accenture

The Changing Joule Dynamic

Five portfolio plays to help oil and gas companies win in the new energy transition

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Executive summary

"Energy transitions" are not a new phenomenon. In fact, the world has witnessed multiple transitions in the past century. But the one we're currently experiencing is different. This one is not driven by changes in supply, but by new demand dynamics that are setting the stage for a more diverse, localized and multi-fuel energy system.

The current energy transition is also different because it is fueled by an urgency to act on climate change and by demands for a shift to fuels with lower carbon intensity (once the very near-term supply chain disruptions and inflationary environment have stabilized). Activist investors and environmentalists are urging companies to take drastic action. We agree that they should.[1]

However, what's lost in much of the dialogue today is the fact that oil and gas will (and must) constitute a large share of the energy mix in the decades ahead. Of course, these energy sources should be produced, developed, refined and transported as cleanly as possible. But suggesting that they be eliminated from the energy portfolio completely is just not realistic.

In 2035, oil and gas will still account for roughly half of the global energy mix. It's too large an energy source to displace.

As global demand for energy continues to grow—by approximately 16% over the next 15 years in Accenture's base scenario—oil and gas will remain the dominant fuel source, accounting for nearly half of the global energy mix. But alternatives are now becoming more economical and viable, chipping away at oil's leading position.

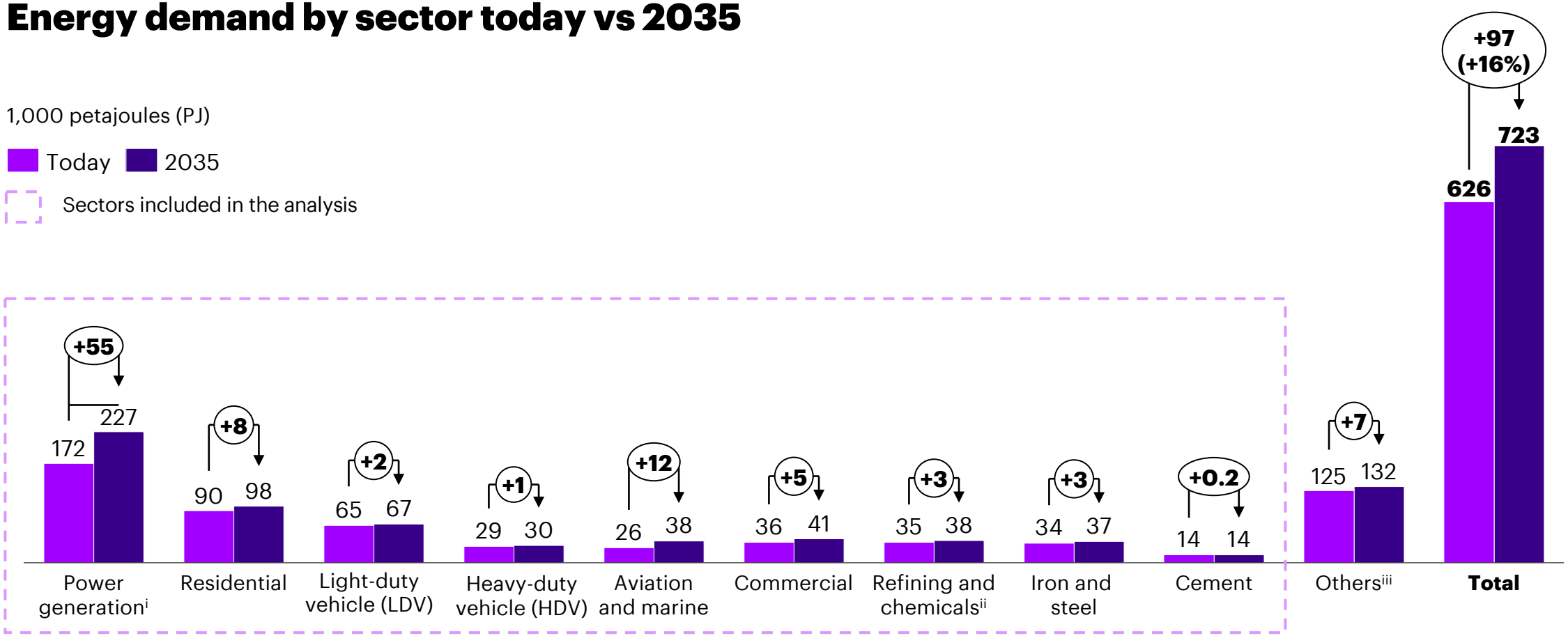
Even within the hydrocarbon portfolio, changes are afoot. The transition away from coal in the power generation and heavy industrial sectors—particularly in Asia—is creating new demand for natural gas. In fact, we project that demand for natural gas will grow by 14% by 2035. That's despite energy efficiency increases across sectors (typically between 0.5 - 5% per year) and demand for renewable fuels (notably, wind and solar) tripling over the next 15 years.

The reality is that the homogenous energy system we've grown accustomed to is becoming much more heterogeneous. The new system will enable consumers to tap different sources of energy to meet the needs of different industries and geographies. The role for both oil and gas will no longer be globally pre-ordained but determined on a region-by-region and sector-by-sector basis.

About the research

In 2021, Accenture developed the Accenture Energy System Model (patent pending) to help companies make capital decisions more dynamically based on absolute value creation in a given region. In early 2022, we expanded our thinking around this model to gain a better understanding of how demand-driven change across eight regions, the top nine energy-consuming sectors and eight fuel sources could affect the energy system and, specifically, the oil and gas industry over the coming 15 years. The findings and projections in this report are based on this analysis.

Energy demand by sector today vs 2035



[i]Net primary energy demand of power generation after deducting output electricity/heat.
[ii]Including feedstock use of hydrogen for refining and ammonia production.
[iii]Others include pulp and paper, non-ferrous metals, agriculture, forestry, fishing, rail transport, mining, light industries and other non-energy use.

Source: Accenture analysis.

The drivers of change

Three factors are driving today's energy transition—or, more accurately, its evolution:

1. Urgency around climate action from all stakeholders, evidenced by consumer pressures, investor activism and governmental regulations, incentives and commitments (e.g., COP26 methane reduction pledges from 100+ countries, the commitment of $130 trillion of private capital toward a net-zero economy, and others).[2]
2. The increasing pace of technology advancements, particularly in renewable generation and energy storage.
3. The need for energy security in a transitioning energy system that allows developing economies to assume more local/regional control with the emergence of renewable fuels.

To compete in the energy future where there are several energy sources, oil and gas companies need to base their decisions on a standardized measure (such as on a per-joule basis) of how, where and when energy is consumed. This shift requires a keen understanding of the market-by-market joule consumption of different regions and sectors.

And that's not always easy to come by.

Beyond differences in regional and sector demand profiles, oil and gas companies need to accommodate varying country regulations, technology advancements and investor pressures. Each of these factors contributes to even greater heterogeneity—and complexity—in the energy market.

A demand-driven energy system: Two scenarios

Accenture recently carried out an extensive analysis to gain a better understanding of how near-term and mid-term demand-driven change will affect the energy system and, notably, the oil and gas industry over the coming 15 years. Specifically, we looked at annual changes in energy demand across eight regions, nine sectors and eight fuel sources.

Our analysis modeled two scenarios:

- **A base case scenario** that assumes relatively stable oil prices and moderate carbon taxes.
- **An optimistic transition scenario** that assumes a more challenging price environment and higher carbon taxes globally.

From this analysis, we identified five portfolio plays oil and gas companies should consider, along with opportunities for various players in the value chain and recommended actions. Our findings suggest that these plays are most likely to help companies meet energy demands while also boosting their profitability and relevance in the new energy system, regardless of the energy scenario that unfolds.

We believe five portfolio plays hold particular potential.

Play 1	Play 2	Play 3	Play 4	Play 5
Natural gas	**Oil**	**CCS**	**Blue hydrogen**	**Biofuels and low-carbon products**
Innovate in sectors to build demand for gas as a fuel of the transition	Drive toward the lowest-cost barrel of oil, which will be the winning barrel in either a $100/bbl world or a $30/bbl	Scale the removal of carbon from the energy system with CCS and industrial efficiency technologies that underpin a flywheel business	Use scaled CCS solutions and low-cost gas to turn the blue hydrogen equation around and accelerate the decarbonization of industries	Win the race in low-carbon transportation with biofuels and low- carbon products such as bio/synthetic lubes

Play 1 - Natural gas

Stop focusing on the immediate supply crunch. Start building demand in end-sectors and high-growth geographies.

Despite increasing energy efficiency improvements in heating, lighting and industrial processes, the demand for natural gas is poised to grow by at least 14% by 2035 in our base scenario. This is largely due to coal-to-gas conversions in industrial sectors (mainly power) and the increasing commissioning of new LNG/natural gas-powered plants in Asia.

Until 2025, natural gas will be an important source of energy as economies recover from the pandemic and dependence on Russian gas is re-evaluated. Thereafter, there is an opportunity to boost demand for gas in emerging markets by creating the needed infrastructure (e.g., regasification facilities, pipelines, etc.) that developing economies need to fuel their transition.

We believe operators should go "all in" in two areas:

- **Providing energy transition support in Asia:** Build the required infrastructure to fuel the transition and secure customers in multiple industrial sectors such as power generation, refining, chemicals and cement
- **Capturing new demand globally:** Support different sectors' (primarily power generation) transition from coal to natural gas globally, while also proactively addressing new uses of gas in transportation and residential cooking/heating

Play 2 - Oil

Stop focusing on the oil super cycle. Start focusing on oil for all cycles by building the lowest-cost and lowest-carbon oil supply.

We expect demand for oil to peak the late 2020s and decline back to 2021 levels by 2035. However, while oil demand will plateau by 2035 the world will require approximately 14-18 billion barrels of "new oil" in 2035 to replace production from depleted assets. That is approximately equivalent to half of the current worldwide oil production.

In the short term, contrary to some expectations, there will likely not be major shifts in consumer demand for oil in key sectors such as road transportation. Rather, two region-sector clusters—petrochemical feedstocks in Asia and heavy transportation globally—will drive growth in oil demand by volume.

Looking ahead, operators should continue to focus on break-even costs to fund the incremental production required to meet the demand for oil.

In the near-term, we believe operators should zero in on:

- **Competing to meet petrochemical feedstock and heavy transportation demand with the lowest break-evens:** Invest in reducing the break-even cost of oil and focus on targeting the rapidly growing demand for petrochemical feedstocks and heavy transportation, mainly in Asia.

Play 3 - CCS

Stop viewing CCS as a negative emissions support technology. Start seeing carbon management and industrial efficiency technology as a $250+ billion business.

Three types of technologies underpin the energy market's transformation: carbon capture solutions, industrial efficiency solutions and fuel-switching solutions.

Our analysis estimates that reaching a net-zero world by 2050 will require between three and 10 billion tons of CCS capacity per year, up to 200 times the current capacity. By 2035, that number will be 70 to 90 times the current capacity.[3]

Our analysis also predicts that the demand for industrial efficiency and end-to-end carbon management technologies will surge, with players of all types (i.e., oil and gas operators, oilfield equipment and services companies, industrial control providers, enterprise software providers and others) fiercely competing to differentiate themselves in what will be a $150+ billion market by the middle of the decade.

Across both CCS and end-to-end carbon management and efficiency solutions, oil and gas companies are uniquely positioned to lead. Their deep understanding of the carbon lifecycle, capabilities in managing depleted reservoirs, and expertise in industrial efficiency give them a significant competitive edge.

We believe that first movers have the chance to seize a $250+ billion opportunity by 2035. Operators should invest in building carbon management and industrial efficiency solutions in:

- **CCS in power generation**
- **CCS+coal in steel**
- **CCS+coal in cement**
- **Asset management solutions**
- **End-to-end carbon management platforms for industrial sectors**

Play 4 - Blue hydrogen

Stop looking at different shades of hydrogen as having equal potential. Start viewing blue hydrogen as the veritable force in the energy mix.

While there are plenty of clean hydrogen options, blue hydrogen and green hydrogen have major advantages—namely, their availability and long-term competitiveness in a high carbon tax environment. The choice between blue or green hydrogen depends primarily on carbon and natural gas prices—and on the cost of generating each type of hydrogen.

In both the base and the optimistic transition scenarios, blue hydrogen is expected to reach market dominance by the early to mid-2030s, mainly due to the availability of low-cost natural gas. In the optimistic scenario, if carbon prices reach levels of ~$200/tn CO_2 in North America and Europe and ~$100/tn CO_2 in China, green hydrogen will start making economic sense in the mid-2030s. In the base scenario, green hydrogen's economics will still be dampened by high electrolyzer costs and significant losses in hydrogen conversion.

To seize the blue hydrogen opportunity, oil and gas companies should focus on creating a **blue hydrogen infrastructure** in the near term. A massive investment market for hydrogen production and refining is forming rapidly.

Play 5 - Biofuels and low-carbon products

Stop ramping up traditional hydrocarbon refining. Start building low-carbon muscle with bio/synthetic products (through ultra-flexible refineries).

Most of the discussion regarding the transportation sector is focused on electricity and the growing popularity of electric vehicles (EVs). Yet, our analysis shows that in the mid-term (2025-2035), biofuels will be the real winners when it comes to demand for decarbonized fuels.

While EVs will definitely win the race in light-duty vehicles (LDV) over the long run, biofuel consumption (especially ethanol) will continue to grow at a compound annual growth rate (CAGR) of 7% until 2035 and will only be surpassed by electricity in terms of total joules consumed in 2035. In the heavy-duty vehicles (HDV), aviation and marine sectors, biofuels are the main viable option for decarbonized fuels in the foreseeable future. Specifically, in the HDV sector, our analysis shows that the demand for renewable diesel and conventional biodiesel will at least double by 2035.

We also forecast that sustainable aviation fuels (SAF) will grow significantly after 2025 at a CAGR of 27% as SAFs become cost competitive with kerosene in the late 2020s (considering subsidies).

Overall, our analysis suggests that biofuels will become a $160 billion market by 2035, ripe for oil and gas companies to dominate.

There are several opportunities for integrated players and independent refiners to leverage their refining assets and capture the value of biofuel's demand growth over the next 15 years. One such opportunity lies in the co-processing of high-energy-density bio-based feedstock (like vegetable oil) with petroleum distillates in existing facilities. It's a natural fit for oil and gas companies, and a capital-efficient way to provide biofuels such as renewable diesel/gasoline and SAF for the transport sectors in North America, Asia and Europe.

Relevance matters

There are several opportunities for oil and gas companies to re-imagine who they are, what they do, where they operate and whom they serve in the next 15 years.

We've identified five.

Some involve refocusing their portfolios on oil and gas, albeit in cleaner and more sustainable ways. Others involve heading into new frontiers. All, however, call on oil and gas companies to develop new capabilities and new business models to meet energy demands, while also boosting their profitability and relevance in the new energy system, regardless of the energy scenario that unfolds.

