from Lester R. Brown, *Plan B 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble* (NY: W.W. Norton & Co., 2006).

I

A Civilization in Trouble

2

Beyond the Oil Peak

When the price of oil climbed above $50 a barrel in late 2004, public attention began to focus on the adequacy of world oil supplies—and specifically on when production would peak and begin to decline. Analysts are far from a consensus on this issue, but several prominent ones now believe that the oil peak is imminent.[1]

Oil has shaped our twenty-first century civilization, affecting every facet of the economy from the mechanization of agriculture to jet air travel. When production turns downward, it will be a seismic economic event, creating a world unlike any we have known during our lifetimes. Indeed, when historians write about this period in history, they may well distinguish between before peak oil (BPO) and after peak oil (APO).

The peaking of oil production is approaching at a time when the world is facing many challenges, such as rising temperatures, falling water tables, and numerous other damaging environmental trends. Adjusting to a shrinking oil supply is part of the economic restructuring needed to put the economy on a path that will sustain progress.

The Coming Decline of Oil

The oil prospect can be analyzed in several different ways. Oil companies, oil consulting firms, and national governments rely heavily on computer models to project future oil production and prices. The results from these models vary widely according to the quality of data and the assumptions fed into the models. Here we review several different analytical methods.

One approach—use of the reserves/production relationship to gain a sense of future production trends—was pioneered several decades ago by the legendary King Hubbert, a geologist with the U.S. Geological Survey. Given the nature of oil production, Hubbert theorized that the time lag between the peaking of new discoveries and the peaking of production was predictable. Noting that the discovery of new reserves in the United States had peaked around 1930, he predicted that U.S. oil production would peak in 1970. He hit it right on the head. As a result of this example and other more recent country experiences, his basic model is now used by many oil analysts.[2]

A second approach, separating the world's principal oil-producing countries into two groups—those where production is falling and those where it is still rising—is illuminating. Of the 23 leading oil producers, output appears to have peaked in 15 and to still be rising in eight. The post-peak countries range from the United States (the only country other than Saudi Arabia to ever pump more than 9 million barrels of oil per day) and Venezuela (where oil production peaked in 1970) to the two North Sea oil producers, the United Kingdom and Norway, where production peaked in 1999 and 2000 respectively. U.S. oil production, which peaked at 9.6 million barrels a day in 1970, dropped to 5.4 million barrels a day in 2004—a decline of 44 percent. Venezuela's production has dropped 31 percent since 1970.[3]

The eight pre-peak countries are dominated by the world's leading oil producers, Saudi Arabia and Russia, producing roughly 11 million and 9 million barrels of oil a day in the fall of 2005. Other countries with substantial potential for increasing production are Canada, largely because of its tar sands, and Kazakhstan, which is still developing its oil resources. The other four pre-peak countries are Algeria, Angola, China, and Mexico.[4]

The biggest question mark among these eight countries is Saudi Arabia. Its production technically peaked in 1980 at

9.9 million barrels a day and output is now nearly 1 million barrels a day below that. It is included as a country with rising production only on the basis of statements by Saudi officials that the country could produce far more. However, some analysts doubt whether the Saudis can raise output much beyond its current production. Some of its older oil fields are largely depleted, and it remains to be seen whether pumping from new fields will be sufficient to more than offset the loss from the old ones.[5]

This analysis comes down to whether production will actually increase enough in the eight pre-peak countries to offset the declines under way in the 15 countries where production has already peaked. In volume of output, the two groups have essentially the same total production capacity. If production begins to fall in any one of the eight, however, this may well tilt the global balance to decline.[6]

A third way to consider oil production prospects is to look at the actions of the major oil companies themselves. While some CEOs sound very bullish about the growth of future production, their actions suggest a less confident outlook.

One bit of evidence of this is the decision by leading oil companies to invest heavily in buying up their own stocks. ExxonMobil, for example, with the largest quarterly profit of any company on record—$8.4 billion in the last quarter of 2004—invested nearly $10 billion in buying back its own stock. ChevronTexaco used $2.5 billion of its profits to buy back stock. With little new oil to be discovered and world oil demand growing fast, companies appear to be realizing that their reserves will become even more valuable in the future.[7]

Closely related to this behavior is the lack of any substantial increases in exploration and development in 2005 even though oil prices are well above $50 a barrel. This suggests that the companies agree with petroleum geologists who say that 95 percent of all the oil in the world has already been discovered. "The whole world has now been seismically searched and picked over," says independent geologist Colin Campbell. "Geological knowledge has improved enormously in the past 30 years and it is almost inconceivable now that major fields remain to be found." This also implies that it may take a lot of costly exploration and drilling to find that remaining 5 percent.[8]

