EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 94 NUMBER 28
9 July 2013
PAGES 245–252

Peak Oil and Energy Independence: Myth and Reality

PAGES 245–246

Despite the recent uptick in production of natural gas and liquid fuels in the United States, increasing energy resource scarcity and reliance on unconventional fossil fuel sources will make energy independence for the nation very unlikely. Rather, geologists, economists, environmentalists, and resource managers are looking with interest at when the use of fossil fuels is expected to peak—will that occurrence be driven by the market or by supply? What level will emissions reach before this peak is reached?

Examining these questions first requires the use of a few common definitions. Conventional oil refers to production from reservoirs that have sufficient pressure, porosity, and permeability to flow freely. Unconventional oil is that which does not flow freely or requires special technologies to extract—as a result, it is more expensive to produce. Unconventional oil includes deep-water oil, tar sands, tight oil (often improperly called oil shale), heavy oil, biofuels, and synthetic oil. Peak oil is a model for when oil production reaches a maximum and then declines [*Aleklett*, 2012]. Given these baseline terms, a key question can now be asked: When will the world reach peak oil production?

The supply-side (or geological) view is that conventional oil production will reach a maximum when about half of the ultimate recoverable resource has been produced, but peak oil may occur for economic reasons. If the price of oil is too high, oil consumption will decline. If the price is too low, more costly reserves (mostly unconventional oil) will not be produced. The net result is that peak production will occur when the marginal consumer (the consumer who will buy the most expensive barrel of oil) is no longer willing to pay the price of the marginal barrel (the most expensive barrel to produce; S. Andrews, An interview with Steven Kopits, http://peak-oil.org/2013/05/interview-with-steven-kopits).

Regardless of whether peak oil will occur due to geological or economic factors, there is a strong likelihood that total ultimate carbon dioxide (CO_2) emissions from oil may not be as large as some estimates project. In an era when most news about climate change is bad news, the idea that the world may not see a worst-case emissions scenario could soften the impact of future climate change but leave us with a different problem of insufficient energy production to meet demand.

Status of Oil Production Over Recent Time: Implications for Unconventional Sources

Global production of crude oil and condensates (hydrocarbons with 3 to 12 carbon atoms per molecule), which generally can be used as transport fuels (see http://www.eia.gov), has essentially remained on a plateau of about 75 million barrels per day (mb/d) since 2005 in spite of a large increase in the price of oil (Figure 1a). Even more important, the global net oil exports from oil-exporting countries (oil production minus internal consumption) have peaked and are in decline (see S. Foucher and J. J. Brown, Declining net oil exports—A temporary decline or a long term trend?, http://www.theoildrum.com/node/3018).

Though total oil production has plateaued, production of oil from older existing fields has been in decline, dropping roughly 5% annually, corresponding to a loss of 3–4 mb/d. To balance that decline, production from all new sources, including unconventional ones, has ramped up. Yet despite a steady stream of emphatic claims that production from unconventional sources will make up for declining production from existing conventional fields and meet growing demands for more supply, production from these unconventional sources is difficult and expensive and has very low energy return on investment (EROI) [see *Hall et al.*, 1986]. Simply stated, it takes energy to get energy, and more is required to produce energy from unconventional sources. With conventional oil production facing production decline rates, the debate about "peak oil" comes down to the prospects for production rate from low-EROI—and thus expensive—unconventional sources to balance the declines (as discussed at Union session U42A at the 2012 AGU Fall Meeting; see http://www.agu.org/cgi-bin/sessions5?meeting=fm12&part=U42A&maxhits=400).

Tar Sands

The recent interest in production of unconventional oil from tar sands (bitumen) is a clear indication that demand for oil has forced oil producers onto ever more marginal