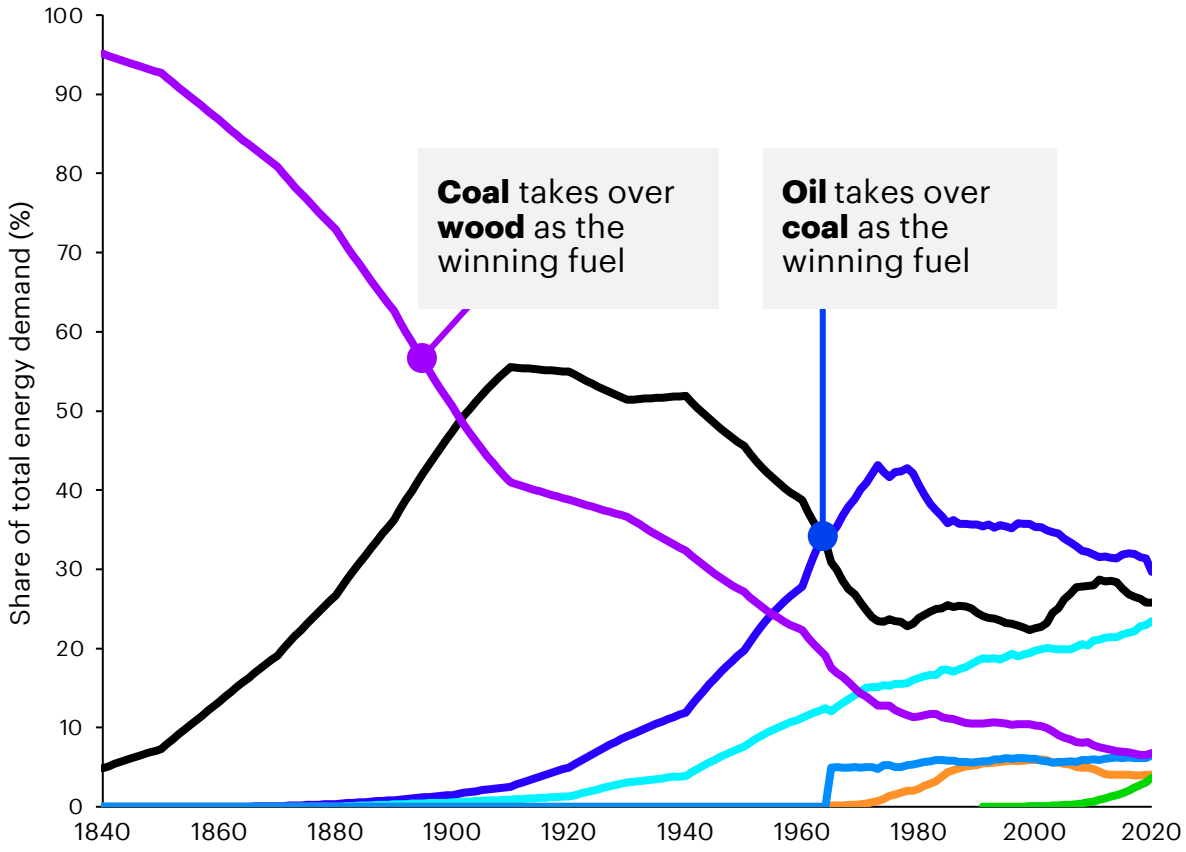
Introduction

Historically, the displacement of fuel sources—coal overtaking wood and then oil overtaking coal, for example—wasn't driven by changes in how people consumed energy (although they were steadily consuming more of it). Rather, the energy industry was adapting to the emergence of better, cheaper fuel alternatives. Those new alternatives, consequently, sparked a change in demand dynamics. The growth of oil, for example, fueled the development of the automotive and transportation sectors. Literally and figuratively.

Today's transition to a cleaner energy system is a variation of this historical theme. Yet, it is quite different. The world is now moving toward a clean-fuel future, driven by the imperative to act on climate. But it's not yet clear how we will get there—or which fuel source will dominate. What we can be certain of, however, is that the demand dynamics of how consumers, industries and governments use the energy at their disposal are forcing the entire energy system to change.

Whereas supply-driven energy transitions of the past gave rise to new demand dynamics, today's demand-driven dynamics are setting the stage for a diverse, localized and multi-fuel energy system.

Previous energy transitions were mainly driven by supply, specifically, the emergence of a more favorable fuel that forced demand transition



The energy transition will manifest itself very differently by region in the next few decades

Source: Accenture analysis based on BP Statistical Review of World Energy 2021, IEA WEO 2021, IEA WEO 2010.

The story of demand

Our analysis modeled two scenarios:

- A **base case scenario** that assumes relatively stable oil prices and moderate carbon taxes.
- An **optimistic transition scenario** that assumes a more challenging price environment and higher carbon taxes globally.

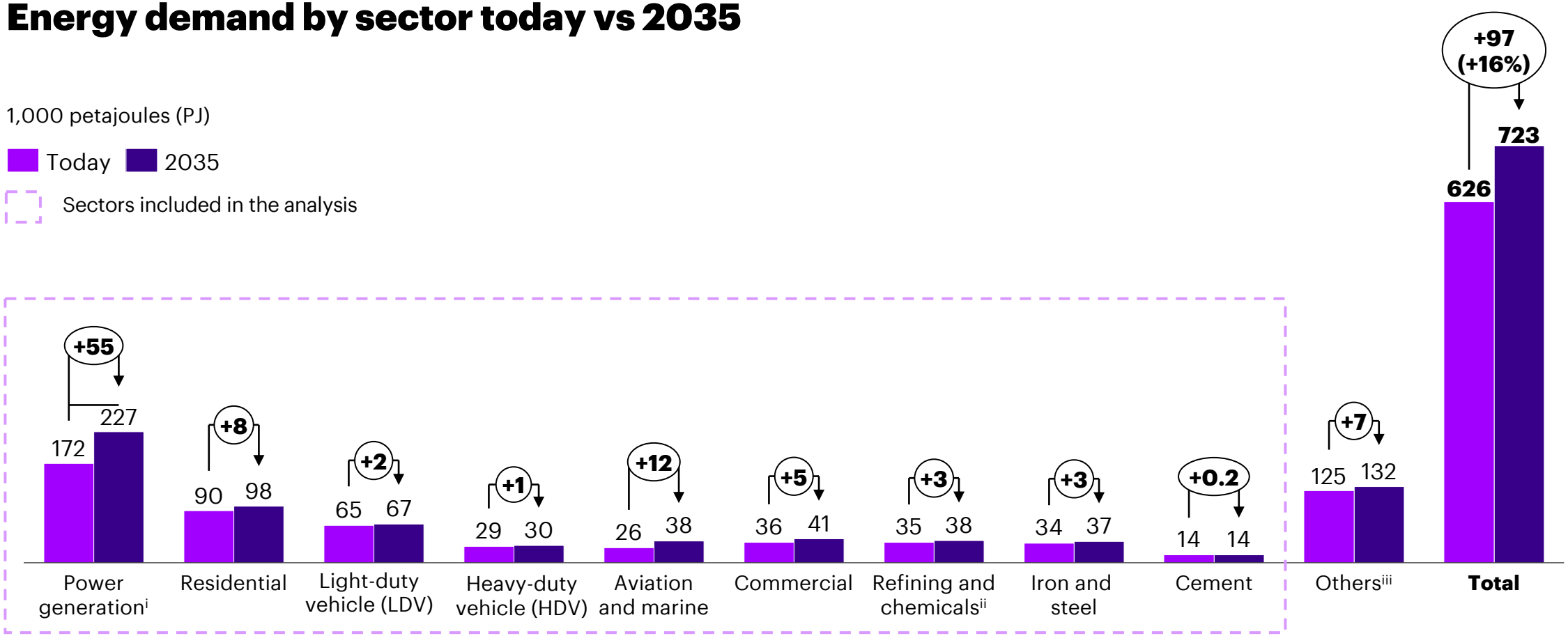
Global demand for energy is expected to grow by 16% by 2035 in our base scenario. Such incremental growth does not constitute a transformation in overall demand but rather an evolution. The mix of energy sources used to meet that demand is shifting.

Further, our analysis suggests that hydrocarbons will remain dominant in the global energy mix (67%). Oil and gas alone would still account for nearly half of the global energy consumption by 2035 in both of our scenarios. It's too large an energy source to replace as of now.

Yet, changes are happening within the hydrocarbon portfolio, itself. Notably, despite the hope around renewable energy and the ever-increasing efficiencies in heating, lighting and energy consumption, in general, natural gas demand is projected to grow by at least 14% to 149 exajoules (EJ), or ~4,300 billion cubic meters (bcm), in 2035. This shift to natural gas will be largely driven by the booming adoption of gas in power generation and heavy industries, primarily in Asia (both for new gas-powered plants and for converting plants from coal).

The energy system is evolving, not transforming.

Energy demand by sector today vs 2035



[i]Net primary energy demand of power generation after deducting output electricity/heat.
[ii]Including feedstock use of hydrogen for refining and ammonia production.
[iii]Others include pulp and paper, non-ferrous metals, agriculture, forestry, fishing, rail transport, mining, light industries and other non-energy use.

Source: Accenture analysis.

Three factors are driving today's transition

1. Urgency around climate action from all stakeholders, evidenced by consumer pressures, investor activism and governmental regulations, incentives and commitments (e.g., COP26 methane reduction pledges from 100+ countries, the commitment of $130 trillion of private capital toward a net zero economy and others).[4]
2. The increasing pace of technology advancements, particularly in renewable generation and energy storage.
3. The need for energy security in a transitioning energy system that allows developing economies to assume more local/regional control with the emergence of renewable fuels.

The confluence of these demand-driven factors is turning the traditional oil and gas paradigm on its head. The reality of a relatively homogeneous energy system, driven by hydrocarbons, is giving way to a multipolar energy system. In this new system, hydrocarbons will still play a significant role. But their dominance will be regionally—not globally—predetermined.

Our analysis shows that while the global demand for energy will likely continue to grow at slightly over 1% per year, it won't grow uniformly. Nigeria, Africa's largest economy, has a per capita energy consumption of just 0.8 million tons of oil equivalent (mtoe)/person.[5] China's consumption rate is 2.36 mtoe/person, while the United States' is 5.7 mtoe/person.

What change looks like

Different regions—and the sectors that operate within them—have different decarbonization targets and strategies. Different physical and process constraints. Different policy requirements. And different economic models.

As a result, sectors in each region will exhibit unique consumption profiles. They will also demonstrate varying patterns of "joule switching." A joule of energy previously delivered through hydrocarbon combustion can now be switched to a cleaner joule served by low-carbon options. For example, the cement sector in Asia is creating significant demand for biomass, which it now sees as an attractive option for reducing carbon and feedstock costs. Steel producers in Europe and the United States are switching from coal-fired processes to green electricity using scrap steel.

The result of this changing joule dynamic is a multi-fuel energy system that will see demand for oil, gas and biofuels fluctuate across regions and sectors.

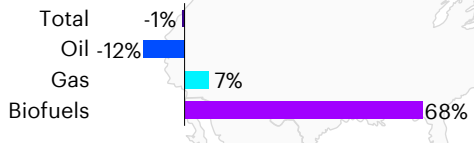
Environmental regulations are also forcing providers to rethink the joules of energy historically served by coal. In sectors and regions in which cleaner joules reach parity with hydrocarbon joules, this switching-based disruption will accelerate and impact the entire value chain—all the way up to the producing assets.

Accenture perspective: The changing joule dynamic is giving rise to a diverse, multi-fuel energy system

North America

Top growth clusters:
- Oil: Aviation, marine, feedstocks
- Gas: Power generation
- Biofuels: Road transport

Top decline clusters:
- Oil: Buildings, power generation
- Gas: Buildings



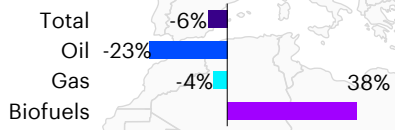
>50 $billion CCS market

>40 $billion industrial asset management (IAM) market

Europe

Top growth clusters:
- Oil: Aviation, marine, construction
- Gas: Power generation[i]
- Biofuels: HDV/aviation

Top decline clusters:
- Oil: Road transport, buildings
- Gas: Buildings, heavy industry



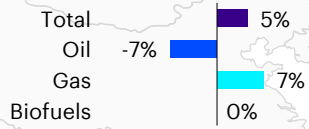
>30 $billion CCS market

>40 $billion IAM market

Russia/CIS

Top growth clusters:
- Oil: Feedstocks, aviation, mining
- Gas: Power, buildings, feedstock

Top decline clusters:
- Oil: Power generation
- Coal: Power generation, buildings

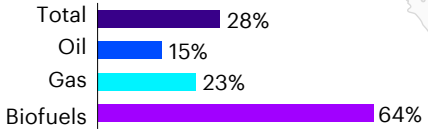


Minor Limited CCS and IAM markets

LatAm

Top growth clusters:
- Oil: Aviation, feedstocks, heavy industries
- Gas: Power, buildings, heavy industry
- Biofuels: Road transport

Top decline clusters:
- Oil: power generation
- Coal, power generation, heavy industry



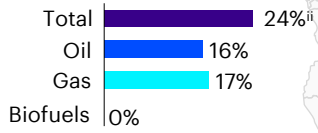
Minor Limited CCS market

<5 $billion IAM market

Middle East

Top growth clusters:
- Oil: Aviation, marine, construction
- Gas: Power generation[1]
- Biofuels: HDV/aviation

Top decline clusters:
- Oil: Power generation, residential buildings



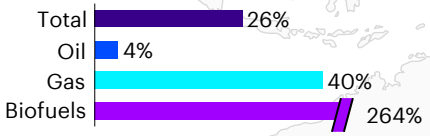
Minor Limited CCS market

<5 $billion IAM market

Asia

Top growth clusters:
- Oil: Aviation, feedstocks, marine, HDV
- Gas: Power generation, buildings, HDV
- Biofuels: road transport

Top decline clusters:
- Oil: LDV transport, power generation
- Coal: Buildings



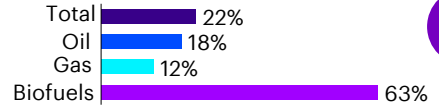
>20 $billion CCS market

>60 $billion IAM market

Africa

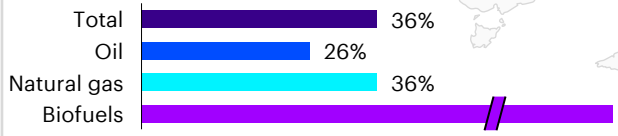
Top growth clusters:
- Oil: Road transport, cement, non-energy use
- Gas: Cement, feedstocks, buildings

Top decline clusters:
- Oil in power generation
- Coal in power generation



Minor Limited CCS and IAM markets

World bunkers (aviation + marine)



iUnabated natural gas in power generation in Europe: growth still expected to approximately 2030.
[ii]Additional average increase driven by electricity/renewables.

Source: Accenture analysis, base scenario.

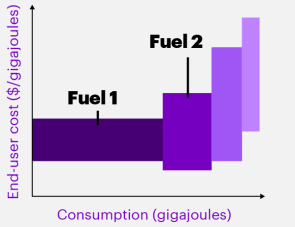
The future energy system will be heterogeneous.

Different **energy sources** will be tapped to meet energy demands of different **regions** and **business sectors**.

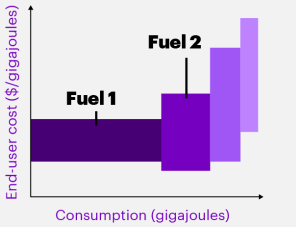
Different **policies** will inform the economic viability of actions oil and gas companies take in different parts of the world. And different **technologies** will unleash new opportunities for achieving energy equity, availability and sustainability goals.