This shrinkage of reserves is strikingly evident in the ratio between new oil discoveries and production of the major oil companies. Among those reporting that their 2004 oil production greatly exceeded new discoveries were Royal Dutch/Shell, ChevronTexaco, and Conoco-Phillips. The bottom line is that the oil reserves of major companies are shrinking yearly. On a global scale, geologist Walter Youngquist, author of *GeoDestinies: The Inevitable Control of Earth Resources Over Nations and Individuals*, notes that in 2004 the world produced 30.5 billion barrels of oil but discovered only 7.5 billion barrels of new oil.[9]

The influence on oil production in the years immediately ahead that is most difficult to measure is the emergence of what I call a "depletion psychology." Once oil companies or oil-exporting countries realize that output is about to peak, they will begin to think seriously about how to stretch out their remaining reserves. As it becomes clear that even a moderate cut in production may double world oil prices, the long-term value of their oil will become much clearer.

The geological evidence suggests that world oil production will be peaking sooner rather than later. Matt Simmons, head of the oil investment bank Simmons and Company International and an industry leader, says in reference to new oil fields: "We've run out of good projects. This is not a money issue…if these oil companies had fantastic projects, they'd be out there [developing new fields]." Kenneth Deffeyes, a highly respected geologist and former oil industry employee now at Princeton University, says in his 2005 book, *Beyond Oil*, "It is my opinion that the peak will occur in late 2005 or in the first few months of 2006." Walter Youngquist and A.M. Samsan Bakhtiari of the Iranian National Oil Company both project that oil will peak in 2007.[10]

Sadad al-Husseini, recently retired as head of exploration and production at Aramco, the Saudi national oil company, discussed the world oil prospect with Peter Maass for the *New York Times*. His basic point was that new oil output coming online had to be sufficient to cover both annual growth in world demand of at least 2 million barrels a day and the annual decline in production from existing fields of over 4 million barrels a day. "That's like a whole new Saudi Arabia every couple of years," Husseini said. "It's not sustainable."[11]

Where are companies looking for more oil? Aside from conventional petroleum, the kind that can easily be pumped to the surface, vast amounts of oil are stored in tar sands and can be produced from oil shale. The Athabasca tar sand deposits in Alberta, Canada, may total 1.8 trillion barrels. Of this total, however, it is thought that not more than 300 billion barrels is recoverable. Venezuela also has a large deposit of extra heavy oil, estimated at 1.2 trillion barrels. Perhaps a third of it can be readily recovered. If Venezuela's heavy oil is developed on a large enough scale, its oil production could one day exceed its 1970 historical peak. Oil shale concentrated in Colorado, Wyoming, and Utah in the United States also holds large quantities of kerogen, an organic material that can be converted into oil and gas.[12]

How much oil can be economically produced from oil shale? In the late 1970s the United States launched a major effort to develop oil shale on the western slope of the Rocky Mountains in Colorado. When oil prices dropped in 1982, the oil shale industry collapsed. Exxon quickly pulled out of its $5-billion Colorado project, and the remaining companies soon followed suit. Since this process requires several barrels of water for each barrel of oil produced, water shortages in the region may limit its revival.[13]

The one project that is moving ahead is the tar sands project in Canada's Alberta Province. This initiative, which began in the early 1980s, is now producing a million barrels of oil per day, enough to supply 5 percent of current U.S. oil use. This tar sand oil is not cheap, however, and it wreaks environmental havoc on a vast scale. Heating and extracting the oil from the sands relies on the extensive use of natural gas, production of which has peaked in North America.[14]

Thus although these reserves of oil in tar sands and shale may be vast, gearing up for production is a costly, time-consuming process. At best, the development of tar sands and oil shale is likely only to slow the decline in world oil production.[15]

The Oil Intensity of Food

Modern agriculture depends heavily on the use of gasoline and diesel fuel in tractors for plowing, planting, cultivating, and harvesting. Irrigation pumps use diesel fuel, natural gas, and coal-fired electricity. Fertilizer production is also energy-intensive: the mining, manufacture, and international transport of phosphates and potash all depend on oil. Natural gas, however, is used to synthesize the basic ammonia building block in nitrogen fertilizers.[16]

In the United States, for which reliable historical data are available, the combined use of gasoline and diesel fuel in agriculture has fallen from its historical high of 7.7 billion gallons in 1973 to 4.6 billion in 2002, a decline of 40 percent. For a broad sense of the fuel efficiency trend in U.S. agriculture, the gallons of fuel used per ton of grain produced dropped from 33 in 1973 to 13 in 2002, an impressive decrease of 59 percent.[17]

