Implications of and Alternatives to Petroleum-Based Farming

PASA Conference Workshop, Saturday Feb. 4, 2006

Gene Bazan, Ph.D. and Tania Slawecki, Ph.D.

A. Personal Introductions

Tania Slawecki is former director of Penn State's Center for Sustainability. She is a materials scientist and researcher at Penn State's Materials Research Institute. She is also an assistant professor in the College of Engineering where she teaches courses she developed in green design & technologies, sustainable living, and integrative medicine. Academic background: BA Astronomy/Physics, MS in Physics, PhD in Materials Science & Engineering, specializing in polymer physics. In spite of all that, she grew up with organic gardening (thanks to dad) and raising rabbits.

Gene Bazan has spent a large part of his last 30 years working with educational, environmental and public organizations here and abroad. He helped create the Center for Sustainability at Penn State. Dr. Bazan was the lead author of "Saving the Farm, Saving the Farmer: Securing a Future for Agriculture in Chester County". He is a Master Gardener through Penn State Extension and teaches the organic gardening component of the training. Academic background: Electrical Engineering & Economics; Ph.D. in City & Regional Planning from Cornell.

The two of us have a long interest in living more lightly on the earth. We have used our own home and property for experimentation and implementation of more "sustainable" technologies and methods. In addition to gradually retrofitting our 1938-built home, we have been practicing John Jeavons' Growbiointensive mini-farming methods to produce about 75% of our year-round vegetable consumption, including winter harvest using Eliot Coleman's 2-layer (low-tunnel, high-tunnel) method for over-wintering cold-tolerant greens and root crops. We have also gradually converted most of our 0.8 acres to edible crops: trees include 2 peaches, 2 pears, 2 apples, 2 paw-paws, 2 plums, a sweet cherry; shrubs include hazelnuts, jostaberry, seaberries, gooseberries, sweet scarlet gumi berry, honeyberries, blueberries, Nanking cherries, plus black and red raspberries; plus strawberries, three mature sugar maples and a wide variety of medicinal and culinary herbs in addition to the biointensive summer and winter garden beds. We analyze and monitor our home retrofits as well as our food yields in an attempt to learn what works best for us – perhaps yielding insights that could benefit others.

B. Motivation

Background: According to global peak oil predictions (Hubbert Peak), we either already have or will soon reach peak oil production, most likely before 2020, after which it will take an increasing amount of energy to prospect for, drill, recover, and refine the "lesser-quality" oil discovered. World population hit 6 billion in late 1999 and today is nearly 6.5 billion; we could be at 10 billion people as soon as 2040. Thus, overall demand for oil will continue to increase rapidly while the global supply is realistically known to be limited and soon to go into decline. It is well known that "it takes energy to make energy", and pretty much all of our "alternative energy" prospects to date depend on cheap fossil fuels for their manufacture (including all raw materials) and transportation. Thus, they are presently regarded as "transition technologies". To what other long-term viable energy source are we transitioning?

Even if we *could* continue to burn fossil fuels, greenhouse gas build-up in our atmosphere is higher than it has been for at least the past 400,000 years, even given "natural" CO_2-level cycling with the ice ages. [See National *Geographic*, Sept. 2004 issue on "Global Warning"] And even if we ignored the resulting global climate change that threatens to submerge Manhattan and some 34% of Florida within the next 20-30 years and to wreak havoc with our weather patterns (bad for farmers), our high energy input farming methods are degrading our soils so quickly globally, that, according to Wes Jackson (The Land Institute, Salina, Kansas), soil losses, degradation, loss of soil fertility, salinization and desertification alone will likely lead to a population crash as soon as 2040.

Thus, our high-energy intensive society must, in the words of Ted Turner, "…do something drastic", lest these unpleasant scenarios unfold. Let us take a careful look at the choices before us. This session provides basic instruction in energy analysis as it relates to farming.

Some additional factoids to consider:

Stan Cox, head of The Land Institute's Plant Breeding team, brought to our attention the work of Vaclav Smil at the University of Manitoba. Smil came up with some alarming back-of-the-envelope calculations (from Fall 2005 issue of "The Land Report"):

- Without the use of nitrogen fertilizer produced from natural gas, 2.5 of today's 6.2 billion people could never have existed;
- If farming depended solely on naturally occurring and recycled nitrogen fertility, the planet's cropped acreage could feed only about half of the present population at today's nutritional levels;
- The U.S., the world's 3rd largest consumer of nitrogen fertilizer, could get by without the stuff only if we did four things: (a) moderated meat consumption; (b) raised all livestock on pasture and rangeland rather than nitrogen-hyped grains; (c) relied on leguminous cover crops; (d) and cut food exports.

And this is just for nitrogen fertilizer derived from natural gas. We here in the U.S. are in a more precarious position if we consider other fossil fuels: namely petroleum, but also coal.

- U.S. energy use is 30% greater than the total solar energy captured by all US vegetation. (Pimentel, 1998, p. 197)
- In the U.S., we require 400 gallons of oil equivalents to feed each American (1994 data, quoted in Pfeiffer, "Eating Fossil Fuels" From the Wilderness, October 2003. Also quoted in Dell Erickson, III-B, 2003)
- It takes 10 kcal of non-human energy (exosomatic) energy to produce 1 kcal of food delivered to the consumer in the U.S. food system, inclusive of all energy inputs except cooking. In other words, the **Energy Ratio is 0.1** (Pfeiffer, from 1994 report by Mario Giampietro and David Pimentel)
- "In Australia the glass of milk we drink is about twenty percent oil. In Europe, it's about fifty to sixty percent oil. In Israel, it's about ninety percent oil! In Saudi Arabia they've gone further than that—they have to desalinate sea water, too. What that shows is if there's enough energy you can do anything, in a way. You might get some very perverted systems, but it's still possible." (From permaculturist David Holmgren http://www.energybulletin.net/524.html)
- Agriculture consumes 85% of all freshwater in the U.S., but surface waters supply only 60%. The balance is drawn down from underground aquifers, which are not being replenished

- The U.S. Ecological Footprint is 24 acres per person. We are in 42% deficit. We are thieving from other cultures and species, and from our children and grandchildren. (Wackernagel and Rees, from their work on Ecological Footprint: Sharing Nature's Interest, p. Figure 7.2, p.120 1995 data)

Whether you are a farmer who believes petroleum will merely get more expensive, or a farmer who believes we're in for a big crash, you should be mightily interested in alternatives, how to analyze them, and how to incorporate them within your farm operation.

Our sole justification for being here today is to give you some "food for thought". What we have to present are **concepts, definitions, ideas and case studies** pointing to, and hopefully leading us out of, the mess that we are facing with petroleum, and farming with petroleum. We don't have any solutions we're trying to convert you to. While the two of us garden, we are engineers and scientists by training. **You** know more about farming than we do.

We have more material than we can present in 90 minutes. Rather than rushing through it, we accept that we will only get as far as a comfortable conversation with you allows. Therefore, we invite you to break in with your questions or comments at any point. To help us have a conversation, we are passing out a CD of our presentation, which contains our references and additional material. We hope this will relieve you of the distraction having to take copious notes. We will take a 5 minute stretch at 11:30.

For the sake of clarity in our discussion, it is important to make the following distinction:
As we proceed to discuss energy options, it is important to distinguish between energy as POWER or ELECTRICITY, which is measured in kilowatts (kW) or kilowatt-hours (kwh), and energy as HEAT from combustion, which can heat a building, melt metals, drive pistons to make your car run, etc. HEAT energy is usually measured in BTUs or British Thermal Units. Sometimes it is also easiest for us to convey that form of energy in terms of gallons of liquid fuel combusted (we all know what our home fuel oil bills amount to). Solar photovoltaics and wind power generators create electricity. Using this electricity to heat your home would be poor use of this resource, since it takes a LOT of electricity running through a resistance-type of heater to generate much heat. So we will be sharing with you energy calculations for various scenarios, and it is important for you to recognize that it isn't simply a matter of generating POWER or ELECTRICITY, but that HEAT, or THERMAL requirements are vital to consider too, for that is a huge chunk of our energy consumption, and there are many things we can do to *reduce* our thermal requirements.

C. The Big Picture of Energy

1) There are other sources of energy besides petroleum, and we have identified five major categories:
   a) Zero-Point Energy (ZPE, or "vacuum energy")
   b) Subtle Energy
   c) Energy derived from the Four Forces of Nature
   d) Geophysical energy
   e) Solar/biologic – which is where we would like to focus this talk
2) We will quickly go over categories a-d, reserving the bulk of the time to focus on where we are stuck – which is near the peak oil point on the global production curve. (15 minutes for a-d, 65 minutes category e)

3) The first two categories, indicated in purple, are the most "far-out" options we present, but worthy of note with follow-up references for those interested. We consider these options too "science fictiony" for most folks who barely grasp the more conventional "alternative energy options"… too few people are aware of them, and some of it is too technical to be of use. In blue are other energy-producing technologies with which we are familiar, but are not those of most interest to the farming sector due to affordability and/or appropriateness of location; a few here are a bit beyond our technical capabilities too. We briefly discuss these first four categories before proceeding to the main category of focus: solar/biologic.
4) Solar/biologic includes human/animal power, solar energy, biofuels, fossil fuels and such. Feel free to skip ahead to section D [p. 11 for format and intro] to learn more about these energy options and how we might evaluate them within a relevant farming context.

Zero-Point Energy (ZPE) is the most incredible energy-producing prospect to our knowledge and is based on our present understanding of the universe as mostly empty space but full of fluctuating energy with extremely high energy density…. So high, in fact, comparing zero point energy densities with nuclear energy densities: one ZPE engine would be the equivalent of 10^{80} nuclear reactors (yes, that is 10 to the 80^{th} power!). Roshchin & Godin are two Russian inventors whose magnetic-based generator is one of perhaps a half dozen (others designed considerably different) around the globe that appear to be ZPE generators. All such devices exhibit similar behavior when they operate: the air around them actually cools (which is the reverse of the heat engines with which we're all familiar) and they get lighter (they need to be bolted to a surface to hold them down).

My colleague, Dr. Thomas Valone, head of the Integrity Research Institute (www.IntegrityResearchInstitute.org) in Washington, D.C. has personally visited with the Russian inventors and claims that he has seen it work and cannot find any other viable explanation for how it works. Still, he estimates it would take another 15 years to bring a ZPE generator to the market in the U.S., assuming that the effort doesn't get wiped out by big-money corporate politicking. Dr. Valone, whose background is physics and electrical engineering, scrutinizes the most "far out" energy technologies, and has conducted numerous studies for the U.S. Department of Energy, as well as testifying in court to protect the most promising technologies.

Subtle Energy Options: these are literally within the reach of most of us. So-called because our conventional scientific detection equipment can't really sense what is going on, yet the results from subtle energy phenomena have proved – even under controlled laboratory conditions – real and repeatable. You might be familiar with one manifestation of "subtle energy" as "the power of prayer" – which has also been scientifically validated in double-blind experiments with large numbers of subjects [Larry Dossey, M.D., has collected such documentation]. Lest you worry that I'm saying "subtle energy replaces God" – I assure you I am not. What I am saying is that, just like we know that conducting metals carry electricity, so the structure of the universe (made by God) allows for "prayer" to propagate through it, like a TV signal in a way… invisible, but clearly hitting the mark! So without venturing into God's turf, as a scientist, we simply ask, "how is the universe constructed to allow this sort of transmission?" Maybe the transmission goes to God and then God responds by bouncing some healing energy back. As a scientist we simply ask, what is the form of such energy and how does it propagate? The Creator constructed the universe to allow such things to happen, so clearly we are missing something in our understanding of how it all works. Take some other examples:

Healing: whether hands-on, nearby with hands not touching, or at a distance… where the distance does not appear to matter; and

Dowsing: the ability to locate water (and other things) with a bent wire or Y-shaped stick… if this isn't valid, why do the workers at Penn State University's office of physical plant find dowsing to be a more accurate way to locate underground utilities than the tens of thousands of dollars of high-tech detection equipment they are given? Why did our military use it extensively? How did emeritus professor Will White at Penn State use dowsing to completely accurately map out – from above - a new, totally unknown underground cave, the opening to which was discovered by a local farmer, and then his findings were validated by having a team of spelunkers and scientists actually enter the cave and map it from the inside?

Thousands of years ago we thought lightning was the "wrath of the gods", but we now understand it is a form of atmospheric electric discharge. Similarly, dowsing is – even today – considered "spooky" or "witchcraft"… recalling our dark past steeped in highly irrational superstition. Good scientists don't ignore data that fails to fit our understanding and comprehension of the universe. We use it as the starting base for gaining a deeper understanding of What Is. And the amount of anomalous data is piling up to the point that one can no longer ignore it:

Bigu – "without food". Practitioners of Dr. Yan Xin's qigong techniques (which does acknowledge the divine) have been verified to attain an apparently energetically balanced state for days, weeks, months, and in some cases, many years, in which they neither desire nor require food to live. Penn State University hosted the first national conference on Bigu phenomenon in June 2000, and respected scientists and medical professionals from around the country and globe convened to examine the data. Medical examinations of those in the bigu state for a prolonged period of time revealed that the digestive tracts of these individuals had literally shut down. Only kidney function was required to pass fluids – most drank only water or Chinese teas. One couple who work at the Rockefeller Institute in NY have experimented on themselves for over 10 years and have maintained the bigu state through birthing two children, both of whom were born in the bigu state and have not eaten solid food in their lives… yet seem to thrive and are growing quite well. Food, candy… none of it even tempts the children. Westerners too can and have achieved this state – almost always inadvertently, as it is not a condition to be sought after, but is simply a consequence of practicing qigong (pronounced Chee-Gong). While living without food has been documented to occur throughout the world – Christian saints, Hindu yogis, Islamic Sufi mystics, Native American Indian shamans – it is often "discovered" by accident, and those who discover it generally don't feel it is appropriate to teach others. It certainly would address the future food shortages that might arise as global oil production diminishes! Acknowledging that another form of energy exists that we cannot measure and yet can sustain us so that we do not need to ingest food is why we regard bigu as another subtle energy phenomenon: the universe allows it to happen, independent of race, creed or geographic location, and so it is worth closer scientific examination.

Be able to germinate "dead" seeds or revert genetically-damaged seeds back to health: We have evidence that this is possible as it has been done by a number of individuals and documented scientifically. I've had the personal experience of working with Ms. Sun Chu-Lin from China in December 2000 when we conducted controlled seed germination experiments in Penn State's horticulture department. We had seen video documentation of how Ms. Sun could take a salted, roasted peanut and – after a 45-minunte qigong routine during which said peanut was clasped between her palms in prayer-like fashion – had successfully germinated the peanut to the point that it had a long tap root plus small side roots and two well-formed cotyledons (the first two leaves). It takes her only 10-15 minutes to germinate viable legume seeds in her hands. Prof. Richard Craig brought up a sealed plastic bag of "aged" geranium seeds from the basement of Tyson building, some 20-30 years old. Geraniums are propagated through cuttings usually because the seeds are so darn hard to germinate. Penn State was the first place to succeed at germinating geranium seeds, and the protocol is somewhat difficult and includes scarifying the seed (scratching off part of the seed cover to allow water and air to enter). Most plant seeds are viable for one to several years after collection… these were so old that they were effectively "dead", although a "less than 5% germination" expectation could be placed on them. The seeds we used were sprinkled into a petri dish directly from the bag. One dish was given to Ms. Sun to handle; another was taken aside as the control. Both petri dishes had a moistened towel on the bottom. Ms. Sun left and the dishes were incubated under identical conditions in a growth chamber: we had 27% germination in the dish "treated" by Ms. Sun while the control seeds rotted; the former smelled fresh, earthy and pleasant; the latter stank of rot and were foul smelling.

