targets. As of February 2020, 16 large operators had launched or announced CCUS projects. We expect CCUS technologies to attract $25 billion in investments by 2030 and reduce emissions by up to 80 MTCO2e per year[26].

Oil and gas operators have a competitive advantage over other industries in deploying CCUS technologies. They have access to an abundance of high-concentration CO_2 streams from natural gas liquids (NGL) processing facilities, reservoir access for underground sequestration and utilization, and the availability of pipeline infrastructure for CO_2 transportation. If they are to meet net-zero targets, including Scope 3 emissions, oil and gas companies will need to sequester a great deal of CO_2 emitted during final hydrocarbon consumption in other industries.

Implications and actions for oil and gas companies

As they look ahead to 2030, operators will need to increase the sophistication of their portfolio strategies to balance breakeven price, emissions intensity and evolving demand outlooks to increase returns, while reducing the risk of future asset write-downs. Being able to show clear linkages between company targets, portfolio decisions and the Paris Agreement target is likely to become increasingly important as a factor in attracting capital to the sector.

In parallel, immediate action is needed to Clean the Core of oil and gas operations. Reducing the emissions intensity of existing portfolios through methane leakage reduction and reduced flaring will have the single greatest impact on the sector's emissions, and much can be done to generate a NPV positive return. Decreasing energy intensity of operations through increased operational efficiency and low-carbon power sources can, likewise, be NPV positive.

As part of a holistic approach to emissions reduction, choosing service providers with the lowest carbon footprint will become increasingly important. Oilfield equipment and services (OFES) firms, as well as engineering, procurement and construction (EPC) companies, need to increase the transparency of their emissions-reduction efforts and demonstrate a clear pathway to reducing the emissions intensity of their activities.

Finally, what the oil and gas industry learns as it decarbonizes can be reapplied to drive new growth opportunities across other industries. For example, the CCUS technology pioneered in upstream oil and gas can be leveraged by heavy industry, opening up new monetization opportunities for the hydrocarbon sector.

We see four discrete sets of actions that oil and gas companies can take to mitigate the risk to core business.

1. Increase sophistication of portfolio management and capital planning to balance financial and environmental objectives.

A. Utilize a dynamic approach that evaluates the competitiveness and fit of assets (based on their economic and emissions profile) and allows for optimization within the hydrocarbon portfolio and across the extended enterprise portfolio, which may include non-hydrocarbon assets and capital-light new energy solutions businesses.

B. Include carbon pricing consistent with net-zero objectives in all capital investment decisions and asset lifecycle forecasts.

C. Aggressively manage exploration and M&A/A&D activity and set up mandates to build up low-emission assets.

2. Monitor and reduce Scope 1 and 2 emissions across portfolios and services.

A. Build capabilities to measure and evaluate emissions and the overall carbon footprint at a granular level.

B. Manage methane by taking advantage of leak-detection programs and satellite information to detect and repair leaks. Integrate predictive analytics to enable changes in operational processes ahead of a leak event.

C. Reduce venting and flaring. Re-assess brownfield capital opportunities to install vapor recovery units and gas collection infrastructure. Prioritize NPV positive investments linked to commercial opportunities for the gas. Over time, install vapor recovery as a matter of course. Evaluate and adopt zero-flaring policies.

D. Collaborate with supply chain partners by letting them play the decarbonization role in some cases and reward / select them based on it. Share the burden of CAPEX investment in turning over the equipment capital stock with the services and equipment sector. Incent the supply chain to adopt low-emissions solutions. Operators should be selective as to where they, themselves, can develop the capability versus leveraging partners.

3. Reduce the energy intensity of operations.

A. Build operations consistency. Take an emissions-centric approach to maintenance and ensure assets operate in the windows that minimize emissions and maximize energy efficiency.

B. Drive automation and digitization. Reduce the need for transportation to and from facilities, reduce the size and complexity of facilities through automation, and reduce the requirement for people on board (lowering requirements for helicopter trips and supply vessels).

C. Shift to low-carbon intensity energy sources. Add solar and wind assets to displace diesel and grid power. Potentially add nuclear power to, for example, reset the emissions profile for oil sands. Focus on reducing waste energy. For example, a leading service company installed automatic hydraulic fracturing pump startup and shutdown and significantly cut fuel wasted during idling.

D. Deploy circular solutions to reuse energy in the field, reduce emissions as waste, and lower demand for materials.

4. Continue to increase CCUS deployment for EOR.

A. Build on the industry's technological advantage in this area with a view to leverage to other industry sectors.

Power generation

Accenture 2050 stretch goal

86 percent reduction from 2050 business-as-usual emissions through accelerated displacement of coal by gas and 70 percent renewables penetration.

The brief

Our top levers to reduce emissions from operations in the power sector.

1. Pause construction of new coal power plants and phase existing coal out of the system through:
   - A. Accelerating transition to competitive "clean" gas (Accelerate the Transition).
   - B. Achieving 70 percent penetration for renewables (Accelerate the Transition).
2. Solve for long-term storage / carbon-free baseload to completely decarbonize the sector (Extend the Frontier).

The power sector is the single biggest contributor to greenhouse gas emissions, accounting for approximately 38 percent of global CO_2 emissions.

Out of this 38 percent, coal-fired generation alone accounts for around 30 percent, with gas and oil making up the remaining 8 percent. The sector is also the single biggest market for gas, making up almost 40 percent of total demand[26].

Globally, today's electricity demand of 28,000 TWh is expected to rise to 41,400 TWh by 2040 (+2.1 percent per year)[27]. That increase is driven by multiple factors: the increased electrification of buildings, transport, and industry; population growth of two billion people; 0.8 billion more people with access to electricity grids; and increased energy usage per capita in developing economies. The contribution of the power sector to emissions, coupled with increased electrification of other sectors, means the success of the Decarbonization Transition is highly dependent on what happens in power.

Gas should play a significant role in the power transition, but economics may get in the way, given that by 2025, LNG costs will need to drop up to 40 percent to ensure gas displaces coal in key markets such as India[28].

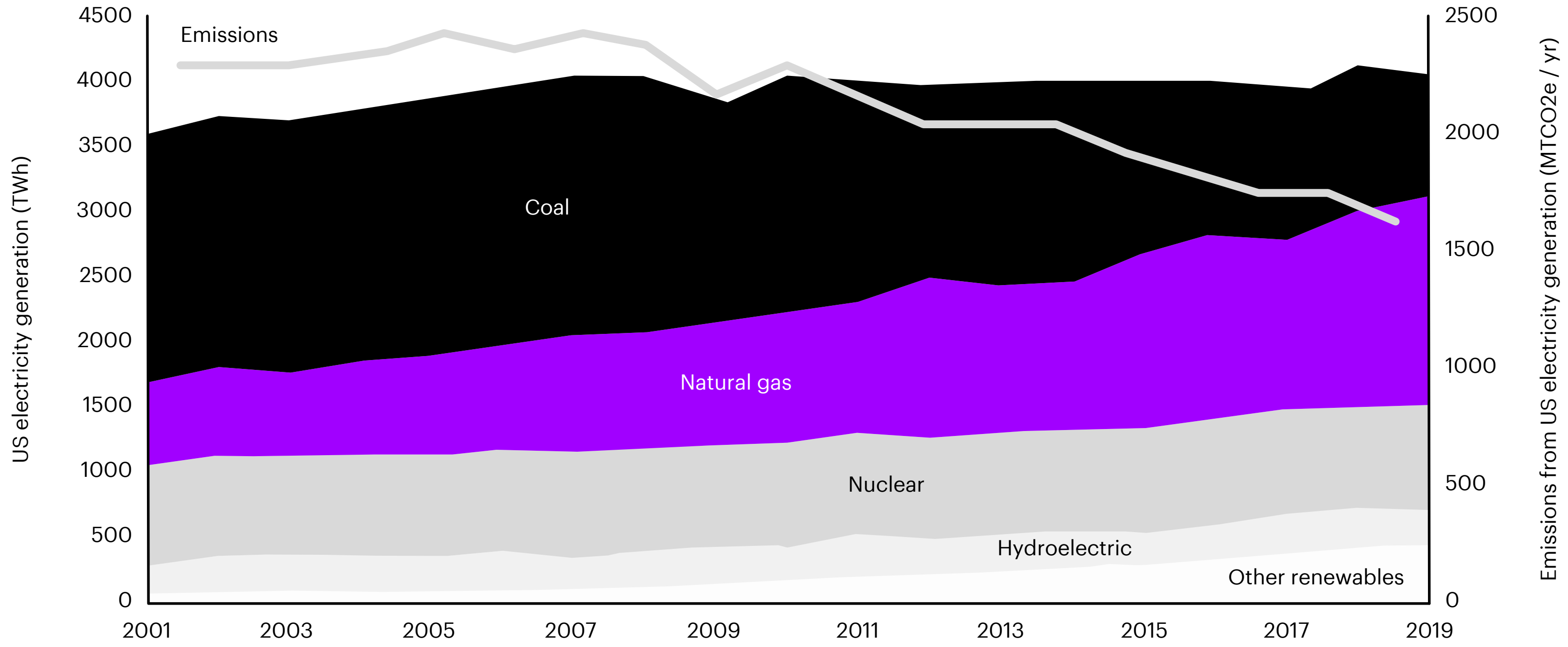
Globally, coal power generation is the single largest contributor to greenhouse gas emissions. The acceleration of its removal from the power sector is the biggest lever that can be pulled in the near-term. Despite coal generation being in relative decline in the OECD, global capacity has doubled since 2000 to 2045 GW, largely driven by India and China. With a further 200 GW of capacity under construction and further 300 GW planned, active intervention will be required to reverse the increase in coal-related CO_2 emissions.

To date, the primary lever used to abate power-generation emissions has been the switch from coal to gas generation, on the basis that CO_2 emissions per unit of energy from gas are about half those from coal.

Historically, gas has replaced coal in markets where cheap gas or implicit carbon pricing—in which the cost of emissions is passed to the polluter—has made the transition economically feasible, and where the stock of existing coal plants was older and less efficient. In Europe, for example, the switch was driven by implicit carbon pricing; in the United States, it was enabled by the availability of inexpensive gas.

Figure 17

US power mix and power-sector emissions 2001 to 2019



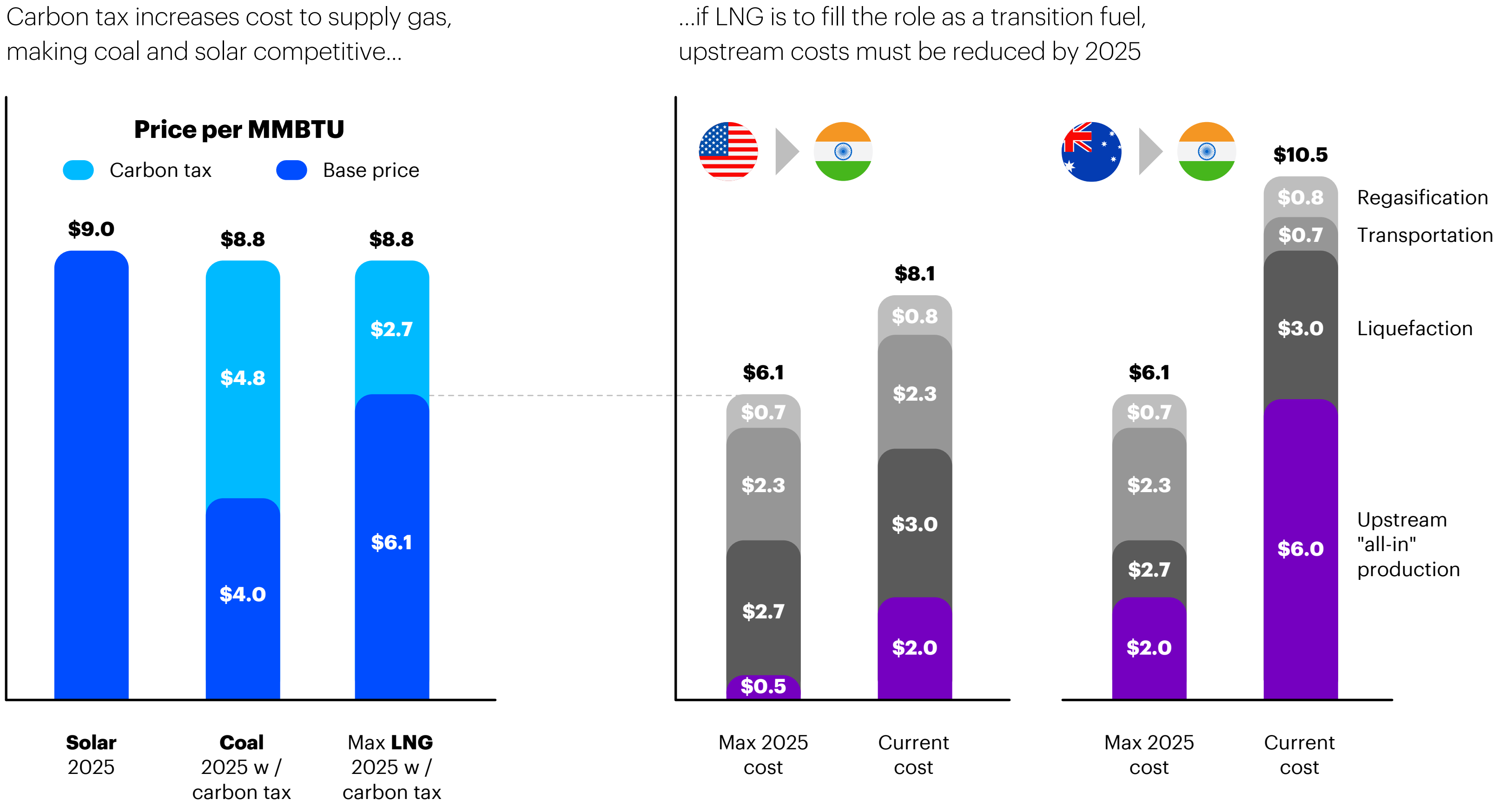
Source: EIA; Accenture Analysis

In most markets, however, the pace of transition to gas is now slowing since remaining coal generation and the opportunities for economic transition have diminished. In China and India, gas continues to be more expensive than coal, requiring a carbon price of $50-$100 per total carbon dioxide (TCO_2) to be cost-competitive[29]. In addition, coal generation in these countries is produced by modern, efficient plants many years off retirement.

For gas to increase its presence in these markets and compete with the ever-decreasing costs of renewable generation, there will need to be either a significant decrease in the cost of landed LNG, a significant increase in carbon pricing, or direct state intervention through mechanisms such as subsidies. For example, in India, our modeling shows that the cost of source gas required to economically land LNG would have to go down significantly to compete with coal and solar, even at a carbon tax of $50/ton[5].

Figure 18

Costing scenarios for gas to enable Decarbonization Transition in India



(a) Coal base price held constant over period. (b) Max LNG prices do not consider cost of expanding LNG production facilities. (c) Carbon tax set to $50/ton
Source: EIA; Accenture Analysis

Up to 70 percent intermittent renewable penetration is now possible without a long-term energy storage solution.[6]

Intermittent renewable costs associated with solar photovoltaics (PV) and wind have plummeted in recent years. During 2019 auctions, renewables were competitive at prices which, just two years previously, were not forecast to occur until 2030. Recent solar PV auctions in Portugal were as low as $16/Mwh. And North Sea offshore wind is now competitive at around $50/Mwh[30].

New-build renewables are now forecast to become cheaper than operating existing gas and coal plants in most emerging markets by 2030. That throws further doubt on a transition to gas at current LNG costs. Once renewables are cheaper than existing hydrocarbon generation, their deployment is likely to accelerate.

There is a second, previously unforeseen, consequence of the falling price of renewables and storage. The new price points have opened up the possibility of having up to 70 percent intermittent renewable generation in the grid before the cost of managing the intermittency becomes greater than existing coal and gas generation. At previous price points, there was just 40 to 50 percent penetration. Admittedly, this will require a shift in mindset from using every kWh of renewable power produced to an acceptance of overcapacity and curtailment.

At a price point of $20/Mwh, 40 to 50 percent renewables overcapacity can be built in and still be economically competitive with alternative power sources. Beyond 70 to 80 percent penetration, the exponential increase in overcapacity required to cover the more extreme supply and demand fluctuations makes it unlikely that the requirement for long-term energy storage or renewable non-intermittent resources will ever go away.

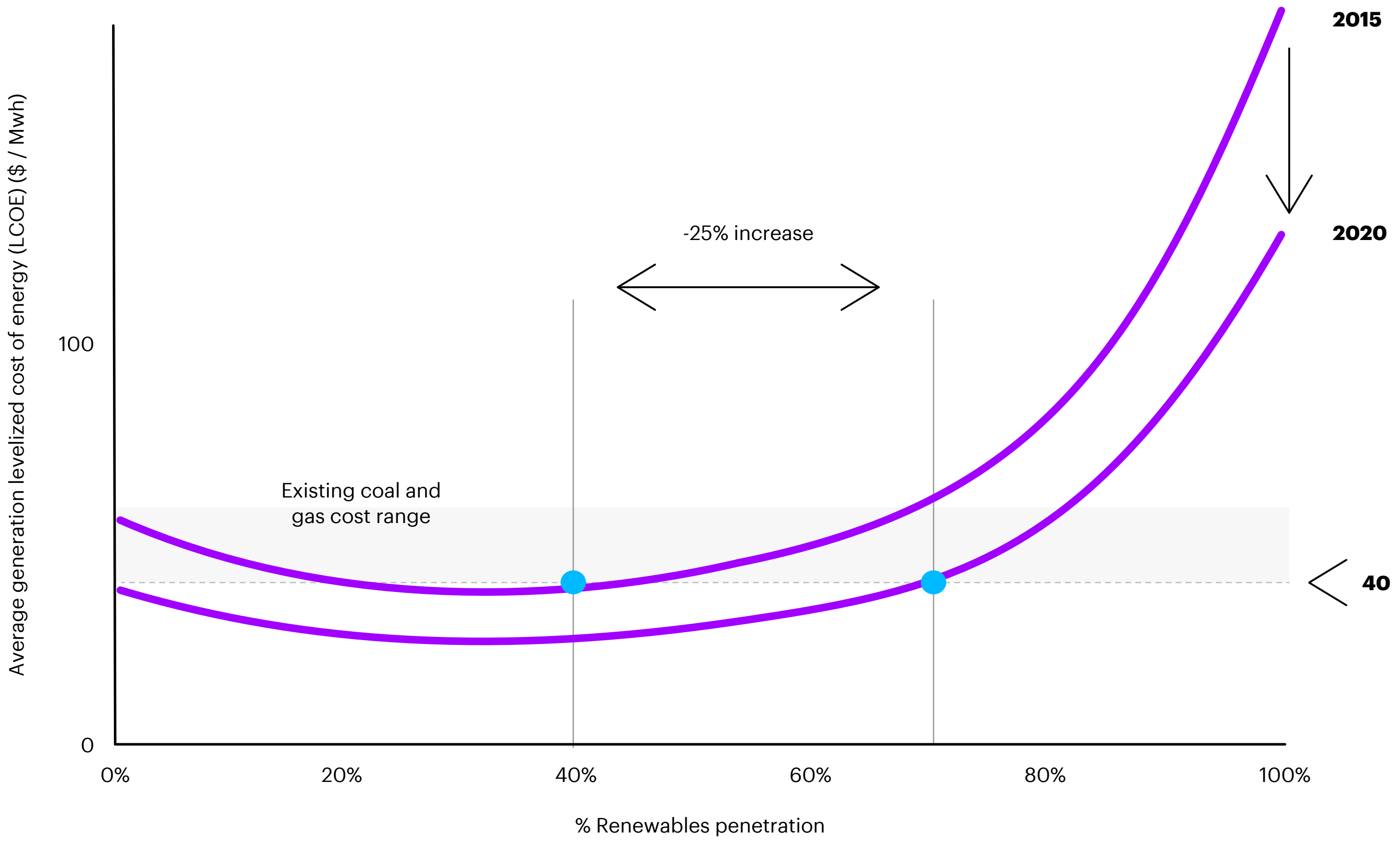
This development does, however, buy time. At the current rate of capacity increase, most countries and regions are many years away from reaching this limit of 70 percent penetration (25 years in China, 60 years in Europe and the United States). This suggests that renewables capacity can continue to increase in an uninhibited way, and the pressure to solve the long-term, inter-seasonal storage problem will recede. The infrastructure focus will instead switch to upgrading and increasing transmission and distribution capacity[5].