Market-specific demand dynamics will drive the profitability of each asset class

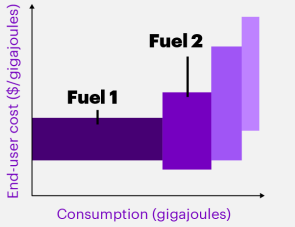
North American power market



European light transport market



Asian petro-chemical market

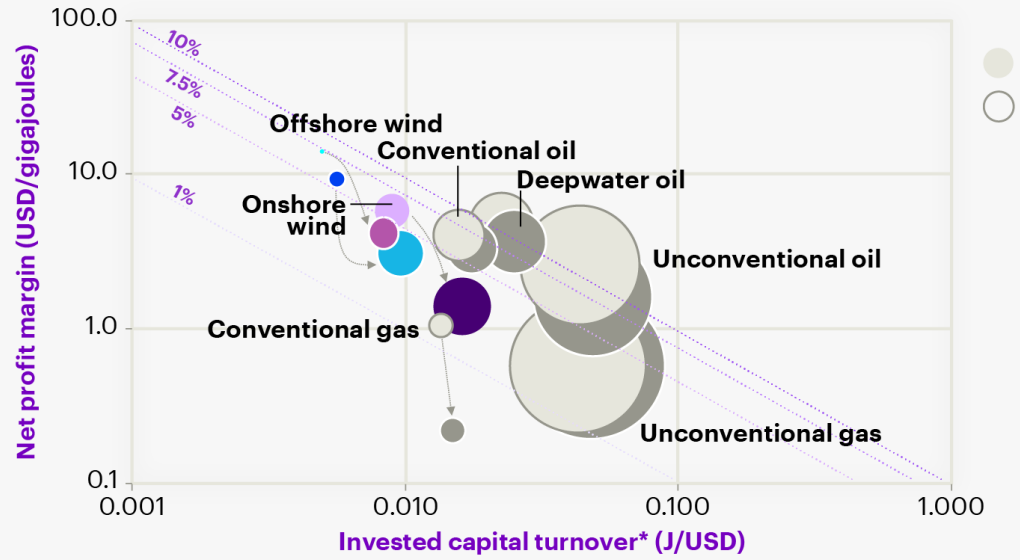


Translating demand dynamics into supply constraints

1. How will demand dynamics impact the price of each energy source?
2. What is the net margin that can be generated from each energy source?
3. What is the impact of carbon and environmental, social and governance (ESG) performance on each market and sector?
4. How are regulations likely to impact energy source swaps?

Illustrative and not exhaustive

What is the most profitable asset mix to respond to the dynamics in each market and sector?



*Invested capital turnover refers to joule delivered per unit of capital.
Assumptions: Carbon tax = $100/tCO$_2$e. Emissions efficiency = 20%.
Hydrocarbon cost efficiency = 15%. 2020 price = $50/barrel (bbl). 2040 price = $40/bbl.
Source: Accenture analysis and assumptions.

The future of oil and gas

To compete effectively, oil and gas companies across the value chain will need to effectively adjust their asset portfolios to the most economic plays, while also offering the supply sources that tomorrow's energy consumers seek. And they'll need to make those adjustments more dynamically than they have in the past.

With technologies, energy sources and demand pathways all evolving so quickly, they should significantly compress their planning cycles. And they need to zero-in on the most viable opportunities.

The industry has generally accepted that competing in the energy system of the future requires changing their back-office operations and even their corporate cultures. But oil and gas companies haven't paid the same attention to the transformation that will be needed in capital allocation and portfolio rebalancing.

It's easy to understand why: With so much "noise" and uncertainty around the energy transition, industry leaders struggle to identify, understand or even acknowledge the imminent risks their existing portfolios may expose them to.

We expect the total demand for oil and gas to grow nearly 3x slower than global energy demand (6.1% vs. 16% by 2035), with increased competition from alternative energy sources.

Using our Energy System Model, we analyzed the oil and gas impact of changing joule dynamics across the top nine consuming sectors through technology and policy lenses.

Lens 1: Technology advancement

Carbon capture

Industrial efficiency

Fuel switching

8 energy sources:

Oil	**Bioenergy**
Natural gas	**Coal**
Electricity[i]	**Hydro**
Wind and solar	**Nuclear**

8 regions:

Europe	**Russia/ Commonwealth of independent states (CIS)**
North America	**Middle East**
Latin America	**Asia/APAC[ii]**
Africa	**World Bunkers**

9 consuming sectors:

Transportation	**Light-duty road**	**Heavy-duty road**	**Aviation and marine[iii]**
Industry	**Cement**	**Iron and steel**	**Refining and petrochemicals[iv]**
Power generation and buildings	**Power generation**	**Residential buildings**	**Commercial buildings**
Others[v]			

Lens 2: Policies and regulations

Carbon policies

Efficiency standards

Government mechanisms (e.g., subsidies)

[i]Electricity in final consumption, generated with other energy sources, e.g. coal.
[ii]Analysis focuses mainly on Asia while figures also cover Oceania including Australia and New Zealand.
[iii]Aviation and marine covered in the biofuels chapter with focus on world bunkers.
[iv]Refining and chemicals include energy use in the sectors but exclude feedstocks.

[v]"Others" includes: Industrial sectors such as pulp and paper, glass, mining, non-ferrous metals (e.g., aluminum/copper); light manufacturing (e.g., textile, food, automotive/industrial); and other non-industrial sectors (e.g., construction, agriculture, forestry, fishing, petrochemical feedstocks) and other non-energy use (e.g., lubricants).

Source: Accenture analysis.

As part of our analysis, we also modeled two scenarios to help oil and gas companies think about where they may want to place their bets.

In the **base scenario**, we looked at the implications of a world with stable oil prices, increasing natural gas prices, and a moderate increase in carbon prices in Europe, North America and China. Combined with moderate adoption of fuel efficiency standards and electric vehicles, we're expecting the demand for oil to stagnate—while increasing strongly for natural gas.

In contrast, the **optimistic transition scenario** looks at the implications of a rapid increase in carbon prices and a more aggressive adoption of fuel efficiency standards, EVs and biofuels in major markets. In this scenario, we expect to see a rapid decline in oil demand and a slight increase in gas demand. We believe the economic conditions of the optimistic transition scenario will also boost the business case for the development of CCS solutions and clean hydrogen production.

Regardless of the future energy scenario that unfolds, oil and gas companies will need to reinvent how they design their portfolios and dynamically allocate capital.

Depending on how aggressive the transition unfolds, a set of key disruptive bets may emerge by 2035

Base scenario

Our base scenario assumes a relatively stable oil price above $70/bbl with a carbon price reaching $100/ton only in Europe and North America

Key Assumptions:

- Carbon price of **$100/ton** by 2035 in Europe and *North America* and $50/ton in China
- Oil prices to remain above **$70/bbl**

0%	+14%	>2 x	+6%
Oil	Gas	Biofuels	Total oil and gas demand
>$15B Clean hydrogen sales[i]	**>$120B** Clean hydrogen infrastructure[ii]	**~$85B** Other CCS[iii]	**>$220B** New opportunity (CCS/hydrogen)

Optimistic transition scenario

Our optimistic transition scenario assumes a more challenging price environment for oil, around $50/bbl and an aggressive hike in carbon price in North America, Europe and China

Key Assumptions:

- Carbon price of **$200/ton** by 2035 in Europe and North America and **$100/ton** in China
- Oil prices to decline to **$50/bbl**

-15%	+1%	>3 x	-8%
Oil	Gas	Biofuels	Total oil and gas demand
>$100B Clean hydrogen sales[i]	**>$510B** Clean hydrogen infrastructure[ii]	**~$170B** Other CCS[iii]	**>$780B** New opportunity (CCS/hydrogen)

[i]Sales of blue or green hydrogen at a maximum price of $2/kg.
[ii]Green hydrogen infrastructure; e.g., electrolyzers and CCS infrastructure for blue hydrogen production.
[iii]Excluding CCS infrastructure for blue hydrogen production

Source: Accenture analysis.

Five portfolio plays

The current energy transition is fueled to a large extent by the perception that oil and gas can be replaced by cleaner, greener alternatives. Activist investors and environmentalists are urging companies to take drastic action.

We agree that they should.

There are several opportunities for oil and gas companies to re-imagine who they are, what they do, where they operate and whom they serve in the next 15 years. Some involve refocusing on oil and gas, albeit in cleaner and more sustainable ways. Others involve heading into new frontiers—developing new capabilities and new business models that will meet energy demands, while also boosting their profitability and relevance in the new energy system, regardless of the energy scenario that unfolds.

We believe five portfolio plays hold particular potential.

Play 1
Natural gas

Innovate in sectors to build demand for gas as a fuel of the transition

Play 2
Oil

Drive toward the lowest-cost barrel of oil, which will be the winning barrel in either a $100/bbl world or a $30/bbl

Play 3
CCS

Scale the removal of carbon from the energy system with CCS and industrial efficiency technologies that underpin a flywheel business

Play 4
Blue hydrogen

Use scaled CCS solutions and low-cost gas to turn the blue hydrogen equation around and accelerate the decarbonization of industries

Play 5
Biofuels and low-carbon products

Win the race in low-carbon transportation with biofuels and low- carbon products such as bio/synthetic lubes

Play 1 - Natural gas

Innovate in sectors to build the demand for gas as a fuel of the transition.

Stop focusing on the immediate supply crunch. Start building demand in end-sectors and high-growth geographies.

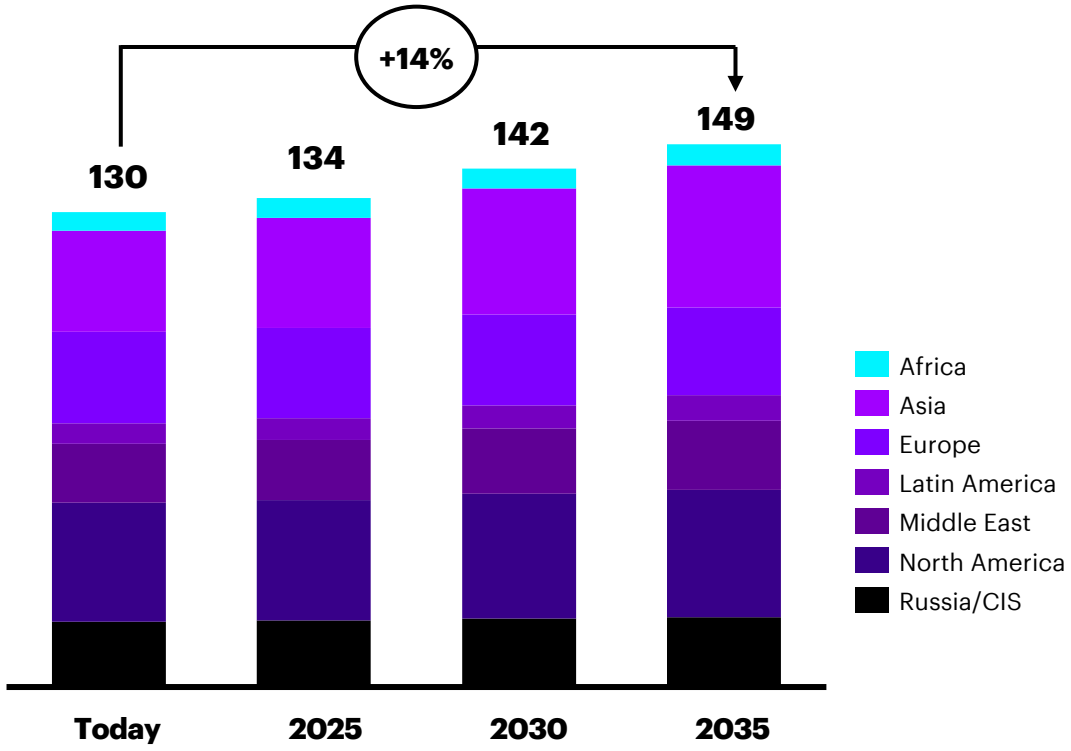
Natural gas is a transition fuel to the energy future. It also has the potential to be a fuel for this transition, especially in growth markets. Demand for gas is expected to grow at a 1% CAGR over the next 15 years, due largely to coal-to-gas conversions in industrial sectors and the increasing commissioning of new LNG/natural gas-powered plants. Asia will be the region with the greatest uptick in demand. The continent will drive 50% of demand growth in the near-term. The rest of the demand growth will come from other Growth Markets.

Over the short term, Russia's invasion of Ukraine is likely to drive a major shift in supply patterns (especially in Europe) as the power generation and residential/commercial heating sectors look to reduce their reliance on Russian gas.[6] In our optimistic transition scenario, Western European countries would switch away from gas to cleaner fuels, especially after 2030. The Ukraine crisis will likely accelerate that shift.

Power generation will be the sector making the biggest transition to gas. In fact, we estimate the sector will account for more than 70% of natural gas demand growth by 2035.

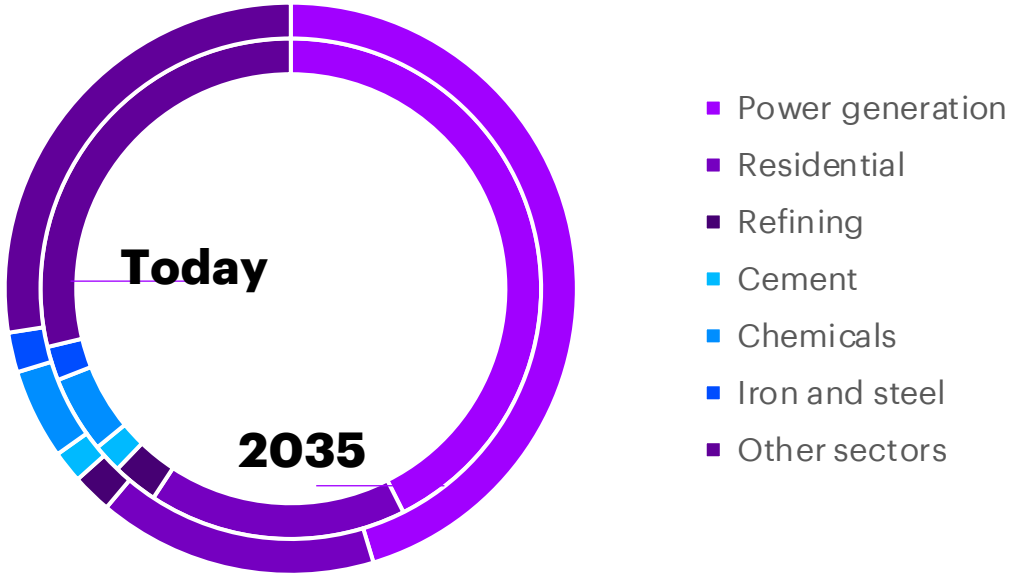
Global natural gas demand is expected to grow 1% compound annual growth rate (CAGR)

Exajoules (EJ) Today - 2035



Globally, growth will be mainly generated by power generation, which remains the dominant sector by volume, and by chemicals, iron, steel and cement

Today - 2035



Source: Accenture analysis.

Near-term outlook (2025)

Until 2025, operators should focus on meeting post-pandemic demand and strengthening their value chains to serve markets that are re-evaluating their dependence on Russian gas in the aftermath of the Ukraine war.

