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UNCOVERING OIL'S UNKNOWNS

DEBORAH GORDON AND CHRIS MALINS | JUNE 19, 2013

The oil market, which traditionally has been slow to change, is transforming in ways that were unthinkable a few years ago. By 2020, the United States is projected to be the world's largest oil producer as well as its largest consumer and exporter of petroleum products.[1] Almost overnight, a whole new assortment of resource and investment choices has emerged in a field that has long been stuck in familiar patterns. With change, however, comes uncertainty and risk.

The profound shifts in North American oil mean that policymakers must find a way to balance the enormous economic value that oil promises with the equally massive threats it could pose to the world's already-at-risk climate and local environments. A new sense of urgency is building with each freak storm, historic drought, unprecedented flood, incendiary heat wave, and deadly tornado. As such evidence of climate change mounts, future threats are becoming present-day problems. Sophisticated models that predict deviations from familiar patterns are currently blinking red in warning, but there is no way to know whether this will convince policymakers to act.

If there is sufficient impetus to act, fossil fuels will be the primary targets. Combusting hydrocarbons produces carbon dioxide. And oil accounts for a greater share—43 percent—of U.S. carbon dioxide emissions than coal or natural gas.[2] Once released, these carbon dioxide emissions last for centuries, and the climate recovers only slightly over thousands of years. On a global scale, the potential climate impacts driven by the sheer magnitude of oil resources are enormous. And as new oils enter into production, they stand to seriously exacerbate this already-tenuous situation.

Oil must be thought about in a whole new way. That will involve uncovering oil's new unknowns and investigating the technological, climate, economic, and policy uncertainties surrounding the next generation of oil. Filling information gaps and developing robust oil policies will be critical for both America and the world.

FROM OIL SCARCITY TO ABUNDANCE

The current American understanding of oil resources and oil markets has been shaped by long-held principles: oil is scarce, the bulk of the world's oil is held by the Organization of the Petroleum Exporting Countries (OPEC), the United States is dependent on oil imports, the market is destabilized because of high prices, and there are no ready alternatives. But circumstances are rapidly changing. The oil sector is undergoing massive shifts that require Americans to challenge that conventional wisdom and reeducate themselves.

ABOUT THE AUTHORS

Deborah Gordon *is a nonresident senior associate in Carnegie's Energy and Climate Program, where her research focuses on oil, climate, energy, and transportation issues in the United States, China, and globally.*

Chris Malins *leads the Fuels Program at the International Council on Clean Transportation.*

Although there is no way of ascertaining exactly how much oil remains stored within the earth, it is estimated that there is an enormous amount of oil in place—on the order of tens of trillions of barrels. And the majority of that oil is unconventional.[3] North America is currently at the center of this dynamic change, but there is some evidence that this extraordinary transformation will occur in other places as well. Oil resource estimates in China, Russia, South America, and elsewhere are collectively larger than those in the United States.

There is the potential for significant diversity among these new, unconventional oils. They range from tight oils trapped in shale in Texas's Eagle Ford or Western Siberia's Bazhenov formations to semisolid, extra-heavy bitumen bound up in sandstone in Alberta's Athabasca Oil Sands to the dense, degraded oils tied up in carbonate source rock in northern Alberta.[4]

And these oils introduce a host of uncertainties. Physically, these new hydrocarbons can be quite distinct from conventional oil. On one extreme, the heaviest low-quality oils tend to be solid and dense, with high viscosities (they are very resistant to flow) and low gravities (they are heavy relative to water). At the other extreme, some tight oils are made up of extremely light gas condensates with low densities and high gravities. Comparing the different consistencies of extra-heavy and ultra-light oils is like comparing window putty to nail polish remover. These disparities affect oil production, transport, refining, and product yields.

Chemically, the carbon-to-hydrogen ratio in many of these crude-oil substitutes is fundamentally mismatched. The heaviest oils have too much carbon and not enough hydrogen; in the lightest oils, the situation is reversed. New techniques continue to be developed to turn raw hydrocarbons into high-value petroleum products, the economic and environmental costs of which vary.

