The Earth, Energy, and Agriculture

Tad W. Patzek
Department of Civil and Environmental Engineering
425 Davis Hall
University of California, Berkeley, CA 94720
Email: patzek@patzek.berkeley.edu

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> "In reading the history of nations, we find that, like individuals, they have their whims and their peculiarities; their seasons of excitement and recklessness, when they care not what they do. We find that whole communities suddenly fix their minds upon one object, and go in mad pursuit; that millions of people become simultaneously impressed with one delusion, and run after it, till their attention is caught by some new folly more captivating than the first." (Charles MacKay, *Memoirs of Extraordinary Popular Delusions*, 1841, Volume I, page 1.)

> "In order for us to maintain our way of living, we must, in a broad sense, tell lies to each other, and especially to ourselves. It is not necessary that the lies be particularly believable. The lies act as barriers to truth. These barriers to truth are necessary because without them many deplorable acts would become impossibilities. Truth must be at all costs avoided. When we do allow self-evident truths to percolate past our defenses and into our consciousness, they are treated like so many hand grenades rolling across the dance floor of an improbably macabre dance party. We try to stay out of harm's way, afraid that they will go off, shatter our delusions, and leave us exposed to what we have done to ourselves and to the world, expose us as the hollow people we have become. And so we avoid these truths, these self-evident truths, and continue the dance of world destruction." Derrick Jensen, *A Language Older Than Words*, Context Books, New York, 2000, Silencing, page 2.

1 Remedial Steps

Reflect. As a society, we are at the mercy of the Earth and her life-supporting systems. Our technological support systems are fragile, inefficient, often obsolete, and they use voraciously the fossil energy resources we do not have. We need to slow down and take stock of where we are vis-à-vis the current and emerging energy supply systems. This initial analysis will be our reference and a starting point for further deliberations.

We need to learn how to mimic natural systems in their ability to produce and conserve energy and recycle all wastes. In nature everything is connected; all parts of every system exert reciprocal controls onto one another (Lovelock, 1988). Nature is dynamic, but likes to operate in steady cycles.

Start Conserving Now. In view of the truly astronomical energy flows from the environment into our society, we need to make the simple adjustments first. Make all producers of durable goods responsible for recycling their products. Put a steep tax on all gas-guzzlers; require all car producers to offer cars with substantially better mileage; do not rely on hybrids only, the efficient diesel engine cars have made Europe much leaner than US; introduce incentives for all sorts of energy-efficient devices; increase energy efficiency standards for all new buildings; propose incentives for upgrading existing homes; steeply tax large low-occupancy houses; gradually remove all crop subsidies, while providing loan buffers to the farmers; encourage farmers to grow multi-specie balanced crops with much less fossil energy and sell their products locally; use some of the highway subsidies to develop functioning mass transit systems; encourage local production and local sales with less transportation and energy, encourage compact urban development; build more large apartment blocks; etc...

Look at Nuclear Energy. With all the talk about the new energy supply schemes, only nuclear reactors could improve our energy supply relatively quickly, in 5-15 years, without major greenhouse emissions. We need a *few* new strategically placed nuclear power stations to make our electrical grid more robust. The main weakness of nuclear technology, its concentrated and very dangerous waste that lasts practically forever, is at the same time its strength. This waste can be relatively easily stored for now and reprocessed later.

Look at Photovoltaic Cells. Photovoltaic cells transform solar energy into grid electricity with efficiency about 100–200 times greater than *all* biosystems (Patzek, 2004; Patzek and Pimentel, 2006). We need to learn how to mass-produce solar cells without major environmental disruptions. We then need to put them in places where they make most sense, and decentralize the electricity grid a little.

Look at Energy Systems Built on Photovoltaics. We need to develop energy storage systems that go with photovoltaic cells (Olah et al., 2006). One obvious choice is to use the free energy of electrons generated by photovoltaic cells to drive chemical reactions that will generate liquid fuels (e.g., methanol from the atmospheric or exhaust CO_2, methane, etc.)

Look at Nature. A living biosystem is open to fluxes of matter and energy, and is able to keep its organisms at constant composition and their physical states intact in a changing environment (Ulanowicz and Hannon, 1987; Schneider and Kay, 1994; Kondepudi and Prigogine, 1998; Tilman et al., 2001; Ho and Ulanowicz, 2005; Reich et al., 2006). A *sustainable* biosystem takes in high-grade free energy as sunlight, reduces its entropy by recycling almost all matter (one organism's waste and dead organic matter are another organism's food), and excretes low-grade energy as infrared radiation to space. It also exchanges chemical materials with the Earth's interior (Smil, 1985).

Understand Natural Systems. In order to estimate how much mass and energy we can extract from a natural system for *any* biotechnology, we need to quantify this system's *annual* net productivity. The dynamic reciprocal controls put most natural systems in steady oscillations and their net productivity is very close to zero. Examples are tropical forests, coral reefs, temperate climate forests, prairies, savannahs, etc. see **Figure 1**.

How Much Can We Extract, and At What Cost? We need to clearly establish that all major ecosystems are in steady oscillations (with very slow drifts), and that no advantage can be obtained from phase differences among their different parts. If so, then at the human time scale the rate of mass/energy extraction from all ecosystems is equal to the rate of their subsidy with external energy and chemicals. This finding will have *the* major impact on the investigations of *all* bio-based or ecosystem-mimicking supply energy schemes.