As the world recovers from COVID-19's disruption, demand for natural gas across all sectors is expected to return to pre-pandemic levels. In some sectors and geographies, it already has.[7] We believe a handful of region-sector clusters will be responsible for the most near-term growth by volume:

- North American power generation
- Asian power generation
- European power generation
- Asian residential and commercial buildings

Growth in demand will call for a corresponding growth in supply. With the price of crude oil projected to remain above $80/bbl until 2024 and natural gas remaining above $4/million British thermal units (MMBtu),[8] companies will have the cash flow they need to sustain drilling operations for new gas supplies. That's good news since natural gas exports—especially in the form of liquefied natural gas (LNG)—are expected to boom. More than 100 million metric tons of new terminal capacity is expected by 2025.[9]

Beyond building new LNG terminals and gas capacity, natural gas players—especially integrated ones—will need to alleviate peak pressures and integrate/digitize their value chains. This will enable them to better meet new demand from economies, notably in Europe, that are re-evaluating their reliance on Russian gas.

Near-term opportunities for oil and gas players (by 2025)

Integrated gas players

- Scale up value chain optimization programs with a focus on supplying affordable and profitable gas to meet European demand
- Aggressively invest in trading and market-making capabilities

Integrated infrastructure operators

- Strengthen market-making capabilities to capitalize on short-term supply imbalances
- Plan or scale infrastructure investments in targeted geography/sector clusters

Independent gas producers

- Focus on operational excellence to keep costs down and meet investor expectations for returns
- Enter partnerships with market-makers to balance long-term offtake with the ability to access spot market pricing

Mid-term outlook (2035)

From 2025 to 2035, operators should bolster the role of natural gas as a fuel for the transition. How? By enabling the creation of new demand in underserved and under-developed markets, especially in Asia.

We expect demand for natural gas to grow by ~19 EJ or 504 bcm by 2035, generating net market growth of $70 to $100 billion. However, global supplies are already growing. With the planned added global capacity, supply will outstrip demand by the second half of this decade.[10]

Because of this, natural gas players will need to help create new demand in key sectors, mainly in under-served or under-developed markets. The good news is that the potential for new gas demand is there. But it's hindered by two key factors. The first is the lack of last-mile infrastructure in developing countries. The second is the difficulty sectors will face when upgrading or reconfiguring their processes and equipment for natural gas.

In our analysis, the industry-geography clusters with the highest potential and readiness for growth are:

- **Power generation**
  This sector will drive over 70% of total growth and increase its share of the natural gas market from 43% today to 45% in 2035. That growth in consumption will be due to several factors: the accelerating switch from coal to gas, mainly in Asia; the ability to combine gas with renewable plants to achieve generation consistency and offset peak load capacity; and natural gas having reached economic parity with coal and oil in China and other Growth Markets. Together, these factors will push most new investments to direct natural gas/LNG.

- **Industrial sectors**
  Cement, refining and petrochemicals in Asia and other Growth Markets will increasingly look to gas to meet their high heat requirements, which are hard to satisfy with electricity. These sectors are expected to create $15 to $20 billion of additional demand by 2035. Industrial decarbonization programs in China, Japan and South Korea will certainly help drive the transition from coal-fired to gas-fired processes.[11]

- **Residential and commercial buildings**
  These sectors—especially in Asia and the Middle East—will increase their natural gas demand by approximately 4 EJ or 106 bcm (representing net market growth of $16 to $23 billion). This will be due largely to the conversion from coal, biomass or oil to gas for heating.

Creating new demand in growth markets presents prime opportunities for oil and gas players.

Mid-term opportunities for oil and gas players (by 2035)

Integrated gas players

Secure demand in Asia and other Growth Markets by creating local gas markets, investing in last-mile transmission and gas-based power generation, and incentivizing the industrial sector to shift to gas.

Integrated infrastructure operators

Continue sweating existing assets in high-margin regions. In the long run, these assets may need to be repurposed to capture new growth areas (e.g., hydrogen or others).

Independent gas producers

Invest in emerging technologies, such as small-scale LNG, to shift gas to Asia or other imbalanced markets.

Natural gas: Recommendations

Go all in

Provide energy transition support in Asia: Build the required infrastructure to fuel the transition and secure customers in multiple industrial sectors, including power generation, refining, chemicals, cement and others.

Capture new demand globally: Support the transition of sectors—especially power generation—from coal to natural gas globally, and proactively address new uses of gas in transportation and residential cooking/heating.

Proceed with caution

European supply diversification: Enhance the end-to-end value chain with a focus on getting affordable and profitable gas to Europe to support the transition away from Russian gas.

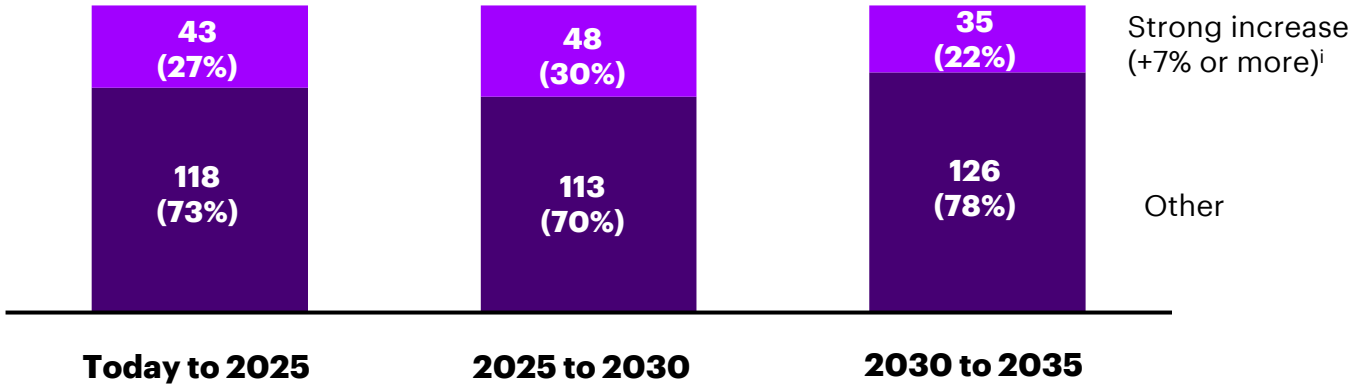
The refining sector: While interim demand increases will be driven by capacity additions in Growth Markets, energy consumption will decline over the longer term, as will demand for oil and plastics.

Wait and watch

Residential and commercial building sectors: Building conversions to gas will likely be driven by an increase in city gas networks in Asia. However, energy efficiency technologies and razor-thin sector margins will ultimately lead to an overall decline in demand globally.

The rise and fall of "customer clusters" in natural gas

As part of our analysis, we looked at the natural gas demand outlook among 160 oil and gas customer clusters (one cluster represents one sector in one region, such as the cement sector in Europe). We found that in the 2025-2030 period, 30% of the customer clusters will drive strong growth for natural gas. After 2030, only 22% will.



Note: Base scenario. One cluster representing one sector within one region; e.g., cement in Europe for a total of approximately 160 clusters.

[i]Total percentage increase in demand over a five-year period.

Source: Accenture analysis.

The clusters expected to exhibit long-term sustainable demand for natural gas include:

- Power generation in Asia
- Cement production and construction sectors in Africa
- Petrochemical feedstocks in all regions
- Mining and commercial building sectors in Latin America
- Iron and steel and power generation in the Middle East

Play 2 - Oil

Drive toward the lowest-cost barrel of oil, which is the winning barrel in either a $100/bbl world or a $30/bbl world.

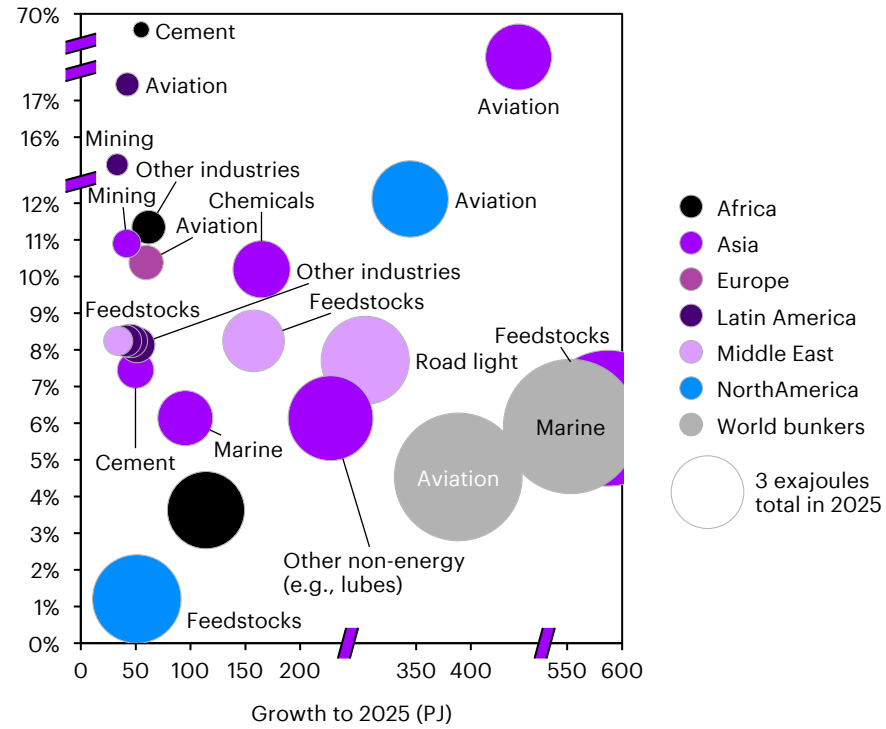
Stop focusing on the oil super cycle. Start focusing on oil for all cycles by building the lowest-cost and lowest-carbon oil supply.

As the world recovers from the pandemic, oil demand has returned. In fact, West Texas Intermediate (WTI) crude prices broke $90/bbl before Russia's invasion of Ukraine and hit $110/bbl after the crisis.[12] That's up from negative prices during the height of the pandemic.[13] Similar to the natural gas findings in the previous section, our modeled price regime reflects this supply shock.

Contrary to some expectations, we do not expect major short-term shifts in consumer demand in key sectors such as transportation. In fact, liquid fuels play an outsized role in the supply of energy for transport, meeting >90% of demand. The global recovery in oil demand (to pre-pandemic levels) is occurring across all sectors. But two region-sector clusters will drive the immediate growth in oil demand by volume:

- Petrochemical feedstocks in Asia
- Heavy transportation globally (and HDV and aviation, specifically)

Growth to 2025 (%)



Source: Accenture analysis.

What does the future hold?

While the current upswing in oil production may last for two or three years, the cycle will inevitably reverse course. A quarter to a third of oil and gas resources at current break-evens may be at risk of being stranded by 2035.

Therefore, oil and gas companies should not consider today's healthy financial situation as an excuse for returning to previous spending habits. It is critical they continue driving to the lowest-cost and lowest-carbon barrel and prioritizing value over volume. By doing so, they can restore investor confidence in profitable and cleaner oil—across all cycles.

Some of the highest-performing upstream independents are heeding this advice. They are already communicating to investors their commitment to low-cost, conservative production growth rates and high shareholder returns. For example, the CEO of Devon (the highest performer in the S&P 500 in 2021) stated: "I want to be clear that there is no change to our cash-return playbook. $100 oil, $150 oil, we're not going to change our growth rate."[14]

Mid-term outlook

While we expect the demand for oil to increase until the late 2020s, it will decline after 2030 and plateau at 2021 levels in 2035. However, oil will lose a significant share in the energy system (approximately 3.5 percentage points in our base scenario, and 9 percentage points in our optimistic transition scenario).

That decline will be driven primarily by the ongoing shift to more efficient engines, EVs and biofuels in road transport. Our analyses suggest that Europe and North America will decrease their gasoline and diesel demand by more than 20% by 2035. Asia and Russia will follow, with a roughly 1% demand decline by the end of the decade.

Overall, we believe the road transport sector will reduce its oil demand by 5.7 EJ or 2.55 mmboe/d by 2035—a drop that will also affect regional refinery fuel oil demand.

The power generation sector will also contribute to oil's downfall. Its use will continue to be phased out in favor of gas and renewables, plummeting 30% (2.5 EJ or 1.12 mmboe/d) by 2035.

Global oil demand will be under high pressure as more alternative, lower-carbon energy sources become available at competitive costs.

A demand drop of 3 EJ or 1.3 mmboe/day would put $45 - $50 billion of value at risk for oil companies...

But it's not all bad news for oil. Our model predicts demand will continue to grow in sectors that require high energy intensity and where alternatives are limited.

For example, demand for jet fuel and heavy oil in the marine and aviation sectors will grow by 35% (9.3 EJ or 4.16 mmboe/d) by 2035. That growth will be driven largely by post-pandemic supply chain recoveries and overall sector growth. Industrial sectors such as mining and cement are also expected to increase oil demand, albeit slightly (0.4 EJ or 0.17 mmboe/d), since companies in this sector will find it economically daunting to shift in the short term.

Additionally, demand for road transport gasoline and diesel will continue to grow in Latin America, the Middle East and Asia as economic growth in these regions' offsets fuel efficiency and biofuel uptake. The chemicals sector's reliance on oil as petrochemical feedstock is also expected to grow.

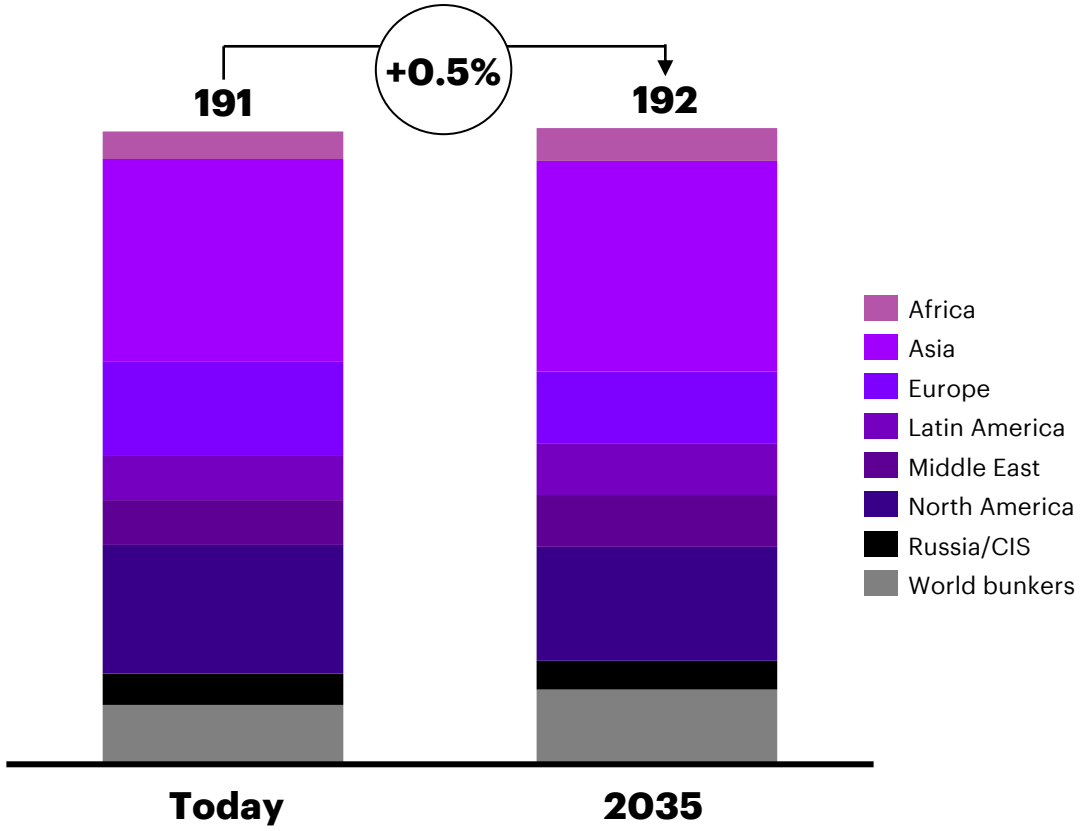
While oil demand will plateau by 2035, the world must develop additional capacity of 14 to 18 billion barrels to replace production from depleted assets.

