

Published by Manhattan Institute

NEW TECHNOLOGY
FOR OLD FUELS:
Innovation in Oil and
Natural Gas Production
Assures Future Supplies

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CENTER FOR ENERGY POLICY AND THE ENVIRONMENT
AT THE MANHATTAN INSTITUTE

EXECUTIVE SUMMARY

In 2012, U.S. oil production rose by 790,000 barrels per day, the biggest annual increase since U.S. oil production began in 1859. In 2013, the Energy Information Administration expects production to rise yet again, by 815,000 barrels per day, which would set another record. Domestic natural gas production is also at record levels.

What has allowed such dramatic production increases? Innovation in the drilling sector. The convergence of a myriad of technologies—ranging from better drill bits and seismic data to robotic rigs and high-performance pumps—is allowing the oil and gas sector to produce staggering quantities of energy from locations that were once thought to be inaccessible or bereft of hydrocarbons.

The dominance of oil and gas in our fuel mix will continue. The massive scale of the global drilling sector, combined with its technological prowess, gives us every reason to believe that we will have cheap, abundant, reliable supplies of oil and gas for many years to come.

The key findings of this paper include:

- Between 1949 and 2010, thanks to improved technology, oil and gas drillers reduced the number of dry holes drilled from 34 percent to 11 percent.
- Global spending on oil and gas exploration dwarfs what is spent on “clean” energy. In 2012 alone, drilling expenditures were about \$1.2 trillion, nearly 4.5 times the amount spent on alternative energy projects.
- Despite more than a century of claims that the world is running out of oil and gas, estimates of available resources continue rising because of innovation. In 2009, the International Energy Agency more than doubled its prior-year estimate of global gas resources, to some 30,000 trillion cubic feet—enough gas to last for nearly three centuries at current rates of consumption.
- In 1980, the world had about 683 billion barrels of proved reserves. Between 1980 and 2011, residents of the planet consumed about 800 billion barrels of oil. Yet in 2011, global proved oil reserves stood at 1.6 trillion barrels, an increase of 130 percent over the level recorded in 1980.
- The dramatic increase in oil and gas resources is the result of a century of improvements to older technologies such as drill rigs and drill bits, along with better seismic tools, advances in materials science, better robots, more capable submarines, and, of course, cheaper computing power.

ABOUT THE AUTHOR

ROBERT BRYCE is a senior fellow at the Manhattan Institute's Center for Energy Policy and the Environment. He has been writing about energy for two decades and his articles have appeared in numerous publications ranging from *The Wall Street Journal* to *The New York Times* and the *Atlantic Monthly* to the *Washington Post*. Bryce's first book, *Pipe Dreams: Greed, Ego, and the Death of Enron*, was named one of the best nonfiction books of 2002 by *Publishers Weekly*. In 2008, he published *Gusher of Lies: The Dangerous Delusions of "Energy Independence"*. A review of *Gusher of Lies* in *The New York Times* called Bryce "something of a visionary and perhaps even a revolutionary." His fourth book, *Power Hungry: The Myths of "Green" Energy and the Real Fuels of the Future*, was published in April 2010 by PublicAffairs. The *Wall Street Journal* called *Power Hungry* "precisely the kind of journalism we need to hold truth to power." *The Washington Times* said Bryce's "magnificently unfashionable, superlatively researched new book dares to fly in the face of all current conventional wisdom and cant." Bryce appears regularly on major media outlets including CNN, FOX News, PBS, NPR, and the BBC. He received his B.F.A. from the University of Texas at Austin in 1986.

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NEW TECHNOLOGY FOR OLD FUELS: INNOVATION IN OIL AND NATURAL GAS PRODUCTION ASSURES FUTURE SUPPLIES

Robert Bryce

INTRODUCTION

Advocates of solar, wind, and other renewable technologies like to claim that the innovation occurring in that sector will transform the energy landscape. For instance, outgoing energy secretary Steven Chu recently claimed that new batteries will “revolutionize the electrical distribution system and the use of renewable energy.” He also claimed that, thanks to federal spending, significant progress was being made in solar cells and electric cars.¹

Environmental groups like to point out that in 2012, some \$268.7 billion was spent globally on “clean energy.”² But many of those same advocates for renewables ignore the innovation—as well as the staggering sums of money being spent—in the oil and gas sector. In 2012 alone, global spending on oil and gas drilling totaled more than \$1.2 trillion, more than four times the amount being spent on “clean energy.” Of that sum, approximately \$400 billion was spent in North America alone.³ The vast amount of money being spent in the drilling sector, combined with the ongoing innovations, has had a clear result: over the past century or so, oil and gas drilling has been transformed from an industry dominated by hunches and wildcatters to one that is more akin to the precision manufacturing that dominates aerospace and automobiles.

