Eating Fossil Fuels

by

Dale Allen Pfeifer

Commentary

I have taken the Author's Note from the end of the original article and moved it up here to the commentary. I must say that the large outcry I expected to follow the release of this article did not materialize. I expected a reactionary attack from the religious right. To my surprise, the reactionary attack came not from the right but from the left. For many years, Progressives and Radicals have held that modern technology can provide for all and that hunger in the world today is caused by power disparities and a lack of true democracy. While this is correct, it ignores the fact that modern agriculture technology relies heavily upon fossil fuels. As pointed out in this report, without the fossil fuel input, modern agriculture will fail and we will no longer be able to produce the food necessary to sustain more than a fraction of our present population. The left cannot see that we are entering a new age of resource depletion. Their old standard that a more equitable society can support us all no longer applies. As environmentalists have warned for years, we have exploited the planet to its limits, and now we are entering a new age of scarcity. The left must adjust their thinking. We can all still profit from a more equitable socio-economic system. But we will have to make some hard choices. Here follows the original Author's Note from the end of the article.

This is possibly the most important article I have written to date. It is certainly the most frightening, and the conclusion is the bleakest I have ever penned. This article is likely to greatly disturb the reader; it has certainly disturbed me. However, it is important for our future that this paper should be read, acknowledged and discussed.

I am by nature a very positive and optimistic person. In spite of this article, I continue to believe that we can find a positive solution to the multiple crises bearing down upon us. Though this article may provoke a flood of hate mail, it is simply a factual report of data and the obvious conclusions.

Introduction

Human beings (like all other animals) draw their energy from the food they eat. Until the last century all of the food energy available on this planet was derived from the sun through photosynthesis. Either you ate plants or you ate animals which fed on plants, but the energy in your food was ultimately derived from the sun.

It would have been absurd to think that we would one day run out of sunshine. No, sunshine was an abundant, renewable resource, and the process of photosynthesis fed all life on this planet. It also set a limit on the amount of food which could be generated at any one time, and therefore placed a limit upon population growth. Solar energy has a limited rate of flow into this planet. To increase your food production, you had to increase the acreage under cultivation, and displace your competitors. There was no other way to increase the amount of energy available for food production. Human population grew by displacing everything else and appropriating more and more of the available solar energy.

The need to expand agricultural production was one of the motive causes behind most of the wars in recorded history, along with expansion of the energy base (and agricultural production is truly an essential portion of the energy base). And when Europeans could no longer expand cultivation, they began the task of conquering the world. Explorers were followed by conquistadors and traders and settlers. The declared reasons for this expansion may have been trade, avarice, empire or simply curiosity, but at the base it was all about the expansion of agricultural productivity. Wherever explorers and conquistadors traveled, they may have carried off loot, but they left plantations. And settlers toiled to clear land and establish their own homestead. This conquest and expansion went on until there was no place left for further expansion. Certainly, to this day landowners and farmers fight to claim still more land for agricultural productivity, but they are fighting over crumbs. Today, virtually all of the productive land on this planet is being exploited by agriculture. What remains is either too steep, too wet, too dry or lacking in soil nutrients.[1]

Just when agricultural output could expand no more by increasing acreage, new innovations made possible a more thorough exploitation of the acreage already available. The process of "pest" displacement and appropriation for agriculture accelerated with the industrial revolution as the mechanization of agriculture hastened the clearing and tilling of land and augmented the amount of farmland which could be tended by one person. And with every increase in food production, the human population grew apace.

At present, nearly 40% of all land-based photosynthetic capability has been appropriated by human beings.[2] In the United States, we divert more than half of the energy captured by photosynthesis.[3] We have taken over all the prime real estate on this planet. The rest of the biota is forced to make due with what is left. Plainly, this is one of the major factors in species extinctions and in ecosystem stress.