Is There Enough Water? Watersheds and aquifers oscillate about their slowly changing average conditions. Therefore, increased water extraction to drive land-based bioenergy systems will result in local water depletion which may or may not recover over our lifetimes. We need to understand the time constants of local water recovery given the increased demand and climate change.

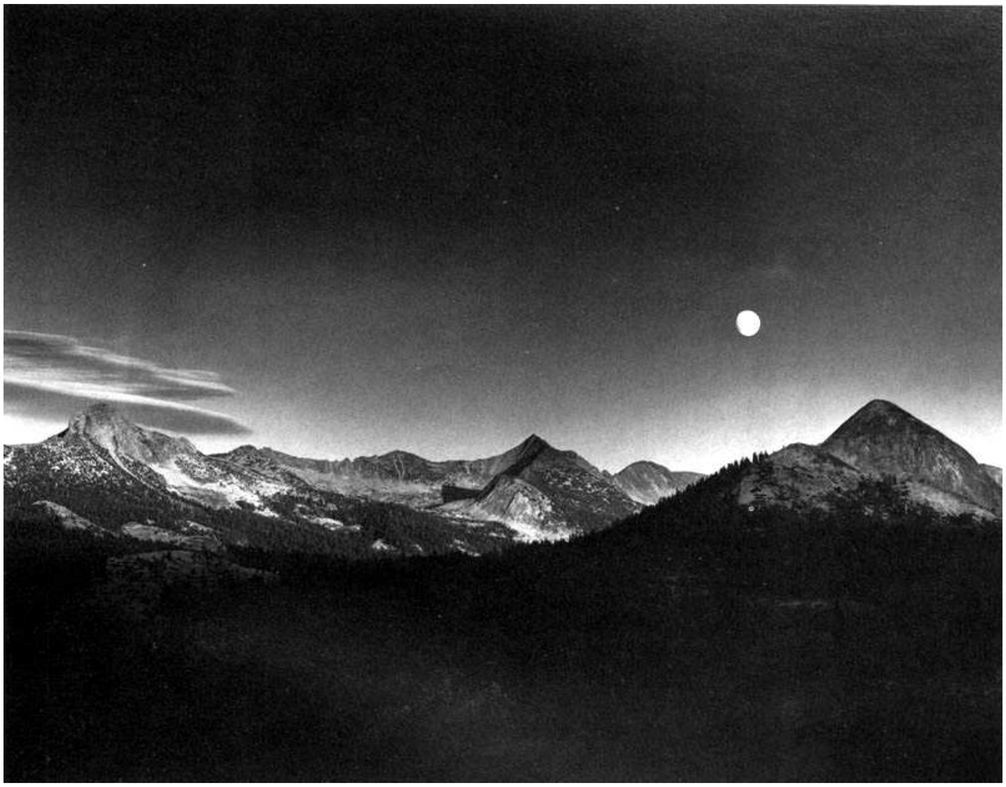

Figure 1: The moon rises over the Clark Mountain Range on Sept. 15, 1948, seen from Glacier Point in Yosemite National Park, Calif. Astronomers have pinned down the exact time and date when photographer Ansel Adams snapped his ethereal picture “Autumn Moon,” and determined that the sun, moon and mountains were to align in the same positions on Sept. 15 at 7:03 p.m. as they did 57 years ago when Adams photographed the scene. Photographed on September 15, 2005, the scene is identical, proving that the forest cover has not changed at all over the last 57 years. In other words, the net productivity of this ecosystem has been zero.

Add Energy Storage. All energy supply schemes require energy storage devices or systems. We need to work on them, see the **Energy Systems Built on Photovoltaics** bullet.

Proceed with Different Energy/Fuel Supply Schemes. Even if by the Second Law of thermodynamics all energy supply schemes are unsustainable, we still need to find those that are least unsustainable, i.e., least taxing on the environment in which they operate, and optimize their performance (Patzek, 2004).

Create Performance Evaluation Procedures. Create transparent, scientifically sound and generally accepted procedure of comparing all existing and future energy systems. These procedures do not exist yet in the US.

2 The Finite Earth

The earth and her crust are made of stellar matter, and the current abundance of each chemical element and its compounds (minerals, ores, etc.) results from chemical composition of that primordial matter and geologic evolution of the earth. The sun powers the earth; life has evolved her atmosphere, stabilized the climate, and made all fossil fuels, coal, crude oil, natural gas, gas hydrates, oil shale, etc. The deposition and transformation rates of these fossil fuels are *very* slow (Patzek and Pimentel, 2006). It is the unimaginable length of deposition time, measured in hundreds of *millions* of years, that accumulated large quantities of these fuels, see **Figure 2**. In a few *hundreds* of years, a geological blink of an eye, humans will practically exhaust the fossil fuels.