Despite the advances in oil and gas production, government policies continue to be skewed toward renewable energy. In 2011, according to the Congressional Budget Office, federal tax preferences for the energy sector totaled \$20.5 billion. Of that sum, \$2.5 billion was allocated to the hydrocarbon sector. Producers of (non-hydro) renewable electricity—the vast majority of which came from wind energy—received production tax credits worth \$1.4 billion. Non-hydro renewable-energy projects also got \$3.9 billion in federal stimulus funds, and producers of ethanol and biodiesel got an additional \$6.9 billion in the form of tax credits.⁴ In total, the non-hydro renewable-energy sector got tax preferences worth \$12.2 billion, or nearly five times as much as those provided to the hydrocarbon sector. And the renewable sector got those tax preferences despite providing about 2 percent of America’s total energy needs. Hydrocarbons provide about 87 percent, and oil and gas together provide nearly 60 percent.⁵

WE’RE NOT RUNNING OUT OF OIL AND GAS

We’re running out of oil and natural gas. And we always have been. For more than a century, various prognosticators have repeatedly told consumers that the world’s supplies of oil and gas are limited and will soon—very soon—be completely exhausted.

In 1914, a U.S. government agency, the Bureau of Mines, predicted that world oil supplies would be depleted within ten years. In 1939, the U.S. Department of the Interior looked at the world’s oil reserves and predicted that global oil supplies would be fully depleted in 13 years.⁶ In 1946, the U.S. State Department predicted that America would be facing an oil shortage in 20 years and that it would have no choice but to rely on increased oil imports from the Middle East.⁷ In 1951, the Interior Department said that global oil resources would be depleted within 13 years.⁸ In 1972, the Club of Rome published *The Limits to Growth*, which predicted that the world would be out of oil by 1992 and out of natural gas by 1993.⁹ In 1974, population scientist Paul Ehrlich and his wife, Anne, predicted that “within the

next quarter of a century mankind will be looking elsewhere than in oil wells for its main source of energy.”¹⁰ In the 1980s, Colin Campbell, one of the most vocal of the peak oil theorists, predicted that global oil production would peak in 1989. Or consider James Howard Kunstler’s 2005 tome, *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*, which declared that the U.S. was teetering on the precipice of disaster because of energy shortages: “We will have to downscale every activity of everyday life, from farming, to schooling, to retail trade,” said Kunstler. “Epidemic disease and faltering agriculture will synergize with energy scarcities to send nations reeling.”¹¹

We’ve also heard plenty of warnings about natural gas shortages.

In 1922, the U.S. Coal Commission, an entity created by President Warren Harding, warned that “the output of [natural] gas has begun to wane.”¹² In 1956, M. King Hubbert, a Shell geophysicist who became famous for his forecast known as Hubbert’s Peak, predicted that gas production in the U.S. would peak at about 38 billion cubic feet per day in 1970.¹³ In 1977, John O’Leary, the administrator of the Federal Energy Administration, told Congress that “it must be assumed that domestic natural gas supplies will continue to decline” and that the U.S. should “convert to other fuels just as rapidly as we can.” That same year, Gordon Zareski, of the Federal Power Commission, testified before Congress and declared that U.S. policies “should be based on the expectation of decreasing gas availability.” He went on to say that annual production of natural gas “will continue to decline, even assuming successful exploration and development of the frontier areas.”¹⁴

In 2003, Matthew Simmons, a Houston-based investment banker for the energy industry who was among the leaders of the “peak oil” crowd, predicted that natural gas supplies were about to fall off a “cliff.” When asked about the future of natural gas supplies, Simmons (who died in 2010) said that “the solution is to pray.... Under the best of circumstances, if all prayers are answered there will be no crisis for maybe two years. After that it’s a certainty.”¹⁵

In 2005, Lee Raymond, the famously combative former CEO of ExxonMobil, declared that “gas production has peaked in North America.”¹⁶ Raymond, who retired from the oil giant in 2006, said that his company was intent on building a new pipeline that would bring Arctic gas from Canada and Alaska south and that more natural gas supplies would be needed, “unless there’s some huge find that nobody has any idea where it would be.”¹⁷

Many more examples of doomsday energy predictions could be cited here. But let’s forgo those and instead consider what has actually happened. Between 1980 and 2011, global natural gas production increased by 129 percent, and oil production jumped by 33 percent.¹⁸ What happened? Why were so many forecasters—including the chairman of Exxon, one of the world’s biggest and most technically savvy companies—so wrong? The answer: all of them underestimated innovation in the Oil Patch. Today, drillers are so precise that they can drill wells that are two miles deep, turn their drill bit 90 degrees, drill another two miles horizontally, and arrive within a few inches of the targeted pay zone.

Innovation occurs for many reasons, but a quick look at the history of the U.S. oil and gas sector helps explain why America continues to lead the world in oil-field technology. The U.S. has long been the most innovative country for drilling technology because it has drilled more oil and gas wells than any other country on the planet. No other country comes remotely close. Between 1949 and 2011, more than 2.6 million oil and gas wells were drilled in the U.S., and that number has been increasing by about 41,000 new wells per year.¹⁹

The cost of drilling an average well is about \$3 million.²⁰ Thus, every year, the U.S. oil and gas sector is spending more than \$120 billion drilling new wells. Given that level of spending, the industry has huge incentives to improve its processes, hardware, training, and personnel. And decades of economic motivation have resulted in continuing innovations that have, over time, unlocked ever-increasing quantities of oil and gas.