The Green Revolution

In the 1950s and 1960s, agriculture underwent a drastic transformation commonly referred to as the Green Revolution. The Green Revolution resulted in the industrialization of agriculture. Part of the advance resulted from new hybrid food plants, leading to more productive food crops. Between 1950 and 1984, as the Green Revolution transformed agriculture around the globe, world grain production increased by 250%.[4] That is a tremendous increase in the amount of food energy available for human consumption. This additional energy did not come from an increase in incipient sunlight, nor did it result from introducing agriculture to new vistas of land. The energy for the Green Revolution was provided by fossil fuels. The Green Revolution was made possible by fossil fuel based fertilizers and pesticides, and hydrocarbon fueled irrigation.

The Green Revolution increased the energy flow to agriculture by an average of 50 times the energy input of traditional agriculture.[5] In the most extreme cases, energy consumption by agriculture has increased 100 fold or more.[6] We are quite literally eating fossil fuels.

In the United States, 400 gallons of oil equivalents are expended annually to feed each American (as of data provided in 1994).[7] Agricultural energy consumption is broken down as follows:

- 31% for the manufacture of inorganic fertilizer
- 19% for the operation of field machinery
- 16% for transportation
- 13% for irrigation
- 08% for raising livestock (not including livestock feed)
- 05% for crop drying
- 05% for pesticide production
- 08% miscellaneous[8]

Energy costs for packaging, refrigeration, transportation to retail outlets and household cooking are not considered in these figures.

To give the reader an idea of the energy intensiveness of modern agriculture, production of one kilogram of nitrogen for fertilizer requires the energy equivalent of from 1.4 to 1.8 liters of diesel fuel. This is not considering the hydrocarbon feedstock.[9] According to The Fertilizer Institute (http://www.tfi.org), in the year from June 30 2001 until June 30 2002 the United States used 12,009,300 short tons of nitrogen fertilizer.[10] Using the low figure of 1.4 liters diesel equivalent per kilogram of nitrogen, this equates to the energy content of 15.3 billion liters of diesel fuel, or 4.04 billion gallons.

Of course this is only a rough comparison to aid comprehension of the energy requirements for modern agriculture.

In a very real sense, we are eating fossil fuels. However, due to the laws of thermodynamics, there is not a direct correspondence between energy inflow and outflow in agriculture. Along the way, there is a marked energy loss. Between 1945 and 1994 energy input to agriculture increased 4-fold while crop yields only increased 3-fold.[11] Since then energy input has continued to increase without a corresponding increase in crop yield. We have reached the point of marginal returns. Yet, due to soil degradation, increased demands of pest management and increasing energy costs for irrigation (all of which is examined below), modern agriculture must continue increasing its energy expenditures simply to maintain current crop yields. The Green Revolution is becoming bankrupt.

Fossil Fuel Costs

Solar energy is a renewable resource limited only by the inflow rate from the sun to the earth. Fossil fuels, on the other hand, are a stock-type resource which can be exploited at a nearly limitless rate. However, on a human timescale fossil fuels are nonrenewable. They represent a planetary energy deposit which we can draw from at any rate we wish, but which will eventually be exhausted without renewal. The Green Revolution tapped into this energy deposit and used it to increase agricultural production.

Total fossil fuel use in the United States has increased 20-fold in the last 4 decades. In the US, we consume 20 to 30 times more fossil fuel energy per capita than people in developing nations. Agriculture directly accounts for 17% of all the energy used in this country.[12] As of 1990, we were using approximately 1,000 liters of oil to produce food of one hectare of land.[13]

In 1994 David Pimentel and Mario Giampietro estimated the output/input ratio of agriculture to be around 1.4.[14] For 0.7 Kilogram-Calories (kcal) of fossil energy consumed, U.S. agriculture produced 1 kcal of food. The input figure for this ratio was based on FAO (Food and Agriculture Organization of the UN) statistics, which consider only fertilizers (without including fertilizer feedstock), irrigation, pesticides (without including pesticide feedstock), and machinery and fuel for field operations. Other agricultural energy inputs not considered were energy and machinery for drying crops, transportation for inputs and outputs to and from the farm, electricity, and construction and maintenance of farm buildings and infrastructures. Adding in estimates for these energy costs brought the input/output energy ratio down to 1.[15] Yet this does not include the energy expense of packaging, delivery to retail outlets, refrigeration or household cooking.