Other experiments with Ms. Sun and others who have similar capabilities (e.g Uri Geller, known for his "spoon bending" ability, has been tested extensively in laboratories around the world. He is not a magician and has no such training, but has some innate ability that he cannot always control) have revealed the potential for human to "will" changes to plants and their offspring, even changing the color of flowers.

Be able to weather cold or heat without discomfort: a well-documented ability of a large number of Tibetan monks, but imagine if we could each personally evolve to the point that we were not discomforted by the temperature of our environment: how much heat would we require in our homes? How much air conditioning would we need in summer? Think of the energy savings!

Grow plants with love: A colleague of mine, Dr. Joie Jones, in the Dept. of Radiology at the U. of California in Irvine has been experimenting with just this: to one plant he gives the usual watering, and to the other he does nothing but send "love energy". He finds the latter thrives – even without water – better than the former. There is an inspiring story from the WWII Nazi concentration camps of "Wild Bill" who thrived on, effectively "love energy". Although he was fed the same starvation diet as those around him for six years, he did not look emaciated and was highly energetic, working 15-16 hrs/day helping others, counseling forgiveness and teaching about love. How did he get this way? His own family – wife and five children – were gunned down in front of him. He said he had to make a choice regarding how to react: it was an easy choice, for he had seen what hate could do to our minds and bodies, and hate had just killed everyone and everything that meant the most to him. His only recourse: to love everyone with whom he came in contact. Think of these examples the next time your fields are dying in drought or drowning in downpour.

Dr. Masaru Emoto's "Messages from Water": More people are hearing about Dr. Emoto's work with crystallizing water. Take identical bottles of water. Label one with "You make me sick. I want to kill you." Label the other with "Love and appreciation". Let them sit overnight with these labels on. The next day, pour the water into dishes and freeze them. Photograph the crystal structures viewed under a microscope: those with the negative label fail to crystallize and look sort of ugly and without any discernable pattern; those with the positive label crystallize with a very similar-appearing elegant and beautiful structure. Contrary to the "no two snowflakes alike" understanding, Emoto is finding that the crystals from a given sample of water all look very similar in pattern. Classical music forms exquisitely beautiful "snowflake-like" crystal patterns in water exposed to it; water exposed to heavy metal music cannot crystallize… forms a non-distinctive ring pattern akin to looking down on a cymbal from above. How is this possible? Polluted water from a dam forms an ugly non-crystalline pattern when frozen, but that same water sampled after a monk said a prayer over the polluted dam water crystallized beautifully. Emoto's findings are getting a lot of attention.

These examples focus on some people that seem "extraordinary" to us, and yet, being human, they help define our greatest potential. They also help us see how subtle energy may be useful for us to understand better and to learn how to use it to our collective advantage to heal ourselves and our planet. Subtle energy has also been harnessed in various forms to use in technologies:

- Wilhelm Reich's "cloud buster" to make rain
- SE-5 (radionics) device to rehabilitate declining forest health
- Dr. William Tiller: raise the pH of water by intention or IIED
- Nikola Tesla's "wireless transmission of power" via "non-Hertzian" or "longitudinal" electromagnetic waves

These are but a few examples of "what's out there". I have met with Dr. Tiller and have visited his laboratory in Payson, Arizona where he continues to conduct very careful experiments. Former head of the Materials Science Department at Stanford University, Tiller is now retired and spends all of his time pursuing a deeper understanding of how the universe is structured. Our conversation includes discussion of "conditioned spaces", "higher symmetry gauges" of the universe, and other things physicists love to talk about. The lab is full of electronic sensors monitoring air, temperature and changes to water samples (as water seems to be especially sensitive to subtle energy), plus Faraday cages and a big mu metal box – "cages" that are used to electrically or magnetically isolate samples during experiments. Tiller has found that a group of four good meditators can, with focused intention, raise the pH of a sealed vial of water by one order of magnitude – i.e. from pH of 7 to pH of 8. Water left in open air drops in pH because carbon dioxide in the air mixes with it and turns it acidic, so it is important to note that the change they achieved with intention is clearly contrary to what happens to water naturally. More intriguing, Tiller created a simple MOSFET (memory) circuit and had the same meditators convey to the chip (called an IIED: Intention-Implanted Electronic Device) their INTENTION to raise the pH of a water sample. At some undisclosed time later, the IIED was placed in an electrically isolated (Faraday) cage next to a fresh vial of water. And the water responded and raised its pH just as if the meditators were present in the room with it! Controlled laboratory conditions. Repeatable.

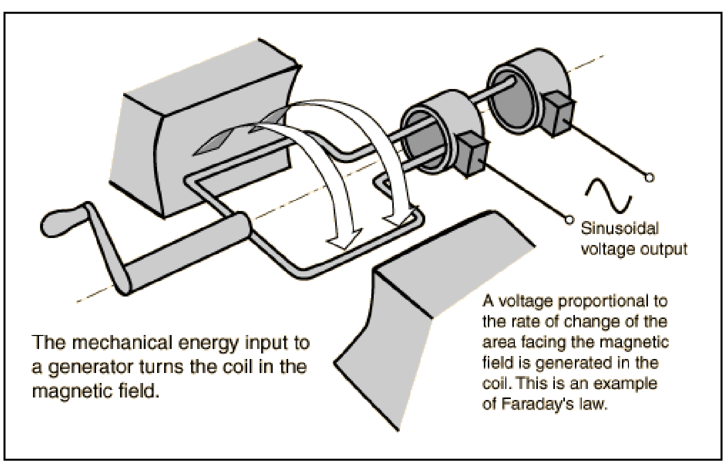
In our college education, we're taught about transverse electromagnetic waves only. That's the visible light we see with our eyes. We have proven in a vacuum that such transverse electromagnetic waves travel at a constant speed – the speed of light. That's fine. But in seismology (earthquakes), the first wave to reach the monitoring stations is the *longitudinal* wave. The slower, transverse wave follows later. When solving Maxwell's Equations for electromagnetism, we conventionally drop "unreaslistic solutions" because we assume that "nothing can travel faster than the speed of light". Well, that is true if it is a transverse wave, but what about if it was longitudinal? That's apparently what Nicola Tesla discovered over a century ago, and he had successfully demonstrated wireless transmission of energy. When he was building his first energy accumulation/transmission station at Wardenclyff, Long Island, J. P. Morgan who was funding Tesla's research pulled the plug on his funding and stopped the project dead because he didn't see how this "free energy" could be metered so that he (Morgan) could charge for it and make big bucks. It is a serious omission in our education system that we never learn about longitudinal electromagnetic waves that are not bound by the "speed of light" limit, and detection of energy of this nature remains elusive to most.

So we see that Subtle Energy has great potential for development - and there are things we can do personally to develop ourselves as constructive instruments along this line. However, for most, it will remain too much as "science fiction"… well beyond their grasp or comprehension, often shunned out of fear of the unknown.

The Four Forces of Nature: Gravitation, Electromagnetism, Strong and Weak Nuclear Forces
We have generally been using the four forces of nature to our advantage whenever, wherever possible. Still, there is room for innovation and improvement.

Gravitation: One innovative use of gravitation can be seen at the Center for Alternative Technology (CAT) in Wales. Their water-balanced cliff railway consists of two "cars" that can be used to transport people or things down the steep cliff of the old slate quarry to their demonstration eco-village and education center. The weight of both cars – one at the top of the pulley and one at the bottom – is noted, and water is added to a tank in the top car to exactly counterbalance the weight of the lower car, thereby allowing a car full of passenger to be lifted to the top; or vice-versa: the water is added to the lower car to counterbalance a carload of people at the top so that their ride to the bottom of the cliff is nice and smooth. The water is added or emptied as needed and can be re-used time and again. No energy, therefore, is required to operate the lift, although it takes a little bit of time and people power to weigh and fill/empty the cars just so. Clever. In what other applications might we be able to use this concept?

Electricity and Magnetism are most commonly employed in power generation through the invention of the motor, which is based on Faraday's Law of Induction: if you rotate a coil of wire between the north pole and south pole respectively of two fixed magnets (or in a fixed magnetic field), a current will be induced in the wire that is sinusoidally varying (switching polarity as one part of the loop first passes near the north magnetic pole and then passes near the south magnetic pole). Picture that instead of you using a hand-crank to physically rotate said coil placed in a magnetic field, that there are blades that catch the wind and rotate it: hence the way a wind power generator works.



Similarly, one can reverse the process: place a loop or coil in a magnetic field and attach a battery to it to allow a current to run through the wire. The interaction of the field around the wire (due to the current flowing through it) with the surrounding fixed magnetic field generates forces that cause the loop or coil to rotate. This is the process you see everyday when you turn on your lawnmower or run your blender or coffee grinder: you input some amount of electricity, and it will turn a coil that then rotates blades attached.

Nuclear Power: Using our knowledge of strong and weak nuclear forces, we have learned of a number of nuclear power options, including fission, and hot and cold fusion processes. Nuclear fission, on which our nuclear reactors and war technologies are based, is costly, hazardous, and globally, is facing a limited fuel supply (even if we could figure out what to do with the "spent" waste – decades of research have not turned up viable solutions except for controversial applications such as "food irradiation"). Nuclear fission reactors have a finite lifetime and require a large amount of concrete to construct. The embodied energy in the facility alone is enormous, and we often overlook the impact of the cement manufactured to create all of that concrete (cement is the "glue" that holds together the other ingredients in a concrete mix). Cement is manufactured in furnaces at extremely high temperatures during which large amounts of CO_2 are given off from the material. I have yet to see a detailed full-cost energy analysis done for a nuclear power plant, but even if it is a net energy producer and even if it saves on production of CO_2 in the long run, we are still faced with its susceptibility to terrorist attack, the problem of proper waste disposal, the increases in thyroid cancer and leukemia from its use, and the limited fuel supply (which requires fossil-fueled machinery to mine, refine and transport).

Nuclear *fusion* prospects are growing better, particularly "cold fusion", which, in spite of all the scandalous negative publicity it initially received, has proven itself in a number of laboratories around the world to be a valid phenomenon. However, its viability as a solution to our energy requirements lies somewhat in the future. Dr. Thomas Valone at the Integrity Research Institute in Washington, D.C., keeps track of some of the most promising advancements in future energy technologies, so you can obtain annual updates on prospects by ordering reports from www.IntegrityResearchInstitute.org .

Geophysical Energy: Tidal and Geothermal Sources

While it is important to mention these, they are not readily accessible to most of us, much less farmers. Tidal energy is most useful along coastlines. Early technologies were very expensive and suffered from corrosion problems (salt water is highly corrosive). New advancements in non-corrosive reinforced ceramic materials have overcome the corrosion challenges, but severe weather along the coasts due to global climate change may wreak havoc with such stations. The latest tidal energy-harnessing technology translates the up and down wave motion of the sea into useable forms of energy that can be directed to coastal regions for use there. [See for example: *Popular Science*, December 2005, p. 74] It continues to be an extremely expensive option.

Geothermal energy is of two types: harnessing the earth's internal heat energy wherever the earth's crust is thin, or "ground source heat pumps". The former is what Iceland is using to propel it into a hydrogen-based society. [By contrast, the rest of us have to generate power to create hydrogen to use.] The latter is what you may have heard from people who claim to be using geothermal heating systems in PA: the temperature of the earth deep below the frostline is a constant 55^{o}F. By drilling deep "wells" into the ground and running water-filled pipes down into these wells, we can use the ground-source heat pump to either cool or heat our homes as needed using the same principles on which refrigerators work. The water-filled tubing is usually embedded in a concrete slab under the house so that adequate thermal exchange can take place between the home and ground temperatures. When it is hot out, the water circulating through the home's slab will pick up the unwanted heat. As it travels down the deep well into the ground, it loses that heat to the ground and cools down. The cool water circulates back up to the house and cools the slab. In this case, the system behaves as a "heat exchanger". In winter when it's cold out, a heat pump is used to extract heat from the earth, deliver it to the home via the concrete slab (i.e. a "radiant floor heating system") and return unwanted coolness to the ground. If you can grasp the way a heat pump works to make your refrigerator work, you will grasp how a ground-source heat pump can work this way – if not, just understand that it does work this way.

Ground-source heat pump systems have a very high initial cost, but are said to pay for themselves in the long run, especially as energy costs increase. However, it does take electrical power to run the pumps that circulate the water and to run the heat pump. There are many advances in this technology in recent years, and it may be worthwhile to investigate what options are available. At a glance, we note that there is a very high embodied energy cost in getting started with a ground-source heat pump system, and it is best to start of with it from scratch; harder to retrofit and take advantage of it. Careful analysis is required that we have not yet been able to do, nor have we seen others do.

D. Solar/Biologic

In this category we have:

- Human, Animal
- Carbon: fossil fuels (gas,oil,coal), wood, crops/crop residues (methane, ethanol, biodiesel)
- Hydrogen (fuel cells, etc.)
- Photovoltaic (PV)
- Active/ Passive solar
- Wind
- Hydroelectric (hydrologic cycle; micro-hydro)
- Microbes (GMO, protein grown in vats)
- Nanobots/motors

In red I have indicated the three forms of energy – Human, Animal and Passive Solar – that are in keeping with earth's natural metabolism. At present we do not know the effect on the environment that wind power generators might have – particularly in affecting wind patterns at certain levels of the atmosphere. We DO know that having dammed all the major rivers to make use of hydroelectric power has not only caused immense greenhouse gas production (when the dammed area was initially flooded and all of the underlying vegetation rotted anaerobically), but has measurably altered earth's rotation through redistribution of mass on the planet's surface. Combustion technologies not only exacerbate climate change and produce waste heat, but they constitute our "industrial metabolism", which is beyond the much slower regenerative rate of our ecosystems. As hydrogen fuel cells are still operating at a net energy loss and are not accessible to us as a viable energy-producing technology, we will not be discussing this option. Nor will we examine genetically-engineered "super" microbes that could produce hydrogen from sewage and whatnot, nor prospects for somehow making "nanobot motors"… all rather science fictiony at present, certainly beyond our grasp as a present opportunity.

