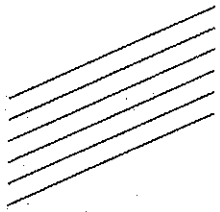
TWO BILLION CARS

DRIVING TOWARD SUSTAINABILITY



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Chapter 5

Aligning Big Oil with the Public Interest

On January 10, 1901, at the Spindletop oil field near Beaumont, Texas, a deafening blast rocketed a column of oil hundreds of feet into the air, wrecking the oil derrick and quickly creating a massive lake. That gusher pumped out nearly 100,000 barrels a day at first, more than the combined production of every other oil well on earth.[1] By tripling U.S. oil production overnight, Spindletop did more than just help push alternative transportation fuels off the table for nearly a century. Together with the birth of the automotive industry, it also launched oil as a premier industry in the United States. Cars and oil became intertwined in a symbiotic relationship.

For many years it was almost exclusively an American affair. As late as 1930, three-quarters of the world's cars and more than 90 percent of the world's oil were being produced in the United States.[2] But as the search for low-cost oil intensified, it soon became clear that most of the world's oil wasn't under U.S. soils. Vast new oil fields were discovered in the Middle East, Africa, and the former Soviet Union. Oil became a global industry. Still, over the past century the large Western investor-owned oil companies—Big Oil—directly or indirectly controlled most of the oil reserves and production in the world. These companies became very good at building huge petrochemical facilities and aggregating massive amounts of capital. Oil became entrenched in the political, social, and economic lifeblood of modern industrialized countries, above all in America. It made possible the dispersed suburbs and far-flung businesses, which in turn became dependent on cheap, plentiful oil.

Now times have changed. The vast majority of the world's conventional oil reserves are no longer controlled by Big Oil, and very little cheap oil is left in the United States and the other rich industrialized nations. The world has uneasily accommodated itself to the reality that more than half of the world's conventional oil is in the Middle East. While oil reserves appear adequate for the time being, access is by no means guaranteed. As global demand for oil grows, Big Oil is looking to fill the gap with unconventional sources of oil and, to a much lesser degree, biofuels. This strategy raises problems. Unconventional oil vastly increases greenhouse gas emissions. And the biofuels option, while promising, does not fit easily with the business approaches and corporate cultures of oil companies.

The oil industry with its large profits is coming under increasing scrutiny, for reasons both environmental and geopolitical. As a result, it's becoming more sensitive to its larger social responsibility. How is Big Oil going to deal with its massive carbon emissions and its increasing dependence on oil from embattled regions? Like the Detroit automakers, Big Oil has come to acknowledge the reality of climate change and the need for a new commitment to energy efficiency and alternative fuels. BP and Shell have been leading the way, with Chevron and finally ExxonMobil following.

But how much is talk and how much is real change?

With conventional oil becoming less available and national oil companies (those controlled by their governments) asserting their dominance, will Big Oil turn to low-carbon renewable fuels or high-carbon unconventional oil? To what extent will the large Western investor-owned oil companies align their business with the larger public interest? With so much at stake and with the oil markets becoming increasingly dysfunctional, government can't sit on the sidelines.

The Changing Oil Supply

The twentieth century was fueled by easily accessible, relatively cheap conventional oil. The world has consumed just over a trillion barrels of oil to date (passing 1.1 trillion barrels in 2007). But the flow of oil is anything but guaranteed—that reality became firmly fixed in the public's mind after the oil supply shocks of the late 1970s—and demand is increasing. Early in the twenty-first century, public discourse became focused once again on running out of oil. From 2003 to 2005, a series of widely read books with titles such as *The End of Oil* and *Out of Gas*[3] were published. Is the world going to

run out of oil, and if so, how soon? The answer is more complicated than one might expect.

How Much Oil Is Left?

First of all, even the experts don't know how much oil is left. Many oil reserve estimates are highly uncertain and premised as much on politics as science. The problem is that most government-owned oil companies, which control the majority of the world's oil, don't disclose field-by-field data, claiming it would put the country's sovereignty at risk. And investor-owned Western companies are reluctant to give away sensitive commercial information. Established companies have been known to manipulate the estimates for their own benefit. Shell's former chairman, Sir Phillip Watts, lost his job in 2004 amid accusations of having "booked his way to the top" by inflating the firm's reserve figures. And these uncertainties don't even consider the question of unconventional oil.

Whatever the true story of recoverable oil reserves might be, what's certain is that oil production has continued to steadily increase. After a hiccup in world oil production in the late 1970s, production increased more than a third from 1980 to 2006, keeping pace with demand. By 2006, worldwide oil production (and demand) was up to 85 million barrels per day and still increasing. With each barrel holding 42 gallons, that means 3.5 billion gallons are sold every day—about a half gallon for each man, woman, and child on the face of the earth (though not all of it used as transport fuels).

While the amount of remaining oil is uncertain, it's widely accepted that at least another trillion barrels of easily accessible oil—what's termed proven reserves—are still left in the ground (see figure 5.1). "Proven" means the oil is extractable with known technology at expected near-term prices. Through 2007, the price used to calculate reserves was less than $50 per barrel. At $70 per barrel, if likely advances are made in finding and extracting oil, at least another one to two trillion barrels of conventional oil would be recoverable globally. And at prices of $150, even more oil could be found. This is just conventional oil we're referring to.

Then there's oil that can be made from unconventional fossil sources, including very heavy oil, tar sands, coal, and oil shale. With oil prices as low as $70 per barrel, still another two trillion barrels of oil could be economically extracted from these unconventional sources—perhaps even more.[4]

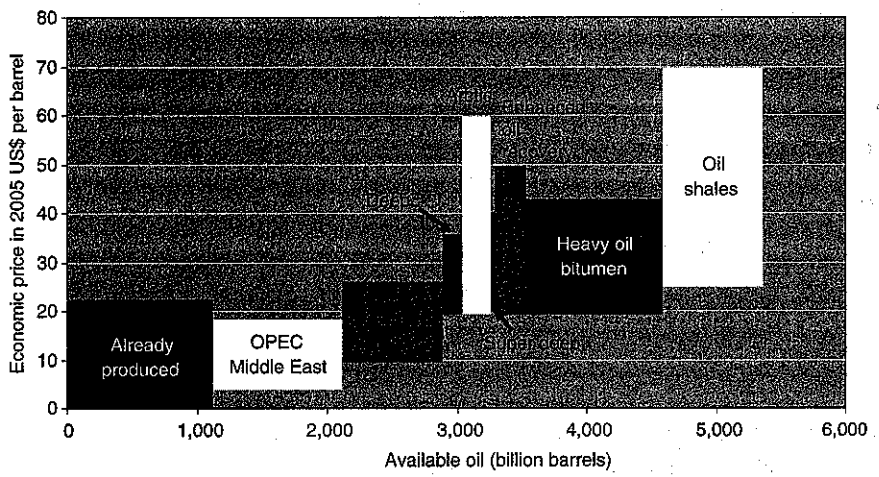

FIGURE 5.1 World hydrocarbon resources, 2005. *Source*: International Energy Agency (IEA), *Resource to Reserves: Oil and Gas Technologies for the Energy Markets of the Future* (Paris, France: OECD/IEA, 2005), figure ES-1.

For the extreme technology optimists, there's another even more bountiful unconventional fossil fuel opportunity—vast amounts of methane hydrates lying on the ocean floor. If ways can be devised to economically extract these frozen methane crystals from the bottom of the sea, an almost unlimited quantity of liquid and gaseous fuels can be produced for our vehicles. Christophe de Margerie, vice president of France's Total, the fifth largest investor-owned oil company in the world, says that new technology will open up the "deep horizons of very strange hydrocarbons."[5]

Keeping Up with Demand: Peaking Pessimists versus Technology Optimists

Virtually every forecast anticipates consumption of oil (conventional and unconventional) increasing from today's 85 million barrels per day to about 120 million barrels in 2030. Is this huge ramp-up plausible, economically and technically, never mind environmentally? Can the oil industry keep pace with growing oil demand? Some very knowledgeable and smart people have sharply contrasting opinions.

Daniel Yergin, who earned a Pulitzer Prize for his widely acclaimed 1991 book on the history of the oil industry, *The Prize: The Epic Quest for Oil, Money, and Power,* and is now chairman of the highly respected energy consulting company Cambridge Energy Research Associates, is a technology optimist. He noted in a 2006 press release accompanying a new report on oil that "this is the fifth time that the world is said to be running out of oil. . . . Each time—whether it was the 'gasoline famine' at the end of WWI or the 'permanent shortage' of the 1970s—technology and the opening of new frontier areas has banished the specter of decline. There's no reason to think that technology is finished this time."[6]

On the other side are Kenneth Deffeyes, Colin Campbell, Matthew Simmons, and others.[7] Deffeyes, a Princeton geologist and author of *Hubbert's Peak: The Impending World Oil Shortage,* is perhaps the most persuasive. These authors argue that the world's production of oil is nearing a peak—that we've run through almost half of all the recoverable oil—and that with peaking, supplies will become more strained, oil prices will become highly volatile, and rapid drop-offs in production will occur.

These peak oil theorists premise their arguments on the work of M. King Hubbert, a famed oil geologist who accurately predicted in the 1950s that oil production would peak in the United States in 1970.[8] Hubbert's approach was based on the notion that oil is finite, that most of the accessible sites have been explored, and that by analyzing reservoirs one can gain a good picture of how much accessible oil is left. It assumes that after peaking, oil fields follow a precipitous decline that mirrors previous increases in production.

But Hubbert's model is flawed, and peak oil arguments that derive from it are overly simplistic. Hubbert's method is based on detailed analyses of reservoirs to determine the ultimate recoverable reserves in an area. His 1956 analysis was correct in predicting when production would peak but underestimated actual production levels by 20 percent. And he was even more inaccurate in forecasting production after the peak. He didn't anticipate the impact of giant discoveries in Alaska and under the deep waters of the Gulf of Mexico. In the lower 48 U.S. states, where Hubbert came closest to accurately forecasting a peak, actual oil production in 2005 was some 66 percent higher than he projected, and cumulative production between 1970 and 2005 was some 15 billion barrels higher, a variance equal to more than eight years of U.S. production at present rates.