With all of these unknowns, the need for transparency is clear. Data availability is currently a huge concern. There are not sufficient data available at present to fully illuminate what lies ahead for tomorrow's oils. And the oil industry has generally not been forthcoming with policymakers or the public.

Oil companies are hesitant to divulge any information that could jeopardize their competitive advantage, so proprietary analysis is the norm. For example, the circumstances under which a refiner will run heavy or light oil, turn its coking unit on or off, or shift operations to yield different petroleum product slates form the essence of a company's competitive advantage. Even academic work can be veiled due to the use of proprietary data sets.

There is also a lack of transparency in oil infrastructure. It is unclear how the industry intends to transport oil, whether by rail, pipeline, barge, or a combination thereof. It is also unclear how the variety of oils is accounted for during transport and refining. For example, how can ExxonMobil accurately report the extra-heavy oil that spilled when its Pegasus pipeline ruptured in Arkansas in March 2013? How much diluted bitumen was spilled in Michigan's Kalamazoo River in July 2010? What will be the long-term outcomes of the petroleum coke (pet coke)—a low-quality byproduct that replaces coal in industrial fuel and feedstock—piling up along the Detroit River in the spring of 2013?

The extraction, transport, and processing of oils cannot be effectively managed if these new resources are not better understood and industry practices are not made transparent. Improved monitoring, reporting, and verification of information will be increasingly necessary to ensure that corporate social responsibility is real and credible.

OIL EXPECTATIONS: ECONOMIC AND MARKET QUESTIONS

Since the start of the Industrial Revolution, the world has consumed an estimated 1.2 trillion barrels of oil.[5] It is the world's most traded commodity and has a remarkable array of marketable uses.[6] Today, petroleum can be found in some 6,000 different products, including baby diapers, perfume, paint, and plastic bottles.

How much of the oil currently in place is accessible is a matter of debate, as new resources are constantly being mapped. Calculations of today's economic reserves—those that are technologically recoverable at current prices—are on the order of 6.5 trillion barrels.[7] However, experience suggests that the share of recoverable oil grows as economic conditions and technological innovation change.

Market Transformation

Nobody predicted the extraordinary surge in North American oil production that has taken place. The United States was considered a mature and declining oil (and natural gas) producer, and Canada's production levels were not expected to rise. In the 1970s, high prices precipitated by two oil crises generated concerns about dwindling supplies. A generation later, the technological frontier has ventured into unconventional oil production, starting in North America, in the form of tight oil, oil sands, and deepwater production. Meanwhile, novel technologies, such as gas-to-liquids or coal-to-liquids processes, could create major market opportunities to capture revenues, generate cash flow, and facilitate increased production.

But the precise drivers of market transformation are uncertain. Technology certainly plays a part. The recent breakthroughs in hydraulic fracturing and horizontal drilling—processes in which rock formations are fissured by injecting fluids to force them open—mean that production of resources buried miles deep in continuous rock rather than hundreds of feet can now take place. This makes it possible to recover within a few years what would otherwise have been produced over the thirty-year life of a well.[8]

Oil prices are another highly uncertain factor in market transformation. Industry insiders believe that every big mistake they have made was based on incorrectly predicting oil-price trends a decade or more in advance.[9] Forecasts of oil demand, energy mix, and product consumption are additional uncertainties that are relatively bounded since this behemoth sector has typically been slow to change. But future oil prices are expected to be dynamic, which raises questions for oil investments, production rates, and future innovations.

Changing Risks

The economic pressure to produce oil is enormous. The resources in place in the oil sands alone are worth hundreds of trillions of dollars. This potential value creates inexorable market momentum to develop the next prospects. But there are risks, and they are shifting along with oils themselves.

