Rethinking the Meaning of Waste in Relation to Energy, Food, and Climate [i]

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With the emergence of the environmental movement in the 1960s, we went from thinking of waste as useless and of no value to thinking of waste as pollution and of negative value because it was costly to mitigate. With the environmental revival of the 1990s, we came to think of waste as something that potentially has positive value, if we can find ways to reuse or recycle it rather than throw it away. Today, with growing concerns about global climate change, fossil energy depletion, and rising food costs, we are again forced to rethink the meaning of waste, particularly biological waste. We may eventually conclude that waste is far more valuable than we have previously thought.

We are confronted today by the greatest environmental challenges ever confronted by humanity: "peak oil" and "climate change." The past 200-years era of industrial development has been driven by an abundance of cheap energy – first wood, next coal, and then petroleum. We cut the old-growth forests, we mined surface coal, and we pumped the shallow pockets of petroleum; energy was cheap because it was abundant and easy. Today, however, there are no abundant sources of easy or cheap energy left. Equally important, we are beginning to understand that fossil energy has been abundant and cheap not because of human ingenuity but instead because it was a gift of nature. The old forests that nature had grown over hundreds of years were cleared during the first century after the industrial revolution. Nearly half of the fossil energy collected and stored by nature over tens of millions of years was extracted during the second century of industrialization. All of the remaining fossil energy will be more difficult to find and more costly to mine and refine. We are not running out of energy, at least not yet, but we are running out of abundant, cheap energy.

In addition, the remaining sources of fossil energy all present significant environmental threats. The buildup of carbon dioxide and other greenhouse gasses in the atmosphere is a direct consequence of the inevitable release of carbon, nitrogen, and other elements from fossil fuels in the process of extracting their stored energy. All fossil energy is biological in origin, solar energy captured in the tissues of biological organisms and stored beneath the earth's crust. Biological energy is stored in the bonds that connect molecules of carbon, hydrogen, oxygen, and other elements from the air with nitrogen, phosphorus, potassium, calcium and other elements from the soil in forming the tissues of living plants. When fossil energy is released, these bonds are broken and the various chemical elements, including carbon dioxide and other greenhouse gasses, are released into the natural environment. Kelly Cain of the University of Wisconsin, River Falls, refers to peak oil and climate change as the "evil twins." We can't confront one evil without running headlong into the other.

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Humanity cannot survive without energy. We are dependent on energy for our houses, our clothes, our cars, our food and everything else. All of these things require energy to make and energy to use. In fact, all materials are simply highly concentrated forms of energy, as Albert Einstein explained in his famous equation, $E=MC^2$. E stands for energy, M for mass, and C for the speed of light. Perhaps more important, we humans, being biological beings, are dependent on particular form of energy, *new* biological energy. We are dependent on living, biological ecosystems for our food and thus for our health and survival.

From the perspective of the other living organisms that make up these ecosystems, many things that we humans consider to be wastes are not wastes but food. As the noted naturalist John Muir is said to have put it, “Everything eats, everything excretes, everything is food for something.” In fact, “everything on earth is interconnected with everything else” – the first principle of ecology. We humans are no exception. Most important, the energy we use to build and fuel our cars and heat our homes comes from the same flow of energy that fuels the living things that fuel our bodies. Furthermore, those other living things that we depend on for our health and life depend on our “wastes.”

Fossil energy is not renewable, at least not in any reasonable timeframe, even though it is biological in origin. The only truly renewable source of energy is the sun, with its daily inflow of solar energy, some of which is captured and stored by biological organisms. Quite logically, scientists and industrialists today are exploring the potentials of “solid biomass fuels” and “biological materials” as sources of *renewable* energy. Both are concentrated forms of solar energy. Biofuels have received the greatest attention, specifically ethanol and biodiesel made from corn and soybeans. However, there seems to be is a growing realization that biofuels produced from food crops are quite limited in their potential as replacement for fossil fuels. And perhaps more important, fuels crops are competitive with food crops.