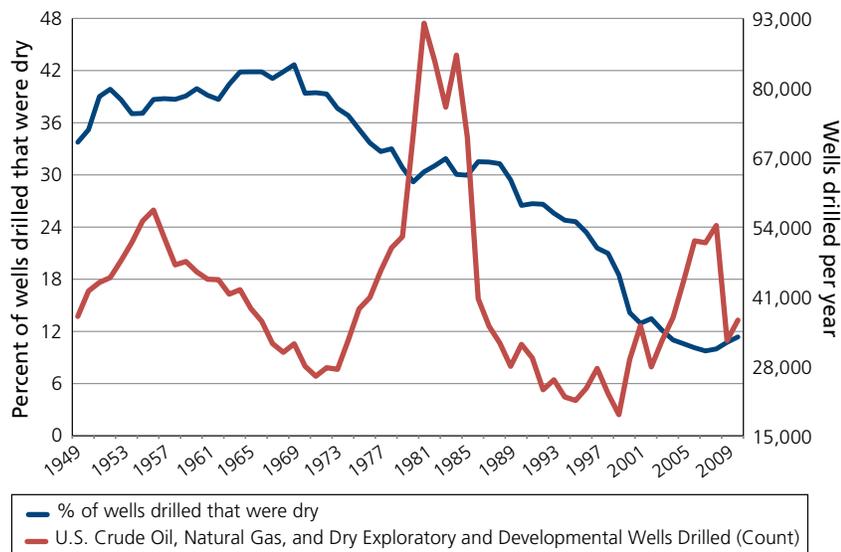
Recall that M. King Hubbert claimed that U.S. natural gas production would peak back in 1970 at about 38 billion cubic feet per day. That didn’t happen. In 2011, domestic gas production hit a record 63 billion cubic feet per day.²¹ That production was a 7.7 percent increase over the amount produced in 2010, and it easily eclipses the previous record-high level, achieved back in 1973, of 59.5 billion cubic feet per day.²² Furthermore, U.S. oil production, which had long been on a downward slope, is rising—and not by a little. In 2011, domestic production was 7.8 million barrels per day, the highest level since 1998. And numerous analysts are predicting that America’s oil output could, within a few years, surpass that of both Russia and Saudi Arabia, the world’s two biggest oil producers.

Better seismic analysis, harder and more durable drill bits, better drill rigs, real-time telemetry systems, and more powerful pumps have all combined to improve our ability to find and produce oil and gas. That is easily shown by the dramatic reduction in the number of dry wells that has occurred over the past six decades. Between 1949 and 2010, the percentage of wells drilled that were dry—known in the industry as “dusters”—has been cut from 34 percent to 11 percent. This dramatic reduction in dry holes is the result of continuing innovation in everything from drill rigs to drill bits.

OPPOSITION TO HYDROCARBONS, BIAS TOWARD INNOVATION IN “CLEAN” ENERGY

Although ongoing innovation in the drilling industry is obvious, the “clean” energy sector is the one that gets most of the attention from politicians, political appointees, and environmental groups. In 2011, in his State of the Union speech, President Barack Obama called oil “yesterday’s energy.” He went on to claim that spending more federal tax dollars on “clean energy technology” would “strengthen our security, protect our planet, and create countless new jobs for our people.... With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015.”²³

Wells Drilled and Percentage of Dusters Drilled, All U.S. Oil and Gas Wells, 1949–2010



Source: U.S. Energy Information Administration

Obama's sound bite may appeal to certain elements of the Green Left, but here's the reality: oil has been "yesterday's energy" for more than a century. Yet it persists. Why? Oil is a miraculous substance. If oil didn't exist, we would have to invent it. No other substance comes close to oil when it comes to energy density, ease of handling, and flexibility. Those properties explain why oil provides more energy to the global economy—about 33 percent—than any other fuel.²⁴ They also explain why, despite a century of effort, oil still dominates the transportation sector, with more than 90 percent of all transportation being fueled by petroleum products.²⁵

Those facts haven't stopped Obama, or his political appointees, or leading environmentalists from demonizing oil at every opportunity.

Obama's outgoing energy secretary, Steven Chu, has frequently lauded the development of "clean" energy technologies. In a February 1, 2013, letter to the employees at the Department of Energy in which he announced that he would not be serving another term, Chu declared that there was "innovation revolution" happening at the agency. He said that "the batteries developed for plug-in EVs [electric vehicles] will

also revolutionize the electrical distribution system and the use of renewable energy." He also said that the Department of Energy is helping give "America's innovators and entrepreneurs a competitive edge in the global marketplace. We have held workshops with industry in materials, computation, solar PV, plug-in electric vehicles, and many other areas."