One reason for this was a shift to minimum and no-till cultural practices on roughly two fifths of U.S. cropland. No-till cultural practices are now used on roughly 95 million hectares worldwide, nearly all of them concentrated in the United States, Brazil, Argentina, and Canada. The United States—with 25 million hectares of minimum or no-till—leads the field, closely followed by Brazil.[18]

While U.S. agricultural use of gasoline and diesel has been declining, in many developing countries it is rising as the shift from draft animals to tractors continues. A generation ago, for example, cropland in China was tilled largely by animals. Today much of the plowing is done with tractors.[19]

Fertilizer accounts for 20 percent of U.S. farm energy use. Worldwide, the figure may be slightly higher. On average, the world produces 13 tons of grain for each ton of fertilizer used. But this varies widely among countries. For example, in China a ton of fertilizer yields 9 tons of grain, in India it yields 11 tons, and in the United States, 18 tons.[20]

U.S. fertilizer efficiency is high because U.S. farmers routinely test their soils to precisely determine crop nutrient needs and because the United States is also the leading producer of soybeans, a leguminous crop that fixes nitrogen in the soil. Soybeans, which rival corn for area planted in the United States, are commonly grown in rotation with corn and, to a lesser degree, with winter wheat. Since corn has a voracious appetite for nitrogen, alternating corn and soybeans in a two-year rotation substantially reduces the nitrogen fertilizer needed for the corn.[21]

Urbanization increases demand for fertilizer. As rural people migrate to cities, it becomes more difficult to recycle the nutrients in human waste back into the soil. Beyond this, the growing international food trade can separate producer and consumer by thousands of miles, further disrupting the nutrient cycle. The United States, for example, exports some 80 million tons of grain per year—grain that contains large quantities of basic plant nutrients: nitrogen, phosphorus, and potassium. The ongoing export of these nutrients would slowly drain the inherent fertility from U.S. cropland if the nutrients were not replaced in chemical form.[22]

Factory farms, like cities, tend to separate producer and consumer, making it difficult to recycle nutrients. Indeed, the nutrients in animal waste that are an asset to farmers become a liability in large feeding operations, often with costly disposal. As oil, and thus fertilizer, become more costly, the economics of factory farms may become less attractive.

Irrigation, another major energy claimant, is taking more and more energy worldwide. In the United States, close to 19 percent of agricultural energy use is for pumping water. In the other two large food producers—China and India—the number is undoubtedly much higher, since irrigation figures so prominently in both countries.[23]

Since 1950 the world's irrigated area has tripled, climbing from 94 million hectares to 277 million hectares in 2002. In addition, the shift from large dams with gravity-fed canal systems that dominated the last century's third quarter to drilled wells that tap underground water resources has also boosted irrigation fuel use.[24]

Some trends, such as the shift to no tillage, are making agriculture less oil-intensive. But rising fertilizer use, the spread of farm mechanization, and falling water tables are making food production more oil-dependent. This helps explain why farmers are becoming involved in the production of biofuels, both ethanol to replace gasoline and biodiesel to replace diesel. (Renewed interest in these fuels is discussed later in this chapter.)

Although attention commonly focuses on energy use on the farm, this accounts for only one fifth of total food system energy use in the United States. Transport, processing, packaging, marketing, and kitchen preparation of food account for nearly four fifths of food system energy use. Indeed, my colleague Danielle Murray notes that the U.S. food economy uses as much energy as France does in its entire economy.[25]

The 14 percent of energy used in the food system to move goods from farmer to consumer is roughly equal to two thirds of the energy used to produce the food. And an estimated 16 percent of food system energy use is devoted to processing—canning, freezing, and drying food—everything from frozen orange juice concentrate to canned peas.[26]

Food staples, such as wheat, have traditionally moved over long distances by ship, traveling from the United States to Europe, for example. What is new is the shipment of fresh fruits and vegetables over vast distances by air. Few economic activities are more energy-intensive.[27]

Food miles—the distance food travels from producer to consumer—have risen with cheap oil. Among the longest hauls are the flights during the northern hemisphere winter that carry fresh produce, such as blueberries from New Zealand to the United Kingdom. At my local supermarket in downtown Washington, D.C., the fresh grapes in winter typically come by plane from Chile, traveling almost 5,000 miles. Occasionally they come from South Africa, in which case the distance from grape arbor to dining room table is 8,000 miles, nearly a third of the way around the earth.[28]