Moving from a mindset of "we must use every megawatt hour produced from renewables" to "we can accept a degree of overcapacity and curtailment" significantly reduces energy storage demand and opens the possibility of "free" surplus electricity to produce hydrogen. Meanwhile, the costs of short-term energy storage for day-to-day balancing have plummeted as lithium-ion battery technology has matured. With economic constraints receding, the other capacity constraints of land use and materials requirements will come to the fore.

Figure 19

Source: IEA; Accenture Analysis

Percentage of renewables penetration possible before intermittency management cost is prohibitive



A completely decarbonized power system will require either a solution to long-term energy storage or expanded sources of non-intermittent, economical carbon-free generation.

At present, there is not an economical solution for completely decarbonizing the remaining 20 percent of the grid that cannot be filled by intermittent generation plus current storage technology. The most likely route for this appears to be nuclear, which is economically uncompetitive and politically sensitive as a viable solution to the long-term energy storage problem.

At this time, the cost of nuclear power generation is more than double the cost of renewables. The proposed Hinkley Point nuclear power station in the United Kingdom has a cost of nearly $100/Mwh, compared to $40/Mwh for offshore wind[31]. Nuclear would, therefore, require subsidies to compete.

Furthermore, nuclear disasters such as Chernobyl and Fukushima have made the future of nuclear power generation extremely uncertain. Countries such as Germany have already turned off their plants and replaced generating capacity with coal. Although small, modular nuclear reactors offer the potential for multiple applications and are considered safer, they are not yet commercially viable and will struggle to compete with other energy sources on a levelized cost of energy (LCOE) basis.

While short-duration battery storage for operating reserve, power fleet optimization and grid shutdown/restart service applications are increasingly economically viable, long-term inter-seasonal storage requirements to allow 100 percent intermittent generation remain unmet. And that is despite investments in areas such as compressed air energy storage, pumped hydro and hydrogen.

Implications and actions for oil and gas

The direction and pace of the Decarbonization Transition in the power sector have stark implications for gas. Many oil and gas companies have shifted their portfolios to gas in the past decade. They believe that gas will act as a transition fuel between coal and renewables, primarily through a sizable share in the growing electricity sector. They further believe that gas demand growth will hold up more than oil. However, the rapidly plunging costs of renewable generation and day-to-day storage facilities put this strategy at risk. By 2030, existing gas generation will be uncompetitive with new-build renewables. The implication is that the number of new gas plants built will be limited.

In some geographies, transition in the power sector, as a whole, may happen faster than expected. And based on current projections, gas demand looks unlikely to keep pace with growth in electrification. In addition, once coal is transitioned out of the power system in OECD countries, gas will increasingly find itself in the crosshairs of decarbonization policies in developed countries.

Gas will still play a key role in peaker plants and in geographies with cheap supply. But it will need to also play a dominant role in pushing coal generation out of the system in countries such as India and China if it is to reach its potential as a transition fuel. Without gaining a significant share of the power supply market in these countries, the role of gas as a transition fuel in power generation may be a localized phenomenon in markets with cheap gas such as North America, the Caucasus and Middle East. Simply put, its prospects as a "true" commodity could be stunted.

We see three discrete actions that oil and gas companies can take to secure a role in the provision of cheap, clean and available power to the world in next 30 years.

1. Drive a step change in the competitiveness of gas.

A. Value chain economics must improve by up to 40 percent to drive coal out of the system in developing countries.

B. Scope 1 and 2 emissions must be cut by 50 percent by working together to collectively decarbonize the gas value chain through methane and flaring reduction, clean gas blending, and the creation of a carbon market for economic CCUS solutions. Deploying and enhancing CCUS during LNG liquification must be a particular focus.

2. Refine "transition to gas" portfolio strategies to reflect the evolving power landscape.

A. Segment target gas markets by the sensitivity of gas in the power mix—that is, its potential to substitute coal, as well as its potential to be substituted by renewables, versus the ability to deliver cheap gas into that market to reduce the risk of stranded assets.

B. Promote the use of gas/clean gas to solve the problem of long-term energy storage.

3. Maintain market share in power generation by moving into renewables where skillsets are complementary or adjacent. Examples include:

A. Offshore wind.

B. Major capital programs in renewables of all types.

Light-duty passenger vehicles

Accenture 2050 stretch goal

71 percent reduction from 2050 business-as-usual emissions by accelerating electric vehicles, penetration to 50 percent, while also doubling internal combustion engine efficiency.

The brief

Our top levers to reduce emissions from operations in the light-duty passenger vehicle sector.

1. Get ICE fuel efficiency back on track (Clean the Core).
2. Accelerate EV total operating cost reduction (Accelerate the Transition).
3. Build out EV-supporting infrastructures and expand supply chains (Accelerate the Transition).

The light-duty passenger vehicle sector currently accounts for roughly 10 percent of global CO_2 emissions and it accounts for 23 percent of oil and gas demand.

All this sector's emissions originate from the combustion of oil and gas products. Demand for light-duty passenger vehicles will likely be influenced by two major trends over the next three decades[2].

Our business-as-usual models project that by 2050 the number of cars on the road increase by 150 percent, from 1.1 billion today to about 2.7 billion. This is aligned with forecasts that predict a doubling of total kilometers traveled to more than 20 trillion per year. The personal mobility surge will be driven largely by GDP growth in developing countries.

The business-as-usual view of this sector suggests internal combustion engine (ICE) vehicles will continue to dominate the market, increasing from about 1.1. billion vehicles today to 2.2 billion by 2050. The remaining 500 million cars will be electric vehicles (EV), largely in the OECD markets[2].

Despite this second trend having the potential to decouple new sales growth from mileage demand growth, it is clear that light-duty passenger vehicles will continue to incur significantly increased CO_2 emissions through 2050 if alternative technologies are not accelerated.

With high hopes for fuel efficiency improvements fading, there are limited opportunities for market forces to get fuel efficiency rates back on track.

Fuel efficiency is a vital component in the emissions-reduction strategy for light-duty passenger vehicles. In fact, our analysis shows that increasing efficiency from 0.7 percent per year to 2 percent would have a greater impact on the sector's emissions in 2050 than doubling the projection of EVs on the road from 500 million to one billion.

Unfortunately, the average fuel economy of light-duty vehicles increased by barely 0.7 percent in 2017, compared to a previous 10-year average of 1.8 percent per year. More than 20 countries even experienced reduced fuel economy compared to previous years[32].

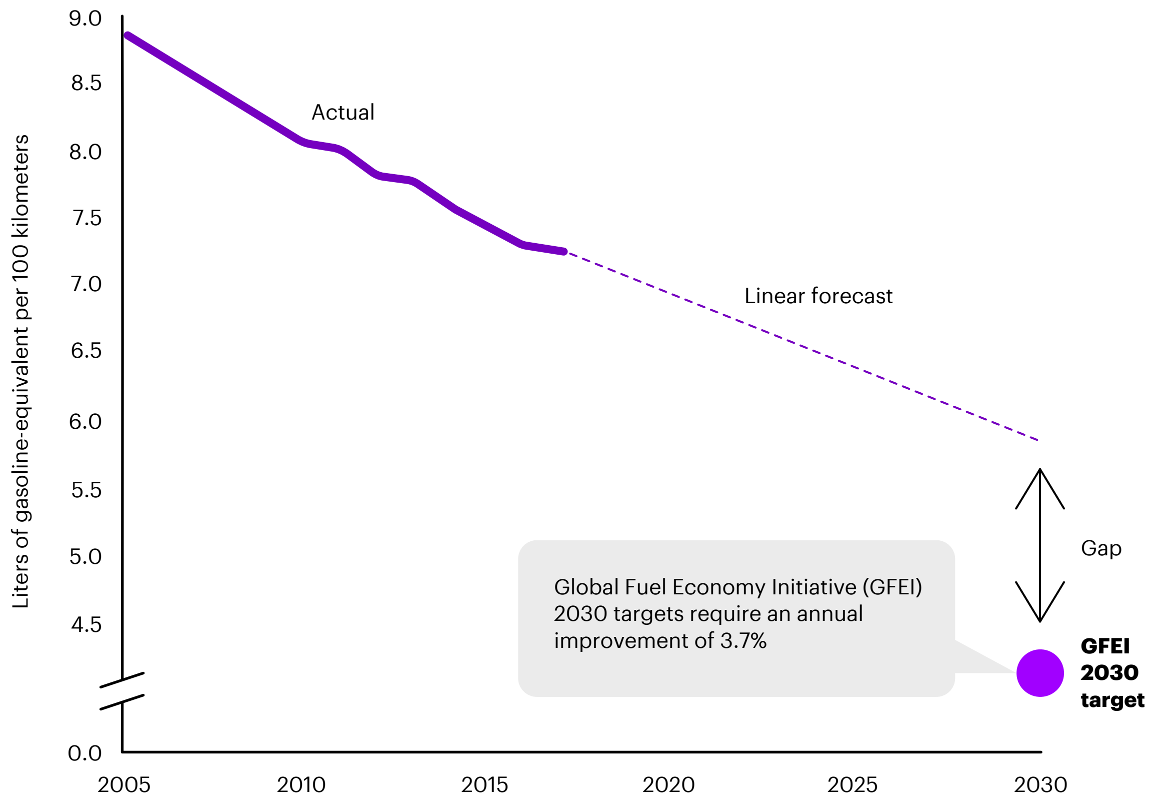
This slowdown is attributed to consumers purchasing both larger, heavier cars like SUVs and fewer diesel cars. As a result, it is highly likely that the 2030 target set by the Global Fuel Economy Initiative (the leading global partnership on fuel efficiency), requiring a 3.7 percent annual rise in efficiency, will be missed.

With EVs on the horizon, automakers have limited incentive to develop the next model of ICE vehicles and several have slowed or stopped development of next-generation ICEs in favor of electric propulsion. Outside the field of battery technologies, R&D is likely to focus on areas that benefit both ICE vehicles and EVs, such as aerodynamics, light-weighting and reduced rolling resistance.

The ball appears to be in the policymakers' court to provide the incentives needed to get the fuel-economy trend back on track. While many countries have a combination of fuel-efficiency policies in place, the major issue with existing fuel economy regulations is duration. Most are not guaranteed to last beyond a few years. The uncertainty this introduces does not spur the action required from fuel producers and retailers, automotive manufacturers and consumers.

Figure 20

Average new global fuel economy of light-duty vehicles



Source: Accenture Analysis; IEA; GFEI

Figure 21

Projected 2050 light-duty vehicles emissions (GT CO_2/yr)

# EVs on the road	Annual internal combustion engine efficiency gains: No gains	0.7% gains	1% gains	2% gains
No EV	8.2	6.6	6	4.3
500M EV	7	5.6	5.1	3.7
1Bn EV	5.5	4.4	4	2.9

Source: Accenture Analysis

The total cost of ownership of smaller electric cars has already reached parity with internal combustion engine vehicles. Larger electric cars are on course to reach parity by 2025.

Light-duty EVs will reach total cost of ownership parity with ICEs in the next five years—and leave them completely behind by 2030.

Electric vehicle costs fell by 20 percent in the four years to 2020. A further 20 percent reduction is expected by 2025 due to rapidly falling battery costs[2]. In fact, thanks to the subsidies and tax breaks offered across the OECD, the total cost of ownership of smaller EV cars and buses has already reached parity with ICEs. Larger EV cars and small-to-medium-sized vans are on course to reach parity by 2025.

Our modeling suggests ICEs will need a crude oil price of around $40/bbl to compete on a total cost of ownership basis with EVs by 2030. This reduces to around $20/bbl if today's fuel taxes are not passed on to EV owners. Fuel producers and retailers will, therefore, need to take it upon themselves to promote greater efficiency to ward off environmental and economic pressures on the ICE.

While EVs have higher upfront costs but lower running costs than ICEs, the annual fuel costs for an EV are 40 to 50 percent lower than those for an ICE. And, because EVs have just 20 moving parts compared to 2,000+ for ICEs, servicing and maintenance cost are also lower, on average[5].

With cheap renewable power generation achieving ever-greater grid penetration, the economic and environmental case for EVs looks only set to improve year-on-year.

Figure 22

US scenario for evolving light-duty vehicle costs and impact on competitiveness of gasoline

Total cost of ownership for EVs will drastically fall by 2030… …meaning fuel costs for ICEs must come down

Assumptions:

- Ford Focus and Nissan Leaf with 12 year life and 10,000 assumed annual miles
- Production costs held constant for ICEs
- Carbon tax of $50 / ton
- Road tax equalized
- EV subsidies excluded from analysis
- 10% refining cost cuts.

Source: Accenture Analysis

With economics looking increasingly favorable for electric vehicles, charging infrastructures and potential rare metal supply chain constraints become the biggest barriers to adoption.

Along with price and range anxiety, the lack of charging infrastructure is seen by many as the major barrier to the adoption of EVs. These concerns, however, appear to be receding. Modern EVs have ranges of over 300 miles on a full charge and a network of superchargers, spaced to enable almost any conceivable journey, can charge a battery to 50 percent capacity (i.e. around 150-mile range) in 20 minutes. An average daily mileage of just 30 miles in the United States, coupled with behavioral trends that show drivers now take regular breaks on longer journeys[2], suggest EVs are feasible today for all but a handful of journeys. It further suggests that the biggest barrier to EV adoption from a charging point of view is the lack of an overnight charging infrastructure for those who don't have their own garages.

A new global supply chain that connects rare metals mining, battery manufacturing and automotive manufacturing will emerge and give rise to potential supply constraints. The global annual power output of electric vehicles in GWh/year is expected to increase tenfold by 2030[33]. That will put the rare metal supply chain, which is required for battery production, under strain. Advances in battery technologies, however, are making them less rare metal intensive. They are also increasingly diversified in terms of source metals, as will be seen in the likely transition from lithium to nickel-manganese-cobalt batteries.

Implications and actions for oil and gas

With EV costs falling faster than predicted, total cost of ownership will hit parity with conventional ICE vehicles for most models in the next five years. In the short term, EV adoption rates will be determined by how fast the charging infrastructure is built, the ability to reduce range anxiety, and further cost reduction. In the medium term, rare metal and battery manufacturing constraints may come to the fore. In all cases, strong acceleration is expected over the next decade, creating a drag on oil demand growth.

Today, we have a shifting perspective on when peak oil for the light-duty vehicle sector will happen. It could be as soon as 2025. But every year, this window of uncertainty will become narrower and the timing clearer. In addition to the substitution threat from electrification, fuel retailers are also at risk of losing the associated sales from stores co-located at the pump. If more regulations are introduced to get fuel efficiency back on track, the nature of fuel retail sales volumes and product characteristics may change.

We see four discrete actions that oil and gas companies can take to accelerate decarbonization and maintain market relevance in the light-duty passenger vehicle market in the next 30 years.

1. **Accelerate the rollout of EV charging stations to existing fuel stations to capture market share before other players move in.**
2. **Double down on efficiency research, blending, branding and pricing to create differentiated fuel products, including additives that maintain engine cleanliness and performance efficiency.**
3. **Engage in the research into hydrogen fuel cell solutions for vehicles.**
4. **Promote fuel efficiency behaviors and driving practices to enhance fuel efficiency.**

Heavy-duty and commercial transportation

The following section covers heavy-duty road transportation, aviation and shipping.

Collectively heavy-duty road transportation, shipping and aviation account for around 12 percent of global CO_2 emissions, of which virtually all are from the combustion of oil and gas products.

Heavy-duty road transportation represents 17 percent of total oil demand, whereas shipping and aviation, combined, represent 12 percent[2].

While the key levers and trends within these sectors are covered separately, the implications for oil and gas are combined at the end of this section. That is because these sectors, collectively, will shape the future of middle distillate demand. Middle distillates are the portion of refined products that sit between the lighter gasoline and the heavier fuel oil (HFO). They include diesel, marine diesel oil (as an intermediary between middle distillates and HFO), extra-light fuel oil and kerosene, including jet fuel.

