ExxonMobil

Mobility reimagined

On the road to lower GHG emissions

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The energy transition

At ExxonMobil, we develop and deploy energy solutions that meet society's needs. Today, that means providing products that support the energy transition, reducing our own carbon emissions and developing technologies to advance a lower-carbon emissions future.

Through 2027, we plan to invest approximately $17 billion on initiatives to lower greenhouse gas emissions. These investments are designed to make possible reduced emissions in our operations and are also directed towards reducing others' emissions through commercializing and scaling carbon capture and storage, hydrogen, and biofuels. We are working to supply approximately 40,000 barrels per day of lower-emissions fuels by 2025 and have a further goal of 200,000 barrels per day by 2030. Moreover, with the support of clear and consistent government policies, ExxonMobil, aims to achieve net-zero Scope 1 and Scope 2 greenhouse gas (GHG) emissions from our operated assets by 2050, and is taking a comprehensive approach centered on developing detailed emission-reduction roadmaps for major operated assets.

Reducing transportation related GHG emissions is viewed by many as essential to managing the global energy transition — particularly as nearly a quarter of worldwide CO_2 emissions are estimated to come from transportation and 78% of those emissions come from the road transport sector[1]. Road transport is vital to modern life, transporting people and goods to meet the needs of society and global economic growth. This has prompted the sector to undertake a transition toward lower GHG emission alternatives, which can be categorized into four areas of opportunities: logistical efficiency improvements, new vehicle technology, electrification and lower GHG emission fuels.

Hydrogen and biofuels will play an important role in helping achieve the transition to a lower-emission future. We will leverage our expertise in technology and scale to help meet the industry's demand. Below we outline our position on road transport's path to reducing GHG emissions.

[1] 2021 ExxonMobil Energy Outlook

Road transportation path to lower GHG emissions

Global transportation energy demand is expected to grow 30% by 2050[1] due to global economic growth and the associated increase in vehicles and freight. Energy providers are expected to increase their collective output to meet these needs while simultaneously providing lower GHG emissions solutions. In parallel, fleets and OEMs should continue to pursue vehicle technology and efficiency improvements such as route optimization planning, electrification and fuel cell technology.

Vehicles on the road will nearly double from 1.5B in 2015 to 2.8B in 2040[2]

Road freight growing from 19T ton-kilometers in 2015 to over 38T by 2050[3]

Road transport is a complex sector with diverse objectives. Passenger vehicles, motorcycles, and buses move people about their daily lives. Light-duty (LD) and heavy-duty (HD) vans and trucks allow freight haulers, consumer goods companies, bulk shipping, and others to get their shipments where they need to be. Route types and duty cycles vary considerably, and can include short-haul/long-haul, return-to-base/point-to-point, and continuous use/interrupted use. Each case requires efficient fueling solutions, balancing downtime and vehicle productivity. It requires affordable fueling that provides potential GHG emission-reducing benefits while meeting operational performance criteria.

Today, the industry faces a number of challenges on the path to lower GHG emissions including varied government policies across jurisdictions, technologies, infrastructure and lack of a single industry-wide GHG emission reduction target, for example. The sector's complexity requires a higher degree of collaboration than ever before. The energy transition for road transportation will likely require multiple solutions and go through several product lifecycle evolutions to achieve the goal of lowering GHG emissions. However, with these challenges comes tremendous opportunity for innovation, societal value creation, and supportive government policies.

[2] The number of cars worldwide is set to double by 2040 | World Economic Forum (weforum.org)
[3] Road freight activity forecast 2050 | Statista

Regulatory policy as a change agent

There are several key elements needed to successfully lower GHG emissions in road transportation: technology, infrastructure, affordability, and market demand. Policy may positively impact one or more of these components.

New solutions can require considerable upfront investment which may carry a higher degree of financial risk. Supportive and effective policy can often mitigate this risk through technology and infrastructure incentives. Beyond infrastructure and technology support, energy solutions must be market competitive to stimulate sufficient demand. Regulatory policy may address this through different mechanisms: fuel or vehicle performance standards, emission caps with credit trading, and a direct tax on GHG emissions.

ExxonMobil advocates for effective policies for fuels, vehicles or infrastructure that drive more rapid GHG emission reductions, while fostering innovation and competition, and preserving consumer choice. This approach is grounded in a framework which emphasizes regulations that should:

- Support pressing societal goals
- Have a clear basis in science and law
- Encourage all solutions
- Promote the wise use of resources
- Provide sufficient clarity and certainty to encourage investment

Canada's Clean Fuels Regulations (CFR) is just one example which has several of the desired features.

