Depletion of Key Resources: Facts at Your Fingertips

Contributed by Peter Goodchild
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Editor's note: The author presents a definitive essay. Learn why:

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• "There are already too many people to be supported by non-mechanized agriculture."

• "To meet the world's present energy needs by using solar power, then, we would need... a machine the size of France. The production and maintenance of this array would require vast quantities of hydrocarbons, metals, and other materials -- a self-defeating process. Solar power will therefore do little to solve the world's energy problems."

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Peter Goodchild's new book The Coming Chaos will be appearing shortly.
- Jan Lundberg, Culture Change

Modern industrial society is based on a triad of hydrocarbons, metals, and electricity. The three are intricately connected; each is accessible only if the other two are present. Electricity, for example, can be generated on a global scale only with hydrocarbons. The same dependence on hydrocarbons is true of metals; in fact the better types of ore are now becoming depleted, while those that remain can be processed only with modern machinery and require more hydrocarbons for smelting. In turn, without metals and electricity there would be no means of extracting and processing hydrocarbons. Of the three members of the triad, electricity is the most fragile, and its failure serves as an early warning of trouble with the other two [6, 7].

Often the interactions of this triad are hiding in plain sight. Global production of steel, for example, requires 420 million tonnes of coke (from coal) annually, as well as other hydrocarbons adding up to an equivalent of another 100 million tonnes [22]. To maintain industrial society, the production of steel cannot be curtailed: there are no “green” materials for the construction of skyscrapers, large bridges, automobiles, machinery, or tools. But the interconnections among fossil fuels, metals, and electricity are innumerable. As each of the three members of the triad threatens to break down, we are looking at a society that is far more primitive than the one to which we have been accustomed.

The ascent and descent of oil production are those of the famous promontory known as Hubbert’s curve. The back side of the mountain probably does not greatly resemble the front. It is likely that the descent will be rather steep, again because of synergistic factors. As oil declines, more energy and money must be devoted to getting the less-accessible and lower-quality oil out of the ground [10]. In turn, as more energy and money are devoted to oil production, the production of metals and electricity becomes more difficult. One problem feeds on another. The issue can also be described in terms of sheer money: when oil production costs about 4.5 percent of the economy, the latter begins a downward spiral [14].

There is a final piece of ill luck that occurs after the peak. When individual countries such as the USA begin to run out of domestic oil, depletion can be mitigated by the importation of oil from other countries, so the descent is not as troublesome as it might have been. When the entire planet begins to run out of oil, however, there will be nowhere to turn in order to make up the difference. We cannot get oil from outer space [17].

Global Energy per Capita

Global consumption of energy for the year 2005 was about 500 exajoules (EJ), most of which was supplied by fossil fuels. This annual consumption of energy can also be expressed in terms of billion barrels of oil equivalent [1, 6, 7, 9]. What is more important in terms of the effects on daily human life, though, is not consumption in an absolute sense, but consumption per capita, which reached what Richard C. Duncan calls a “rough plateau” in 1979.

Use of electricity worldwide rose by 70 percent from 1990 to 2008 [1]. This means an increase per capita of 41 percent. Since global energy per capita is not increasing significantly, there may come a point at which there is insufficient energy to prevent widespread brownouts and rolling blackouts [6, 7].

Fossil Fuels

The entire world’s economy is based on oil and other fossil fuels. These provide fuel, lubricants, asphalt, paint, plastics, fertilizer, and many other products. In 1850, before commercial production began, there were about 2 trillion barrels of oil in the ground. By about the year 2010, half of that oil had been consumed, so about 1 trillion barrels remain. At the moment about 30 billion barrels of oil are consumed annually, and that is probably close to the maximum that will ever be possible. By the year 2030, some analysts say, oil production will be down to about half of that amount [3]. [Editor's note: we must consider the factor of oil-industry inflexibility to contract and to maintain extraction if collapse has already hit the economy.]

A vast amount of debate has gone on about “peak oil,” the date at which the world’s annual oil production will reach (or did reach) its maximum and will begin (or did begin) to decline. The exact numbers are unobtainable, mainly because oil-producing countries give rather inexact figures on their remaining supplies. The situation can perhaps be summarized by saying that many studies have been done, and that the consensus is that the peak is somewhere between the years 2000 and 2020. Within that period, a middle date seems rather more likely. Among the many who have contributed to that debate are Kenneth S. Deffeyes, Colin J. Campbell, Jean Laherrère, Dale Allen Pfeiffer, and Matthew R. Simmons, and the Association for the Study of Peak Oil has done its own appraisals [2, 3, 5, 18, 21].

