



# The Petroleum Revolution III: What About Technology?

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A main concern of this book has been that—given the extreme dependence of most contemporary societies and economies on energy and the finite nature of fossil fuels—what kind of a future can the young readers of this book expect if our economic needs and expectations face severe constraints in the future availability of fossil fuels? As we have developed previously in this book (► Chap. 8) and frequently elsewhere, the two principle concerns we have about future availability and affordability of fossil fuels have been absolute supplies (e.g., “peak oil,” the idea that oil will reach a peak in production and then inevitably decline) and declining EROI. But what if these issues were not to occur or to do so only so far in the future that they would have no meaning to anyone alive today? Certainly there have been economists who have argued that technology and substitutions will indefinitely hold off the effects of depletion [e.g., 1]. Could they be right?

At the time of this writing (mid-2017), it is ambiguous whether resource limitations in the petroleum industry, and for energy more generally, are causing any severe constraints in economic activity, at least for the relatively wealthy parts of the world. Gasoline is not cheap, but it is not as expensive as it had once been either, as had been predicted by many. In inflation-corrected terms, it is more expensive than in the past, which may be related to economic impact. There is no shortage; if you have the money, you can buy as much as you want. There are two principle reasons for this: the production of oil in the United States, which had been declining (as predicted by M. King Hubbert) since 1970, began an upward surge again in 2008, causing an increase in global oil production which was otherwise flat (■ Fig. 13.1). And the increase in consumption, which had been increasing in both the United States and especially the world for 150 years, began to level off. We examine the first reason in some detail here.

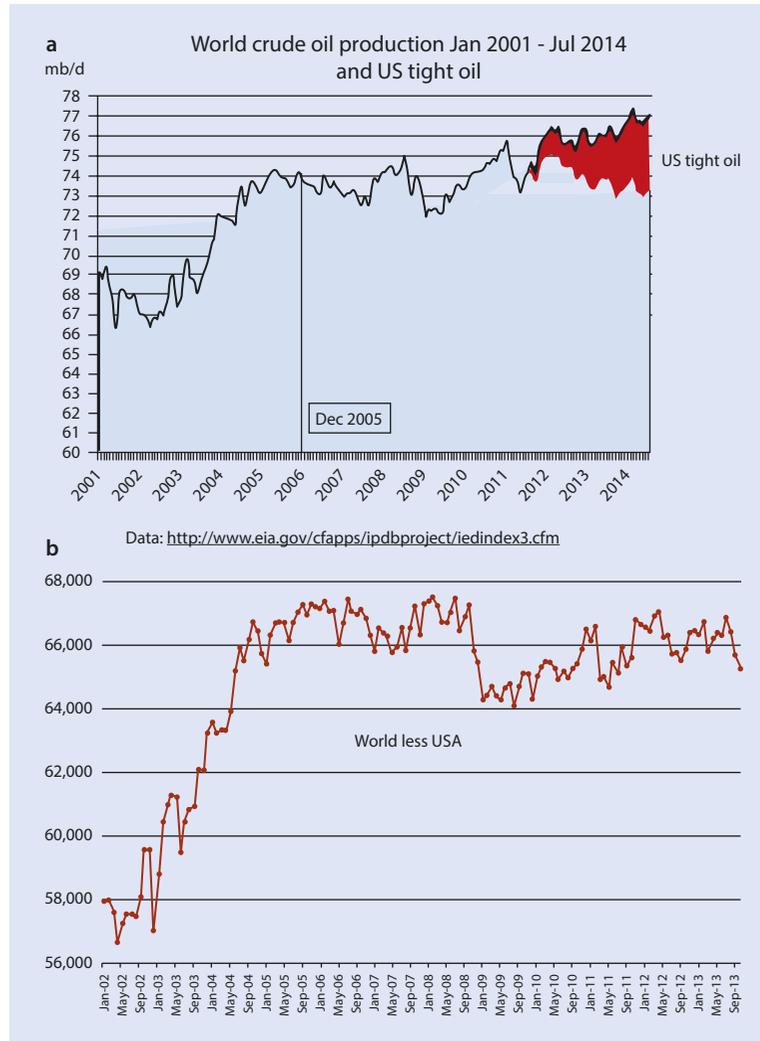
Starting in about 2008, there has been a great deal of excitement and debate about whether “unconventional” oil from, for example, the Bakken Formation in North Dakota and the Eagle Ford field in Texas and natural gas from shales, such as the Marcellus shale, can provide or were providing an energy renaissance for the United States. While the amount of oil in these formations is enormous, the rocks (as likely to be sandstone or limestone as shale) have low porosity

