

Renewable Energy and Agricultural Sustainabilityⁱ

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Conferences such as this one are being held all around the globe because the world is running out of *abundant, cheap* energy. The entire industrial era of the past 200 years was defined and supported by abundant cheap energy – first old growth forests, then surface mining of coal, and finally oil that gushed from the ground when wells were drilled. However, the old forests are gone; mountains are now being leveled to get to the remaining coal; and most of what's left of the oil lies deep beneath the ocean floors. We are not running out of energy; but we are running out of abundant, cheap energy.

Oil has been the cheapest, most convenient, and cleanest of all the energy sources. Today, however, there is a general consensus among petroleum geologists – in government and private sectors – that we are either at or near a “peak” in global oil production. Beyond the peak, oil will inevitably be less available and more costly. The concept of “peak oil” refers to the fact that once a new oil field is discovered, it takes about 30 to 40 years to bring it into peak production.¹ At that point, about half of the total quantity of recoverable oil remains in the ground, but that remaining half is more difficult and costly to retrieve. Equally important, production inevitably declines after the peak in production has been reached.

U.S. oil discoveries peaked in the late 1930s and 1940s, with major discoveries in Oklahoma and Texas. U.S. oil production peaked in 1971 and has been declining ever since. The peak in *global* oil discoveries occurred in 1962, indicating a peak in global production sometime in the early 2000s. Peak estimates range from 2005 to 2025 – some saying we have already peaked. Most seem to agree we are currently on a plateau of conventional oil production and will not be able to significantly increase oil production in the future. Even the major oil companies – BP, Exxon-Mobil, and Chevron-Texaco – have begun to focus on alternative energy sources for *their* future.

We have not yet reached a production peak in natural gas or coal, but most of the experts expect similar peaks and declines in all fossil energy sources within the next few decades. More important, we cannot replace declining supplies of petroleum by relying on other fossil energy sources – particularly coal – without exacerbating the risks of global climate change.

Fossil 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 organism. These bonds are broken when the energy is released from fossil sources. At that time, the various chemical elements, including carbon dioxide and other greenhouse gasses, are released back into the environment. Kelly Cain of the

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University of Wisconsin-River Falls refers to peak oil and climate change as the “evil twins.” We can't deal with one without running headlong into the other.

The only realistic solution to this dilemma is to find sources of renewable energy to replace today's dwindling supplies of affordable and usable fossil energy. Solar energy is the only source of truly renewable energy – renewable at least for the next few billion years. Windmills, falling water, solar collectors, and photovoltaic cells are all sources of renewable solar energy. The most common solar energy collectors are green plants. After all, plants were the original collectors of today's fossil energy. So, it's only logical to look to agriculture as a renewable source of alternative energy for the future.

However, we need to be realistic about the extent to which energy from agriculture can replace our current use of fossil energy. While the energy experts may not agree on specific quantities or percentages, the overall limits on energy from agriculture are fairly basic and straightforward.

- If all of the solar energy collected by all of the green plants in the U.S. could be converted into fossil energy, without using fossil energy in the conversion process, it would replace only about *one-half* of the fossil energy used each year in the United States.²
- Agriculture and forestry account for less than *one-third* of all green plants. 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.³
- Since we rely on agriculture for food, we obviously can't convert the whole of agriculture into energy production.
- The bottom line, agriculture cannot replace more than a small fraction – likely less than ten percent – of our current fossil energy use.

We also need to be realistic about the capacity of today's fossil energy dependent farming operations to produce energy that is truly renewable.

- The U.S. food system uses about *one-sixth* of the total fossil energy used in the U.S., in addition to the solar energy captured and stored by plants.⁴ About *one-third* of that total is accounted for by farm-level agriculture.
- The “*old fossil energy*” required for ethanol and biodiesel production offsets *one-half* to *two-thirds* of the “*new bioenergy*” produced, when energy used in crop production and transportation are considered. When the energy embodied in labor and machinery is included, some experts claim there is *no net gain* in energy.⁵
- Conventional agricultural production, particularly corn, relies heavily on importing nitrogen fertilizers produced with natural gas from Russian and Middle East.
- The bottom line, the primary benefits of producing bioenergy from *food crops* is the conversion of *immobile* energy – mainly natural gas & electricity – into *mobile* energy.

Regardless of the source of bioenergy, we need to keep in mind that we humans are biological beings. We are inherently dependent on the same flow of energy as the plants and other biological organisms from which we extract bioenergy. 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 *one-tenth* 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.”⁶ 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.”⁷

A critically important layer of this living pyramid is its foundation: the billions and trillions of microorganisms in the soil. These *decomposers* 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. The various “wastes” reclaimed by the decomposers amount to about *one-fourth* of all of the solar energy captured by green plants.

