Bioenergy in the USA – Success with Decentralized Bioenergy Utilization

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Introduction

To what extent can expansion of domestic bioenergy utilization improve energy and economic security in the United States? Deciding how to best increase bioenergy production and use in the U.S. is not as simple as focusing on the growth of a particular market sector or the development of a promising new technology. Understanding how to foster appropriate growth in U.S. bioenergy production and use requires a thorough understanding of both the fossil-energy supply problem and the hardships it creates. Only then can projects be developed that make optimal use of bioenergy's ability to mitigate these hardships. Fortunately, this is understood to some extent at the United States Department of Agriculture, which funded this paper and the bioenergy projects on which it is based.

This paper takes a detailed look at the U.S. energy problem, assesses the current state of its bioenergy development and the potential for expansion, and proposes several criteria for evaluating future bioenergy projects to ensure that they directly address America's core energy problem and its consequences.

The U.S. Energy Problem

The U.S. is facing a critical energy problem characterized by rising energy prices, declining productive capacities for oil and gas, increasing reliance on foreign oil, and the weakening of its currency. The root of this problem is the inexorable decline of its two most important energy sources – petroleum, which accounts for nearly 40 percent of total energy consumption and 96 percent of transportation energy [6], and natural gas, which provides for 23 percent of all energy consumed in the U.S. See Table 1 and Figure 1.

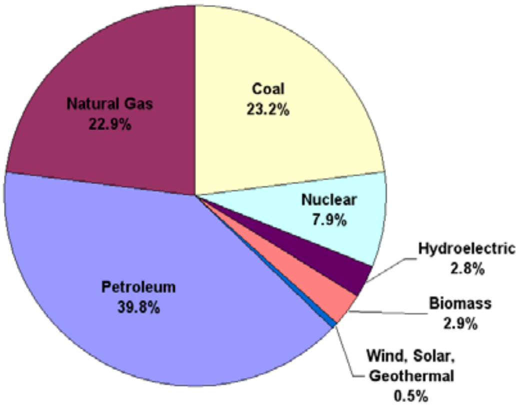
The decline of the energy resources on which the U.S. is currently so heavily dependent is presented here in some detail because it serves as a basis from which to discuss and evaluate bioenergy development and its potential to alleviate the problem.

Table 1: U.S. Energy Consumption 2003

Source	Million MWH
Petroleum	11,449
Natural Gas	6,590
Coal	6,672
Nuclear	2,284
Hydroelectric	814
Biomass	839
Wind, Solar, Geothermal	142
Total Consumption:	**28,790**

Source: U.S. Energy Information Administration

Figure 1: U.S. Energy Consumption 2003



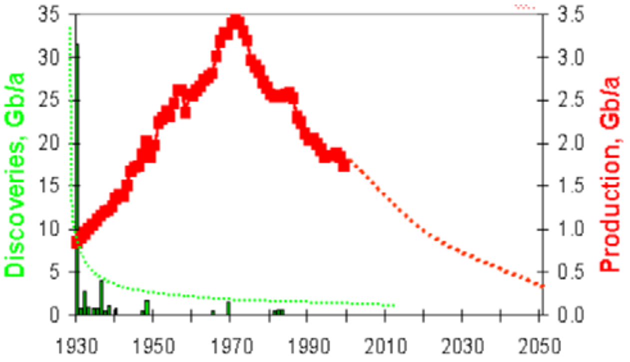
Petroleum Decline

U.S. oil production peaked at about 11.6 million barrels per day (million bbl/d) in 1970 and has since declined to its present level of 7.5 million bbl/d. [1]. The steady decline is not for lack of trying: the 165 active oil-drilling rigs in the U.S. brought 5,694 new wells on line in 2003, adding to the more than 500,000 wells already producing [2]. In comparison, Saudi Arabia produces 9.8 million bbl/d from 1,560 active wells [1,3]. Oil consumption in the U.S. has meanwhile increased from 14.7 million bbl/d in 1970 to the current level of 20.0 million bbl/d [1]. The net result is that 62 percent of all oil demand is now met with imports. Petroleum decline for the continental U.S. is shown in Figure 2.