Within the following section, we will explore the feasibility of a number of decarbonized fuels based on their volumetric and gravimetric energy density and their emissions-reducing and economic credentials. In short, we set out to answer two questions:

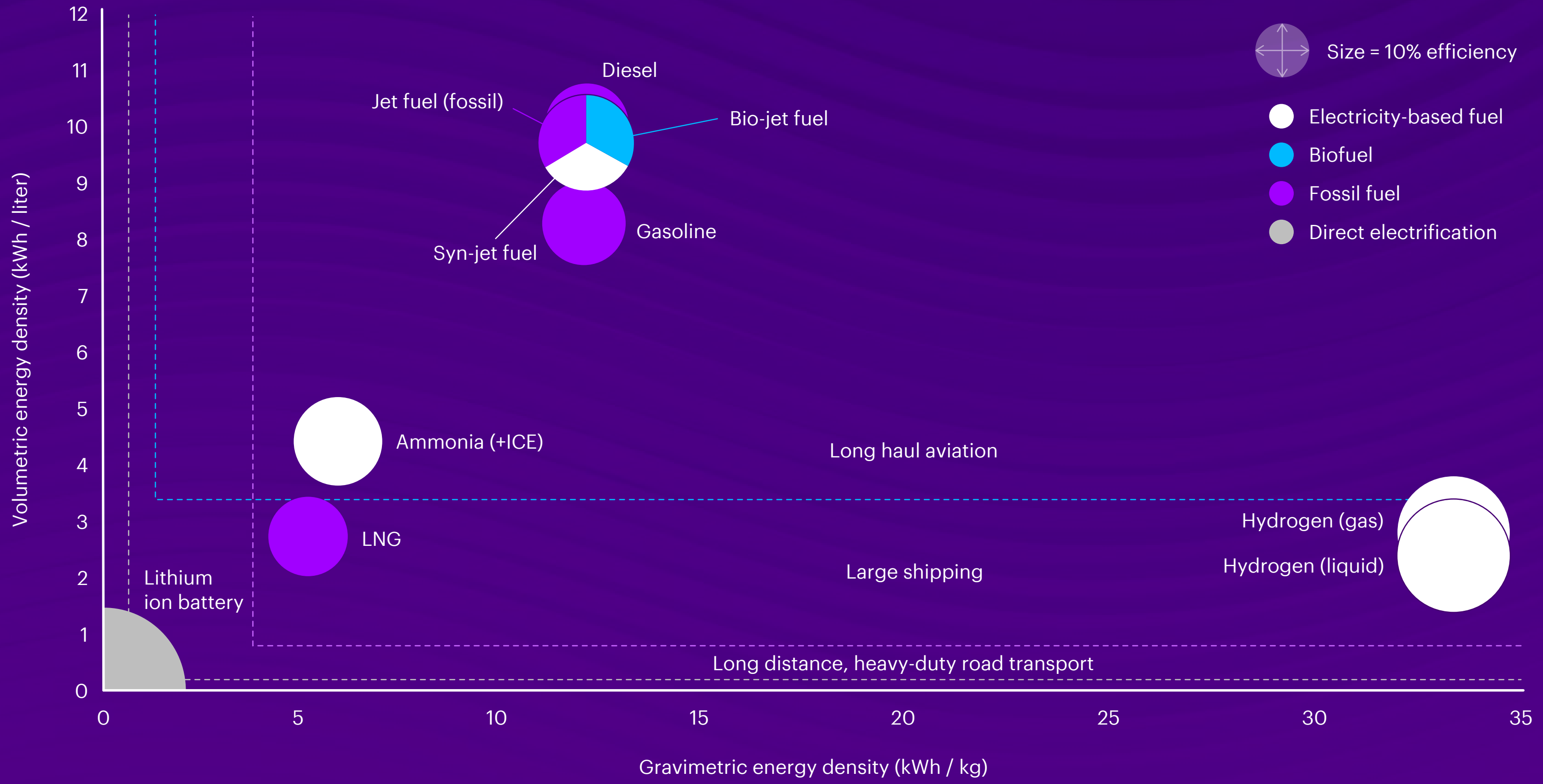
1. Do these decarbonized fuels produce enough energy for the storage volume they need, and do they produce enough energy given their weight?
2. Are they cost-competitive and carbon-reducing given today's carbon-pricing mechanisms and the carbon intensity of electricity?

Figure 23

Source: Accenture Analysis; Energy Transitions Commission; IEA

Technical feasibility of energy sources for transport based on volumetric and gravimetric energy density and efficiency

To answer the first question, the different fuel sources have been plotted on these two axes with the feasible envelopes for different modes of transportation superimposed on top. This presentation provides an indication of which fuel types are suitable for each application. The size of the bubble represents the efficiency of the solution at the point of consumption.



To answer the second question, we've plotted different fuel sources and their applications (light/heavy-duty road, shipping, aviation) on two axes:

1. Carbon pricing in $/ton required to achieve economic parity with today's incumbent solutions.
2. The electricity carbon intensity in gCO_2/kWh required to be less emitting than today's incumbent solutions.

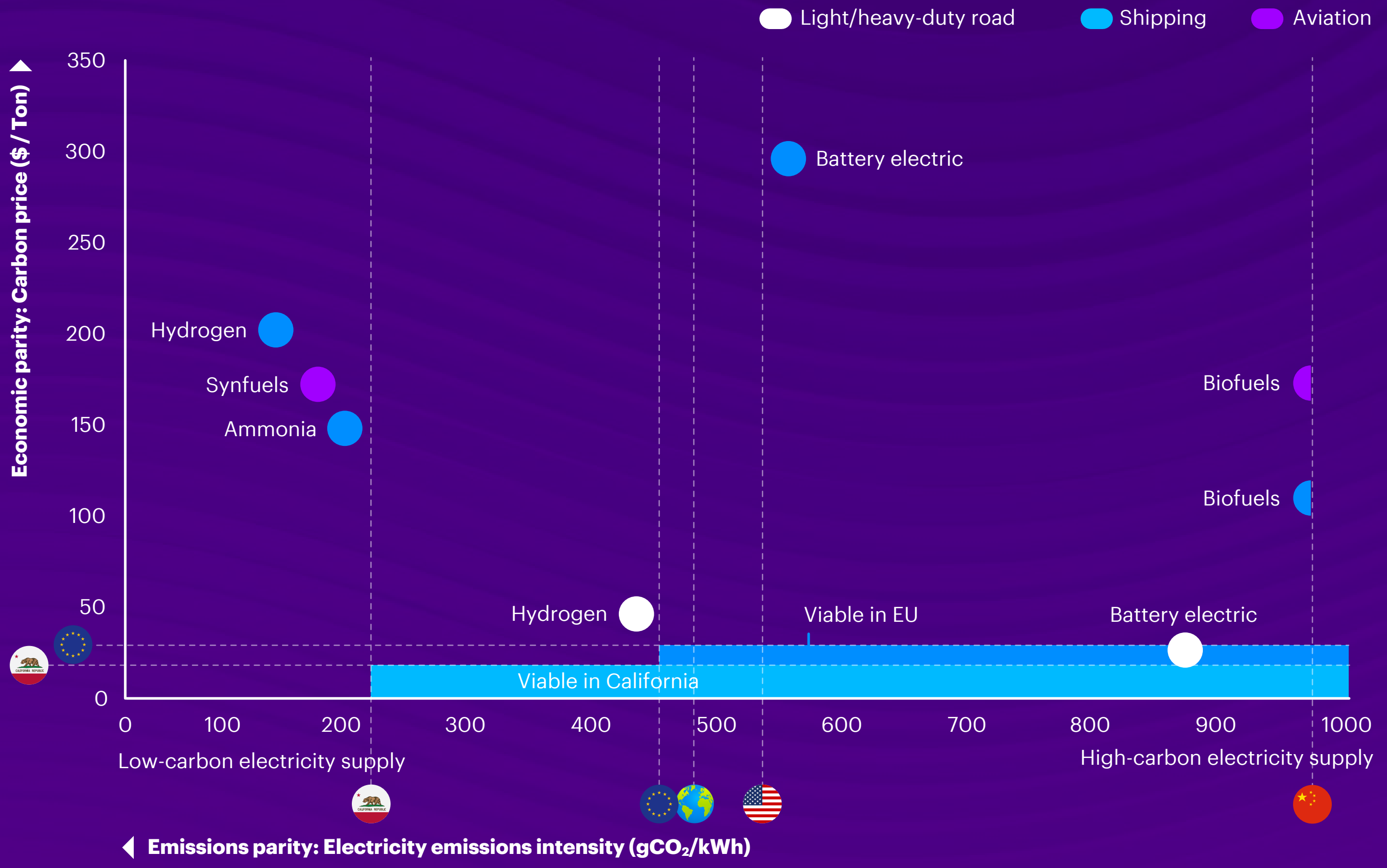
The viable envelope will, therefore, differ by geography and depending on its specific carbon price and electricity carbon intensity. The most viable solutions can be found in the bottom right, while the least viable are found in the top left. As electricity grids decarbonize over time, increased carbon pricing is introduced, and learning curves bring costs down, more of these solutions will become viable alternatives.

To illustrate this, we have shown the viable windows in California and the European Union today.

To avoid repeating the same charts multiple times, we have set out this viewpoint upfront and will refer to the conclusions as we turn the discussion to the heavy-duty transportation sector.

Figure 24

Economic and emissions parity required for clean transport fuels



Source: Accenture Analysis; IEA, Energy Transitions Commission

Heavy-duty road transportation

Accenture 2050 stretch goal

78 percent reduction from 2050 business-as-usual emissions through efficiency increases and electrification.

The brief

Our top levers to reduce emissions from operations in the heavy-duty road transportation sector.

1. Maximize operational, logistical and energy efficiency (Clean the Core).
2. Accelerate EV total cost of ownership reduction (Accelerate the Transition).
3. Increase investment in renewable fuel decarbonization pathways (Accelerate the Transition).

In a business-as-usual scenario, heavy-duty road freight volumes are expected to triple by mid-century, in part because they are strongly correlated with rising prosperity.

Growth will be concentrated in major emerging economies such as India, the ASEAN economies and Africa, whereas growth is expected to slow in mature economies such as the European Union, United States and even China.

Non-urban, long-distance traffic is forecast to grow more rapidly than short-distance traffic, say, within a city. This makes it particularly important for the heavy-duty vehicle sector to develop decarbonization options.

Demand management and energy efficiency are under-used levers today and could contribute most of the required emissions reductions in heavy-duty road transportation.

The reduction in emissions from demand management would arise from a combination of the following.

1. **Curbing traffic volumes** through better demand management, for example, routing, timing and hub optimization; platooning; co-loading and crowd-shipping; and use of high-capacity vehicles (25 percent reduction).
2. **A shift of heavy-duty freight volumes** to more carbon-efficient rail networks or inland and coastal shipping (up to 10 percent reduction).
3. **Local and national interventions** to improve driver training, limit speeds and reduce fuel consumption (5 percent reduction).

When it comes to energy efficiency, heavy-duty vehicles have stagnated in recent years and fallen behind the light-duty vehicle sector, which has a much stronger regulatory environment. Our modeling estimates that a total efficiency gain up to 40 percent is theoretically possible with improved aerodynamics and greater energy efficiency[2].

Electrification of heavy-duty road transportation is taking off.

Heavy-duty road transportation sits on the edge of feasibility limits for batteries, given their volumetric and gravimetric energy densities. But continuous advances in battery technology will likely make all but the heaviest of loads for the longest journeys feasible.

Several companies are betting big on the electrification of heavy-duty road transportation, with new models starting to hit the market and others expected through 2021. While there are still questions around the optimal charging strategy for such trucks, and production at scale has yet to begin, cost parity with ICE trucks is expected to be achieved by the end of the decade.

A switch to EVs in heavy-duty trucking is likely to be more complete than for light-duty vehicles. That's because logistics companies focus on the bottom line more than consumers do, and because fleets will be replaced en masse once cost parity is surpassed. The development of the autonomous driving capabilities of trucks could also significantly reduce operational costs by ultimately removing the need for a driver.

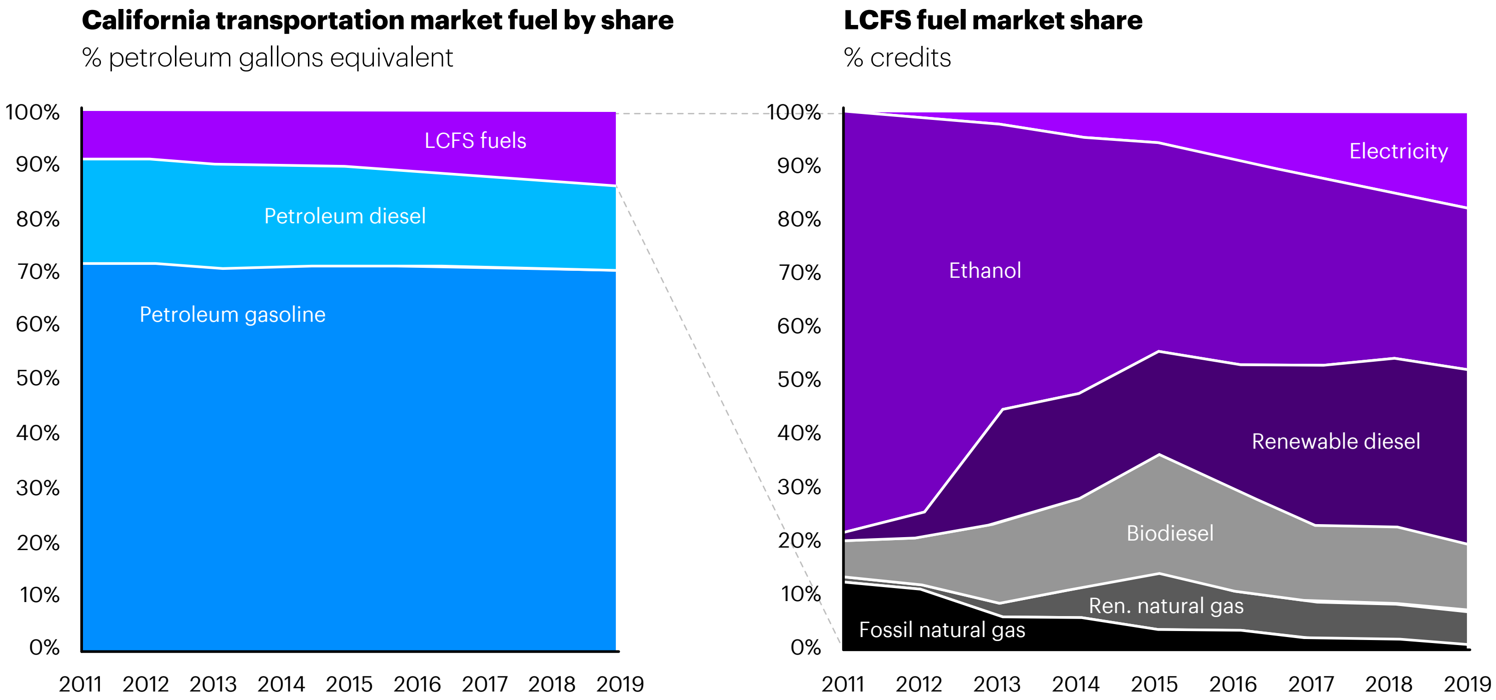
As more near-term solutions to decarbonization are emerging in this space, biodiesel, renewable diesel and renewable natural gas are also putting pressure on petroleum diesel demand.

While these solutions may be more localized and supported by generous tax credits and subsidies, their impact on petroleum diesel in select markets should not be understated. In California, petroleum diesel usage has dropped over the past decade despite an increase in heavy-duty transport miles. Refiners producing renewable diesel in the market have seen profit margins of up to 45 percent, with operating costs covered by subsidy breaks alone.

The threats to these bio-based renewable fuels posed by decreased cost of electrification, potential feedstock supply constraints as demand increases, and removal of subsidies may limit the development of this market in the mid- to long-term.

Figure 25

Localized impact of biofuels in California's incentive-driven market



Source: California Air Resources Board; Accenture Analysis

Aviation

Accenture 2050 stretch goal

63 percent reduction from 2050 business-as-usual emissions through a multi-faceted approach.

The brief

Our top levers to reduce emissions from operations in the aviation sector.

1. Maximize demand management and energy efficiency levers (Clean the Core).

2. Accelerate electrification of short-haul flights (Accelerate the Transition).

3. Reduce costs of biofuels and synfuels for long-haul flights (Extend the Frontier).

Passenger miles have increased 12-fold since 1970 and are forecast to grow by 238 percent through 2050 in a business-as-usual scenario, primarily driven by income-elastic tourism demand.

While domestic flights carry more passengers every year, international flights account for around 65 percent of passenger-miles flown. Both segments are expected to grow significantly through 2050[34].

Both passenger and freight air traffic are strongly correlated with growing global income. The largest increases in passenger air travel will be concentrated in parts of the world experiencing rapid income growth. The Asia-Pacific region is expected to account for more than 50 percent of new passengers by 2036[2].

Demand management measures could reduce 2050 business-as-usual emissions by 10 to 15 percent[2].

Demand reduction and energy efficiency improvements both play a role in reducing emissions in the aviation industry. However, both also face stiff challenges—the former, because of the high elasticity of air travel demand; the latter, because of slow fleet turnovers and a conservative approach to implementing innovations.

Our modeling suggests that up to 15 percent of emissions could be reduced through better demand-side management.

1. **Shifting short-haul passenger flights to rail**
   Successful examples include China's high-speed network, Japan's Shinkansen and the Eurostar (up to 6 percent reduction).

2. **Reducing demand for leisure travel**
   (up to 4 percent reduction).

3. **Reducing demand for business travel***
   (up to 3 percent reduction).

4. **Improving operational efficiency through better air-traffic management**
   by optimizing routing, minimizing flight waiting times and distances, etc., (up to 2 percent reduction).

The fuel efficiency of aircraft has improved by 80 percent since the 1960s, thanks to improvements in engine efficiency and aerodynamics. Additional improvements of up to 20 percent are possible before the limits of thermodynamics are reached[35].

New engine designs and use of lighter, composite materials could decrease emissions by 10 to 20 percent in the early 2020s. Additional reductions of up to 30 to 40 percent are possible by 2030 through innovations like laminar flow control and fuel cells for onboard energy. Beyond 2030, improvements are harder to foresee[36].

However, the lifespan of passenger aircraft is 25 to 30 years which, coupled with the sector's conservative approach to adopting new materials and designs, will hamper its ability to curb emissions through increased efficiency. Retrofits by carriers are, therefore, an important lever and are expected to yield a 6 to 9 percent reduction[2].

* The long-term impacts of COVID-19 on business travel are yet to be seen but could have a more significant effect on this sector than the pre-crisis estimates indicate

Short-haul electric flights are taxi-ing, ready for take-off.

Networks of electric planes are beginning to emerge in countries such as Norway for short-haul flights. The country has set ambitious goals; it anticipates having the first all-electric domestic flights in service by 2030, followed by a fully electric fleet of aircrafts by 2040. However, the short distances between airports in Norway, coupled with the ability to use smaller planes (e.g., 10-15 seats) due to limited demand, suggest that other countries with greater landmasses and population densities will struggle to replicate these goals. While more ambitious designs—such as those with more than a hundred seats and longer range—are in the works, their concept is unproven and may only be viable after 2030.

At present, the only feasible solution for long-haul flights is a decarbonized liquid hydrocarbon (i.e. a product similar to today's aviation fuel, which has net-zero emissions).

Batteries do not have the energy and gravimetric density to power long-haul flights. Hydrogen takes up too much volume. And although storing hydrogen as ammonia would reduce the fuel storage volume requirements, the jury is out on whether the solution is compatible with long-haul flights. This suggests that the only sure route to complete decarbonization of long-haul aviation is a non-fossil-fuel-based liquid hydrocarbon fuel. Such fuel would be derived either from a bioenergy source or via a "power-to-liquid" synthesis, which combines CO_2 (extracted from the air or captured at an industrial plant) with hydrogen to create synfuels.