In a subsequent study completed later that same year (1994) Giampietro and Pimentel managed to derive a more accurate ratio of the net fossil fuel energy ratio of agriculture.[16] In this study, the authors defined two separate forms of energy input: Endosomatic energy and Exosomatic energy. Endosomatic energy is generated through the metabolic transformation of food energy into muscle energy in the human body. Exosomatic energy is generated by transforming energy outside of the human body, such as burning gasoline in a tractor. This assessment allowed the authors to look at fossil fuel input alone and in ratio to other inputs.

Previous to the industrial revolution, virtually 100% of both endosomatic and exosomatic energy was solar driven. Fossil fuels now represent 90% of the exosomatic energy used in the United States and other developed countries.[17] The typical exo/endo ratio of pre-industrial, solar powered societies is about 4 to 1. The ratio has changed tenfold in developed countries, climbing to 40 to 1. And in the United States it is more than 90 to 1.[18] And the nature of the way we use endosomatic energy has changed as well.

The vast majority of endosomatic energy is no longer expended to deliver power for direct economic processes. Now the majority of endosomatic energy is utilized to generate the flow of information directing the flow of exosomatic energy driving machines. Considering the 90/1 exo/endo ratio in the United States, each endosomatic kcal of energy expended in the U.S. induces the circulation of 90 kcal of exosomatic energy. As an example, a small gasoline engine can convert the 38,000 kcal in one gallon of gasoline into 8.8 KWh (Kilowatt hours), which equates to about 3 weeks of work for one human being.[19]

In their refined study, Giampietro and Pimentel found that 10 kcal of exosomatic energy are required to produce 1 kcal of food delivered to the consumer in the U.S. food system. This includes packaging and all delivery expenses, but excludes household cooking).[20] *The U.S. food system consumes ten times more energy than it produces in food energy.* This disparity is made possible by nonrenewable fossil fuel stocks.

Assuming a figure of 2,500 kcal per capita for the daily diet in the United States, the 10/1 ratio translates into a cost of 35,000 kcal of exosomatic energy per capita each day. However, considering that the average return on one hour of endosomatic labor in the U.S. is about 100,000 kcal of exosomatic energy, the flow of exosomatic energy required to supply the daily diet is achieved in only 20 minutes of labor in our current system. Unfortunately, if you remove fossil fuels from the equation, the daily diet will require 111 hours of endosomatic labor per capita; that is, *the current U.S. daily diet would require nearly three weeks of labor per capita to produce.*

Quite plainly, as fossil fuel production begins to decline within the next decade, there will be less energy available for the production of food.

Soil, Cropland and Water

Modern intensive agriculture is unsustainable. Technologically enhanced agriculture has augmented soil erosion, polluted and overdrawn groundwater and surface water, and even (largely due to increased pesticide use) caused serious public health and environmental problems. Soil erosion, overtaxed cropland and water resource overdraft in turn lead to even greater use of fossil fuels and hydrocarbon products. More hydrocarbon based fertilizers must be applied, along with more pesticides; irrigation water requires more energy to pump; and fossil fuels are used to process polluted water.

It takes 500 years to replace 1 inch of topsoil.[21] In a natural environment, topsoil is built up by decaying plant matter and weathering rock, and it is protected from erosion by growing plants. In soil made susceptible by agriculture, erosion is reducing productivity up to 65% each year.[22] Former prairie lands, which constitute the bread basket of the United States, have lost one half of their topsoil after farming for about 100 years. This soil is eroding 30 times faster than the natural formation rate.[23] Food crops are much hungrier than the natural grasses which once covered the Great Plains. As a result, the remaining topsoil is increasingly depleted of nutrients. Soil erosion and mineral depletion removes about $20 billion worth of plant nutrients from U.S. agricultural soils every year.[24] Much of the soil in the Great Plains is little more than a sponge into which we must pour hydrocarbon-based fertilizers in order to produce crops.

Every year in the U.S., more than 2 million acres of cropland are lost to erosion, salinization and water logging. On top of this, urbanization, road building and industry claim another 1 million acres annually from farmland.[24] Approximately three-quarters of the land area in the United States is devoted to agriculture and commercial forestry.[25] The expanding human population is putting increasing pressure on land availability. Incidentally, only a small portion of U.S. land area remains available for the solar energy technologies necessary to support a solar energy-based economy. The land area for harvesting biomass is likewise limited. For this reason, the development of solar energy or biomass must be at the expense of agriculture.