Investment opportunities for international oil companies have been shrinking in recent years because the conventional oil reserve base is largely nationalized and politically risky. As such, companies are hunting for bookable reserve replacements to bolster shareholder value.[10] Venturing into North America for deep, difficult- and dangerous-to-access, or environmentally damaging oils may ease the political risks, but it raises operational, safety, and environmental hazards.

The repercussions of these developments, such as the impact on climate change, when they are considered by industry at all, are not central to decisionmaking. There is evidence that some international oil companies place shadow prices on carbon to evaluate market risks from future implementation of climate policies,[11] but that is not a universal practice. The limited scope of shadow pricing often only considers the climate impacts of oil extraction and not the major impact from petroleum product combustion. Some in the industry may actually foresee benefits from climate change due to melting Arctic Sea ice that could make new oil production possible. Either way, as the oil industry experiences generational shifts away from climate denial, it is unclear how climate risks will figure into project assessments.

On the other side of the equation, investors, bankers, and insurers involved in oil-development projects have begun to calculate climate risks. Banks, such as HSBC and Citigroup, and the rating agency Standard & Poor's are beginning to think about what a carbon budget might mean for the valuation of publicly traded companies.[12]

Economic risks are also very real. If North American oil production increases too quickly, surplus supplies could flood the market and exacerbate already-large price distortions. Current distortions are driven by asymmetries among production locations, transport capacity, oil types, and refinery capabilities. As more oils enter the market, competition will increase, resulting in greater economic risks for any individual investment.

Infrastructure Investments

More than $1 trillion has already been sunk into oil wells, refineries, pipelines, and service stations in the United States alone. Trillions more will be invested over the next decade. Recent investments in complex refineries in the Gulf Coast and Midwest to handle the lowest-quality oils, such as extra-heavy oil from Venezuela and bitumen from Alberta, are not wholly compatible with new volumes of light tight oils. Further complicating matters, new pipeline capacity is competing with new rail facilities while existing pipelines are reversing direction to balance flows and converting from carrying gas to oil.

Given the wide divergence among new oil resources, it is not clear which oil the industry plans to develop. But what is clear is that all of this retrofitting or shuttering of infrastructure can be difficult, costly, and disruptive. For this reason, it will be imperative to discern how long infrastructure will be in use, what the permit conditions are, and whether future public opinion and public policy might alter today's infrastructure investments before committing to them.

Changing Industry

The industry is changing along with oil itself. International oil companies like ExxonMobil and Shell, which have historically dominated oil markets, have been losing market power to national oil companies. Today, Saudi Aramco, Russia's Gazprom, and the National Iranian Oil Company are the world's largest oil and gas companies. Nationalized oil production currently outpaces that of international oil companies by three to one.[13] But the emergence of tight oil does not play to the strengths of either of these industry leaders. Independent oil companies, like Continental Resources, and firms that typically do not venture into oil, like General Electric, are part of an emerging reconfigured oil sector. Global investors are also investing billions in joint ventures with U.S. firms to learn about fracking technology, develop petrochemical feedstock processing facilities, and transfer complex refining techniques abroad.[14]

Where the industry chooses to operate could also change. In North America, oil development has occurred on private and state lands with private capital. In 2012, total U.S. oil production on private, state, and federal lands amounted to 6.5 million barrels per day, up 27 percent since 2006.[15] Oil production on federal public lands, however, has maintained relatively stable levels, averaging 1.7 million barrels per day since 2006.[16] Still, the federal government owns 700 million energy-endowed acres, 31 percent of the nation's viable oil plays.[17] Questions remain about whether and how much private industry investments will venture into federal lands.

CONFRONTING COMPLEXITY: TECHNOLOGICAL AND CLIMATE QUESTIONS

International, national, and independent oil companies are all wedded to petroleum. Some are shifting back to natural gas, as evidenced by ExxonMobil's purchase of the natural gas giant XTO, making a high-priced, long-term bet on the resource. But it is unlikely that these companies will invest comparable sums in biofuels, solar, wind, or nuclear energy.[18] High oil prices are turning on more oil supplies, not alternatives to oil.