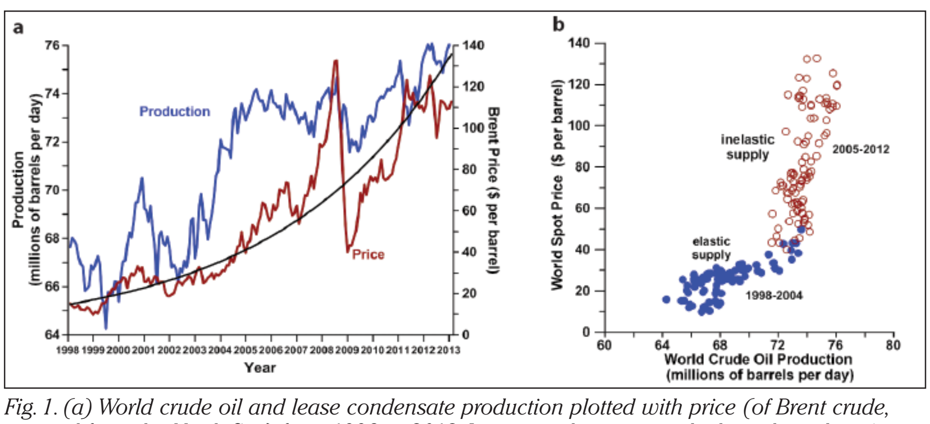

Fig. 1. (a) World crude oil and lease condensate production plotted with price (of Brent crude, sourced from the North Sea) from 1998 to 2013. Lease condensates are hydrocarbons heavier than pentanes (with 5 to 12 carbon atoms per molecule) that are recovered as a liquid during natural gas production. The Brent price is a representative price used to reflect the prices of crude oil sold around the world. The solid line represents an increase in price of 14% per year. While production has grown by nearly 2 million barrels per day since 2005, this represents an annualized growth rate for the past 8 years of only 0.25% per year. After Murray and King *[2012], updated to 2013. (b) Since 2005, world crude oil production has been unresponsive to price.*

BY J. W. MURRAY AND J. HANSEN

sites of production (C. Nelder, Tar sands: The oil junkie's last fix, http://www.energyandcapital.com/articles/oil+sands-tar-peak+oil/499). Canadian tar sands, which are the most significant source, presently produce about 1.7 mb/d, and forecasts for production by 2035 range from 2.5 mb/d [*Aleklett,* 2012] to 6.6 mb/d [*U.S. Energy Information Administration,* 2011]. However, as of now, the increased production will offset only a small fraction of the annual decline in the rate of production of existing global conventional oil fields.

Shale Gas

The "shale revolution" has been touted as a game changer. Energy companies have promoted the idea that production of natural gas from shale rock will lead to "The Age of Natural Gas." A major new report, based on analysis of all available drilling and production data for shale gas and tight oil in the United States through June 2012 [*Hughes,* 2013, p. iii], states that "new technologies of large scale, multistage, hydraulic fracturing of horizontal wells have allowed previously inaccessible shale gas and tight oil to reverse the long-standing decline of U.S. oil and gas production. This production growth is important and has provided some breathing room. Nevertheless, the projections by pundits and some government agencies that these technologies can provide endless growth heralding a new era of 'energy independence,' in which the U.S. will become a substantial net exporter of energy, are entirely unwarranted based on the fundamentals."

Hughes's report shows that reserves and future production rates have been substantially overstated. For fields such as the Barnett and Fayetteville Shales, in Texas and Arkansas, respectively, where the production history has been sufficiently long to provide robust evaluation, the declines in gas production over the first year have been extremely large (ranging from 29% to 52%).

There is no doubt that the nation's shale gas resources are immense, but the contention that the United States has a 100-year supply of natural gas is unfounded. The upper limit of supply is likely closer to 23 years using present-day rates of consumption (K. Cobb, The oil industry's deceitful promise of American energy independence, http://scitizen.com/future-energies/the-oil-industry-s-deceitful-promise-of-american-energy-independence_a-14-3746.html). Nevertheless, the resulting supply glut produced from the initial shale gas extraction drove U.S. prices down so sharply that now production companies are losing money, businesses are consolidating, assets are being sold, and drill rigs are being moved to oil production [*Rogers,* 2013].

It is important to note that the price of gas in the United States (less than $2 per million cubic feet (Mcf) in 2012 and increasing to $4.41 per Mcf in April 2013) has been much lower than required to meet the costs of shale gas production and make a profit (~$7 to $8 per Mcf when all lease and production costs are included; see A. E. Berman, After the gold rush: A perspective on future U.S. natural gas supply and price, http://www.theoildrum.com/node/8914). One main reason production continues with such low prices is that some producers have "use it or lose it" lease contracts for the land. ExxonMobil chief executive officer Rex Tillerson told *MarketWatch* in June 2012, "We are losing our shirts" (http://www.marketwatch.com/story/exxon-ceolosing-our-shirts-on-natural-gas-price-2012-06-27). Chesapeake Energy (the largest shale gas operator in the nation) announced in January 2012 that it would curtail drilling in shale gas plays. Shale gas may provide a temporary boost to the natural gas market, but it will not be easy and gas is unlikely to stay cheap.

Tight Oil

The story for tight oil—oil derived from shale formations—is pretty much the same as for shale gas. Tight oil in the United States is mostly produced from the Bakken Formation in North Dakota and the Eagle Ford Formation in southern Texas. There are considerable spatial variations in productivity, and the areas with the best production (sweet spots) are being developed first. The increased production from the Bakken is largely responsible for the increase in U.S. oil production by nearly 2.2 mb/d from previous lows.