Our energy analysis will therefore focus primarily on carbon-based fuels, including biofuels, plus wind, solar and micro-hydroelectric. When it comes to SOLAR energy, we must differentiate between photovoltaics (PV) which generate electricity, and solar heating technologies (solar hot water heaters, solar hot air collectors, and good passive solar design which is based on the ability of certain materials to absorb, store and re-radiate heat from the sun). We will not discuss PV at length because it is so expensive, with lengthy payback periods that are likely formidable to farmers. Further, PVs are seen as a transition technology, and at present, fossil fuels are required to provide the raw materials and manufacturing of PV cells and all the infrastructure (panel mounts, wiring, combiner box, charge controller, inverter, battery banks, etc.) needed to make them usable. We simply ask the question: what happens after the PV cells begin to degrade and you need to replace them? How long does the infrastructure last? The batteries? What will be available to us to replace them in the future?

Wind power, akin to solar energy, can work in two ways: to generate electricity, or to work as a pump to pump either water or air. Its use on farms for water pumping and for aerating fish ponds is well-established, although used far less so today than in the past. Although not as pricey as PV for power generation, a careful analysis of your investment into wind power should be done in advance of your purchase of a wind power generator. Our case study below will outline the procedure you might use.

Micro-hydroelectric power, from what we've been able to learn about it so far, appears to be the cheapest "best bet" for on-site power generation IF you have running water and sufficient head pressure on your property, and if this stream is close to the place where you intend to use the energy. We visited the Earthaven Community (N. Carolina) in 1997 where they had just installed their community's first micro-hyrdro station. By the time they ran the power line from the station by the stream, across the road and to one of their buildings, it only produced enough power to light a single light bulb. That's a lot of effort and infrastructure for such a little amount of power generated! Clearly a more careful understanding and design/layout might have led to a more usable amount of power generated!

APPROACH TO OUR PRESENTATION OF ENERGY ANALYSIS

- **Evaluate energy in real cases**
- **Introduce key energy concepts in each case study**
- **Integrate findings and project to possible future scenario for PA farmers**

Overview of Case Studies used to Demonstrate Energy Analysis

- **Efficiency – key concept and mis-concept**
- Case 1: Concept of **Efficiency** Applied to CSAs vs Other Farming Methods
- Case 2: Concept of **Net Energy** and **Energy Ratio** as Applied to Agriculture: The Sunshine Farm
- Case 3: Concept of **Rate of Return on Investment and Payback**: The Wind Power Generator
- Case 4: **Underlying Assumptions in Energy Analysis**: Ethanol and Biofuels
- Case 5: **Costs/Savings/Payback** from Retrofits
- Case 6: **Embodied Energy and Ecological Footprint Analysis** in PA and Centre County Food Production

Gene will present Cases 1-5; Tania will conclude with Case 6.

Recall, we're focusing in this category of energy sources on **concepts, definitions, ideas and case studies.** We start with the fundamental concept of efficiency.

Concept of Efficiency (from "The Energy We Overlook", by Robert U. Ayres. World Watch. November/December 2001)

1) Four years ago Robert Ayres wrote an article that appeared in World Watch magazine. He turned around completely my understanding of **efficiency**.
2) **Efficiency is often defined as = "Useful" Energy Output/Actual Input Energy**. You're concerned with getting **out** of a device a large measure of the energy you put in. Thus, the gas industry likes to claim that their furnaces are 80% efficient, by which it means that 80% of the heat from the gas burned goes into the house and only 20% goes up the chimney.
   a) **Note to myself:** from Serway, Physics for Scientists and Engineers, p. 479, $e=W/Q_h$, where W = work output and Q_h = heat from high temp source
   b) **COP** (coefficient of performance) = Q_h/W = heat transferred by heat pump/work of pump: typically hope for ratios of 4
3) A study conducted by the Livermore National Laboratory in 1973 for Congress concluded that the economy of 1970 was achieving an astonishing overall efficiency of **47.5%.** With such high efficiencies, policy makers concluded that there was little room for improvement.
4) However, this study was flawed. The error was pointed out by the American Physical Society in 1975, but the report of this error did not get much press. Engineers and economists continued using the wrong definition of efficiency – the one I just mentioned.
5) **The error arose as follows:** The denominator of the fraction, **Input Energy,** is the energy actually used – by the economy as a whole, an industry, a factory, or some appliance. However, the **numerator,** the number on top, **"Useful Energy Output", should be "the minimum physically possible amount of energy required to achieve the same outcome".**
   a) **Note to me:** Andy says "2nd law efficiency can also be written as Actual Output/Output Best Imaginable Device (but how limited – to achieve same output??). Andy Lau 's example of theoretical effic of light is 683 lumens/watt, compared with 80/watt for fluorescent and 20/watt for incandescent. Therefore, divide 20/683 is effic of incandescent.
6) Let us return to the gas furnace example to illustrate this **(Power Point slide using table below)**. We start with the **old efficiency calculation.** Let us assume that your present gas furnace burns 1,000 therms of natural gas to heat your house to 70 degrees during an average heating season. 200 therms goes up the chimney, leaving you with a net of 800 therms to heat your house.
7) You could take your task to be fine-tuning the present furnace (Example 2). (Story of our furnace repairman installing a better nozzle and getting 2 more efficiency points – he was tickled!)
8) Let's suppose you consider superinsulating your house and using triple-pane windows (Example 3). You projected energy use shows you will require only 200 therms for the season. Your **present** heating efficiency is now only 200/1000 therms or 20%. The 80% efficiency **device** efficiency is IRRELEVANT. **What matters is the minimum energy required to get the same job done, not how much you're getting out of the furnace.**

Efficiency Calculations

Old Efficiency Equation:	Efficiency = Useful Energy Output/ Actual Energy Input
Example 1: gas furnace to heat house to 70 deg F	Efficiency = 800 therms / 1,000 therms = 80% of gas furn
Example 2: Device trap – improve the gas furnace – less goes up chimney.	Efficiency = 840 / 1,000 = 84%
Updated Efficiency Equation:	Efficiency = the minimum physically possible amount of energy required to achieve the same outcome / Actual Energy Input
Example 3: superinsulate, triple-pane windows, heat to 70 deg F	Efficiency = 200 therms / 1,000 therms = 20% of gas furn
Example 4: new design by bright engineer, heat to 70 deg F	Efficiency = 60 therms / 1,000 therms = 6% of gas furn

Note: 1 therm = 100,000 BTU. 1 gallon of fuel oil = 140,000 BTU. So, 1,000 therms ~ 714 gallons

9) **Example 4.** Let's suppose further that you hire a bright engineer, and using passive solar design she figures out that the theoretical minimum required to heat your house for the season is only 60 therms. The efficiency of your present heating arrangement is only 60/1000 or 6%.
10) **Six percent, by the way,** is the efficiency arrived at by the American Physical Society for oil or gas heating using contemporary hot water or steam radiators.
11) Ayres' calculation of the energy efficiency of the entire U.S. economy is only 5%. In short, **THERE IS LOTS OF ROOM FOR IMPROVEMENT – Both in home heating and throughout the entire U.S. economy. Under our present arrangements, we're flaring off gas!**

12) **We must properly re-define efficiency:**

Efficiency = minimum energy required to get the job done/ Input Energy

13) **What this means for farmers and farming** is that we can realize tremendous energy savings by stepping **outside** the various boxes that trap us in standard ways of thinking.

To Summarize Key Point: Efficiency

Common definition ("device efficiency"):

Efficiency = "Useful" Energy Output / Input Energy

Self-referential… sets no benchmark for improvement!

American Physical Society (and Ayres) redefines:

Efficiency = Minimum energy to do X / Input Energy you are using to do X

Now you can see how much improvement is possible!

14) Let us apply this new concept of efficiency to CSAs – Community Supported Agriculture.

Case 1: Concept of Efficiency Applied to CSAs: a Case Study

1) One of my farming heroes is Eliot Coleman. I've learned a lot about winter gardening from him. In an appendix to his **Winter Harvest Manual**, he undertook to answer for himself whether growing lettuce in his winter greenhouse for sale was really more energy efficient than trucking lettuce across the country from California. **(Ask: "How many have read his Manual? How many recall the calculation in that appendix?)**
   a) The essential comparison was between the energy content of his 6 mil plastic vs the diesel fuel required to truck lettuce from California to Maine. Otherwise, he assumed, the growing and distribution of lettuce would involve the same costs.
   b) He determined that the energetic content of his greenhouse lettuce was 1,855 BTU/head. By contrast, the energetic content lettuce trucked across the country was 64% higher (3,034 BTU/head [average of 3 estimates]).
2) If we want to calculate the **energy efficiency** of trucking lettuce from California, we can take the **old** efficiency definition and use Eliot's greenhouse number in the numerator and the trucked lettuce number in the denominator, for an efficiency of 1,855/3034 or **61%. (Power Point Slide)**:

$$\text{Efficiency} = \frac{\text{Coleman's lower energy required to grow 1 head of lettuce}}{\text{Input energy required to get the job done by cross-country truck}} = \frac{1{,}855}{3{,}034} = 61\%$$

3) In the light of what we have just said about efficiency, 61% is way too high. We should be getting efficiencies much lower. What is wrong here?
   a) **Primarily,** Eliot has done only a partial calculation. There are **other** energy requirements to producing lettuce for market **beyond** those Eliot included in his calculations. He assumed that those energetic requirements were the same in Maine or in California, and therefore not relevant to his question. The omitted inputs include on-site energy costs of growing lettuce, costs of delivering lettuce to his customers, his share of the roads and public infrastructure on which he drives his truck, energetic costs of fertilizers, compost, insecticidal soaps, etc.
   b) His approach was akin to comparing electricity for space heating produced by a nuclear power plant to electricity produced by a coal-fired plant. One may be more efficient than the other, but both are horribly **inefficient** ways to heat your house. Eliot got caught up in the "device efficiency" trap – his **greenhouse** device vs the **trucking** device.
4) To sort this out, we have to do two things:
   a) **First,** we have to do a proper and full energy accounting;
   b) **Second,** we have to ask, "What is the real goal here?" If it's to get fresh greens on people's plates, a third way to do this is through people growing their own greens. A fourth way is through community gardens.
   c) Now, those of you who are thinking as fast as I can talk might be saying to yourselves, "But, but – those two ways would put vegetable farmers out of business!" I would reply in two ways. FIRST, "How is your thinking different from pharmaceutical CEOs who oppose herbal remedies for the same reason?" SECOND, showing someone else how to do it falls into "educational services", a much higher and easier line of work than growing and selling vegetables. **Think "workshops".**
5) "Let's do the math and see where we come out!" **(Power Point Slide** with Table below) .

a) I emphasize this is a back-of-the-envelope calculation to show you how you **might** approach this for **your own** operation.
b) Show table and describe what it contains.
c) I can calculate efficiency of various modes of production:
   i) **CA** lettuce production = the **<u>"minimum energy required to get the job done"</u>**
      Actual Input Energy
      For **Actual Input Energy**, I use CA lettuce total as denominator. I use **Self-grown total as minimum** energy required. Therefore, Efficiency = 7,316/30,340 = 24%.
   ii) To calculate the efficiency of **Eliot Coleman** lettuce production, I divide 7,316/22,596 = 32%.
   iii) To get the efficiency of **CSA lettuce**, I divide 7,316/47,503 to get 15%.
d) Lots of room for efficiency improvement in all these modes of production.
e) Notice that under the assumptions I made here, CSA production uses more BTUs/head of lettuce than **any** of the other modes of production.

		BTUs per head of lettuce [2]			
Energy Category	**%** [1]	**CA lettuce**	**Eliot**	**Self-grown**	**CSA**
Farming	18%	5,461	5,461	5,461	5,461
Winter plastic		0	**1,855**	1,855	1,855
Food Processing	30%	9,102	9,102	0	2,276 [5]
Distribution	10%	**3,034**	6,178 [3]	0	28,578 [4]
Commercial Food Service	17%	5,158	0	0	0
Home Food Prep	25%	7,585	0	0	0
Total	100%	30,340	22,596	**7,316**	38,170
Efficiencies:		**7,316**/30,340 = 24%	**7,316**/22,596 = 32%.		**7,316**/38,170 = 19%

1/ quoted in Bender (From A.B. Lovins, L.H. Lovins, and M.H. Bender. 1995. Agriculture and energy. Pp. 11-18 in: *Encyclopedia of Energy Technology and Environment.* Vol. 1. John Wiley and Sons, NY). Comment: I don't know whether these % also include embodied energy.

2/ We assume that % distribution among energy categories holds for lettuce as for farming as a whole. I took his calculation of truck transport from CA (3034) and applied it to the Distribution category, divided by 0.10 to get the total for CA lettuce of 30,340.

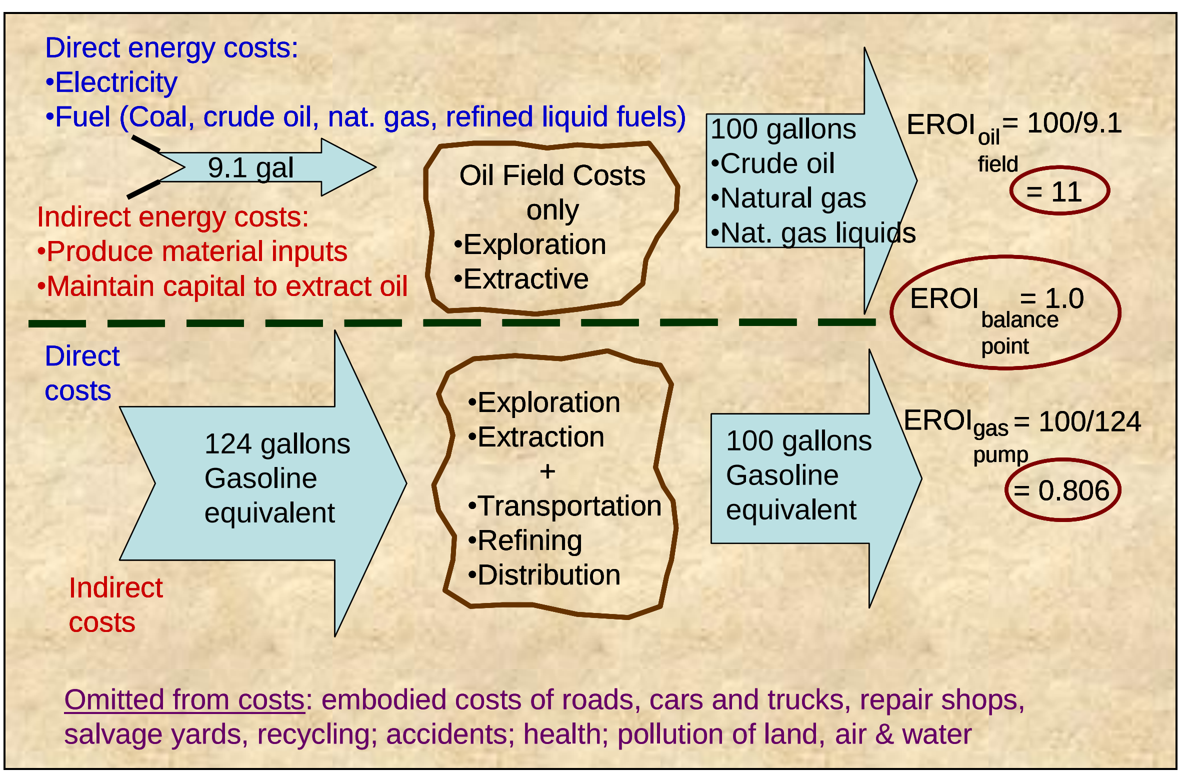
3/ Eliot's truck use/head lettuce (he did not include embodied energy in his calculation, nor use of his own truck to make local deliveries)
   a. Embodied (50 BBL x 55 gal/BBL)(30 miles/100,000 miles)(1/100 heads) (1 gal diesel/2 gal oil)(140,000 BTU/gal) = 578 BTU/head
   b. Operating (30 miles/100 heads)(1 gal/15 miles)(140,000 BTU/gal)(2[maint, repair]) = 5,600 BTU/head
   c. Total truck use = 578 + 5,600 = 6,178 BTUs/head

4/ Assume CSA member drives 20 miles round trip to farm:
(20 miles/order)(1 gal/20 miles)(140,000 BTU/gal)(2[maint, repair])(0.1 order/head) = 28,000. Add embodied energy from 3(a) for truck of 578. Get 28,578 BTUs. (We know a solar engineer at Penn State who belongs to a local CSA. He figured that it cost him 5# of gas to get 5# of vegetables per trip, which he did weekly. His gas consumption is 5/8th my calc.)