Modern agriculture also places a strain on our water resources. Agriculture consumes fully 85% of all U.S. freshwater resources.[26] Overdraft is occurring from many surface water resources, especially in the west and south. The typical example is the Colorado River, which is diverted to a trickle by the time it reaches the Pacific. Yet surface water only supplies 60% of the water used in irrigation. The remainder, and in some places the majority of water for irrigation, comes from ground water aquifers. Ground water is recharged slowly by the percolation of rainwater through the earth's crust. Less than 0.1% of the stored ground water mined annually is replaced by rainfall.[27] The great Ogallala aquifer which supplies agriculture, industry and home use in much of the southern and central plains states has an annual overdraft up to 160% above its recharge rate. The Ogallala aquifer will become unproductive in a matter of decades.[28]

We can illustrate the demand which modern agriculture places on water resources by looking at a farmland producing corn. A corn crop that produces 118 bushels/acre/year requires more than 500,000 gallons/acre of water during the growing season. The production of 1 pound of maize requires 1,400 pounds (or 175 gallons) of water.[29] Unless something is done to lower these consumption rates, modern agriculture will help to propel the United States into a water crisis.

In the last two decades, the use of hydrocarbon-based pesticides in the U.S. has increased 33-fold, yet each year we lose more crops to pests.[30] This is the result of the abandonment of traditional crop rotation practices. Nearly 50% of U.S. corn land is grown continuously as a monoculture.[31] This results in an increase in corn pests which in turn requires the use of more pesticides. Pesticide use on corn crops had increased 1,000-fold even before the introduction of genetically engineered, pesticide resistant corn. However, corn losses have still risen 4-fold.[32]

Modern intensive agriculture is unsustainable. It is damaging the land, draining water supplies and polluting the environment. And all of this requires more and more fossil fuel input to pump irrigation water, to replace nutrients, to provide pest protection, to remediate the environment and simply to hold crop production at a constant. Yet this necessary fossil fuel input is going to crash headlong into declining fossil fuel production.

US Consumption

In the United States, each person consumes an average of 2,175 pounds of food per person per year. This provides the U.S. consumer with an average daily energy intake of 3,600 Calories. The world average is 2,700

Calories per day.[33] Fully 19% of the U.S. caloric intake comes from fast food. Fast food accounts for 34% of the total food consumption for the average U.S. citizen. The average citizen dines out for one meal out of four.[34]

One third of the caloric intake of the average American comes from animal sources (including dairy products), totaling 800 pounds per person per year. This diet means that U.S. citizens derive 40% of their calories from fat—nearly half of their diet. [35]

Americans are also grand consumers of water. As of one decade ago, Americans were consuming 1,450 gallons/day/capita (g/d/c), with the largest amount expended on agriculture. Allowing for projected population increase, consumption by 2050 is projected at 700 g/d/c, which hydrologists consider to be minimal for human needs.[36] This is without taking into consideration declining fossil fuel production.

To provide all of this food requires the application of 0.6 million metric tons of pesticides in North America per year. This is over one fifth of the total annual world pesticide use, estimated at 2.5 million tons.[37] Worldwide, more nitrogen fertilizer is used per year than can be supplied through natural sources. Likewise, water is pumped out of underground aquifers at a much higher rate than it is recharged. And stocks of important minerals, such as phosphorus and potassium, are quickly approaching exhaustion.[38]

Total U.S. energy consumption is more than three times the amount of solar energy harvested as crop and forest products. The United States consumes 40% more energy annually than the total amount of solar energy captured yearly by all U.S. plant biomass. Per capita use of fossil energy in North America is five times the world average.[39]

Our prosperity is built on the principal of exhausting the world's resources as quickly as possible, without any thought to our neighbors, all the other life on this planet, or our children.