One of the most routine long-distance movements of fresh produce is from California to the heavily populated U.S. East Coast. Most of this produce moves by refrigerated trucks. In assessing the future of long-distance produce transport, one oil analyst observed that the days of the 3,000-mile Caesar salad may be numbered.[29]

Packaging is also surprisingly energy-intensive, accounting for 7 percent of food system energy use. It is not uncommon for the energy invested in packaging to exceed that of the food it contains. And worse, nearly all the packaging in a modern supermarket is designed to be discarded after one use.[30]

The most energy-intensive segment of the food chain is the kitchen. Much more energy is used to refrigerate and prepare food in the home than is used to produce it in the first place. The big energy user in the food system is the kitchen refrigerator, not the farm tractor.[31]

While the use of oil dominates the production end of the food system, electricity (usually produced from coal or gas) dominates the consumption end. The oil-intensive modern food system that evolved when oil was cheap will not survive as it is now structured with higher energy prices. Among the principal adjustments will be more local food production and movement down the food chain as consumers react to rising food prices by buying fewer high-cost livestock products.

The Falling Wheat-Oil Exchange Rate

While we focus on the oil used to produce food, the amount of oil that food will buy is falling precipitously. The shift in terms of trade between wheat and oil is both dramatic and ongoing. From 1950 to 1973, the prices of both wheat and oil were remarkably stable, as was the relationship between the two. At any time during the 23-year span, a bushel of wheat could be traded for a barrel of oil in the world market. (See Table 2–1.)[32]

Since 1973, however, the relative values of wheat and oil have shifted dramatically. In 2005, it took 13 bushels of wheat to buy a barrel of oil. The two countries most affected by this dramatic shift are the leading exporters of these two commodities: the United States and Saudi Arabia.[33]

Table 2–1. *The Wheat/Oil Exchange Rate, 1950–2005*

Year	Bushel of Wheat	Barrel of Oil	Bushels Per Barrel
	(dollars)		(ratio)
1950	1.89	1.71	1
1955	1.81	2.11	1
1960	1.58	1.85	1
1965	1.62	1.79	1
1970	1.49	1.79	1
1975	4.06	11.45	3
1980	4.70	35.71	8
1985	3.70	27.37	7
1990	3.69	22.99	6
1995	4.82	17.20	4
2000	3.10	28.23	9
2005*	3.90	52.00	13

*2005 figures are author's estimates based on January–August data.
Source: See endnote 32.

The United States, both the largest importer of oil and the largest exporter of grain, is paying dearly for this shift in the wheat-oil exchange rate. The 13-fold shift since 1973 is contributing to the largest U.S. trade deficit in history and a record external debt. In contrast, Saudi Arabia—the world's leading oil exporter and a leading grain importer—is benefiting handsomely.[34]

While the exchange rate between grain and oil was deteriorating, U.S. oil imports were climbing. During the early 1970s, before the OPEC oil price hikes, the United States largely could pay its oil import bill with grain exports. But in 2004, grain exports covered only 13 percent of the staggering U.S. oil import bill of $132 billion.[35]

The first big adjustment between oil and wheat came when OPEC tripled the price of oil at the end of 1973. During 1974–78, it took roughly three bushels of wheat to buy a barrel of oil. Then after the second OPEC oil price hike, which boosted oil from $13 per barrel in 1978 to $30 in 1980, it took eight bushels of wheat to buy a barrel of oil.[36]

This steep rise in the buying power of oil led to one of the most abrupt transfers of wealth in history. The coffers of Saudi Arabia, Kuwait, Iraq, and Iran began to overflow with dollars while those of oil-importing countries were being emptied.

No one knows exactly what will happen to the wheat-oil exchange rate in the years ahead, but as the number of grain-based ethanol distilleries producing automotive fuel grows, the profitability of converting grain into fuel may stabilize the wheat-oil exchange rate.

The United States is pressing the Saudis to produce more oil. Yet the answer is not for the Saudis to produce more, even if they can, but for the United States to consume less. Unless the United States assumes a leadership role, Saudi Arabia will continue to dictate not only the exchange rate between oil and grain but also U.S. gasoline prices.

Food and Fuel Compete for Land

Historically, the world's farmers produced food, feed, and fiber. Today they are starting to produce fuel as well. Since nearly everything we eat can be converted into automotive fuel, the high price of oil is becoming the support price for farm products. It is also determining the price of food. On any given day there are now two groups of buyers in world commodity markets: one representing food processors and another representing biofuel producers. The line between the food and fuel economies has suddenly blurred as service stations compete with supermarkets for the same commodities.