Nonetheless, having exhausted the best petroleum reservoirs, industries are moving on to ones that are more resource- and capital-intensive to effectively utilize. The first-year average well decline rates are about 40%. Hughes's new report shows that if we were to stop drilling new wells, the growth in production from tight oil fields would abruptly end. The steep declines in production from tight oil wells over time require an ever-increasing treadmill of new drilling just to stay constant. This Red Queen Effect (from Lewis Carroll's *Through the Looking Glass*) states that "it takes all the running you can do, to keep in the same place" (R. Likvern, Is shale oil production from Bakken headed for a run with "The Red Queen"?, http://www.theoildrum.com/node/9748).

In the short run, extensive drilling can replace declines. The North Dakota Bakken, for example, requires 100 new producing wells per month to maintain present production. As of March 2013, there were 5047 wells in the Bakken producing 705,000 barrels per day, an average production per well of 140 barrels per day. These numbers are vanishingly small considering that conventional wells usually produce at rates of thousands of barrels per day. Furthermore, this oil is expensive, and the estimated price for commercial profitability is $80 to $90 per barrel. The lesson is that it looks difficult for tight oil to replace the decline of conventional oil fields (A. E. Berman, After the gold rush: A perspective on future U.S. natural gas supply and price, http://www.theoildrum.com/node/8914).

Economic Consequences of High Oil Prices

There are serious economic consequences of continuing high oil prices—high oil prices make expensive extraction from unconventional sources more affordable. For example, shale formations (with low permeabilities) were formerly considered source rocks too costly to develop. The shale revolution began not because producing oil and gas from shale was a good idea but because more attractive opportunities were exhausted and market prices climbed to support the higher cost of extraction.

But let's take a step back. Since 2005, the supply of oil has been essentially unresponsive to price (Figure 1b)—though the price has increased, production has plateaued. This inelastic response suggests that supply is no longer able to match demand. The economic consequences of this inelastic oil production are likely to be significant [*Tverberg,* 2012]. For example, the United States and Europe each spend $1 billion per day on oil imports even as the import volumes decline due to higher crude prices.

The inelastic supply of oil logically results in a price-production buffer against increasing economic growth [*Murphy and Hall,* 2011]. This negative-feedback buffer works as follows: Increased global demand for oil is driven significantly by economic growth in China and India. The demand leads to an increase in the price of oil, which is set by the global markets. As the price of oil increases, more unconventional resources become economically viable for development. Oil production increases due to increased production from unconventional sources.

However, because an increase in the price of oil set this cycle in motion, the potential for recession increases. Of the 11 recessions in the United States since World War II, 10 were preceded by a spike in oil prices [*Hamilton,* 2009]. The increased price of oil leads to a sudden loss of demand (demand destruction) followed by a decrease in the price of oil (countering the initial increase that set this cycle in motion). If the price decreases enough, production of the expensive unconventional resources is no longer profitable.

This feedback induces a drag on the economy, and consistent economic growth is difficult against this price-production buffer. This buffer can be seen in the recent price history—the price of oil increased to about $110 and then stopped rising. This appears to be the threshold at which consumers would rather reduce oil consumption than pay more. Historically, there has been a strong correlation (slope = 0.68) between global economic growth (measured by an average of gross domestic product (GDP)) and oil production

[*International Monetary Fund,* 2011]. A 4% growth in GDP would require an annual increase in oil supply of 3%, and that would amount to an increase in oil production of 17 mb/d over the next 5 years. Because production of conventional oil appears stuck on a plateau of 75 mb/d, it is likely that economic growth may be difficult unless there is a transformation away from the historical relationship between energy use and economic growth.

What About Climate Change?

Usually, when researchers refer to uncertainties in climate change, they are referring to variability of climate change effects driven by the increasing atmospheric CO_2 concentrations from now to 2100. The uncertainties in the scenarios for increasing CO_2 are rarely addressed [*Tans,* 2009]. Those CO_2 concentrations were estimated in the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (SRES) [*IPCC,* 2000]. Starting in 1990 the IPCC Assessment Reports developed families of CO_2 production scenarios that involved different projections of population growth and energy reserves of oil, gas, and coal. The IPCC SRES scenarios are still used (especially the business-as-usual scenario; SRES A2) in many climate change models.