The only mentions of oil in Chu's parting letter to the employees at the Energy Department were made in reference to the Deepwater Horizon accident in the Gulf of Mexico in 2010, or to America's "dependence on foreign oil" or to "oil addiction." Chu said that in 2012, the U.S. spent about \$430 billion on imported oil, an expenditure that, he said, is "a direct wealth transfer out of our country." Although Chu rightly pointed out that "our oil imports are projected to fall to a 25-year low next year," he didn't mention the innovations in the drilling sector that have allowed those imports to decline. Instead, he concluded his brief discussion on petroleum by saying that "we still pay a heavy economic, national security and human cost for our oil addiction."

Chu's letter mentions natural gas just two times, both occurring in reference to making solar-generated

electricity cost-competitive with natural gas. The word “solar” appears 15 times.²⁶

In February 2013, Bob Deans, the associate director of communications for the Natural Resources Defense Council, appeared on PBS’s *NewsHour* to express his group’s opposition to the Keystone XL pipeline. Deans declared that “we need to turn away from the fossil fuels of the past, invest in efficiency and renewables and build a twenty-first century economy on new fuels.”²⁷ Deans did not specify what those fuels might be.

In a March 2013 speech, Robert F. Kennedy, Jr., president of the Waterkeeper Alliance, an environmental group, said that “we need to free ourselves from the tyranny of oil.” Kennedy claimed that the U.S. could quit using all forms of hydrocarbons—coal, oil, and natural gas—if only it would agree to spend \$3 trillion on alternative energy sources.²⁸ (Kennedy has been among the most strident opponents of Cape Wind, a large offshore wind project that has been proposed for Nantucket Sound, near the Kennedy family’s property in Hyannis Port.)²⁹

In February 2013, Michael Brune, executive director of the Sierra Club, called shale gas “an extreme fossil fuel.” He stated: “Natural gas is not a bridge; it’s a gangplank to a destabilized climate and an impoverished economy.”³⁰ He also said that “the potential to develop renewable energy is limitless—if we don’t allow ourselves to be seduced by the false economies of cheap shale gas.”³¹ The Sierra Club—2011 revenues: \$43 million—isn’t just opposed to natural gas, the cleanest of the hydrocarbons.³² The group also has a “beyond oil” campaign and a “beyond coal” campaign. The group claims that “we have the means to reverse global warming and create a clean, renewable energy future.”³³

BETTER RIGS

Drilling rigs are relatively simple devices. Of course, they can range in size from small truck-mounted units that drill water wells to massive 100,000-ton ships that can drill wells in 10,000 feet of water. But

the principles are basically the same. They must be stable, powerful, and capable of producing the torque needed to punch a deep hole into the earth.

The latest, most important innovation in onshore drill rigs is the AC top-drive rig. The technology—first deployed offshore—is now gobbling up the onshore market. The AC top-drive’s key innovation: moving the rig’s main drive mechanism from the floor of the rig onto the mast. Doing so has allowed a major step forward in the digitization of the drilling process. With the AC top-drive, silicon and software have replaced key inputs that required the judgment of humans. Although many of the operations on the AC top-drive rig still must be done by humans—including connecting pipe, bits, and other equipment onto the drill string—an automatic-drilling system manages key data points: rate of penetration, flow rates, and other information. It feeds those data into an automated controller that then operates the drill rig at maximum efficiency, with optimum weight on the drill bit, mud-flow rates, and rotational speed.

Let me divert here for a moment to explain some basics of drilling technology.

Older rigs use what is known as a “kelly” drive, a rotating table that spins on the floor of the rig deck. That spinning table grips the pipe and drives the entire length of pipe and bit—known as the drill string—into the earth. The pipe is added to the drill string in 30-foot sections and is connected to a series of high-pressure pumps that push fluid, known as mud, from the top of the well downward. The drilling mud exits the pipe at or near the tip of the bit. The mud lubricates the bit and captures the rock cuttings and returns them to the surface, thereby allowing continuous drilling. If the cuttings are not removed quickly enough, they can accumulate in the well bore and cause the drill string to get hung up inside the well.

While the kelly drive rigs provided a big breakthrough in drilling technology when compared with the older, more dangerous, cable-tool rigs, they had limitations. A key limit: the ability to add new pipe to the drill string. With a standard kelly drive, only one 30-foot

section of drill pipe can be added to the drill string during the drilling process. If you are drilling a well that is 10,000 feet deep and has a 10,000-foot lateral section, for a total depth of 20,000 feet, that is 667 sections of pipe.

By contrast, the AC top-drive rig is much faster at getting pipe into the ground, thanks to its ability to use “threefers”: 90-foot stands of pipe that have been put together in racks on the drill-rig floor, where they can easily be added to the drill string during drilling. Whereas the kelly-drive rig has to stop for every 30 feet of drill string being inserted into the well, the AC rig only stops for every 90 feet of drill string. The time savings obtained by using threefers is obvious and quickly adds up.