First triggered by the oil shocks of the 1970s, production of biofuels—principally ethanol from sugarcane in Brazil and corn in the United States—grew rapidly for some years but then stagnated during the 1990s. After 2000, as oil prices edged upward, it began to again gain momentum. (See Figure 2–1.) Europe, meanwhile, led by Germany and France, was starting to extract biodiesel from oilseeds.[37]

Production of biofuels in 2005 equaled nearly 2 percent of world gasoline use. From 2000 to 2005, ethanol production worldwide increased from 4.6 billion to 12.2 billion gallons, a jump of 165 percent. Biodiesel, starting from a small base of 251 million gallons in 2000, climbed to an estimated 790 million gallons in 2005, more than tripling.[38]

Governments support biofuel production because of concerns about climate change and a possible shrinkage in the flow of imported oil. Since substituting biofuels for gasoline reduces carbon emissions, governments see this as a way to meet their carbon reduction goals. Biofuels also have a domestic econom-

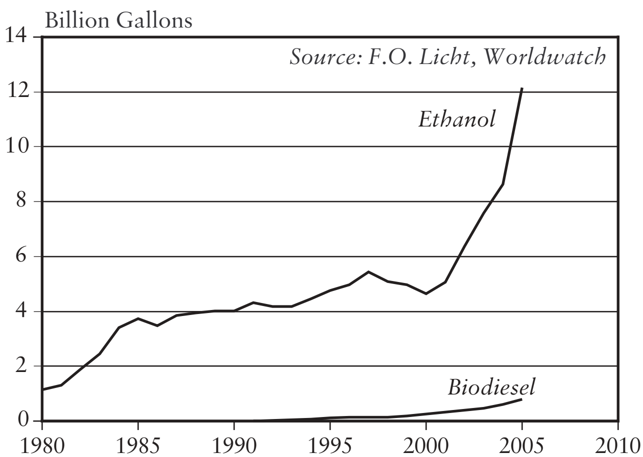

Figure 2–1. *World Ethanol and Biodiesel Production, 1980–2005*

ic appeal partly because locally produced fuel creates jobs and keeps money within the country.

Brazil, using sugarcane as the feedstock for ethanol, is producing some 4 billion gallons a year, satisfying 40 percent of its automotive fuel needs. The United States, using corn as the feedstock, produced 3.4 billion gallons of ethanol in 2004, supplying just under 2 percent of the fuel used by its vast automotive fleet. Forecasts for 2005 show U.S. ethanol output overtaking that of Brazil, at least temporarily. Europe ranks third in fuel ethanol output, the lion's share from France, the United Kingdom, and Spain. Europe's distillers use mostly sugar beets, wheat, and barley.[39]

Interest in biofuels has escalated sharply since oil prices reached $40 per barrel in mid-2004. Brazil, the world's largest sugarcane producer, is emerging as the world leader in farm fuel production. In 2004, half of its sugarcane crop was used for sugar and half for ethanol. Expanding the sugarcane area from 5.3 million hectares in 2005 to some 8 million hectares would enable it to become self-sufficient in automotive fuel within a matter of years while maintaining its sugar production and exports.[40]

Even though Brazil has phased out ethanol subsidies, by mid-2005 the private sector had committed $5.1 billion to investment in sugar mills and distilleries over the next five years. Thinking beyond its currently modest exports of ethanol, Brazil is discussing ethanol supply contracts with Japan and China. Producing ethanol at 60¢ per gallon, Brazil is in a strong competitive position in a world with $60-a-barrel oil.[41]

U.S. ethanol production, almost entirely from corn, benefits from a government subsidy of 51¢ per gallon. Ethanol produced from $3-a-bushel corn in the United States costs roughly $1.40 per gallon, more than twice the cost of Brazil's cane-based ethanol. Although it took roughly a decade to develop the first billion gallons of U.S. distilling capacity and another decade for the second billion, the third billion was added in two years. The fourth billion will likely be added in even less time. In addition to corporations, U.S. farm groups are also investing heavily in ethanol distilleries.[42]

India, the world's second largest producer of sugarcane, has 10 ethanol plants in operation and expects to have 20 additional plants up and running by the end of 2005. China is projected to bring on-line four plants producing up to 360 million gallons of additional fuel ethanol by the end of 2005, mostly from corn and wheat.[43]

Colombia and the Central American countries represent the other biofuel hot spot. Colombia is off to a fast start, opening one new ethanol distillery each month from August 2005 through the end of the year. The challenge is to coordinate growth in distillery construction with growth in the land in sugarcane.[44]