All *new* energy enters the biological pyramid at the plants layer, which represents the solar collectors. This energy flows through the pyramid and eventually is dissipated as heat – through entropy. The inorganic nutrients are continually recycling through the pyramid. However, many of the inorganic nutrients in the soil become available to plants only after they have been released from wastes and stored by the decomposers. So, plants depend on the decomposers for their ability to collect and store solar energy. Bioenergy production is neither renewable nor sustainable if it deprives the decomposers in the soil of the energy they need to support the bioenergy *collector* – the green plants.

In addition, our first concern must be with agriculture as a source of food rather than fuel. As we saw with the dramatic increase in the use of corn for ethanol, the margin between surplus and scarcity in food production is very fragile. A relative small diversion of agricultural land from producing food to producing fuel can have a dramatic effect on food prices – particularly in those parts of the world that depend heavily on basic food items such as rice, corn meal, and wheat flour for their nourishment. Taking bioenergy from the energy flow to produce fuel rather than food ultimately is an important ethical issue.

In addition, energy from agriculture is *renewable* only to the extent that the energy going into agriculture is renewable. Unfortunately, much of the energy going into agriculture today is nonrenewable fossil energy. Today's industrial approach to agriculture not only contributes to fossil energy depletion but also to its “evil twin,” global climate change. In looking to agriculture for energy, we must face the fact that most conventional systems of agriculture production today

clearly are not sustainable, neither in terms of renewable energy nor their impacts on the natural environment and society.

- Each kcal of food energy produced in the U.S. requires approximately *ten* kcals of fossil energy.⁸
- 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.
- Globally, food production accounts for about *one-third* of the global total of greenhouse gas emissions, including clearing of land for food production.⁹
- Farming accounts for more than *one-fifth* of the global total of greenhouse gasses – about *two-thirds* of the total associated with food production.

It's certainly not impossible to reduce the dependence of agriculture on fossil energy or to reduce greenhouse gas emissions by agriculture. This 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 responsible farmers. These farmers are farming in ways that rely less on fossil energy 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.

- Farmers are able to reduce their fossil energy use by *thirty- to sixty-percent* by pursuing various strategies of sustainable farming.^{10,11}
- A complete shift from conventional to organic farming in the U.S. could sequester about *fifty-percent more* CO₂ than U.S. agriculture currently emits – by restoring the organic matter levels needed for healthy, productive organic soils.¹²
- By switching all corn and soybean production to organic farming, the U.S. could accomplish *three-fourths* of the greenhouse gas reduction needed to comply with the Kyoto protocol.
- The bottom line, sustainable global food production is possible and practical; it will just require an approach to farming that relies on solar energy rather than fossil energy.

Sustainable farms must sustain a continuing flow of biological energy as they recycle nutrients through the biological pyramid. This means sustainable farmers must 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 and maintain healthy, productive organic soils.

We cannot sustain agriculture or humanity if we deprive the decomposers of the “biological wastes” they need to support the green plants that ultimately must feed us. The living systems of the earth were once capable of sequestering 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 or replace nature. To sustain anything even like the current number of humans that occupy the earth, we must work with nature to create a sustainable agriculture.

As we confront the twin challenges of peak oil and global climate change from an ecological perspective, we may discover we can produce significant quantities of bioenergy 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. We can also be more careful about which energy streams we tap for biofuels production.

Our search for sustainable sources of bioenergy from agriculture ultimately will lead us away from food crops and toward forage crops. Food crops were chosen first because the conversion processes were easier. Forage crops have far more potential than food crops as a source of *renewable* biological energy, if efficient means can be found for transforming plants with high cellulosic content into affordable bioenergy.

- Forage crops account for about *two-thirds* of the total solar energy captured by agriculture – *twice* the amount of solar energy as the rest of agriculture and forestry combined.
- Most foragers use less nitrogen fertilizer and pesticides than corn and soybeans, meaning less reliance on fossil energy and less pollution of streams and groundwater.
- Most forage crops are perennial crops that require no annual tillage and thus cause less soil erosion of soils. Soils are storehouses of biological energy.
- Bioenergy from forage crops does not compete as directly with food production as bioenergy from food crops. Forages are used by livestock, which are less energy efficient than crops.
- The bottom line, forage crops are more ecologically efficient sources of bioenergy than are food crops.