(pore space) and permeability (ability of oil to flow through the formation) so that only 5% of the oil in place can be extracted even by new, energy-intensive “heroic” efforts. This compares with an average of 38% from conventional fields. New technologies were required, including horizontal drilling, shooting a series of holes into the horizontal pipe, and the shattering or “fracking” of the rocks with very high-pressure water. Then special sand is added to keep the strata apart, and then the water is withdrawn, allowing the oil to drip from the rock and go back through the pipe to a collection location at the initial vertical hole (■ Fig. 13.2). This is obviously a very sophisticated procedure, and it requires a great deal of very sophisticated and expensive equipment. Lateral extensions up to 2 miles long are now routinely used.

The concept of fracking is actually an old one, initially done, with sometimes fatal results, with nitroglycerin, which had been occasionally used to enhance oil production as long ago as about 1930. Likewise, horizontal drilling has been around for a very long time. What is new is their combination along with the use of special sand to prop open the cracks made by high-pressure water sent downhole. This new technological package has been used to exploit extensive horizontal source beds of oil in Texas, North Dakota, and elsewhere (■ Figs. 13.2 and 13.3). While there is a lot of oil in these formations, and it is often of good quality, the low porosity and permeability are problems. As a result, production in these wells tends to decline very rapidly compared to conventional oil wells. On the plus side, there are few dry holes because the oil is in massive, relatively uniform “source rock” formations rather than more concentrated “trap rock” reservoirs.

The result has been a dramatic reversal in the long-term decline of oil production in the United States and the world (■ Figs. 8.5 and 13.1). A peak nearly at the level of the 1970 peak was achieved in 2015, although production since then has declined but then trended upward again. Whether the decline was due to the depletion of the “sweet spots” or the decline in effort due to the low price of oil is not quite certain. In 2016, the United States again began importing about half the oil it consumes. An analysis of top counties in fracked plays such as the Bakken and Eagle Ford shows that average well productivity has begun to

**Fig. 13.1** a Time series of oil production in the United States 1983–2017. The peak in US oil production of 10,500 thousand barrels per day occurred in 1970 (Source U.S. EIA; ► <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WCRFPU2&f=W>). b Production of world conventional crude oil without including the oil from the United States



decline (► Fig. 13.4), meaning that the best locations have been exhausted along with possible well interference (from “infill drilling”—wells being drilled too close together—robbing Peter to pay Paul). David Hughes, a geologist with a lot of experience and credibility analyzing fracked oil and gas resources, estimates that the total quantity of oil that will be recovered from these “fracked” fields will be in total no more than about 25% of remaining conventional oil—significant but not really a game changer [2].

Curiously, according to Art Berman [3], almost no companies that have invested in fracking have turned a profit, and at least at about \$50 per barrel, the main reason, that most companies continue to frack is to remain in business, and to generate enough revenue to repay the debts incurred to

commence drilling, not make a profit (as we saw with oil in its early history in the United States in ► Chap. 10). There is much being made about “increasing efficiency” but that turns out to be mostly due to decreasing the payments to the oil-field servicing companies. It is quite curious as to why investors (and the service companies) keep investing in companies that are not making money.