Balancing this oil opportunity against the challenge of staying below the threshold of disruptive global warming will require a much fuller understanding of tomorrow's oils and the energy inputs and carbon outputs associated with their development, conversion, and use.

Changing Production Techniques

There are various ways to extract oil resources. The simplest method involves drilling a well from which oil gushes freely under its own pressure. Unconventional resources, however, need additional measures to be extracted. For example, the heaviest hydrocarbons need heat, or other means of enhanced recovery, to flow. In many fields, steam is injected into the ground to soften the oil and improve recovery. In other cases, electricity, in a process called electric resistive heating, can be passed through soil or fires can be lit in reservoirs containing these oils in order to make them flow. New methods, such as chemical flooding with surfactants and biological recovery that uses microbes to separate oil droplets from other substances, are currently under development.[19]

In the United States, unconventional production techniques—such as hydraulic fracturing and horizontal drilling—are being used to liberate continuous oil and gas resources trapped in impermeable source rocks. These tight oils differ markedly in their compositions, ranging from ultralight oils that resemble natural gas resources to light oil to medium crudes.[20]

The geology of tight oils, which are trapped continuously over vast regions and not pooled in limited locales, affects the long-term production rate of any given play. While each tight oil well tends to deplete more rapidly than a conventional oil well, the potential to drill repeatedly exists. As such, the long-term outlook for tight oil (and gas) production is enhanced by the large magnitude of the resource play and the millions of wells that can be drilled.

Changing Refining Operations

Once they have been extracted, different raw oils require different refining methods to turn them into petroleum products.

When refined, extra-heavy feedstocks produce smaller yields than conventional crude of the valuable oil fractions that make gasoline and diesel. They also create larger volumes of high-carbon residual fractions that require further refining to get the full product value. Refining extra-heavy oils requires removing (referred to as rejecting) carbon—which produces pet coke—or adding hydrogen through hydrocracking. Depending on the refining approach taken, there are vastly different outcomes and environmental impacts.

At the other end of the spectrum, condensates and natural gas liquids are associated with the lightest tight oil plays. These oil feedstocks cannot be handled optimally in the complex refineries set up to deal with extra-heavy oils. The lighter the oil, the better suited it is as a chemical feedstock for petrochemical plants or propane fuel.

Looking ahead, additional refinery changes may be on the horizon. Outside the traditional refining sector, gaseous and solid hydrocarbons can be turned into liquid petroleum products. So-called XTL technologies—shorthand for “X to liquids” and referring to any technology that turns carbonaceous materials into liquid fuels—could turn new stores of shale gas and methane hydrates into liquid fuels or liquefy biomass or coal.[21] These technologies are highly energy intensive and represent even deeper fundamental changes to the carbon equation for liquid fuels.

Life-Cycle Greenhouse Gas Emissions

The emissions that result from extracting different oils (upstream processes) can vary by a factor of ten or more from the lowest to the highest carbon content.[22] For example, production emissions can be low when oil is light, extraction is relatively easy, and gas flaring is strictly limited. In contrast, extra-heavy oil fields that require energy-intensive production methods like thermal oil recovery, fields that flare their associated gas, and fields where large volumes of water are associated with every barrel of oil produced can have much higher production emissions. For such fields, including the Canadian oil sands, Venezuelan extra-heavy bitumen, California thermal production, and high-flaring fields in Nigeria, emissions are estimated to be at least ten times higher than the level the California Air Resources Board has calculated for the least carbon-intensive Californian fields (2 grams of carbon dioxide equivalent per megajoule oil). Moreover, refining heavier oils using complex “high conversion” techniques to maximize gasoline and diesel and minimize residual fuel production can have four or more times the amount of greenhouse gas emissions than simple refining of lighter oils.[23]

The knowledge base for assessing oil life-cycle emissions—that is, the amount emitted from the time of extraction through combustion—is building. Models such as Stanford University’s Oil Production Greenhouse Gas Emissions Estimator (OPGEE) for upstream emissions and the University of Calgary’s Petroleum Refinery Life-Cycle Inventory Model (PRELIM) for refinery emissions provide estimates of energy use and emissions based on reservoir characteristics, production methods, and refinery processes.