The fundamental flaw of the Hubbert model and peak oil analyses is the focus on geology and new discoveries and the failure to appreciate the role of economics and recovery technology. Peak oil theorists emphasize that new discoveries aren't sufficient to replace annual production. But this focus

on discovery ignores the fact that most of the increase in oil reserves comes after discovery—from better understanding the size and location of the oil fields and from development and deployment of improved technology to get more oil out of the oil fields. Just as problematic is the tendency of peak oil advocates to ignore the role of aboveground factors in determining exploration, investment, and production. Consider that more than 60 percent of all producing oil wells in the world are in the United States, even though it has less than 3 percent of the world's oil. This has to do with geopolitics, investment climate, and infrastructure availability.

The role of technology is particularly critical. Not so long ago, drilling was a hit-or-miss affair. Geologists and engineers had only a vague sense of what lay underground. They sent a drill straight down and hoped it perforated an oil reservoir. Now they apply advanced digital technology and seismic testing techniques to map underground oil reserves in extraordinary detail before starting to drill. They can identify oil fields deep under the Arctic and below miles of ocean water. They use robotic drills that can slither horizontally and seek out nooks and crannies. And they inject carbon dioxide and other gases to push out more and more of the oil in those nooks and crannies and at the bottom of fields.

It used to be that many smaller fields were never found, and less than a third of the oil was extracted from those that were. Now the extraction rate is more than 50 percent and still increasing. Moreover, the technology for finding and extracting oil from remote and difficult locations is vastly improved. Now the oil companies can drill miles below the ground and miles below ocean water to find oil.

Many believe the state of oil technology is advancing more rapidly than ever before. With continuing advances in materials, information, and robotic technologies, the opportunity to increase extraction rates from existing fields and to find new fields in deepwater and remote locations is expanding. Don Paul, chief technology officer at Chevron, noted that "the history of the [oil] industry and technology has always been to deliver lower capital and operating costs, extend access to new resources (for example, deepwater and extra-heavy oil) and increase the recoveries from existing production assets. Most in the industry do not believe we are anywhere near the end of this process."[9] The debate over how much recoverable oil is left pivots on this question of technology.

Observing the vast differences of opinion and the importance of the issue, the U.S. National Academies convened a high-level two-day workshop in October 2005 on the future of oil. It was attended by the secretary general of OPEC and by senior government, industry, and academic experts and

leaders. Some, such as Matthew Simmons, argued that world oil production, including Saudi Arabian production, was about to peak, and that many countries and companies were overstating their oil reserves. Robert Hirsch, a former oil company president, argued that an impending oil peak puts the world on the brink of economic cataclysm. Most others, from the U.S. government and industry, were more sanguine.

By the end of the meeting, these broad understandings had largely (but not totally) been accepted:[10]

- The global production profile most likely won't be the simple bell curve postulated by Hubbert but rather will be asymmetrical, with the slope of decline more gradual and not mirroring the rapid rate of increase. The "undulating plateau" of global production may well last for decades before declining slowly.
- Non-OPEC sources of conventional oil will likely peak in the very near future, well before 2020.[11] The lower 48 U.S. states peaked in 1970, and other non-OPEC regions have been peaking in the interim.
- OPEC conventional oil production will peak much further into the future, perhaps as late as 2050. This date is uncertain partly because the OPEC countries are much less explored than the United States and don't share oil field data, and also because national oil companies operating in OPEC and other countries have lagged in using advanced technology. As more technology is brought to bear, oil reserves and yields may increase.
- During the latter years of the "undulating plateau," unconventional oil will replace conventional oil, and will continue to do so in increasing proportions thereafter.

In other words, the more dire forecasts of oil peaking are simplistic and largely incorrect. Those forecasts usually refer only to conventional oil and are conservative about the use of improved technology to recover additional oil from existing fields and to develop new fields. With optimistic assumptions about technology and development of unconventional oil resources, the U.S. Geological Survey[12] and Yergin's company estimate that vast amounts of additional oil could be produced. On top of the 1 trillion barrels of oil consumed through 2005, Yergin's company estimates another 3.7 trillion barrels of conventional and unconventional oil could be produced, more than enough to meet demand beyond the middle of this century (see figure 5.2).[13]

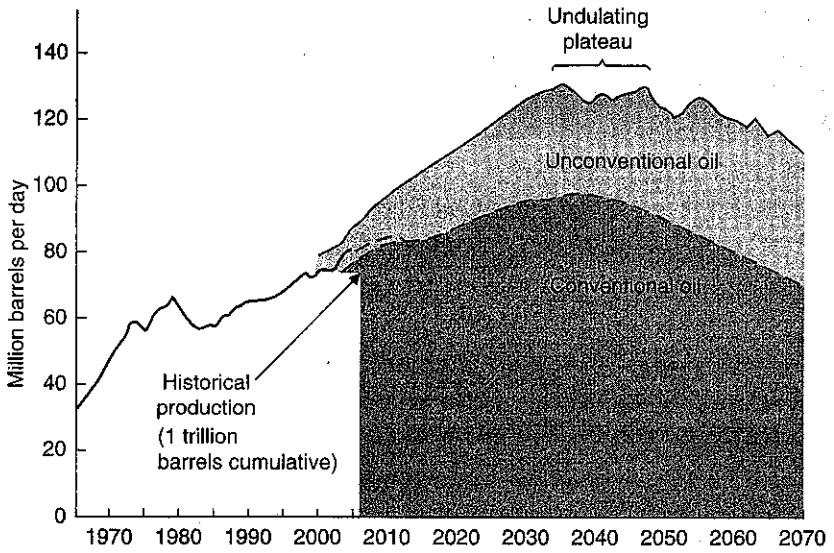

FIGURE 5.2 Oil supply scenario: Undulating plateau versus peak oil. *Source*: Cambridge Energy Research Associates, 60907-9, Press Release, November 14, 2006 (graph adapted by authors).

It appears that the oil industry could indeed ramp up to 120 million barrels and maintain that production level for many decades. Or not.

Much could go wrong. We come back to the two problems highlighted at the beginning of this chapter: conventional oil being concentrated in just a few locations in the world, and unconventional oil being abundant but causing huge environmental impacts. The soaring oil prices in 2008 illustrated the mismatch between production potential and production reality. One oil executive described the situation to us as follows: "Two trillion barrels extractable at $70 per barrel is really like a million bucks in the bank, but being allowed to withdraw only $100 a week." That is what is happening with oil supply. The national oil companies don't have the capability to increase production, the western oil companies control only a small share of oil reserves, and oil rigs and petroleum engineers are in short supply. So, yes, there is plenty of oil still available around the world, but it is not being made available in a timely manner. The root problem, as we will see, is that the concentration of reserves in politically unstable regions means that technical and geological oil peaking becomes less important than political peaking (see table 5.1). Political peaking occurs sooner, due to terrorism, wars, and supplier countries underinvesting, holding back, and even collapsing.

TABLE 5.1 The mismatch between those who have the oil and those who use it, 2006

World oil reserves		World oil consumption	
Country	Share	Country	Share
Saudi Arabia	19.9%	United States	25.1%
Canada*	13.6%	Western Europe	18.9%
Iran	10.3%	China	8.6%
Iraq	8.7%	Japan	6.5%
Kuwait	7.7%	Russia	3.7%
U.A.E.	7.4%	India	3.0%
Venezuela**	6.1%	Canada	2.6%
Russia	4.6%	Brazil	2.5%
Libya	3.2%	Saudi Arabia	2.4%
Nigeria	2.7%	Mexico	2.4%
United States	1.7%	Iran	1.9%
China	1.2%	Kuwait	0.4%
Western Europe	1.1%	Nigeria	0.4%
Mexico	0.9%	Libya	0.3%

Countries shaded black represent 60% of global reserves and consumption, respectively. This excludes unconventional reserves.

*Canada'a reserve share is listed at 13.2% (174 billion barrels), but 12.8% of it is unconventional oil (tar sands).

**Venezuela's estimated reserves do not include heavy oil. If included, Venezuela would move above Saudi Arabia in the rankings to 21%.

Source: Energy Information Administration, *International Energy Outlook 2007*, tables 3 and A5.

The Concentration of Oil Wealth

The problem of oil being concentrated in a few countries has three faces. First, many oil exporters have vulnerable governments that could collapse into civil war. Second, tensions between the Middle East and oil-importing countries could result in still more disruptions. Third, the highly centralized oil infrastructure—pipelines, supertankers, oil refineries—is vulnerable to terrorism and natural catastrophes. How likely are these wars, natural catastrophes, and terrorism? No one knows.

Why are so many oil-exporting nations unstable? Nations that possess oil might seem to be blessed. They are. But oil wealth can also be a curse.[14] Some countries—including the United States, Norway, and Canada—have exploited their oil resource to great advantage, but most have not. The evidence is overwhelming that a massive infusion of oil wealth undermines and weakens the institutional and legal structures needed for a healthy society and a vibrant economy. It undermines the work ethic, reduces government accountability because people aren't taxed, and invites corruption because so much easy money flows through so few hands. The result, all too often, is huge social and economic inequities and autocratic governments—a setup for instability.

The curse is especially debilitating for newly created countries. Most of the African and Middle Eastern countries were newly independent or newly established when they struck it rich. The large revenues that followed negated the need for general taxation. They encouraged massive subsidies that increased dependence on the state. And because the oil industry is capital intensive, it needs only a few workers and managers. The result is a few people controlling massive infusions of wealth, with little employment or business activity generated.