Population & Sustainability

Considering a growth rate of 1.1% per year, the U.S. population is projected to double by 2050. As the population expands, an estimated one acre of land will be lost for every person added to the U.S. population. Currently, there are 1.8 acres of farmland available to grow food for each U.S. citizen. By 2050, this will decrease to 0.6 acres. !.2 acres per person is required in order to maintain current dietary standards.[40]

Presently, only two nations on the planet are major exporters of grain: the United States and Canada.[41] By 2025, it is expected that the U.S. will cease to be a food exporter due to domestic demand. The impact on the U.S. economy could be devastating, as food exports earn $40 billion for the U.S. annually. More importantly, millions of people around the world could starve to death without U.S. food exports.[42]

Domestically, 34.6 million people are living in poverty as of 2002 census data.[43] And this number is continuing to grow at an alarming rate. Too many of these people do not have a sufficient diet. As the situation worsens, this number will increase and the United States will witness growing numbers of starvation fatalities.

There are some things which we can do to at least alleviate this tragedy. It is suggested that streamlining agriculture to get rid of losses, waste and mismanagement might cut the energy inputs for food production by up to one-half.[35] In place of fossil fuel based fertilizers, we could utilize livestock manures which are now wasted. It is estimated that livestock manures contain 5 times the amount of fertilizer currently used each year.[36] Perhaps most effective would be to eliminate meat from our diet altogether.[37]

Mario Giampietro and David Pimentel postulate that a sustainable food system is possible only if four conditions are met.

1. Environmentally sound agricultural technologies must be implemented.
2. Renewable energy technologies must be put into place.
3. Major increases in energy efficiency must reduce exosomatic energy consumption per capita.
4. Population size and consumption must be compatible with maintaining the stability of environmental processes.[38]

Providing that the first three conditions are met, with a reduction to less than half of the exosomatic energy consumption per capita, the authors place the maximum population for a sustainable economy at 200 million.[39] Several other studies have produced figures within this ballpark (**Energy and Population**, Werbos, Paul J. http://www.dieoff.com/page63.htm; **Impact of Population Growth on Food Supplies and Environment,** Pimentel, David, et al. http://www.dieoff.com/page57.htm). Given that the current U.S. population is in excess of 292 million,[40] that would mean a reduction of 92 million. *To achieve a sustainable economy and avert disaster, the United States must reduce its population by at least one-third.* The black plague during the 14th Century claimed approximately one-third of the European population (and more than half of the Asian and Indian populations), plunging the continent into a darkness from which it took them nearly two centuries to emerge.[41]

None of this research considers the impact of declining fossil fuel production. The authors of all of these studies believe that the mentioned agricultural crisis will only begin to impact us after 2020, and will not become critical until 2050. The current peaking of global oil production (and subsequent decline of production after 2010), along with the peak of North American natural gas production will very likely precipitate this agricultural crisis much sooner than expected. Quite possibly, a U.S. population reduction of one-third will not be effective for sustainability; the necessary reduction might be in excess of one-half. And, for sustainability, global population will have to be reduced from the current 6.32 billion people[42] to 2 billion—a reduction of 68% or over two-thirds. The end of this decade could see spiraling food prices without relief. And the coming decade could see massive starvation on a global level such as never experienced before by the human race.

Three Choices

Considering the utter necessity of population reduction, there are three obvious choices awaiting us.

We can—as a society—become aware of our dilemma and consciously make the choice not to add more people to our population. This would be the most welcome of our three options, to choose consciously and with free will to responsibly lower our population. However, this flies in the face of our biological imperative to procreate. It is further complicated by the ability of modern medicine to extend our longevity, and by the refusal of the religious right to consider issues of population management. And then there is a strong business lobby to maintain a high immigration rate in order to hold down the cost of labor. Though this is probably our best choice, it is the option least likely to be chosen.

Failing to responsibly lower our population, we can force population cuts through government regulations. Is there any need to mention how distasteful this option would be? How many of us would choose to live in a world of forced sterilization and population quotas enforced under penalty of law? How easily might this lead to a culling of the population utilizing principles of eugenics?