The horizontal drilling-fracking technique has been applied in China and England with uncertain results and in Poland where it has been abandoned as too low yielding and expensive. It is unlikely that fracking will do other than delay the inevitable US peak and decline by more than about a decade. On the other hand, it seems that so far every time the United States is about to have a catastrophic decline in oil production, something

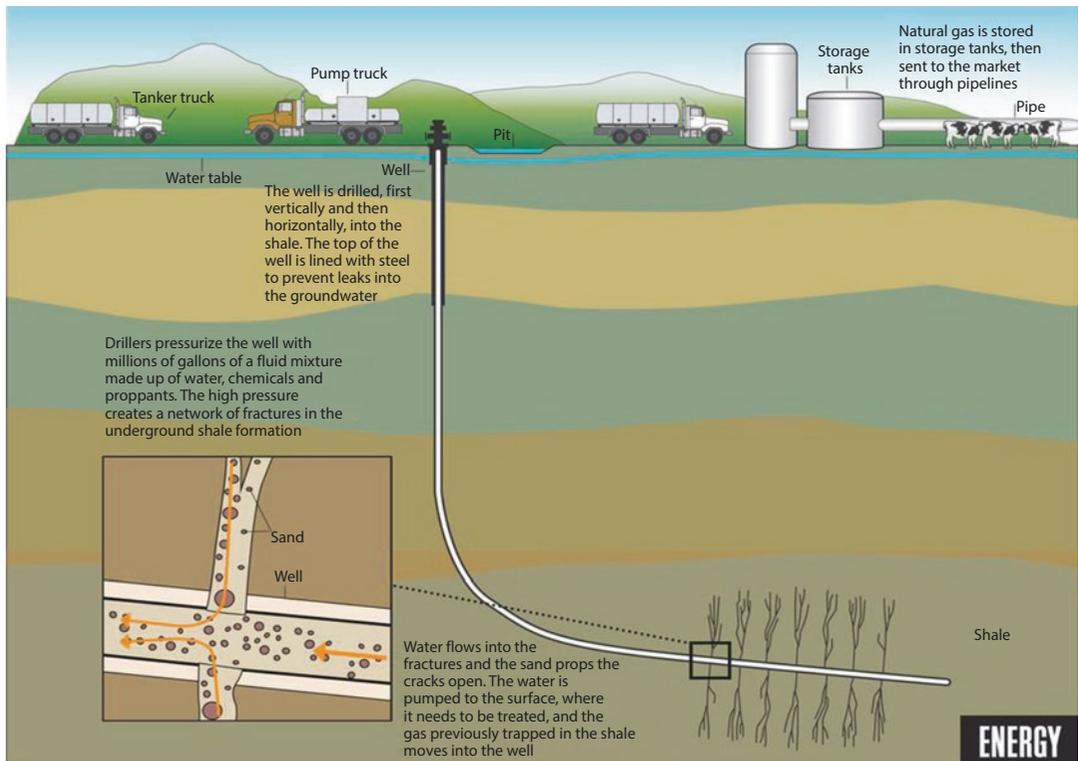


Fig. 13.2 Fracking procedure (From Kaufmann and Cleveland 2016)