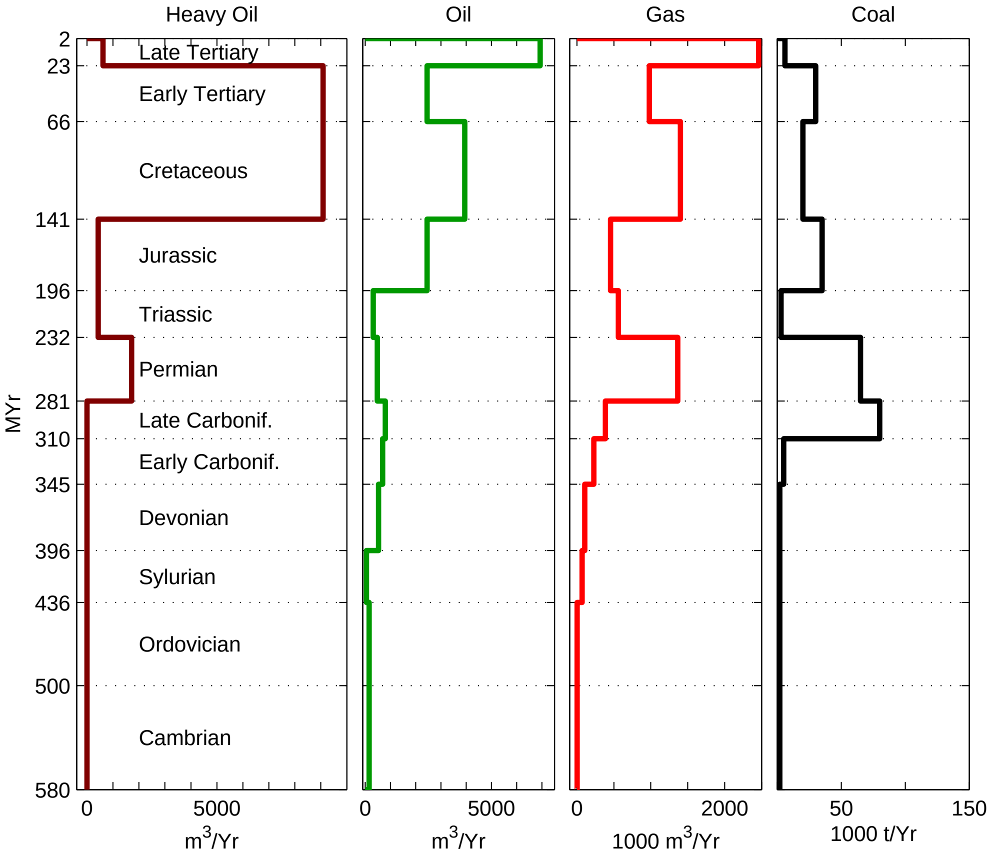

Figure 2: The average rates of accumulation of fossil fuels in the earth over geological time. The average rates of heavy oil deposition are from Demaison (1977). The average rates of oil and gas deposition are from Bois et al. (1982). The coal deposition rates are from Bestougeff (1980). Note the almost imperceptible global annual deposition rates of fossil fuels, and the unimaginably long duration of their deposition processes. These rates were scaled up by factors 3-8 to reflect the best current estimates of fossil fuel endowments: Heavy Oil = 12×10^{11} m^3, Oil = 8×10^{11} m^3, Gas = 3.5×10^{14} sm^3, Coal = 2×10^{13} tonnes.

All resources that feed our civilization: the highly concentrated or pure ("low-entropy") compounds (Georgescu-Roegen, 1971) – clean water, clean air, pure minerals, finished metals, high-quality fossil fuels, wood, uncontaminated food –, as well as the self-sustaining ecosystems that let us live by cleaning our waste, come from the earth's crust and the biosphere (Odum, 1998).

The limited high quality resources from the environment are the ultimate inputs to our civilization and economics (Daly, 1977). The low entropy embedded in these resources can only be used *once* (Georgescu-Roegen, 1971; Patzek, 2004).

Many American economists and politicians disregard this fundamental physical limitation of economy, and talk about the unfettered economic growth, unrestricted future payments for the Social Security, medical care, and military spending. This thinking was best captured by a Nobel Laureate economist Robert Solow: "... the world can, in effect, get along without natural resources ... at some finite cost, production can be freed of dependence on exhaustible resources altogether..." (his 1974 lecture to the American Economic Association).

The low environmental entropy exists in two forms: an accumulation or *stock* – as in a coal deposit – and *flow* – as in inflow of solar energy to the biosphere, and outflow of heat from the Earth to the Universe (Patzek, 2004) –, see **Figure 3**. The earth's stock is of two kinds: resources accumulated only on geological time scale (all the *nonrenewable* fossil fuels listed above), and resources accumulated on human time scale (the *renewable* biomass). The earth's nonrenewables are limited in the total amount available, just how a water bottle can only hold a certain amount of water. The earth's renewables are also limited in the total amount available and can be exhausted[1]. If exploited at a rate that can be sustained by nature, the renewable resources are *funds*, whose rates of return, crops, are very much limited by the rate of conversion of solar energy to biomass. Finally, the sun is a practically unlimited source of energy, but the rate of flow of solar energy is *low*.

