Investing in Solid Biomass Fuels[i]

John Ikerd[ii]

We are here today because the world in running out of cheap fossil energy. The past 200 years of industrial development has been driven by an abundance of cheap energy – first wood, next coal, and then petroleum. We are not running out of energy, but we are just running out of abundant, cheap energy. We cut the old-growth forests, we mined surface coal, and we pumped the shallow petroleum; energy was cheap because it was abundant and easy. Today, there is no abundant source of easy or cheap energy left. Equally important, we are beginning to understand that energy has been abundant and cheap only because it was a gift of nature from times past. The old forests that 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 fossil energy is biological in origin, solar energy captured by biological organisms and stored in the earth by natural phenomena. All biological energy originates from the sun. Each day we receive an endowment of "solar income." Instead of living off of this "solar income," however, we have been using up tens of millions of years worth of nature's "solar investment." Many of us are beginning to question nature's wisdom in trusting humanity with this investment. If we continue to withdraw energy from nature's account, without making offsetting deposits, eventually we will simply run out of energy. Sooner of later, humanity must confront the uncomfortable reality that the industrial approach to economic development is not sustainable.

We face an additional challenge in that the remaining sources of fossil energy all represent significant risks to the natural environment and to the earth's biological solar energy collectors. The buildup of carbon dioxide and other greenhouse gasses in the atmosphere is a direct consequence of the inevitable release of carbon and other elements from fossil fuels in the process of extracting their stored energy. This conference is about finding ways to make a transition from fossil energy to renewable energy by learning to live off of "solar income" before the earth's "solar investment" is gone and its "solar collectors" are disabled.

"Everything on earth is interconnected with everything else," so proclaims the first principle of ecology. Or as the noted naturalist John Muir is said to have put it, "Everything eats, everything excretes, everything is food for something." We humans are no exception. We are not nearly as dependent on our cars, houses, clothes, or adult toys as we are on the things we eat. Sure, we need clothing, shelter, and some means of mobility but humans can do very well with relatively few of life's necessities. We are most critically dependent on the things we eat and they are just as dependent upon us. The energy we use to fuel our cars and heat our homes comes

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[ii] John Ikerd is Professor Emeritus, University of Missouri, Columbia, MO – USA; Author of, *Sustainable Capitalism*, http://www.kpbooks.com , *A Return to Common Sense*, http://www.rtedwards.com/books/171/, *Small Farms are Real Farms*, Acres USA , http://www.acresusa.com/other/contact.htm,and *Crisis and Opportunity: Sustainability in American Agriculture*, University of Nebraska Press http://nebraskapress.unl.edu;
Email: JEIkerd@centurytel.net; Website: http://faculty.missouri.edu/ikerdj/

from the same flow of energy that fuels the living things that fuel our bodies. Everything we do affects everything else.

The scope of this particular discussion of "solid biomass fuels" is limited to the use of wood, agricultural residues, dried manure, sewage sludge, and dedicated fuel crops such as switchgrass and poplar trees. Biomass fuel sources also include food crops, particularly corn ethanol and biodiesel, but these sources are being addressed by others at this conference. Solid biofuels can be converted into liquids and gases before combustion, but the discussion here focuses on questions of renewability and sustainability, which are involved primarily with the energy embodied in solid biomass rather than methods of energy extraction.

Our quest for renewable energy is a quest for sustainability and sustainability ultimately is a matter of energy. Everything that is of use to humanity – our houses, clothes, food – requires energy to make, energy to use. In fact, all material objects are just concentrated forms of energy. All useful human activities – working, managing, thinking – also require energy. And equally important, the usefulness of human energy is a product of society. We are not born as productive individuals but as helpless babies. We have to be nurtured, socialized, and educated by society before we are capable of being useful to society, all of which requires energy.

According to the laws of thermodynamics, energy inevitably changes form whenever it is used to do anything useful, which physicists call *work*. Specifically, anytime energy is used to do work, it always changes from more concentrated to less concentrated forms, as when gasoline explodes when ignited in the engine of a car. Energy is never destroyed by use, but each time it is used and reused, it becomes less concentrated and thus less useful. So each time energy is used to do something useful, some of its *usefulness* is lost. This is the essence of the law of entropy. Conserving, reusing, and recycling stored energy can improve the efficiency of energy use, but cannot offset the inevitably loss of energy to entropy. The only source of energy available to offset entropy is solar energy – the only truly renewable energy.