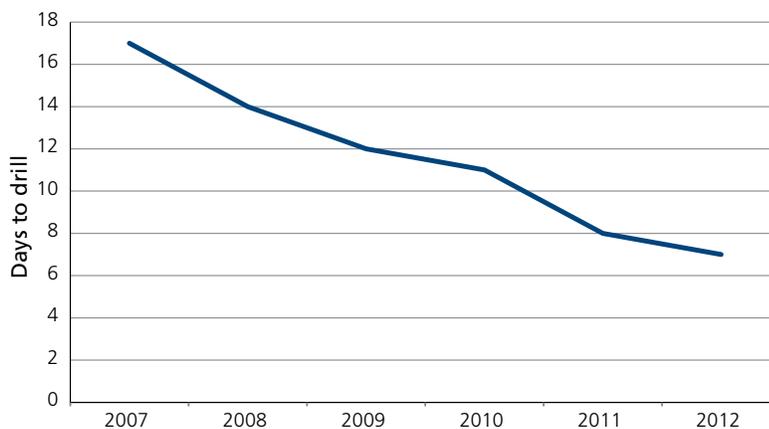
The AC rigs are also easier to move than older rigs. For instance, in many shale formations, companies drill multiple wells from a single location, known as a pad. In western Oklahoma’s Cana Woodford Shale, Devon Energy often drills three wells per pad. The wells are drilled in a line and are spaced about 15 feet apart. When drilling is completed on the first well, the entire intact rig is scooted to the next well by deploying hydraulic pistons or by dragging it with bulldozers. Some of the latest designs—called “walking” rigs—are even more advanced and can move the entire intact rig by as much as 40 feet per

hour.³⁴ And because the rig’s key components don’t have to be disconnected, drilling on the next well can resume far more quickly.

The AC top-drive designs are excellent for moving short distances on individual pads, and they are also easier to move longer distances via the highway. Older rig designs required as much as eight days to turn around—that is, to go from fully set up and ready to drill to complete breakdown and back again. The AC rigs can do the same turnaround in about three days.

While all those factors are important, the most crucial capability of the AC top-drive design, one that is not available in kelly-drive rigs, is their ability to keep optimum pressure on the bit at all times. Prior to the AC top-drive rig, the driller on the rig—the man who acts as crew foreman and is in charge of what happens on the rig floor—monitored the amount of weight on the bit, and did so by hand. That meant that one of the most critical inputs on the rig, the amount of pressure being applied to the bit, depended on “feel” rather than on hard operational data. Anyone who has drilled a hole in sheetrock or wood knows that application of proper pressure is key. Press too hard, and the drill freezes or gets stuck. Not enough pressure or insufficient speed, and the drill bit makes little progress. The same factors are at play on a drill rig that is boring a four-mile-long well.

Faster Means Cheaper: From 2007 to 2012, Southwestern Energy Cut the Number of Days Needed to Drill a Well in the Fayetteville Shale from 17 Days to 7 Days



Source: Southwestern Energy³⁵

The AC top-drive rig's ability to keep the bit spinning within optimum parameters assures that the machine is achieving the maximum rate of penetration at all times. Adding that key breakthrough to the rig's ability to use longer sections of pipe and be moved more quickly than older rig designs assures that more wells get drilled in less time. And when more wells are drilled, more hydrocarbons can be produced more cheaply.

BETTER DRILL BITS

A century ago, long before bits and bytes—described in all manner of peta, giga, mega and kilo—we had the fishtail bit. And it wasn't good at cutting holes into the earth.

The business end of the bit did look somewhat like a fish's tail. It also looked somewhat like the business end of a very wide screwdriver. It was a solid piece of steel with curved, sharpened edges. The fishtail bit's limitations were many. The bits tended to wander off course and couldn't drill effectively in hard-rock formations. Whenever it struck hard rock, the bit would dull quickly, and crews would have to pull the entire drill string out of the well and replace the bit—a costly and time-consuming process. Those limits meant that wildcatters were limited to looking for oil deposits that lay close to the surface. For instance, the famous gusher at Spindletop, just outside Beaumont, Texas, came from a well that was drilled to just 1,160 feet.³⁶

The breakthrough technology—introduced in 1908—was the twin roller-cone bit created by Howard Robard Hughes, Sr., and his partner, Walter Sharp. Hughes's son, Howard Hughes, Jr.—known to modern readers as the eccentric, reclusive playboy who loved fast airplanes and faster women—gained fame as an aviator and moviemaker, but his fortune was based on drill bits.

The Hughes bit was vastly superior to the fishtail design. Instead of scraping rock like the fishtail, Hughes and Sharp designed a rolling-cone mechanism that chipped, crushed, and powdered the rock.