ExxonMobil, as an advocate, is engaged in a number of supportive efforts. We are working with university partners, such as the Singapore Energy Center, on the research and science with a focus on energy innovation and lower GHG emissions technologies.[4] We participate in trade associations like the American Petroleum Institute and Advanced Biofuels Association, where we are active in developing and promoting policy to reduce life-cycle GHG emissions in the U.S. transportation sector.[5] We are working with governments at various levels to advance policy that will have a meaningful impact on road transport GHG emissions.

Benefits of Canada's CFR

- Encourages all solutions and rewards them proportional to their lifecycle GHG reduction achieved
- Promotes market competition, innovation, and consumer choice
- Leverages markets, not taxes
- Is less reliant on vehicle fleet turnover
- Drives CO_2 emission reductions across the entire existing fleet

[4] Collaborating with leading universities to meet global energy demand | ExxonMobil
[5] ExxonMobil Report on Climate Lobbying 2021

Supply and demand

Increasing numbers of vehicles worldwide and greater need for road freight combined with the need for lower GHG emission solutions will undoubtedly impact supply and demand balance. This impact is expected to be different for LD versus HD vehicles. Between 2019 and 2050, we expect 44% energy demand growth for the HD segment. In contrast, we anticipate a 9% decline among LD.[1]

Furthermore, demand for conventional fuels will vary by product and market. We expect global gasoline demand to decline by nearly 14% between 2019 and 2050, with the largest impact in North America. This anticipated decline is due to a number of factors, including improved LD fuel efficiency, biofuels, and an increase in EVs. However, conventional diesel fuel is projected to increase 12%, led by Asia Pacific and its economic growth.[1]

As the energy transition progresses, we anticipate the demand for lower GHG emission alternatives for both gasoline and diesel will increase. For example, global supply of biofuels is currently 2.0M barrels/day (MBDOE).[1] By 2050, we project the market will need 5.4M barrels/day (2.7X current supply).[1] Hydrogen and EV are emerging as lower carbon intensity (CI) solutions that have long-term potential in the sector. As vehicle manufacturers scale the technologies and refueling infrastructure emerges, we expect demand for these alternatives to increase. The International Energy Agency (IEA), under a 2050 Net Zero scenario, expects that demand for hydrogen will be 93M metric tons by 2050.[6] We estimate that more than 50% of light-duty vehicles sales in 2050 will be electric.[1]

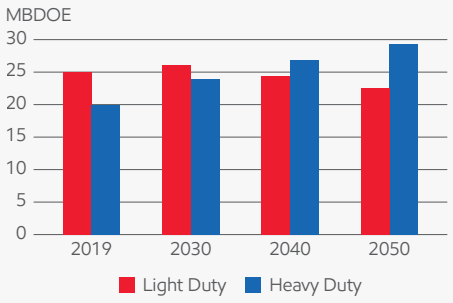
2.7X

more biofuel supply needed by 2050

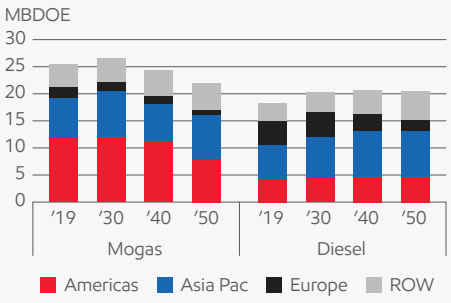
93M mt hydrogen = 93B gallons diesel (energy equivalency)[7]

Achieving the desired scale requires price points for biofuels and hydrogen that are market competitive versus conventional products. To be effective, EV adoption depends on a sufficient renewable power grid, an effective charging infrastructure and affordable vehicles. Delivering the needed supply requires investment and collaboration within the sector driven by a supportive regulatory policy.

Vehicle energy needs (2019–2050)



Mogas and diesel demand (2019–2050)



[6] Net Zero by 2050 A Roadmap for the Global Energy Sector (IEA Report)
[7] Hydrogen Data (DOE Hydrogen Program)

Multiple solutions to lower GHG emissions

There are many potential pathways to lower GHG emissions in the road transport sector. In fact, a portfolio of solutions approach will be required as each solution has advantages and limitations (*figure 1*). In one illustration (*figure 2*), a fleet may begin with biofuels and then transition to hydrogen or EV to achieve greater GHG emissions reductions over time as infrastructure is built and policy evolves to support certain pathways.