David Pimentel of Cornell University estimates that if all of the solar energy collected by all of the green plants in the United States could be magically converted into fossil energy, it would replace only about *one-half* of the fossil energy consumed each year in the United States.[1] Some bioenergy advocates have attempted to discredit Pimentel's work, but he has been focusing his research efforts on bioenergy since the 1970s and is highly respected among those who have followed his work over the years. He also estimates that agriculture and forestry account for less than one-third of all green plants, and thus, the solar energy captured by the whole of farms and commercial forests amounts to less than *one-sixth* of annual U.S. fossil energy use.[2] Obviously, we can't devote the whole of agriculture to fuel production. Eventually, humanity will conclude that eating is more important than driving.

Pimentel's estimates were confirmed by other energy experts in a 2006 Academy of Science report which indicated that converting the total U.S. corn and soybean crops to ethanol and biodiesel would replace only about 12-percent of gasoline and six-percent of diesel use, respectively. [3] In addition, Pimentel claims the “old fossil energy” required for ethanol and biodiesel production is more than the “new bioenergy” produced, when the energy involved in crop production and transportation are included. Others experts claim net energy gains up to two kcals of “new energy” for each kcal of “old energy.” Regardless, any *net* energy produced is considerably less than the *total* energy embodied in ethanol and biodiesel.

Certainly, if more farmland is devoted to fuel crops, biofuels could replace somewhat larger percentages of fossil fuels, but not without affecting food production, as we have seen the past couple of years. Increasing meat consumption in China and India and global weather problems most certainly are responsible for some of the recent increases in global food prices. However, the economic trends in China and India have been underway for some time as has the drought in Australia. There are always weather problems somewhere. The dramatic rise in global food prices has coincided with the diversion of farmland from producing food for people to producing fuel for automobiles, in the U.S. and globally. The margin between scarcity and surplus in global food markets is very narrow and fragile. Most people don't eat a lot more when food prices fall and can't eat much less even when food prices rise. The Achilles heel of biofuels is their inevitable competition with food. It's not just a matter of economics; it's a matter of ethics. Ethical and moral questions inevitably will arise whenever the poor are deprived of food for their families so the wealthy can have fuel for their SUVs, regardless of the economic rationalizations.

Biofuels from non-food crops at least blunts the ethical questions associated with using food crops for fuel. Ethanol can be produced from the indigestible cellulous in the fibrous tissue of forage crops and trees, such as switch grass and poplar. Utilization of non-food crops for fuel also adds considerably to the total bioenergy potential of agriculture. Of the total solar energy captured by agriculture and forestry, food crops account for only about one-sixth, whereas forage crops account for about two-thirds, and forests account for the remaining one-sixth. Most non-food crops also are perennial crops that require less tillage and typically result in less soil erosion than corn or soybeans. Most perennials also use less nitrogen fertilizer and pesticides than corn, meaning less reliance on fossil energy and less pollution of streams and groundwater.

Understandably, cellulosic ethanol has become the latest political favorite in the quest for renewable replacement for fossil energy, even though its technical and economic feasibility is still uncertain. However, forages are typically used as feed for livestock, which produce meat and dairy products and trees can produce fruits and nuts – food. So, the competition of cellulosic ethanol with food production still exists; it's just less obvious because the connections are less direct and more complex. The ethical questions are no different. Each kcal of biofuels potentially deprives someone somewhere of a kcal of food.

This would seem to leave agricultural wastes as the ideal source of bioenergy. Much of the solar energy captured by agricultural crops is left in the fields as crop residues, to be burned, buried, or to dissipate into the air as it rots. Eighty percent or more of the energy in feed grains and forages fed to livestock is excreted as livestock urine and manure, much of which fouls streams and groundwater or volatizes into the air as noxious odors and greenhouse gasses. In fact, all livestock-related activities, including feed grain production and clearing of forests for livestock forages, are estimated to account for 18-percent of total U.S. greenhouse gas emissions and approximately 80-percent of greenhouse gasses emitted by agriculture.[4] Much of the remainder of agriculture's estimated 22.5-percent contribution to total U.S. greenhouse gas production is accounted for by deforestation, crop residues, and nitrous gasses released through soil fertilization. Clearly, using agricultural wastes for bioenergy and biomaterials could make a significant contribution to the twin challenges of fossil energy depletion and global climate change. Furthermore, if all biological wastes were truly wastes, there would be no competition with food production. No ethical compromise would be involved.

