Future of Oil in a Low-Carbon World

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Our world faces a dual challenge: meeting growing demand for energy while reducing environmental impacts, including the risks of climate change. This is a global issue that requires the collaboration of governments, industries, consumers and other stakeholders.
From reducing the environmental impact of our operations, to developing advanced products that help our customers reduce their emissions, ExxonMobil is committed to doing our part. We are investing in next-generation technologies such as carbon capture and storage and advanced biofuels from algae. We have been vocal in our support for the Paris Agreement, an important framework for addressing the risks of climate change.
Each year we produce an *Outlook for Energy*, our view of energy demand and supply through 2040. We use the *Outlook* to help inform our long-term business strategies and investment plans. The below highlights some of the key takeaways from our most recent *Outlook*, and the actions we are taking as the world shifts toward a lower-carbon energy system.

There is always much conversation and speculation about the future of oil – from discussions about peak oil decades ago, to the historic rise in unconventional production today and those who believe oil has a significantly diminished role in a future powered by wind and solar energy.

To understand this complex and multi-faceted topic, ExxonMobil first looks at the fundamental role energy plays in supporting modern life. Energy powers economies and fuels prosperity. Today, access to energy is critical to supporting rising living standards around the world.

By 2040, the world's population is expected to reach 9.2 billion people, up about 20 percent from today. Over that same period, global GDP is likely to double and per capita GDP is projected to rise significantly. Despite gains in efficiency, global energy needs will likely rise at a pace similar to population growth over the period to 2040.

The world will need to pursue all economic energy sources to keep up with this considerable demand growth. From the oil and natural gas in America's shale regions, to the deepwater fields off Brazil; from new nuclear reactors in China, to wind turbines and solar arrays in nations around the world. Society's gradual shift to lower-emissions energy sources is expected to drive substantial increases in renewables such as wind and solar. By 2040, nuclear and all renewables will be approaching 25 percent of global energy supplies.

Oil critical to personal mobility, commercial transportation and chemicals

However, oil and natural gas will continue to supply about 55 percent of the world's energy needs through 2040. Oil continues to provide the largest share of the energy mix essential to three key areas – personal mobility, commercial transportation and chemicals.

First, personal mobility. As incomes rise, the billions of individuals joining the global middle class will want more personal mobility, so demand for cars and motorcycles will increase. As personal mobility increases, average new-car fuel efficiency (including SUVs and light trucks) will improve as well, reducing by more than 3 liters per 100 kilometers by 2040.

Recently, some car manufacturers and governments have announced plans to limit emissions of light duty vehicles either by setting targets for future electric vehicle sales, including hybrids, plug-in hybrids and battery electric vehicles, or targeting a phase out of gasoline and diesel new car sales. More electric cars and efficiency improvements in conventional cars will likely lead to a peak in liquid fuels demand for the light-duty vehicle fleet before 2030.

Growth in economic activity and personal income drives increasing trade of goods and services. This in turn leads to higher energy demand in the commercial transportation sector to move raw materials, component parts and finished goods across cities and continents. Heavy-duty vehicles (e.g., long-haul trucks, buses) is the sector with the largest volume growth, but aviation grows the largest by percentage. Marine and rail demand are projected to grow, too.

Efficiency gains resulting from improvements in fuels, engine design, aerodynamics, body design and logistics across commercial modes of transport lead to significant

reductions in the rate of energy demand growth. Electrification in most commercial transportation grows slowly due to upfront costs, range limitations, payload requirements and infrastructure development. Advance in other alternative fuels (e.g., biofuels, natural gas, hydrogen) make inroads approaching 2040, but challenges such as infrastructure build-outs and energy density limit penetration.

Consumer demand for plastics, fertilizer and other chemical products increases with rising incomes. Manufacturers see plastics as light-weight, durable materials that can improve the performance of their products, from auto parts to medical devices. Consumer demand outpaces GDP growth for olefins and aromatics which are basic building blocks for plastics, adhesives and other consumer products. The chemical sector uses energy both as a fuel, representing one third of this segment's demand, but mainly as a feedstock, representing two thirds of this segment's demand; chemical energy demand grows to around 1.5 billion tonnes oil equivalent to 2040.

Sensitivity Testing

Government policy and the pace of market penetration for various technologies could have a significant impact on energy demand. We use sensitivity analyses to provide greater perspective on how changes to our own base *Outlook* assumptions could affect the energy landscape.

For example, we looked at the possible impact of 100 percent EV penetration in light-duty vehicles, along with an associated possible impact on electricity generation requirements. The sensitivity assumed the global light-duty vehicle fleet is 100 percent electric by 2040, requiring all new light-duty vehicle sales to be electric starting in 2025.

In this sensitivity, total liquids demand in 2040 could be similar to levels seen in 2013 as growth in chemicals and commercial transportation would mostly offset a decline in light-duty vehicle demand. Additionally, electricity needed to power a 100 percent all-electric light-duty fleet could increase total electricity demand by about 15 percent in 2040 relative to the base *Outlook*.