For biofuels used in diesel engines, Europe is the leader. Germany, producing 326 million gallons of biodiesel in 2004, is now covering 3 percent of its diesel fuel needs. Relying almost entirely on rapeseed (the principal source of cooking oil in Europe), it plans to expand output by half within the next few years.[45]

France, where biodiesel production totaled 150 million gallons in 2004, plans to double its output by 2007. Like Germany, it uses rapeseed as its feedstock. In both countries the impetus for biodiesel production comes from the European Union's goal of meeting 5.75 percent of automotive fuel needs with biofuels by 2010. Biofuels in Europe are exempted from the hefty taxes levied on gasoline and diesel.[46]

In the United States, a latecomer to biodiesel production, output is growing rapidly since the 2003 adoption of a $1-per-gallon subsidy that took effect in January 2005. Iowa, a leading soybean producer and a hotbed of soy-fuel enthusiasm, now has three biodiesel plants in operation, another under construction, and five more in the planning stages. State officials estimate that biodiesel plants will be extracting oil from 200 million bushels of the state's 500-million-bushel annual harvest within a few years, producing 280 million gallons of biodiesel. The four fifths of the soybean left after the oil is extracted is a protein-rich livestock feed supplement, which is even more valuable than the oil itself.[47]

Other countries either producing biodiesel or planning to do so include Malaysia, Indonesia, and Brazil. Malaysia and Indonesia, the major producers of palm oil, would likely use highly productive oil palm plantations as their feedstock source. Brazil, which has ambitious plans to ramp up biodiesel production, will also likely turn to palm oil.[48]

There are two key indicators in evaluating crops for biofuel production: the fuel yield per acre and the net energy yield of the biofuels, after subtracting the energy used in both production and refining. For ethanol, the top yields per acre are 714 gallons from sugar beets in France and 662 gallons per acre for sugarcane in Brazil. (See Table 2–2.) U.S. corn comes in at 354 gallons per acre, or roughly half the beet and cane yields.[49]

With biodiesel production, oil palm plantations are a strong first, with a yield of 508 gallons per acre. Next comes coconut oil, with 230 gallons per acre, and rapeseed, at 102 gallons per acre. Soybeans, grown primarily for their protein content, yield only 56 gallons per acre.[50]

For net energy yield, ethanol from sugarcane in Brazil is in a class all by itself, yielding over 8 units of energy for each unit

Table 2–2. *Ethanol and Biodiesel Yield per Acre from Selected Crops*

Fuel	Crop	Fuel Yield
		(gallons)
Ethanol		
	Sugar beet (France)	714
	Sugarcane (Brazil)	662
	Cassava (Nigeria)	410
	Sweet Sorghum (India)	374
	Corn (U.S.)	354
	Wheat (France)	277
Biodiesel		
	Oil palm	508
	Coconut	230
	Rapeseed	102
	Peanut	90
	Sunflower	82
	Soybean	56*

*Author's estimate
Note: Crop yields can vary widely. Ethanol yields given are from optimal growing regions. Biodiesel yield estimates are conservative. The energy content of ethanol is about 67 percent that of gasoline. The energy content of biodiesel is about 90 percent that of petroleum diesel.
Source: See endnote 49.

invested in cane production and ethanol distillation. Once the sugary syrup is removed from the cane, the fibrous remainder, bagasse, is burned to provide the heat needed for distillation, eliminating the need for an additional external energy source. This helps explain why Brazil can produce cane-based ethanol for 60¢ per gallon.[51]

Ethanol from sugar beets in France comes in at 1.9 energy units for each unit of invested energy. Among the three principal feedstocks now used for ethanol production, U.S. corn-based ethanol, which relies largely on natural gas for distillation energy, comes in a distant third in net energy efficiency, yielding only 1.5 units of energy for each energy unit used.[52]

Another perhaps more promising option for producing ethanol is to use enzymes to break down cellulosic materials, such as switchgrass, a vigorously growing perennial grass, or fast-growing trees, such as hybrid poplars. Ethanol is now being produced from cellulose in a small demonstration plant in Canada. If switchgrass turns out to be an economic source of ethanol, as some analysts think it may, it will be a major breakthrough, since it can be grown on land that is highly erodible or otherwise not suitable for annual crops. In a competitive world market for crop-based ethanol, the future belongs to sugarcane and switchgrass.[53]

The ethanol yield per acre for switchgrass is calculated at 1,150 gallons, higher even than for sugarcane. The net energy yield, however, is roughly 4, far above the 1.5 for corn but less than the 8 for sugarcane.[54]