Alternative energy solutions that may be leveraged within the portfolio include:

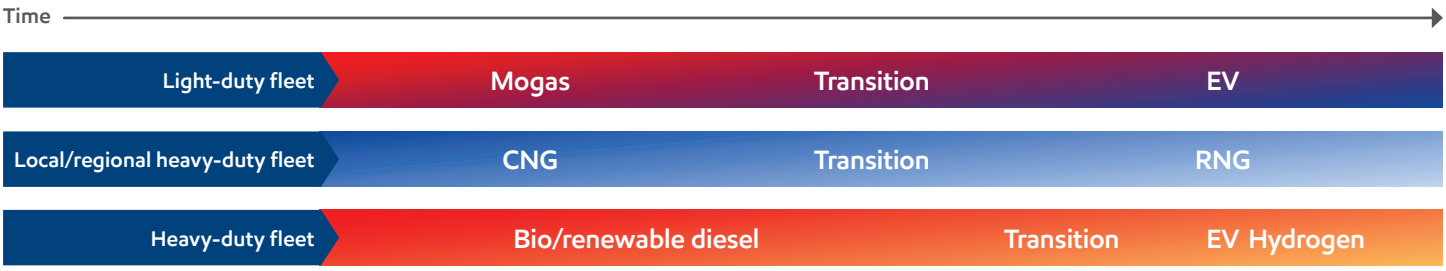
- Biofuels/synthetic fuels that can blend with or replace existing conventional gasoline and diesel fuels
- Hydrogen for a lower GHG emission alternative in hard-to-decarbonize transportation such as HD trucking
- Renewable natural gas as a lower GHG emissions substitute for compressed natural gas
- Electrification/EV charging that may provide a lower GHG emission alternative where operating conditions are conducive

Factors that require a portfolio approach (***figure 1***)

- **Scale (supply/infrastructure)**
- **Vehicle/fuel compatibility**
- **Technology readiness**
- **Affordability**
- **Varied transportation needs** (use cases, LD vs. HD)
- **GHG emission reduction potential**

This portfolio will likely vary from one market to another and among customers as ambitions, access to specific solutions, and regulatory environments vary. The portfolio will also change over time with some solutions becoming less relevant while others rise in importance.

Illustrative Fleet Transition — portfolio approach (***figure 2***)



Biofuels

We expect biofuels to play a vital role in the energy transition. They are produced from various biomass sources and have different applications.

Bioethanol is an alcohol produced from corn, sugar or cellulosic material that is blended with gasoline at levels typically ranging from 5–15%, and in some cases as high as 85%.[8] The blending levels are usually driven by regulatory mandates and credit systems. Ethanol blended gasoline is an engine-ready fuel (for most applications) most often used in passenger cars and light-duty vehicles.

There are two types of alternative diesel products: biodiesel and renewable diesel. Both biodiesel and renewable diesel are primarily sourced from vegetable oils and animal fats. What distinguishes the two is the manufacturing process, transesterification for biodiesel and hydrotreating for renewable diesel.[9] Renewable diesel, also known as hydrotreated vegetable oil (HVO), has similar chemical properties as conventional diesel and can serve as a substitute for diesel, whereas biodiesel does not. Biodiesel and renewable diesel are blended with conventional diesel at levels ranging from 5–20% for biodiesel and 5–100% for renewable diesel. These engine-ready products can be used in many passenger cars or commercial vehicles that utilize diesel fuel.

Biofuels have the potential to lower lifecycle greenhouse gas emissions by up to 85% compared to petroleum-based diesel.[10] The amount of GHG emission reduction will depend on the percent of biofuel blended, the source material, and the manufacturing process used.

ExxonMobil is making considerable investments in biofuels production and technology and sees it as a solution that can:

- Meet the needs of current vehicle fleets
- Require little to no incremental customer investments
- Deliver an affordable alternative
- Provide high levels of GHG emission reductions

Strathcona

In Canada, our affiliate Imperial Oil is advancing a project to produce renewable diesel at its Strathcona refinery in Edmonton. They'll use plant-based feedstock and hydrogen with carbon capture and storage (CCS) to help offset GHG emissions during operation.