Key tight oil and shale gas regions

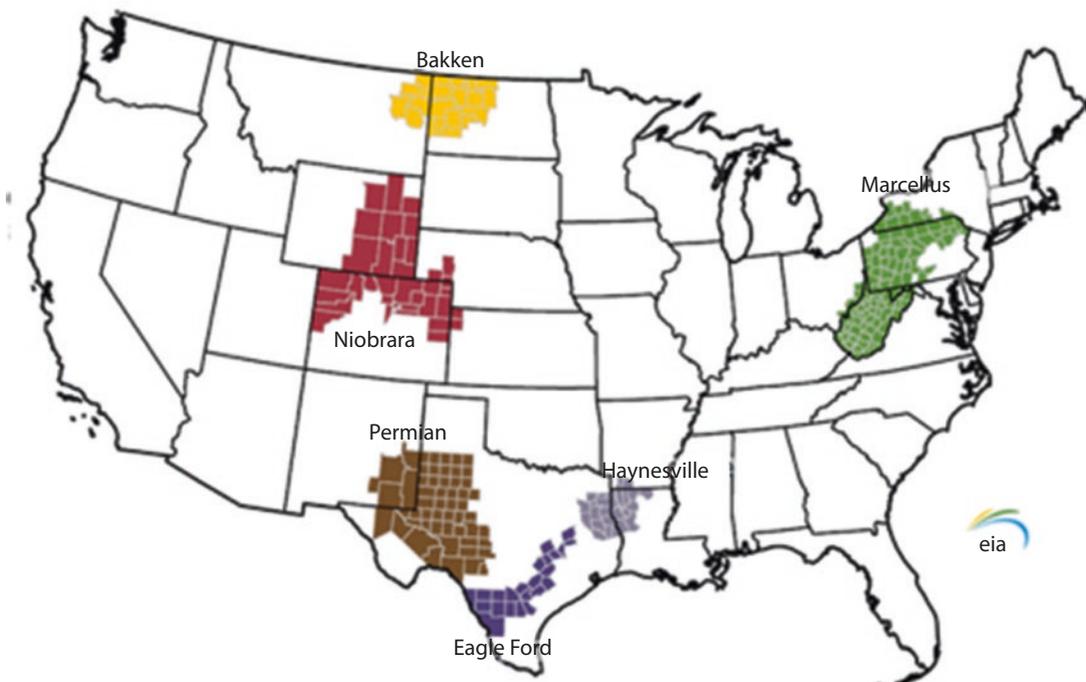
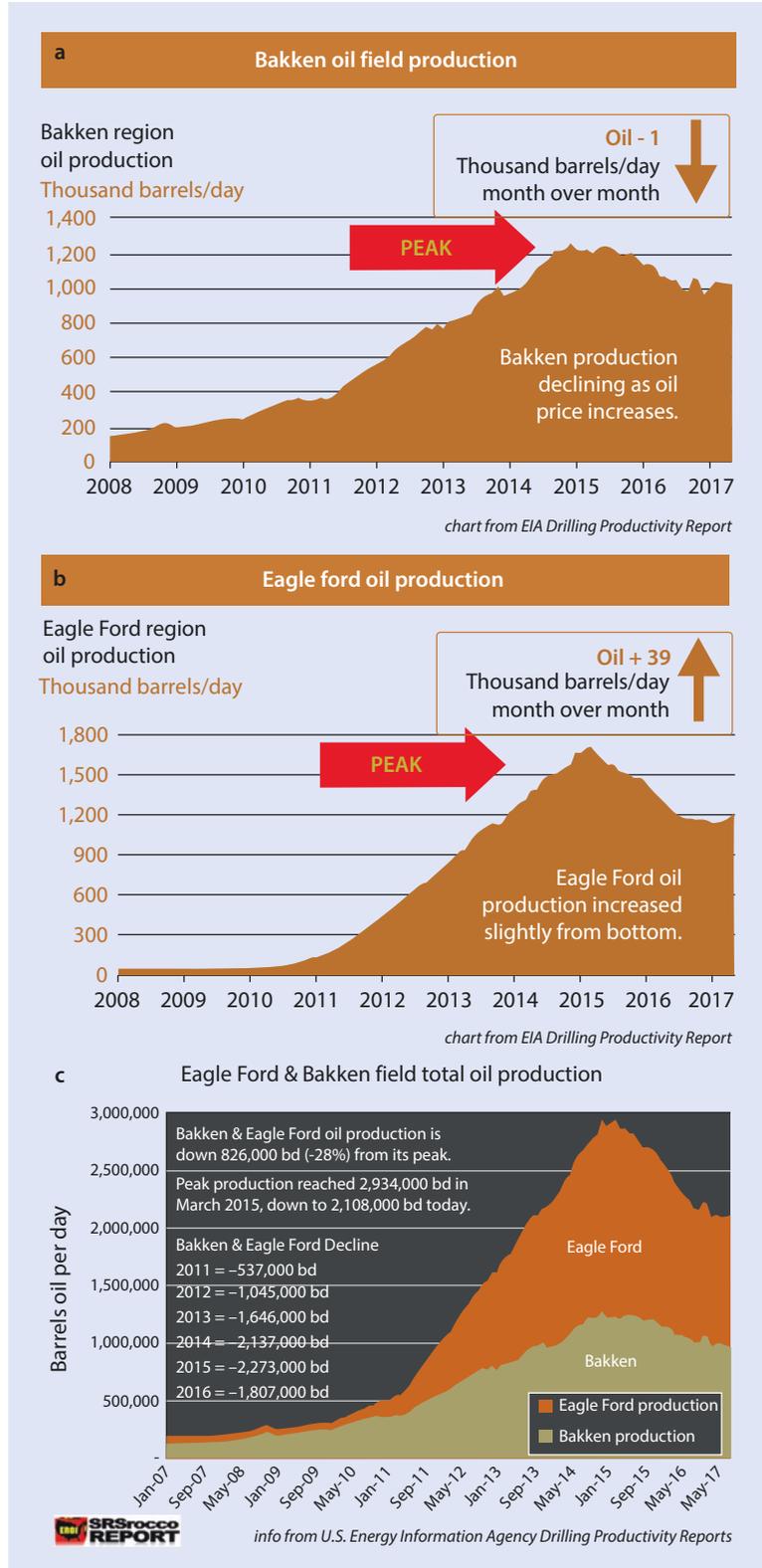