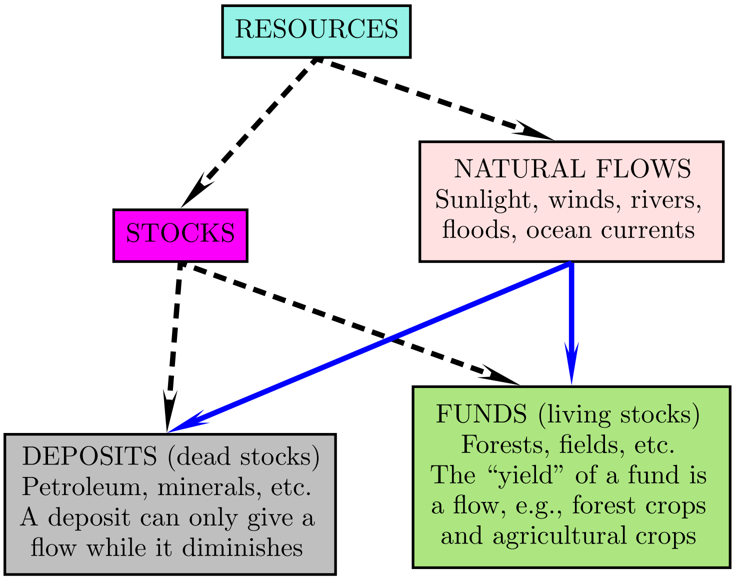

Figure 3: A physical resource classification.

All physical inputs into human economy are limited in size and/or rate.

Humans need air, water, food, and energy to survive. Clean air is an increasingly rare natural resource in industrialized nations[2]. Much of drinking water must now be manufactured in the energy-intensive chemical purification factories[3]. Uncontaminated food is increasingly more difficult to catch, even in seemingly pristine ecosystems[4]. Industrial agriculture and forestry for food and fuels are funded from massive fossil fuel subsidies and, in good part, groundwater mining. As such, they are unsustainable (Patzek, 2004; Patzek and Pimentel, 2006).

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[1] An old-growth forest can only be clear cut once in tens of human generations and is *de facto* a geological deposit of organic carbon.

[2] In recent decades, increased aerosol loadings (soot and other particles from burning coal, oil, wood, etc.) were at least partially responsible for the observed decreases in global radiation and direct radiation, the clearness index, and the monthly percentage of possible sunshine duration over much of China (Che et al., 2005).

[3] As of now, MTBE has been detected in 1861 water systems in 29 states, serving more than 45 million Americans. Per customer of United Water in Woodbury, Conn., it costs $500 in the first year and $125/yr thereafter to produce drinking water free of MTBE. A. Barrionuevo, *A Dirty Little Footnote to the Energy Bill*, NYT, 4/15/2005, pp. C1-C4.

[4] Health officials urged that children and women of child-bearing years avoid eating a half-dozen species of fish caught in the Adirondack and Catskill Mountain regions. The fish are feared to be contaminated with mercury. L. W. Fodebaro, *Caution Urged in Eating Fish from Mountains of New York*, NYT, 4/16/2005, p. A11.

As new energy resources are tapped[5] and substitute for the old ones[6], they remain subject to the same laws of physics, and are limited in total volume and rate of production.

If we bring more technology to produce these resources, their depletion will occur faster, and the environmental destruction their production and use bring about will be more severe.

So the question most relevant to energy supply for the living is as follows: *Not* can we produce more energy (we can), but what will be the consequences of doing so for the earth's life-support systems on which we depend for breathing, drinking, eating, and enjoyment of life? It appears that the U.S. and China[7], the largest consumers of energy and the environment on the earth, will have to answer this question first.

3 The Need for New Thinking

Each year for 20 years now, the United States of America has been using more fossil and nuclear energy than all its vegetation can produce (Good and Bell, 1980), see **Figure 4**. In addition to consuming 1/4 of world's energy with 1/22th of world's population, we are now producing far too little crude oil relative to our appetite, see **Figure 5**, and insufficient natural gas, see **Figure 6**. Therefore, our competitiveness will suffer severely in a global economy constrained by very expensive hydrocarbons. Creative ways of moving the U.S. economy towards conservation and efficient alternative energy sources must be found soon.

When searching for new sources of energy, it becomes obvious that we do not have a common language to talk about their relative merits and disadvantages. For example, it is very difficult to compare objectively ethanol from corn with gasoline from a tar sand, or with biodiesel from soybeans or palm seed oil. Today, it is almost impossible to meaningfully compare liquid fuels with photovoltaic cells, fuel cells, and other more exotic energy systems,

Since the United States must soon make epic choices for the future directions of its society and economy, it is imperative that these choices be based on a solid scientific foundation. When retooling much of our future economy, we want to preserve the environment and our quality of life, not endanger them by the hasty pursuit of poor energy technologies.

4 Industrial Agriculture

Background. Industrial agriculture in the US, or the agroindustrial-government complex, is the second largest user of fossil energy and the biggest source of distributed pollution of our environment. The largest user of energy is us, the American people, living in our appliance-filled, wired, heated and air-conditioned homes with poor insulation, and commuting long distances in inefficient cars. Out of the 11 kW used continuously by every man, woman, and child in the US, over 2 kW (20%) are used to produce crops, manufacture agricultural raw materials, reassemble these materials as industrial food (processed food products; assembly-line chicken, pigs and cattle), biofuels (ethanol and biodiesel), and to drive these products around and refrigerate most of them.

Commodity Crops. The vast monocultures of corn, soybeans, and wheat form a totally unsustainable scheme for laundering fossil fuels into industrial raw materials masquerading as food.