Aside from the prospective use of cellulose, current and planned ethanol-producing operations use food crops such as sugarcane, sugar beets, corn, wheat, and barley. The United States, for example, in 2004 used 32 million tons of corn to produce 3.4 billion gallons of ethanol. Although this is scarcely 12 percent of the huge U.S. corn crop, it is enough to feed 100 million people at average world grain consumption levels.[55]

In an oil-short world, what will be the economic and environmental effects of agriculture's emergence as a producer of transport fuels? Agriculture's role in the global economy clearly will be strengthened as it faces a vast, virtually unlimited market for automotive fuel. Tropical and subtropical countries that can produce sugarcane or palm oil will be able to fully exploit their year-round growing conditions, giving them a strong comparative advantage in the world market.

With biofuel production spreading, the world price for oil will, in effect, become a support price for farm products. If food and feed crop prices are weak and oil prices are high, commodities will go to fuel producers. For example, vegetable oils trading on European markets on any given day may end up in either supermarkets or service stations.

The risk is that economic pressures to clear land for expanding sugarcane production in the Brazilian *cerrado* and Amazon basin and for palm oil plantations in countries such as Indonesia and Malaysia will pose a major new threat to plant and animal diversity. In the absence of governmental constraints, the rising price of oil could quickly become the leading threat to biodiversity, ensuring that the wave of extinctions now under way does indeed become the sixth great extinction.

With oil prices now high enough to stimulate potentially massive investments in fuel crop production, the world farm economy—already struggling to feed 6.5 billion people—will face far greater demands. How the world manages this new incredibly complex situation will tell us a great deal about the prospect for our energy-hungry twenty-first century civilization.[56]

Cities and Suburbs After Peak Oil

Modern cities are a product of the oil age. From the first cities, which apparently took shape in Mesopotamia some 6,000 years ago, until 1900, urbanization was a slow, barely perceptible process. When the last century began, there were only a few cities with a million people. Today there are more than 400 cities that large, and 20 mega-cities have 10 million or more residents.[57]

The metabolism of cities depends on concentrating vast amounts of food and materials and then disposing of garbage and human waste. With the limited range and capacity of horse-drawn wagons, it was difficult to create large cities. Trucks running on cheap oil changed all that.

As cities grow ever larger and as nearby landfills reach capacity, garbage must be hauled longer distances to disposal sites. With oil prices rising and available landfills receding ever further from the city, the cost of garbage disposal also rises. At some point, many throwaway products may be priced out of existence.

Urban living costs will likely rise as oil production turns down and oil prices escalate. One of the intriguing questions this raises is whether urbanization will continue APO, after peak oil. Or might the process even be reversed when people seek less oil-dependent lifestyles?

Cities will be hard hit by the coming decline in oil production, but suburbs will be hit even harder. People living in poorly designed suburbs not only depend on importing everything, they are also often isolated geographically from their jobs and shops. They must drive for virtually everything they need. Living in suburban housing developments often means using a car even to get a loaf of bread or a quart of milk.

Suburbs have created a commuter culture, with the daily roundtrip commute taking, on average, close to an hour a day in the United States. While Europe's cities were largely mature before the onslaught of the automobile, those in the United States, a much younger country, were shaped by the car. While city limits are usually rather clearly defined in Europe, and while Europeans only reluctantly convert productive farmland into housing developments, Americans have few qualms about this because of a frontier mentality and because cropland was long seen as a surplus commodity.

This unsightly, aesthetically incongruous sprawl of suburbs and strip malls is not limited to the United States. It is found in Latin America, in Southeast Asia, and increasingly in China. Flying from Shanghai to Beijing provides a good view of the sprawl of buildings, including homes and factories, that is following the new roads and highways. This is in sharp contrast to the tightly built villages that shaped residential land use for millennia in China.

Shopping malls and huge discount stores, symbolized in the public mind by Wal-Mart, were all subsidized by artificially cheap oil. Isolated by high oil prices, suburbs may prove to be ecologically and economically unsustainable. Thomas Wheeler, editor of the *Alternative Press Review*, observes that "there will eventually be a great scramble to get out of the suburbs as the world oil crisis deepens and the property values of suburban homes plummet."[58]

The World After Oil Peaks

Peak oil is described as the point where oil production stops rising and begins its unavoidable long-term decline. In the face of fast-growing demand, this means rising oil prices. But even if oil production growth simply slows or plateaus, the resulting tightening in supplies will still drive the price of oil upward, albeit less rapidly.