The IPCC built the SRES primarily from two contributions by energy economists [*Rogner,* 1997; *Gregory and Rogner,* 1998] who synthesized earlier literature on (now very out-of-date) fossil fuel resources and reserves. Their optimistic message was that there are vast unconventional energy reserves and that technology will evolve to allow their production. These scenarios assume that CO_2 production depends on political choices that would control energy demand. They assume that all the demand would be met without any geological or economic limitation. Oil consumed by the SRES emission scenarios range up to 325 mb/d (for scenario A1G AIM) in 2100, with an average maximum of 126 mb/d [*Hook et al.,* 2010].

Le Quéré et al. [2013] have shown that up to 2012, atmospheric CO_2 has increased along the path of the highest scenarios. These increases are due to all fossil fuels (gas + coal + oil), but the contributions due to oil are likely unsustainable. With present oil production on a plateau of 75 mb/d and the production limitations of unconventional oil, it is very unlikely that such production rates would ever be reached. The production of CO_2 from oil consumption in many of the IPCC CO_2 scenarios has probably been overestimated.

Myth Versus Reality

Peak oil is not about oil reserves or resources, neither of which translates directly into production rate. Peak oil is not about running out of oil but about its peak in production. Production is the key metric because price is controlled by the balance between supply and demand.

So is the idea of peak oil a myth? If readers are expecting an abrupt decrease in oil production, then it is. But if they understand that the manifestation of peak oil is a struggle between supply and demand that is resolved through global oil markets, they will understand that the data show that peak oil can originate from economic as well as geological factors.

With conventional oil production on a plateau and with expensive unconventional sources the only means by which oil production may be increased in the short term, it is clear that societies face a major dilemma. Will the price remain high enough to develop unconventional sources and, in doing so, limit economic growth? Even so, can the production rate of unconventional oil ever be enough to support the concept of an "energy revolution," much less "oil energy independence"?

References

Aleklett, K. (2012), *Peeking at Peak Oil,* 345 pp., Springer, New York.

Gregory, K., and H. H. Rogner (1998), Energy resources and conversion technologies for the 21st century, *Mitigation Adapt. Strategies Global Change, 3*(2–4), 171–229.

Hall , C. A. S., C. J. Cleveland, and R. Kaufmann (1986), *Energy and Resource Quality: The Ecology of the Economic Process,* 577 pp. Wiley-Interscience, New York.

Hamilton, J. D. (2009), Causes and consequences of the oil shock of 2007–08, *Brookings Pap. Econ. Act., 40,* 215–283.

Hook, M., A. Sivertsson, and K. Aleklett (2010), Validity of the fossil fuel production outlooks in the IPCC emission scenarios, *Nat. Res. Res., 19*(2), 63–81.

Hughes, J. D. (2013), Drill, baby, drill: Can unconventional fuels usher in a new era of energy abundance?, report, 166 pp., Post Carbon Inst., Santa Rosa, Calif.

Intergovernmental Panel on Climate Change (IPCC) (2000), *Emissions Scenarios: Summary for Policy Makers,* edited by N. Nakicenovic and R. Swart, 570 pp., Cambridge Univ. Press, Cambridge, U. K.

International Monetary Fund (2011), *World Economic Outlook: Tensions From the Two-Speed Recovery; Unemployment, Commodities, and Capital Flows,* 221 pp., Washington, D. C.

Le Quéré, C., et al. (2013), The global carbon budget 1959–2011, *Earth Syst. Sci. Data, 5,* 1107–1157.

Murphy, D. J., and C. A. S. Hall (2011), Energy return on investment, peak oil, and the end of economic growth, in *Ecological Economics Reviews,* edited by R. Costanza, K. Limburg, and I. Kubiszewski, Ann. N. Y. Acad. Sci., *1219,* 52–72.

Murray, J. W., and D. King (2012), Climate policy: Oil's tipping point has passed, *Nature, 481,* 433–435.

Rogers, D. (2013), Shale and Wall Street: Was the decline in natural gas prices orchestrated?, report, Energy Policy Forum.

Rogner, H. H. (1997), An assessment of world hydrocarbon resources, *Annu. Rev. Energy Environ., 22,* 217–262.

Tans, P. (2009), An accounting of the observed increase in oceanic and atmospheric CO_2 and an outlook for the future, *Oceanography, 22*(4), 26–35.

Tverberg, G. E. (2012), Oil supply limits and the continuing financial crisis, in *7th Biennial International Workshop, Advances in Energy Studies,* edited by M. Giampietro, J. R. Martin, and S. Ulgiati, *Energy, 37*(1), 27–34.

U.S. Energy Information Administration (2011), International energy outlook 2011, *Rep. DOE/EIA-0484(2011),* Washington, D. C.

Author Information

James W. Murray, School of Oceanography, University of Washington, Seattle; E-mail: jmurray@u.washington.edu; and Jim Hansen, Ravenna Capital Management, Lake Forest Park, Wash.