That allowed the cuttings from the well to be easily removed by the drilling mud. The bit was easier to control in the well and had less tendency to deviate. The earliest tests of the roller bit immediately proved its superiority. On a well drilled in Humble, Texas, a crew using a fishtail bit was able to bore just 38 feet over 19 days, or two feet per day. When the same crew used one of Hughes's new roller bits, they were able to drill 72 feet in six days, or 12 feet per day.³⁷ In 2009, the American Society of Mechanical Engineers named the Hughes two-cone drill bit a “historic mechanical engineering landmark.” The group said that Hughes's bit and the rotary drilling system “were pioneering inventions that paved the way for the development of technologies and processes still used in the oil field today.”³⁸

It is difficult to overstate the importance of the Hughes bit. Henry Ford began manufacturing the Model T on October 1, 1908.³⁹ Hughes filed for a patent on his drill bit less than eight weeks later, on November 20.⁴⁰ Without the Hughes bit, there would not have been enough oil production—and therefore enough gasoline—to fuel all the cars that Ford was building. The proof of the importance of the Hughes roller bit can be seen by looking at the history of U.S. oil production. Throughout the 1890s, and during the first decade of the 1900s, production growth was slow. In the decade from 1890 to 1899, production grew from 126,000 barrels per day to just 156,000 barrels per day. By 1909, when Hughes was granted a patent for his design, U.S. oil production was at 502,000 barrels per day. A decade later, it had doubled. By 1929, it had doubled again. Forty years later, in 1969, when Neil Armstrong walked on the moon, domestic production of oil was 9.2 million barrels per day—18 times as large as it was in 1909.⁴¹

While the Hughes-style bit dominated the drilling sector for decades, many drillers now prefer PDC (polycrystalline diamond compact) bits. The Hughes-style roller-cone bits grind and crush the rock. PDC bits shear it because diamond is ten times harder than steel. The key technology in the newer bits—polycrystalline diamond compact cutters—was developed by General Electric in 1973. But it has taken decades of investment and experimentation to find the opti-



A polycrystalline diamond compact, manufactured by Halliburton, awaits use near a drilling rig in western Oklahoma. A bit like this one costs about \$20,000. Drilling an average shale well in western Oklahoma will use about ten drill bits like this one.

mum blend of synthetic diamonds with metals such as cobalt and tungsten carbide.⁴² That innovation has paid off. By 2010, PDC bits were being used to drill about 65 percent of all the footage in oil and gas wells. PDC bits are critical enablers of faster drilling. In some cases, drillers are able to drill 8,000 or even 9,000 feet while using just one PDC bit.⁴³

The results of optimized drill rigs and better drill bits can be seen in the drastic reduction in the time needed to drill wells. In 2007, Devon Energy needed about 60 days to drill an average well in the Cana Woodford Shale in western Oklahoma. By 2012, a well of similar depth could be drilled in about 30 days. Devon is not alone in showing major speed improvements. Southwestern Energy is a Houston-based company that has pioneered the development of the Fayetteville Shale in Arkansas. Between 2007 and 2012, the cost of an average well that Southwestern drills in the Fayetteville has stayed fairly constant, at about \$3 million per well. But over that same period, Southwestern reduced the number of days needed to drill a well in the Fayetteville from 17 days to just seven days. In addition, the average initial

production rate—the amount of energy produced from the well over the first month of operation—on the wells being drilled has more than doubled. When costs stay flat, drilling times fall by half, and production doubles, it's easy to understand why American natural gas production has soared.

Remarkable speed improvements can be seen in the oil-rich Eagle Ford Shale in Texas. In February 2013, an executive with Houston-based Baker Hughes, a large oil-field services firm, said that drillers working in the Eagle Ford have cut the number of days needed to drill an average well by half, to about 16 days, and they have done so in a span of just two years.⁴⁴

Drillers are relentlessly focused on cutting the time needed to drill wells because of the enormous costs involved. The total cost of operating an onshore rig in one of the shale plays like the Barnett, Marcellus, Fayetteville, Eagle Ford, or Haynesville may be \$4,000 per hour—or more. Given that expense, the ability to drill wells faster is imperative.⁴⁵ The recent record shows that the remarkable advances in speed are likely to continue.

THE DYNAMIC OFFSHORE

In 1947, the oil industry drilled its first offshore oil well—the Kermac 16—out of the sight of land.⁴⁶ The well, located off the Louisiana coast, was drilled in 20 feet of water, and all the machinery used on the project was on the cutting edge of technology.