This leaves the third choice, which itself presents an unspeakable picture of suffering and death. Should we fail to acknowledge this coming crisis and determine to deal with it, we will be faced with a die-off from which civilization may very possibly never revive. We will very likely lose more than the numbers necessary for sustainability. Under a die-off scenario, conditions will deteriorate so badly that the surviving human population would be a negligible fraction of the present population. And those survivors would suffer from the trauma of living through the death of their civilization, their neighbors, their friends and their families. Those survivors will have seen their world crushed into nothing.

The questions we must ask ourselves now are, how can we allow this to happen, and what can we do to prevent it? Does our present lifestyle mean so much to us that we would subject ourselves and our children to this fast approaching tragedy simply for a few more years of conspicuous consumption?

(Endnotes)

[1] **Availability of agricultural land for crop and livestock production**, Buringh, P. Food and Natural Resources, Pimentel. D. and Hall. C.W. (eds), Academic Press, 1989.

[2] **Human appropriation of the products of photosynthesis**, Vitousek, P.M. et al. Bioscience 36, 1986. http://www.science.duq.edu/esm/unit2-3

[3] **Land, Energy and Water: the constraints governing Ideal US Population Size,** Pimental, David and Pimental, Marcia. **Focus**, Spring 1991. **NPG Forum**, 1990. http://www.dieoff.com/page136.htm

[4] **Constraints on the Expansion of Global Food Supply,** Kindell, Henry H. and Pimentel, David. Ambio Vol. 23 No. 3, May 1994. The Royal Swedish Academy of Sciences. http://www.dieoff.com/page36htm

[5] **The Tightening Conflict: Population, Energy Use, and the Ecology of Agriculture,** Giampietro, Mario and Pimentel, David, 1994. http://www.dieoff.com/page69.htm

[6] Op. Cit. See note 4.

[7] **Food, Land, Population and the U.S. Economy,** Pimentel, David and Giampietro, Mario. Carrying Capacity Network, 11/21/1994.

http://www.dieoff.com/page55.htm

[8] **Comparison of energy inputs for inorganic fertilizer and manure based corn production,** McLaughlin, N.B., et al. Canadian Agricultural Engineering, Vol. 42, No. 1, 2000.

[9] Ibid.

[10] **US Fertilizer Use Statistics.** http://www.tfi.org/Statistics/USfertuse2.asp

[11] **Food, Land, Population and the U.S. Economy, Executive Summary,** Pimentel, David and Giampietro, Mario. Carrying Capacity Network, 11/21/1994. http://www.dieoff.com/page40.htm

[12] Ibid.

[13] Op. Cit. See note 3.

[14] Op. Cit. See note 7.

[15] Ibid.

[16] Op. Cit. See note 5.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Op. Cit. See note 11.

[22] Ibid.

[23] Ibid.

[24] Ibid.

[24] Ibid.

[25] Op Cit. See note 3.

[26] Op Cit. See note 11.

[27] Ibid.

[28] Ibid.

[29] Ibid.

[30] Op. Cit. See note 3.

[31] Op. Cit. See note 5.

[32] Op. Cit. See note 3.

[33] Op. Cit. See note 11.

[34] **Food Consumption and Access,** Lynn Brantley, et al. Capital Area Food Bank, 6/1/2001. http://www.clagettfarm.org/purchasing.html

[35] Op. Cit. See note 11.

[36] Ibid.

[37] Op. Cit. See note 5.

[38] Ibid.

[39] Ibid.

[40] Op. Cit. See note 11.

[41] Op. Cit. See note 4.

[42] Op. Cit. See note 11.

[43] **Poverty 2002**. The U.S. Census Bureau. http://www.census.gov/hhes/poverty/poverty02/pov02hi.html

[35] Op. Cit. See note 3.

[36] Ibid.

[37] **Diet for a Small Planet,** Lappé, Frances Moore. Ballantine Books, 1971—revised 1991. http://www.dietforasmallplanet.com/

[38] Op. Cit. See note 5.

[39] Ibid.

[40] **U.S. and World Population Clocks.** U.S. Census Bureau. http://www.census.gov/main/www/popclock.html

[41] **A Distant Mirror,** Tuckman Barbara. Ballantine Books, 1978.

[42] Op. Cit. See note 40.