5/ Assume CSA food processing 0.25 that of commercial production (CA, Eliot)

Case 2: Concept of Net Energy and Energy Ratio as Applied to Agriculture: The Sunshine Farm Case Study More recent article: http://www.landinstitute.org/vnews/display.v/ART/2002/09/24/3dbeba6338ac3 ; 2nd article with 3 pdf tables used below: (http://www.landinstitute.org/vnews/display.v/ART/2001/03/28/3accb0712)

1) In our next case we look at the **Sunshine Farm** project run by Marty Bender at The Land Institute in Salina, Kansas. **(Ask "How many have heard of this project?")** It is a mixed crop and livestock farm. Bender's aim over the ten years of the study (1991-2001) was to determine how much of their own energy requirements farmers could meet on the farm, in particular by exploring the possibilities of farming **without** fossil fuels, fertilizers or pesticides.
2) In this case study, you will hear three concepts mentioned frequently: **Net Energy, Energy Ratio,** and **Embodied Energy**.
   a) In petroleum extraction, **Net Energy** is simply the difference between the energy of the oil produced by your drilling and the energy required to produce this energy. We can write this as **Net Energy = Output Energy – Input Energy.**
      i) **Thus,** if it took 1 barrel of oil to produce 2 barrels of oil, your **Net Energy** is +1.
      ii) **On the other hand,** if the numbers were reversed, your Net Energy would be negative, so why are you bothering. You want the difference to be positive, and high.
   b) The **Energy Ratio = Output Energy/Input Energy.**
      i) Ratios **> 1** indicate that you are getting more out than you are putting in.
      ii) Ratios **< 1** indicate you are putting more in than you are getting out.
      iii) You will **also** find this concept expressed as **Net Energy Ratio**, **EROEI** (Energy Return on Energy Invested) or **EROI** (Energy Return on Investment).
   c) **As with efficiency, Energy Ratios have their own slipperiness.** The questions here have to do with what you **include** in the inputs and outputs – and what you **omit**.
   d) Let us look at oil drilling and gasoline refining deduced from Cutler J. Cleveland, "Net Energy From the Extraction of Oil and Gas in the United States, 1954-1997" http://www.bu.edu/cees/research/workingp/pdfs/Net__Energy_w=figures.doc.pdf



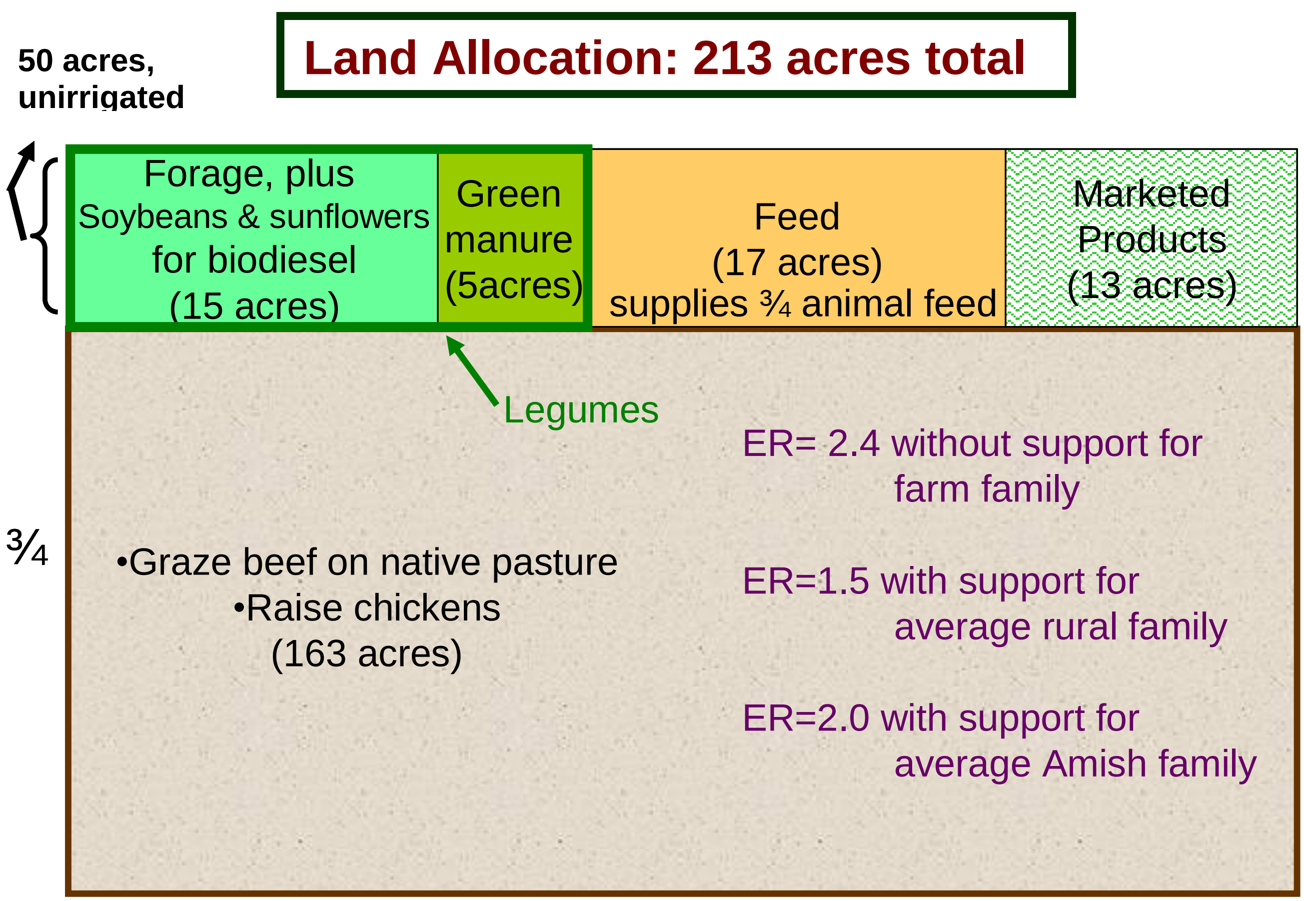
e) The third scenario in this slide leads to an **Energy Ratio** for gasoline, **0.806,** that is less than one. **I didn't make this up.** This was the figure arrived at in a study done by the Minnesota Dept. of Agriculture (Groschen, Ralph "Energy Balance/Life Cycle Inventory for Ethanol, Biodiesel and Petroleum Fuels". Minnesota Department of Agriculture. 2005). http://www.mda.state.mn.us/Ethanol/balance.html

f) I wouldn't have thought much of this, except I also came across an article in our local paper reporting that the ER for **diesel fuel** was 0.83.

g) **ERs < 1** say is that it takes more energy to get gasoline to your gas tank than the energy you get out of that gasoline. This energy input does **not** include the energy required to build and maintain the roads; build, maintain, and repair cars and trucks; the energy required to dismantle and recycle them; health costs from accidents; and costs of pollution, soil contamination from petroleum runoff, etc.

h) **Embodied Energy** is the **third** concept you will hear. The energy input of the tractor you use to grow corn is more than the fuel it takes to run the tractor. To do a correct energy analysis of the tractor, you have to include the energy required to **make** the tractor.
   i) **This includes the mining**, smelting and shipping of steel, and the tractor's share of the factory and supportive infrastructure including electrical network, water lines, public roads.
   ii) **Next you'll** want to include the energy costs of keeping the tractor repaired and in tires.
   iii) **Finally, you'll want** to include the energy costs of recycling the tractor and correcting for any pollution, damage, or soil runoff caused by your tractor farming.
   iv) **When you're done,** you can say that over its life, the **embodied energy** of a tractor can be represented by **X** barrels of oil.

3) **With these three concepts defined**, we turn to the highlights of the Sunshine Farm Project:
   a) First, what did the farm consist of?



i) 212 acres of which 50 acres was given over to unirrigated cropland, and the balance grazed to beef on native prairie and used to raise chickens.
ii) 1 bio-diesel fueled tractor
iii) 1 team of two Percheron draft horses
iv) a 4.5 kw photovoltaic array for workshop tools, electric fencing, water pumping, farmhouse. ER of PV array = 1.6 over its 20 year life – that is, it will produce 1.6 times more energy than was consumed in its manufacture and installation, including a bank of batteries and a prorated portion of the power company grid to which it is connected . (Note that the ER of 1.6 does **not** include embodied costs of ecological damage or recycling/disposal of the PV array.)

b) **Summing up the results of the Sunshine Farm –** **(review** diagram of farm)

i) **3/4th** of the farm was given over to grazing livestock, and **1/4th** of the farm given over to producing crops, and **30%** of that cropland given over to producing vegetable oil for biofuel use on the farm and for off-farm transportation. This farm produces **half** of its **embodied costs.** The **remaining half** has to be imported through cash purchases.
ii) **3/4ths** of the animal feed consumed on Sunshine Farm was supplied by the oats, grain sorghum and alfalfa grown on the farm for the draft horses, beef cattle and poultry. The rest, I assume, was purchased.
iii) The **25%** of the farm's cropland devoted to oilseeds. The contribution was determined on a **net-energy basis** in which the gross energy content of the harvested biodiesel fuel was **reduced** by the energy inputs for raising the oilseed crops and chemically converting them into biodiesel, including **amortized embodied energy** in machinery and buildings. It was also **increased** by an energy credit for high-protein meal cake, a by-product from biodiesel production that would be fed to livestock.
iv) **The Resulting Energy Ratio was calculated by dividing** energy contained in marketed products **by** embodied energy in purchased inputs and capital, including transportation from factories to dealers). The ERs were:
   (1) ER=2.4 without including support of the farm family.
   (2) ER=1.5 when you included support for **average** rural family.
   (3) ER=2.0, higher, when you included support for average **Amish** family.

c) Important in this assessment to treat farm-produced energy (e.g., from solar) properly: **not** as an output of the farm, but as an input whose production on the farm is priced to include its **embodied cost** – that is, the farm's share of the total cost of producing – mining and manufacturing – the solar array over its life.

4) Let us compare various kinds of farms with the Sunshine Farm **(Power Point Slide,** table 1 from Bender) (http://www.landinstitute.org/pages/EnergySSF_tables.pdf)

Table 1. Inputs and outputs per acre and energy ratios for mixed crop and livestock farms.

Farms	Marketed crops (C)	All marketed outputs (O)[a]	All purchased inputs (I)[b]	Farm energy ratio (O/I)	Energy ratio of marketed crops to outputs (C/O)
	Per acre of cropland				
	million Btu			unitless	
Sunshine Farm					
Without photovoltaic array	5.5	5.8	3.4	1.7	0.95
With photovoltaic array	5.5	5.8	3.3	1.8	0.95
Pennsylvania dairy farm[i]	2.4	3.5	2.0	1.8	0.69
Groups of Amish farms[c]					
2 groups (PA)[ii]	0.7-0.9	2.8-6.6	3.3-9.4	0.7-0.8	0.14-0.25
4 groups (PA, WI, IL)[iii]	—	2.1-5.1	1.3-5.2	1.0-1.6	—
Groups of conventional farms[c]					
3 groups (PA)[ii]	0.8-1.6	5.5-6.9	13.2-17.5	0.4[d]	0.14-0.29
3 groups (PA, WI)[iii]	—	2.7-4.9	8.3-9.8	0.3-0.6	—
Group with greatest marketed output (IL)[iii]	10.9	18.4	9.2	2.0	0.59

[a] Outputs from crops and animals.
[b] Inputs for crops, animals, and things used on the farm.
[c] The reported data are averages for individual groups, not unaveraged numbers for individual farms, and are given as ranges of averages. States are indicated in parentheses.
[d] The ratio was the same, by coincidence, for the three groups of farms defined by dairy herd size.

5) Implications of Sunshine Farm Energy Results
   a) The Energy Ratio for farming in the US (ratio of marketed outputs to purchased inputs) is around 1. Since typically half of the energy in the outputs is lost during conversion, farms are not now a source of net energy to the American Economy.
   b) For mixed farms or US agriculture to have some net output available as energy for society, the energy ratios must be raised. If the Energy Ratio were 4, then 50% conversion losses leaves 2 units of output for every one of input. If one of these is used internally by the farm, that leaves a surplus of 1 for export to society. **We are currently a long way from that.**
   c) **Two strategies for increasing Energy Ratio of US agriculture:** (1) reduce purchased inputs; and (2) increase marketed outputs. **(Powerpoint Slide of text below)**

Reduce Inputs By:	**Increase Marketed Outputs By:**
• Purchasing less fertilizer, pesticides • Changing crop mix • Adopting another mode of farming: e.g., organic, biodynamic • Letting animals graze or forage rather than feeding them machine harvested grain and hay • Suppling your own fuels and electricity	• Diverting cropland from animal feed to direct human consumption (each 1 lb of feed releases 5-10 lbs of food crops) • Increased crop yield may **not** be an option under a regime of lower commercial inputs • Substituting fuel crops for feed or food crops will **not** improve outputs, as each has similar yields under equivalent farming practices

d) How does the US fare compared to other countries? **(See Power Point Slide,** Table 2 from Bender) **.** (http://www.landinstitute.org/pages/EnergySSF_tables.pdf)

Table 2. National energy ratio of marketed outputs to purchased inputs for farming in the US and UK[1] and in other countries.