Natural Gas Decline

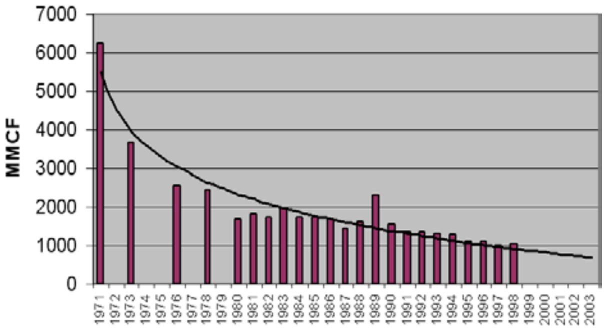
Annual natural gas production in the U.S. peaked at 21.6 trillion cubic feet (tcf, 624 Billion cubic meters) in 1971, and has since declined to its current level of 19.1 tcf (550 billion cubic meters, bcm) in 2003. Consumption stands at 22.2 tcf (629.8 bcm). Imports, mainly from Canada, comprise about 17% of consumption [1]. The steady decline once again is not for lack of effort: The natural gas industry drilled an estimated 20,011 wells in 2003, but no increase in production resulted [2]. The drilling required deployment of more than 1000 drilling rigs, whereas in 1995 only about 400 rigs were needed to maintain the same production level [4]. Declining productivity in Texas gas wells, dominated by the decline of the important Texas Gulf region, is shown in Figure 3.

Figure 2. Oil Discovery and Production in the Continental (lower-48) United States



Source: Colin Campbell, Association for the Study of Peak Oil
Note: Excludes heavy, deepwater, polar, and natural gas liquids.

Figure 3: Average Projected Ultimate Recovery from a Texas Gas Well, by Year Drilled



Source: Gary S. Swindell and Associates

Understanding the Implications of Oil and Gas Decline

The depth of the problem that results from the decline of fossil-energy resources can be understood on the three levels detailed below. Each higher-order understanding eliminates more misconceptions about the problem, especially regarding the substitutability of energy resources and overestimation of the potential of new technologies.

First-Order Understanding: The quantity of the resources is finite. This premise – that the fossil-energy endowment is limited – is widely accepted based on the nearly uniform concurrence that the earth's fossil-energy resources were formed in the geologic past and are not being renewed, at least not within a time frame that is useful to us. One contrasting theory suggests that petroleum is still being produced in large quantities by chemical reactions within the earth's mantle, but overall the premise that the geology is well understood and that fossil-energy resources are finite is widely accepted. Failure to move from here to higher-order levels of understanding leads to incorrect conclusions regarding the energy problem, most notably the belief that the problem manifests only after all of the oil has been consumed.

Second-Order Understanding: The production rate of the resources has a maximum. This premise is actually nothing more than a logical extension of the first, but its acceptance is nonetheless limited, and its consequences are not widely understood. Further, calculating where we are relative to this maximum requires an understanding of energy resource *quality*, which shows that the amount of effort required to extract and process a resource increases over time as the easier-to-extract (higher quality) resources, such as onshore gusher wells, become depleted and we turn to ever harder to get (lower quality) resources (i.e. ones that are distant, in deep water, or not as "sweet"). Organizations studying energy from both a quantity and quality perspective, including the Association for the Study of Peak Oil and Gas (ASPO), understand that world petroleum production levels are at, or very near, their peak.

Third-Order Understanding: Declining energy-resource quality leads to destabilization. This is the least accepted level of the energy problem because, in addition to second-order comprehension, it requires an understanding of thermodynamics, economics, and the relationship between the two. The comprehension of thermodynamics is needed primarily to appreciate the importance of life-cycle analyses of energy processes, which characterize the degree to which energy extraction and production methods yield net-excess energy. Economics tells us that healthy economies are fundamental prerequisites for maintaining social and geopolitical stability. The interrelationship of thermodynamics and economics is, first and foremost, that energy is the fundamental building block of the economy, without which there can be no goods or services; second, that the energy that runs the economy is the net-excess energy produced by a supply technology; and third, that chemical and physical differences in energy resources and the fuels produced from them dictate that not every unit of energy is capable of producing the same amount of economic activity.