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[5] The new fossil fuel resources are tar sands, ultra heavy oil, oil shale, tight-rock gas, and coal-bed methane. The new biomass resources are wood, sugarcane stems and bagasse, corn grain and stover, soybeans, palm oil, rape seed oil, various plant and animal plants abbreviated as "waste," etc.

[6] The classical fossil fuels are coal, conventional crude oil, and conventional natural gas.

[7] China's wholesale destruction of its rich and diverse environment has more than offset its economic growth (Diamond, 2004), Chapter 12.

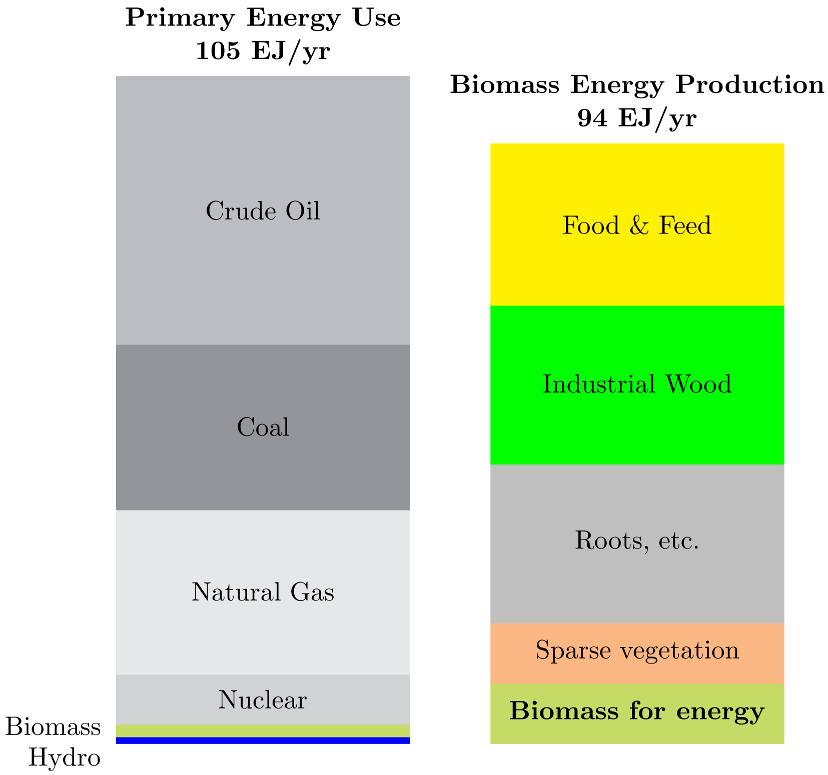

Figure 4: Annual fossil and nuclear energy consumption in the U.S. is now larger than *all* biomass yield over its territory. Sources: EIA; GOOD & BELL (1980); PATZEK, 2005 calculations. **Left:** Primary energy use in the U.S. in 2003, see **Table 1**. Biomass burning provided about 2 percent of primary energy supply. **Right:** A very optimistic estimate of annual biomass production over the entire U.S. area. This biomass production has been converted to equivalent energy. Over 3/4 of the biomass production is committed to food and animal feed, wood for paper, lumber and fiber, or is energy stored in plant roots and other inaccessible parts. This part of biomass production is *heavily subsidized* with fossil fuels. One half of the remainder is remote and sparse vegetation. The other half may serve as the source of bioenergy, but a large part of it will be used to produce biofuels. So the ultimate sustained biofuel production capacity in the U.S. may be 2-3 percent of the U.S. consumption *today*. We already are at this level. Current proposals to replace a good part of the fossil energy devoured each year by us with the biomass-derived fuels are pure fantasy. The only way to *increase* the biomass share of primary energy use in the U.S. is to *decrease* the fossil fuel consumption. To make U.S. competitive with the rest of the developed world, we should strive to decrease our fossil energy consumption by a factor of *two*, so that each American uses daily only 50 times more energy than we need as food to live.

The side-effects of this scheme are: the wholesale destruction of soil, rivers, groundwater, wetlands, and costal waters over at least 1/2 of the US area, and massive GHG emissions. The US population is significantly fattened and injured by the excessive supply of unhealthy industrial food, while subsidizing it from taxes and huge payments for medical care and environment remediation.

Crop Production. The modern agroindustrial-government complex has been created to produce gigantic quantities of industrial commodities, mostly corn, soybeans, and wheat, at rock bottom prices. These low prices benefit primarily ADM, Cargill, and Monsanto, and then General Mills, Kelogg, Tyson Foods, McDonalds, Coca-Cola, Nestlé, ConAgra Foods, Anhauser-Busch, and many others. The large agribusiness companies control most of the raw materials

Table 1: Annual use of energy in the U.S. in the year 2003. Sources: U.S. DOE Energy Information Administration, www.eia.doe.gov, Patzek CE24 Class Notes, Spring 2005

Source	Use EJ/year	Comments
Petroleum	41.8	Primary
Coal	26.1	Primary
Natural Gas	25.9	Primary
Nuclear	7.8	Primary
Biomass	2.0	Primary
Hydro	1.0	Primary
TOTAL	**104.6**	**Primary energy**
Food	1	Food products to live
Gasoline	18	All uses
Electricity	14	All sources
Nuclear	2.8	Electricity
Biomass	0.4[a]	Electricity
Wind	0.04[b]	Electricity
Photovoltaics	0.002[c]	Electricity