Country	Year(s)	Energy ratio
US	1940	2.3
	1970	0.9
	1974	1.0
UK	1950	0.4
	1972	0.3
Israel	1969-70	0.3
Netherlands	1964-65	0.5
France	1970	0.7
China	1978	1.2
New Zealand	1978-79	1.4
Egypt	1972-74	1.8
Pakistan	1977	2.9
Australia	1965-69	3.1[a]

[a] A ratio of 2.8 has also been calculated.[v]

e) Places like Pakistan in the above table rely less on machines, and have higher **energy ratios** than the U.S. Europe has much lower **energy ratios**, as much of the crop output is used to feed animals for meat, and therefore, much energy is lost in converting the grain to meat.

f) We Americans think that our highly productive agriculture puts us at the top of the pack. It is easy to confuse productivity with efficiency. They are not the same. Productivity is about yield per unit area or per person. Efficiency is about how much output you get for the inputs you supply. American agriculture is **highly productive**, in its destructive sort of way, **but it is highly inefficient.** It takes too many inputs to produce the output. (Dave Darlington, What is Efficient Agriculture? (http://www.veganorganic.net/agri.htm)

g) To get a sense of this, let us look at **Energy Ratios** for different kinds of agriculture (Darlington Notes Dave Darlington, What is Efficient Agriculture? http://www.veganorganic.net/agri.htm **(Power Point Slide**: below)

Farming regime	**Output/Input ratio**
Subsistence farming 2/	61-11
Shifting agriculture (slash & burn) 1/	28
New Guinea 2/	20
Congo 2/	65
Maize production in Guatemala (manual) 2/	14
Hunting and gathering 1/ 2/	4-4.5
Maize production Guatemala (oxen) 2/	4
Intensive wheat production in UK 2/	3.35
West as a whole (US,W.Europe, Israel, Japan, Australia, N. Zealand) 3/	< 2
UK potato production 2/	1.57
US rice production 2/	1.3
UK agriculture as a whole 2/	0.35
UK beef production 1/	0.08

Sources: 1/ Steinhart, J.S. and Steinhart, C.E., 1974, Energy history of the U.S. food system, Science, vol. 184.
2/ Leach, G., 1976, Energy and Food Production .
3/ Conforti P. and Giampietro, M., 1997, Fossil energy use in agriculture: an international comparison, Agriculture, Ecosystems and Environment vol.65.

6) Darlington quotes John Ikerd and his co-authors as saying **"much of...... our food supply problems could be solved by eating lower on the food chain"** (Ikerd , et al., 1996, Evaluating the sustainability of alternative farming systems: a case study, American Journal of Alternative Agriculture, vol. 11, 1)

7) What if we compare farms as producers of net energy with other modes of energy production? Let us look at the next table. This table reveals that over time, **energy ratios** are going down. This means that it takes more and more energy to get energy from some source. **(Power Point Slide**: Table 3 from Bender) (http://www.landinstitute.org/pages/EnergySSF_tables.pdf)

Table 3.
Energy Ratio of Output to Input for Various Energy Sources

Energy Source: ag crops in yellow, bolded ERs >4	**Energy Ratio**	
1. Nonrenewable Fossil Fuels		
Oil & natural gas (US wellhead)		
Discoveries – 1940s	> 100	
– 1970s	8	
Coal – 1950 US Mine	80	
– 1970 US Mine or strip	30	
2. Renewable Fuels		
Methanol (tree planatation)	2.6	<4
Biomass crop, then gasification	2-5	<4
Vegetable oil (precursor to biodiesel)	1.8-4.6	<4
Ethanol (grain, sugarcane, crop residues)	0.7-1.8	<4
Biomass herbaceous crops (fertilized)	**11-12**	**>4**
Biomass tree crops	**6-13**	**>4**
Anaerobic digester biogas (8 countries)	1.5-3.1	<4
Solar flat plate collectors (heat)	2-5	<4
3. Non-solar electricity production		
Coal-fired, US average	9	
Western surface coal fired, with scrubbers	2.5	
Natural gas fired	2.3	
Nuclear light water reactor	4	
4. Solar-related electricity production		
Photovoltaic arrays	1.7-10	
Parabolic thermal collectors	3-8	
Wind turbines	3-18	
Hydroelectric	10-12	
Biomass-fired (plus crop production)	3.3-3.7	<4
With advanced co-generation	**8-9**	**>4**
5. Energy Conservation		
Double-pane windows	136	
Ceiling insulation	61	
Passive solar housing	10-25	

<u>Case 3: Concept of Rate of Return on Investment and Payback: The Wind Machine Case Study</u>
Adapted from Dell Erickson III-A (Minnesota's Energy Future?, October 2003: (http://www.mnforsustain.org/erickson_dell_minnesotas_energy_future_part_IIIA.htm)

1) Let's take the example calculation for a small, farm-oriented wind machine of 20 kW capacity. **(Power Point Slide** using table below).
2) Details:
   a) Total installed cost is $45,000 with maintenance cost of $500/yr. Amortizing these costs over 20 years implies a fixed annual windpower expense of $2,250($45,000/20). Let us assume you have an annual maintenance cost of $500. PA has low wind regimes, so at 10 mph, the windmill will average roughly 20,000 kWh per year output (at 12 miles per hour, 32,500 kWh, and at 18 miles per hour, about 54,000 kWh per year).
   b) 20,000 kWh per year translates to 55 kwh/day, or 15 150 watt bulbs burning continuously. Not a lot. In a recent month, our household of 4 adults consumed 900 kwh, or 30 kwh/day. So, your wind machine would supply not quite enough power for two households like ours. If you know what your farm plus household consumes monthly, you can easily figure out what percentage of your total requirements this device would supply.
   c) Whenever you have excess power, you can sell back to the utility and forgo the cost of storage batteries. When you sell electricity back to the grid, you may get $0.10/kwh. Hmmm. Without batteries, It costs you $0.14 and you get 0.10 in return. This is like selling milk for less than it costs to produce it.
   d) In case you want storage batteries, add another cost of $2,000/year for 3 banks of deep cycle marine batteries with a discounted cost of $60 each and an overly favorable life of 5 years. That brings the cost of electricity up to ($2,750 + $2,000)/20,000 = $0.24/kwh.
   e) Keep in mind that with a load factor of 0.3, most of the time your wind machine is not turning sufficiently fast (or slow if a storm) to produce power. Therefore, 2/3rds of the time you will be discharging your batteries. Up to 15% of your total capacity will be required to feed storage. Thus, you must reduce your output of 20,000 kwh/yr by 3,000 kwh/yr. That increases your kwh cost to ($4,750)/17,000 = $0.28/kwh.

20 kw Wind Machine

COST FACTORS:	**DATA:**
Total wind machine cost:	$45,000
Annual capital cost for 20 year amortization period:	$2,250
Annual maintenance cost:	$500
Annual (wind) power production (PA)	20,000 kwh
Your cost of power	0.08/kwh
Price you get for selling power to utility	0.10/kwh
Annual **Rate of Return on Investment** = (annual income-annual costs)/annual capital cost = (20,000kwh x $0.08/kwh – $2,250-$500)/$2,250 = -$1,150/$2,250 = -51%	- 51%
Your **Payback** = Total Cost/(annual income-annual expenses) = $45,000/(20,000 kwh x $0.08/kwh – $500) = 40.9 yrs, > than the life of the wind machine!	40.9 yrs
Breakeven: power price you require to recover all your costs over the 20 year life of your wind machine: = ($45,000 + 20x$500)/(20,000kwh/yr x 20 yrs) = $0.14 (but the utility charges you only $0.08/kwh!)	$0.14
Kwh cost w. batteries: ($2,750 + $2,000)/20,000 kwh =	$0.24
Kwh cost w. batteries debited by recharge factor 15%: = $4,750/$17,000 kwh = $0.28/kwh	$0.28

3) **This is a simplified example.** For example, you may get tax breaks, be able to take accelerated depreciation. The point here is: do the math before you invest in alternative energy devices for your farm. They are less than promoters say they are. For example, we looked at a solar house project in Maine, touted by a famous solar designer. For the photovoltaic panel portion, I calculated that the rate of return on investment was -77% and the payback period was 111 years.

Case 4: A Closer Look at Ethanol

1) You may have heard something about the production of ethanol from corn. Ethanol fuels are available to motorists in Brazil and Iowa. Race car drivers use them. By another name, ethanol is corn likker, an old time value-added product.
2) It is Wes Jackson's contention that were it not for corn subsidies, farmers wouldn't be growing corn for ethanol. From Bender's table you will recall that he gives ethanol ERs ranging from 0.7 to 1.8. Nonetheless, I felt I should give it a closer look.
3) USDA has done a number of studies, largely it seems, in response to two studies done by David Pimental at Cornell University, who calculated that the **Net Energy** in producing ethanol was negative: -23,000 BTU's per gallon of ethanol for an **Energy Ratio of 0.82.** (1991 study, updated in 1996)
   a) (Bear in mind that a gallon of gasoline has a BTU of 116,000/gallon).
4) The USDA's studies showed ERs ranging from 1.24 to 1.67, with the latest 2005 study coming in at 1.34. **Picture grown men arguing over such precision.** Imagine you are in a rowboat out on the

ocean. Does it make sense to argue over whether the distance from gunwales to water is 1.24 inches vs. 1.34 inches?? **Also, recall Bender's assertion that we require ERs > 4 so that American agriculture produces an energy surplus.**
(For USDA articles, see http://www.ethanol-gec.org/corn_eth.htm July 1995; http://www.ethanol-gec.org/netenergy/NEYShapouri.htm ; http://www.eere.energy.gov/biomass/net_energy_balance.html)
For Pimentel's 1996 data, see: http://greatchange.org/bb-alcohol1.html .

5) Using cellulose rather than corn starch (corn stover rather than the ear), USDA claims that ethanol with an **Energy Ratio** of 2.62 can be produced. **Notice again, the ER < 4.** What USDA's claim fails to consider is that such corn cellulose is not waste, but should be returned to the field. Without such return, we are engaged in the irreversible mining of soil humus.
6) We must look at these studies carefully (hmmm – do we have time for this point? Skip to next point).
    a) For example, the USDA calculations decry Pimentel's use of low national averages for corn production, but then USDA uses high corn yields from **irrigated** lands. So, we're replacing the pumping of fossil oil with the pumping of fossil water. How is this sustainable?
    b) Ethanol enthusiasts assert that ethanol replaces imported oil with domestically produced ethanol, at a massive savings in military and other costs. All true of course. However, to say that every dollar spent on ethanol generates seven for the total economy is rather silly, because by their own argument, the vast military expenditures also adds to our GNP. Both arguments are perverse, and should not be the basis for a sane policy.
    c) Cannot claim the corn would be grown anyway. It is grown with subsidies. If it weren't subsidized, would it be grown? Subsidies distort production, and redistribute national wealth from mass transit to individual car use, which further aggravates suburban sprawl….
    d) Environmental damage due to Midwestern industrial corn production is substantial: soil loss, tons of insecticides and herbicides, nitrogen fertilizer runoff. Using USDA calculations, the net energy produced by 125 million acres (1/3 available crop land in US) comes to 1.2% of the per capita energy requirements, too small to justify allocation of 1/3 our cropland. (From Pimental inspired article: http://www.optimumpopulation.org/opt.af.ethanol.journal03apr.PDF)
    e) If consider contribution to **liquid fuels replacement**, 1/3rd of our cropland could supply 19% of gasoline requirements or 11% of all liquid fuels requirements for transport. However, as population is growing, this same amount of cropland would only supply the growth increment for 10 years (at a growth rate of 1.06%/yr – the actual average annual growth rate for the last 3 decades of the 20th century). (From same Pimental inspired article: http://www.optimumpopulation.org/opt.af.ethanol.journal03apr.PDF)
7) If the **Energy Ratio** claims of university researchers and USDA are problematic, you enter a veritable snakepit when you encounter **corporate** claims.
    a) For example, corporate interviewees on a Living on Earth article on NRP 12/11/05 www.loe.org claimed that 1 ton of straw → 300 l ethanol – but without saying how much energy was required to produce this.
    b) Even corporate claims for the cost of ethanol production run to $1.30/gal, twice the cost of gasoline. By 2020, the cost is projected to decrease to $0.80/gal. One source estimated an **Energy Ratio** of 3.1, still way below 4
    (Bill Yerkes http://sustainabilityzone.com/comments.php?load_this=44). Another site is: http://treehugger.com

c) Jeff Passmore, VP Iogen, claims his company uses a special enzyme (Trichoderma reesei) that not only breaks down cellulose to glucose but also frees up the lignin to power the process. Yields an 80% reduction in greenhouse emissions. (Iogen Corp, Canada http://www.iogen.ca) However, a Business Week article reported only modest reduction in emissions compared to gasoline. (Discrepancy may derive from comparing or confusing fossil CO_2 with recycled CO_2 from annual straw. Again, note the sloppiness in thinking.)
d) **I emailed Passmore** of Iogen to ask what their calculated **Energy Ratio** was; he had not replied.
e) **Another website claimed Iogen was using a genetically engineered yeast** to convert glucose AND xylose into ethanol. (They added three genes to plain old Saccharomyces yeast so that it can break down both sugars.) **This same site revealed that Purdue University** owns this technology and is leasing it to Iogen (http://www.running_on_alcohol.tripod.com).
f) **Thus, at the heart of a corporate process is a land-grant university trafficking in GMOs.**
g) An unrelated but somewhat parallel effort to produce a GMO yeast produced very high toxic levels of a mutagenic product, methyl glyoxal, with the potentially undesirable effect of getting loose into the food chain.