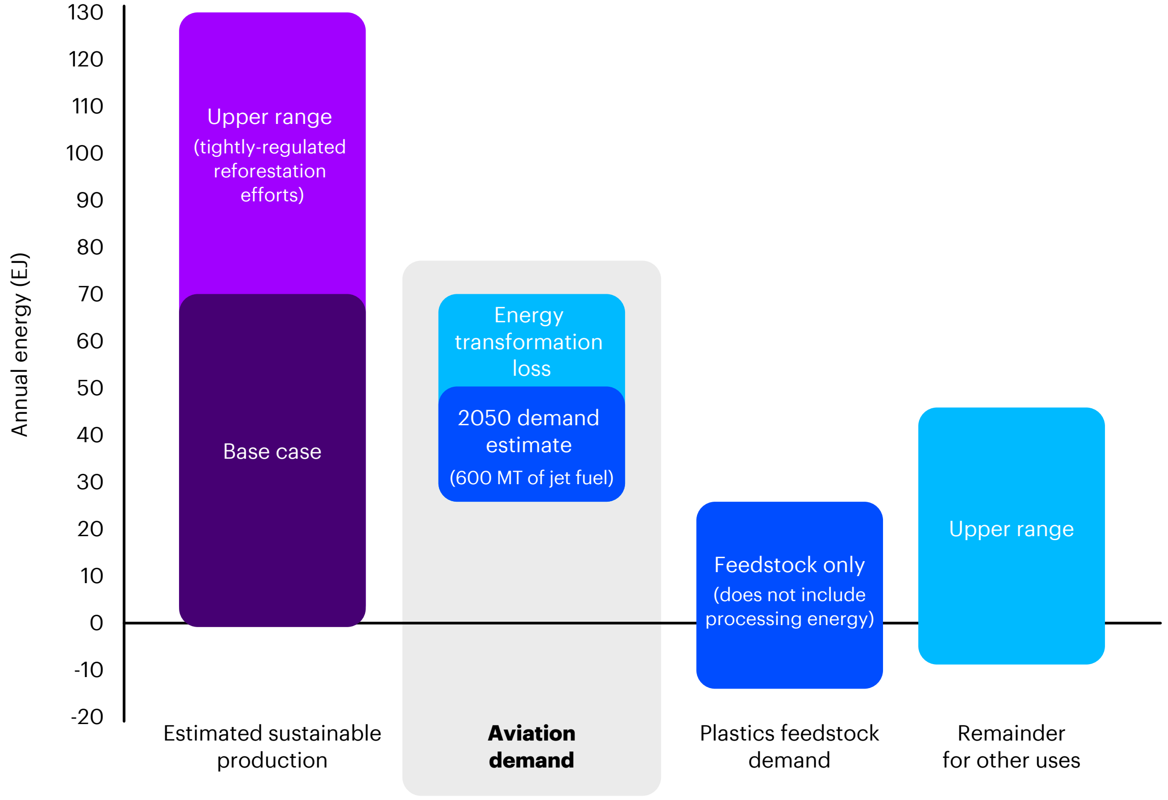
The advantage of such fuel sources is that they can be used in conjunction with existing infrastructures, which reduces the need for large capital outlays to replace assets. In the short- to medium-term, new fuel types can also be increasingly blended with jet fuel. However, the cost is prohibitively high today. Given the existing cost structure and production methods, bio-based jet fuels might cost two to three times more than traditional, fossil-based jet fuel.

Aviation will likely be one of the sectors given priority usage of a limited, sustainable biofuel supply, considering the lack of technically feasible energy alternatives in the mid-term (see sidebar and figure on page 105).

However, the current cost differential of biofuels and synfuels with fossil fuels translates into a \$115 to \$230 abatement cost per ton of CO_2[36], making aviation one of the costliest sectors to abate (along with heavy industry, particularly cement). In the absence of other options, this cost penalty will be the price of doing business.

Figure 26

Sustainable biomass supply estimates and priority demand in aviation



Source: Energy Transitions Commission; IEA; Accenture Analysis

A sustainable and cost-effective biofuel supply

Biomass will require strict sustainability measures to ensure it is carbon neutral over its lifecycle. The International Energy Agency's global, sustainable biomass projection is in the range of 70 to 130 exajoules (EJ)/year (10-15 EJ from municipal waste, 45-95 EJ from agricultural residues, and 15-30 EJ from wood-harvesting residues).

For biofuels to be sustainable with regard to land use, they must avoid deforestation, not impede on productive arable land (which could otherwise be used for food production) and avoid the destruction of biodiversity in the immediate area.

The cost of biofuel supply varies significantly by source and region. In some markets, biomass is economically competitive today. However, it is likely that a carbon price of around $100/ton will be required to enable biomass to fulfill its potential in the energy transition.

Unlike electricity-derived fuels, biomass cannot draw on the potential for low-cost renewable generation to bring prices down further. That means it may only be used in niche global applications (e.g., aviation and petrochemicals) or at scale in selected markets such as Brazil.

Only by participating in, and architecting, cross-sectoral actions can oil and gas companies hope to mitigate emissions across the energy system. This will be a new and valuable role for the industry to play.

Shipping

Accenture 2050 stretch goal

73 percent reduction from 2050 business-as-usual emissions through fuels-based decarbonization.

The brief

Our top levers to reduce emissions from operations in the shipping sector.

1. Implement energy efficiency measures across fragmented fleets (Clean the Core).
2. Accelerate use of LNG in shipping for near-term decarbonization (Accelerate the Transition).
3. Reduce costs of ammonia-based systems for larger vessels (Extend the Frontier).

Seaborne shipping traffic has grown continuously over recent decades, and this trend is likely to continue since international freight is strongly correlated with economic growth.

Worldwide seaborne trade has experienced a 3 percent annual growth rate since the 1970s, with most of that growth coming from the increase in the number of container ships. Projections for total freight volumes, measured in ton-kms, suggest a possible global growth of more than 240 percent by 2050, representing a 3.4 percent average annual growth rate. Passenger ship traffic represents less than 10 percent of emissions today[36].

Fragmented industry structures limit the impact of potential operational and energy efficiency measures.

Seaborne shipping is one of the lowest-emitting forms of transport per ton-km. That limits opportunities to reduce emissions by shifting to other modes of transportation. Better demand management can only reduce shipping emissions up to 4 percent[2].

An alternative is rail freight. But that move requires substantial infrastructure investments. And, in some cases, rail is a higher-emitting mode of freight transportation. Operational efficiency management (e.g., fleet management, voyage optimization, optimized speeds) could result in a 5 percent emissions reduction in fleets[36].

New ship designs should focus on improving hull shapes and materials, building larger ships to reduce drag, and reducing onboard consumption emissions—improving efficiency by 30 to 45 percent compared to today's fleets[36].

Given the long lifetime of ships, some of these technologies could be retrofitted to existing fleets, improving energy efficiency by up to 15 percent. However, the fragmented structure of the shipping industry (between owners and operators and flagging jurisdictions) reduces the potential for coordinated action and removes incentives for any one sector to make the required changes.

Use of LNG to power shipping could reduce emissions by approximately 10 percent, but only if upstream operations run with low emissions intensity[36].

While LNG is not a complete decarbonization option, it would be a viable near-term solution to emissions reduction in shipping. It sits within the envelope of potential fuels for large shipping and has energy-density properties similar to ammonia.

Upstream operations would have to significantly cut methane emissions to make the fuel as clean as possible. Electrifying the LNG process could provide additional emissions savings.

LNG carriers are already powered by LNG through steam turbines. But a new generation of dual-fuel engines capable of intaking natural gas and bunker fuel (usually heavy fuel oil) is emerging as a solution to the International Maritime Organization's (IMO) 2020 regulations aimed at tightening sulfur emissions in the shipping industry.

Ammonia is the front-runner for longer-term shipping decarbonization.

The use of biofuels, ammonia and hydrogen (the latter combusted through fuel cells or internal combustion engines) are all technically feasible for shipping.

For biofuels to be a feasible option, significant scale-up in production would be required to provide the volume of fuel needed. Given the limitations of sustainable biofuel production, they would likely need to be reserved for those sectors with the fewest abatement options. This means that sectors such as aviation and chemical industry feedstock would be prioritized ahead of shipping.

While technically feasible, hydrogen has economic challenges when it comes to shipping. Its low volumetric energy density means a large amount of monetizable cargo space needs to be sacrificed to store the fuel.

The properties of ammonia, on the other hand, make it an attractive fuel option for shipping. Ammonia has a higher volumetric energy density than hydrogen (4kWh/liter versus 2.4 to 2.8kWh/liter) and a greater gravimetric energy density than batteries (5.8kWh/kg versus 0.2kWh/kg). Additionally, ammonia is easier to store than hydrogen. It becomes liquid at minus 33°C compared with minus 253°C for hydrogen, making it cheaper and safer to handle. Ammonia can either be used to make electricity (using a reformer and a fuel cell) or combusted directly in an internal combustion engine. Zero-carbon ammonia can be produced with zero-carbon hydrogen and the Haber-Bosch process.

The near-ubiquitous use of ammonia for agriculture has conveniently generated a global network of ports where the chemical is traded or stored. That means the infrastructure for storing chilled ammonia as a shipping fuel already exists.

Cost and production emissions issues prevent ammonia from being feasible today[36]. Ammonia requires a carbon intensity of electricity below 200gCO_2/kWh to produce lower carbon emissions than the current fuel mix in ships. The average carbon intensity of the EU's electricity network today is currently around 450gCO_2/kWh. Also, the costs of running a ship on ammonia would be about 120 percent higher than with heavy fuel oil[36].

Some European countries are approaching the carbon intensity of electricity required for ammonia, but the global mix requires significant decarbonization. Ammonia would have to be produced in select regions or specialized plants powered by low-carbon electricity to be environmentally viable. The United Kingdom, for example, has a medium-term objective to place ammonia-powered domestic vessels in operation within the next five to 15 years.

Implications and actions for oil and gas

The implications and actions noted below refer to all heavy-duty and commercial transportation sectors.

The demand outlook for middle distillates is of great importance for the oil and gas industry. While gasoline is generally burned in passenger vehicles, which have a short-term decarbonization solution in the form of EVs, middle distillates are consumed in harder-to-abate sectors whose demand is correlated with economic growth. Those sectors are heavy-duty road transportation, shipping and aviation.

Demand for middle distillates is likely to grow faster and hold up for longer than lighter distillates such as gasoline.

This will impact refinery configurations as downstream operators attempt to retain margins from a more constricted mix of distillates.

Diesel demand in heavy-duty road transportation will be the first to plateau. But it will be held up in the shipping sector by increased diesel usage as IMO regulations force a shift away from heavy fuel oil, which is sulfur heavy, as the preferred fuel.

Gravimetric and volumetric energy density requirements limit the technically feasible alternatives for long-haul aviation and long-distance marine, making them two of the hardest sectors to abate. However, this does open up the opportunity for oil and gas companies to be part of a much-needed solution in these areas.

Within aviation, there is an opportunity to blend increased biofuel into jet fuel to create a premium, decarbonized product. A segment of the increasingly environmentally aware public would likely be willing to pay a higher airfare in exchange for its usage.

We see three discrete sets of actions that oil and gas companies can take to accelerate decarbonization and maintain market relevance in the heavy-duty and commercial transportation market.

1. **Collaborate closely with each transportation mode to co-develop solutions for hard-to-abate sectors.**

   This can be accomplished in several ways, including the following.

   A. Ramping up blending of biofuels into jet fuels to create premium, differentiated products.

   B. Taking a leading role in promoting LNG usage in shipping as a high-impact, near-term decarbonization solution that is synergistic with portfolios that have transitioned to gas (upstream and midstream operations will need to be decarbonized for greatest impact).

   C. Exploring how to economically produce and refine biofuels and synfuels (through green or blue hydrogen) combined with carbon capture.

   D. Co-designing the next generation of hardware that can be powered by fuels of the future.

2. **Prepare for refinery reconfigurations as the share of middle distillate demand grows compared to light distillates.**

3. **Explore short-term opportunities to produce high-margin renewable fuels in selected markets such as California, while hedging bets for electrification of the heavy-duty road sector in the mid-term (e.g. through deployment of charging infrastructure).**

Heavy industry

The following section covers cement, iron and steel, and chemicals.

The industrial sector accounts for around 22 percent of global CO_2 emissions, comprising iron and steel (6 percent), cement (5.6 percent) and chemicals (4 percent), with other industries such as paper and light manufacturing making up the remainder. The sector is the third biggest market for gas after power and buildings, comprising 18 percent of total gas demand[2].

Heavy industry utilizes energy-intensive processes that cannot be readily carried out with electric solutions. Within the heavy industry sector, the cement, steel, and chemical industries together contribute 6.5 GT CO_2e per year of carbon emissions[2]. Given the limited ability to electrify, coupled with the cost of alternative fuels and feedstock, emissions reduction in this sector is highly reliant on energy and materials efficiency, as well as CCUS solutions.

Cement is considered one of the most difficult sectors to decarbonize because about 55 percent of associated emissions derive from the chemical process required to produce it, rather than during the generation of the heating itself[36]. The only feasible pathway to emissions reduction today is CCUS. Another reason the heavy industry is hard to decarbonize relates to the growing demand for construction materials and plastics from the developing world. In India, for example, a country of one billion people, consumption of plastic per capita is 10 times less than that of the United States. This implies that large growth in demand may be coming from the developing world to reach parity with consumption in the OECD.

Collectively, cement, iron and steel, and chemicals account for approximately 25 percent of global coal consumption[2]. Like the power sector, this means a near-term transition to natural gas would have a high impact on decarbonization. We will explore this opportunity in the iron and steel section since this industry alone accounts for 17 percent of global coal consumption[2].

Ultimately, emissions reduction in heavy industry will be shaped by five key factors:

1. Transitioning from coal to natural gas for heavy industry heating.
2. Materials efficiency and circularity.
3. Increased energy efficiency.
4. Use of CCUS.
5. Use of low-carbon, high-heat alternative fuels and feedstocks.

Cement

Accenture 2050 stretch goal

60 percent reduction from 2050 business-as-usual emissions through demand management and decarbonized production processes.

The brief

Our top levers to reduce emissions in the cement sector.

1. Maximize demand management and circularity levers (Clean the Core).
2. Transition to decarbonized heat sources (Extend the Frontier).
3. Accelerate economic deployment of CCUS to reduce process emissions (Extend the Frontier).

We see demand for cement growing from 4.2 billion tons per year to 4.7 billion tons per year by 2050[36].

That demand growth will be driven by increased construction of buildings and infrastructure. The highest surges in demand are expected in emerging markets, which are urbanizing rapidly. China, for example, accounts for about 60 percent of cement production. This proportion will fall as China passes the peak of its construction phase. However, in other economies such as India and Africa, demand for cement is expected to triple between now and 2050.

Importantly, growth in cement demand is expected to be greatest in regions that are not likely to make significant progress on decarbonization. Cement is unique among the heavy industry sector in creating direct process emissions (accounting for 55 percent of its totals) and emissions as the product itself is manufactured.

Decarbonizing the cement sector will be a costly and lengthy endeavor. Demand management and energy efficiency levers will be essential if cement emissions are to be reduced in the near-term.

There are four main ways to reduce emissions through better demand management and circularity. When combined, these actions could reduce emissions by up to 35 percent[2].

1. **Recycling of unhydrated cement**, reprocessing of hydrated cement, and reusing concrete as aggregate could reduce emissions by around 15 percent[2].

2. **Reducing the material demand per building** by reducing over-specification, reducing construction-related waste and reusing structural elements of older buildings. In Europe, for example, this waste is estimated at 10 to 20 percent. Collectively, this could reduce emissions by about 15 percent[36].

3. **Improving the use of buildings**—adapting existing buildings to extend their lifetimes and using space more efficiently—could reduce emissions by about 5 percent.

4. **Using materials other than cement for construction**—such as timber—would also reduce emissions. However, this development could be constrained by the amount of available sustainable timber.

Using energy-efficiency levers could reduce emissions by a further 10 percent. The key levers in this space include retrofitting older plants, using a dry kiln process (which is less energy intensive than a wet kiln process), increasing the use of technologies that reduce energy intensity (such as pre-calciners and multistage cyclone heaters), and decreasing the clinker-to-cement ratio (which leads to lower energy use and emissions).

Adopting CCUS could address both the emissions produced from heat generation and process emissions.

As a single solution, CCUS could be used to decarbonize cement or for fuel switching to reduce emissions from heat production.

Cement is problematic since there are currently no viable alternatives to CCUS technologies for reducing process-related emissions released through a chemical reaction during manufacturing. While technically feasible to abate through CCUS, these process emissions are among the most expensive to abate because the CO_2 concentration of the emitted gases is very low (CCUS costs are generally proportional to CO_2 concentration of the air from which the carbon is extracted). Currently, there appears to be no pathway pointing to significant cost reduction in this area.

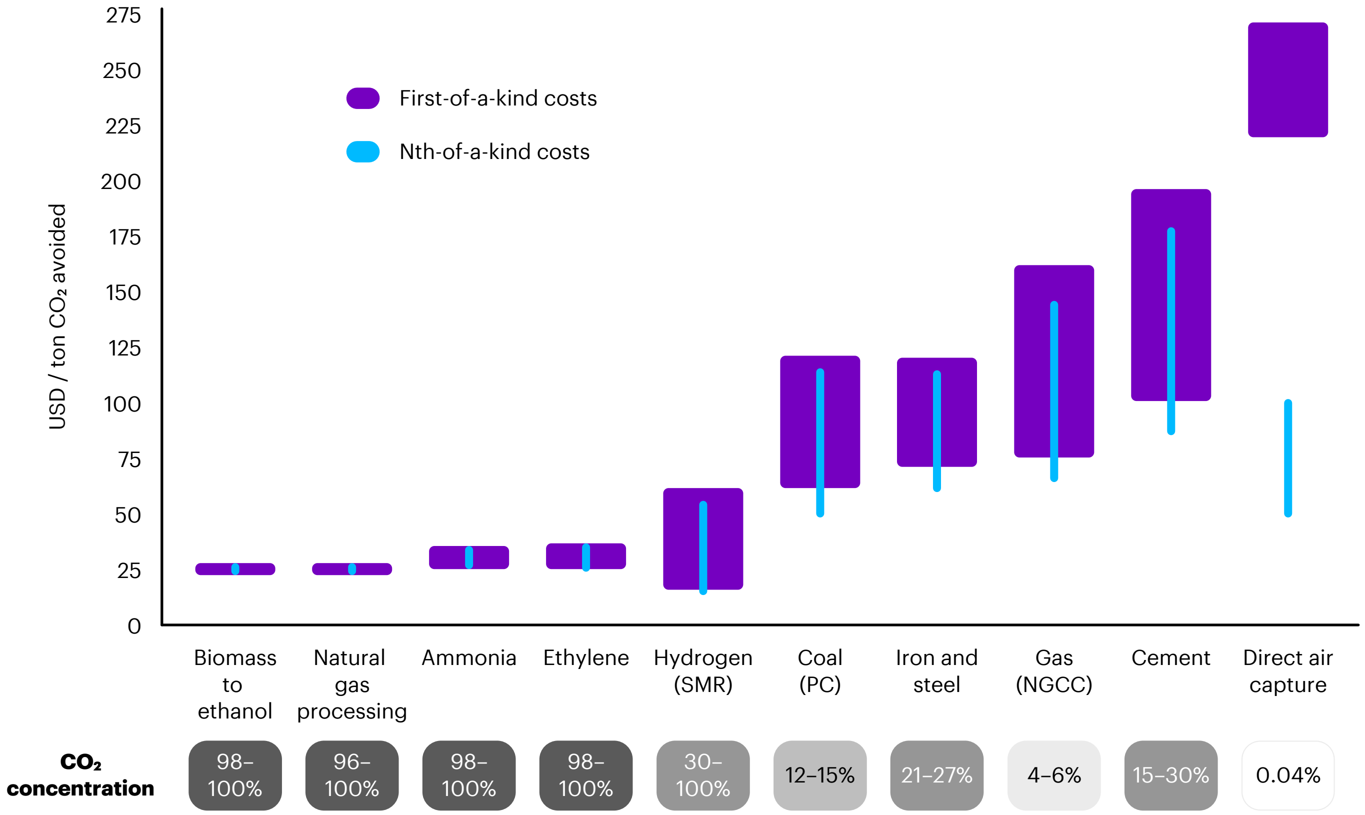
However, captured CO_2 can be used in the construction industry itself by absorbing it into concrete during the curing process. This potentially reduces the need for CO_2 storage and transport.