An extreme example is Nigeria, one of the world's largest exporters of oil. Despite the bountiful oil, "it imports all the refined oil products it consumes, its infrastructure is crumbling, and most Nigerians lack access to basic medical treatment and education.... Some 70 percent of Nigerians must get by on $1 a day.... Electricity is scarce, and clean water is rare."[15] The United Nations ranked Nigeria 159 out of 177 in human development in its 2006 report. Corruption is rampant. The country's Economic and Financial Crimes Commission estimates that $400 billion has been wasted since 1960. Some 60 percent of its northern college graduates are reportedly jobless. The Niger Delta, where most of that country's oil is produced, generates 80 percent of its GDP from oil, yet is among the poorest and most miserable areas of that already poor country.[16]

The oil curse isn't just a local curse. It's also a global curse. It flows beyond local borders to threaten the entire world. Columnist Thomas Friedman asserts that "the biggest threat to America and its values is not communism, authoritarianism, or Islamism. It's petrolism... my term for the corrupting, antidemocratic governing practices in oil states from Russia to Nigeria and Iran."[17]

The concentration of oil resources results in massive transfers of wealth between nations—an estimated $7 trillion in excess profit transferred from

consumers to producers over the past 30 years, including about $340 billion in OPEC oil export revenues in 2004 alone.[18] When prices topped $100 per barrel in 2008, OPEC's oil revenues exceeded $1.25 trillion annually.[19] This massive transfer creates global tensions and tempts the fortunate few who gain control of the oil to create authoritarian regimes, indulge dangerous fancies, and create strong militaries to entrench their power. All too often, especially when oil prices are high, the result is militarization that causes trouble around the world.

On top of that, oil importers are forced into problematic alliances with petroleum-rich totalitarian and rogue regimes. Witness America's flip-flops in Iran and Iraq. First it allied itself with the Shah of Iran against Iraq until he was overthrown by Ayatollah Khomeini. The United States then switched sides and helped Saddam Hussein fight Khomeini. Then it turned on Hussein, and found itself mired in Iraq's civil war and terror. These machinations had everything to do with the vast amounts of oil lying beneath the soil of these two neighboring countries. Alan Greenspan, longtime head of America's Federal Reserve Board, notes in his 2007 book, *The Age of Turbulence,* "I am saddened that it is politically inconvenient to acknowledge what everyone knows: the Iraq war is largely about oil."[20] Kevin Phillips, political commentator and former Republican strategist, adds, "Today's United States, despite denials, has obviously organized much of its overseas posture around petroleum, protecting oil fields, pipelines, and sea lanes."[21]

Other nations have done the same. For instance, China's dependence on oil and gas imports from Sudan and Iran had much to do with its resistance to international efforts to stop atrocities in Darfur, Sudan, and to restrain Iran's nuclear ambitions.[22]

In the end, though, the world's biggest problem may not be the geopolitics of oil. It may well be oil's ugly brethren: heavy oil, tar sands, and oil shale, commonly lumped under the label of unconventional oil.

Unconventional Oil: Savior or Disaster?

While the public eye has been drawn to debates over peaking oil and alternative fuels, while Midwest farmers have been lobbying for ethanol, and while President George W. Bush has become fixated first on hydrogen and then on biofuels, what increasingly attracts the interest and investment dollars of Big Oil is something that's rarely mentioned in the media or public discussions—high-carbon unconventional oil.

The big oil companies are seeing their most secure reserves dwindle—those located in open economies such as the United States, Canada, and the European Union. They're losing control of oil reserves elsewhere as oil-rich countries increasingly turn away outsiders and nationalize oil reserves under the control of their state-owned companies. The large international oil companies need to replace these resources to survive. Their solution is to embrace unconventional fossil energy—to convert tar sands, heavy oil, coal, and oil shale into liquids. These unconventional sources of fossil energy are available in abundance in North America, Asia, and some other non-OPEC countries. These resources can be converted into petroleumlike transportation fuels. It's already happening. It fits perfectly with the corporate culture and core capabilities of Big Oil, since building huge petrochemical facilities and aggregating huge amounts of capital are exactly what's needed to develop unconventional oil sources. But there are big downsides to unconventional fossil sources: they pose dire environmental threats, including a surge in carbon dioxide emissions.

First some background on unconventional fossil oil, before we look at its environmental cost.

Prelude: The Synfuels Debacle

Today's oil situation is in some ways a replay of the 1970s. It was widely believed at that time that the end of the oil era was approaching. Even Big Oil was convinced. In 1979, President Carter, with enthusiastic support from the oil industry, unveiled a massive $88 billion program (roughly $260 billion in today's dollars) to develop alternatives to petroleum—then known as synfuels and now as unconventional oil.[23] The oil industry ramped up its investments in synfuels, ultimately spending tens of billions of dollars of its own money. Huge mines and process plants were constructed. Entire towns were built to house workers.

In 1980, when synfuels mania reigned, it was widely believed that oil prices would continue to ratchet up, perhaps even surpassing $200 per barrel (in today's dollars). They didn't. High oil prices motivated the development of better oil production techniques and reduced demand, eventually causing oil prices to crash in December 1985. In the end, most synfuel investments were abandoned. One ghost town was later resurrected as a retirement community. Even much of the technology was eventually abandoned as too costly and too environmentally destructive. It was an economic and environmental disaster—and an instructive lesson. That debacle is seared into the minds of oil executives. The resurrection of synfuels as unconventional oil is proceeding more cautiously and more environmentally than during the synfuels era.

Tar Sands: A Viable Canadian Industry

The only successful venture to emerge from the synfuels frenzy was oil production from tar sands, renamed "oil sands" by Canadians who wish to burnish their image. Almost all the economical tar sands in the world are located in Alberta, Canada. The venture started small. By 1990, about 400,000 barrels of fuel per day were being produced. As the processes were improved and costs reduced, and especially after oil prices started rising at the turn of the twenty-first century, investments accelerated. By 2003, production was up to 1.1 million barrels a day, with plans to ramp up to 5 million by 2030. Counting tar sands as part of the oil reserve base, as Canada now does, pushes Canada into second place in the world in proven and recoverable oil reserves, with 179 billion barrels, trailing only Saudi Arabia (see table 5.1).

Tar sands are actually bitumen, a tarlike substance mixed with water, clay, and sand. Bitumen feels and smells like cheap asphalt and is difficult and expensive to recover. The large oil companies, most notably ExxonMobil, Shell, ConocoPhillips, and Chevron, have formed joint ventures to extract and process the tar sands. Tar sands production has been steadily increasing for many years. Significant amounts were produced even when oil was priced at $20 a barrel in the early years of this century, suggesting it was profitable even at those prices. Now production costs are increasing as a result of the rising costs of equipment, labor, and the natural gas used to heat the tar to extract it. Nevertheless, increasing oil prices have made tar sands production highly profitable.

The environmental costs are also massive. Extracting oil from sand disturbs the surrounding land and requires gargantuan amounts of energy and water.[24] Most mines initially were open pit mines. Now the oil companies are developing underground processes (known as in-situ) to extract deeply deposited tar sands without digging them out. They inject steam to heat the tar sands, which allows the substance to flow freely. But enormous amounts of water and energy are necessary to heat and combust the bitumen and extract it as a liquid. The energy needs for extraction are so vast that construction of on-site nuclear reactors is under serious consideration.[25] In addition, drinking water supplies are at risk, and restoration of mined areas

is extremely difficult due to the fragility of the land, the sheer volume of waste sludge produced, and the high levels of salt remaining from the waste streams.

Most troubling is the enormous amount of carbon dioxide produced. About 40 percent more greenhouse gases are emitted when extracting and refining a gallon of gasoline and diesel fuel from surface mines than when extracting and refining gasoline and diesel from conventional oil. And when fuels from tar sands are produced in-situ (or in place) deep within the earth, as they increasingly are, the emissions are a whopping 60 percent greater. Taking into account the full energy cycle, from "well to wheel," the increase in greenhouse gases per vehicle mile traveled is about 15 percent.[26] These emissions can be reduced by using nuclear energy to power the process and by sequestering some of the carbon, but at significant cost.

The reason millions of barrels of unconventional oil from tar sands are being produced in Canada, while extra heavy oil languishes in Venezuela (as described next), has everything to do with the business and political environment. The costs are roughly comparable. Oil companies prefer to invest billions of dollars in Canada because they're certain their facilities won't be nationalized. They're certain the government won't abruptly increase royalty rates or impose other costly conditions. They know there won't be a revolution or a civil war. They face market risks with tar sands in Canada, but not political risks.

Very Heavy Oil: Inconveniently Located in Venezuela

About 85 percent of the economical sources of very heavy oil are in Venezuela. Venezuela claims reserves of 250 billion barrels, an amount similar to Saudi Arabia's conventional reserves. Other regions have this tarlike oil but not so concentrated as in Venezuela. Very heavy oil is an extreme version of petroleum—the densest and most viscous, as thick as honey or even peanut butter. Heavy oil that's less dense is extracted in many locations, including California.[27] But the heaviest and densest oils are far more plentiful.

Development of extra heavy oil has been delayed mostly because of where it's located. Production requires sophisticated technology and very large long-term investments. The national oil company in Venezuela has limited technical capability to extract and process this dense and viscous oil, and the large Western oil companies are reluctant to invest where governments are unreliable or unstable. Venezuela produced about 500,000

barrels per day of very heavy oil in 2006, about a fifth of the country's total oil production.

Oil Shale: Inconveniently Located in the Arid and Fragile Mountain States

Oil shale—rocks in which unmatured petroleum is embedded—is even more abundant than tar sands. The largest and densest concentration is found in the Colorado River Basin of the western United States, in Utah, Wyoming, and Colorado. Much smaller reserves are found in many regions around the world, including Russia, Brazil, Estonia, Jordan, and Israel. Oil shale is the most uncertain of all the unconventional oil sources, largely due to its location in these arid and fragile areas.