Our increasing reliance on fossil energy and the resulting challenges of sustainability are a natural consequence of industrial economic development. The economy provides powerful incentives to use and reuse energy put provides no incentives to collect and store new solar energy to offset the energy lost to entropy. Even the solar energy captured through agriculture and forestry has been put in the marketplace for consumption rather than used to regenerate and renew the energy resources needed to sustain future productivity. This basic problem arises from the fact that economic value is inherently individualistic; it accrues to individuals, and thus, must be expected to accrue during the lifetime of the individual decision maker. Investments for the sole benefit of others, including those of future generations, are of no economic value.

The diminishing time-value of economic benefits is clearly reflected in market rates of interest, which heavily discount the value of future events. For example, economic benefits expected to accrue a decade in the future are worth less than fifty cents today for each dollar expected later (using a discount rate of seven percent). Fossil energy depletion and global climate change are of little *economic* importance today because their ultimate impacts are still beyond the five-to-ten year planning horizons of most corporations. From everything we know about the basic nature of natural ecosystems and human societies, today's economic planning horizons are simply too "shortsighted" to ensure the long run sustainability of humanity.

Less appreciated but no less important, capitalist economies also dissipate the *social* energy needed to sustain humanity because they weaken human relationships. Economic efficiency requires that people relate to each other *impartially*, which means *impersonally*. People must compete rather than cooperate, if markets are to work efficiently, and competition degrades personal relationships. Economic incentives encourage people to devote the maximum time possible to work, which leaves little time and energy for sustaining families, communities, or society. An economy driven by economic self-interests cannot sustain the civility of human society or the economic productivity of humans.

All economic value comes either from nature or from society. An economy creates nothing; it is simply a means of facilitating relationships among people and between people and the earth. When an economy has extracted all of the energy or usefulness from its natural and human resources, there will be nothing left from which to extract additional economic value. Today's capitalist economies are degrading the productivity of nature and society and quite simply are not sustainable.

Sustainability is ultimately a matter of intergenerational equity, of meeting the needs of the present without compromising opportunities of the future. It is a matter of stewardship, of ethics. Most investments in sustainable energy will be public rather than private investments because the private economy simply doesn't address matters of ethics; that's why economics places so little value on the future. Most such public investments will take the form of higher energy prices resulting from laws and regulations that limit the economic exploitation and depletion of fossil energy. The primary objectives of energy policies should be to make renewable energy economically competitive with fossil energy and to protect the natural ecosystem from energy-related pollution and degradation. The economy simply cannot generate enough tax revenue to allow the government to compensate everyone for every ethical act of stewardship needed to ensure the future of humanity. The best government can do is to create a market environment in which ethical individuals who choose to develop renewable energy and protect the environment don't have to compete with those who would choose to extract and exploit.

Public policies that support investments in the transition to renewable energy must be grounded in the principles of living, biological systems. Living plants have the capacity to capture and store new solar energy to offset the loss of usefulness of energy to entropy. Living things produce but they also reproduce, by nature. Even we humans are capable of capturing and storing solar energy; we just do it with windmills, dams, and photovoltaic cells. Humans also have an inherent tendency to produce and reproduce, even when we have no economic incentive to do so. Otherwise, few of us would ever choose to raise children. We are living, biological beings. Obviously, an individual life is not sustainable but communities of living individuals clearly have the capacity to be productive while devoting a significant part of their life's energy to conceiving and nurturing the next generation.

Thus, it is quite logical that we turn our attention to living, biological sources of energy in our quest for sustainability, but in doing so, we must respect the ecological realities of biological energy. 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, 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] These estimates are confirmed by other energy experts, as in a recent 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 6 percent of diesel use respectively. [3]

Energy from solid biofuels would seem to address some of the growing concerns associated with ethanol and biodiesel. Some experts claim 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 claim net energy gains of two or more kcals of “new energy” for each kcal of “old energy.” Regardless, the *net* energy gained is considerably less than the *total* energy embodied in ethanol and biodiesel. The net energy ratios for different solid biofuels vary considerably but some are far superior to ethanol and biodiesel. Some solid biofuels are combusted without significant processing, as with wood-fired power plants, and others are converted and used on site, as with methane digesters of manure. Solid biofuels also have environmental advantages over corn and soybeans. Most solid biofuels crops are perennial crops, with less soil erosion than corn or soybeans, and most use less nitrogen fertilizer and pesticides than corn, meaning less pollution of streams and groundwater.

Perhaps the greatest perceived advantage for solid biofuels production is that they don't compete with food production. Solid biofuels production utilizes wastes and residues from food crop and livestock production and fibrous tissue from trees and other plants that cannot be consumed directly by humans. The use of corn and soybeans, both food crops, to produce ethanol and biodiesel has raised increasing questions regarding the ethics of turning food into fuel. Prices for all food crops have risen dramatically as a consequence of the ethanol demand for corn, which only adds urgency to the ethical questions that arise from depriving the poor people of the world of food so the wealthy can continue to drive their SUVs. Utilization of residues, wastes, and non-food plants for biofuels at least blunts such questions.