Additional research and development, as well as the scaling of technologies, will be required in the areas of electricity-based and hydrogen-based heat.

In theory, using electricity as a heat source for cement is possible, but further research, development and piloting of solutions would be needed before a commercial rollout would be possible. Replacing fossil fuels with hydrogen derived from clean electricity would require significant furnace redesign and lower electricity costs.

Figure 27

Global ranges for carbon avoidance costs using CCUS



Source: Energy Transitions Commission; IEA; Accenture Analysis

The outlook for CCUS

Most 2°C scenario outlooks assume a major role for CCUS by the middle of the century, although forecasts vary considerably between from 3 to 10 GT CO_2/yr.

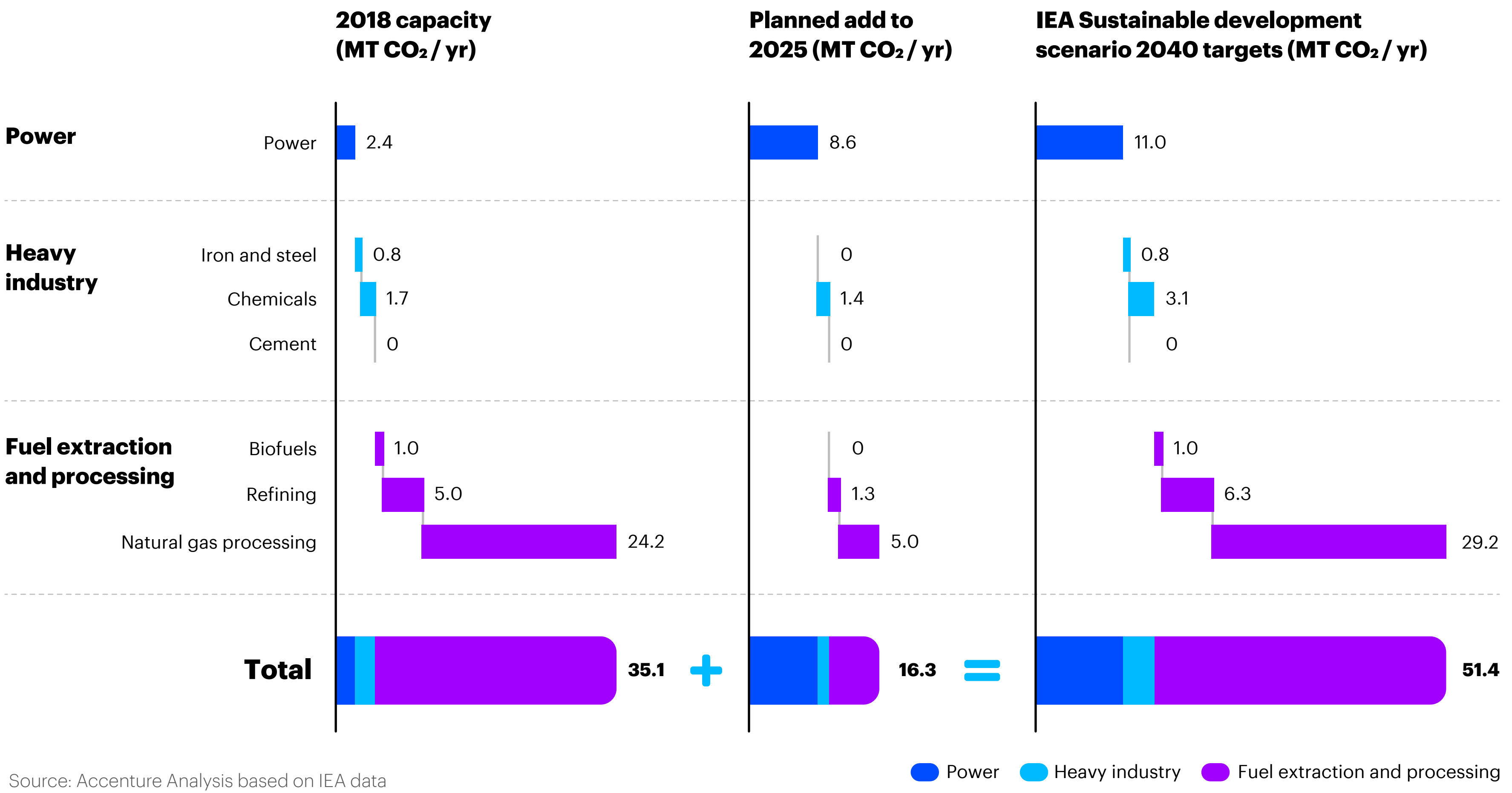
CCUS is expected to play a greater role toward the end of the century. By then, bioenergy with carbon capture and sequestration (BECCS) is projected to be available to provide net-negative emissions. Two-thirds of the Intergovernmental Panel on Climate Change (IPCC) models assume BECCS will account for more than 20 percent of primary energy by 2100.

Total capture today though, from 37 projects, amounts to a small 35 MTCO$_2$/year, about 85 to 285 times less capacity than the target ranges of 3 to 10 GT CO_2/year would imply. Looking at the development pipeline, 2025 capacity would be a little over 50 MTCO$_2$/yr. Deployment needs to accelerate significantly to be on track for these 2050 targets.

Within heavy industry, the sector most likely to be dependent on CCUS, capacity today accounts for just 2.5 MTCO$_2$/year, rising to 3.9 MTCO$_2$/year by 2025. There is notably no current or pipeline capacity for cement, for which no current alternative to abating process emissions exists.

Figure 28

2018 Global CCUS capacity and planned additions to 2025, by industry



Source: Accenture Analysis based on IEA data

Iron and steel

Accenture 2050 stretch goal

94 percent reduction from 2050 business-as-usual emissions through reduction in coal usage and transition to increased electric arc furnace production.

The brief

Our top levers to reduce emissions from the iron and steel sector.

1. Maximize demand management and circularity levers (Clean the Core).
2. Accelerate transition from basic oxygen blast furnace to electric arc furnace (Accelerate the Transition).
3. Transition from coal to decarbonized heating sources including natural gas in the near-term (Extend the Frontier).

Global steel production is forecast to grow by 30 percent between now and 2050—from 1.6 GT per year[36] to 2.2 GT per year, driven by increased demand for buildings, infrastructure and vehicles.

Two major trends will define the emissions profile of this growth.

1. **The switch from ore-based to scrap-based production** as existing steel stock grows and as more demand is met through recycling.
2. **The move from blast furnaces (BF-BOF) to electric arc furnaces (EAF)** as a result of more scrap-based production.

Overall, the iron and steel sector has several viable pathways to decarbonization and is not considered as hard to abate as cement.

Increased use of recycled steel in electric arc furnaces could reduce sector emissions by 20 percent by 2050[36].

Ore-based production is expected to remain steady as a reduction in demand from China will be offset by increases in emerging markets. The use of EAF in scrap-based steel production, produces just 0.4 tons of CO_2 per ton of steel. That compares to 2.3 tons for BF-BOF and 1.1 tons for the direct reduced iron-electric arc furnace (DRI-EAF) process, an alternative process for producing new steel[36].

As the global stock of steel increases, and infrastructure ages, the proportion of scrap-based steel production should grow. A reduction in ore-based steel production through increased recycling and materials circularity could result in up to a 20 percent emissions reduction by 2050.

Reductions in end-use demand and economical energy efficiency improvements could reduce steel emissions by a further 15 percent[36].

Two principal levers can reduce total steel demand. The first is the design of more efficient products that require less steel to perform the same job—such as lightweight automobiles. Globally, and across all sectors, product efficiency could account for a 15 percent decline in steel demand by 2050. The second demand-side lever is a reduction in steel demand through an increase in shared mobility services. This could have a tremendous potential impact, but it is too early to quantify with accuracy.

There is significant untapped potential to increase the energy efficiency of steel production without needing to make fundamental changes to the process. For example, coke dry quenching is a heat recovery system that can reduce energy consumption by up to 40 percent. The reuse of production gases for power generation (hot water, steam, electricity)—which can either be fed back into the steel production process or the broader grid—could increase efficiency by up to 35 percent[2].

Both these approaches appear to be economically favorable, but implementation is challenged by the large capital expenditure required and pressure on margins in a highly competitive industry.

There are two promising routes to full decarbonization of the steel industry: processing iron ore by electrolysis and expanding the role of hydrogen as a reducing agent in BF-BOF production.

The iron and steel industry is responsible for 17 percent of the emissions from the use of coal as an energy source, second only to power generation[36]. Switching from coal to natural gas for the direct reduced iron-electric arc furnace (DRI-EAF) process could reduce carbon emissions by 1.2 tons per ton of steel. This represents a more than 50 percent reduction and is a critical near-term lever for the decarbonization of the sector.

The reduction of iron ore by direct electrolysis (similar to the aluminum manufacturing process) and the use of hydrogen as a partial substitution to coking coal reduction in blast furnace to basic oxygen furnace production could have a significant impact on decarbonization in economies with lower stocks of scrap steel in circulation.

Chemicals

Accenture 2050 stretch goal

78 percent emissions from 2050 business-as-usual emissions through the promotion of the circularity and decarbonized heat sources.

The brief

Our top levers to reduce emissions in the chemical sector.

1. Promote circularity to reduce demand (Clean the Core).
2. Accelerate use of electricity and hydrogen-based fuels (Extend the Frontier).
3. Transition to biofuel-based feedstock for the chemical sector (Extend the Frontier).

The chemical industry accounts for 14 percent of petroleum demand today; this share is expected to increase as the demand for plastics increases and as oil transportation demand growth slows and eventually declines.

Petrochemicals are likely to account for over a third of the growth in oil demand to 2030, and nearly half to 2050[36].

Within the chemical sector, 60 percent of direct emissions come from just three sources: ammonia (30 percent), ethylene (16 percent), and methanol (14 percent). Methanol is the fastest-growing chemical segment. It has multiple applications as the base for formaldehyde and fuel additives, as well as an intermediate product for plastic production[2].

The demand for ammonia, the basis of synthetic fertilizers, has leveled off in recent years. But it is forecast to increase evenly across the globe to 2050. Also, ammonia may become a clean transportation solution in the shipping sector, further increasing the importance of reducing emissions from its production.

Substantial efforts to increase recycling and curb single-use plastic in the OECD will be offset by growing demand in emerging economies. Plastic usage correlates with income. Per capita demand for plastics is almost 20 times higher in South Korea and Canada than in Africa, and 10 times higher than in India.

Beyond the carbon emissions associated with their production, plastics cause multiple environmental issues, including the accumulation of microplastics in the ocean. Total emissions from the chemical sector in 2050 will depend significantly on the lifetime of the plastics produced and whether incineration is a preferred disposal method to landfill.

The use of virgin plastics could be reduced by more than 50 percent by 2050 through material efficiency, the substitution of hydrocarbon-based monomers, greater reuse, and increased mechanical and chemical recycling.

Improving materials efficiency in products by limiting over-specifications of packaging, extending product life, and product sharing (e.g. carsharing) would result in a more intensive use per unit of plastic and could reduce demand by 35 percent from the automotive and building sectors alone. That would translate to a 15 percent reduction in overall chemical demand.

Reducing the use of plastic-based products by banning single-use plastic is another powerful lever. For example, in the United Kingdom, banning just seven common items from straws to earbuds would reduce plastic consumption by 13 percent.

The potential of recycling to cut emissions is high and could lead to as much as 20 times less CO_2 emissions per ton of plastic. But the extent of recycling around the world is generally low and is mainly mechanical-based—involving processes such as grinding, washing, separating, drying, regranulating and compounding. The percentage of total plastics recycled today is estimated at as little as 10 percent[36].

There needs to be an increase in chemical recycling, which can return post-use plastics to their basic chemical building blocks, increase the versatility of their reuse and require less virgin plastic. The chemical approach is only a small percentage of overall recycling treatments today. Changing that situation will require large cost cuts, more significant efforts to ensure that waste plastics can be made into new monomers rather than simply fuel, and clean, high-heat energy for the process.

As in other heavy industry sectors, zero-carbon heat generation is required to fully decarbonize petrochemicals with hydrogen-based and direct electrical heating going head-to-head with CCUS. Decarbonization of heat generation will be required for complete emissions reduction. The preferred method will likely depend on local carbon markets, storage availability and local electricity prices. Hydrogen could be competitive at today's electricity prices and a carbon price of $75/t$CO_2$, whereas direct electrification is cheaper than carbon capture and storage at electricity prices of under $25/Mwh. In some regions, renewables prices have already reached this level[36].

Decarbonization of feedstocks has a priority claim on the limited, sustainable biofuel supply.

Decarbonization of feedstock using biomass fuel would reduce end-life emissions of plastic. Given the lack of suitable feedstock alternatives that are free of fossil fuels, biomass for chemical feedstock will be a priority usage (as for the aviation industry). Plastics may eventually be made from zero-carbon electrochemical processes, given the availability of low-cost, carbon-free electricity. However, these techniques are currently at an early R&D stage. A thorough assessment of the viability of using such a large amount of electricity for electrochemical processes is needed.

Implications and actions for oil and gas companies

The implications and actions noted below relate to all heavy industry sectors.

Heavy industry is one of the harder-to-abate sectors of the economy. There is a real opportunity for the oil and gas industry to help define much-needed solutions. For example, extensive CCUS deployment is required in heavy industry. It is a technology for which oil and gas companies are the lead adopters today.

There is a large opportunity to drive highly emitting coal out of heavy industry by increasing natural gas use. However, as with the power sector, this will likely require a step-change in landed LNG costs in key countries like China.

A longer-term opportunity in which the oil and gas industry can take the lead is in the identification of hydrocarbon replacements for both feedstock (for petrochemicals) and fuels (for all heavy industries) in a decarbonized world. For example, hydrogen, could be a cost-efficient alternative to direct electrification or the use of fossil fuels along with CCUS for cement heating. For example, hydrogen could be an alternative to direct electrification or the use of fossil fuels along with CCUS for cement heating. In the iron and steel industry, hydrogen can be used as a reduction agent and a heat source. In the chemical industry, hydrogen is an input to the Haber-Bosch process (an artificial nitrogen fixation process) that could potentially be used as a heat source in the petrochemical sectors. However, given the multiple conversion losses for creating and combusting hydrogen, its economic viability is likely to remain challenged compared to other pathways.

Finally, integrated oil and gas companies with petrochemical portfolios have an opportunity to redefine their role from manufacturing and selling plastic products to managing the full lifecycle of plastic demand. This would extend their role to include the gathering and recycling of products for reuse.

We see three discrete sets of actions that oil and gas companies can take to accelerate decarbonization and maintain market relevance in the heavy industry sector in the next 30 years.

1. **Collaborate closely with each industry sector to co-develop solutions for hard-to-abate areas of emissions.**
   - A. Explore how to economically produce, and refine biofuels and synfuels (through green or blue hydrogen combined with carbon capture) for the creation of premium plastic products.
   - B. Use the industry as a test space for the hydrogen economy, given the relative competitiveness of hydrogen versus other decarbonization routes to high-temperature, high-volume heat.
   - C. Reimagine the plastics value chain and relationships with customers; create circularity by moving to a services-based model.
2. **Leverage CCUS expertise for heavy industry and use captured carbon for EOR or syngas creation, in addition to monetizing both transport networks and storage in depleted reservoirs.**
3. **Enhance the competitiveness of LNG to drive coal out of heavy industry as a heat source.**
4. **Participate in the research agenda to accelerate the adoption of low-emission processes, such as alkali-activated cement.**
5. **Actively engage the customer to adopt energy efficiency and energy management solutions that lower their waste energy and emissions intensity.**

Commercial and residential buildings

Accenture 2050 stretch goal

72 percent reduction from 2050 business-as-usual emissions through high-efficiency buildings and the shift to electricity-based heating.

The brief

Our top levers to reduce emissions in the building sector.

1. Enhance building design to be energy efficient (Clean the Core).
2. Accelerate penetration of smart devices for demand-side management (Clean the Core).
3. Transition from gas to electric heat pumps (Accelerate the Transition).

Buildings account for around 9 percent of global CO_2 demand, split roughly 60/40 between residential and commercial buildings.

Collectively, buildings represent the second largest market for gas, comprising 20 percent of total demand[2].

Energy use in the commercial and residential buildings sector has increased steadily since 2000, at an annual average growth rate of around 1.1 percent. Usage grew from 2,820 Mtoe in 2010 to around 3,060 Mtoe in 2018, accounting for 20 percent of global delivered energy consumption in 2018. Direct emissions from buildings increased to a little more than 3 GT CO_2 in 2018, up slightly from previous years when direct emissions were under 3 GT CO_2. In our 2050 business-as-usual scenario, emissions will edge up to 3.8 GT CO_2/year.

It is projected that global energy consumption in buildings will grow by 1.3 percent on average per year from 2018 to 2050[37]. In non-OECD countries, consumption is expected to grow by more than 2 percent per year, or about five times the rate of OECD countries.

This growth in energy use is driven principally by the following trends.

1. **Increases in the area of floor space used**, which have grown by around 65 percent since 2000[38].
2. **Population growth of two billion people** and the rising standard of living in non-OECD countries.
3. **Rapidly growing demand for energy-**consuming equipment and services in buildings, particularly in emerging economies.
4. **Extreme weather patterns**, which increases the demand for heating and cooling equipment.

Given projections for large expansions in floor space demand in populous regions such as India and Africa, enhanced building design will be an important way to contain emissions. Renovation-based efficiency must account for broader emission impacts in other geographies.

In developing countries—especially in Africa and Asia, where building growth will be rapid—enhanced building design will be especially important. The floor area in India is expected to double by 2035[39]. Yet, only part of the sector is subject to mandatory building energy codes. The impact of such growth in floor space usage can be mitigated by using more effective layouts, natural light and ventilation, green roofs, better insulation and windows, and lower-carbon, recycled construction materials.

In OECD countries, where 65 percent of total expected building stock in 2060 is already built, energy renovations of existing buildings will be key to reducing emissions. These renovations need to deliver 50 to 70 percent energy intensity improvements. Moving to high-performance, low-carbon or near-zero emissions buildings is a priority for the next 20 years[2]. Some caution about deep renovations must be exercised here, however, as the risk of simply passing emissions from buildings to other sectors such as construction and heavy industry is high.

Adopting smart, connected devices in buildings can significantly reduce energy usage demand and energy usage peaks without impacting lifestyle.

The adoption of smart devices could help drive behaviors that use less energy. Behavior change can also be accomplished through awareness campaigns, gamification techniques, and by enabling people to compare their energy usage with their neighbors.