The vast oil shale reserves have been well known for many years. President Taft created the Naval Oil Shale Reserve before World War I to provide fuel for the navy, and President Carter's synfuels program in the early 1980s featured oil shale. Several of the largest oil companies each have invested a billion dollars or more in oil shale over the years. But after all that, the only production has been from small pilot plants. A new miniboom is under way, though. Shell, Chevron, and little-known private companies are investing in entirely new techniques to produce the oil.[28] They've rejected the high-cost, environmentally destructive mining techniques used earlier. Now they're experimenting with heating the oil underground, sometimes for years, and then extracting the liquids.[29] Shell hopes to begin large-scale production before 2020.

The goal of these modern techniques is to reduce costs, water needs, land devastation, and leaching of toxic materials into the groundwater. This last concern is especially critical in the arid Southwest. Any contamination of the Colorado River would devastate the region, which depends on the water for irrigation and household use. Another challenge is how to limit—and sequester—the very high greenhouse gas emissions that will be produced.

Coal: Conveniently Located Near Growing Demand

Coal is the most extensive fossil energy resource on earth. Like petroleum, coal encompasses a wide diversity of materials, from peatlike soft, low-density materials to very hard, dense rocks. What's especially intriguing about coal is that the largest reserves are located in nations with huge and expanding

energy demands—the United States, China, Russia, and India. Bound up in the very bedrock of the planet, coal is far more difficult to transport than oil and therefore has played second fiddle. But it can be mined at very low cost and thus is attractive if used or converted to more portable forms near its source. To replace petroleum as a vehicular fuel, coal must be converted into a liquid or gas. German scientists developed two different methods to do so in the 1920s.

One approach is to gasify the coal and then synthesize the gases into liquids that approximate gasoline and diesel fuel. An attraction of this process is that the CO_2 can easily be separated from the waste stream and thus captured at relatively little cost. The two key pieces of this technology pathway, coal gasification and gas synthesis technologies, are well known and have been commercialized. Coal gasification is employed to make methane that can be used to generate lower carbon electricity, and gas synthesis technologies are utilized by a variety of major oil companies to convert natural gas into high-quality liquid fuels.

South Africa refined coal gasification and synthesis processes during its apartheid era. The cost of making fuel from coal in this manner was huge, far greater than the world price of oil, but because the country was isolated by United Nations sanctions it had little choice. Liquid fuels made in this way eventually filled upward of 35 percent of South Africa's domestic petroleum needs.[30] In the United States, a large commercial plant was built in North Dakota during President Carter's synfuels era to gasify coal into natural gas—the front end of the process to produce liquid fuels. This plant was the only large commercial facility built during the synfuels program, and it still operates today. More recently, the George W. Bush administration committed funds to construct a billion-dollar demonstration plant to gasify coal and convert it into a variety of gases and liquids, adding a special feature on the back end—carbon capture and sequestration; but plans were suspended in late 2007 when costs skyrocketed.

The second "direct liquefaction" approach, which is less advanced than the gasification-synthesis processes, uses high temperatures and pressures to convert coal directly into liquids. A variety of different techniques are possible. Some were pursued during the Carter synfuels era. China is following up with refinements of those designs and with its own new designs.

From an environmental perspective, gasification-synthesis is more attractive than direct liquefaction. With gasification, CO_2 and impurities can more easily be captured and removed, making it possible to sequester the carbon.[31]

Carbon capture is more difficult and costly with the direct liquefaction processes. Of course, even if CO_2 is captured, the challenge remains for finding a safe and easily accessed underground location to sequester it.[32]

Challenges Posed by Unconventional Oil

Unconventional oil poses a variety of challenges. It can be expensive to extract (though it's anticipated that much of it can be produced at less than $70 per barrel). It also has a huge environmental downside—in most cases it contains high levels of nitrogen, sulfur, and heavy-metal contaminants, and its mining and processing consumes huge quantities of water and energy and causes extreme damage to surrounding ecosystems. Of special concern are the vast amounts of CO_2 that would be released, ranging from perhaps 15 percent more CO_2 per gallon of gasoline from very heavy oils and tar sands to at least 100 percent more for fuels made from coal.

Nevertheless, the transition to unconventional oil is already under way. Most of the Western oil majors are plowing big money into tar sands, shale, heavy oil, and coal. Some national oil companies are as well, including Venezuela with heavy oil and China with coal. The transition to unconventional oil promises to be smooth in an economic and technical sense, since there's no break between the cost of producing conventional oil and unconventional oil, with some unconventional oil costing less to produce than some conventional petroleum. The amount of unconventional oil that can be recovered at $70 per barrel is uncertain but is vast by any measure—far more in volume than all the conventional oil produced in the world to date.[33]

The transition will continue and likely accelerate, not just because of economic factors but also, as we will see, because oil company culture and business approaches favor unconventional oil over biofuels, hydrogen, and other renewables. One oil industry expert, Professor Emeritus Peter Odell from the Netherlands, winner of the 2006 OPEC Award from the International Association for Energy Economics, suggests that by 2100 the oil industry will be larger than in 2000 but up to 90 percent dependent on unconventional oil.[34]

The story on oil supply, therefore, is that the world won't run out of oil for a very long time. But the price tag for this oil addiction will be far greater than the $100 or more per barrel that we might pay. The real price we eventually pay will have much to do with increasing dependence on a small number of unreliable suppliers for conventional oil and the *recarbonization* of

the transport energy system with unconventional oil. Thus, the reasons to get off oil have as much to do with climate change as dwindling supplies and geopolitical instability. As Sheikh Zaki Yamani, Saudi Arabian oil minister for three decades, is reputed to have said in the 1970s, "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."

The Changing Oil Industry

When the simmering public debate about running out of oil again heated up in the early twenty-first century, oil industry executives largely dismissed these concerns. They vividly recalled the synfuels debacle of the early eighties. They recounted how high oil prices inspired conservation and improved oil production technology. But in 2006, oil industry thinking reached a turning point when Big Oil executives realized that they were well on their way to losing control of the oil supply and that even with high oil prices, continued economic growth around the world was likely to boost world oil demand even higher than they had anticipated.

There was no single event that can be pinpointed as the turning point. It was the culmination of a process begun in about 1998 when OPEC held back investments to push oil prices higher. But the events of 2006 removed any doubt that it was a new world. The large Western oil companies observed civil war in Iraq, instability and corruption in Nigeria, Venezuela's aggressive renegotiation of contracts with foreign oil companies, and Russia's takeover of its largest (at the time) private oil company, Yukos.

Unlike Detroit, Big Oil isn't headed for financial trouble anytime soon. It has turned in record high profits in recent years. But it *is* faced with a disturbing reality: it's losing access to low-cost conventional oil. For reasons best understood by tracing changes in the oil industry and the oil market over time, this serves only to encourage its embrace of unconventional oil regardless of the huge social and environmental costs.

Emergence of the Oil Giants

The U.S. oil industry grew out of John D. Rockefeller's Standard Oil Company.[35] Rockefeller formed the company in 1870. He was remarkably successful in linking the entire stream of oil activities, from upstream oil fields to downstream refineries and fuel stations. He focused on reducing costs to a

bare minimum and building profit through volume. Standard Oil, organized as an opaque "trust," eventually garnered 90 percent of the U.S. market and much of the international market as well.

But Rockefeller proved too successful, a ruthless businessman who cut too many corners. He undercut prices of smaller competitors and bought them out on terms favorable to himself. He did anything he could to crush competition and create a monopoly. Having done so, he was so audacious he exacted transportation rebates from railroads for not only his oil but also his competitors' oil! No trust was bigger than Standard Oil. In 1913, Rockefeller's net worth was said to be equal to 2 percent of the U.S. economy—nearly $190 billion in today's dollars.[36]

It wasn't to last. Opposition to U.S. trusts mounted, fueled by Americans' distrust of monopolies. In 1911, Standard Oil was broken up under U.S. antitrust laws into eight smaller integrated oil companies, which remained divided throughout most of the twentieth century (see figure 5.3).

Meanwhile, European companies were beginning to explore for oil as well. In contrast to American companies who had access to abundant oil in their home country, European oil companies planted roots outside their continent—mostly in the Middle East. British Petroleum, now known as BP, started in 1908 in the Middle East as the Anglo-Persian Oil Company and

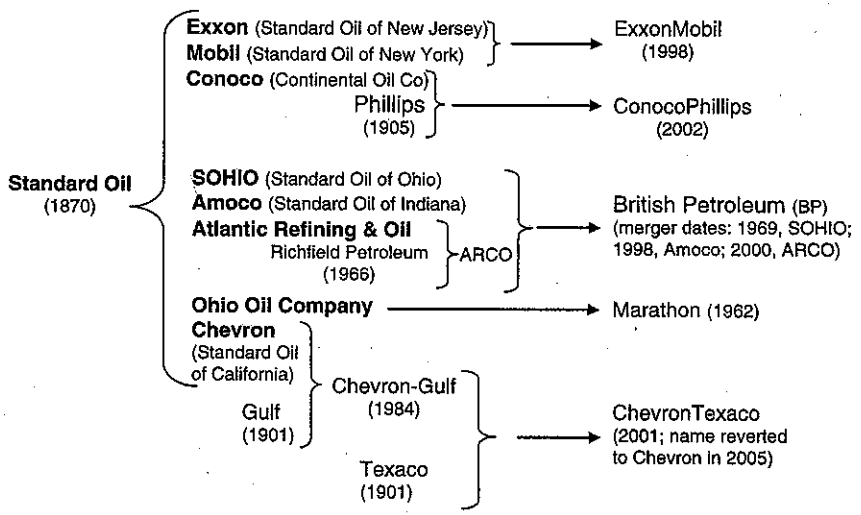

FIGURE 5.3 Breakup and reconsolidation of U.S. oil companies. Note: Bolded companies were part of Rockefeller's original Standard Oil.

didn't begin producing oil in Europe until the 1950s. In 1969, BP made its first foray into the United States, acquiring Standard Oil of Ohio (SOHIO). In 1998, it acquired the U.S. company Standard Oil of Indiana (Amoco) and in 2000 added ARCO of southern California. Royal Dutch Shell has similar international roots. Starting in London in 1892 with Russian petroleum stocks, the British-Dutch company then moved to Romania, Egypt, Venezuela, and Trinidad for production. Shell consolidated its interests in the United States in 1922 by acquiring the Union Oil Company of Delaware. Not until the 1970s did it begin pumping oil close to home in the North Sea of Europe. The third European oil goliath, Total, was founded in 1924 when the French assumed shares of the Turkish Petroleum Company. It first developed oil fields in Iraq and then Algeria, and now relies on oil fields in Africa and Russia.