8) Are there any ethanol producing devices you can use on the farm?
   a) Homeland Fuels claims to have a refrigerator-sized device that can make biofuel @ $0.35/gal above the cost of the feedstock.
   b) Other firms: Wintersun, Advanced Diamond Energy, Helios, www.biofueloasis.com .
9) Where does all this controversy on ethanol leave the individual farmer?
   a) With the warning to sit down and do your own calculations and see what it costs, dollar-wise and energetically to produce ethanol fuel or biodiesel **on your farm**.
   b) With increasing energy prices, farmers will adjust their operations to use less energy and to recycle biomass on the farm – either into the soil, or via feed for animals. Hauling corn, soybeans, or other biomass for ethanol, methanol, biodiesel, or erecting windmills for export are all ill-advised practices. You're better off burning corn cobs in a cob stove than trucking it to a methane plant. **Or making ethanol the old fashioned way your grand-daddies did.**
   c) To quote David Pimentel, "*Ethanol does not provide energy security for the future. It is not a renewable energy source, is costly in terms of production and subsidies, and its production causes serious environmental degradation*."
   d) Dell Erickson made the following observation: "The best and possibly only sustainable policy is for farmers to plant reduced energy and water dependent locally adapted crop species. In some future season, today's removal of locally adapted genes by agricultural interests may be seen as an historic crime against Humanity." (Dell Erickson, Part IV, Real World Examples)

10) Let us now extend our scope to sources of biomass other than corn. (**Power Point** Slide from table below)

Energy Ratios for Different Alternative Fuels

Alternative Fuel Source	**Energy Ratios**
Ethanol: Pimentel 1/ …………………………….	**0.78-.82**
British study (wheat bioethanol) 2/	**1.11**
" + burning wheat straw 2/	1.34
USDA 3/ ………………………………	2.51
Switch grass: Pimentel 1/	0.69
Promoter 4/	4.4
Wood biomass: Pimentel 1/	0.64
Promoter 5/	11-16
Soybean biodiesel: Pimentel 1/	0.79
Sunflower biodiesel: Pimentel 1/	**0.46**
Rape seed oil: **British study** 2/	**1.78**
" + burning wheat straw 2/	3.71

Notes:
1/ http://www.futurepundit.com/archives/002881.html, http://greatchange.org/bb-alcohol1.html
2/ http://www.biodiesel.co.uk/levington.htm
3/ http://www.eere.energy.gov/biomass/net_energy_balance.html
4/ http://www.westbioenergy.org/july98/0798_01.htm
5/ http://www.esf.edu/willow/PDFs/multibene04.pdf

11) Why do the **British figures** differ so markedly from those of Pimentel? Let us look at the energy factors the British study considered and **those energy factors it omitted:** **(Power Point slide)**

Energy Factors Included in British Study

Crops	**--Relationship between yield and fertilizer N application.** **--Harvested yields and energy contents.** **--Loss of N following fertilizer application**
Field operations	**--Fuel energy employed** **--Fuel consumed** **--Emissions of NOx and CO2**
Fertilizers	**--Energy employed in mining of P & K in process-ing of N & P melts and in granulation of N & P.** **--Losses of N & P during manufacture**
Agrochemicals/fuels/seeds	**--Energy expended in their manufacture**
Distribution	**--Fuel energy employed in moving fertilizers agrochemicals and seeds from store to farm.** **--Fuel energy employed in moving harvested seed or grain from farm to processing site.** **--Fuel energy employed in moving straw from the farm.** **--Emissions of NOx and CO2 from diesel vehicles.**
Processing	**--Energy employed in processing rapeseed into biodiesel and of grain into ethanol**

12) The authors fully recognize what they are omitting, as the following quote reveals (bolding below is mine for emphasis!): **(Power Point slide)**

Quote from British Study

"The energy employed in farm machinery and buildings and in lorries used for transport is not considered as these items would be in-place already for other purposes**. Processes downstream to manufacture of biodiesel' & bioethanol are not considered** (e.g., fuel energy and infrastructure involved with transport and distribution of ethanol/biofuel [roads, trucks, truck fuel, stations]. **Emissions involved in the manufacture of agrochemicals and packaging and in the provision of seeds … are not considered.** These would be small relative to the main sources in vehicle operations and fertilizer manufacture"

(Unless you have done the calculations, how do you know?? From our CSA case study, the overlooked transportation component is the most energy-intensive one! Also, the study authors took an energy credit from the manufacturing of phosphate fertilizer from energy released as heat! But, this heat was not reclaimed within the technology used!)

13) We sum up with our conclusions on **Net Energy** Analysis: This material is broader than the topic of ethanol.

a) Indicators are abstract. Because we offload costs on the future and on the environment, the shoe doesn't really begin to pinch at ERs approaching 1 or less.

b) Second, when comparing energy alternatives with each other, we must keep in mind the insights of Howard Odum:
   i) Different kinds of energy cannot all be reduced to mere BTUs and toted up. You cannot easily or efficiently run your car on wood or solar. You can't fly a plane with coal nor run bulldozers or steel mills with windmills or pv panels. There are ways to adjust the energetic value of different sources to take this into account, but few analysts do this (eMergy and exergy analysis).
      (1) Unlike standard energy analysis, eMergy considers the free services of nature and the value of human inputs, rather than just energy used in economic inputs.
   ii) "H.T. Odum's calculations show that the only forms of alternative energy that (are renewable and) can survive the exhaustion of fossil fuel are muscle, burning biomass (wood, animal dung, or peat), hydroelectric, geothermal in volcanic areas, and some wind electrical generation. Nuclear power could be viable if one could overcome the shortage of fuel." (From http://dieoff.org/synopsis.htm)
   iii) In the absence of careful accounting, we must limit our use of **Energy Ratios to comparing alternatives within categories, simply because what we count as inputs and outputs differs from one application to another. Thus, we can compare Energy Ratios for farm production, Energy Ratios for oil production, but not ERs for farm production <u>with</u> ERs for oil production.**

c) Third, relaxation of rigor undermines an important principle: an energy source is sustainable only if it can recapitulate itself. That is, solar cells must be able to produce enough energy to make more solar cells to be considered sustainable as a source of energy.

d) Instead, the dominating criterion for moving ahead on ethanol, fuel cells, and many other alternatives is that **"we NEED them – cost be damned".**

e) However, this "cost be damned" mentality often ignores the cost to the environment. Here, the only solid indicator which measures the environmental impact of human activity, including alternative energies, is **Ecological Footprint Analysis**, which we will cover shortly.

<u>Case 5: Retrofitting Your House</u>

1) In the Sunshine Farm analysis, Marty Bender dealt only briefly with the **lifestyle** energy requirements of the American farm family. The range extends from the austere Amish to mainstream middle Americans. With this case study, we consider what **you** can do to reduce the energy requirements in your **own farmhouse, home or other heated buildings.**
2) Over the past 7 years, Tania and I have worked mightily to improve the energy efficiency of our older house. We have added more and better insulation to attics, installed internal foamboard shutters on large and north-facing windows, added two active hot water solar collectors, and considered other devices and steps we could take. We summarize our results in the following table: **(Power Point slide of Table below)**
3) Our overall strategy has been: **start with least expensive actions,** and move up the chain, considering cost-benefit/payback period as you go along.
4) Notice that the total savings of all our active steps to reduce fuel oil use have not approached the savings of that first step: reducing use through lowering our thermostat! And that first step cost us nothing.
5) We kept the costs down by doing a lot of the work ourselves.

6) Payback period is calculated by knowing (a) $ cost of retrofit and (b) estimated or measured savings of fuel oil per year as a result of doing that retrofit. Consider the example of foam board shutters placed on all large windows, especially on north & west sides of the house. We assume that fuel oil to heat the house is $1.39/gallon, so if we expect to save 25 gal/year (a reasonable estimate), then ($1.39/gal) x (25 gal/yr) = $34.75 savings per year. Divide the investment cost of $100 by the $34.75/year savings and you get the 2.9 year payback period.

House Retrofits in Lemont, PA

Strategy	Cost	Saving	Status	Payback
Reduce use: lower thermostat and wear warmer clothes indoors	$0	200 gals/yr	Done ('89)	0 yrs
Prevent Loss of Heat: (see Note 1)				
make foam board shutters ……………………	$100	25 gals/yr	Done ('00)	2.9 yrs
improve insulation in 2 attic areas ……………	$400	25 gals/yr	Done ('00)	11.5 yrs
improve insulation in 3rd attic ………………	$1,600	25 gals/yr	Done ('01)	46 yrs
replace old insulation in 3 living room walls with polyicynene foam ……………………	$7,600	75 gals/yr	Done ('01)	73 yrs
replace key windows (old Andersons) ……….	$6,000 est	? cf foam-board	On hold	
Increase solar insolation: (see Note 2)				
Install salvaged hot water collectors for domestic heat (winter) and summer hot water…	$2,100	38 gals/yr +$135 elec;	Done ('05)	10.9 yrs
Hot air collector for space heat (see Note 3) ….	$2,000-2,700	50-100 gal/yr	On hold	9.5-20 yrs

Table Notes:

1) Fuel oil for "Prevent Heat Loss" figured at $1.39/gal. As fuel oil prices increase, the payback period drops.
2) Fuel oil cost for "Increase Solar Insolation" was figured at $1.50/gal when analysis was done in 2003. By July 2005, when hot water collector was in service, fuel oil had risen to $2.10/gal.
3) Paybacks are sensitive to projected savings in energy. For paybacks greater than the 10 years we assumed, the rate of return on investment is negative, that is, that is, you cannot get your money back in savings sufficiently high to pay for the collector (and therefore its replacement) within the life of the collector.

Case 6: Ecological Footprint Case Study

1. Intro to concept

Reference: Mathis Wackernagel & William Rees, *Our Ecological Footprint*; Nicky Chambers, et.al., *Sharing Nature's Interest*; www.rprogress.org (Redefining Progress)

A very simple Ecological Footprinting calculator is included with this file (on CD or with your e-mail message) and runs in Microsoft Excel as a spreadsheet program. The existing "responses" to the questions in the program are the "average American" responses leading to the 25 acres/person average

American footprint listed at the bottom. Use the computer mouse to click on the "Answer" box to each question and then type in the letter corresponding to your own response. The footprint will total up your ecological footprint at the bottom, and by playing with the responses, you can get an idea about what things you could choose to do to lower your ecological footprint.

The Ecological Footprint is the **area of ecologically productive land** needed to provide **all of the resources consumed** and **to absorb all the wastes produced** **in the manufacturing of any product, in carrying out a given process or activity** (such as driving your car) **or**, when totaled up for all things we "require" to live, **to support your lifestyle**. Everything we "consume" as part of our lifestyle can be analyzed in terms of the amount of land needed to produce it and to absorb pollutants created as a result of it: computers, cell phones, French fries, cars, clothing, housing, heating, shampoo, etc.

The Ecological Footprint is useful because it includes embodied energy costs that are not included in other "sustainability metrics" as well as environmental costs of pollution. It is a conservative estimate – even when you use more detailed "calculators". Assumptions in the calculator discussed here include that all harvests are "sustainable" (which we know they are not!), that we only include basic services of nature (e.g. absorbing CO_2 – things generally easy to calculate); it doesn't double count land that provides two or more services; it assumes a simple taxonomy of eight ecosystem categories, and it is only beginning to include marine areas (the role of the ocean is complex).

How the Ecological Footprint is actually calculated for any item in a particular country, say, the U.S.:

A. Determine the trade-corrected consumption of that item = production + imports - exports e.g.: for wheat, or beef, or a computer, or a car. Let's take pounds of potatoes as an example.

B. Determine average annual productivity or yield of that item. This is easy to do for food crops: just use the USDA tables on average annual yield for the wheat or beef or whatever. It's trickier for something like a computer. For a computer you'd need to know the average annual productivity (how many computers did we make in the U.S. **and** how much land was required to provide the resources to construct the computer (including energy) and to absorb the wastes produced (toxic compounds, energy waste products, etc.). This value will be in some amount per acre. For potatoes, we'd have the average annual yield of potatoes in pounds per acre.

Divide A by B: (trade-corrected consumption in pounds) / (yield in pounds per acre). **This is the land area needed to produce the item in the U.S. to satisfy the U.S. population's consumption of it.** In the case of a potato, additional acreage would be required for potatoes grown industrially because of the ecological footprint contribution from the fertilizers, herbicide, pesticides, irrigation and so forth. Locally produced/consumed potatoes will require less footprint acreage than potatoes shipped from great distances.

Do this for **all the food items consumed by Americans and total up** to get an ecological food footprint. Divide by the U.S. population and you have the per capita ecological footprint for food.

Similarly **add up all other contributions** to our lifestyle: **our homes, our transportation** – these are major categories (see footprint calculator in spreadsheet program) to get the total per capita average American ecological footprint.

To get the total ecological footprint of the U.S. – the total acreage of land needed to support the average American lifestyle in the U.S. (resources consumed and wastes produced) – multiply again by the U.S. population. Compare the ecological footprint acreage with the total acreage available in the U.S.…

Sample Ecological Footprint Calculator Questions

- FOOD
  - Q1: Amount Animal-based Products Consumed:
  - Q2: Food (caloric) intake:
  - Q3: % Food Waste:
  - Q4: How Much Locally Grown Food Consumed:

- TRANSPORTATION
  - Q5: Miles driven by car per year:
  - Q6: Ride Sharing:
  - Q7: Fuel Efficiency [miles/gallon]:
  - Q8: Public Transportation [miles/week]:
  - Q9: Air Travel [hours of travel per year]:

- HOUSING
  - Q10: Number of people in home:
  - Q11: Square footage of home (add up all rooms):
  - Q12: “Green” electricity provider [y/n]?:
  - Q13: Est. how much you use energy-efficient lightbulbs or appliances:

Average American Footprint for FOOD=7.09 acres; for TRANSPORTATION=5.1 acres, for HOUSING=6.22 acres

Note the EMBODIED energy in many of these items + wastes produced whose noxious effects our ecosystem must mitigate (or absorb). For example, if you eat more animal-based products (which have higher embodied energy in them), your food footprint will increase. If you increase the amount of locally-grown, unprocessed, seasonal foods consumed while decreasing the amount of industrial food consumed, your food footprint will decrease.

2. Ecological Footprints: Comparison of Nations and Quality of Life

Per Capita Ecological Footprints of Nations			
Highest	**Medium High**	**Medium Low**	**Lowest**
U.S. 25 acres	Ireland: 13.8 acres	Israel: 8.6 acres	Nigeria: 2.5 acres
Australia: 23 acres	France: 13.1 acres	Malaysia: 7.9 acres	India: 2.5 acres
Canada: 17.8 acres	Iceland: 12.4 acres	Hungary: 7.7 acres	Pakistan: 2.2 acres
Singapore: 16.3 acres	Germany: 11.4	Argentina: 7.4 acres	Ethiopia: 1.7 acres
New Zealand: 16 acres	U.K., Switzerland: 11.4	S. Africa: 7.4 acres	Bangladesh: 1.5 acres

Factors that INCREASE Per Capita E.F.	Factors that DECREASE Per Capita E.F.
High energy consumption (esp. fossil fuels)	High population
Imports (embodied energy in transportation)	Low per capita energy consumption
Colder climates (need to heat & insulate buildings)	Warm/hot climates (no need for heat, insulation)
Automobile, air travel	Walking, public transportation, metro/railway
Waste and pollution	Recycling, re-use, pollution-eliminating methods...
Processed industrial foods	Local non-industrial, unprocessed food
Large single family houses with few occupants	Shared housing: apartments, extended family
Farming with machinery & petrol	Farming with hand tools and animal labor
High industrial meat & dairy diet	Vegetarian/vegan diets, esp. local organic

Here we note what factors lead to higher or lower ecological footprints. The total ecological footprint for a nation may be modest, but if the population is large, then the PER CAPITA ecological footprint may be low.

Students of Mathis Wackernagel experimented with attempting to live with as small a footprint as possible in Canada, succeeding in getting it to be under 5 acres per person. In doing so, they voluntarily got rid of a lot of "stuff" in their lives and found that they had a much higher "quality of life", eating healthier foods, getting healthy exercise as transportation, and having more time for quality human interactions, unencumbered by technology. Their efforts demonstrated that quality of life in our culture could, in fact, be enhanced by voluntarily decreasing our personal ecological footprint.

As many of the developing countries, including India and China, strive to attain a similar "quality of life" as that we currently enjoy in the U.S., which would likely come with its attendant waste, pollution and high demand for resources, we might ask what human population could earth "sustain" ecologically at the U.S. ecological footprint level.