The quest for the date of peak oil is somewhat of a red herring. In terms of daily life, what is more important is not peak oil in the absolute sense, but peak oil per capita. The date of the latter was 1979, when there were 5.5 barrels of oil per person annually, as opposed to 4.5 in 2007 [1, 6, 7]. This per-capita date of 1979 for oil consumption is the same as that noted above for per-capita consumption of energy in general.

Coal and natural gas are also disappearing. Coal will be available for a while after oil is gone, although previous reports of its abundance in the US were highly exaggerated [23]. Coal is highly polluting and cannot be used as a fuel for most forms of transportation. Natural gas is not easily transported, and it is not suitable for most equipment.

Solar Power

The world’s deserts have an area of 36 million km2, and the solar energy they receive annually is 300,000 EJ, which at a typical 11-percent electrical-conversion rate would result in 33,000 EJ [13].

As noted above, annual global energy consumption in 2005 was approximately 500 EJ. To meet the world's present energy needs by using solar power, then, we would need an array (or an equivalent number of smaller ones) with a size of 500/33,000 x 36 million km2, which is about 550,000 km2 -- a machine the size of France. The production and maintenance of this array would require vast quantities of hydrocarbons, metals, and other materials -- a self-defeating process. Solar power will therefore do little to solve the world's energy problems.

Minerals Other than Petroleum

Depletion of other minerals on a global scale is somewhat difficult to determine, partly because recycling complicates the issues, partly because trade goes on in all directions, and partly because one material can sometimes be replaced by another. Figures from the US Geological Survey indicate that within the US most types of minerals and other nonrenewable resources are well past their peak dates of production [26]. Besides oil, these include bauxite (peaking in 1943), copper (1998), iron ore (1951), magnesium (1966), phosphate rock (1980), potash (1967), rare earth metals (1984), tin (1945), titanium (1964), and zinc (1969). The depletion of these resources continues swiftly in spite of recycling.

In the past it was iron ores such as natural hematite (Fe_2O_3) that were being mined. For thousands of years, also, tools were produced by melting down bog iron, mainly goethite, FeO(OH), in clay cylinders only a meter or so in height. Modern mining must rely more heavily on taconite, a flint-like ore containing less than 30 percent magnetite and hematite [10].

Iron ore of the sort that can be processed with primitive equipment is becoming scarce, in other words, and only the less-tractable forms such as taconite will be available when the oil-powered machinery has disappeared — a chicken-and-egg problem. To put it more bluntly: with the types of iron ore used in the past, a fair proportion of the human race would have been able to survive in the post-industrial world. With taconite it will not.

Grain

Annual world production of grain per capita peaked in 1984 at 342 kg [8]. For years production has not met demand, so carryover stocks must fill the gap, now leaving less than 2 months' supply as a buffer. Rising temperatures and falling water tables are causing havoc in grain harvests everywhere, but the biggest dent is caused by the bio-fuel industry, which is growing at over 20 percent per year. In 2007, 88 million tons of US corn, a quarter of the entire US harvest, was turned into automotive fuel.

Water

The production rate of fresh water is declining everywhere. According to the UN's Global Environment Outlook 4, "by 2025, about 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress   the threshold for meeting the water requirements for agriculture, industry, domestic purposes, energy and the environment. . . ." [25]

Arable Land

With “low technology,” i.e. technology that does not use fossil fuels, crop yields diminish considerably. The production of so-called field or grain corn (maize) without irrigation or mechanized agriculture is only about 2,000 kilograms per hectare (10,000 m2), about a third of the yield that a farmer would get with modern machinery and chemical fertilizer [19, 20].

Yields for corn provide a handy baseline for other studies of population and food supply. More specifically, corn is one of the most useful grains for supporting human life; the native people of the Americas lived on it for thousands of years. Corn is high-yielding and needs little in the way of equipment, and the more ancient varieties are largely trouble-free in terms of diseases, pests, and soil depletion.

A hard-working (i.e. farming) adult burns about 2 million kilocalories (“calories”) per year. The food energy from a hectare of corn is about 7 million kilocalories. Under primitive conditions, then, 1 hectare of corn would support only 3 or 4 people.