The use of integrated, connected systems has a large impact. An upgrade to a single component or isolated system such as smart heating can result in energy savings of 5 to 15 percent and a smart building upgrade with integrated systems can achieve 30 to 50 percent savings in existing, inefficient buildings[2]. Smart, connected devices and systems may include the following.

1. Heating, cooling and ventilation, which limit energy consumption in unoccupied zones.
2. Advanced controls and sensors to optimize lighting.
3. Plug loads, auto-controlled receptacles and power strips that rely on time scheduling, motion sensing, or load detection to turn power off when equipment is not being used.
4. Window shading with electrochromic switchable windows.
5. Automated system optimization, which uses real-time feedback to collect and analyze building systems' operational and energy performance data to make anticipatory changes in operations based on weather patterns, occupancy numbers, etc.
6. Mobile apps and real-time reporting to help control energy usage and influence behavioral change.

As the electricity grid becomes more decarbonized, the emissions advantages of heat pumps over natural gas will grow.

The largest direct use of fossil fuels in buildings is heating. Electricity-based heat pumps now represent a viable pathway to abating these emissions. The decarbonization of the electricity sector, coupled with an efficiency two to four times greater than that of natural gas heating, means that heat pumps can potentially reduce building emissions by up to 50 percent[2].

Implications and actions for oil and gas companies

In the short-term, the oil and gas industry's ability to impact the decarbonization of the commercial and residential buildings sector is limited to decarbonization of the natural gas value chain. Beyond this, oil and gas companies can lead by example. In an industry characterized by large workforces and significant office footprints, oil and gas businesses can deploy energy-efficient programs across their locations and leverage their digital expertise to explore energy usage optimization.

Over the longer term, the oil and gas industry can help transform the building sector in a more significant way. How? By offering alternative clean power options such as renewables and hydrogen to commercial and (to an extent) residential buildings when connecting to the grid is not an option or even desired. One avenue involves partnering with key industry clusters to offer integrated suites of clean energy solutions to power both the operations and the buildings.

We see three discrete sets of actions that oil and gas companies can take to accelerate decarbonization and maintain market relevance in the commercial and residential buildings sector in the next 30 years.

1. **Identify opportunities for oil and gas in repurposing existing buildings and designing new buildings** for energy efficiency. The starting point for this involves enhancing the energy efficiency of all owned infrastructure and facilities.

2. **Take a lead role in scaling new fuels (e.g. hydrogen) and cleaning existing fuels (e.g. decarbonized natural gas)** that will be used in buildings of the future.

3. **Move close to the end customer** and take a much more expansive role in energy management services and potentially car-to-grid charging and storage solutions.

Through the 2020s, value and investment are poised to migrate away from oil and gas companies' core business, toward electricity-linked energy.

Near-term priorities will be focused on transforming today's core portfolio, while also creating optionality to win in adjacent sectors. The Decarbonization Transition won't be as effective—or may not happen at all—if oil and gas companies don't play an active role in developing solutions for their customers in those sectors.

That means more than investing. It means innovating and collaborating with partners to make the transition to a low- or no-emission future a reality. Cross-sector R&D teams can, for example, work together to identify potential uses for hydrogen with biofuels in the aviation industry. Or oil and gas companies might join up with utilities to extend the traditional value chain to cross-sector offerings like mobility-as-a-service solutions. In these and countless other ways, oil and gas companies will be actively architecting and creating the low-carbon opportunities in which they can invest—and through which they can grow.

+ Section 3

Completing the journey stronger

The end game for the Decarbonization Transition is not an energy system without fossil fuels; Accenture predicts that fossil fuels will provide close to 50 percent of the 2050 energy mix[2]. Rather, the objective is to decarbonize the energy system.

The oil and gas industry will play a central role architecting ecosystems and enabling other sectors to manage effective transitions. It will also lead the charge in pursuing new opportunities across the energy system. A new focus on process efficiency and demand management, a growing portfolio of decarbonized and electricity-based solutions, and an ambition to extend the boundaries of today's hydrocarbon-based business models will converge to extend the license of oil and gas companies to create value for years to come.

As they navigate the Decarbonization Transition, oil and gas leaders will need to definitively choose what type of business or "archetype" they want to be. We believe that there are only three options open to today's oil and gas industry and every company will have to choose to be just one: "**Decarbonization Specialists**" that double down on operating the cleanest, highest-margin portfolio of oil and gas assets; "**Energy Majors**" that will broaden their reach into the wider energy system of the future; or "**Low-Carbon Solutions Leaders**" that will represent a new type of energy company, providing energy solutions and services without the burden of the heavy assets that previously weighed them down. While it may be tempting to adopt a hybrid role in the transition, as some integrated oil companies have done recently, doing so will almost certainly fail. Finding and developing the investments, capabilities and business models to bring any one of these archetypes to life is a significant, complex and expensive undertaking. Success in any will require full and unwavering commitment. Many, of course, will have to outright exit the oil and gas, and potentially the energy, business. Making the right choice requires balancing the priorities of the Decarbonization Transition with returns and performance. It calls for bold decisions, if not educated leaps of faith.

The case for change

The oil and gas landscape will be radically different as decarbonization accelerates. New challenges will emerge, which will not only reset how the core business creates value, but also shape oil and gas companies' ambitions for the future. Let's consider some of these.

Volumes and value will decouple, placing assets at risk of never being produced.

The industry can take only limited comfort from the fact that hydrocarbons will continue playing a key role in supplying energy well beyond 2050. The choices oil and gas companies make today about where to play and where to invest must be geared to optimize cost structures and create free cashflow. In times of uncertainty, financial discipline translates into flexibility. Examples from other sectors, including coal, show that even while product demand is on the rise and prices are holding up, the ability to attract capital and generate returns can collapse. In the oil and gas industry, as supply abundance is no longer rewarded, there will not be an orderly and predictable set of impacts. Asset owners and operators need to build in new levels of resilience.

Not all assets and projects will make it.

In light of revised energy price forecasts, many long-cycle projects currently underway are projected to be unprofitable. Impairments totaling tens of billions have been announced just within the first half of 2020[40]. Infrastructure built over the past 150 years—from pipeline networks to storage, distribution and retail assets—might be abandoned if it cannot be repurposed during the transition. Carbon will increasingly figure in portfolio and investment decisions and is increasingly used by industry leaders to prioritize their capital expenditures.

The talent shortage will stifle growth.

The perception of the oil and gas industry as damaging to the environment is limiting its ability to attract the best people. The process of shedding jobs to reset the cost base does little to help the perception of the industry. Based on data from Texas Tech, the number of students pursuing petroleum engineering degrees in the United States has dropped by 60 percent over the past three years[41]. That trend spells trouble. Navigating the challenges and delivering on the opportunities during the Decarbonization Transition will require new talent and innovation. Oil and gas companies must, therefore, change the narrative to rebuild trust. It is difficult to see how a cautious or incremental approach will make the industry more appealing to the future workforce.

Carbon will become priced in implicitly (by investors) and then explicitly (by markets).

Carbon taxes have long been seen as an effective Pigouvian approach to address carbon emissions. Accenture analysis suggests that, on average, carbon taxes will raise the cost of oil production across all asset classes by about $6 per barrel[42]. In a world without alternatives to oil and gas, the primary effect would be redistribution across asset classes; in a world where oil and gas co-exist within a wider, converged energy system, even a relatively small tax could strand high-cost and high-carbon assets entirely.

The oil and gas industry relies heavily on oilfield and equipment services (OFES) companies, engineering, procurement and construction (EPC) contractors, and a host of other equipment, chemical and logistics players. The responsibility for identifying, managing and mitigating carbon-creating processes lies, therefore, not only with operators, but across the entire ecosystem connected to the oil and gas value chain. The Scope 1, 2 and 3 emissions framework reinforces that shared accountability. Operators, however, are in the position to lead the effort by establishing expectations and incentives to drive decarbonization initiatives across the supply chain.

As investors pressure oil and gas companies to address sustainability and carbon challenges, the competition for scarce capital is already tightening. A growing number of investment funds are adopting policies that shift capital away from companies that don’t meet environmental social and governance (ESG) guidelines. That is further exacerbating the underlying trend of investment moving away from oil and gas.

The IEA reports that the projected investment in the oil and gas industry in 2020 will drop by more than 30 percent over 2019 levels. By comparison, the share of global investment directed toward clean energy and energy efficiency is expected to increase by 5 percent. Consistent and auditable reporting of ESG performance can rebuild investor trust in the industry, but only if that reporting is backed up with tangible actions and operating practices that are beneficial to both the environment and the bottom line.

The three archetypes for tomorrow’s oil and gas leaders

We believe there are three—and only three—archetypal roles oil and gas companies can play during the Decarbonization Transition and beyond. Within each, there are multiple approaches to value—each supported by different assets and capabilities. These roles are not necessarily mutually exclusive; a few elements from each can be combined. The three archetypes described below present the only distinct choices for oil and gas leaders committed to taking a bold new direction. Industry players must go “all in” on one.

Figure 29

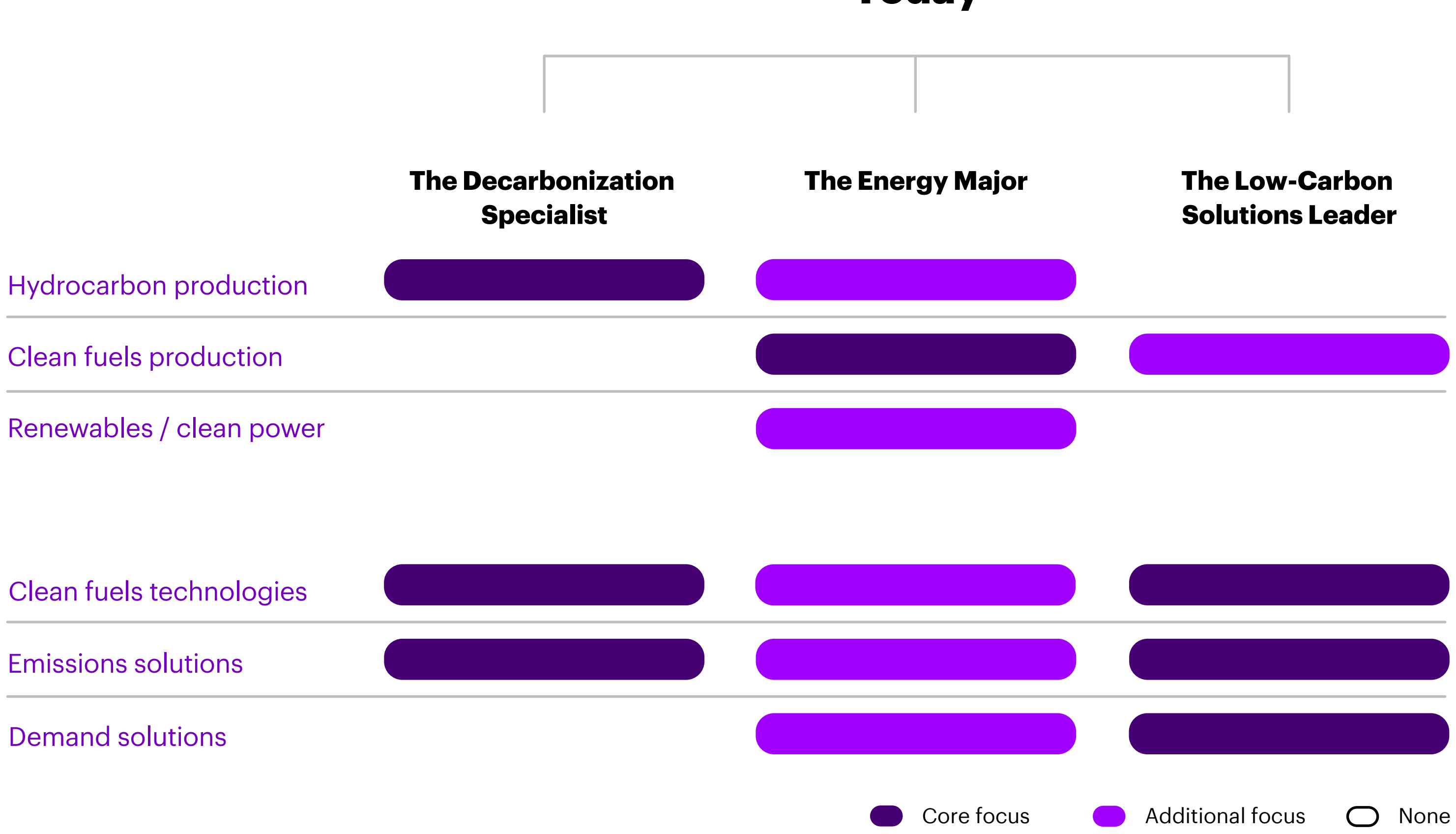


Figure 30

The dimensions of the three archetypes

Strategic archetypes	Clean the Core	Accelerate the Transition	Extend the Frontier
The Decarbonization Specialist	100% focus on creating a resilient, high-performing core: lowest emissions, highest value creation		
The Energy Major	Maintain a resilient, high-performing core, enhanced by its integration with the energy value chain beyond oil and gas	Pivot intentionally into investable, scalable opportunities with integration value linked to the core	Establish future leadership positions across energy value chain over time
The Low-Carbon Solutions Leader	Refocus on asset-light, market / trading solutions linked to low-carbon, efficiency and reduced environmental impact	Pivot into clean energies. Redefine role to be energy integrator and solution provider	Co-create new markets, platforms and positions as technology and regulation unlock new opportunities

Strong focus

Secondary focus

Source: Accenture Analysis

Figure 31

The dimensions of the three archetypes

	The Decarbonization Specialist	The Energy Major	The Low-Carbon Solutions Leader
Scope	Decarbonized oil and gas production	Full energy-system	Low-carbon energies and technologies
Business model	Asset owner / operator	Assets and solutions	Solutions provider
Sources of value	Supply-side (resource)	Resource, customer and integration	Demand-side (customer)
Scale and margin	**Scale:** med-large **Margin:** low-med	**Scale:** large **Margin:** med-high	**Scale:** small-med **Margin:** high

Source: Accenture Analysis

The Decarbonization Specialist

Sustaining and growing value from the core oil and gas value chain

The Decarbonization Specialist will be one of few hyper-competitive companies that outperforms others in the core hydrocarbons value chain through the middle of the century. They will focus on Clean the Core actions while delivering differentiated returns.

What is the Decarbonization Specialist's strategy?

Demand for oil and gas volumes will continue to grow at least through 2030 before plateauing[22]. Until then, oil and gas companies will continue investing in new wells, pipelines and facilities. Because the annual 5-7 percent decline factor exceeds the expected reduction in demand, few of today's assets such as wells and infrastructures will still be operating by 2050.

Decarbonization Specialists will be those companies best able to operate in the oil and gas value chain—upstream, midstream and/or downstream—in a low-carbon world. They will deliver the most efficient, lowest-cost production and integrate CCUS technologies and methane emissions management capabilities. They will create value through a low-emissions operating model and high-performing ecosystem that other players can't readily emulate. Because of their distinctive capabilities, Decarbonization Specialists will build a competitive asset portfolio, extend their assets' viable lives, and capture disproportionate value from oil and gas beyond the upcoming volume peak. Finally, to capitalize on their economies of scale and efficiency, it is likely that Decarbonization Specialists will manage larger businesses than the average oil and gas player of today.

Decarbonization Specialists will take proactive and meaningful steps to mitigate methane emissions. Each ton of methane emissions from oil and gas operations increases the climate impact of the fuels and makes a 2-degree future temperature reduction more difficult to achieve. The greenhouse gas potential of methane is 86 times more than that of CO_2 over a 20-year timeframe[43]. Beyond the environmental impact, the economic loss associated with methane emissions is significant. Every year, methane worth an estimated US$30 billion is released into the environment[44].

In the oil and gas industry, only a limited number of companies currently publicly recognize the reduction of methane emissions as a priority. This is short-sighted. A study conducted by the ICF revealed that, within the upstream sector, venting and pneumatic devices represent a methane reduction potential of 22 percent and 30 percent, respectively. Fugitive emissions from various sources, most notably compressors, account for the remaining 48 percent.

Circularity will feature strongly for Decarbonization Specialists. The reuse of equipment across the value chain will diminish the sector's carbon footprint. The capture and repurposing of waste will deliver additional benefits in terms of reducing the environmental impact of plastics, chemicals and other by-products of today's oil and gas operations.

Similar to some of today's mature field specialists, Decarbonization Specialists will focus their investment on technologies and processes that minimize Scope 1 and 2 emissions and lower the breakeven cost of production. Over time, they will move to develop cleaner energy sources—but only in a way that complements the core business and provides sufficient returns on capital. Examples include blending biofuels into transportation fuels, blending blue or green hydrogen into gas networks, or potentially creating fully fledged syngas.

Decarbonization Specialists will give special consideration to the topic of Scope 3 emissions. With a concentrated role in the energy value chain, they will not have options to offset, control or reduce the intensity of the emissions created through the combustion of their product. Decarbonization Specialists will, therefore, form partnerships with their customers and other players across the energy value chain in order to bend their total emissions trajectory.

A further imperative for Decarbonization Specialists is the development and incentivization of the supply chain. Oil and gas operations are highly dependent on oilfield and equipment services companies—with their high energy needs and sizable carbon footprints—for critical processes such as drilling and fracking. The Decarbonization Specialist must ensure their suppliers remain viable, aligned and effective in their efforts to deliver lower-emission outcomes and incentivized to collaborate in reducing total emissions.

Today's oil and gas businesses will not automatically become Decarbonization Specialists. It is a role that only the highest-performing asset and infrastructure operators can seek to play. And while it offers the perceived certainty of a continued focus on the core, it will be far from business as usual.

With a concerted role in the energy value chain, Decarbonization Specialists will form partnerships with their customers and other players across the energy value chain in order to bend their total emissions trajectory.

What are the capabilities required to win as a Decarbonization Specialist?

One

Measure, manage and reduce CO_2 and methane emissions from existing assets.

Oil and gas companies can enhance their operating practices to, for example, reduce flaring or take advantage of digital solutions and automation. In selected cases, they can add incremental CAPEX to target specific emission reduction opportunities. Basic predictive operations solutions can be deployed to avert the need to flare gas throughout facilities. Specifically, they should focus on the imperative to manage and monetize methane through leak management, detection and repair programs, as well as adopting an asset-specific focus on capturing and monetizing methane along the value chain.

Two

Scale and deploy CCUS technologies and decarbonize the gas value chain.

Reduce the intensity of CO_2 production. New markets are developing for CO_2, and while the oil and gas sector is a large consumer of CO_2 in EOR activities, CO_2 is less likely to be captured and utilized for other purposes. Focusing on reducing the emissions from gas (and especially LNG) will enable cleaner, decarbonized gas to competitively support new electrification.

Three
Focus the portfolio.