In the year 2000, Wackernagel estimated that there were approximately 30 billion acres of ecologically productive land left in the world – a number that diminishes daily due to soil desertification, cutting down of rainforests, paving over and building. Just considering humans (not other species on the planet), 30 billion acres / (25 acres/person) = 1.2 billion people. The U.S. population is nearly 1/3 of a billion, so we're not hogging it all… yet. However, with nearly 6.5 billion people on the planet already, it is clear that not everyone will be able to attain our level of consumption and waste production and survive the ecological cataclysm that would likely result.

In fact, if you were to divide the available ecologically productive land equally among all 6.5 billion of us, and – to be "eco-minded", allocate 1/3 of the land to species other than humans – then you'd have: 20 billion acres of ecologically productive land / 6.5 billion people = 3 acres/person. Now compare that with the footprints of nations. At 3 acres/person, we'd be on par with where India, Nigeria, Indonesia, Peru, and China are (or were, as of 1995 data). What are the "quality of life" trade-offs required to live with an ecological footprint this small?

Between 2040 and 2050, world population is expected to reach 10 billion. Something to think about.

3. Applying Ecological Footprint locally

Do we have any reserve Natural Capital? Compare our physical footprint (available per capita area of land) with our average American ecological footprint of approx. 25 acres/person:

Average American Ecological Footprint	AVAILABLE LAND:	Per capita in U.S.	Per capita in Pennsylvania	Per capita in Centre County
N/A	Total land:	8.0 acres/person	2.3 acres	5.2 acres
Total: 25 acres	Eco-productive:	6.2 acres	2.0 acres	4.75 acres
Food: 7.09 acres	Agricultural:	3.1 / 1.5 acres	0.62 acres	0.8 acres
Transport: 5.10 acres				
Housing: 6.22 acres				
	Populations:	295,735,000	12,406,000	139,000

The reference table at the conclusion of this section provides the raw data, references and explanations for how the numbers in the tables above were found or calculated, including assumptions made.

Look at Centre County: 4.75 acres of ecologically productive land per person is physically available, but we require 25 acres/person to ecologically "sustain" us. It gets worse at the state level: less than 2.3 acres of ecologically productive land per person is physically available. What does this mean?

It means we are living well beyond our ecological limits. How is this possible?

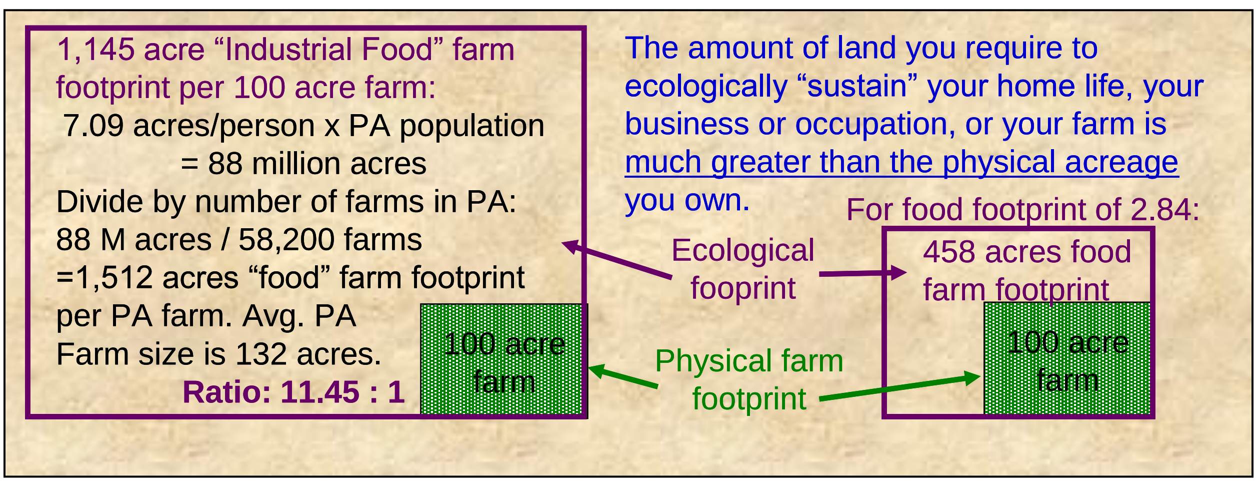
We are taking from other species, other countries, and future generations

Two values are listed for per capita agricultural land available in the U.S.: the first was taken by dividing the estimated acreage of U.S. agricultural land by the population, and the second was taken by dividing the acreage of arable land left in the U.S. by the population. I don't know how to account for this discrepancy except to guess that maybe grazing land – which is counted as agricultural - is not arable?? Pimentel and Younquist calculated that it takes 1.2 acres to 1.5 acres of arable land to feed the average American. If these numbers are correct, it suggests that we are close to or AT the limit of food self-sufficiency in the U.S. unless Americans shift to eating less meat. If we continue to draw down our fossil water aquifers and degrade our farmland, it will not be long before we no longer have the capacity to meet the food requirements of our own population. **It is difficult to "sense" this point because of the whole global food system that obfuscates food self-sufficiency limits of nations.** We export foods to other countries while importing other foods for ourselves.

[A recent newspaper article in our local Centre Daily Times spoke of "Avian flu" contamination concerns from butchering our livestock here in the U.S., shipping it to China for "processing" and then having them ship it back to the U.S. - how could we not also be alarmed at the absolute insanity of wasting our dwindling oil supplies to exploit cheap Chinese labor for food processing?]

If we compare our ecologically productive land available locally, statewide and overall in the U.S., we still come up far short of the 25 acres/person indicated is needed to provide the resources we consume and to absorb the subsequent wastes produced.   If we compare the physical per capita agricultural land available with the area of land required to satisfy our "food footprint" for the average American diet, it likewise comes up short. The ecological footprint of food is large because of the high use of energy in our industrial agriculture, but also because of energetic costs embodied in processed foods, transportation to markets, industrial meat production, etc. Thus, the farm is shadowed by this "industrial food farm footprint" that is much larger than the physical footprint of the farm, as it must include land from elsewhere to provide external inputs, other resources consumed and to absorb all wastes produced both on the farm and in the manufacturing of these external inputs and other resources consumed.

To get a sense of the magnitude of that "ecological footprint shadow" we do the following rough estimate: Pennsylvanians eating the average American diet require 7.09 acres/person x (PA's population) = 88 million acres to satisfy their ecological food footprint. There are 58,200 farms in PA of average physical size: 132 acres. However, the "industrial food footprint" size of these farms in PA would have to be (88 million acres) / 58,200 farms = 1,512 acres each to satisfy the "industrial food" farm footprint. This is a discrepancy of 1,512 acres/132 acres = a ratio of 11.45 to 1 in terms of "real land" needed to ecologically support the diet of Pennsylvanians.



Using this ratio, we see that per 100 acre farm, the "Industrial food footprint" shadow is 1,145 acres. Returning to the Ecological Footprint calculator, if Pennsylvanians made the following dietary changes:

- From (frequently eating animal-based products) to (infrequently eating them or being lacto-ovo vegetarian)
- From (about a quarter of food wasted) to (less than 5% food wasted)
- From (1/4 of food is locally grown, unprocessed, in-season) to (most food eaten is locally grown, unprocessed, in-season)

These changes would decrease the food footprint to 2.84 acres/person. The resulting "Industrial food footprint" shadow would then be 458 acres (using the same procedure as above).

IN GENERAL: The amount of land you require to ecologically "sustain" your home life, your business or occupation, or your farm is <u>much greater than the physical acreage</u> you own.

Reference Table: Data used to calculate per capita land use values and their sources			
Data	U.S.	Pennsylvania	Centre County
Population:	295,734,134 [1]	12,406,000 [2]	139,000 [3]
Total land:	2,378,036,156 acres [1]	28,684,800 acres [4]	709,486 acres [5]
Ag land:	907,000,000 acres [1]	7,700,000 acres [6]	109,851 acres [5]
Arable land:	454,918,316 acres [7]		
Developed land	107,300,000 acres [8]	4,302,720 acres [9]	51,501 acres [5]
Ecologically productive land	1,830,400,000 acres [8]	24,382,080 acres [10]	657,985 acres [10]
Forested land:	404,900,000 acres [11]	~15,000,000 acres [11]	514,429 acres [5]
	Per capita values are calculated by dividing the acres of land by the population		
	Per Capita	Per Capita	Per Capita
Total land:	8.0 acres/person	2.3 acres/person	5.2 acres/person
Eco-productive:	6.2 acres/person	2.0 acres/person	4.75 acres/person
Agricultural:	3.1 acres/person	0.62 acres/person	0.8 acres/person
Arable:	1.54 acres/person		
Forest land:	1.4 acres/person	1.2 acres/person	3.7 acres/person

References

1/ CIA website found via Google "United States population" – includes 50 states + D.C.
2/ I think that was from wikipedia on Pennsylvania website w/ 2004 estimate of population
3/ Susan Krosunger, Centre County Planning Office: rounded up from 2002 population of 138,599
4/ From Rand McNally Road Atlas, 1998: 44,820 sq. mi x 640 acres/sq. mi.
5/ Online Centre County Land use report 2002
6/ USDA National Ag Statistics Service, PA Office: PA Ag. Statistics 2004-2005, "Farm Numbers, Land In Farms & Average Size, 2004" table of all counties and total for PA
7/ CIA website reports 19.13% of U.S. land is arable – includes 50 states + D.C.
8/ "Total Surface Area by Land Use and Year" table from online 2002 Annual Nat'l Resources Inventory report at www.nrcs.usda.gov/technical/land/nri02/nri02lu.html; their reference surface area was 1,937.7 million acres for the contiguous U.S., which differed from the CIA statistics number. The ecologically productive acreage was therefore calculated by subtracting the developed acreage from 1,937.7 million acres to maintain internal consistency.
9/ Department of Environmental Protection online report "Indicator #4: Acres of land by use" on Statewide Land Use Patterns, based on the Governor's 21st Century Environment Commission recommendations which produced the "2000 Annual Report on Land Use" in January 2000. At that time, they stated "the state's share of developed land accounts for an above average 15% of its total land compared to 5% nationally." So I took 15% of the total acreage of PA to get the acres of developed land. Similarly, the Ecologically productive land area will be the balance: 85% of PA's total acres.

10/ These numbers can be calculated by subtracting the developed land from the total acreage of the state or county. While certainly there is a small ecological capacity for some developed areas – depending on the density of development – one could also say that the "undeveloped" regions are lacking full ecological capacity due to farming and other human intrusions, so it is assumed that there is error in either direction that would tend to cancel one another.
11/ Taken from refs. 8 and 9 above: ref. 8 lists 404.9 million acres of forested land, but they also list 401.9 million acres of "Federal land" with no further ecological breakdown of it, so it is a bit murky. Ref. 9 states "Forestland is the largest land cover in the state, accounting for slightly over half of Pennyslvania's 29 million acres compared to 21% nationally". Back to ref 8: if you divide 404.9 million acres by their reference acreage for the U.S. of 1,937.7 million acres, you get 20.9%, which agrees with what is reported in the DEP report of reference 9. Now it could be that DEP took its assessment from ref. 8 anyway, which does not include "Federal lands" in the forested land. Thus, the actual acreage of forested land may be greater than what is reported here.

<u>Observations:</u>

- At 4.75 acres/person in Centre County, we are at an ecological deficit relative to our Ecological Footprint (est. 20-25 acres/person). This means we are borrowing from other places around the globe and from future generations; it also can indicate that we are degrading the ecological systems that support us in the U.S.

- Expanding to the state level doesn't help. Not even excluding "developed land" that is not really ecologically productive, we're down to 2.3 acres/person.

- You can use the Ecological Footprint calculator and fiddle with your responses to the questions to see what could you PERSONALLY do to try to bring your own Ecological Footprint down to the level of the ACTUAL PHYSICAL per capita amount of land available to you in your county or state. This will give you a sense of the kinds of things we will need to address if we are to survive. Embodied energy in agriculture/food production, transportation and in heating/powering our homes are key contributors to our footprint.

- Ecological Footprints give us a sense of ecological limits. We have exceeded our ecological capacity in the U.S. Unfortunately, developing nations are eager to attain a similar level of consumption and quality of life that we enjoy. Therefore, a scramble to achieve this is already occurring, with some recognition that there are insufficient resources and energy to achieve it.

- Global limits can be grasped: in the year 2000, there was an estimated 30 billion acres of ecologically productive land left in the world. This number shrinks daily due to more "development" and land degradation (especially desertification and deforestation) around the globe. If EVERYONE were to enjoy a 25 acre/person footprint, then – looking only at the ecology needed to support the lifestyle of humans – Earth could "support": 30 billion acres / (25 acres/person) = 1.2 billion people. Clearly most of the 6.5 billion people here (heading for 10 billion by 2050 or so), will not be able to enjoy the same level of consumption we enjoy here in the U.S. prior to severe ecological consequences. Even at 20 acres/person, that's 1.5 billion people.

- One way to lower our ecological footprint is to reduce our dependence on oil and fossil fuels, and to significantly reduce the embodied energy in our ways of living. Peak oil estimates run from "we've peaked already" to ~2040 or so. We won't know until about a decade after the fact, at which point, the crises could be severe.

With Ecological Footprint reflecting not only our embodied energy in agriculture, but also our ecological impact, one can begin to identify useful directions for farming by combining this understanding with findings from our earlier energy analyses…

4. Summary of What We Learned From the Earlier Cases (Cases 1-5)

- Efficiency:
  - Growing vegetables in your own back yard using hand tools is the most energy efficient (subsistence); Coleman's 5-acre organic farming method delivered to local markets ran a distant second in our analysis
  - CSA's fared worst because of round trips of individuals to the farm to pick up their produce → in a world with less oil: could shares be delivered for in-town pickup?
- Net Energy/Energy Ratios (ER); Energy Return On Investment (EROI):
  - Sunshine Farm: Pastured animals on natural pastures is least energy
  - Horse wins out over biodiesel tractor in the long run: grows its replacement; broader band food base; **both** require ¼ farmland as "feed" to farm remaining ¾ of farmland.
  - Energy conservation has high ER and generally lower cost than most alternative energy options; Biofuels do not make sense energetically for export from farm.
- Payback (Rate of Return on Investment):
  - Payback on alt. energy devices may be longer than their life expectancy (we've looked at wind power, solar photovoltaics)
  - Robert Ayres & others: small-scale hydroelectric is "cheapest" - after conservation
- Underlying Assumptions in Energy Analysis:
  - Factors "assumed negligible" in energy analysis can turn out to be pivotal
- Cost/Savings Analysis of Retrofits:
  - Biggest ($, energy) savings comes from turning down thermostats, wearing thermals in winter (conservation, using less energy!)
  - Improved insulation in attic and on windows also affordable and energy efficient
  - Short of good passive solar design to start with: solar hot air/water heating
  - Regarding electric: how much do you really NEED?

I state this last question because, as oil prices increase, "alternative energy" options spring up like weeds, and "hype" about them abounds. When I ask students how they will live a more energy smart life in the future, they nearly always focus on solar cells and wind power. **Yet our analyses reveal that conservation measures are the single most energy efficient measures to take. Electricity generation is usually less important than heating and machinery powering.** In farming, there are similarly many things that one can do to shift from energy-intensive to low-input practices to diminish energy costs on the farm – so before laying out $38,000 to install a photovoltaic array or wind power generating tower, think of how else you could use that money to reduce or eliminate your dependence on oil or other fossil fuels for various stages or elements of your farming operation.