Utilization of agricultural wastes and fibrous plants for fuel also adds considerably to the total bioenergy potential of agriculture and forestry. Food crops account for only about one-sixth of the total solar energy captured by agriculture and forestry, whereas forage crops account for about two-thirds, and forests account for the remaining one-sixth. Thus, the solar energy collected by food crops amounts to only about 2.5 percent of U.S. fossil energy use whereas forage crops and forests account for about 12.5 percent. Of course, forage crops are currently used for feed for meat animals that end up as human food. But 80 to 90 percent of the energy in crops grown for forages, as well as for feed grains, either remains in the fields as crop residues or is excreted in livestock manure. Both types of wastes are potential sources for biofuels.

However, this brings the discussion of solid biofuels back to ecology. Crop residues and livestock 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 made up of various layers. The bottom layer is 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 10% of the energy available in one layer will be passed on to the next level. "Not everything in the lower levels gets eaten, not everything that is eaten is digested, and energy is always being lost as heat"[4] – to entropy. So each higher level of the pyramid contains only about 10 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."[5]

A critically important part of this pyramid of life 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 levels in the pyramid, including crop residues and livestock manure. All *new* energy enters the biological pyramid at the level of plants, the solar collectors, and ultimately escapes into space as heat, the product of entropy. However, the inorganic nutrients – nitrogen, phosphorus, potassium, calcium – that plants must combine with carbon and hydrogen in storing energy – as carbohydrates or sugars – are continuously recycled through the soil's biological system. Many of these inorganic nutrients become available to plants only after they have been released from wastes and stored by decomposers. The foods that support earthworms, bacteria, fungi, nematodes, and other decomposers in the soil is the energy left in the things that we humans call wastes, the energy that we now propose to extract from as solid biomass.

Everything we do affects everything else, including us. When we generate energy from wood, we are depriving the decomposers in forest soils of food and thus deprive future forests of food, which can hardly be called sustainable, renewable energy. When we generate energy from crop residues, forage crops, animal manure, and other agricultural wastes, we are depriving the decomposers in agricultural soils of the food they need to make food available for plants. We humans are biological beings; we eat other biological organisms. We can't eat the sun or digest the electricity generated by windmill, falling water, or photovoltaic cells. If we replaced even ten percent of our current fossil fuels with biomass fuels, we would be depriving the decomposers of approximately 75 percent of waste energy currently available to produce food for plants. When we generate energy from agricultural residues and wastes, we are depriving people of food just as surely as when we generate energy from food crops; the process is just a bit more complex.

The same basic ethical and ecological questions are raised by solid biomass fuels as are raised by 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 depriving the earth of its remaining fossil energy. Even if we deplete the earth of its "solar investment" in fossil energy, humanity might still learn to live from the earth's "solar income." If we destroy the foundation of the earth's living pyramid, the decomposers, we may well have deprived future humanity of any possibility of living from the earth's "solar income."

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.[6] In fact, each kcal of food energy produced requires approximately ten kcals of fossil energy. Most of this energy is used in food manufacturing, distribution, and marketing, but even at the farm level, three kcals of fossil energy are required for each kcal of food energy. The highest priority for agriculture today should be learning how to produce enough food for more people with less fossil energy, not learning how to produce fuel for automobiles. It's certainly not impossible to reduce the dependence of agriculture on fossil energy, 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 “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.[7,8] Perhaps most important, these new sustainable farmers are committed to leaving the land and their communities a healthy and productive as they found them. They are committed to intergenerational equity, to ensuring the future of humanity. The key to the sustainability of human life on earth will not be found in another source of energy to extract and exploit to serve the short-run, economic interests of individual or corporate investors. The key to sustainability will be found in working together informally and through government, on farms, in rural communities, and in cities, to create an economic and social environment in which humanity can learn to live – willingly, peacefully, in harmony – from the earth's “daily income” of solar energy.

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] Dave McShaffrey, “Environmental Biology- Ecosystems,” Department of Biology and Environmental Science, Marietta College http://www.marietta.edu/~biol/102/ecosystem.html.

[5] Aldo Leopold, A Sand County Almanac, “The Land Ethic” (1949, New York: Ballantine Books, 1966), 252.

[6] Energy estimates in this paragraph also from Pimentel, *Food, Energy, and Society*.

[7] 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.

[8] Helena Norberg-Hodge, Todd Merrifield, and Steven Gorelick. *Bringing The Food Economy Home: Local Alternatives to Global Agribusiness*. (Bloomfield , CT : Kumarian Press. 2002), 45.