However, crop residues and livestock urine and manure are not wastes when viewed from an ecological perspective. The complex ecological system through which all bioenergy flows may be represented as a pyramid with various layers of living organisms. The bottom layer is made up of the organisms in the soil, the next layer is plants, the next is all those things that feed on plants, including insect and animal *herbivores*, next is the things that feed on both plants and animals, the *omnivores*, mainly humans, and finally the things that eat only animals, the meat-eating *carnivores*. A generalization exists in ecology that on average, about ten-percent of the energy available in one layer will be passed on to the next level; thus the pyramid narrows dramatically as it rises. “Not everything in the lower levels gets eaten, not everything that is eaten is digested, and energy is always being lost as heat”[5] – to entropy. So each higher level of the pyramid contains only about ten-percent as much as energy as the level immediately below it. As Aldo Leopold put it, “for every carnivore, there are hundreds of his prey, thousands of their prey, millions of insects, and uncountable plants.”[6]

A critically important layer of this living pyramid is its foundation: the billions and trillions of microorganisms in the soil, the *decomposers* that extract and live from the energy remaining in the wastes generated at all other levels in the pyramid, including human wastes, livestock wastes, and crop residues. All *new* energy enters the biological pyramid at the plants layer, made up of the solar collectors. Energy is stored by all levels of the pyramid but all the energy captured ultimately escapes into space as heat – the process of entropy. However, the inorganic nutrients – nitrogen, phosphorus, potassium, calcium – that plants must combine with carbon, hydrogen, oxygen in the process of storing energy – as carbohydrates or sugars – are continuously recycling through the pyramid, with the soil's biological system as its foundation. Many of these inorganic nutrients become available to plants only after they have been released from wastes and stored by decomposers. The food energy that supports earthworms, bacteria, fungi, nematodes, and other decomposers in the soil is the energy left in the things that we humans call wastes. The various “wastes” reclaimed by the decomposers amount to about one-fourth of all of the solar energy currently captured by green plants. This is the energy that some now propose to extract from the energy flow to use for biofuels and biomaterials.

Everything we do affects everything else, including us. When we generate energy from wood wastes or sawdust, we are depriving the decomposers in forest soils of food and thus deprive food from forests of the future. When we generate energy from crop residues, animal manure, and other agricultural wastes, we are depriving the decomposers in agricultural soils of the food they need to make soil nutrients available for plants of the future. We humans are biological beings; we eat other biological organisms. We can't eat the sun or digest the electricity generated by windmills, falling water, or photovoltaic cells. If wastes equivalent to ten percent of our current fossil energy use were diverted from the agricultural waste stream, it would deprive the decomposers of about 75-percent of so-called wasted energy they use to help feed agricultural crops. When we generate energy from agricultural residues and wastes, we are depriving people of food just as surely as when we generate bioenergy from food crops; the process is just a bit more complex.

The same basic ethical and ecological questions are raised by using agricultural wastes to produce biofuels and biomaterials as are raised by using corn and soybeans to produce ethanol and biodiesel. In addition, depriving the soil decomposers of their life's energy may represent an even more serious threat to the future of humanity than does depleting the earth's remaining fossil energy. Even if we deplete the earth of fossil energy, humanity might still learn to live from the daily inflow of new solar energy – we would still have biological sources of food. If we starve the biological foundation of the earth's living pyramid, the decomposers, we may well have deprived future humanity of their only significant source of biological energy – their only source of food.

Every kcal of energy we take from the energy flow of the biological pyramid potentially deprives someone of some future generation of food energy. This doesn't mean that we should halt research and development of biofuels or biomaterials, just that we should remain ever conscious and vigilant regarding the potential long run ecological and social implications of our short run economic decisions. We need to remember that everything we do affects everything else. The current twin evils of peak oil and climate change are direct consequences of a mechanistic, rather than ecological, thinking about how the world works and the place of humans within it. As Albert Einstein observed, we can't solve problems using the same thinking that we used when we created them.