[a] The EIA data seem to be inconsistent. The summary statistics table lists biomass as the source of 3% (0.4 EJ/yr) of all electricity produced in the U.S. The detailed statistics list 37 and 22.9 billion kWh from wood and other biomass respectively (0.22 EJ/yr). The more optimistic estimate is used in the table

[b] The wind electricity was 10 260 150 000 kWh/year in 2002 or 0.04 EJ/yr according to www.mnforsustain.org/windpower_schleede_costs_of_electricity.htm, if the windmills operated with a 25% capacity factor (accessed March 5, 2005)

[c] The solar electricity was 0.003 EJ/yr in 2003 according to www.solarbuzz.com/StatsMarketShare.htm (accessed March 5, 2005)

and products, and make most profits. The current design of our food "system" dates back to 1973, when Nixon's secretary of agriculture Earl "Rusty" Butz dismantled the New Deal farm loans and introduced direct cash subsidies to farmers. The farmers are now rewarded for growing as much as the fertilizers and herbicides will yield, regardless of the price and environmental damage. The age of the cheap agroindustrial commodities, especially the #2 Yellow Corn, has arrived (Pollan, 2006).

Fossil Fuels. The National Corn Growers Association lobbies enthusiastically to produce more oil and gas from ANWAR, the outer continental shelf, and from every square mile of private and federal land in the middle 1/3 of the US. Their Congressional lobbyist, Ms. Theresa Schmalshof, has issued dire warnings about the future of industrial agriculture without cheap and abundant fossil fuels, and methane-derived nitrogen fertilizers (Patzek, 2006a).

Environment Damage. Industrial agriculture has a disproportionately large share of GHG emissions and water use (Patzek, 2006a; Patzek, 2006b). Agricultural emissions come from the soil erosion by wind and humus oxidation; ammonia, N_2O and NO_x emissions from nitrogen fertilizers in the fields and manufacturing facilities; fossil fuel emissions; and giant methane emissions from the tens of millions of cattle processing excess corn. Industrial agriculture in the US consumes over 85% of clean water and causes untold damage to water quality and public water supplies. Surface water and ground water are contaminated across most of the Mississippi River drainage basin, so is the Gulf of Mexico. Agricultural parts of the Central Valley in California are among the most polluted regions of the country.

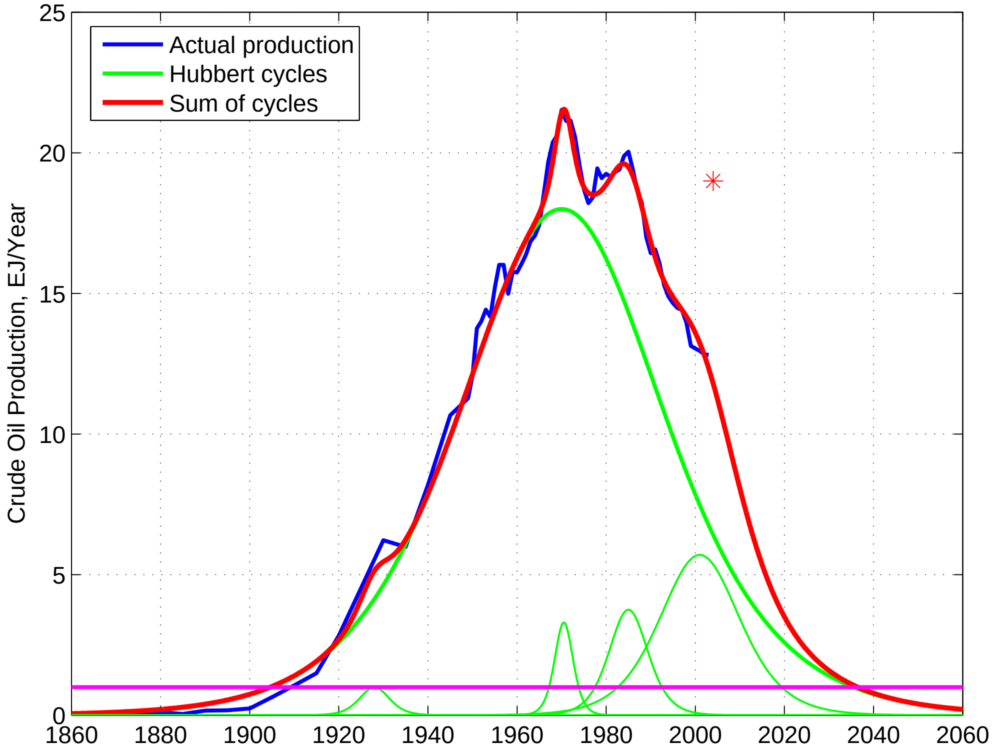

Figure 5: The HUBBERT cycle analysis of the U.S. crude oil endowment, Patzek's calculation. The total endowment is 230 billion barrels of oil, less than 1/2 of the U.S. Geological Survey's 1961 estimate of 590 billion barrels. The largest green cycle was predicted by M. KING HUBBERT in 1956. The small cycles describe oil production from waterflood, thermal EOR, Alaska, Austin Chalk, Gulf of Mexico,. . . , and the new drilling technologies. The area underneath the small cycles is 200 Exa Joules (1 EJ = 10^{18} J), equal to 2 years of primary energy consumption by the U.S. This has been the value of petroleum R&D. The magenta line at 1 EJ/yr is the amount of energy necessary to feed the U.S. population for one year. The star is the energy consumed as motor gasoline, 19 EJ/yr in 2004. Note that in 2004 the U.S. produced as much oil as in 1950, when President Truman was in the White House. Also note that the energy in just the motor gasoline consumed in 2004 was about ∼30% higher than the energy of all crude oil produced in the U.S.