20K
barrels per day of renewable diesel

3M
metric tons of emissions annually

650K
passenger vehicles off the road for one year

500K
metric tons of CO_2 annually

[8] Alternative Fuels Data Center: Ethanol Fuel Basics (energy.gov)
[9] Biofuels explained — Biodiesel, renewable diesel, and other biofuels — U.S. Energy Information Administration (EIA)
[10] Turning Wood Waste into Biofuel — Energy Factor (exxonmobil.eu)

Hydrogen

Achieving robust GHG emissions goals will require several lower GHG emission technologies and fuel sources, such as hydrogen. Hydrogen holds great potential as a long-term solution that can achieve significant GHG emissions reductions, versus current conventional fossil fuels, particularly for hard to decarbonize sectors.

Although hydrogen is colorless, it is referred to by color based on the different methods of production. Most hydrogen produced today is "grey" and created by splitting natural gas into hydrogen and carbon dioxide (CO2), with the CO_2 released into the atmosphere during the manufacturing process. Blue hydrogen uses the same process, but the CO_2 that is produced during manufacturing is captured and stored using carbon capture and storage technology. Green hydrogen is produced by using renewable energy (e.g., solar, wind) to split water into hydrogen and oxygen.

The difference between the GHG emissions intensity of blue and green hydrogen can be small, but blue hydrogen is often less expensive to produce.[11] Price will be influenced by policy, infrastructure, and availability of renewable power (for green hydrogen).

Fuel cell vehicles (FCV) convert hydrogen fuel to electricity on board the vehicle to power an electric motor. Fuel cells are highly efficient compared to gasoline and diesel internal combustion engines in most applications. FCVs are especially well-suited to uses requiring high uptime, fast refueling, or heavy payloads. They can be refilled in minutes and can cover longer distances per fueling, with less weight devoted to energy storage than a battery electric vehicle (BEV).

ExxonMobil views hydrogen and its derivatives as a viable solution for hard-to-decarbonize transportation sectors, including HD road transportation. Hydrogen combined with carbon capture and storage provides potential advantages versus current alternatives:

- Substantial supply once infrastructure is scaled and supportive policy is in place
- High GHG emission reduction potential (green, blue hydrogen) and zero carbon tailpipe emissions
- Faster refueling and lightweight relative to EV (particularly for HD vehicles) potentially increasing productivity and payload capacity

Hydrogen production

ExxonMobil is planning a hydrogen production plant and one of the world's largest carbon capture and storage projects in Baytown, Texas.

Facility would produce 1B ft^3 of "blue" hydrogen per day

ExxonMobil has extensive experience with hydrogen and already produces 1.5B ft^3 per day

[11] Hydrogen what you need to know (xom.com)

Renewable natural gas

Renewable natural gas (RNG) has great potential to lower greenhouse gas emissions in select applications. It is available as a fuel today in relatively small quantities. RNG is compatible with the existing natural gas infrastructure, which means it could take less time and cost less money to bring online than other lower GHG emission pathways.

RNG is a lower GHG emission version of natural gas that is chemically equivalent. It is produced from agricultural waste (e.g., from dairy farms) or municipal waste (sewage, landfill). This fuel has application in both LD and HD trucks and buses. It is most applicable in return-to-base operations due to the current limited network of refueling sites. A popular application of RNG is onsite vehicle fueling, close to the source of the biogas. This eliminates the need for pipeline transportation and interconnection costs. This is one reason why landfill operator fleets, waste-hauling trucks, and neighboring fleets are users of RNG. Any vehicle using compressed natural gas (CNG) or liquefied natural gas (LNG) today can convert to RNG without modification. Diesel trucks can also be retrofitted for RNG use, reducing cost relative to a new vehicle purchase.

A unique aspect of RNG, in the case of certain feedstock (manure and organic waste), is the potential to deliver a negative CI product. Directly converting the RNG feedstocks eliminates the methane emissions that would ordinarily occur through their continued existence. The potential for low or negative GHG emissions impact is attractive from a sustainability perspective. The question is can it be sufficiently scaled? The ability for RNG to be a long-term or transitional solution will depend on the answer.