But questions remain about additional drivers of oil-processing-derived greenhouse gas emissions. Several resource and operating conditions factor into life-cycle emissions and economic impacts. For example, oils with large amounts of water mixed in are heavier than those with lower water-to-oil ratios, and they require additional equipment to process, take extra energy, raise costs, and increase greenhouse gas emissions. Oils that experience rapid declines in production due to anticipated or unanticipated factors require more input for limited oil output. The inability to handle the natural gas associated with oil production can result in high flaring rates that also increase greenhouse gas emissions. Uncontrolled venting and fugitive emissions during both upstream and downstream processes lead to the release of volatile hydrocarbons, including methane gas, that leak out of equipment. Other factors that can impact emissions include high steam-injection rates, high levels of hydrofracturing, increased use of enhanced oil recovery, use of high-carbon waste byproducts, and changes to refining processes.

OIL POLICY CHOICES

There is an inextricable link between burning oil and climate change that underscores the important choices confronting policymakers. As oil markets shift, there is an urgent need for new policies to deal with the heterogeneous collection of hydrocarbons rushing to replace conventional crude. The full environmental impacts of oil must be addressed upstream as oil is extracted, downstream through the refineries, and through the consumption of petroleum products.

Reducing greenhouse gas emissions requires supply-and-demand strategies that directly and indirectly internalize the external costs throughout the oil supply chain. Prices can be direct, such as a carbon tax, and indirect, such as through cap-and-trade systems or regulations. Getting the prices right will matter—too low and external impacts are not taken into account, too high and the impacts may be economically and politically unsustainable.

Upstream Oil Policies

During the process of exploration and production, industry decides what comes out of the ground and what remains buried based on total marginal costs. Because marginal social costs—such as climate change—are often not fully considered in this decision, policymakers must step in to fill the void.

In California, for instance, the state's Low-Carbon Fuel Standard regulates the carbon intensity of processes that take place between the point at which oil is removed from the ground and its entrance into refineries. The standard requires that any increase in upstream emissions be offset by alternative fuel use or increased upstream efficiency measures.[24] In Europe, the Fuel Quality Directive is intended to distinguish among types of oil feedstock to reduce upstream emissions.

Compiling data on the full range of oils is enormously challenging. In California, regulators have gathered a database of 172 U.S. crudes and 60 from the rest of the world. In Europe, the International Council on Clean Transportation is following the proprietary modeling of over 3,000 fields by developing a database of public domain information.[25] The more that is known about the characteristics of different oils, the easier it is to distinguish their upstream—and downstream—impacts and determine how best to address them.

Downstream Oil Policies

Refining is a major emissions source. It is also the point at which decisions are made about which types of products oil gets turned into—gasoline, diesel, jet fuel, petrochemical feedstocks, or a host of low-quality residual products. California and the European Union have adopted carbon cap-and-trade mechanisms—a combined policy of regulation and pricing—that govern downstream operations.

Emissions vary widely based on oil feedstocks, energy and chemicals added during processing, and refining techniques employed. The heavier the oil, the more carbon intensive refining is. If carbon is not priced, there is no impetus to minimize the production of high-carbon residual—bottom-of-the-barrel—products during the refining process, especially in global markets with fewer existing environmental protections. And that raises questions about how to manage the carbon in byproducts such as pet coke.[26]

Oil transportation and processing connect upstream and downstream activities and are another critical part of oil policy decisionmaking, with the heaviest oils generally resulting in the highest emissions.

Greater transparency and additional policies are needed in the U.S. refining sector since the United States refines more oil than any other nation. As a technological leader, the practices employed at home are likely to be adopted internationally.

Oil-Use Policies

The combustion of petroleum products plays a significant part in the overall carbon equation. While a portion of oil is transformed into noncombustible petrochemicals, the lion's share of petroleum products directly fuels cars and trucks. Today, liquid hydrocarbons provide at least one-half of the world's motorized transport.