5 Industrial Biofuels

Ethanol Production. Ethanol fuel from corn is the last stage of development of the agroindustrial-government complex (Patzek, 2004; Pollan, 2006). After saturating all other markets (animal feed, processed foods, and exports), we now also feed our cars with corn. When I say that at least six gallons of ethanol are required to replace the energy in one gallon of gasoline, many people shake their heads (Patzek, 2004; Patzek, 2006b; Patzek, 2006c). When ethanol supporters claim that the positive net energy ratio of the corn-ethanol cycle is 1.34, many people nod their heads (Wang, 2001; Shapouri et al., 2002; Shapouri et al., 2003; Shapouri and McAloon, 2004; Farrell et al., 2006a; Farrell et al., 2006b). The ratio of 1.34 means that 4 gallons of ethanol are required to produce 1 gallon of ethanol fuel. Since this gallon of ethanol has only 64% of the energy in 1 gallon of gasoline, it turns out that to displace one gallon of gasoline, one needs 6 gallons of ethanol (Patzek, 2006c). The acclaimed energy ratio of 1.34 has been obtained after much circular thinking and can be easily debunked, see (Patzek, 2004; Patzek, 2006b). In reality, this ratio hovers near 1.00.

Corn and Ethanol Price. As of May 15, 2006, the average wholesale price of ethanol was $2.94.

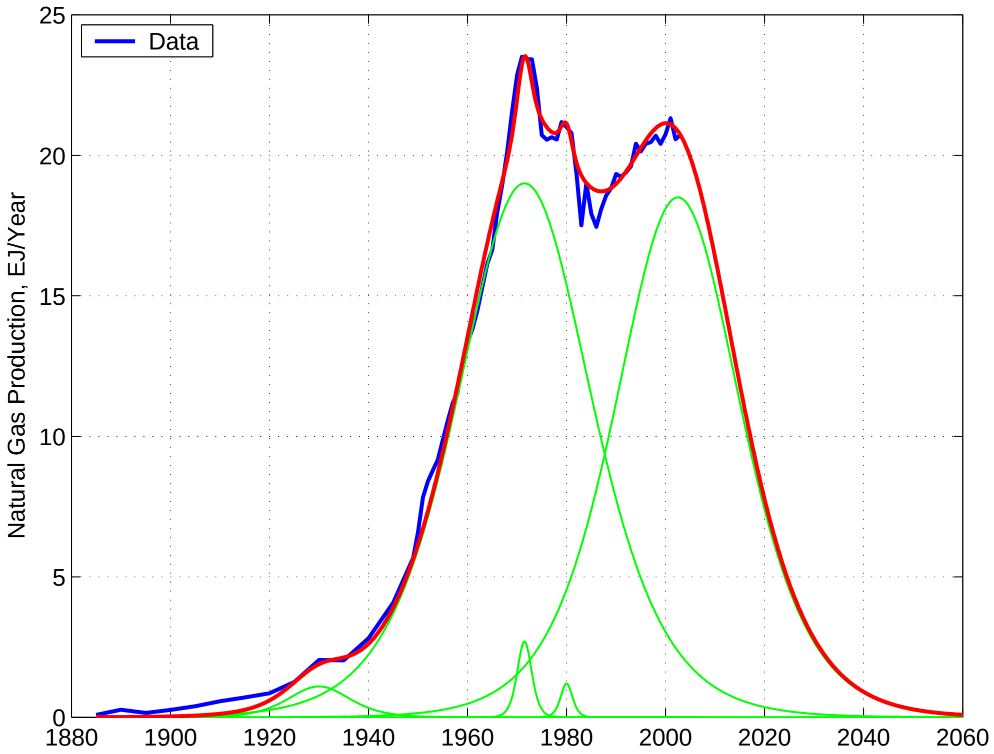

Figure 6: The Hubbert cycle analysis of the U.S. natural gas endowment, Patzek's calculation. There are two main cycles. The original Hubbert cycle for conventional natural gas peaked in 1973. The second comparable cycle, mostly from the Gulf of Mexico gas fields and unconventional gas fields, saw the peak drilling activity in 1981. Note that the domestic production rate of natural gas will be declining soon at 15-20% per year. The gas produced from the second main Hubbert cycle will be exhausted in the next 20 years.