Fig. 13.3 Most important locations for fracking oil and gas (By county)

■ Fig. 13.4 a–c Increase and then decline in the major US shale oil plays (From ► *SRSrocco Report*, April 20, 2017)



comes on line to give us at least temporary relief: Alaska in 1975 and fracking in 2008. For how long can we count on such miracles? Will the world shift to non-carbon sources of energy if relatively cheap oil is still available? The next quarter to half century is likely to be extremely interesting with respect to energy, although we have hardly a clue to predict the unknown technologies.

Meanwhile conventional gas production in the United States has peaked and dropped off to less than half the peak, while unconventional gas of all kinds is mostly compensating for the decline in conventional gas while increasing production slightly [4]. The United States continues to import large quantities of oil and some gas from abroad. Thus, while fracked oil and natural gas are likely to be very important as conventional oil production declines, the decline in conventional resources is at least as important a story.

### 13.1 New Hubbert Peaks?

There is another huge change occurring with respect to the production of oil and other fossil fuels. Over the past five decades, those of us who have been thinking about “peak oil” would perceive of oil peaking first, then natural gas a decade or two later, and then coal much later [e.g., 5]. In our perception the amount of coal was very large and would more than compensate for the decline in oil and gas that would occur by, say, 2025. But starting in about 2012, new assessments suggested that while the peak in oil might take a little longer to unfold, there might be a peak much sooner in coal! Three different and independent assessments have concluded that a peak in all fossil fuels might occur as soon as 2025 [6–8].

### 13.2 New Technologies to the Rescue?

It is possible that a production peak could come even earlier, based on human efforts to reduce CO<sub>2</sub> emissions [9]. Several authors are very enthusiastic about the possibility of a relatively “carbon-free” future [10, 11]. But that would not be easy.

Energy authority Vaclav Smil [12] has summarized the challenges of moving off mostly fossil fuels:

There are five major reasons that the transition from fossil to non-fossil supply will be much more difficult than is commonly realized: scale of the shift; lower energy density of replacement fuels; substantially lower power density of renewable energy extraction; intermittence of renewable flows; and uneven distribution of renewable energy resources.