ExxonMobil is exploring opportunities to supply RNG in the marketplace, given the possibilities and advantages:

- High GHG emission reduction potential, at scale
- Faster refueling time and payload impact relative to EV (particularly for HD vehicles), leading to increased productivity
- Ability to use existing pipeline networks, reducing infrastructure cost

Electrification (EV)

BEVs and plug-in hybrids (PHEV) are rapidly increasing in market share among passenger vehicle and some light-duty fleets, although total car population is relatively small.[1,12] It is a more challenging proposition for long-haul fleets where charging downtime, payload displacement (due to battery size/weight) and range are important considerations. EVs paired with low carbon electricity sources are expected to play an important role in reducing GHG emissions from road transportation.

Electrification is more than a vehicle charger. It includes power generation, whether renewable or conventional. There is the power grid and associated infrastructure requirements. There is electricity storage through battery technology to manage the timing/cost of distribution. Finally, there is the sale of power whether for vehicle charging or other uses.

EV charging has several use cases suited for different needs: at home charging, destination charging (e.g., shopping malls), on-the-go (service stations), commercial fleets (on location). The utilization of these solutions depends on things like: dwell time (full charge versus top off), fleet optimization/utility cost management, alternative needs (food/convenience items, vehicle wash), and payment options. The EV charging solutions that support these different cases vary from the inexpensive at-home solutions that require up to 10 hours to charge a typical passenger car to an expensive ultra high-speed charger that can charge a passenger vehicle in 20–60 minutes.[13]

EV has significant potential as a lower GHG emission solution, however the impact depends on the electricity source: wind, solar, nuclear, natural gas, or coal. The impact can range from near zero GHG emissions for a fully renewable source to GHG emissions that exceed conventional gasoline, if electricity is sourced from certain non-renewables.

ExxonMobil continues to explore product solutions that support EV deployment. We are piloting EV charging in several markets either directly or in cooperation with our channel partners. We also have our MobilEV line of fluids in the market today. This innovative lubricant technology provides thermal management for batteries, wear protection and thermal stability for electric motors and gearboxes on EVs.

[12] Global Electric Vehicle Outlook 2022 (windows.net)
[13] Electric Vehicle Charging Speeds | U.S. Department of Transportation

ExxonMobil as a trusted partner

For more than 100 years, ExxonMobil has been a leader in ground transportation providing product solutions to serve the industry's evolving energy needs.

Today, we serve over 8,000 commercial customers with a network of more than 500 fuel terminals in over 20 countries. We collaborate with leading OEM companies to develop lower GHG emission fuels and lubricants suited for the vehicles of today and tomorrow. Our products are manufactured with the highest regard for safety, quality, and reliability.

We expect ExxonMobil's expertise in scaled projects and production to help facilitate meaningful GHG emissions reduction with solutions such as carbon capture and storage, biofuels, and hydrogen. But it's not just about the ability to deliver scale, it's also about having the technical knowledge to deliver solutions that make a difference. Every day more than 20,000 scientists and engineers at ExxonMobil are working to develop lower-carbon technologies and innovations to help lower GHG emissions from transportation, so we can help our customers navigate through the energy transition.

Amidst the changing energy landscape, ExxonMobil will continue to create sustainable solutions that improve quality of life and meet society's evolving needs.

Notable innovation

- Mobil developed the first detergent gasolines in the 1950s
- In 1976, Mobil invented a process for converting methanol into high-octane gasoline
- Today, ExxonMobil offers additized diesel in North America
- Synergy Diesel Efficient and Mobil Diesel Efficient deliver higher fuel economy, improved engine performance, and reduced GHG emissions

Partner spotlight

BIOJET

ExxonMobil is expanding our interest in biofuels by acquiring a stake in **Biojet AS**, a Norwegian biofuels company that plans to convert forestry and wood-based construction waste into lower GHG emissions biofuels and biofuel components. The resulting fuels can help reduce life-cycle greenhouse gas emissions by 85% compared to petroleum-based diesel. Future commercial production will take place at a manufacturing plant to be built in Ringerike, Norway for distribution throughout northwest Europe. The agreement enables ExxonMobil to purchase as much as 3 million barrels of the products per year, based on the potential capacity of five facilities.

The journey of reducing emissions to support a net-zero future for the road transport sector will require a portfolio of approaches. At ExxonMobil, we have demonstrated capabilities in large-scale solutions, proven technology expertise, and experience working with key industry stakeholders to create meaningful energy product solutions.

Russ Green
Low Emissions Fuels Venture Executive, ExxonMobil

Learn more about our commitment to climate solutions in the ExxonMobil Advancing Climate Solutions Progress Report and Commercial Fuels site on www.exxonmobil.com