... but certain sectors will demand 14 to 18 billion barrels of "new oil" by 2035 to replace production from depleted assets.

5 EJ or 2.2 mmboe/day of new oil will be needed. This translates into $75 - $80 billion in new market opportunities waiting to be claimed.

While global oil demand stagnates....

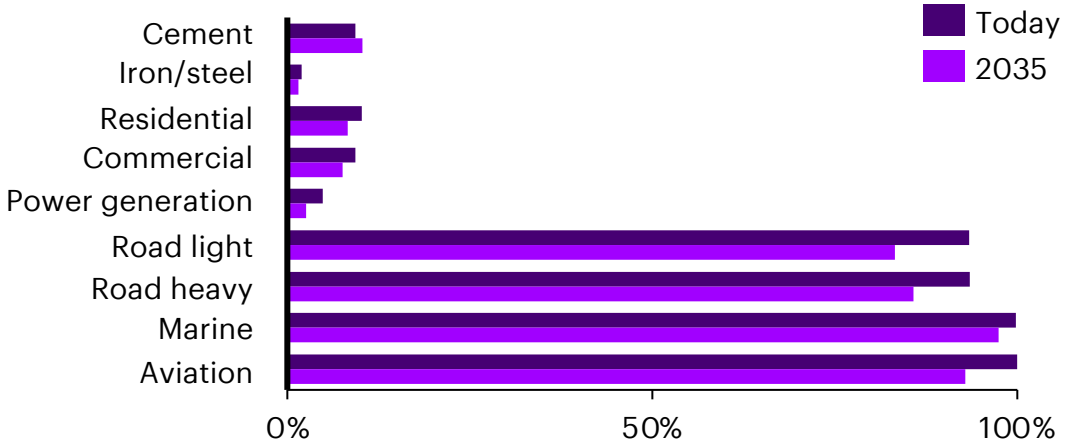
Exajoules (Today – 2035)



Note: Global primary demand of oil in the base scenario, per-unit conversion by oil product.

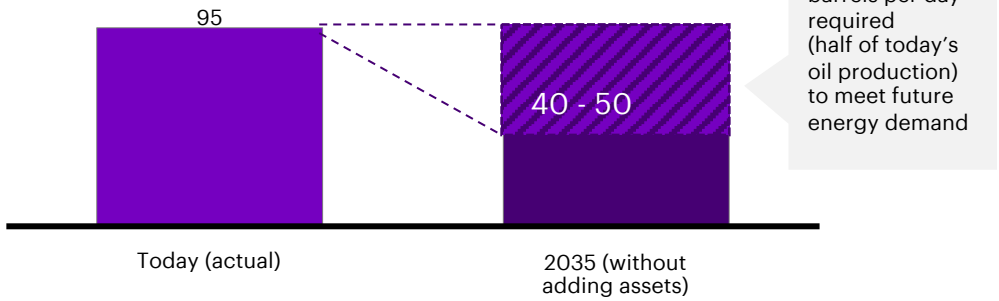
...oil retains its role in end-sectors....

% of oil in energy demand (Today - 2035)



...requiring incremental new production

Million barrels/day



Source: Accenture analysis.

Key opportunities for oil and gas players

Volatility brings uncertainty and risk. But it also presents opportunities for those companies that have a strong foundation and the ability to operate, if not thrive, in all cycles. In good times. And in bad.

We have identified near-term (by 2025) and medium-term (by 2035) opportunities for different energy system players.

Near-term opportunities for oil and gas players (by 2025)

Integrated oil companies (IOCs)

- Focus on operational and capital efficiency
- Contribute to the creation of energy security and availability in the geographies you serve
- Return cash to shareholders and/or strengthen balance sheets

Independent upstream operators

- Focus on operational and capital efficiency
- Contribute to the creation of energy security and availability in the geographies you serve
- Return cash to shareholders and/or strengthen balance sheets

Independent downstream operators

- Focus on operational efficiency and refining flexibility in anticipation of shifts in transportation demand
- Secure feedstock to assure refinery utilization and protect refining margins

Near-term opportunities for oil and gas players (by 2025)

Integrated oil companies (IOCs)

- Focus on operational and capital efficiency
- Contribute to the creation of energy security and availability in the geographies you serve
- Return cash to shareholders and/or strengthen balance sheets

Independent upstream operators

- Industrialize cost-efficient CCS in upstream operations, prioritizing locations and most suitable terrains for CO2 storage

Independent downstream operators

- Customize traditional product supply to meet the needs of local sectoral demand centers
- Lead the augmented market for low-carbon oil products (e.g., CCS-based gasoline production)

Oil: Recommendations

Go all in

Cost efficiency and carbon reduction: Continue investing in reducing break-even costs and the carbon footprint, regardless of the price of oil.

Petrochemical feedstock: The demand for oil-based products such as feedstock for petrochemicals will continue to grow rapidly.

Road fuels in emerging markets: Demand for road fuels, especially in the heavy-duty transport and mining sectors, is likely to grow along with the economies and populations of emerging markets, offsetting the impact of fuel-efficiency policies.

Proceed with caution

Marine and aviation sectors: We believe these sectors will be reliant on oil products over the medium term. However, demand could vary as key fuel-switching technologies are developed and proliferate.

Residential heating: Oil companies should be cautious about meeting the heating needs of the residential sector since other energy sources such as natural gas and electrification can be quickly activated.

Wait and watch

Power generation sector: The use of oil will continue to be phased out in power generation, replaced by gas and renewables. This will lead to a sharp decline in oil consumption in the sector. However, the rate of change could differ based on geography, regional policies, and the economics of switching.

Oil and product trading: Incremental trading value can be gained by capturing arbitrage opportunities across various commodities. Access to risk capital and assets (hard or soft via tolling) is key to capture trade flows as they change, as is the ability to make real- time decisions based on market intelligence and digital capabilities.

Play 3 - CCS

Scale the removal of carbon from the energy system with CCS and industrial efficiency technologies that can underpin a flywheel business.

Stop viewing CCS as a negative emissions support technology. Start seeing carbon management and industrial efficiency technology as a $250+ billion business.

Other than a handful of visionaries and pioneers, most energy leaders see CCS and other decarbonization solutions as supporting—even necessary—technologies to curb emissions in oil and gas processes.

But the energy transition and sectors' unique decarbonization objectives are expected to change that perception. We are already seeing the emergence of a large technology solutions market that generates financial rewards for companies that can develop or implement greener and more sustainable products. It's a market that is ripe for oil and gas companies to capture.

However, just as fuel selections will be based on local dynamics, the technology market will also look vastly different by region. While the demand for efficiency and fuel-switching solutions is rather universal across sectors, incentivizing regulations for carbon capture solutions will depend on a given region's regulatory environment and transition pace.

Our base scenario estimates that the confluence of sector demand and regulation will create a carbon management and industrial efficiency technology market worth well over $250 billion by 2035.

The rise of decarbonization solutions

Three types of technologies underpin the energy market's transformation:

- Carbon capture solutions
- Industrial efficiency solutions
- Fuel-switching solutions

In each category, several sector-specific solutions are currently under development. Some, such as process and energy efficiency technologies, have already reached maturity in heavy industrial operations. Others, such as technologies that enable providers to switch to clean hydrogen-based fuels, will require a decade or more before they are economically attractive. And others, such as CCS, will deliver economic potential in the next few years.

In all categories, oil and gas companies are uniquely positioned to lead. Their deep understanding of the carbon lifecycle, unique capabilities in managing depleted reservoirs and expertise in energy efficiency give them a significant competitive edge.

Knowing when different decarbonization solutions will reach maturity in a sector or region is critical for oil and gas companies looking for first-mover advantage or even "fast-follower" status.

As part of our analysis, we looked at nine emerging technologies to project when they might offer viable economic returns across 12 sectors, nine of which are "heavy B2B," including heavy industries, power generation, HDV transport, rail, marine and aviation.

Our analysis—which assessed the "green premium" associated with a fuel/technology switch and included energy costs, carbon pricing, and capital and operating expenditures—revealed that of 80 sector-specific decarbonization solutions, 55% will be attractive by 2025. In 2030, that number climbs to 64%.

By 2035, we expect carbon-management and industrial-efficiency technologies to be a $250+ billion market ripe for the taking by oil and gas companies.

Breakeven year for B2B decarbonization solution deployment in first deployed region

Energy consuming sector	Carbon capture		Industrial efficiency			Other fuel switching		
	CCS[1]	Direct air capture	Industrial asset mgmt	Solar thermal preheating	Electrifi-cation of industrial processes	Switch to bioenergy / renew-ables[2]	Switch to natural gas (from coal/oil)	Switch to clean H_2 based fuel[3]
Heavy-duty road	--	--	--	--	--	2020	2020	2030
Rail	--	--	--	--	--	2020	2020	2030
Power generation	2025	after 2030	2020	--	--	2020	2020	after 2030
Cement	2030	after 2030	2020	2025	--	2025	2030	after 2030
Iron and steel	2025	after 2030	2020	2025	2025	2030	2025	after 2030
Refining	2025	after 2030	2020	2025	after 2030	after 2030	2020	2030
Chemicals	2025	after 2030	2020	2025	after 2030	after 2030	2020	2030
Marine	--	after 2030	--	--	--	2030	2025	after 2030
Aviation	--	after 2030	--	--	--	2030	after 2030	after 2030

[1]Considering also available government support/subsidies in cement, iron and steel, refining, chemicals; gas processing as a special case within refining demonstrating a break-even already today.

[2]Mainly renewable diesel for HDV, rail and marine (second generation waste-fat based biodiesel), sustainable aviation fuel for aviation, biomass in heavy industries, biomass or wind/solar for power generation. Excludes switch to green electricity consumption.

[3]The lowest-cost combustion option between blue or green hydrogen. Marine includes clean ammonia. Aviation includes electrofuels (e-fuels)/synthetic jet fuel based on clean methanol from clean hydrogen.

Key technology markets for oil and gas (excludes fuels)

Source: Accenture analysis.

CCS

The most attractive decarbonization play for oil and gas companies to consider is CCS (and the associated hydrogen production technologies). CCS is also the most under-developed set of technology solutions relative to its necessity for a net-zero world. Our analysis estimates that reaching a net-zero world by 2050 will require between 3,000 and 10,000 million tons of CCS capacity per year. That's up to 200 times the current capacity.[15] By 2035, that number will be up to 90 times the current capacity.

CCS solutions are expected to achieve economic viability in the next several years for four sectors:

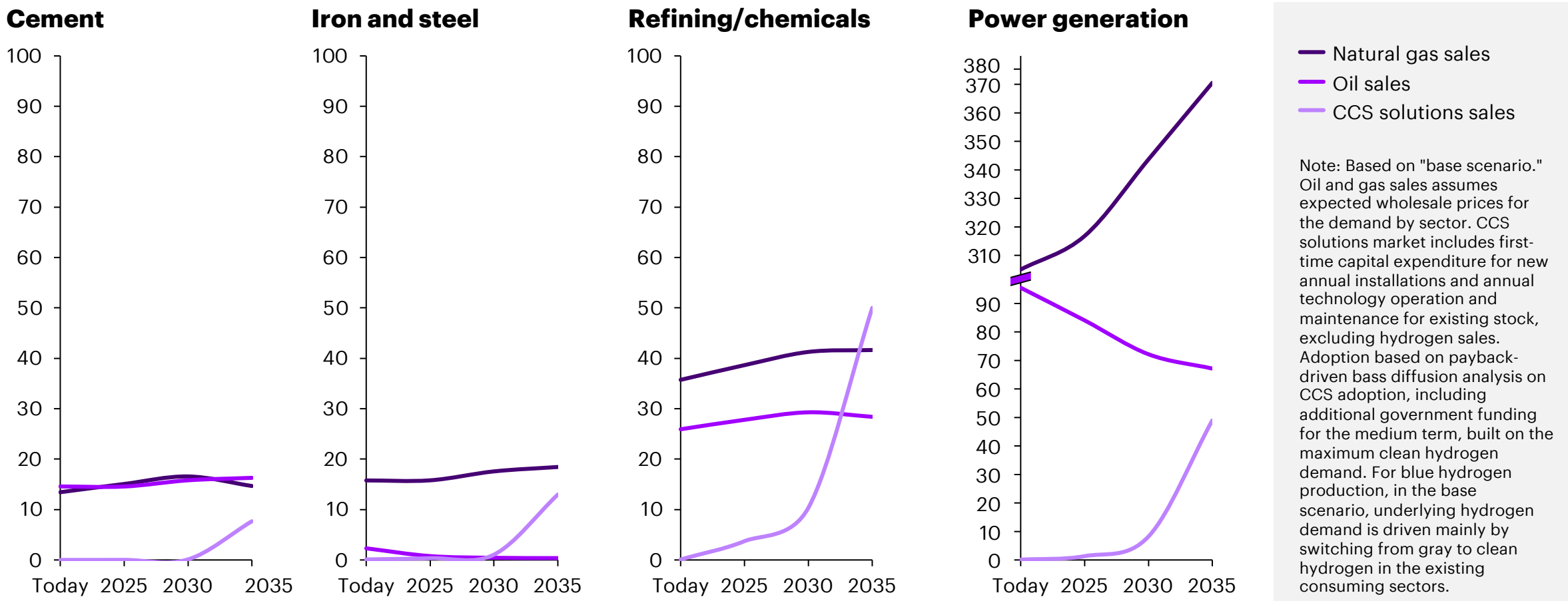
- Cement
- Iron and steel
- Refining and chemicals
- Power generation

Power generation is likely to be the dominant CCS market, despite uncertainty about the gas+CCS role in Europe, North America and Asia (depending on the pace of switching from coal to gas) and uncertainty about the coal+CCS role in China (due to the country's limited carbon taxes).

Coal+CCS in cement is also a potentially lucrative play, given the sector's high-temperature, high-emissions processes.

There, high emissions in production processes (including non-energy emissions associated with heating raw materials) cannot be abated by reducing energy consumption.

Annual revenue potential in selected industrial markets ($billion)



Note: Based on "base scenario." Oil and gas sales assumes expected wholesale prices for the demand by sector. CCS solutions market includes first-time capital expenditure for new annual installations and annual technology operation and maintenance for existing stock, excluding hydrogen sales. Adoption based on payback-driven bass diffusion analysis on CCS adoption, including additional government funding for the medium term, built on the maximum clean hydrogen demand. For blue hydrogen production, in the base scenario, underlying hydrogen demand is driven mainly by switching from gray to clean hydrogen in the existing consuming sectors.

Source: Accenture analysis.

Our analyses of CCS uptake in both the base and optimistic transition scenarios show the revenue potential is significant.