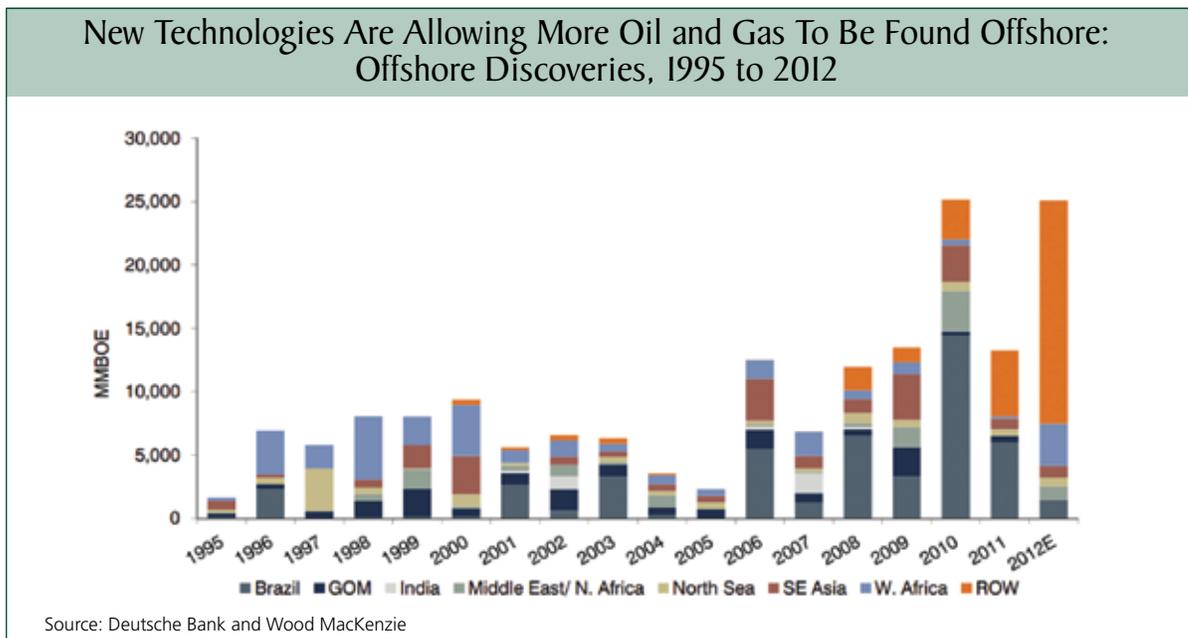
Today, about 100 rigs are capable of drilling wells in more than 7,000 feet of water.⁴⁷ The capability to drill in even deeper water continues to grow each year. While many consumers love to hate the energy industry, the reality is that some of the world's biggest companies (Shell, BP, Exxon Mobil, Chevron, and others), by drilling in the deepwater offshore, are conducting the marine equivalent of the space program—and all their efforts are privately funded.

The innovative nature of the offshore oil exploration business was clearly demonstrated in September 2006 when Chevron, Devon Energy, and Norway's Statoil ASA announced a major discovery with a well called the Jack No. 2. The three companies found a huge oil field in the deepwater of the Gulf of Mexico, about 270 miles southwest of New Orleans.⁴⁸ The Jack well, drilled in 7,000 feet of water, found a huge hydrocarbon deposit in what

is known as the Lower Tertiary trend. That formation may hold up to 15 billion barrels of oil. Drilled to a depth of more than 20,000 feet below the sea floor, that single well cost more than \$100 million to drill.⁴⁹ Developing the resources at Jack and a related prospect called St. Malo will cost Chevron and its partners about \$7.5 billion. A production platform now being built for Jack and St. Malo will have the capacity to handle 177,000 barrels of oil equivalent per day.⁵⁰

In March 2013, Anadarko Petroleum Corp. and four partner companies announced another major discovery of oil in the Lower Tertiary. The Shenandoah-2 appraisal well found a deposit that may contain as much as 3.7 billion barrels of oil equivalent. The well was drilled to a depth of 31,000 feet below the ocean floor in 5,800 feet of water.⁵¹

Back in 1947, all that oil potential in the Lower Tertiary may as well have been located on the dark side of the moon.⁵² The industry simply did not have the technical ability to tap the potential. With Jack, Shenandoah, and other discoveries like it, the oil industry has succeeded in drilling for oil—and finding it—in locations that require the extensive use of submarines, robots, and a host of other ex-



pensive technologies that continue to be improved and refined.

The deployment of better robots, platforms, and submarines has allowed unprecedented growth in offshore oil and gas development. In 2012 alone, global offshore oil discoveries totaled some 25 billion barrels. Among the biggest discoveries: the Johan Sverdrup field in the North Sea, one of the world's most-prospected regions. The Sverdrup field alone contains up to 3.3 billion barrels of recoverable hydrocarbons, making it the largest discovery in the North Sea since 1980.⁵³

The innovations in offshore drilling technology can easily be seen in the production numbers. In 1990, oil production from the deepwater—generally defined as locations that are more than 1,200 feet of water—in the U.S. Gulf of Mexico was less than 800,000 barrels per day. In 2012, it was nearly 1.2 million barrels per day, and projections from the Energy Information Administration show that production from those deepwater regions should hit 1.5 million barrels per day by 2014.

Of course, the gains in offshore production are not limited to the United States. The North Sea, offshore Africa, offshore Australia, and other locations have long been hotbeds of offshore exploration. A recent report by the Boston Company estimated that between 2002 and 2012, more than 100 billion barrels of new oil resources were discovered in offshore locations around the world. Few countries provide a better demonstration of offshore oil innovation than Brazil. In 1990, Brazil, the largest country in South America, was producing 650,000 barrels of oil per day. In 2011, production had increased to nearly 2.2 million barrels per day.⁵⁴ The vast majority of that production was coming from deepwater offshore wells.