When we approach the twin challenges of peak oil and climate change from an ecological perspective, we may discover we can produce significant quantities of bioenergy from agricultural wastes, while still leaving enough for the decomposers to feed the plants that must feed us. We could most certainly be more efficient than we are today in returning agricultural wastes to the earth in the forms, places, and at times that would be most beneficial to the decomposers. In fact, much of the agricultural residues and wastes today are not returned to the soil to feed the decomposers but instead pollutes and destroys the diversity of life in our streams or is volatized directly into the atmosphere in the form of greenhouse gasses. We could certainly generate energy from wastes currently burned or buried in landfills without removing anything more from the energy flow than we are currently removing. Thus we might be able to generate significant quantities of bio-materials from the energy flow without compromising the integrity of the biological pyramid if we simultaneously improved the efficiency of the biological energy recycling processes. But, we simply cannot afford to ignore the ecological limits of our biological reality because we cannot avoid the ultimate ecological consequences of our actions, regardless of our intentions.

The highest priority for American agriculture today should be finding ways to produce more food while using less fossil energy and creating fewer greenhouse gas emissions. Our food system currently requires about 17-percent of the total fossil energy used in the U.S., in addition to the solar energy captured and stored by plants.[7] Each kcal of food energy produced requires approximately ten kcals of fossil energy. Most of this energy is used in food manufacturing, packaging, and transportation, but even at the farm level, three kcals of fossil energy are required for each kcal of food energy. In addition, the global food system in total – production, processing, and distribution – creates about one-third of all greenhouse gas emissions, with farming accounting for something over three-fifths of the total for food production.[8]

It's certainly not impossible to reduce the dependence of agriculture on fossil energy or to reduce greenhouse gas emissions by agriculture, as is proven every day by farmers all across the continent and around the world who call themselves organic, holistic, biodynamic, ecological, practical, grass-based, free-range, management intensive, or just stewards of nature. All of these farmers are farming in ways that rely less on energy intensive inputs, specifically commercial fertilizers and pesticides. These "solar energy" farmers are attempting to farm by methods that are ecologically sound, socially responsible, and economically viable. They are farming for sustainability.

Although no comprehensive studies have been done, various individual studies indicated that farmers are able to reduce their fossil energy use by 30- to 60-percent by pursuing various strategies of sustainable farming.[9,10] The potential for reducing greenhouse gas emissions maybe even greater. The Rodale institute estimates that a shift from conventional to organic farming – with restoration of the organic matter levels needed for healthy, productive organic soils – could not only offset the current net CO_2 emissions by U.S. agriculture but could also sequester about 50-percent more CO_2 than U.S. agriculture currently emits.[11] Just switching U.S. corn and soybean production to organic farming could accomplish three-fourths of the reduction needed to bring the U.S. into compliance with the Kyoto protocol. In addition, confinement animal feeding operations, or CAFOs, account for a large percentage of total greenhouse gas emissions by agriculture. According to animal science professor, David Tisch, a 12-ounce beef steak from a grain-fed animal results in about 1.6-pounds of emissions – including emissions from grain production but not transportation.[12] The same steak from a grass-fed beef animal results in about 0.3-pounds of CO_2, only about one-fifth as much. Grass-fed and pasture-based production of meat, milk, and eggs are some of the most common and most economically successful examples of sustainable agriculture.

However, farming sustainably will require that we return more, not less, of what we currently call wastes – particularly crop residues and livestock manure – to the soil. These wastes are the source of organic matter needed to restore healthy, productive organic soils. Sustainable farms must be self-renewing and regenerative, meaning they must rely on solar energy for their productivity. Furthermore, the solar energy they rely on is captured by green plants that rely on the decomposers in the soil. Those same green plants are capable of capturing tremendous quantities of greenhouse gasses from the atmosphere – carbon, oxygen, hydrogen, even nitrogen -- in the process of storing solar energy. After all, the buildup of greenhouse gasses originated from the release of energy previously stored by green plants. The living systems of the earth were once capable of capturing more greenhouse gasses than they released and perhaps are still capable of doing so, if we learn to work with nature rather than try to conquer it. But, we cannot sustain agriculture or humanity if we deprive the decomposers of the "biological wastes" they need to support the green plants that feed us. To sustain anything even like the current number of humans that occupy the earth, we must have a sustainable agriculture, which means we must rethink our concept of waste.