Continued investment in liquid supply is needed to mitigate decline and meet growing demand

The oil industry is a depletion business. That means continued investment to develop new liquid fuel supplies is needed to offset natural production decline and meet growing demand. Without investments, we estimate the supply of existing oil naturally declines at a rate of approximately 7 percent per year.

When combined with an expected average annual demand growth rate of approximately 1 percent, the amount of new supply needed every year approaches 7 to 8 percent of the prior year, underscoring the tremendous amount of investment required over the coming decades.

To meet projected demand and offset the impact of natural field decline over the period to 2040, the estimated amount of new oil and natural gas supply is 78 billion tonnes and 59 trillion cubic meter, respectively. This equates to about 16 times the level of oil and natural gas supplies in the year 2016 and highlights the magnitude of the supply challenge facing the industry.

The climate challenge: pursuing a 2°C pathway

Addressing the risks of climate change implies a variety of potential future pathways that could affect supply and use of energy across society. Advancing the application of cost-effective technology solutions will likely be critical to pursue a 2°C pathway, while helping keep energy reliable and affordable.

According to the International Energy Agency (IEA), setting upon a "well below 2°C" pathway in concert with the Paris Agreement implies "comprehensive, systematic, immediate and ubiquitous implementation of strict energy and material efficiency measures [1]. Given a wide range of uncertainties, no single pathway can be reasonably predicted. As a result, many governments, universities and non-governmental organizations are seeking to analyze potential 2°C scenarios or pathways. Such studies may be useful in helping identify options to address climate risks and ensure energy remains reliable and affordable.

A key consideration relates to advances in technology that may influence the cost and potential availability of certain pathways toward a 2°C scenario. Many potential pathways are designed to utilize a full range of technology options, which may have significant benefits for society by minimizing related costs of a dramatic transition process.

Considerable work has been done in the scientific community to explore energy transformation pathways. A comprehensive multi-model study coordinated by the Energy Modeling Forum at Stanford University (EMF 27) brought together many energy-economic models to assess technology and policy pathways associated with various climate stabilization targets (e.g., 450, 550 ppm CO_2 equivalent or CO_2e), partially in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). The review of the assessed 2°C scenarios relative to ExxonMobil's *Outlook* suggests several key takeaways:

The assessed 2°C scenarios generally include significant reductions in coal and growing utilization of carbon capture and storage (CCS) technologies for coal, natural gas and bioenergy. The cost-effective availability and deployment of many different technologies is likely to be critical to ensure reliable, affordable energy while also moving toward a 2°C pathway.

All energy sources remain important across all the assessed 2°C scenarios, though the mix of energy and technology shifts over time. Regardless of any likely demand scenario, market fundamentals are expected to underpin the need for significant, continued investments in new supplies of oil and natural gas.

(1) IEA, "Perspectives for the Energy Transition", p. 57.

Transformation of the world's energy system as envisioned by a 2°C scenario is unprecedented. Therefore, it is understandable that governments, businesses and individuals will exercise care in weighing its potential implications. A key consideration is the significant value for society in providing a full suite of options to ensure that billions of people have access to reliable, affordable and practical energy systems.

Practical solutions to the world's energy and climate challenges will benefit from market competition as well as well-informed, well-designed and transparent policy approaches that deliberately weigh costs and benefits. Such policies are likely to help manage the risks of climate change while also enabling societies to pursue other high priority goals around the world – including clean air and water, access to reliable, affordable energy, and economic progress for all people.

The dual challenge

ExxonMobil is working across its businesses to find effective solutions that meet the needs of society. Since 2000, we have invested more than $9 billion in these and other energy efficiency and low-emission technologies.

In the near-term, we are expanding the supply of cleaner-burning natural gas; transitioning the company's refining facilities to producing higher-value distillates, lubricants and chemical feedstocks; mitigating emissions from our facilities through energy efficiency, cogeneration and reduced flaring, venting, and fugitive emissions, and supplying products that help others reduce their emissions, such as premium lubricants and fuels, lightweight materials and special tire liners. We support Fuels Europe's Vision 2050 as a potential pathway for how the refining industry may evolve in the future.

For the longer term, more technological solutions are needed. The global energy system is massive. The world needs solutions that can scale. ExxonMobil has been a leader in researching and developing potential game-changing energy technology.

That includes researching breakthroughs that make carbon capture and sequestration technology more economic for power generation, industrial applications and possible hydrogen production. We are also developing technologies to reduce energy requirements of refining and chemical manufacturing facilities, and progressing advanced biofuels for commercial transportation and petrochemicals.

In summary, providing reliable, affordable energy to support prosperity and enhance living standards is coupled with the need to do so in ways that reduce impacts on the environment, including the risk of climate change. This is a dual challenge ExxonMobil takes seriously.

This article includes forward-looking statements. Actual future conditions and results (including energy demand, energy supply, the relative mix of energy across sources, economic sectors and geographic regions, imports and exports of energy) could differ materially due to changes in economic conditions, technology, the development of new supply sources, political events, demographic changes, and other factors discussed here and under the heading "Factors Affecting Future Results" in the Investors section of ExxonMobil's website at: www.exxonmobil.com.