Few countries are planning a reduction in their use of oil. Indeed, the projections of oil use by both the International Energy Agency and the U.S. Department of Energy show world oil consumption going from roughly 84 million barrels a day at present to 120 million barrels a day by 2030. According to these analyses, oil consumption in individual countries will be increasing on average by nearly half over the next 20 years. How did they come up with these "rosy" forecasts? To quote Thomas Wheeler again, are many analysts and leaders simply "oblivious to the flashing red light on the earth's fuel gauge?"[59]

Even though peak oil may be imminent, most countries are counting on much higher oil consumption in the decades ahead. Indeed, they are building automobile assembly plants, roads, highways, parking lots, and suburban housing developments as though cheap oil will last forever. New airliners are being delivered with the expectation that air travel and freight will expand indefinitely. Yet in a world of declining oil production, no country can use more oil except at the expense of others.[60]

Some segments of the global economy will be affected more than others simply because some are more oil-intensive. Among these are the automobile, food, and airline industries. Stresses within the U.S. auto industry were already evident before oil prices started climbing in mid-2004. Now General Motors and Ford, both trapped with their heavy reliance on sales of gas-hogging sport utility vehicles, have seen Standard and Poors lower their credit ratings, reducing their corporate bonds to junk bond status. In June 2005, General Motors announced that it planned to cut its U.S. workforce of 110,000 by 25,000 workers in 2007.[61]

Although it is the troubled automobile manufacturers that appear in the headlines as oil prices rise, their affiliated industries will also be affected, including auto parts and tire manufacturers.

The food sector will be affected in two ways. Food will become more costly as higher oil prices drive up production costs. As oil costs rise, diets will be altered as people move down the food chain and as they consume more local, seasonally produced food. Diets will thus become more closely attuned to local products and more seasonal in nature.

At the same time, rising oil prices will also be drawing agricultural resources into the production of fuel crops, either ethanol or biodiesel. Higher oil prices are thus setting up competition between affluent motorists and low-income food consumers for food resources, presenting the world with a complex new ethical issue.

Airlines, both passenger travel and freight, will continue to suffer as jet fuel prices climb, simply because fuel is their biggest operating expense. Although industry projections show air passenger travel growing by some 5 percent a year for the next decade, this seems highly unlikely. Cheap airfares may soon become history.[62]

Air freight may be hit even harder, perhaps leading to an absolute decline. One of the early casualties of rising oil prices could be the use of jumbo jets to transport fresh produce from the southern hemisphere to industrial countries during the northern winter. The price of fresh produce out of season may simply become prohibitive.

During the century of cheap oil, an enormous automobile infrastructure was built in industrial countries that requires large amounts of energy to maintain. The United States, for example, has 2.6 million miles of paved roads, covered mostly with asphalt, and 1.4 million miles of unpaved roads to maintain even if world oil production is falling. Higher energy prices may create a maintenance crisis.[63]

In addition to needing to use oil more efficiently, the world is also looking to other sources of energy. Although nuclear power has been getting some press attention as an alternative to fossil fuels, electricity from nuclear power plants is costly. On a level playing field with no taxpayer subsidies, nuclear power is dead. If utilities pay the full costs of nuclear waste disposal, of insurance against an accident, and of decommissioning plants that are worn out, the expense of nuclear power will take it out of the running. And with international terrorism on the rise, the vulnerability of nuclear power plants to attack combined with their use by countries as a steppingstone to the acquisition of nuclear weapons virtually eliminates nuclear fission as a future energy source.[64]

The relative abundance of coal makes it an attractive energy source in some quarters, but it is likely to soon become a victim of mounting public concern about climate change. This means a future of renewable sources of energy, including wind energy, solar cells, solar thermal panels, solar thermal power plants, geothermal energy, hydropower, wave power, and biofuels.

In the coming energy transition, there will be winners and losers. Countries that fail to plan ahead, that lag in investing in more oil-efficient technologies and new energy sources, may experience a decline in living standards. The inability of national governments to manage the energy transition could lead to a failure of confidence in leaders and to failed states.

National political leaders seem reluctant to face the coming downturn in oil and to plan for it even though it will become one of the great fault lines not only in recent economic history but in the history of civilization. Trends now taken for granted, such as urbanization and globalization, could be reversed almost overnight as oil becomes scarce and costly.

Developing countries will be hit doubly hard as still-expanding populations combine with a shrinking oil supply to steadily reduce oil use per person. Such a decline could quickly translate into a fall in living standards. If the United States, the world's largest oil consumer and importer, can sharply reduce its use of oil, it can buy the world time for a smoother transition to the post-petroleum era. What the world needs today is not more oil, but more leadership.