An important component of the third-order understanding is the recognition that energy resources and technologies are not economically interchangeable. The amount of economic activity that can be produced depends on both the amount and the type of excess energy produced. The misguided faith in substitutability is likely the result of undergoing so many past substitutions, each one bringing new energy resources and technologies into use. But the substitutions of the past – from solid fuels such as biomass and coal to liquid and gaseous petroleum and natural gas – have always been from lower-quality resources and source technologies to higher-quality ones. Each change brought economic advantages that enabled growth.

Petroleum spawned unprecedented world-economic growth because the net excess energy (also called the energy profit ratio or energy return-on-investment) of the exploration, extraction, refining, and transport process was enormous, and because the energy could be delivered in a highly useful form – an energy-dense liquid. The hypothesis that our current economic level, built and powered by the highest quality fuels known, can be maintained as these resources decline, may not be grounded in sound scientific and economic principles.

The Onset of Destabilization

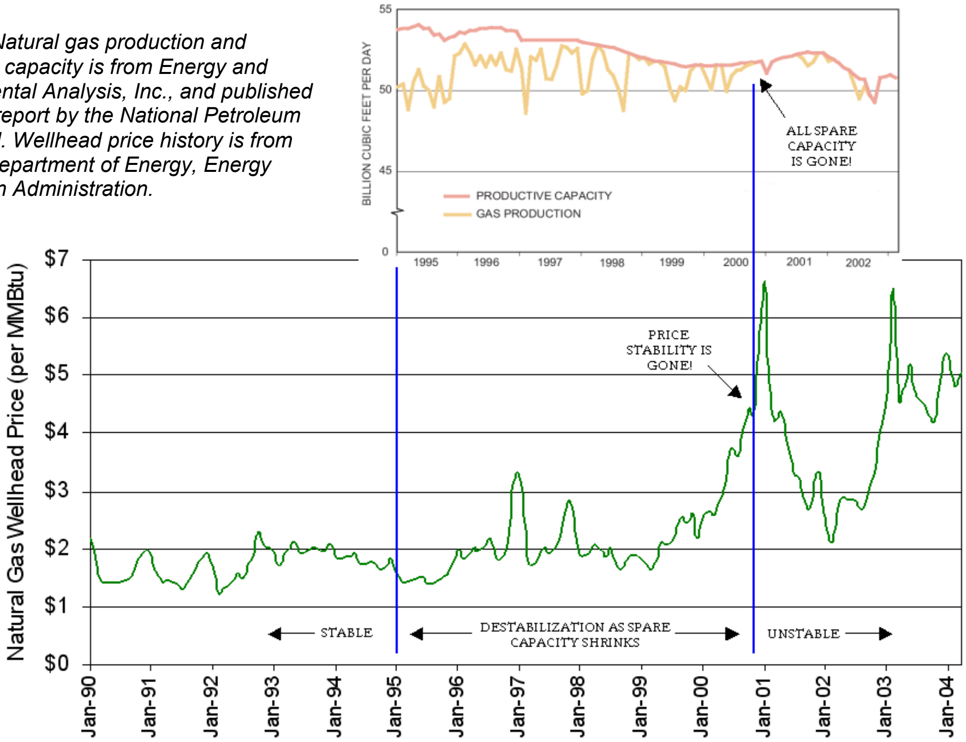
The instability precipitated by the decline of oil and gas has already begun in the form of price destabilization. Maintaining a stable energy price requires the existence of excess production capacity. Excess production capacity for world petroleum is not known exactly, but is believed to be less than 2 percent of market volume – far less than needed for price stability. Crude oil prices now sometimes fluctuate by 5 percent per day on speculation of changing political or climatic conditions. The inability to increase production elsewhere when political or weather events threaten a particular energy supplier makes each event significant from a market perspective.

Spare productive capacity for continental U.S. natural gas had been shrinking for many years before it finally vanished in the fall of 2000 [4]. This phenomenon, and its effect on prices, are shown in Figure 4.

The destabilization of energy prices, particularly for oil and gas, has immediate economic consequences. Higher energy prices reduce the amount of money consumers have to spend while simultaneously raising the cost of consumer goods (which are made and transported with energy). The effect is highly regressive because low-income households spend a disproportionate share of their income on energy. Energy purchases for home-heating, cooking, and transportation are furthermore basically non-discretionary.

Research of the process by which energy price instability develops into economic instability, and how this in turn leads to social and geopolitical instability, is ongoing. The growing body of empirical evidence correlating the worsening fossil-energy supply problem with economic and geopolitical events suggests that the process may already be well underway.