After the breakup of Standard Oil, the oil industry became quite diffuse, only to begin reconsolidating in the latter part of the twentieth century. This reconsolidation accelerated in the 1990s, with the pieces of the old Standard Oil merging into three U.S. companies, plus parts of BP. The same happened in Europe.

The large Western oil companies are now among the largest companies in the world, dwarfing the budgets of many countries (see table 5.2). ExxonMobil is the largest, with $390 billion in revenue in 2007—four times the budget of the State of California.

Big Oil's Loss of Control of Oil Supplies

The mammoth size of the Western investor-owned oil companies is misleading in one important way. They used to directly or indirectly control virtually all the oil reserves and production in the world. Now they control less than 10 percent.[37] ExxonMobil, although the largest investor-owned company in the world, amazingly is only the fourteenth largest oil company in terms of oil reserves. The other large Western oil companies—BP, Chevron, and Shell—rank seventeenth, nineteenth, and twenty-fifth.[38] The remainder of the oil is controlled by a variety of companies that are owned or claimed by their national governments. We refer to these other companies as national oil companies, even though a few have minority ownership by private corporations.[39] In 2006, these national oil companies controlled 80 percent of the world's proven oil reserves (895 billion barrels), with investor-owned companies controlling 6 percent and the remaining 14 percent controlled

TABLE 5-2 Financial standings of major private oil companies, 2007 (billions of US$)

Oil company	Revenue	Total net income
ExxonMobil	$390	$41
Royal Dutch Shell	$356	$31
BP	$284	$21
Chevron	$204	$19
Total	$200	$19
ConocoPhillips	$172	$12

Source: CNNMoney.com, accessed September 17, 2008.

by Russian companies and joint ventures between Western and national oil companies.[40]

The oil-exporting nations have been squeezing access to their oil. In Saudi Arabia, Aramco continues to control exploration and production with a tight fist, limiting Shell and Total to gas exploration only in remote areas. Russia limits foreign ownership of energy ventures and access to pipelines. It sent a clear signal of its intentions when it presented BP in 2005 with an arbitrary $1 billion tax bill[41] and in 2006 when it stripped Royal Dutch Shell of majority ownership of Sakhalin, the largest combined oil and natural gas development company in the world at the time. In recent years, Bolivia, Venezuela, and Ecuador all have boosted government shares in foreign-led oil ventures and raised royalties and taxes more than 80 percent on major gas fields.

Big Oil is plenty worried. As Paul Roberts asserts in his book *The End of Oil,* "From the standpoint of an oil company's long-term profitability, this inability to... replace reserves is akin to a diagnosis of cancer—and the industry knows it.... The market now watches company production numbers and so-called reserves-to-production ratios—or how many years a company's reserves will last—as closely as it used to watch profits."[42]

The scramble to secure oil supplies isn't just a problem facing the Big Oil companies of the West. It faces all oil importers, including national oil companies in countries with less-abundant supplies. Petrobras of Brazil, for instance, has been investing in politically unstable regions of Nigeria and the Persian Gulf. The national oil companies in China and India, with little oil available at home, are also vying to lock in reserves in Africa, the Middle

East, and Canada. The chairman of China's National Offshore Oil Corporation asserted, "Technology I can get. Money I have. But if you don't have reserves and production, nobody can help you."[43]

Dave O'Reilly, CEO of Chevron, has voiced concerns about long-term alliances forming between Asian and Middle Eastern governments, arguing that it's "very important that [the U.S.] government recognizes and understands the implications of that."[44] These sentiments expose Chevron's fears of being outbid by China, India, and others for the shrinking pool of world oil reserves. For now, though, the Exxons and Chevrons of the world make large profits from high oil prices, especially from the oil they directly control. But over time, as they're forced to bid for shrinking supplies, profits will subside—unless they shift their business. Unfortunately, the world oil market and policymakers aren't working to encourage them to shift their business toward low-carbon renewable fuels.

The Dysfunctional Oil Market

High oil prices in the 1970s and early 1980s had two profound effects. They motivated the development of better oil production techniques and they reduced demand. Oil companies invented new and better ways to find and extract oil. Electricity producers switched away from oil. Automakers built more efficient cars and consumers bought them. The market was working.

Government policy helped on the demand side. The U.S. government imposed fuel economy standards, gas-guzzler taxes, and a 55-mph speed limit. Oil prices eventually plummeted in December 1985 from $28 per barrel to $12 almost overnight. The oil crisis passed at least temporarily for oil-importing countries such as the United States. From the mid-1980s until 2005, oil prices remained below $30 a barrel.

In recent years, oil markets have been among the most distorted and flawed in the world. Oil prices have little relationship to cost. Retail fuel prices are determined mostly by politics, with taxes guided by government budgets. Rising world oil prices take a long time to dampen oil consumption, inspiring only modest investment in oil production and motivating a lot of talk about alternative fuels but little investment. The market is so distorted and unpredictable that even the oil companies are befuddled. ExxonMobil CEO Rex Tillerson quips, "If I knew [what the price of oil would be], I'd be living on a Caribbean island with my flip-flops and a laptop, working just two hours a day."[45]

As oil began ratcheting up to $100 per barrel in 2007 and surpassed that benchmark in 2008, it was still costing less than $10 per barrel to produce in most locations and, with the exception of oil from tar sands, almost never more than $30. Gasoline was selling for more than $10 per gallon in some countries and as little as $0.07 in others.[46]

As distorted as the market already is, it's only getting worse. No wonder politicians keep investigating oil companies. U.S. Senator Byron Dorgan (D-North Dakota), a leader in energy policy, theatrically charged in 2006, "These major oil companies have hooked their hose up to the pocketbooks of American citizens and are sucking money from ordinary Americans into the treasury of the giant oil companies."[47]

Dramatized and largely inaccurate characterizations such as this reflect the poor public image of oil companies. Standard Oil's ruthless quashing of competition more than a hundred years ago created the lasting image of oil companies as large, ravenous predators that ignore the public interest. Although Rockefeller himself always lived modestly and later became a generous philanthropist, his company's rapacious ways bestowed a legacy that persists to this day. Oil companies remain an icon for the worst excesses of capitalism, even though the world of energy is very different now.

Modern oil companies aren't monopolists and they don't earn obscene profits. Oil profits are about average based on their revenue and investments, and they are far smaller than those for industries such as pharmaceuticals and information and computer technology.[48] Whenever oil prices spike and a new round of price-gouging investigations is launched, the companies are found innocent of wrongdoing. By any measure, oil companies are managed responsibly and are remarkably efficient at delivering uninterrupted supplies of conventional oil products to consumers.

If Big Oil isn't responsible for the flawed oil market and what seem like extortionate prices, then who is? The first place to look is the OPEC cartel. OPEC, the Organization of Petroleum Exporting Countries, was established in 1960 by Iran, Iraq, Saudi Arabia, Kuwait, and Venezuela. It later expanded to include Algeria, Indonesia, Libya, Nigeria, Qatar, and the United Arab Emirates.[49] OPEC's formation was part of the 40-year struggle by oil-rich nations to reclaim ownership of their resources. Until OPEC came into being, U.S. and European companies extracted oil from the Middle East, Africa, and Latin America with minimal benefit and compensation to the local countries.

In late 1973, OPEC made a big splash with its oil embargo. Since then, however, OPEC has largely shed its revolutionary behavior, throwing its

considerable weight into moderating prices. When prices soar, OPEC has historically tried to dull price spikes by increasing production.[50] It did exactly that in the early 1980s, and indeed oil prices tumbled, stranding billions of dollars in synfuel investments and stalling vehicle fuel economy improvements. Adel al-Jubeir, foreign policy adviser to Crown Prince Abdullah of Saudi Arabia, offered this frank assessment to the *Wall Street Journal* in 2004, just as oil prices began to increase sharply: "We've got almost 30 percent of the world's oil. For us, the objective is to assure that oil remains an economically competitive source of energy. Oil prices that are too high reduce demand growth for oil and encourage the development of alternative energy sources." In 2005, it ramped up oil production, from 8.8 million barrels per day in 2002 to 11.1 million, hoping to slow the steep rise in oil prices.[51] What's surprising, especially to Saudi Arabia, is that global oil consumption hasn't curtailed significantly even as oil prices topped $140 a barrel in mid-2008. Major changes are beginning to happen, but slowly. SUV sales are down and commuters are seeking alternative ways to get to work. Oil consumption flattened in the United States for the first time in three decades. Yet demand continues to increase in China, India, Russia, and other high-growth economies.

The cartel has also been wary of low prices over the years. When prices tumble, OPEC tries to reduce production so as to create a price floor. It now plays the role that Big Oil did earlier: it imposes price and production controls to moderate the oil market. Or at least it tries to. In any case, while it seeks to maintain relatively high prices, it doesn't seek to maximize prices. It wasn't OPEC that pulled oil prices into the $100 range. The principal cause of the dysfunctional market isn't the OPEC cartel itself. Then who and what *is*? Why do high oil prices fail to significantly reduce demand and fail to stimulate investment in alternative fuels? Three sets of actors are responsible.