The ethanol subsidies were 90 cents/gallon of ethanol: 51 cents in VEETC, 6 cents in small ethanol producers tax credit, 18 cents in corn-for-ethanol subsidies, and about 15 cents in state/local subsidies. So, to the US taxpayers, the average wholesale price of ethanol was \$3.84/gal. The energy-equivalent price of this ethanol was \$5.84 per energy in one gallon of gasoline. On May 15, 2006, premium gasoline retailed for \$3.26 on the average (Patzek, 2006c). I have not counted yet the 9-30 billion dollars per year in indirect subsidies to repair the fields, rivers, lakes, public water supplies, and the untold billions of dollars we all pay for the industrial agriculture-related health problems. For example, each year tens of pounds of high fructose corn syrup are consumed by a statistical American, helping to cause Type 2 diabetes in some 20 million people. The price tag for disposing of industrial corn this way is about \$135 billions/year.

Ethanol and Reduction of CO_2 Emissions. The GHG emissions from the corn-ethanol cycle are between 1.5-2 times higher than those from gasoline charged with extra emissions for its production (Patzek, 2004; Patzek, 2006b). Prof. Jacobson at Stanford has just completed (Jacobson, 2006) a thorough study of ethanol emissions and its health effects, and concluded that E85 fuel will increase atmospheric levels of ozone and PAN, leading indicators of photochemical smog, in the Los Angeles basin, the most polluted airshed in the US. E85 will increase two major carcinogens, acetaldehyde and formaldehyde while slightly reducing another, butadiene, and reducing a fourth, benzene. E85 vehicles are at best an equal and at worst a greater risk to public health than equivalent gasoline vehicles. E85 will continue to contribute to the thousands of cases of premature mortality and millions of cases of asthma and respiratory disease in the U.S. that gasoline and diesel vehicles currently cause.

Brazil and Biofuels. In 2005, Brazil used 6 billion gallons of gasoline and the US used 140 billion gallons of gasoline. The population of Brazil is about 185 million people and the US population is about 300 million people. If an average US driver drives once every two weeks, he/she will become an average Brazilian driver. When this happens, we can talk about replacing a fair portion of gasoline with biofuels. Recently, the average gasoline price in Brazil was close \$4.50 per gallon. In 1975, 89% of agricultural output in Brazil was paid for with agricultural subsidies. Today, I am told, these subsidies are less. While aggressively expanding sugarcane plantations in the Cerrado, Brazil is displacing other crops, e.g., soybeans, into the Amazon Forest, which is being cut and burned at an undiminished rate. The biodiversity hotspots in the Cerrado region have been reduced to 1/5 of their original size, and pollution is rampant. Whole sugarcane plants are used to produce ethanol and no biomass is recycled back to the plantations (Patzek and Pimentel, 2006). There are few environmental controls of effluents from the sugarcane ethanol plants and the incredibly polluting vinasse, whose volume is up to 15 times that of ethanol, is allowed to damage the environment.

The Tropics. The ultimate development of industrial crops for energy must occur in the tropics, because that is where most of solar energy and plentiful water supplies are (Patzek and Pimentel, 2006). Massive plantations in Brazil, Indonesia, Malaysia, Myanmar, Columbia, equatorial Africa, etc. are being developed in places now covered with virgin tropical forest. There are UN plans to develop some 380 million hectares (twice all arable land area in the US) of these new plantations. Carbon dioxide releases from the burned forest and oxidized peat will dwarf emissions from agriculture in the developed countries, the pristine tropical waters will be polluted with eroded soil and chemicals, and the global climate will be changed in many catastrophic ways.

Other Impacts of Industrial Agriculture. The cheap highly-subsidized commodities, mostly corn, are being exported to the developing countries, and have damaged their subsistence agriculture. The emptying villages in Mexico and Central America add to the masses of desperate people who enter the US illegally. The common starvation episodes in Africa have the same root cause. The only cash crops that can compete with our agribusiness are coca plants and opium poppies. The costs of border protection and the war on drugs easily exceed \$100 billion per year.

6 Closing Remarks

Propaganda and Hysteria. We need to understand that there are many economic and political interests at the heart of the biofuel industry that are abusing our valid concerns about the state of the environment and the health and happiness of our communities. We must not fall into the trap of believing that the solutions to our major problems will come as an easy fix-it scheme. We can only solve our societal ailments by changing the way we live our lives, and this is a multidimensional pursuit.

Better Solutions. To avoid worsening the already terrible reliance of US on foreign oil and natural gas, we must cut down our primary energy consumption by a factor of 2 for starters and then by another factor of 2. Since transportation consumes about 2/3 of the 21 million barrels of crude oil we devour every day, doubling the car mileage, using more freight trains, mass transit, and more efficient planes will save at least 7 million barrels of crude oil per day. This solution is perfectly doable in 20 years, without ravaging the US economy and environment with excessive biofuel production and the silly hydrogen car. The federal government has just announced plans to cut 5 million barrels of oil/day in 20 years by replacing them with other biofuels, but without boosting the fuel mileage requirements of the US vehicle fleet.

This plan will be a disaster for the US economy, and it will not save the ailing GM and Ford companies.

Future Guidelines. I propose to create The Berkeley Institute of Energy Systems (BIES), whose mission will be to create a consistent framework for thinking about all energy resources for humanity, use this framework to rank most classical choices of energy supply, and propose several new ones. This comprehensive approach will fully integrate the life-supporting earth systems with the economic considerations.

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