Furthermore, technologies other than those currently used to produce ethanol and biodiesel seem to hold far more promise for realizing the limited potential of agriculture as a sustainable source of renewable energy. The rush to ethanol and biodiesel was driven by the short-run economic bottom-line, not by long-run ecological, social, or economic sustainability. More sustainable renewable energy alternatives seem to have been bypassed in the rush to short-run profitability.

We are now seeing the consequences of short-run economic thinking in the collapse of the global economy. Perhaps this will cause more potential investors in bioenergy to take a longer-run perspective, which will give a higher priority to the sustainability of bioenergy. If so, “pyrolysis” seems to be one of the most promising technologies on the horizon.

Pyrolysis is formally defined as chemical decomposition of organic materials under high temperatures and in the absence of oxygen. The resulting biological materials include various types of fuel, biochar, and tars. The process has been used extensively in the chemical industry to

produce charcoal, activated carbon, and methanol from wood, to produce coke from coal, and syngas from various types of biomass. The technology only needs to be adapted, not created.

Using pyrolysis to convert biomass into bioenergy has several significant advantages over current methods of producing ethanol and biodiesel from corn and soybeans.

- Low-cost technologies on the horizon can use a wide variety of feedstocks, including forages and other non-food crops, as well as wood and various kinds of waste materials.
- A variety of usable products can be produced by pyrolysis, including bio-gas, bio-oil, various chemicals, biochar, and tars in small amounts, which also may have commercial uses.
- Bio-oil can be converted into either ethanol or biodiesel and bio-gases. Biogases are typically used to fuel the pyrolysis process, leaving the ethanol or biodiesel for other uses.

The potential advantages of pyrolysis appear to be even more compelling when viewed from the perspective of ecological and environmental sustainability.

- Pyrolysis does not require large amounts of water and does not pollute the air.
- Biochar can be incorporated back into croplands to promote soil fertility and by increasing soil organic matter.
- Biochar improves soil ecology by promoting synergistic relationships between the soil, soil organisms, roots of the plants, water, and carbon-dioxide and nitrogen in the atmosphere.
- Bioenergy crops grown for use by pyrolysis may actually sequester more greenhouse gasses than are released, as some carbon is retained in the roots of perennial plants.

Bioenergy from pyrolysis also would seem to have advantages for sustaining family farms and farming communities, if the technology is developed and utilized at an appropriate scale.

- The basic pyrolysis technology is adaptable to a wide variety of sizes, making *decentralized* systems of renewable energy production more feasible and cost competitive.
- Smaller systems allow individual farmers, or small groups of farmers, to produce fuel for their farm and home energy needs, without depleting the natural productivity of their soil.
- Mobile systems allow farmers to realize the benefits of an on-site system without mastering the pyrolysis process, while benefits of better by-product utilization offsetting some of the operating cost of the mobile units.
- Community-based operations allow recycling of bioenergy and biochar within local communities – reducing energy losses in transportation, retaining fertility of land for local food and energy production, and reducing energy costs for local residents – thus enhancing the ecological, social, and economic integrity of the community.

Economic viability may prove to be the greatest challenge in producing truly renewable energy on farms. The key to success may well be to utilize pyrolysis technologies as integral aspects of more sustainable approaches to farming and community economic development. Their comparative economic advantage may turn out to be their relative efficiency at the smaller scales of production needed to accommodate farm-based and community-based systems of renewable energy production. Their contribution to the economic viability of farms and communities as wholes may well exceed the market value of the various energy products. For example, transportation costs of energy feedstocks and energy products become increasingly important as energy prices rise. Producing energy “closer to home” will be increasingly important in the future.

Regardless of whether pyrolysis proves to be the ultimate technology for producing renewable bioenergy, the economic, ecological, and social criteria of sustainability are the criteria that must be used in producing *renewable* energy. Energy from agriculture is no more renewable than is the energy upon which the agriculture that produces it depends.

We may be able to find ways to generate significant quantities of bioenergy from the earth's bioenergy flow without compromising the integrity of the biological pyramid if we simultaneously improve the efficiency and integrity of the biological energy flow and nutrient recycling processes. But, we simply cannot afford to ignore the ecological limits of the biological reality of the world in which we live. The only truly renewable energy is solar energy. Renewable energy from agriculture must come from a solar-energy-dependent, sustainable agriculture.

End Notes

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⁵ Susan S. Lang, Cornell University News Service, “Cornell ecologist's study finds that producing ethanol and biodiesel from corn and other crops is not worth the energy,”

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