The difference between the gasoline used in a vehicle that gets 20 miles per gallon and one that gets 40 is greater than the difference in emissions between refining light oil and bitumen. The more stringent vehicle fuel-efficiency standards recently adopted in the United States will reduce oil demand by 2 million barrels per day by 2025.[27]

Globally, the International Energy Agency estimates that economically viable efficiency measures could reduce oil demand by 13 million barrels a day by 2035.[28] These policies can obviate the need for increased oil production.

The greatest carbon emissions reductions will be delivered by a synergy between reducing oil demand by increasing vehicle efficiency and introducing new policies that govern which oils are produced and what products they are turned into.

Oil-Pricing Policies

Pricing policies that account for the life-cycle carbon impacts of oil are needed. Often policies fall short because carbon leaks into other sectors, such as power or industry, or into other geographies, such as through exports of pet coke. For example, Alberta's carbon tax only applies to extraction emissions and not to the total carbon contained in the bitumen bound up in the oil sands, such as its complex refining needs or high-carbon residual byproducts.

The revenue stream generated through a carbon tax can help reduce America's budget deficit. Pricing carbon can be an enabler for serious tax reform, with the possibility that revenues can be rebated to taxpayers and reinvested in low-carbon infrastructure.

A recent survey shows economists support a U.S. carbon tax of $20 per ton, increasing at 4 percent per year and raising an estimated $150 billion per year in federal revenues over the next decade.[29] An astounding 98 percent of economists surveyed agreed that given the negative externalities created by carbon dioxide emissions, a federal carbon tax at this rate would involve fewer harmful net distortions to the U.S. economy than a tax increase that generated the same revenue by raising marginal tax rates on labor income across the board. In other words, adopting a carbon tax to reduce the budget deficit and burdensome taxes makes economic sense.

Charges must also be assessed for other externalities that are affected by the oil supply chain, including water pollution, solid waste, and habitat protection. Renewed regulatory oversight through the U.S. Clean Air Act, Safe Drinking Water Act, Clean Water Act, and other policies that regulate waste, toxic substances, and carcinogens is urgently needed. A coordinated approach of information and reporting, regulation, and pricing will be required.

But there remain serious knowledge deficiencies when it comes to the full effects of new oils. These gaps in knowledge must be closed on both the supply side and the demand side of the market. Light must also be shed on a number of economic sectors, such as transportation, industry, and utilities, as well as the energy sectors of oil, gas, coal, and renewables on state, national, and international levels.

NEXT STEPS FOR NAVIGATING GLOBAL OILS

The oil sector is betting on the resource it knows, unfazed by the challenges unconventional oils pose as a result of the externalities and uncertainties associated with their supply chains. But if the potentially damaging impacts of these resources are not incorporated directly or indirectly into oil prices, then the welfare benefits of free markets and global trade become questionable.

First and foremost, as global oils proliferate, greater transparency is needed. Developing an oil index that ranks global oils based on their relative life-cycle greenhouse gas impacts will help policymakers prioritize the development of oils, identify which oils pose the greatest climate risks, and heighten competition among oils. Putting oils in rank order could also invite increased transparency to help better characterize aspects of oil and its supply chain that are not currently well understood.

As these oils are ranked, policymakers should set priorities to keep the most carbon-intensive oils locked in the ground as nature's own carbon sequestration plan, reduce the greenhouse gas intensity of petroleum products, and use petroleum as efficiently as possible. In public policy terms, a successful oil strategy depends on differentiating oils by pricing carbon, discouraging the development of high-carbon oils through low-carbon fuel standards, decoupling oil from global transportation demands with vehicle efficiency standards and alternative fuel vehicles, and making sure the next-best use for oil does not result in more carbon dioxide emissions.

As scarcity transforms into abundance and supply choices abound, policymakers need to develop new rules for the next century of oil.

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