First, it's the individual countries that belong to OPEC, together with their nationalized oil companies. It started with the first price hike in 1973. Oil revenues grew so fast and so much that oil-producing countries were wallowing in money. They had the flexibility to ramp production up or down to enforce OPEC policy. No longer. They've become so dependent on oil revenues that they can no longer reduce production when prices are low, nor do they have the capacity to expand production when prices are high. By 2005, spare capacity was globally at a twenty-year low.[52] Whether prices are high or low, they continue pumping what they can. By 2006, even Saudi Arabia, which was the foremost swing producer, able and willing to quickly

ramp production up or down by millions of barrels per day, was becoming more constrained. It has less budgetary flexibility to ramp down and lacks the large excess capacity to ramp up.[53] The oil-producing countries in general find themselves in a situation where they're reluctant to reduce production and therefore revenues, and for internal political reasons they haven't invested enough in expanded capacity.

The slippery slope of underinvestment was greased by the nationalization of oil resources.[54] The national oil companies' first priority is to serve their political masters. They're viewed domestically as cash cows, with most of the revenue being used to run the national government. In 2006, the Venezuelan company, Petroleos de Venezuela, spent two-thirds of its revenue on social welfare rather than oil-related activities.[55] From 2001 to 2006, it reported doubling its spending on "social development" to $13.3 billion and increasing employment by 29 percent while allowing funding of exploration to trail well behind that of other international oil companies. Production slowly declined from more than three million barrels per day in 1998 to an estimated 2.5 million in 2006. Even Mexico, a country with a large diversified economy, siphoned $79 of $97 billion in total oil revenues into the country's general budget in 2006—with the $79 billion accounting for 40 percent of the government's total budget.[56]

While the desire of a country to retain control of its most valuable resource and use it to enhance the lives of its people is legitimate, the end result of nationalization has been less innovation and less investment. National oil companies invest much less than Big Oil in improved oil production technologies. And thus they're less able to expand production, even when prices rise. Nationalization has also led to oil companies and consumers outside OPEC facing a dearth of information about the vast nationalized segment of the industry, which creates a cloud of uncertainty that further discourages investment.

Without shareholders, a probing government, an inquisitive media, and public interest groups, there's no incentive for oil nations to change. The net effect is that the oil-producing nations and their national oil companies are now largely unresponsive to world oil prices, barely adjusting their production volumes regardless of the world oil price (and regardless of what OPEC as a cartel might desire).

A second player in the dysfunctional oil market is Big Oil. While the large Western oil companies are innovative and competent, they are part of the problem, largely because they have become unresponsive to prices. Until

about 2005, Big Oil was using very low hurdle rates of about $20 per barrel to determine whether it should invest in a project—whether a new oil field, pipeline, or alternative fuel.[57] By 2007, the oil companies were using somewhat higher hurdle rates, but still under $40, even as prices were soaring above $100 per barrel. They remain conservative because, just like everyone else, they aren't able to predict oil prices accurately. Plus, they recall those disastrous synfuels investments of the 1970s and early 1980s when they incorrectly forecast high oil prices. They're determined not to overinvest again. But they have few options to buy conventional oil supplies. Big Oil, with all its expertise, is boxed out of most oil fields and reluctant to invest in other politically risky regions, such as Russia and Venezuela, where it's vulnerable to the whims of politics.

And thus, the big companies sit on piles of cash. They invest increasing amounts in unconventional oil and frontier areas in politically safe locations. But the most favored option in recent years has been to buy back their stock and return profits to their shareholders. ExxonMobil returned $29 billion to its shareholders in 2006, a tenfold increase since 2000. They weren't alone. In the first half of 2007, the top four oil companies in the world (ExxonMobil, Chevron, BP, and Shell) together earned $57.5 billion in profits and devoted 40 percent of it, $22.9 billion, to buying back their shares.[58] High oil prices didn't stimulate large new investments.

The third major player in the dysfunctional oil market is the consumer. Consumers also have become less sensitive to fuel prices. This phenomenon is documented in chapter 6 for U.S. consumers. Cities are sprawling and transit alternatives have not historically kept pace with auto mobility. Travelers are becoming ever more dependent on cars and thus less sensitive to oil prices. Moreover, in most rich countries, with the notable exception of the United States, fuel taxes are so high that they largely camouflage economic signals of oil price fluctuations. Consumers in the United States are unresponsive to high fuel prices because they lack viable travel options, while consumers in other rich countries are largely unresponsive because taxes swamp the effect of changing market prices. Even in developing countries such as China and India, prices aren't instrumental. While consumers are responsive to high fuel prices in developing countries, this sensitivity is overwhelmed by rapid increases in income and a proliferation of cheap cars and motorcycles. The net effect across the globe is that even more than a fourfold increase in oil prices from 2004 to 2008 didn't stop increases in world oil consumption.[59] That's an extreme example of the lack of responsiveness to price signals, unseen with any other major consumer product.

In summary, the oil market is clearly not functioning. It's out of whack. No one knows what the price will be, and producers and consumers largely ignore price shifts. It's a market characterized by underinvestment and volatile prices, with costs disconnected from prices. Market information is unreliable, price forecasts are guesses, and most oil producers are barely responsive to market conditions. And perhaps worst of all, the public interest is being ignored.

The Winners: Large Fossil-energy Projects

Oil companies are biding their time. They know they're in a quandary, but they also know they have considerable time to adjust. For now they're being very cautious. ExxonMobil proudly asserted well into 2006 that it was sticking to the same capital investment budget of $15 billion per year from years past—even though oil prices had tripled, profits had soared, and oil reserves were becoming increasingly difficult to replace.[60]

With low hurdle rates, most are cautious about expanding investments. To the extent they do invest, they prefer large fossil-energy projects, including oil production in deep oceans offshore of the United States and other secure countries, oil in the Arctic and other inhospitable terrains—and unconventional oils in secure locations. They're highly capital-intensive companies that know how to design, build, and manage these mammoth multibillion-dollar projects. ExxonMobil, with almost $400 billion in revenue in 2006, employed only 83,700 people. In contrast, GM with half as much revenue employed four times as many people—even after waves of layoffs.

Oil companies can't be blamed for favoring large fossil-energy projects. That's what they're best at. And it could be lucrative for a very long time. If oil prices shift from their old range of the past two decades of about $25 to $35 per barrel to a new plateau above $75 or even $100, oil companies are going to be very profitable. That's because they've become highly efficient suppliers of oil over the years, pushing down production, distribution, and refining costs and restraining risky new investments.

Profits will shrink over time, though. As companies increasingly invest in very expensive deep wells, heavy oil, and so on, as oil-producing countries continue to negotiate higher royalties and fees, and as carbon reductions become binding, profits will recede. Still, the industry is far from troubled.

Normally, the prospect of high profits entices a flood of new companies into the business. Not so with oil, because the entry barriers are too great. Building a new offshore well, a new refinery, or a new pipeline often costs billions of dollars and many years and much effort to acquire permits. Plus, one needs to somehow buy access to oil in remote lands. One must compete with the huge Western oil companies as well as the even better-endowed government-supported national oil companies. Big Oil is further protected by the fact that most national oil companies, their only serious competitors, lack the technology and efficiency to thrive outside their insulated cocoons.

Big Oil is well positioned for a long time to come. The Detroit malaise won't strike the oil patches anytime soon. That's good news for the industry but problematic for those concerned about the addiction to fossil energy and keen on transitioning to a low-carbon future. What's good for Exxon may not be good for the United States and the world.

Big Oil's Environmental Epiphany

In the past, oil companies have tried to maintain a low profile, as much as immensely profitable companies serving the public can hope to. They've tried to burnish their image, some more than others, with support of public radio and television, image advertising, and such, but mostly they've gone about the business of making money in the United States and Europe and buying access in oil-producing countries.

Around 1995 a change began to occur. Some industry leaders began to come to terms with environmentalism. They each came to environmental epiphanies at different times and in different ways. But by 2006, almost all of the Big Oil companies were on board. They were accepting the grave challenge posed by climate change and—with one large exception, ExxonMobil—beginning to invest in renewable fuels.

How the Major Companies Stack Up on the Environment

ExxonMobil has been more conservative on environmental issues and more dismissive of climate concerns than any other major oil company. Its long-time chairman, Lee Raymond, routinely dismissed fears of global warming, claiming there was still significant uncertainty about the causes of climate change. A January 2007 report by the Union of Concerned Scientists

accused ExxonMobil of spending millions of dollars to manipulate public opinion on the seriousness of global warming, and of drawing upon tactics from the tobacco industry's 40-year "disinformation campaign." The report notes that "the relatively modest investment of about $16 million between 1998 and 2004 to select political organizations has been remarkably effective at manufacturing uncertainty about the scientific consensus on global warming."[61]

Yet ExxonMobil has maintained its reputation as perhaps the best run and most disciplined oil company. It has the largest stock market valuation of any oil company, indeed of any investor-owned company in the world. It also has the greatest profits. But the company has resolutely resisted investments in renewable energy and alternative fuels. By its own account, ExxonMobil spent less than 1 percent of its 2005 revenues on environmental concerns, and half of these expenditures were for capital and cleanup operations at older, dirtier refineries.[62]

ExxonMobil claims that it would rather reinvest in what it knows, which is why it invests much more on upstream oil R&D than its rivals.[63] Company executives continue to affirm that they have chosen not to pursue renewable energy options and aren't interested in chasing alternatives that offer little prospect of replacing fossil fuels.

Chevron, the second largest U.S. oil company, sometimes characterized as ExxonMobil's little brother, until recently had also been skeptical of climate concerns and also wasn't investing much in renewable and alternative fuels. It did have some investments in advanced batteries and other small nontraditional projects, but that was the result of the technology venture division it inherited from Texaco when it purchased that company.