The push to drill in even deeper water is continuing, and the industry is using new materials, cheaper computers, sensitive subsea sensors, and other technologies to allow that to happen. It is also developing drilling equipment that can handle extremely high pressures and temperatures. One recent offshore project in the Gulf of Mexico re-

quired equipment able to handle pressures of 25,000 pounds per square inch and temperatures of higher than 130 degrees C.⁵⁵

Given the remarkable achievements that have occurred in the offshore drilling sector over the past few decades, it is reasonable to assume that the sector will continue innovating. As those innovations occur, we can assume that offshore oil and gas production will continue rising.

TECHNOLOGICAL ADVANCEMENT UNLOCKS RESOURCES

For decades, various prognosticators have been claiming that we will exhaust our supplies of oil and gas. Much to their chagrin, that hasn't happened. Instead, reserves of both fuels continue to grow. Although we cannot know which technologies will prove to be most important in the future, we can look at two promising innovations that may affect future hydrocarbon development.

One of those innovations is “smart dust”—the name that researchers at the Advanced Energy Consortium have given to tiny devices that could amplify the electromagnetic, acoustic, and seismic signatures that are used to map hydrocarbon reservoirs. The devices could help expose oil and gas deposits that cannot be “seen” with existing seismic technologies. The Advanced Energy Consortium, an affiliate of the Bureau of Economic Geology at the University of Texas, has allocated about \$40 million to 34 projects at more than two dozen universities around the world to develop nanotechnologies that can be used in the drilling process. In addition to the seismic-enhancing nanoparticles discussed above, the consortium is developing an electronic sensor with an expected volume of one cubic millimeter. For reference, one million of those devices could fit into a one-liter bottle. The idea is to pump the micro sensors into an oil or gas well, circulate them through the hydrocarbon reservoir, and then “interrogate” them when they are pumped back to the surface. The information derived from that interrogation—on temperature, pressure, chemistry, and so on—could

be used for more accurate exploration and production. Similar devices could also be dropped into a pipeline to detect variations in pressure over a given length of pipe.

The other promising innovation is drones. Although drones are usually associated with the war in Afghanistan and other conflicts, the unmanned aircraft may be used by energy companies drilling in the Arctic. The aircraft could be used for mapping and to locate small icebergs, which can be hazardous to ships. The machines could also be used to monitor for spills and to locate marine life, such as whales and seals.

While smart dust and drones could be added to the technology portfolio, it is readily apparent that the industry will continue improving the tools that it has always used: drill rigs and drill bits. As the industry's ability to produce hydrocarbons from shale—the world's most common form of sedimentary rock—improves, there is good reason to assume that oil and gas production will continue apace.⁵⁶ Indeed, as technology advances and unlocks more resources, industry analysts are having to rethink their assumptions about the future availability of oil and gas.

In February 2013, the consulting firm PricewaterhouseCoopers (PwC) released a report that estimated that global shale oil resources could be as much as 1.4 trillion barrels. Several countries, including Mexico, Argentina, Russia, China, and Australia, are known to have significant shale deposits.⁵⁷ PwC is predicting that as new drilling technologies are deployed around the world, shale oil and shale gas will claim a bigger share of the world energy market. The consulting firm believes that global production of shale oil could reach 14 million barrels per day by 2035. If that occurs, shale oil could be providing about 12 percent of the world's supply. Even more remarkable is PwC's estimate that shale oil production could reduce oil prices in 2035 by 25 to 40 percent. "In turn, we estimate this could increase the level of global GDP in 2035 by around 2.3–3.7 percent (which equates to around \$1.7–\$2.7 trillion at today's global GDP values)."⁵⁸

Perhaps the most striking reexamination of global energy resources occurred in 2009, when the International Energy Agency more than doubled its prior-year estimate of global gas resources to some 30,000 trillion cubic feet—enough energy to last for nearly three centuries at current rates of consumption. In 2008, the agency had estimated global gas resources at about 14,000 trillion cubic feet. The IEA changed its estimate in response to the soaring production of gas from shale deposits, coal-bed methane deposits, and other so-called tight gas locations.⁵⁹ The impact of the surge in natural gas production was so profound that in 2010, the Paris-based IEA was openly discussing the "global oversupply" of natural gas and the "duration of the gas glut."

Or consider what has happened with regard to global proved oil reserves. In 1980, the world had about 683 billion barrels of proved reserves. Between 1980 and 2011, global oil consumption totaled about 800 billion barrels, an amount well in excess of the proved-reserves estimate in 1980. Yet in 2011, despite that enormous amount of consumption, global proved oil reserves stood at 1.6 trillion barrels, an increase of 130 percent over the level recorded in 1980.⁶⁰

The punch line here is apparent: the more oil and natural gas we find, the more oil and natural gas we find. And that ability to find more has been due to technological improvement.

CONCLUSION

Cheap, abundant, reliable energy supplies are essential for economic development. Despite many decades of dire predictions of energy shortages, along with the calamity and economic problems that would come from such shortages, the world continues to increase production of hydrocarbons. Those increases are a direct result of continuing innovation in the drilling sector, and those innovations provide plenty of reason to assume that oil and natural gas will remain dominant players in the global energy market for decades to come.

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FELLOWS

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