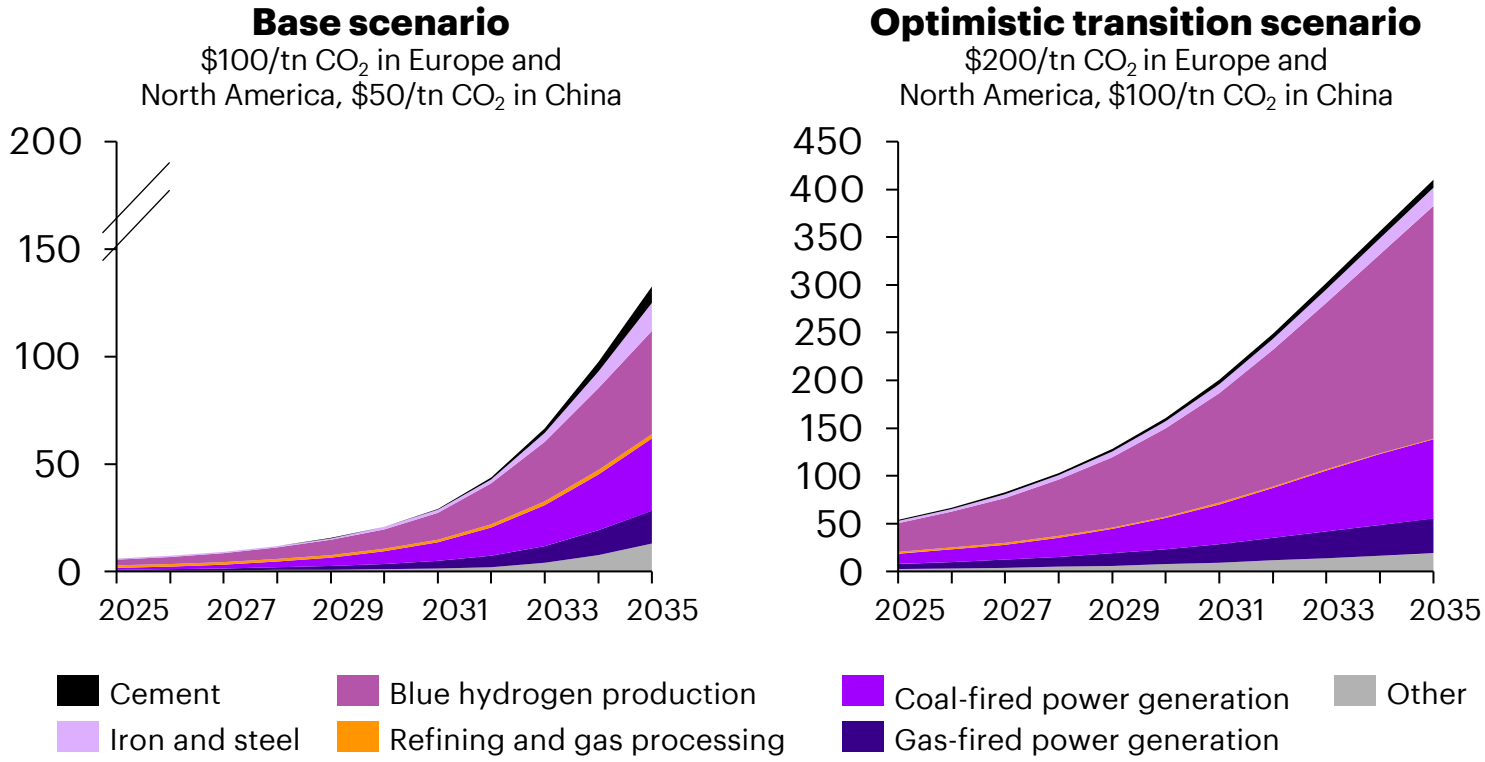
In the base scenario—which presumes a carbon price of $100/ton of carbon equivalent in Europe and North America and $50/ton of carbon equivalent in China—sector spending on CCS technologies in the four target sectors is expected to be almost as much as spending on oil and gas.

In the optimistic transition scenario—which presumes a carbon price of $200/ton of carbon equivalent in Europe and North America and $100/ton of carbon equivalent in China—our analyses suggest that CCS solutions will drive revenue sooner and to a much higher degree over the next 15 years. Even in our optimistic transition scenario, there would still be the potential for the CCS market to grow to the levels required for a net-zero world by 2050.

Revenues from CCS solutions are poised to match or exceed oil and gas revenues in several industrial sectors by 2035.

CCS and hydrogen production solutions annual global market potential by sector to 2035

($billion revenue/year)[i]



[i]Infrastructure/solutions includes first-time capital expenditure for new annual installations and annual technology operation and maintenance for existing stock, excluding hydrogen sales. Adoption based on payback-driven bass diffusion analysis on CCS adoption including additional government funding for the medium term, built on the maximum clean hydrogen demand. For blue hydrogen production, in the base scenario underlying hydrogen demand is driven mainly by switching from gray to clean hydrogen in the existing consuming sectors, and in the optimistic transition scenario new hydrogen demand emerges through switching from natural gas or oil to clean hydrogen in new consuming sectors.

CCS applications

Other opportunities worth exploring include CCS+gas in manufacturing and hydrogen production.

In the former, a business case is already emerging. But CCS+gas solutions may be displaced by the sector's switch from gas to clean hydrogen or electrification. There is also synergy potential if hydrogen production occurs adjacent to CCS-enabled production in high-emitting industries.

A discussion of the CCS potential for various sectors would be incomplete without a review of regional uptake of these technologies. Over the long term, China will dominate this space, with a large CCS and hydrogen production infrastructure. In the interim, however, multiple sectors in Europe and North America will achieve a CCS tipping point. Early investments (and short-term dominance) will position early leaders competitively for the post-2030 period.

Year by which CCS and hydrogen production is estimated to break even, by application and region (base scenario)

	Europe	North America	China	Middle East	Other regions
Carbon price by 2035 ($/tn CO_2)	$100	$100	$50	$30	<$30
CCS power generation (coal)	2025	2025	2030	after 2035	after 2035
CCS power generation (gas)	2025	2025	2030	after 2035	after 2035
CCS cement	2030	2030	after 2035	after 2035	after 2035
CCS iron and steel	2025	2025	2030	after 2035	after 2035
CCS gas processing	2020	2020	2030	2035	after 2035
Blue hydrogen production	2025	2025	2030	after 2035	after 2035
Green hydrogen production	2025/ 2030[i]	2025/ 2030[ii]	2025	2030	after 2035

[i]2025 assumes policy support. [ii]2030 assumes no policy support.

Source: Accenture analysis.

Industrial efficiency and fuel-switching solutions

Beyond CCS, industrial efficiency and fuel-switching solutions (especially electrification and pre-heating) represent early, potentially attractive markets that oil and gas companies can serve and monetize.

Industrial efficiency solutions are already enabling gradual process efficiency and energy efficiency improvements in the cement, iron and steel, refining and petrochemical sectors. While some solutions are already mature and cost efficient, large white spaces still exist in the industrial software and hardware market. For example, Accenture estimates that the asset management market may be worth $150+ billion by 2025.

Oil and gas companies can capitalize on their century-long experience of managing large, remote and complex assets to develop innovative industrial efficiency solutions (especially high- margin software plays) and extend these solutions to other industrial sectors.

Fuel-switching solutions are also gaining traction, but they will take a bit longer to achieve maturity.

Solar thermal pre-heating technologies—such as concentrating solar power (CSP) solutions—can be installed directly in a plant. They can replace a portion of the heat generated by fossil fuels, thus reducing carbon emissions and energy consumption and cost. Importantly, pre-heating solutions in general can command an additional "green premium" by utilizing green electricity from the grid or through a power purchase agreement directly from independent producers.

The **electrification of industrial processes** replaces molecules with electrons to meet the energy needs of specific processes, such as the combustion process in internal combustion engines.

Within the iron and steel sector, some processes can be electrified and are expected to achieve an economic break-even cost by 2025. Electric arc furnaces in the steelmaking process are an example. In the chemicals and refining sectors, the technologies required to electrify processes are still expensive and, therefore, do not justify investment at this time. In the cement sector, underlying processes either are already electrified or require high temperatures not achievable with electricity.

	Industrial efficiency	Solar thermal preheating	Electrification of industrial processes
Cement	2020	2025	Limited additional electrification
Iron and steel	2020	2025	2025
Refining	2020	2025	after 2030
Chemicals	2020	2025	after 2030

Source: Accenture analysis.

The high cost of low carbon?

It is commonly assumed that a decarbonized energy supply chain will translate into higher costs (or a "green premium") for customers. That's not necessarily the case in B2B, nor in B2C, scenarios.

The upfront investment and higher operating costs of decarbonization solutions will initially result in higher production costs in heavy industries. Moving to electrified processes in steelmaking or CCS in cement isn't cheap. Yet, the impact of such costly actions on the end customer product is less pronounced.

Residential building construction provides an example. In other sectors, too, customers' willingness to pay minor premiums for low-carbon products can mitigate the increased costs, accelerate industrial adoption and bring down the decarbonization costs even faster.

Greenhouse growth

In response to homeowner demands and investor pressures, many residential building developers are looking to decarbonize their supply chains to create cleaner, greener homes. Yet, they may be hesitant because they believe decarbonization efforts will be too costly and ultimately require them to raise the price of their homes. Our analysis has found this is not the case.

Specifically, we looked at the projected costs (and environmental benefits) of building a decarbonized home in the United States in 2025. Decarbonization efforts will raise costs in four important supply areas: aluminum, steel, cement/concrete and material transport.

But those "green premiums" aren't as high as homebuilders think. And the environmental value, in terms of carbon reductions, may be much higher.

We concluded that decarbonizing the building supply chain for four construction elements would only translate into a 1% to 3% increase in the final cost of the home—a premium customers may be willing to pay for in exchange for knowing they live in a home built to higher environmental standards.

By transitioning fuel sources to cleaner alternatives, oil and gas companies can play a valuable role in helping builders achieve their sustainability goals—and capture their sustainability premiums.

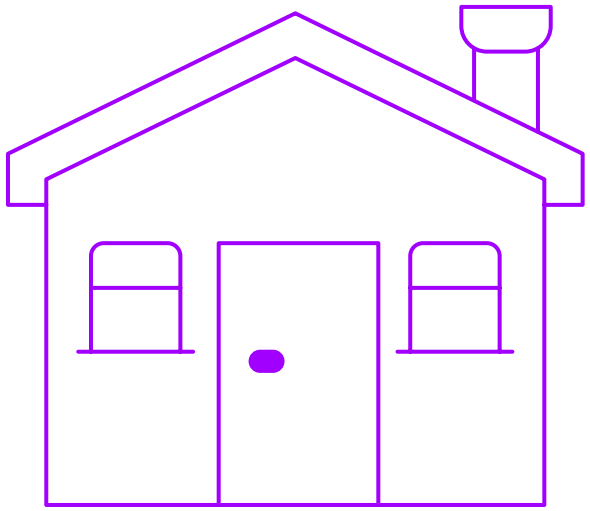
Decarbonized 2025 US home, building cost impact by selected levers

B2B / producer price premium (%)	Tons of carbon reduced (%)
Aluminum: + 0% to 40% via switch to fully green electricity in production	**+ 10% to 20%**
Steel: + 5% to 30% via switch to electric arc furnace using recycled steel	**+ 75% to 85%**
Cement / concrete: + 1% to 70% via replacing coal with biomass/waste or applying CCS	**40% to 95%**
Material transport: + 0% to 5% By replacing road diesel with biodiesel	**Up to 100%**

B2C house buyer total price premium (%)[i]

+ 1% to 3% only

Customers may soon be ready to absorb the remaining additional costs of decarbonization



[i]Total price increase in proportion to the selected material cost increases within the total building costs including other materials, labor and overheads. Assumes a carbon tax of $30 to $50 in the US by 2025 and continued policy support for renewable diesel in road transport.

Decarbonization solutions: Recommendations

Go all in

Invest now to build carbon and energy management solutions, mainly in:

- CCS in power generation
- CCS+coal in steel
- CCS+coal in cement
- Industrial efficiency solutions
- Solar thermal preheating for selective solutions adjacent to the oil and gas core

Proceed with caution

Explore building capabilities in:

- CCS+gas in manufacturing
- Process electrification in steel

Wait and watch

Hold back at this point on investing in:

- Grid power pre-heating
- Process electrification in chemicals and refining
- Negative emissions solutions, such as bioenergy CCS and direct air capture

Play 4 - Blue hydrogen

Use scaled CCS solutions and low-cost gas to turn the blue hydrogen equation around and accelerate the decarbonization of industries.

Stop looking at different shades of hydrogen as having equal potential. Start viewing blue hydrogen as the veritable force in the energy mix.

Today's demand for hydrogen (10 to 15 EJ, or 4.5 to 6.7 mmboe/d) as an alternative to oil or natural gas is driven primarily by traditional uses of hydrogen in refining and ammonia production. Supplying clean hydrogen is poised to become a big business.

How big? That depends.

In our optimistic transition scenario analysis, the clean hydrogen market could exceed $600 billion by 2035. In the base scenario analysis, it would grow to more than $100 billion.

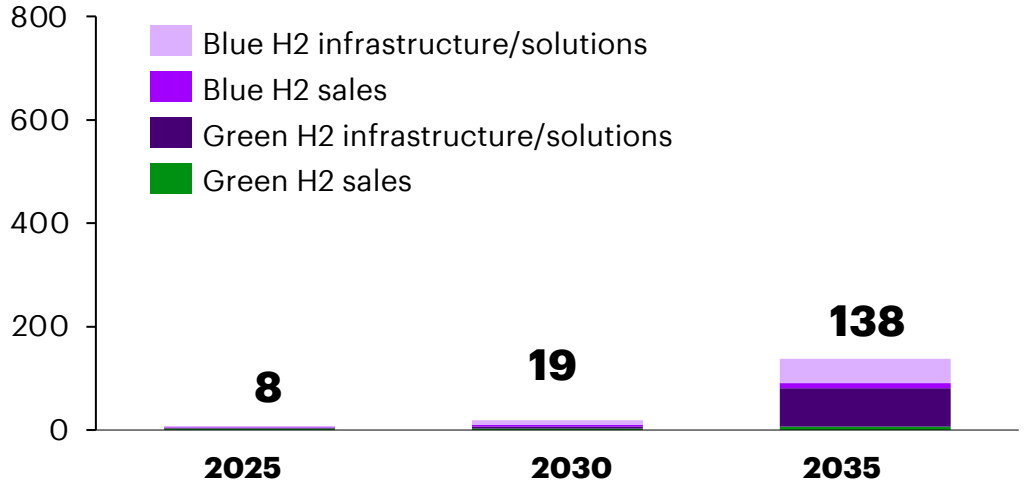
In our base scenario, adoption would be limited to those businesses that are already taking advantage of hydrogen's cleaner properties—namely, the chemicals and refining sectors. No additional changes are required to these sectors' industrial processes.

But that's not the case in other sectors. For them, the adoption of hydrogen is currently hindered not just by the higher prices of clean hydrogen, relative to natural gas or oil, but also by the high initial investments required to change the underlying manufacturing processes. Those costs offset the annual savings associated with carbon reductions.