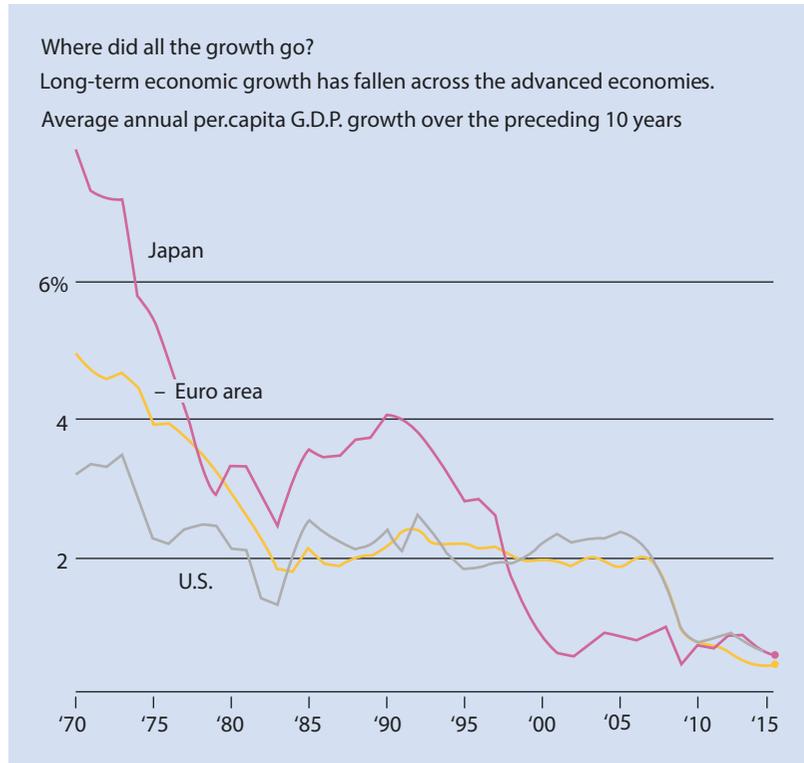
Trainer [13] likewise found that costs of renewables (including wood and hydropower) in the United States were extremely large.

Whether renewable energies, such as wind, biomass, and solar PV, could replace some large part of the fossil fuels anytime soon seems to be highly unlikely, although advocates suggest that it is possible (In *Our Renewable Future*, Heinberg and Fridley believe the need to avoid climate catastrophe will make the investment worth it even at the enormous cost it would entail (estimated on page 123 as 20 times the present rate of all investments in renewables for many decades).

David MacKay [14] concluded: “we must have no delusions about the area required for large-scale solar power; about the challenge of transmitting energy over large distances; about the additional costs of handling intermittency; and about the need for breakthroughs not only in the whole-system costs of photovoltaics but also in the cost of systems for storing energy. CSP (concentrating solar) plants need to be in safe locations, and the ultra-high voltage direct current transmission (UHVDC) system required in order to transport the electricity to points of final use must be built. This is not currently feasible in North Africa, for example.”

To give an example of the difficulties, today most renewable energy comes from hydropower and biomass, and the contribution of the latter is declining, so that the total contribution from all renewable in the United States has barely increased from 11% in 2010 to 12.6% in 2016 to a projected 16.1% by 2040 (U.S. EIA). Meanwhile, the EIA projects that all fossil fuels will continue to increase in absolute terms. So much for reducing CO<sub>2</sub> emissions! Some solar advocates project a much higher transformation rate, in line with what these authors see as necessary, as prices for, e.g., PV-generated electricity decline. We shall see. Whatever happens the fossil energy cost of

■ **Fig. 13.5** Decline in economic growth rate for the United States, Europe, and Japan



the transition to solar will be enormous. Simply contemplating transportation without oil is almost impossible to imagine [15].

### 13.3 EROI

Of perhaps greater concern than the quantity of oil and other energy sources is their declining EROI. The world will not run out of hydrocarbons. Instead it has, and will increasingly, become difficult to obtain cheap petroleum, because what is left is an enormous amount of low-grade hydrocarbons which are likely to be much more expensive financially, energetically, politically, and environmentally. As conventional oil becomes less available, society probably will make investments in different sources of energy and improvements in energy use efficiency, in theory reducing our dependence on hydrocarbons but possibly decreasing the EROI of our overall fuel mix. Meanwhile much of the world's economy has essentially stopped growing, perhaps in response to increasing resource limitations, implying a very different future that might greatly change our projections and options (■ Fig. 13.5).

### 13.4 Conclusion

The number of possible scenarios for future energy production is very large. Some indicate a major decline in energy availability; others suggest that renewables can take up the slack. Our assessment is that it is unlikely that we can build alternatives rapidly enough to fill in for declining oil and possibly other fossil fuels once serious declines begin, which seems inevitable [16].

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