To place such options in the context of something "real" we next consider…

5. A Quick Look at Cuba: A First Look at Coping with "Life Without Oil"

- Cuba is included to use for comparison with PA in this case study since Cuba has had to face living without oil, and it is nearly identical in size to PA with nearly identical population size…. If THEY could do it, could we??? Our similarities end there, and we need to confront significant differences that would hopefully stimulate us to consider – well in advance of an oil crisis – how we might cope with such a situation.

	Centre County	Pennsylvania	Cuba*
Total land area	709,486 acres	28,684,800 acres	28,264,960 acres
Developed land	51,501 acres	4,302,720 acres	
Agricultural land	109, 851 acres	7,700,000 acres	
Forested land	514,429 acres	~15,000,000 acres	
Current population:	138,599 [2002]	12,406,000 [2004]	11,346,670 [2005]
Projected population:	177,850 [2030]		
Per capita area of land	5.1 acres/person	2.3 acres/person	2.5 acres/person
Per capita Ecologically productive area of land	4.75 acres/person (now) 3.7 acres/person (2030)	2.0 acres/person	?
Per capita Ag land	0.8 acres/person	0.62 acres/person	?
Climate factors:			
Average Summer Temp	77 degrees with heat waves in 90's		77 degrees F
Average Winter Temp	25 degrees with dips down to below zero		82 degrees F
Rainfall	40"		60"
Sunny days per year	120?		330
Winds	variable		Constant trade winds
Major City population:		Phila: 1.5 million	Havana: 2.3 million
		6.2 million metropolitan	

- **It is useful to compare our situation to Cuba**, since Cubans have had to deal with the consequences of a sudden lack of oil. Similar in size and population, Cuba has recovered from near starvation and has created an exemplary sustainable agricultural system to feed its people. Aside from climate differences, another key difference is that **PA is not an island**: we are surrounded by states whose per capita land area is even less than ours – NY, NJ, Delaware, MD, particularly. Other things to consider:
    - As oil prices escalate or oil becomes unavailable, production of food from the Midwest will likely be severely compromised: yields will decline; cost of food imported from those distances will be high

- The U.S. economy, which thrives on oil consumption in almost every aspect, will suffer greatly as oil becomes pricey and/or scarce. While some believe moving to the city to reduce commuter distance to work is "smart", what jobs will there be in the city, and who will feed all those people? Learn from Cuba, where many people had to then go into farming – urban farming [e.g. an 8-acre park "farmed" by 55 farmers whose income was 4x that of the average professional – at last! Farming is a valued profession!]
- Local food production of calorie crops will be essential to meet the food requirements of the high populations of the coastal states. Animal agriculture will be limited. Cuba as example: the most efficient dairy size was found to be 20 cows. Cubans eat rice as their main calorie crop. Rice is primarily grown industrially in Cuba with limited oil supplies.
- Translate to us in PA: Expect less meat and dairy; more legumes and varied grains (not as much wheat); different grains have different amino acid compositions, so with less meat and dairy, complete and balanced protein requirements could be met with a diversity of grains rather than just wheat [e.g. buckwheat + millet = complete protein combo]
- Because of heating requirements in winter, retrofitting NOW will be essential to surviving the changes to come… avg. American believes he/she can just burn wood for heat…but there are too many of us for that to work: the trees are needed to clean the air, compensate for our ecological deficit and the forests are key natural capital. [In PA: 1.2 acres/person forestland; in U.S., 1.4 acres/person forestland]
- A forest protection plan therefore, would be essential to consider well ahead of time – whether through education of people or other creative incentives.
- Food growing strategies: in Cuba, hand tools and oxen are used, primarily. We might take a similar cue.
- From our previous net energy ratio analysis, we learned that growing biofuels does not make sense except for use on the farm – and even then, according to the findings of the Sunshine Farm Research project, the horse wins out in the long run over the biodiesel tractor because (a) it can live on a broader band of vegetation (while the biodiesel tractor will starve if its monocrop expires in a drought) and (b) it grows its own replacement (apparently at lower embodied energy cost compared to manufacturing a new tractor).
- As the U.S. manufacturing base is just about non-existent at present (less than 4% of the U.S. economy is in manufacturing … all else is done overseas), we need to think and plan ahead to attain the kind of farming equipment we would require if we were to consider using animal power or plan to try to keep our tractors going for as long as possible. In Cuba: all farms are equipped with their own small machines shops to use to repair things, and they have stockpiles of old scrap metal to use as needed.

What other things might we consider implementing in the "much less oil available" scenario for PA?

- Adopting lowest embodied energy agricultural methods will be key:
    - Pastured animals, rotational grazing – for optimal health, consider Joel Salatin's integrated animal farming methods and lessons therein
    - No-till perennial polyculture for grain production: the work of Wes Jackson and the Land Institute has almost got a set of grains ready that would work in Kansas. We might consider similar research & development for applications in PA [can Rodale's help?]; otherwise, employ similar principles

- Winter food storage and production – something Cuba cannot help us with!
    - Eliot Coleman's simple 2-layer "winter harvest" method is low-cost option at present for growing fresh local cold-tolerant greens through winter in high tunnels or greenhouses; can be taken down in summer to save on lifetime of materials (don't subject them to the heat) and to expose soil to natural elements (to minimize buildup of pest problems).
    - Darrell Frey's Three Sisters Bioshelter in New Lebanon, PA combines a sturdy permanent greenhouse structure, insulated & reflective north wall, passive solar "thermal mass" to moderate temperatures in the greenhouse, compost bins to add heat during the winter months, and animal housing (BTUs of body heat + CO_2 exhaled by animals benefits the growing of plants in the winter greenhouse). Darrell houses chickens in his bioshelter; Anna Edey (see her book *Solviva*) included bedding areas for sheep, chickens and angora rabbits in her bioshelter (which ultimately fell apart because she constructed it with pine wood).
    - Energy and cost analysis of these winter-growing options would have to be done to determine whether they are appropriate for a given farm/farmer. There is plenty of room for further experimentation with winter-growing solutions along these lines. Maintenance & repair of such winter-growing facilities, including replacement materials, should also be considered in the analysis. If you are bedding animals on your farm anyway, you might consider integrating a winter greenhouse with the barn akin to bioshelter design to take advantage of BTUs of body heat from the animals.
    - Root cellaring, spring houses, and grain storage facilities – can we combine old fashioned know-how with present day innovations to improve these?
    - Refrigeration/freezing: Thermo-acoustic refrigerators (developed by Dr. Steve Garrett at the Applied Research Lab at Penn State) are in their infancy, but could be useful for cold storage in the heat of the summer because when you heat one end of the thermo-acoustic refrigerator, the other end gets cold! A very precisely made audio speaker acts as the heat exchanging mechanism, eliminating the need for a mechanical heat exchange system (no moving parts!) which lowers the operational energy costs of the device. For winter storage: could we cleverly take advantage of the cold outdoors?

6. Scenario for Future Farming in PA under conditions of diminishing availability of oil

First, it is worthwhile to note that the **Cubans** now regard their success at food-growing as their ultimate **national security**. They have successfully countered the mass misery our government expected would result from our oil embargo policies, and those surveyed by visitors to Cuba (including Lyn Garling from Penn State University and Brian Snyder, President of the PA Association for Sustainable Ag (PASA)), contend that even if the embargo is lifted, the Cubans will continue to farm with hand tools and oxen – will continue to ensure that they are never again in such a vulnerable position in which they would face mass starvation. **Their triumph has brought them international recognition as "exemplary in sustainable agriculture".**

Second, from teaching since 1998 and surveying students, plus inquiring of visitors to the Center for Sustainability, I feel I have grasped the thinking of the average American when faced with expensive and increasingly scarce oil:

- When "the crash" comes, we'll move to the woods, live in cabins, use woodstoves, and shoot deer for food
  - There goes the wood (shrinking resource) and our carbon sink (no more leaves on trees to absorb CO_2)
  - Too many people, not enough deer
- When we have to, we'll grow our food
  - On Chem-lawn poisoned lawns with no experience?
- Too busy to deal with it… "stuck" in everyday hassles, personal woes, financial struggles… assume government, technology will save us

Given these attitudes: what scenarios could unfold as we're faced with less oil production?
Given what we've learned from Energy Analyses and Ecological Footprinting, what are our best options & strategies to implement **now** for our "homeland security"?

I envision five key strategies:

1. Retrofit NOW and devise forest-protection strategies

- Invest in decent thermal clothing;
- Improve building insulation;
- Add passive solar thermal mass to buildings;
- Include animals for BTU's of body heat;
- Protect water pipes from freezing
- Remember: burning wood for heat or cooking cannot be a solution due to our ecological deficit, limited forest land (1.2 acres/person in PA), and recognizing from history that cutting down the forests leads to soil death and famine: changes the hydrologic cycle – therefore farming would also be lost, developing and implementing a forest-protection plan now would be very wise

2. Locally grow calorie crops, winter vegetables organically

- **Local farms**:
  - Transition to low-input organic [Rodale Research Center's focus];
  - *Focus on production of Calorie crops (grain)*;
  - Limited integrated animal agriculture (e.g. Joel Salatin);
  - Return to use of horses, oxen, mules; share machinery; re-tool now
  - Also, local production of fiber crops for cloth, string, etc.
- **CSA's**:
  - produce calorie crops (legumes, tubers (potatoes));
  - fruit, small animal ag (eggs, goat milk, etc.),
  - plus *veggies for the infirm and those without access to land* → deliver to town
- **CSA's and local farms**:
  - winter vegetable production in bioshelters, high tunnels, greenhouses
- **Food storage**
  - root cellars
  - granaries

- other improved local bulk food storage?
- Eventually… local meat butchers again??

3. *Use lowest-embodied energy practices*

- Pastured animals (rotational grazing; Salatin's rotations as example)
- Permaculture design principles [Bill Mollison]
- "Edible forest garden" forage crops [David Jacke's recommendations]
- No-till perennial polyculture grain production [Land Institute]
- Biodiversity restoration for forage crops on "Commons" and other available land – nuts, berries, fruit, medicinals, etc.- for humans and other animals

4. *Encourage backyard and community vegetable production*

- Note that vegetables are mostly water and require the most energy for transportation because they are heavy. Why waste energy moving around water when you can have it right at hand in your own backyard, closest to the point of consumption?
- All able-bodied persons or families who have access to land (front yards and backyards): **Suburban mini-farming** [www.GrowBiointensive.org] for vegetables, fruits, some seeds and nuts;
- *use hand tools*
- Some measure of backyard winter food production using Eliot Coleman's 2-layer winter harvest method + biointensive mini-farming practices. Even a single 5' x 25' bed for greens & root crops goes a long way to support two adults through most of the winter, relieving local farms and CSA's of the burden from trying to meet all of the winter food requirements locally (they will still have *plenty* to do to feed those who are not able-bodied and/or without access to land!)
- **Local community gardens** for veggie production + high-maintenance fruits – again, keeping the water-laden foods as close to the consumers as possible to allow larger scale farming operations (local farms and CSAs) to specialize in calorie crops and limited meat production. [Good examples from Havana in Cuba]
- **Local seed banks** (proper storage, etc.) – [Good examples from Havana, Cuba]

5. *Use "free energy" or most appropriate technologies*

- Reduce on-farm power requirements wherever possible:
  - Wind powered water pumps?
  - Energy efficient lighting, appliances, equipment
  - Consider solar food dehydrators, solar kilns, solar ovens, etc.
- Use the energy analysis tools presented to evaluate your options, as guide to reduce operational energy
- Innovate!

Minimizing embodied and operational energy in farming is not only smart, but might be essential in redefining what we mean by "sustainable agriculture" as we move into and beyond global peak oil production.

Overall, as Wes Jackson calls for: "More eyes on the land"

And so as we begin to move into an increasingly insecure future with regard to oil and energy, we understand that our very social fabric is intimately woven with our oil-dependence to such an extent, that all is poised to unravel ungracefully unless we take a very careful look at our options and make very careful decisions particularly with regard to energy and agriculture. Recognizing the insanity of our high-energy input agriculture and food system, decades ago Bill Mollison wisely observed:

"Without a permanent agriculture there is no possibility of a stable social order."
–Bill Mollison, *Permaculture*

References and for further reading

Lowest embodied energy agricultural practices:
How to Grow More Vegetables…., by John Jeavons [www.GrowBiointensive.org]
Permaculture: A Designer's Manual, by Bill Mollison
Edible Forest Garden, by David Jacke
Designing and Maintaining Your Edible Landscape, Naturally, by Robert Kourik
You Can Farm, by Joel Salatin
Eliot Coleman's books: *The New Organic Grower*, *Four Season Harvest*, *Winter Harvest Manual*
The Land Institute: www.LandInstitute.org
For Ecological Footprint research, updates, visit Redefining Progress: www.rprogress.org

Peak Oil: www.dieoff.org , Richard Heinberg's *The Party's Over* and *Power Down*; DVD documentary www.endofsuburbia.com and references therein

Population, Energy & Ag issues: articles posted at www.mnforsustain.org

Zero Point Energy: Lynne McTaggart's *The Field*; Tom Bearden's *Energy from the Vacuum*; Moray B. King's *Quest for Zero Point Energy*; Tom Valone's publications at www.IntegrityResearchInstitute.org .

Subtle Energy: Dr. John Hasted's *The Metal Benders*; Z. Lu's *Scientific QiGong Exploration*; 1st National Conference on Bigu (Penn State, June 2000); books by Dr. William Tiller, esp. *Science & Human Transformation*, Dr. Masaru Emoto's *Messages From Water*, Richard Gerber, M.D's *Vibrational Medicine*; George Kachadorian's *Divining Mom* video; Christopher Bird's *The Divining Hand*; Penn State U. research experiments with Ms. Sun Chu-Lin; publications by Larry Dossey, M.D.; *The Autobiography of a Yogi*; publications by Dr. Howard Hall on Sufi rapid wound healing; Proceedings from the Science of Whole Person Healing (www.wholepersonhealing.com) Conferences.

Subtle Energy Technologies: IRI publications by Tom Valone (see above); www.SE-5.com; Christopher Bird's *The Secret Life of Plants*; Rupert Sheldrake's books;

Four Forces: IRI publications by Tom Valone; "Gravity Lift" at www.cat.uk.org (Center for Alternative Technologies, Wales)

Importance of Forest Protection and Role of Trees: Thom Hartmann's *The Last Hours of Ancient Sunlight* – chapter on "The Death of Trees" plus passages on ancient Sumeria (*The Epic of Gilgamesh*), Mesopotamia, the Greeks & Romans; Clive Ponting's *A Green History of the World*, and Vernon Gill Carter and Tom Dale's book, *Topsoil and Civilization*, (1974); Derrick Jensen's *A Language Older Than Words* (select passages)