That changed in 2006, as Chevron veered away from Exxon onto a new path. In full-page spreads splashed across opinion-leader magazines and newspapers, Chevron began emphasizing that oil demand was expected to grow 50 percent over the next 20 to 30 years and that a newfound commitment to energy efficiency and alternative fuels was needed. The company began investing in biofuels, advocating greater energy efficiency, and accepting the need to reduce carbon dioxide to prevent climate change. Rick Zalesky, a former refinery manager who took over Chevron's hydrogen and biofuels programs, described to us the epiphany Chevron experienced in early 2006. Until then, the company had seen alternatives to petroleum as competition. More biofuels had meant less oil sold. But they now accepted the reality that conventional oil supplies, especially those from non-OPEC

sources, were not going to meet projected demand. What he didn't say but surely understood was that international oil companies were having greater difficulty gaining access to oil controlled by the Saudis, Venezuelans, Iranians, and others, who were increasingly protective of their national resource and increasingly inclined to use it for political purposes. In any case, Chevron was now enthusiastic about finding new ways of supplying fuels to that thirsty market.

The second- and third-largest oil companies in the world, Shell and BP, are both located in Europe—Shell in The Netherlands and London, BP in London. They've both pursued more environmentally friendly public positions for a longer time. Shell formed a Shell Hydrogen subsidiary in 1999 and successfully developed a gasoline-to-hydrogen reformer by the following year in an attempt to facilitate the transition to fuel cell vehicles. In 2006, John Hofmeister, president of Shell Oil Company in the United States, said, "If we want to decrease our energy dependence to improve our energy security, we can. This will require us to manage demand, perhaps in new and somewhat different ways. And it will call for a culture of conservation that supports aggressive solutions for greater energy efficiency, without jeopardizing economic growth. We can focus on the areas of mobility, construction, urban planning, homes, high-rise and office buildings. All lend themselves to a culture of conservation, using energy in ways more efficient than we know about today."[64]

BP was even more dramatic. It gets credit for kicking off the industry's embrace of environmentalism. Lord Browne was the first oil CEO to acknowledge the reality of climate change. In May 1997, Lord Browne gave a speech at Stanford University in which he said that global warming was a real problem and that oil companies needed to both acknowledge that reality and begin dealing with it. The next year, when BP bought Amoco, an American oil company with extensive natural gas reserves, Lord Browne took that moment to reposition the company. The name was changed from British Petroleum to BP, and in 2002 it began using the tagline "beyond petroleum." BP's logo includes the letters BP in lowercase type with a green and yellow sunburst to emphasize its focus on environmentally friendly fuels and alternative energy, along with the words "beyond petroleum." Virtually all BP marketing since about 2000 speaks to the company's commitment to the environment. The repositioning was a dramatic success. A senior ad agency executive says, "There probably isn't a P.R. guy around who didn't wish he'd come up with that."[65]

Was BP "greenwashing" its public image, or was this a real shift in corporate responsibility? BP has certainly accumulated a credible track record. It owns a big solar energy company that held a 10 percent share of the world market in 2005; it has made significant efforts to reduce its own greenhouse gas emission; it funded a $20 million research program at Princeton on carbon sequestration and a massive $500 million program on biofuels at the University of California, Berkeley, and the University of Illinois; it coinvested in a $1-billion joint-venture hydrogen-fueled power plant in California; and it launched a thriving biofuels program.

At the same time, though, BP suffered a number of troubling setbacks. In an October 2007 court settlement with the U.S. government, the company paid $373 million in fines for manipulation of the propane market in 2004, a devastating accident in March 2005 at a BP refinery in Texas that killed 15 workers and injured hundreds more, and pipeline leaks in Alaska in 2006 that resulted from inadequate maintenance. While the company was straightforward in acknowledging its errors and offering immediate apologies, the image of the company as environmentally and socially responsible was tarnished. Indeed, ExxonMobil, which environmentalists love to hate, hadn't had problems of this magnitude in years, not since the *Exxon Valdez* spill in 1989.

In any case, whatever doubts one might have about Big Oil "greenwashing" its image instead of investing in actual social responsibility, the national oil companies are far, far worse societal stewards. They're far less concerned about the environment and human rights. They barely make a pretense of caring.[66]

The national companies also have little interest in energy efficiency and alternative fuels. Saudi Aramco is perhaps most active and most engaged. The company has been conducting in-house research on fuel cells, carbon sequestration, and fuel desulfurization for many years.[67] Aramco, like other national oil companies, knows that oil could eventually be replaced by a different fuel, such as hydrogen, and it knows that stiff CO_2 restrictions could harm its business. But Aramco and the others still have massive amounts of petroleum. In a major study of the five largest national oil companies in the Middle East, Valerie Marcel found in 2004 that "all the companies showed a lack of interest in the impact of the Kyoto Protocol and climate negotiations on future demand for oil and gas.... There was little awareness of the issue."[68] The OPEC cartel fully expects to usher in the next 60 to 70 years until a replacement for oil might appear. And

thus, even Aramco is putting at best a minimal effort into concerns about carbon.

Big Oil's Investment in Biofuels: Will It Step Up?

Regardless of the obliviousness of the national oil companies, the shift in Big Oil attitudes does seem genuine. The shift is highlighted by a July 2007 report by the National Petroleum Council, an organization that advises the U.S. Secretary of Energy and represents the U.S. oil industry. The report, chaired by Lee Raymond, the ex-CEO of ExxonMobil, emphasized the difficulty of meeting increasing energy demand and—for the first time—recommended increased emphasis on energy efficiency, production and use of alternative fuels, and carbon dioxide reduction.[69]

Yet the oil industry remains the oil industry. No matter how much BP or Chevron or Shell says it wants to create more environmentally sensitive sources of energy, its basic task is still to stick holes in the ground in search of hydrocarbons and to make as much money as possible doing that.

Spending $100 million over 10 years on climate change and carbon sequestration research at Stanford University, as ExxonMobil did, or even $500 million at UC Berkeley and Illinois as BP did, is still trivial considering that each of these companies is generating at least $150 billion per year in revenue and $10 billion or more in profit (much more in the case of ExxonMobil). The amounts they're spending for renewable energy are minuscule compared with the money going to their oil and gas divisions. Consider, for instance, that in 2006 Shell announced it was partnering with Qatar in the Persian Gulf to spend $12 to $18 billion on a massive project to convert natural gas into liquids.[70] Chevron was saying that it could imagine biofuels accounting for up to 10 million barrels of fuel per day in 20 years or so—but that still represents less than 10 percent of future oil needs.

Could it be that the large oil companies really do see a future in renewable energy? Perhaps, but it's better characterized as a tentative experiment. Big Oil is simply not suited to managing a proliferation of biofuels investments. Biofuels and other renewables by their very nature are a fundamentally different business from the fossil-energy business. Even the largest corn ethanol facilities are a fraction of the size of large fossil-energy facilities, for the simple reason that the resource is very dispersed and very expensive to collect in one large central location. That's not the case with coal or oil or even natural gas.

The process of change may be accelerated by the Energy Independence and Security Act signed into law by President Bush on December 19, 2007. The act mandates an astounding 36 billion gallons of biofuels per year by 2022, of which 21 billion must be "advanced" biofuels from cellulose and other materials. How will the oil companies respond? Will they fight it and eventually undermine it? Will they ramp up their investment and become major players? Or will they follow a cautious path of partnering with small biofuels companies? The most likely scenario is the last. It's difficult to imagine they'll embrace biofuels as part of their core business.

If the mammoth energy companies don't embrace biofuels, it casts a shadow over renewable alternatives. Where will the hundreds of billions of dollars come from that are needed to develop and launch renewable fuels—especially considering the high risk and market unpredictability? The venture capital community is investing large sums in biofuel technology, but those sums are tiny compared to what's needed for commercialization and compared to the resources available to oil companies. And the large food-processing companies that have played a central role in the expansion of the ethanol fuel industry haven't stepped up to the plate either. ADM, the largest investor in ethanol to date and the beneficiary of billions of dollars in ethanol fuel subsidies, didn't even create a serious cellulosic R&D program until 2005. The second-largest biofuel company, Cargill, has indicated even less interest in moving beyond corn ethanol.

BP says on its Web site, "We are determined to add to the choice of available energies for a world concerned about the environment and we believe we can do so in a way that will yield robust returns."[71] Perhaps. If BP and others do live up to this claim, there's hope that they can grow beyond petroleum into truly robust energy companies that learn to make money from energy efficiency, alternative fuels, and climate change mitigation.

But without more carrots and sticks, it's difficult to imagine this evolution taking place anytime soon. The wildcard may be the huge biofuels mandate in the 2007 Energy Act. If that act is enforced and oil companies divert their substantial financial resources to biofuels, much could happen. The stark reality, though, is that the corporate culture and core competence of oil companies favors big centralized investments and thus unconventional oil. If the oil industry decides to become a major player, the biofuels industry will likely take off. But even if it does, it's difficult to imagine oil companies leading this new biofuels industry. The real impetus for change will likely need to come from elsewhere.

Big Carrots and Big Sticks

The world is caught in a trap and oil is the bait. The global energy system, especially oil, is in big trouble. But it's not the oil companies that are in trouble, at least not in the short term. It's modern society. While today's oil industry is behaving rationally and responsibly in private terms given the nature of the marketplace and the absence of strong climate policies, its behavior isn't in the public interest. The rules need to change. Government intervention is needed—to assure timely investments in clean energy. But when the price of gasoline mounted at the pump in 2007 and continued climbing in 2008, just the opposite occurred. Instead of thinking of ways to stimulate innovation, influential politicians, were calling for gas tax "holidays."

Even ExxonMobil CEO Rex W. Tillerson is finally coming on board, stating in June 2007, "It has become increasingly clear that climate change poses risks to society and ecosystems that are serious enough to warrant action—by individuals, by businesses and governments."[72] ExxonMobil and others recognize that whatever goodwill they have is slowly eroding in the face of huge profits.