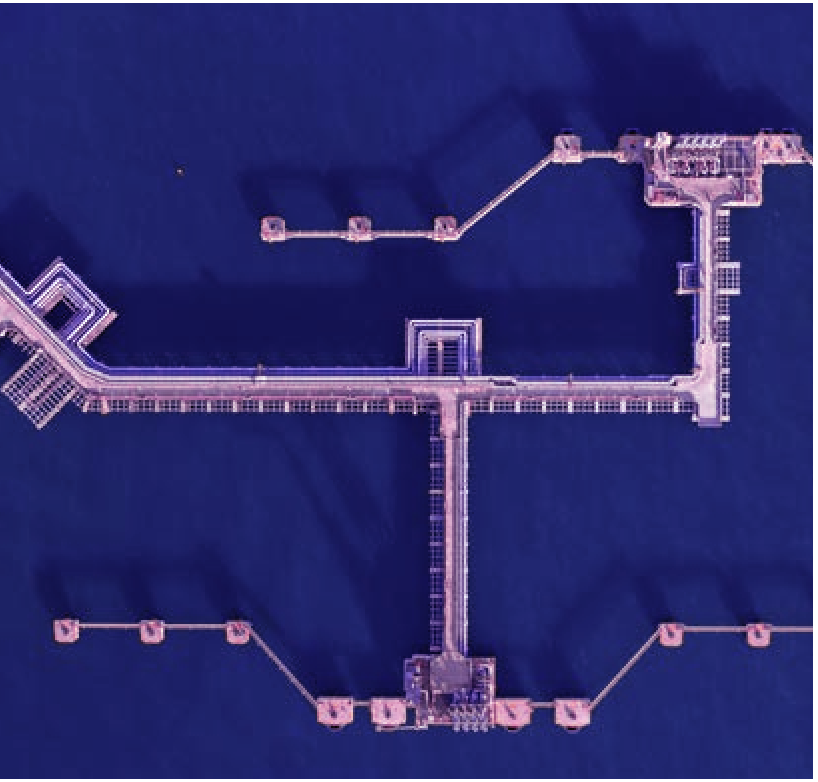
Oil and gas companies should take a capability-driven approach to their portfolios. For some, this will mean focusing on lower-emission plays. Others with distinctive carbon-management capabilities will be able to manage more complex assets but deliver lower-carbon energy. That opens up the opportunity for them to acquire assets that others can no longer operate successfully. An agile approach to managing the portfolio will set the leaders apart and will, in itself, be a significant source of new value.

Four
Deploy energy efficiency and circular solutions.

By doing this, companies can leverage less carbon-intense clean electricity, displace diesel with gas or electricity alternatives, and reduce waste energy consumption. Accenture research has found that up to 20 percent improvement in energy efficiency is possible across oil and gas assets by insulating pipelines, installing variable frequency drives or deploying permanent magnet motors[5]. Companies can also use circular solutions in the oil value chain to extend the life of critical equipment such as hydraulic fracturing pumps. This involves leveraging reconditioned equipment, increasing the recovery and redeployment of components deployed in the field, and increasing the portion of circular materials throughout the refining process. Those that play in the downstream value chain will focus their refining operations for maximum material and energy efficiency and add optionality to process recycled fuel and renewable fuels. For Decarbonization Specialists that operate a chemical business as part of their portfolios, circular feedstock solutions and crude-to-x feedstock processing will grow in importance over the upcoming decade.

Five
Engage the customer.

Decarbonization Specialists will help their oil and gas customers in industry and heavy-duty transportation, for example, leverage energy management, efficiency and CCUS solutions to reduce the end-to-end emissions associated with the oil and gas value chain.



Who should consider becoming a Decarbonization Specialist?

The Decarbonization Specialist archetype should be considered by players that have deep operational capabilities, occupy an early leadership position in carbon management and measurement, and currently operate carbon-advantaged assets.

Upstream independents, downstream players (including refiners and in petrochemicals), as well as service companies could select to be a Decarbonization Specialist. This is one of two viable archetypes; the other is Low-Carbon Solutions Leader.

A Decarbonization Specialist focuses on refining products at the lowest incremental emissions by being a leader in energy efficiency, CCUS, synfuel manufacturing, process control and emissions management. Similarly, a chemicals-focused Decarbonization Specialist can expect to complement advanced decarbonization capabilities with a conscious shift away from single-use plastics to degradable alternatives and lead in low-emission crude-to-x feedstock processing.

The journey to becoming an Energy Major or a Low-Carbon Solutions Leader will demand a more significant portfolio and operating model shift. While there might, in the long run, be less upside to becoming a Decarbonization Specialist, it stands out as a leading alternative in delivering near-term returns and margins.

What are the immediate priorities to establish momentum?

The journey to becoming a Decarbonization Specialist starts with a rigorous and honest, self-assessment of whether the company has what it takes to succeed, as well as an understanding of the known gaps and how to close them. Where these gaps are insurmountable, certain assets might be better owned and operated by others.

Laying out a clear journey to top-quartile or better performance in both emissions and cost across the portfolio, the Decarbonization Specialist will leverage its insights in carbon measurement and management, along with an agile approach to portfolio management, to pivot the business to lower carbon intensity energy production. Additionally, the company will share its ambition and expectations with its supply chain partners, ensuring that a reliable and cost-efficient set of low-emission service and equipment providers are aligned and committed to achieving the joint aims of low-carbon oil and gas. The Decarbonization Specialist will likely need to establish partnerships in order to manage, or offset, Scope 3 emissions.

By intentionally timing and managing the deployment of its carbon-management capabilities, the Decarbonization Specialist will stay ahead of changing regulations, weather the consequences of carbon pricing, and be in a strong position to provide lower-emission products as commodity markets evolve to assign value to products' carbon-intensity.

Today's oil and gas businesses will not automatically become Decarbonization Specialists. It is a role that only the highest-performing asset and infrastructure operators can seek to play.

The Energy Major

There are reasons to believe that now is the time for a well-executed extension of oil and gas companies' scope of operations into a wider energy arena.

Feeling both a push from its current assets and a pull to new opportunities, the Energy Major will build or add clean energy businesses to its oil and gas existing assets. Over time, the Energy Major will increasingly rotate to low-carbon energy, while unlocking trapped value by integrating oil and gas into a portfolio of energy businesses.

What is the Energy Major's strategy?

The Energy Major will carry out a balanced set of activities across each of Clean the Core, Accelerate the Transition and Extend the Frontier dimensions, with the first two driving the majority of investment and action over the upcoming decade.

The oil and gas industry is standing up to powerful threats and opportunities. Liquid hydrocarbons will take a lower share of the growth in energy consumption into the future. Demand is shifting toward alternative energy solutions for transportation and, over the long run, gas will fall back as a direct source of energy consumption in buildings and industrial processes. Stock market valuations of oil and gas companies no longer turn on reserves or production, and the growth premium the sector earns is a fraction of that in other sectors of the economy such as technology.

Leading oil and gas businesses have value to protect. The largest are counted among the few organizations that manage truly global operations on a massive scale, sometimes spanning more than 100 countries. Downstream and integrated players have well-established retail brands. Re-establishing trust, committing to the Decarbonization Transition, and leveraging brands many consumers already associate with "energy" all point to an opportunity to become an Energy Major.

As energy converges, there is opportunity. Mobility is being redefined, business models are evolving, and technology is enabling innovative solutions that create distinct roles that previously did not exist. The oil and gas industry's 100+ years of experience building customer relationships provides a strong starting point to anchor the future of connected, low-carbon mobility.

The global trend of growth in electricity consumption is now turning its focus to lowering the carbon intensity of the electricity being produced, ensuring its dispatchability, and solving the challenge of having more intermittent renewables in the mix. The Energy Major will focus on providing solutions to these issues.

For example, in 2022, offshore wind is expected to outstrip oil and gas for the first time to become Europe's largest area of upstream energy capital expenditure[45]. Offshore wind offers several advantages, including its relative reliability as an energy source and its potential to be developed closer to major urban populations without the costs or public opposition that are often associated with on-land developments. Offshore wind also presents challenges, however. The engineering complexity associated with constructing turbine foundations in the ocean cannot be overstated. This is where the Energy Major can shine. As leaders in offshore engineering and construction, asset operators and service companies are capable of operating in almost any environment. Energy Majors will, for example, scale offshore wind, integrate wind resource with existing offshore assets, and redeploy the offshore supply chain to facilitate the development of the required infrastructure.

The Energy Major will be advantaged by working across an integrated portfolio of assets. Gas will be both a complement to and a substitute for intermittent renewables for the foreseeable future in power generation. Being able to drive value across both energy sources and manage between them enables the Energy Major to provide a complete solution to the customer. Energy Majors can also achieve greater flexibility by adding geothermal solutions to the mix, which can lower and smooth energy demand even more. With expertise in drilling and geothermal engineering, the Energy Major is perhaps the only company able to offer a range of tailored solutions to meet specific energy needs.

The Energy Major archetype will likely look quite different from one company to the next. Some will continue to have portfolios dominated by oil and gas and they will need to adopt several of the attributes of the Decarbonization Specialist to manage those assets. Others will emphasize clean power across their businesses. And still others will likely focus on new fuels like biofuels, electricity-based fuels and hydrogen. The infrastructure, technology and customer synergies of their current business, as well as their track record in R&D and innovation, positions them well to be winners as these solutions mature.

It is important to understand what the Energy Major should not do. It is not realistic to expect oil and gas companies to succeed in areas of the value chain where they do not have an advantage or capabilities that can be reapplied. Companies across all sectors have struggled to grow or successfully acquire and integrate businesses that operate very differently to their core. Solar PV, onshore wind, power transmission and power retailing currently present few overlaps with oil and gas's core business. Furthermore, these areas have thus far exhibited high growth, but mixed profitability. The Energy Major will not succeed by making small, incremental steps. They will win by entering areas of the value chain they can disrupt at scale.

What are the five capabilities required to win as an Energy Major?

The Energy Major requires a broad set of complementary capabilities, over and above those required to be a successful oil and gas major. Specifically, they need to take the following steps.

One

Maintain two distinct operating models simultaneously.

The Energy Major will operate its legacy portfolio alongside its future areas of growth in the energy value chain. These distinct lines of business call for distinct operating models, capital intensity and talent and will deliver very different cashflow and return profiles. Many businesses have failed to maintain multiple operating models within a single organization. Winners will adopt solutions and mechanisms that preserve the integrity of both models. Structural changes, such as a spin-off company or new, ring-fenced divisions, may be required during the period of scale-up.

Two

Lead with both the "molecule" and the "electron."

The Energy Major will cultivate businesses that work across and between oil and gas products and electricity and electricity-based decarbonized fuels. The energy market has bifurcated along these lines over the past 100 years, and while there are multiple signposts for convergence, few, if any, players have emerged with leadership across both domains.

Three

Build a resilient portfolio of oil and gas assets alongside emissions-management capabilities.

The core distinction between the Energy Major and a Low-Carbon Solutions Leader is that the Energy Major will continue to be a leader in the direct development, production, processing and refining oil and gas value chain. The growth into the wider energy space reduces the imperative for the oil and gas company to fully stand on its own and creates internal optionality to reduce emissions intensity by combining low or zero-emissions businesses into the overall company picture. However, the Energy Major will need to operate and maintain the oil and gas assets it retains as a Decarbonization Specialist would. If Energy Majors fall too far behind in oil and gas performance, the integrated value they earn over and above those who only play in oil and gas is unlikely to be sufficient to justify their continued participation.

Four

Create integrated solutions combining multiple sources of energy.

The Energy Major can emerge as the complete solution provider, with an integrated offering comprising gas, offshore wind, geothermal and energy storage solutions along with the ability to manufacture decarbonized fuels and promote circularity. Such integrated solutions can be game-changers as cities of the future look to transform their energy supplies. The Energy Major will be at the forefront of developing integrated solutions of a very different structure, commercial applicability and risk profile to the provision of commodity hydrocarbons. The ability to drive a wider, partnership-oriented narrative with the customer will be differentiating.

Five

Become a clear leader to net zero.

The Energy Major will be a dominant player across the energy landscape. As such, this company will face intense scrutiny—not least because of its retained oil and gas portfolios and the negative attention the sector attracts. To operate successfully across the energy landscape and secure a wider mandate, Energy Majors must be trust-focused, purpose-driven leaders committed to net-zero energy. Targets and announcements will need to be replaced by transparent reporting, material progress and demonstrated commitment early in the journey to becoming an Energy Major.

Who should consider becoming an Energy Major?

The Energy Major will likely be the most challenging of the three archetypal models to achieve. Prerequisites include portfolios of emission and cost-advantaged upstream/ midstream assets, and refining or LNG and gas processing together with downstream customer businesses. Arguably this restricts the companies that can realistically pursue this path to the current integrated oil players and selected national oil companies. Those that have already tentatively entered new areas of the energy system, even where not fully successful, have started to accumulate the knowledge, relationships and assets that can set them apart. This archetype can only be achieved by those that move decisively now.

At the same time, these businesses will need to overcome the inertia that characterizes many large and historically successful organizations. Strong and visionary leadership and a willingness to accept near-term trade-offs for long-term success will be critical. The pathway to becoming an Energy Major is not open to all. There are questions remaining around financing and access to lower cost of capital, balance sheet structures, the immense scale required to replace fossil fuel energy provision, and the ability to drive value across regulated markets. Those challenges must be balanced with the opportunities that moving into this space might afford. It is up to the oil and gas companies to demonstrate why they will outperform the incumbent on their own turf. There will be no red-carpet welcome for them.

Those oil and gas businesses that do not have access to the range of capabilities required for success as an Energy Major—but who nonetheless need to pivot into new areas of the energy system given the structural limitations of their existing portfolios—ought to consider transitioning into the third archetype, the Low-Carbon Solutions Leader.

What are the immediate priorities to establish momentum?

The journey to becoming an Energy Major starts with an objective assessment of the components of the current portfolio that will be retained, the determination of the specific areas of the extended value chain that will become the new sources of growth and, perhaps most importantly, the tangible identification of how synergy will be delivered across the old and new businesses.

The Energy Major will need to fuel growth within new areas with either cash generated from the oil and gas core, or through asset sales. Transparently communicating this intention to internal stakeholders and investors will de-risk the tough journey ahead. At the same time, the Energy Major must remain focused on maximizing value from its existing portfolio. The window for growth in core oil and gas is already closing and action must accelerate.

The timing of the move must be carefully planned and balanced with trends in areas of the energy system outside current operations. The areas of maximum available synergy for an Energy Major (with the exception of offshore wind) are out of sync with the timing of the Decarbonization Transition. In short, the Energy Major can expect to be in the "investment period" if it enters hydrogen, biofuels, electricity-based fuels and energy storage—or if it takes any of the Extend the Frontier actions. An intention plan must be in place to avoid jumping too quickly or opening too many new fronts at the same time.

Establishing unstoppable momentum in the journey to becoming an Energy Major depends on making, and delivering on, a material commitment—equivalent to a double digit or greater share of annual CAPEX. It is about getting in shape to undertake the transformative deals required to make a fundamental shift.

The Energy Major will not succeed by making small, incremental steps. They will win by entering areas of the value chain they can disrupt at scale.

The Low-Carbon Solutions Leader

The Low-Carbon Solutions Leader will exit its current direct asset-owning and production role in oil and gas.

It will refocus, instead, on leading in one or more clean areas of the energy system such as offshore wind, biofuels, hydrogen or decarbonized fuels. It may also potentially move to providing technical and decarbonization solutions back to the energy system, including to Decarbonization Specialists.

What is the Low-Carbon Solutions Leader's strategy?

The Low-Carbon Solutions Leader will take the lead across one or more Extend the Frontier opportunities, while also carrying out some Accelerate the Transition actions. Some of these companies might even selectively provide Clean the Core solutions in energy management services, CCUS technologies, emissions trading and emissions management to decarbonize other players' asset-centric portfolios.

This archetype represents the most profound strategic and operational departure from the past. It is not for the faint of heart. The companies choosing this path will monetize their core assets, then reinvest and leverage their capabilities and expertise to win in new areas across the clean energy sector. While several integrated oil and gas companies have set objectives to become leaders in low-carbon solutions (often starting by scaling a renewables-centric power portfolio, typically with a significant commitment to offshore wind), this archetype represents a bolder, holistic shift from hydrocarbon ownership to a clean-energy-only portfolio. Only a couple of companies have planned for or executed this shift to date, with an encouraging response from investors.

Potentially, some oil and gas companies will consider opportunities in negative emissions businesses. Climeworks is pioneering a filter-based technology that combines direct air capture with underground carbon sequestration. The company believes that within five years it can be competitive with other natural climate solutions such as reforestation. Bioenergy with carbon capture and sequestration (BECCS) has also been highlighted as a critical component of achieving net-zero emissions. However, success in BECCS projects requires capabilities that companies focused on oil and gas likely don't have. Energy Majors, therefore, may find it challenging to pursue BECCS opportunities. Low-Carbon Solutions Leaders would be in a better position.

The Low-Carbon Solutions Leader archetype offers oil and gas companies the opportunity to reinvent themselves into clean energy companies. It not only removes the burden of running existing oil and gas assets, but also opens up the potential for new, asset-light positions linked to the energy value chain. Differentiated margins, leverage and growth trajectories can replace the scale and capital of the former businesses.

Companies considering the Low-Carbon Solutions Leader archetype must articulate what they bring to the future energy services table (beyond funding) and identify "why they will win." Furthermore, while this archetype can be appealing for an individual company, there's no guarantee that new owners of divested assets will successfully lower those assets' emissions intensity.

What are the capabilities required to win as a Low-Carbon Solutions Leader?

The Low-Carbon Solutions Leader that shifts fully into a new area of focus in clean energy will develop and deploy distinctive technical, project or operational leadership capabilities in the priority areas of the clean energy system in which it is focused. It won't necessarily be the technology leader, but rather a leader in delivering technical solutions to its customers through, among other things, access to the right ecosystem partners.

The Low-Carbon Solutions Leader that offers decarbonization solutions to energy asset owners and operators will require technical excellence and execution excellence in order to win. These companies will draw on both digital and operational technologies to stitch together new solutions and innovations. In addition to maintaining and developing its portfolio of solutions, the Low-Carbon Solutions Leader will focus on managing and retaining its people. They also recognize the importance of intellectual capital and relationships with customers.

The move is certainly not without risk. The Low-Carbon Solutions Leader will create value in new markets across the energy value chain. This will require establishing commercial structures and value propositions that might not yet be tested. Strengthening operational and financial risk management capabilities will be critical. Equally important, the financial structure of the new business—everything from its balance sheet requirements to cashflow and returns—will need to be fundamentally changed. Careful management will be needed to effectively manage financial liabilities and exposure.

Who should consider becoming a Low-Carbon Solutions Leader?

The Low-Carbon Solutions Leader archetype can appear the most accessible. Integrated players are best positioned to make the move. Their exposure to the full oil and gas value chain typically enables them to bring the most capabilities to the table. However, integrated oil and gas companies might prioritize becoming an Energy Major, since the operating model disruption and requirements for change are likely lower. Furthermore, the Low-Carbon Solutions Leader will initially be a smaller business, with significant need for capital for the first few years. The need for boldness and a willingness to shrink will be a tough pill for some integrated players to swallow.

The burning platform, however, can be a great motivator. For many, it can be the significant financial pressure across the oil and gas business that will reduce the opportunity cost of divesting hydrocarbon assets and doubling down on clean energy such as offshore wind.