Hydrogen global market potential by 2035 ($billion revenue/year)

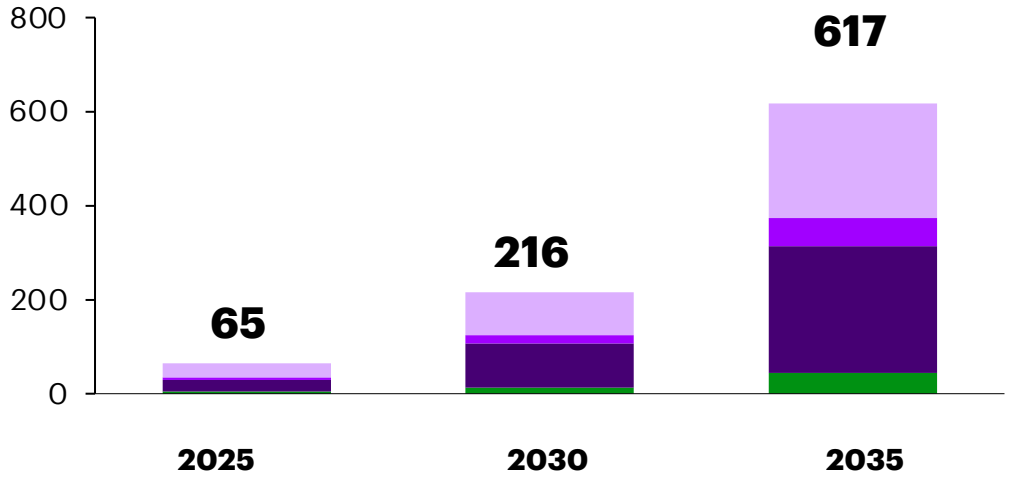
Base scenario

$100/tn CO_2 in Europe and North America,
$50/tn CO_2 in China



Optimistic transition scenario

$200/tn CO_2 in Europe and North America,
$100/tn CO_2 in China



Assumptions:

- Infrastructure/solutions includes first-time capital expenditure for new annual installations and annual technology operation and maintenance for existing stock. Adoption based on payback-driven bass diffusion analysis on clean hydrogen production including additional government funding for the medium term, built on the maximum clean hydrogen demand.
- In the base scenario, clean hydrogen demand is driven mainly by switching from grey to clean hydrogen in the existing consuming sectors, and in the optimistic transition scenario new hydrogen demand through switching from natural gas or oil to clean hydrogen in new consuming sectors.
- Hydrogen sales based on demand of clean hydrogen multiplied by cost of production and minor wholesale margins.

There are some sectors, however, that are forging ahead. In the heavy-duty road transport sector, for example, the business case of switching to fuel-cell electric vehicles (FCEV) powered by hydrogen is rapidly approaching break-even. That's due to carbon taxes applied to diesel, the relative price parity between new FCEVs and diesel vehicles, lower annual maintenance costs of a FCEV engine, and the potential synergies that come from building hydrogen fueling infrastructures in industrial areas served by heavy freight.

The rail freight sector, heavily reliant on diesel engines today, will see similar advantages of switching to fuel cell engines. Both sectors are expected to achieve hydrogen break-even costs by 2030.

Thereafter, we expect to see hydrogen emerge as a viable alternative to oil and gas in the iron and steel and power generation sectors. Uptake in those sectors will be driven by their ongoing transition from coal to natural gas; gas-fired industrial processes are most suitable for a replacement with hydrogen.

Breakeven year for hydrogen-based fuel adoption in first deployed region (base scenario)

	Switch to clean hydrogen- based fuel [i]
Light-duty road	after 2030
Heavy-duty road	2030
Rail	2030
Power generation	after 2030
Cement	after 2030
Iron and steel	after 2030
Refining	2030
Chemicals	2030
Residential	after 2030
Commercial	after 2030
Marine	after 2030
Aviation	after 2030

[i]The lowest-cost combustion option between blue or green hydrogen. Marine covers clean ammonia, and aviation covers e-fuels/synthetic jet fuel based on clean methanol from clean hydrogen.

Blue vs. green

While traditional gray hydrogen, which is derived from natural gas and produced from fossil fuels using steam-methane reforming (SMR), is the lowest-cost option for meeting the hydrogen demand today, it is emissions-intensive and exposed to rising carbon prices in several regions.

There are plenty of cleaner hydrogen production options available, including blue hydrogen (SMR+CCS), green hydrogen (electrolysis with water and green electricity), pink hydrogen (electrolysis with nuclear power), yellow hydrogen (grid electricity) and turquoise hydrogen (methane pyrolysis). Of these options, blue hydrogen and green hydrogen have a couple of advantages:

- They are available in nearly any region (versus, for example, pink hydrogen, which is limited to regions with sufficient nuclear power generation).
- They exhibit long-term competitiveness in a high-carbon tax environment (versus, for example, yellow hydrogen where the grid electricity used isn't emissions-free).

By 2030, we believe blue hydrogen will achieve market dominance—making up 40% of CCS solutions and 50% of the clean hydrogen commodity/infrastructure market.

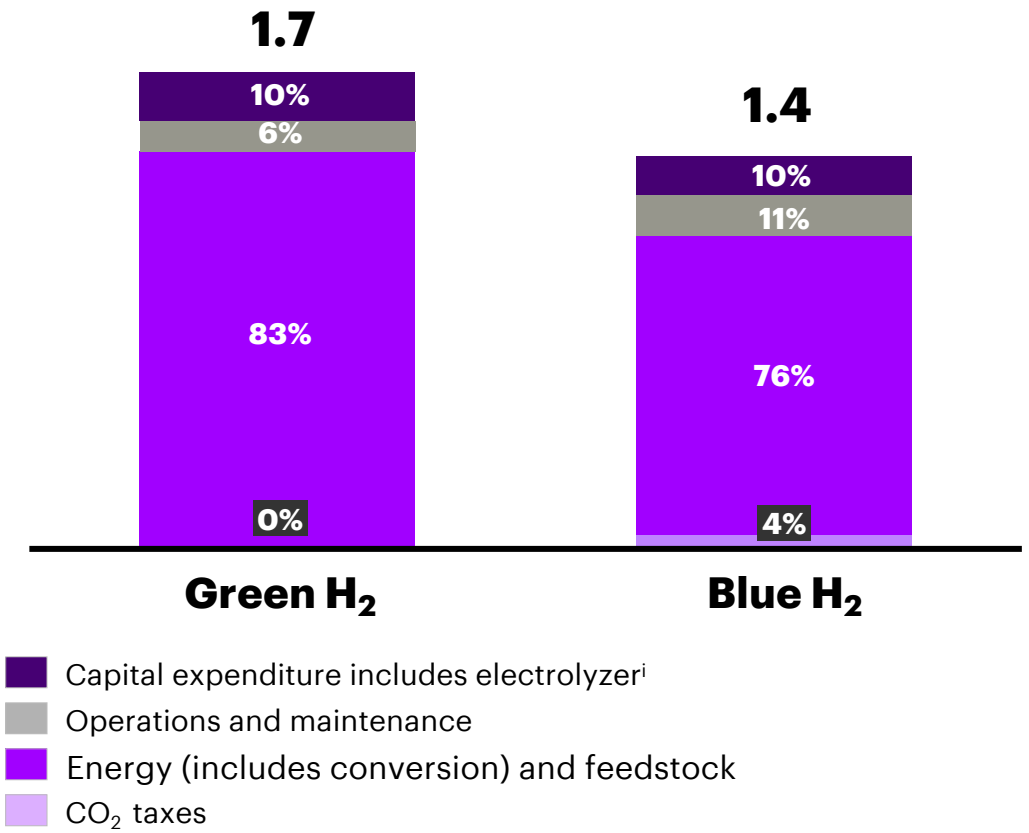
The choice between blue or green hydrogen depends primarily on carbon and natural gas prices and on the cost of generating this hydrogen. An environment combining low-cost natural gas and high-cost green electricity lends itself to blue hydrogen. An environment with rapidly decreasing electricity prices is more amenable to the use of green hydrogen.

Then there are the costs of hydrogen. The incremental cost of blue hydrogen versus gray hydrogen is already relatively low—and falling rapidly. Conversely, green hydrogen is today a relatively expensive option due to high electrolyzer costs and significant losses in hydrogen conversion, despite experiencing the fastest long-term cost decline across all forms of hydrogen.

From our analysis, we predict that blue hydrogen will reach market dominance by 2030 in both our scenarios. Its dominance will show itself in two ways: in the CCS markets, where it will make up more than 40% of CCS solutions by 2030; and in clean hydrogen production, where it will make up approximately 50% of the clean hydrogen commodity/ infrastructure market by 2030.

Blue hydrogen still holds advantages vs. green hydrogen

Annualized costs of clean H_2 production in 2035
North America, $/kg H_2



[i]New capital expenditure required vs. conventional solution (SMR) Base scenario.

Near-term opportunities for oil and gas players (by 2025)

Integrated (downstream) players:

- Secure early advantages in blue hydrogen for either clean hydrogen or CCS by securing government support and participating in emerging hydrogen clusters/alliances. The goal is to decrease high capital risk while capturing early market share.

Technology providers:

- Secure a pioneering role in the fast-moving market. Take advantage of green recovery policies, lower thresholds for large players and clean hydrogen alliances investing in large-scale CCS implementation projects

Mid-term opportunities for oil and gas players (by 2035)

Integrated (downstream) players:

- Lead the hydrogen economy. Drive production of the lowest-cost clean hydrogen through economies of scale. Target the B2B sectors (including steel and cement) with the most attractive business case for a fuel switch from natural gas to clean hydrogen.

Technology providers:

- Lead the twin markets for blue hydrogen. Be a market leader for clean hydrogen by serving the growing number of first-time implementations, as well as by growing the market for after-sales, operations and maintenance.

Blue hydrogen: Recommendations

Go all in

Blue hydrogen infrastructure:

Boosted by green recovery policies today, a massive investment market in CCS infrastructure for hydrogen production and refining is forming rapidly.

Proceed with caution

European heavy transport:

Besides industries able to produce blue hydrogen themselves, clean hydrogen demand is likely to start in the HDV sector, with a rapidly emerging business case for FCEV vehicles (especially in markets with increasing carbon taxes).

Wait and watch

Blue hydrogen sales elsewhere:

The financial business case for switching from natural gas to clean hydrogen in steel, cement, marine transport or building heating will take some time to mature. However, when it does, expect a large market, especially in regions with high carbon prices.

Play 5 - Biofuels and low-carbon products

Win the race in low-carbon transportation with biofuels and low-carbon products such as bio/synthetic lubes.

Stop ramping up traditional hydrocarbon refining. Start building the low-carbon muscle with bio/synthetic products (through ultra-flexible refineries).

Most of the hype regarding the transportation sector is focused on electricity and the growing popularity of EVs. Yet, our analysis shows that in the mid-term (2025-2035), biofuels will be the real winners when it comes to demand for decarbonized fuels—especially when looking across transportation modes (beyond just light-duty vehicles).

We predict that the demand for biofuels will grow by more than 2X over the next 15 years. The sectors most responsible for this demand growth will be heavy-duty vehicles, as well as global aviation and marine. In the heavy-duty road transportation sector, overall energy demand is projected to grow by approximately 4.4% (or 1.3 EJ or 0.58 mmboe /d). Within the mix of fuel types used by the sector, growth in renewable diesel and conventional biodiesel demand will at least double across regions.

A similar story is unfolding within the aviation sector. There, demand for SAF is projected to grow significantly after 2025 (a 27% CAGR between 2025 and 2035 to reach approximately 1.6 EJ, or 0.7 mmboe/d) as SAF becomes cost competitive with traditional kerosene (considering subsidies).

Biodiesel and sustainable aviation fuel will overtake ethanol as dominant fuels sources by 2035, representing a $30 to $50 billion opportunity in the medium term—and paving the way to a total biofuels market of $160 billion. We believe oil and gas companies have a prime opportunity to capture a significant share of this market.

Biofuel demand by region

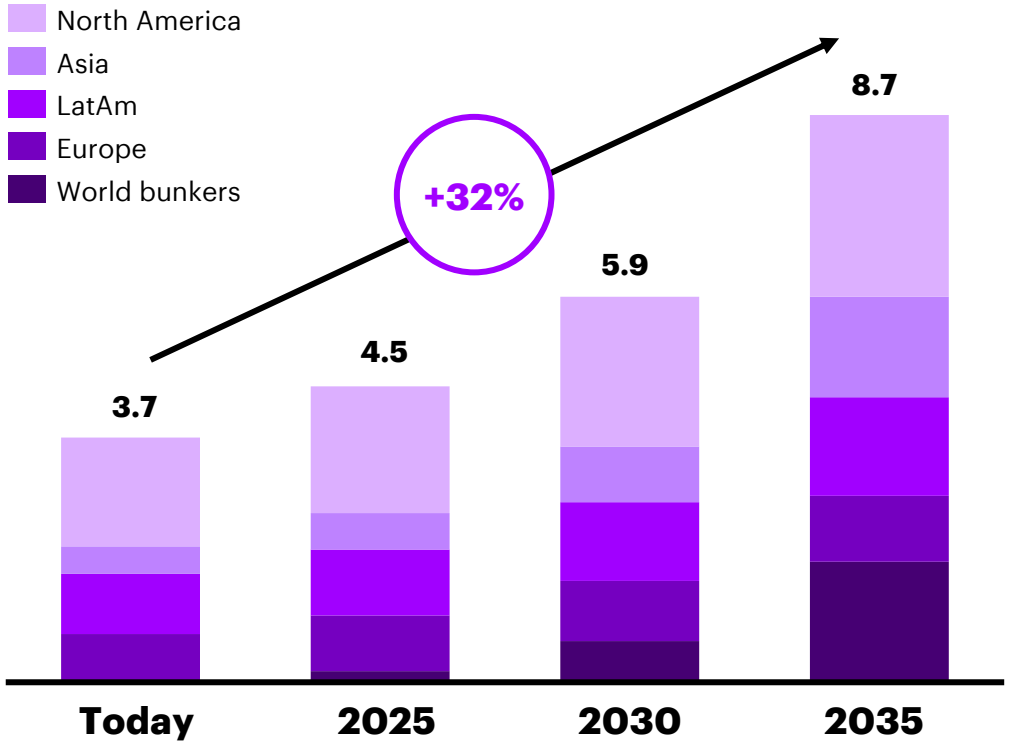
There are geographical differences when it comes to demand, however. In North America and Europe, the switch to biofuels is enabled by favorable policies and regulations, as well as the compatibility of biofuels with internal combustion engine technologies.

Asia and Latin America are expected to see even faster growth in demand for biofuels than developed countries. That's due, in large part, to existing strong demand markets and policies for ethanol biofuel production. However, in these regions, there is still a lot of uncertainty about the willingness and conviction of local governments to convert refineries to process biofuels.

The switch to biofuels will be less likely in the Middle East and Russia/CIS, given their inexpensive supplies of oil and their lack of policy incentive mechanisms

Global biofuels demand will more than double in 15 years...