But why should we even be concerned about sustainable agriculture, decomposers, or even whether people of future generations have anything to eat? There probably will be enough fossil energy left to support the current fossil energy-intensive agriculture for another fifty years. Even if food is a good bit more expensive by then, most Americans will likely be able to afford what they need. The major economic impacts of global climate change may be even further in the future. So why should we be concerned about the well-being of people we will never know?

To understand why it's in our self-interest to care about those of the future, we need only think ecologically; we need only respect the value of relationships. We need only understand that positive relationships with other people and the other things of nature make our lives better. We depend on them and they depend on us. We are all made of the same molecules and the same energy; we are all part of the same whole. We need only understand that ethical and moral relationships with other people and with nature give purpose and meaning to our lives. What we do matters; we can make a positive contribution to the long run well-being of the whole.

Our devotion of time and energy to the well-being of others is only a more enlightened concept of self-interest, of happiness. Historically, humans have understood the difference between happiness and wealth. It's only in the past few decades what we have come to equate happiness with economic success. Certainly, we are material beings; we need to be concerned about our individual, economic well-being. But we are also social being; we need positive personal relationships with other people that are not predicated on economic benefits. We are also ethical and moral beings; we are a part of some higher order of things that transcends space and time, within which our life takes on purpose and meaning. We are ecological beings.

This is a more enlightened concept of self-interest. In the 300s BC, Aristotle called it "virtuous living," in the early 1800s, Alex De Tocqueville, called it "self-interest rightly understood," today, the Dali Lama calls it being "wisely selfish." It is the true meaning of happiness and human well-being. Only when we think of self-interest from an ecological perspective, will we see true value of rethinking how the world works and our relationships within it, including the meaning of waste in relation to energy, climate, and food.

End Notes

[1] From a presentation by David Pimentel, Cornell University, at *Local Solutions to Energy Dilemma*, New York City, April 28-29, 2006. Revised to account for increased energy use from earlier estimate published in David and Marcia Pimentel, *Food, Energy, and Society* (Niwot, CO: University Press of Colorado), 1996.
[2] David and Marcia Pimentel, *Food, Energy, and Society* (Niwot, CO: University Press of Colorado), 1996, 20.
[3] Jason Hill, Erik Nelson, David Tilman, Stephen Polask, and Douglas Tiffany, 2006, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," National Academy of Science Report, http://www.pnas.org/cgi/content/short/103/30/11206.
[4]Wikipedia, "greenhouse gas", and "Climate Change and Agriculture," http://en.wikipedia.org/wiki/Greenhouse_gas and http://en.wikipedia.org/wiki/Climate_change_and_agriculture .
[5] Dave McShaffrey, "Environmental Biology- Ecosystems," Department of Biology and Environmental Science, Marietta College http://www.marietta.edu/~biol/102/ecosystem.html.
[6] Aldo Leopold, A Sand County Almanac, "The Land Ethic" (1949, New York: Ballantine Books, 1966), 252.
[7] Energy estimates in this paragraph also from Pimentel, *Food, Energy, and Society*.
[8] Helen York, "From the Farm to Your Table," *World Ark*, Heifer International, May/June 2008: 28-31.
[9] David Pimentel, Paul Hepperly, James Hanson, David Douds, and Rita Seidel, 2005,"Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems," *BioScience,* 55, No. 7: 573–582.
[10] Helena Norberg-Hodge, Todd Merrifield, and Steven Gorelick. *Bringing The Food Economy Home: Local Alternatives to Global Agribusiness*. (Bloomfield , CT : Kumarian Press. 2002), 45.
[11] Laura Sayre, "The New Farm Field Trials," Rodale Institute, October, 2003. http://www.newfarm.org/depts/NFfield_trials/1003/carbonsequest.shtml
[12] David Tisch, in an interview with Bruce Gellerman, host of radio program, "Living on Earth, February 8, 2008, Tisch is a Professor in the College of Agriculture and Technology, State University of New York, Cobleskill, NY, http://www.loe.org/shows/shows.htm?programID=08-P13-00006#feature4