Businesses with strong technical, project and R&D capabilities will be most likely to create a sustainable advantage outside of their current core businesses. They are the ones that can set the ambition of becoming tomorrow's Low-Carbon Solution leaders.

What are the immediate priorities to establish momentum?

The pathway to becoming a Low-Carbon Solutions Leader starts with selecting and embracing the new areas of focus along the value chain. This is a make-or-break choice, which means companies need to carefully consider the growth potential, competitiveness, barriers to entry, and expected returns of the opportunity areas.

The Low-Carbon Solutions Leader must honestly assess whether it will truly be able to lead in, and reinvent, the sectors into which it's moving. Does it have the right technology expertise? Partners and customers? Business model? Innovation capacity?

The transition to becoming a Low-Carbon Solutions Leader can occur quickly or via a phased, asset-by-asset approach. The second option is likely smoother. But it requires more time to implement and might be more challenging to manage in terms of funding and operating multiple businesses at the same time.

Pure-play downstream oil and gas companies face a particularly challenging choice. But one that must be made. Some are best positioned to become Decarbonization Specialists, reducing operational emissions to a minimum, collaborating with customers to offset emissions, and running the most competitive crude-product slate combinations in high-growth markets, doubling down on their core market, and creating value even if volumes diminish. Others must prioritize the Low-Carbon Solutions Leader and extend their capabilities and assets into new energy solutions; refineries can be repositioned for blending biofuels, hydrogen and synfuel manufacturing and retail businesses augmented with electric vehicle charging infrastructures and energy storage.

A similar opportunity exists for today's oilfield and equipment services companies. Operators are asking themselves whether they need to develop expertise or if they should leverage their supply chain partners. Service companies have already started to redefine their value propositions to the industry and as they go further will increasingly need to select their specialty—be it the decarbonization partner to the oilfield, or as the one to enter boldly into new energy solutions.

The Low-Carbon Solutions Leader archetype represents the most profound strategic and operational departure from the past. It is not for the faint of heart.

The imperative for action cuts across all archetypes

Common to the winners emerging across all three archetypes is a commitment to pursue a low-carbon (or net-zero) ambition and account for it in all business decisions. They will each work to reform / rebalance their portfolios, rethink their operating models and capabilities, redefine customer value propositions and build customer intimacy, ramp up their innovation engines, and act to create true ecosystems that will support the complex transition.

Every oil and gas company must now prepare for the profound change that lies ahead. All will be affected. Many already are. A company deciding not to act decisively today is implicitly deciding to become a Decarbonization Specialist. That's a risky journey even for those that intentionally set out on the path. A frank conversation is required.

The path forward

Emerging safely from the storm requires that oil and gas companies take the right paths to their decarbonized futures. Those paths will rarely follow a straight line. Obstacles must be overcome. Threats must be continually assessed. Routes recalibrated. Destinations reconsidered.

The window of opportunity to pursue new value is open. But it could close quickly. Leaders who are effectively starting their journey, as well as others who are ramping up or assessing their alternatives, need to consider seven factors. And then take corresponding actions to ensure their path forward is the right one.

Factor One

Reset decarbonization commitment

It's clear that oil and gas companies need a social and financial license to operate. That license is bestowed by customers and investors in exchange for authentic actions to address environmental, social and governance imperatives and, specifically, to fight climate change. A public commitment for achieving net-zero carbon targets across Scope 1, 2 and 3 emissions in a practical, yet balanced timeframe must be a foundational element of any archetype transition.

Action: Leaders will need to bring their decarbonization commitment to life with investments, risk assessments, and transparency around the impact of their future operations. They will also need to have an internal carbon price built into their financial decisions and rewards.

Factor Two

Refresh risk

Transitioning to any of the archetype models comes with a certain amount of risk. A lot of that risk is based on the uncertainty of how the Decarbonization Transition will play out in the oil and gas industry, and in other industries, as well. What industry changes are coming in the next five years? The next ten? What new regulatory pressures might emerge? How will society's reliance on (and trust in) energy companies evolve—and how might that affect a company's license to operate? How will a move into areas outside of hydrocarbons affect a company's way of working? Its value? Its culture?

Action: Leaders need to honestly assess the amount of risk (and uncertainty) they are willing to take on—and the type of risk investors will tolerate. They will also need dynamic portfolio management capabilities to constantly assess the risk and reward tradeoffs of their decisions and executed actions.

Factor Three

Rethink the business model

Companies need to identify where the greatest value potential lies. Will it stem from making operations as lean as possible, perhaps by jettisoning costly assets or businesses? Will profitability come from delivering new services and experiences for customers or business partners? Will it come from carving out a winning competitive position in new lines of business or via integration across existing value pools? Or will it come about as a combination of factors?

Action: Leaders need to assess value propositions for customers, optimize their portfolios for a net-zero carbon world, improve their capital allocations, and explore non-traditional growth opportunities, including partnerships with customers or adjacent industry players. They need to determine how much of a business model revamp—incremental or fundamental—the transition path they've selected will require in the near and long terms.

Factor Four

Revamp the operating model

The transition to any of the archetypal roles will require entirely new sets of capabilities, partnerships and organizational structures. Many oil and gas companies have built their success (and their balance sheets) largely on the basis of their expertise in asset management and large-scale project execution. Others have global reach, strong brand recognition, and a long history of working with governments and regulators. Still others have infrastructures that can be modified to accommodate new sources of energy. Oil and gas companies should review their existing assets and capabilities for portability and the risk and cost of upending so much of their existing models.

Will the rewards potentially outweigh the risk of so much change?

Similarly, those revamping their operating model from the ground up to capture new value pools and/or transition into other industries will need to assess the compatibility of the new assets, capabilities and investor value proposition with those of their existing, or traditional, operating model built for oil and gas.

For example, an Energy Major will need to determine how to manage two business models concurrently.

Action: In making their strategic decisions about how to compete in the decarbonized future, leaders should determine which assets and capabilities are potentially transferable to new business models and new areas of the energy system—and whether that portability would deliver a meaningful cost or competitive advantage. Transferability of assets will be primarily a consideration for those companies looking to become Decarbonization Specialists or Energy Majors. Also, they need to determine the effort (and cost) associated with either revamping their capabilities, structures, and even culture or developing specialty capabilities within a specific value chain section or as a new kind of service provider.

Factor Five

Reimagine the customer experience

The target customer is changing, as can be seen in the shift from B2B customers to emerging B2C end-consumer customers. With these changes come tremendous opportunities for oil and gas companies to develop a new range of low-carbon sustainable offerings, from distributed generation services for prosumers to biodegradable packaging.

At a minimum, companies will need to reassess their customer value propositions and ability to compete in the direct-to-consumer markets. Some can take advantage of existing capabilities such as retail experience and infrastructure, to meet new customers' demands in new ways. And some—often for the first time—will need to develop customer-centric products, services, experiences and interfaces. Access to end-customer data and insights into changing behavior patterns will be critical to creating compelling customer experiences. New digital platforms and tools will also be necessary to not only analyze consumer data, but also drive new forms of marketing and facilitate non-traditional partnerships. This becomes particularly important in the context of the sharing economy and emergence of new B2B, B2C and C2C channels.

Action: Reassess the customer value proposition and develop customer-centric products, services, experiences and interfaces. Identify what it will take to access the data and build the relationships that customer-centric business models will require.

Factor Six

Recharge innovation

Technology-driven disruption and innovation within and across industries are changing everything from value propositions, business boundaries and new decarbonization opportunities to operating models and the economics of running a new or existing business. Companies that can't keep up with the increasing pace of change won't just fall behind. They'll disappear.

Oil and gas companies that excel during and after the Decarbonization Transition will invest in building a strong innovation DNA. According to Accenture's *Technology Vision 2020*, that means they not only make optimal use of new digital technologies such as artificial intelligence, but also build new partnerships to share ideas and solutions and, together, create ground-breaking change. Innovation ecosystems should include suppliers, customers, academics and even governmental or non-governmental organizations. They may also welcome unlikely collaborators such as competitors. And of course, they will use their innovation muscle to architect cross-sectoral transitions that will ultimately determine the pace and success of the overall Decarbonization Transition.

Action: Establish a culture of ongoing innovation to develop future-proof business models and ways of working. Continuously reassess R&D capabilities, refine them and bolster them with innovative partnerships. Continue moving forward with digital transformation programs. Aim to become a digital pioneer that leverages technology advancements to drive operational efficiencies, new customer products and business models.

Factor Seven

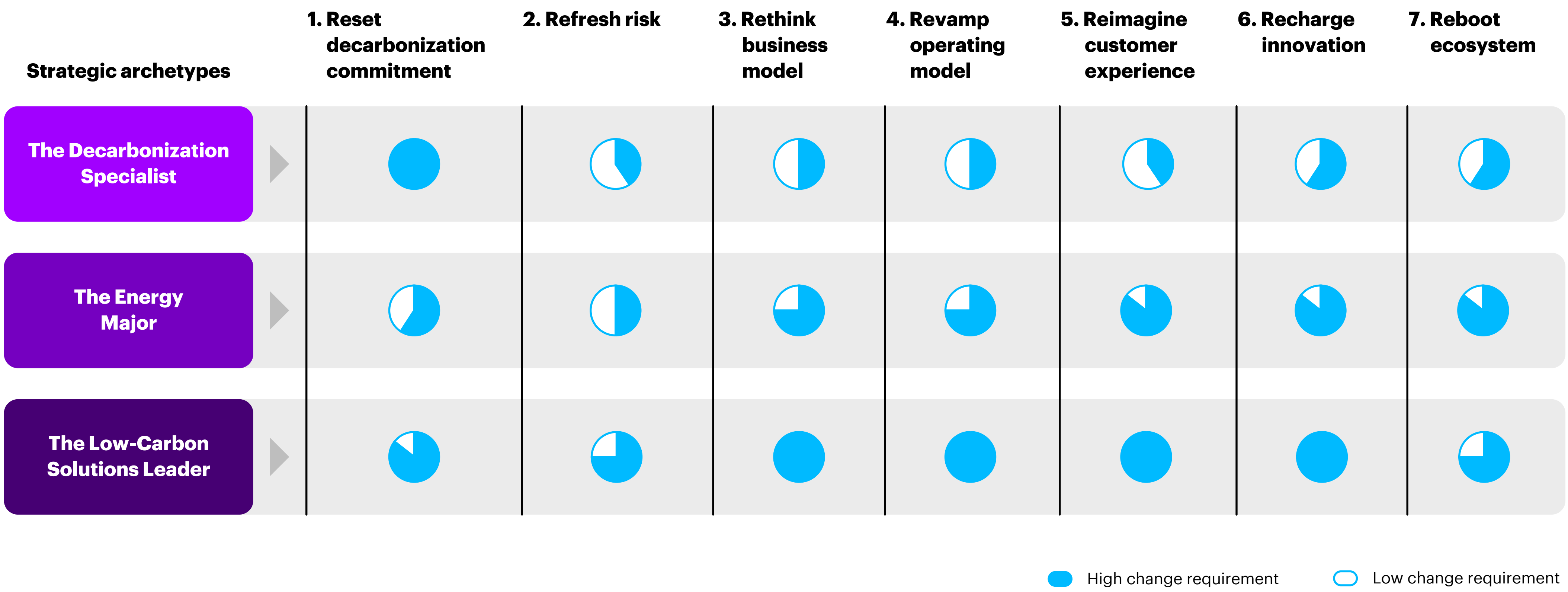
Reboot the ecosystem

The transition to new business models and archetypes will require oil and gas companies to pursue new opportunities within the traditional oil and gas business (Decarbonization Specialists and Energy Majors) and far beyond (Energy Majors and Low-Carbon Solutions Leaders). And the risk of that uncertainty will typically be too great for one company to bear. Oil and gas companies will, therefore, need to reimagine their ecosystem partnerships—within the sector, across sectors, and with technology companies. For example, transitions within the harder-to-abate sectors such as heavy industries and aviation will only happen if an ecosystem of cross-sectoral and technology partners come together to reengineer the current system. Proactively orchestrating ecosystem partners to bring a united vision of the energy future to life is one of the most important roles oil and gas companies will play.

Action: Identify partners with complementary skills across industries that could be inspired to develop joint offerings and go-to-market strategies. At the same time, look to existing partnerships and ecosystems across sectors into which your business may infuse needed skills, assets and expertise. Establish consortiums to share funding and ideas.

Figure 32

Factors to consider in assessing the change journey required for success in the different archetypes



Source: Accenture Analysis

Shelter in the storm

When a storm is raging, it's often hard to think about more than staying safe. But for oil and gas companies, there are no longer any safe bets.

Investors, consumers, regulators and new entrants are no longer supporting a business-as-usual approach. And market dynamics have revealed that old ways of working are no longer rewarded. Growth today means pursuing higher-value opportunities.

Oil and gas companies need to look beyond the here-and-now and envision a time when the storm has passed. When they are no longer struggling to navigate the disruption swirling around them and, rather, leading others on the journey to a secure, robust and decarbonized energy future. That journey will almost certainly extend beyond 2050.

While the industry's net-zero emissions targets by the middle of the century will likely be missed, that's no reason to end the journey prematurely. Indeed, it's why oil and gas companies should redouble their efforts to lead in the energy transition. The value they will ultimately deliver when their transitions are complete will be worth waiting for.

For generations, oil and gas companies have fueled the world's potential. There's no reason to think they will or should stop now.

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 business-as-usual 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 2ºC. It can also refer to the quantity of CO_2 or greenhouses 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.

References

1 "According to New IPCC Report, the World Is on Track to Exceed its Carbon Budget in 12 Years"; October 7th 2018; World Resources Institute © 2020 World Resources Institute

2 Accenture decarbonization scenarios – for an explanation see P174

3 "'Sustainable' funds a safer harbour in coronavirus market meltdown", April 6th 2020, Reuters © 2020 Reuters via Factiva

4 "The Decade to deliver a call to business action"; 2019; Accenture © 2020

5 Accenture Analysis

6 "A more potent greenhouse gas than carbon dioxide, methane emissions will leap as Earth warms"; March 27th, 2014; ScienceDaily © 2020 ScienceDaily.com

7 UNFCC 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

19 "Flaring Emissions"; June 2020; IEA © IEA 2020

20 "World Energy Outlook"; November 2019; IEA © IEA 2020

21 "Supermajors all have ambitious, and widely varying, net-zero goals"; May 2020; World Oil © 2020 World Oil, © 2020 Gulf Publishing Company LLC, via Factiva

22 "The Oil and Gas Industry in Energy Transitions"; January 2020; IEA © IEA 2020

23 "Flaring Emissions"; June 2020; IEA © IEA 2020

24 "Putting out the Fire: How Nigeria has quietly cut Flaring by 70%, and is now moving to cut methane emissions from the Oil And Gas sector"; September 9th 2019; Center for Clean Air Policy © 2020 Center for Clean Air Policy

25 "World Energy Outlook"; November 2018; IEA © IEA 2020

26 "Transforming Industry through CCUS"; May 2019; IEA © IEA 2020

27 "World Energy Outlook"; November 2019; IEA © IEA 2020

28 "Outlook for Competitive LNG Supply 2019"; March 2019; The Oxford Institute for Energy Studies © Oxford University 2020

29 "Average cost of potential emissions savings from coal to gas switching in the power sector, 2025"; November 26th 2019; IEA © IEA 2020

30 "Portugal reveals winners of record-breaking solar auction"; August 8th 2019; PV Tech © Solar Media Limited 2020 via Factiva

31 "Nuclear Power"; June 2020; IEA © IEA 2020

32 "Average new global fuel economy of light-duty vehicles, 2006-2017, and GFEI 2030 target"; November 22nd 2019; IEA © IEA 2020

33 "Global EV Outlook 2020"; June 2020; IEA (c) IEA 2020

34 World Air Transport Statistics, IATA 2019

35 "Aviation"; June 2020; IEA © IEA 2020

36 "Mission Reaching Net-Zero Carbon Emissions from Harder-To-Abate Sectors by Mid-Century Possible"; July 2018; Energy Transition Commission © 2020 Energy Transitions Commission

37 "Global energy consumption driven by more electricity in residential, commercial buildings"; October 21st 2019; U.S. Energy Information Administration © 2020

38 "Perspectives for the Clean Energy Transition"; 2019; IEA © IEA 2020

39 "Global Status report 2017"; 2017 United Nations © 2020 United Nations

40 "Oil major Shell to write down up to $22 billion of assets in second quarter"; June 30th 2020; CNBC © 2020 CNBC LLC.via Factiva

41 "Petroleum Engineering Enrollment Is In Decline: Should Industry Worry?"; May 23rd 2019; The Fuse © 2020 The Fuse

42 Accenture Analysis

43 "Methane: The other important greenhouse gas"; EDF website © EDF 2020

44 "Fueling a Digital Methane Future"; EDF website © EDF 2020

45 "Offshore wind expenditure set to match upstream oil and gas in Europe in 2021, surpass it in 2022"; June 5th 2020; Rystad, © 2020 Rystad Energy

Authors

Muqsit Ashraf

Senior Managing Director,
Global Energy Industry Sector Lead

Muqsit is a Senior Managing Director and Global Industry Lead for Energy. He advises Energy executives and senior stakeholders on strategy, transformation, and technology/innovation. Muqsit also serves on Accenture's Global Leadership Council. Muqsit has nearly 20 years of experience working in the energy industry across the value chain—upstream, oilfield services, downstream and petrochemicals. He specializes in corporate strategy, operating model design and large scale business (and digital) transformation programs. Muqsit sponsors Accenture's partnership with the World Energy Council, manages the relationship with the World Economic Forum's Energy team, and is part of Accenture's Global Energy Board. He features regularly on major industry conferences and forums, and publishes internally and externally. Before joining Accenture in 2015, Muqsit managed the North America business for SBC (Schlumberger Business Consulting).

David Rabley

Managing Director – Energy,
Strategy & Consulting

David is a Managing Director based in Houston and leads the Accenture Energy Transition practice for oil and gas globally and in North America. With over two decades of experience in the energy industry, David collaborates with majors, national oil companies, US-based independents and oilfield services companies to develop and execute strategies and programs to understand and lead the energy transition, transform and protect value for their stakeholders, society and for the environment. David works closely with international organizations including the World Economic Forum and the World Energy Council with a focus on future energy scenarios and priorities for the successful development of the energy system.

Tom Beswetherick

Senior Manager – Energy,
Strategy & Consulting

Tom is a Senior Manager within Accenture Strategy & Consulting's Energy practice. He has extensive experience working with oil and gas companies and governments in the areas of portfolio strategy, M&A and capability development across North America, Asia Pacific and Europe. Having started his career in clean technology-related research and publication, Tom recently returned to this area and is a member of Accenture's growing Energy Transition practice. He now focuses on conducting research, advising clients and publishing articles.

About Accenture

Accenture is a leading global professional services company, providing a broad range of services in strategy and consulting, interactive, technology and operations, with digital capabilities across all of these services. We combine unmatched experience and specialized capabilities across more than 40 industries—powered by the world's largest network of Advanced Technology and Intelligent Operations centers. With 506,000 people serving clients in more than 120 countries, Accenture brings continuous innovation to help clients improve their performance and create lasting value across their enterprises. Visit us at **www.accenture.com**