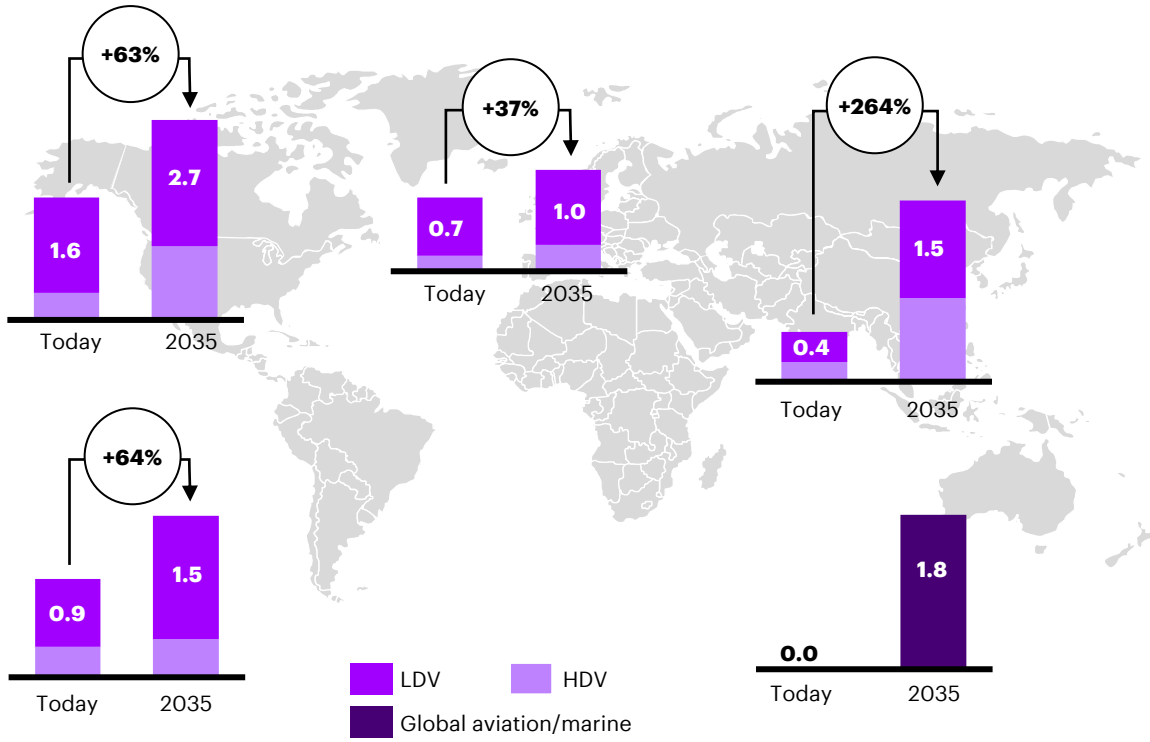
Exajoules (Today - 2035)



Including also (proportionally minor) regional demand in aviation/marine

...driven mainly by road transport in NA, Europe, Latin America and Asia as well as by global aviation/marine

Exajoules (Today - 2035)



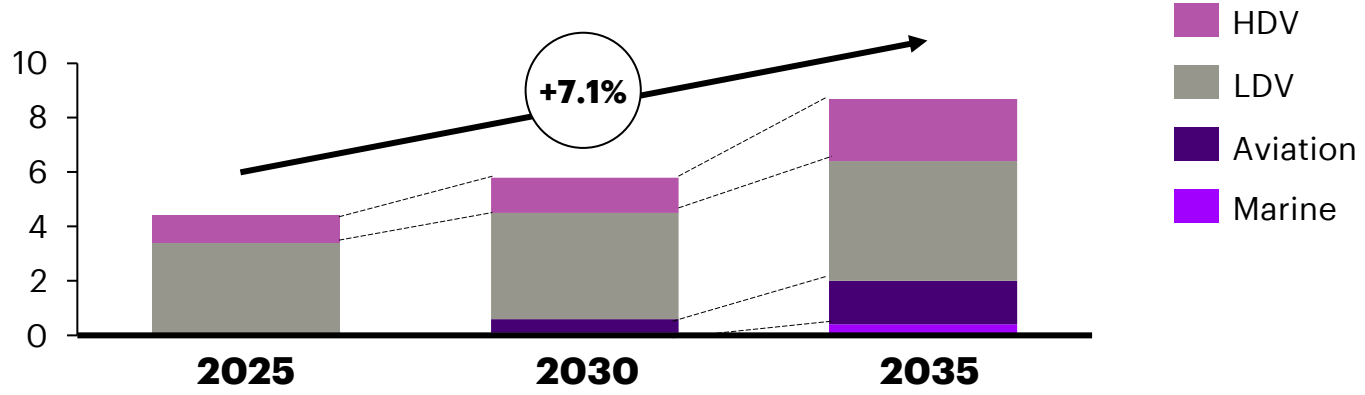
Source: Base scenario.

But what about electricity?

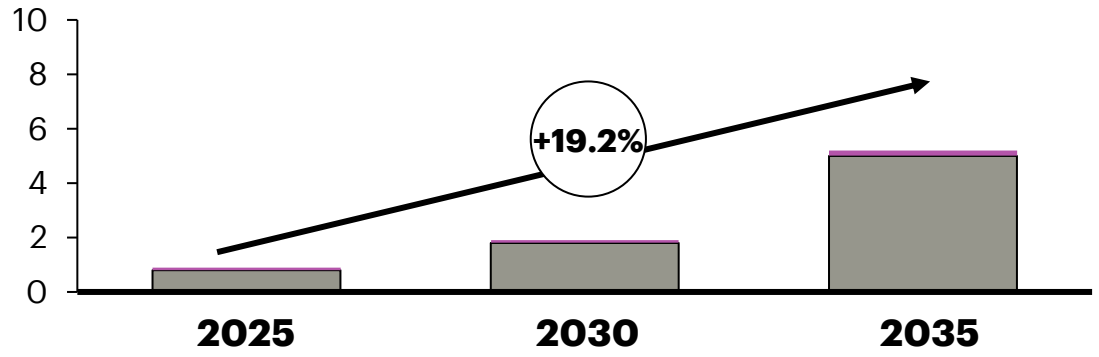
We believe biofuels will remain the larger source of joules (compared to electricity) across the four main transportation sectors: HDVs, LDVs, aviation and marine.

While consumption of electricity will grow faster, it will likely only account for a slightly larger total demand in 2035 (4.4 EJ of biofuels demand vs. 5.0 EJ of electricity demand by 2035). We foresee that electricity will surpass biofuels in the LDV sector in 2035, but the remaining sectors will likely not "electrify" in the foreseeable future, leaving room for biofuels to grow over the longer term.

Biofuels consumption by transportation sector (EJ)



Electricity consumption by transportation sector (EJ)



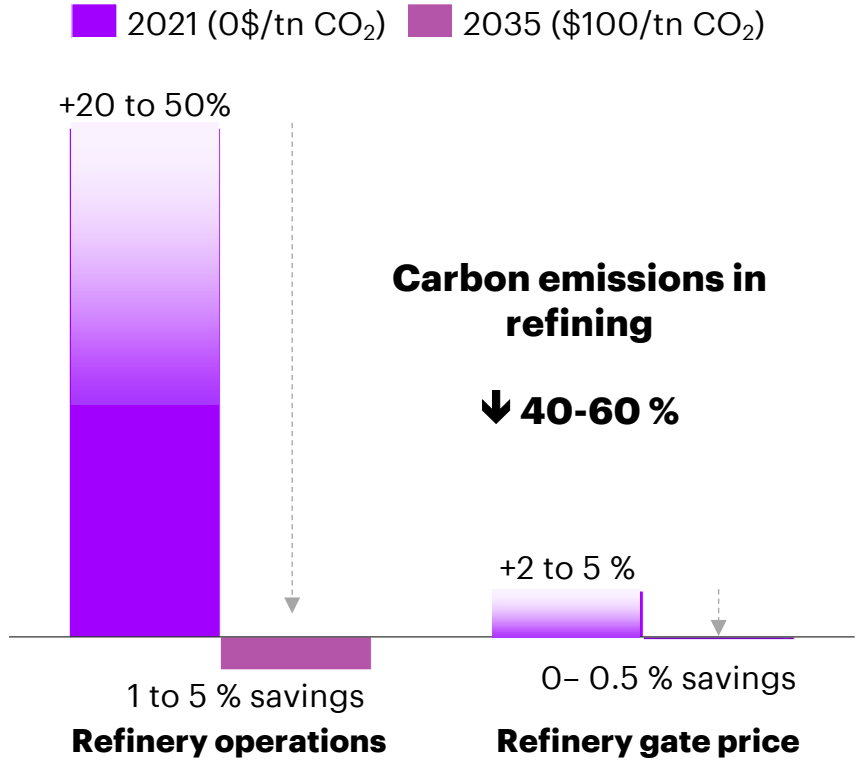
Source: Base scenario.

Low-carbon products

Beyond traditional biofuels, there are other avenues through which oil and gas companies can offer low-carbon products to the market, either through low-carbon operations or low-carbon feedstocks.
For example:

- Reducing carbon emissions in upstream and downstream operations by using CCS and a higher share of green power through power purchase agreements and/or captive renewables. Such changes will allow them to produce greener process-based fuels such as lower-carbon gasoline. According to our analysis, a 40-60% reduction of CO_2 emissions in refinery operations is possible. Also, in an environment of a $100/tn CO_2 price, companies could achieve comparable operating cost savings in their refineries.
- Reducing emissions of the hydrocarbon products themselves through synthetic zero-carbon feedstocks based on clean hydrogen. Making this shift would allow companies to develop greener synfuels such as synthetic jet fuels.

In a $100/ton carbon world, lower-carbon gasoline is expected to reach parity with traditional gasoline by 2035[i]



[i]Calculated based on financial green cost premiums and carbon reduction in an average oil refinery in the US or Europe resulting from applying CCS in the FCC and hydrogen (via SMR process) units. Also considering on the increased energy demand from carbon capture in this scenario/example, both units are assumed to each represent: 20-30% of total refinery carbon emissions and 20-30% of total refinery operating costs of $5-10/bbl of refined products. The final cost impact range depends on the synergy from, for example, common carbon pipeline and storage infrastructure.

Key opportunities for oil and gas players

There are several opportunities for integrated players and independent refiners to leverage their refining assets and capture the value of biofuel demand growth over the next 15 years. To do so, they must:

- **Ensure their refining assets can produce biofuels.** Driving toward ultra-flex refining capacity today will not only ensure resiliency of the existing refining portfolio by creating new opportunities for aging assets, but also allow oil and gas players to capture first-mover capacity advantage to serve the growing demand for biofuels in the transport sector and/or scale where necessary.
- **Bring forth low-carbon products.** Over the mid- to longer-term (2030+), there are opportunities for refiners to diversify their product lines further. One involves leveraging their growing renewable hydrogen capacity to produce synthetic fuels (e.g., synthetic diesel and lubes).[16] Another involves taking advantage of their growing presence and expertise in CCS markets to decarbonize traditional hydrocarbon products and offer low-carbon alternatives to the transport sector.
- **Connect and optimize operations.** To take full advantage of the biofuel opportunity while continuing to serve existing markets for traditional hydrocarbon products, refiners need to ensure that the right product is produced at the right location and at the right time. This requires an end-to-end approach that can deliver margin improvements of $0.5-$1.5/bbl and yearly profitability gains of $60 million to $180 million for the average refiner.[17]
- **Secure supplies of bio-feedstock.** Currently, the supply chain is fragmented. Oil and gas players should consider implementing end-to-end traceability and agility in the supply chain through digital solutions such as control towers, by acquiring stakes in crop developers, or by incenting the market consolidation of smaller players.

Biofuels and low-carbon products: Recommendations

Go all in

Biofuels for HDVs, aviation and marine:

Derived from animal/plant/waste fats, liquid bioenergy is a natural fit for oil and gas companies—especially when these bio-feedstocks are co-processed with petroleum distillates as a capital-efficient way to provide biofuels for the HDV sector in North America, Asia and Europe.

Proceed with caution

Bio-alcohols for LDVs:

Interim demand growth will be driven by the LDV sector. But we expect electricity to surpass biofuel demand in LDVs by 2035. Also, bio-alcohols are generally derived from biomass feedstock like corn or sugarcane. These sources require energy and fertilizers to produce, harvest and process, thus releasing carbon.

Wait and watch

Biofuels in Growth Markets:

The uncertainty about the resolve and willingness of local governments to enforce policies presents too much risk.

Where do we go from here?

The oil and gas industry is at a pivotal moment. The energy transition is forcing all industry players to re-evaluate how they will compete and the role they will play in the new energy system.

Although uncertainties exist due to the Ukraine crisis and the worldwide recovery from the pandemic, our analyses allow us to predict the near-term (2025) demand patterns with good confidence. The current supply and demand imbalance will be solved by operators and oilfield equipment and services companies. That imbalance is creating significant opportunities for them to increase their cash flows.

In the medium term (2035), the role of oil and gas in the energy system is also clear. Industry players will need to deliver additional incremental supplies to meet customer demand as the energy transition evolves.

The longer-term consequences for the industry are harder to predict. But there are many reasons for oil and gas companies to be hopeful. Energy transition technology breakthroughs, combined with societal and policy pressures to transition to clean energy, pose a once-in-a-generation opportunity for operators and oilfield equipment and services companies to partner with their customers and create unique value propositions.

It is through these partnerships—and through the industry's granular understanding of energy demand shifts at a sectoral and regional level—that oil and gas portfolios will evolve to ensure their own resilience and energy availability, equity and sustainability for all.

Our analyses have revealed five key portfolio moves that oil and gas companies should consider. These moves, described in detail in this report, are applicable across all future energy scenarios.

However, pivoting multi-billion-dollar hydrocarbon portfolios is challenging. That effort requires companies to build and strengthen a new set of capabilities that will enable them to:

- Identify the most profitable opportunities on a per-joule basis
- Understand the capabilities and intentions of sectors to switch fuels—and the commercial implications for doing so
- Build commercial muscle to trade and/or market molecules, electrons and carbon
- Retain and strengthen exploration capabilities (if they remain committed to oil and gas)
- Innovate in order to access capital, investor and consumer support
- Accelerate their acquisition and divestiture capabilities—from identifying targets to integrating acquisitions and divesting businesses

Guaranteeing their relevance in the energy system of the future requires oil and gas companies to rebalance their portfolios and build the capabilities to do that. Starting today.

Methodology

Methodology

In early 2022, Accenture carried out extensive analyses to gain a better understanding of how demand-driven change will affect the energy system and, specifically, the oil and gas industry over the coming 15 years. We developed the Accenture Energy System Demand Model to forecast annual changes in energy demand across eight regions, nine sectors and eight fuel sources.

First, we looked at the changes in overall energy demand (across fuels) for each region-sector "cluster" (e.g., iron and steel in Europe) that were due to:

1. production or economy growth
   (e.g., ton/year steel produced in Europe); and
2. the efficiency increase
   (e.g., 1%/year more steel produced with the same energy per year).

Next, we looked at the expected fuel switching and adoption of alternative fuels across sectors, driven by an economic business case (e.g., investment in a gas-fired process would likely replace a coal-fired process, generating annual savings in terms of energy and carbon costs and positive net cashflow within limited number of years). We assumed the resulting adoption of the new fuel (which included, for example, “natural gas” or “coal+CCS”) would lead to an annual decline in demand for the incumbent fuel (e.g., coal without CCS).

The model's key inputs include selected historical data from OECD, IEA, IRENA, EIA, BEA, ILO, World Bank, UNSD, S&P Capital IQ, USAGov, Eurostat and selected national statistical agencies including Destatis, NBS and UK Office of National Statistics.

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Glossary of acronyms

Bbl	Barrel of oil
Bcm	Billion cubic meters
Bn	Billion
Boe	Barrel of oil equivalent
CAGR	Compound annual growth rate
CAPEX	Capital expenditure
CCS	Carbon capture and storage
CSP	Concentrating solar power
EJ	Exajoule (one quintillion joules)
EV	Electric vehicle
FCEV	Fuel-cell electric vehicle
FCC	Fluid catalytic cracking
H_2	Hydrogen
HDV	Heavy-duty vehicle
IAM	Industrial asset management
J	Joule
LDV	Light-duty vehicle
LNG	Liquefied natural gas
mmb/d	Million barrel/day
Mmboe	Million barrel of oil equivalent
MMBtu	Metric Million British thermal unit
Mtoe	Thousand ton of oil equivalent
PJ	Petajoule
SAF	Sustainable aviation fuel
SMR	Steam-methane reforming
tn CO_2	Tons of CO_2
WTI	West Texas Intermediate

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