So where is the government intervention we sorely need? There's still little agreement on precisely what it will take, both in terms of carrots and sticks. So far, U.S. oil policy, to the extent there is such a policy, is to maximize domestic production, minimize prices to consumers, and assure an open global market. In Europe, oil policy is focused on diesel while maintaining high fuel taxes to fund government programs. In Japan, oil policy acknowledges that "hurdles must be surmounted...and, unless we change our lifestyles and the socio-economic system, we will not be able to overcome them. Japan may be required to make some painful energy choices in the future."[73] In China, oil policy is concentrated on procuring as many oil-rich trading partners as possible. Everywhere, even where changes are under way, oil policies need rethinking and retooling. Circumstances have changed.

New policies are needed that spur existing oil companies and outsider companies to invest in biofuels, hydrogen, and electricity to power our vehicles. There must be increased emphasis on energy efficiency. Big Oil will be investing vast sums of money in energy production and infrastructure in the coming years, an estimated $1 trillion over a decade[74] and $3 trillion over the next 25 years.[75] If these investments go disproportionately toward high-carbon unconventional fuels, high emissions will be locked in through the twenty-first century. The challenge is to direct some of this massive investment toward low-carbon alternatives. Oil companies must be encouraged to evolve into energy companies with broader visions and investment portfolios—and soon.

What are the pressure points for Big Oil and national oil companies, and what policies might be most effective at facilitating change?

A Nonsolution: Small Carbon and Fuel Taxes

Carbon and fuel taxes are compelling. Many support them. Former Federal Reserve chairman Alan Greenspan, the car companies at one time or another, and economists on the left and the right all have supported carbon and fuel taxes as the principal cure for both oil insecurity and climate change. But taxes attract political opposition and public ire and are of limited effectiveness—unless quite sizable—at least with respect to transportation fuels.

Carbon taxes—taxes on energy sources that emit carbon dioxide—aren't a bad idea. Indeed, they're an excellent idea, but they work better in some situations than others. They work well with electricity generation because electricity producers can choose among a wide variety of commercial energy sources—from carbon-intense coal to lower-emitting natural gas to zero-emission nuclear or renewable energy. A tax of $25 per ton of carbon dioxide would increase the retail price of electricity made from coal by 17 percent, widening its cost differential with clean renewables. Given the many choices, this would motivate electricity producers to seek out lower carbon alternatives. The result would be innovation, change, and decarbonization. Carbon taxes (and equivalent carbon caps) would be effective in transforming the electricity industry.

But transportation is a different story. Producers and consumers would barely respond to even a $50-a-ton tax, well above what U.S. politicians have been considering.[76] Oil producers wouldn't respond because they've become almost completely dependent on petroleum to supply transportation fuels and can't easily find or develop low-carbon alternatives within a short time frame; besides, a transition away from oil depends on automakers as well.

Drivers also would be unmotivated by a carbon tax. A tax of $50 a ton would raise the price of gasoline only about 45 cents a gallon. This wouldn't induce drivers to switch to low-carbon alternative fuels because

virtually none are available. In fact, it would barely reduce their consumption, especially when price swings of more than this amount are a routine occurrence.

In the transport sector, a carbon (or fuel) tax would have to be huge to induce change. Politically, the United States is unlikely to implement large gas taxes as are common in Europe and Japan. But perhaps it will find a "price floor" palatable.[77] A price floor involves imposition of a tax if the inflation-adjusted gasoline pump price goes below a specified level, say $4 per gallon. At that time, a variable gas tax would kick in to make up the difference and keep the price stable at $4. A price floor might be seen as a way of avoiding the export of trillions of dollars to OPEC, keeping the money at home while the nation weans itself off oil.

Another Nonsolution: Fuel Mandates

At the other end of the policy spectrum from taxes are fuel mandates. They don't work either because it's impossible to know which fuel to back. We two authors have decades of experience in transportation technology, policy, and consumer behavior—yet we still can't predict which fuels are likely to succeed. What we do know is that there are many low-carbon fuel options available and that many industry, government, and university labs are making rapid progress in developing more. The potential for new fuels with dramatically lower emissions is very real, but there's no clear winner yet.

And elected officials are no more qualified to pick winners than are university scientists. Powerful farm lobbyists advocate ethanol, and powerful coal lobbyists advocate coal-based liquids. But ethanol made from corn provides little reduction in greenhouse gas emissions, and coal liquids threaten huge increases. Leave it to politicians, and they'll mandate fuels made from food and coal.

Although the 2007 boost of biofuels by the U.S. Congress and President Bush is a step in the right direction, they succumbed to the allure of a mandate by specifying a certain number of gallons of biofuels and advanced biofuels, with targets for cellulosic biofuels and biodiesel. To their credit, they did add a greenhouse gas performance metric, defining advanced biofuels as achieving at least a 50 percent reduction in life-cycle greenhouse gas emissions, and cellulosic biofuels at least a 60 percent reduction. A more effective approach would have been to set greenhouse gas targets and let the best fuels win, including electricity and hydrogen—neither of which are even mentioned in the law. Congress will continue to debate climate legislation. It should look closely at converting the renewable fuel standard into a low-carbon fuel standard. And Europe should do the same with its even more rigid biofuels mandate. A low-carbon fuel standard has the benefit of including a broader range of fuels and imposing an explicit and ironclad requirement on oil companies to reduce the carbon content of the fuels they sell. The result will be more low-carbon alternatives, as well as fewer high-carbon unconventional fossil fuels.

A Third Nonsolution: Cap and Trade

Another innovative policy approach that we predict would have relatively modest effect on the transport sector is carbon "cap and trade," the most highly touted policy instrument for reducing greenhouse gas emissions in the United States and worldwide. It was adopted in Europe in 2005 and is the leading greenhouse gas reduction policy under consideration in both California[78] and Washington, D.C., as this book goes to press. This policy, as usually conceived, involves placing a cap on the carbon dioxide emissions of large industrial sources and granting or selling emission allowances to individual companies for use in meeting their capped requirements. Emission allowances, once awarded, can be bought and sold.

In the transportation sector, the cap would be placed on oil refineries and would require them to reduce carbon dioxide emissions associated with the fuels. The refineries would be able to trade credits among themselves and with others. As the cap was tightened over time, pressure would build to improve the efficiency of refineries and introduce low-carbon fuels—creating a market signal for consumers to drive less and producers of cars to make them more energy efficient. But unless the cap was very stringent, this signal would likely be relatively weak. It is unlikely to be tough enough, however, because politics and economics dictate that the oil industry cap not be any more stringent than a cap on other industries.[79] The most likely outcome, therefore, would be oil refiners buying credits from electricity companies to meet the cap, causing gasoline prices to increase 20 to 50 cents per gallon (depending on the stringency of the caps), with very little effect on oil demand and little influence on oil alternatives.

Some day, when biofuels and electric and hydrogen vehicles become commercially viable, cap and trade will become an effective policy with the transport sector. But until then, it is better to focus on more direct forcing mechanisms, such as a low carbon fuel standard for refiners, coupled with fuel and greenhouse gas standards for vehicle makers and incentives and rules to reduce driving.[80]

Other, More Promising Approaches

As mentioned above, we think a low-carbon fuel standard would be a more effective approach than small fuel taxes, fuel mandates, or economy-wide cap-and-trade programs. A low-carbon fuel standard sets a specific target for oil companies and lets them determine how best to meet it. California's low-carbon fuel standard, scheduled for adoption in 2009, sets a target of 10 percent carbon reduction by 2020, with the intent of tightening it substantially thereafter. Others are likely to follow. The low-carbon fuel standard, as described in chapter 7, is a powerful policy tool, and its implementation is central to solving the greenhouse gas problem attributed to transport fuels.

A second important approach is to establish a price floor for gasoline and diesel fuel. As indicated above, the price floor would assure that the fuel price would never drop below a specified level. Setting this price floor would reduce uncertainty for those investing in biofuels and hydrogen, as well as more efficient vehicle technologies.

This price floor would not only stimulate innovation but would also generate revenue that could be used for public investment in clean energy R&D. As indicated in chapter 4, research and development will expand the suite of transport fuel options available to energy suppliers, automakers, and consumers. Government should take responsibility for very fundamental research, but most of the effort must be by energy companies, who have much greater resources available. An important role of government is to create the conditions—through incentives, regulations, and other actions—that encourage energy companies to make those R&D investments.

The United States and Europe are starting to transition toward low-carbon fuels, albeit slowly. But the temptation is great to veer toward high-carbon unconventional oil. California is showing leadership, and many other politicians and companies across the nation are also embracing the need for a more coherent approach to energy. But much more leadership and much more innovation are needed.

Chapter 6

The Motivated Consumer

Two strategies dominate discussions about curbing greenhouse gas emissions and oil use: vehicle efficiency and low-carbon fuels. But there's a third strategy that's also very important: motivating better behavior. People, acting as consumers, travelers, voters, and investors, are central to all strategies to reduce oil use and carbon footprints. With the rest of the world following America's lead in mobility matters, it's especially important for Americans to adjust their behavior. The primary challenge is to awaken an American public largely ignorant of the energy and climate implications of their decisions, and to motivate American consumers to align their choices with the greater public good—what U.S. Senator John McCain has repeatedly called "a cause greater than self-interest."

Consumers have a lot of say about the future of global mobility. If consumers demand more socially and environmentally responsible products, manufacturers must respond to these demands or risk market loss. Changes in consumers' purchasing preferences can fundamentally alter the marketplace, as demonstrated recently by the shrinking market share of big SUVs and the growing market share of hybrid vehicles. Consumers have the power to motivate market shifts and technological innovation.

They also have the power to force oil-producing nations and international corporations to behave more in the public interest. By reducing their demand for oil and choosing alternatives, consumers have the power to reduce the geopolitical value of oil resources. Consumers also have power as voters and shareholders to change government policy and industry investments.