Even those figures are rather idealistic. We are assuming that people will follow a largely vegetarian diet; if not, they will need even more land. We also need to allow for fallow land, cover crops, and green manure, for inevitable inequities in distribution, and for other uses of the land. On a global scale a far more realistic ratio would be 2 people to each hectare of arable land.

The average American house lot is about 900 m2, i.e. less than a tenth of a hectare, including the land the house is sitting on. Those who expect to get by with “victory gardens” are unaware of the arithmetic involved.

In the entire world there are 15,749,300 km2 of arable land [4]. This is 11 percent of the world’s total land area. The present world population is about 6,900,000,000. Dividing the figure for population by that for arable land, we see that there are 438 people per km2 of arable land. On a smaller scale that means about 4 people per hectare. Less than a third of the world’s 200-odd countries are actually within that ratio. In other words, there are already too many people to be supported by non-mechanized agriculture.

The UK, for example, has a population-to-arable ratio of slightly more than 10 people per hectare. What exactly is going to happen to the 8 people who will not fit onto the hectare? But many countries have far worse ratios.

Population

The world’s population went from about 1.6 billion in 1900 to about 2.5 in 1950, to about 6.1 billion in 2000. It is now (2010) approaching 7 billion. It has often been said that without fossil fuels the population must drop to about 2 or 3 billion [27]. The above figures on arable land indicate that in terms of agriculture alone we would be able to accommodate only about half the present number of people.

Another calculation about future population can be made by looking more closely at Hubbert’s curve. The rapid increase in population over the last hundred years is not merely coincident with the rapid increase in oil production. It is the latter that has actually allowed (the word “caused” might be too strong) the former: that is to say, oil has been the main source of energy within industrial society. It is only with abundant oil that a large population is possible. It was industrialization, improved agriculture, improved medicine, the expansion of humanity into the Americas, and so on, that first created the modern rise in population, but it was oil in particular that made it possible for human population to grow as fast as it has been doing. It is not only fossil fuels that form a bell curve: there is also a bell curve for human population.

Of course, this calculation of population on the basis of oil is largely the converse of the calculation on the basis of arable land, since in industrial society the amount of farm production is mainly a reflection of the amount of available oil.

If we look further into the future, we see an even smaller number for human population, still using previous ratios of oil to population as the basis for our figures. But the world a hundred years from now might not be a mirror image of the world of a hundred years in the past. The general depletion of resources could cause such damage to the structure of society that government, education, and intricate division of labor no longer exist. In a milieu of social chaos, what are the chances that the oil industry will be using extremely advanced technology to extract the last drops of oil? Even then we have not factored in war, epidemics, and other aspects of social breakdown. The figure of 1 to 3 billion may be wildly optimistic.

Looking Forward

A great deal of silliness goes on in the name of preparing for the future. Global collapse should not been seen in terms of middle-class country elegance. At present there are no “transition towns” that acquire food, clothing, or shelter without large quantities of fossil fuels somewhere in the background. The post-oil world will be much grimmer than most people imagine, and that is partly because they are not looking at the big picture. Hydrocarbons are the entire substructure of modern society. The usual concept of “transition towns” evades the sheer enormity of the problems.

Whatever a “transition” polity might be, it most certainly will not be a city or town. Those who are living at the end of all the bell curves will prosper only if they are far from anything resembling an urban or suburban area. It has always been possible for small rural communities to live close to the land, somewhat avoiding the use of fossil fuels, metals, and electricity, but modern large centers of population are founded on the premise of an abundance of all three. Urban areas, in fact, will be experiencing the worst of each form of depletion described above.

In view of the general unpopularity of family-planning policies [24], it can only be said euphemistically that nature will decide the outcome. Even if his words owe as much to observation of the stages of collapse as to divine inspiration, it is St. John’s Four Horsemen of war, famine, plague, and death who will characterize the future of the industrial world. Nor can we expect people to be overly concerned about good manners: although there are too many variables for civil strife to be entirely predictable, if we look at accounts of large-scale disasters of the past, ranging from the financial to the meteorological, we can see that there is a point at which the looting and lynching begin. The survivors of industrial society will have to distance themselves from the carnage.

The need for a successful community to be far removed from urban areas is also a matter of access to the natural resources that will remain. With primitive technology, it takes a great deal of land to support human life. What may look like a long stretch of empty wilderness is certainly not empty to the people who are out there picking blueberries or catching fish. That emptiness is not a prerogative or luxury of the summer vacationer. It is an essential ratio of the human world to the non-human.

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