Figure 4: Loss of Spare Productive Capacity and its Relation to Price, Continental U.S. Natural Gas

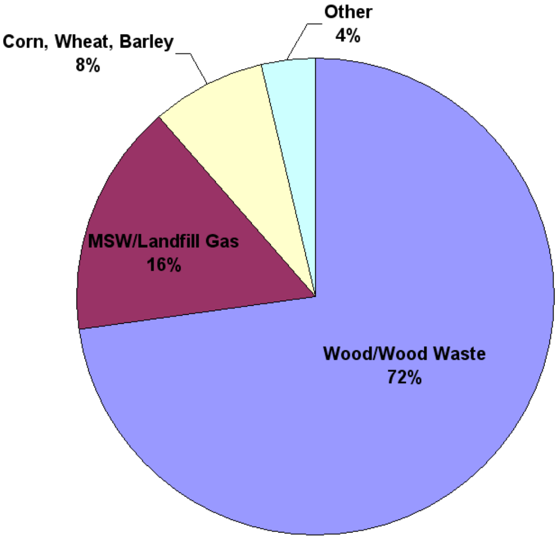


Sources: Natural gas production and productive capacity is from Energy and Environmental Analysis, Inc., and published in a 2003 report by the National Petroleum Council [4]. Wellhead price history is from the U.S. Department of Energy, Energy Information Administration.

The U.S. Bioenergy Industry

The bioenergy industry is receiving considerable attention in the U.S. due to its perceived potential to improve energy independence. The current state of the industry and its potential for growth are profiled below.

Figure 5: U.S. Bioenergy Consumption by Source, 2003 (5) .



Total bioenergy consumption in the U.S. was 839 million megawatt-hours (MWh) in 2003, accounting for about three percent of all energy consumed. (Figure 1.) Nearly three quarters of this energy (72 percent) was produced from wood and wood waste. (Figure 5.) Municipal solid waste and landfill gas provided another 16 percent of bioenergy, and corn for ethanol production (and, to a much lesser extent, wheat and barley) accounted for 8 percent. The remaining 4 percent is comprised of agricultural byproducts, sludge waste, tires, and other biomass solids, liquids, and gases.

Bioenergy consumption by end-use is shown in Figure 6. The largest use of bioenergy in the U.S. is industrial process heat, accounting for 367 million annual MWh, or 43 percent of total bioenergy consumption. Most of that amount – an estimated 241 million MWh[1] – was consumed by the paper industry. Paper mills generate heat primarily by burning the “black liquor” lignin residue produced during the pulping process. Paper

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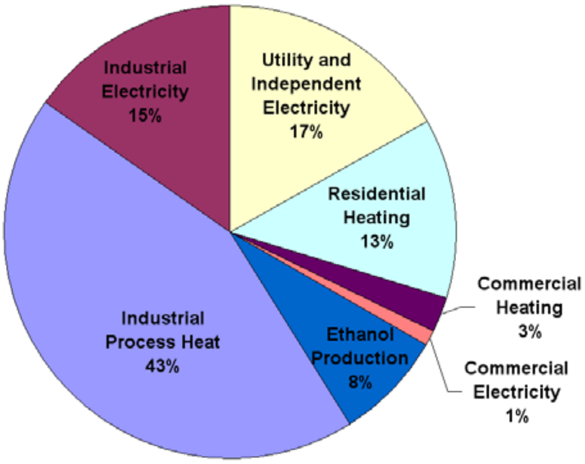
[1] This value is estimated using consumption data from 2002 and scaling it for the total consumption for 2003.

mills also consume a considerable amount of wood and wood-waste solids for process heat. Other biofuels consumed for industrial process heat include, in declining order of prevalence, landfill gas, agricultural byproducts, wood-waste liquids, sludge waste, tires, and municipal solid waste.

Electricity generation at industrial sites consumed 128 million MWh of bioenergy in 2003 (15 percent of total consumption), again dominated by the paper industry. Many paper mills have cogeneration facilities, thus the fuel composition for their electricity generation is also predominantly black liquor and, to a lesser but still significant extent, wood and wood waste.

Figure 6: U.S. Bioenergy Consumption by End Use, 2003 (5) .



Electricity generation by utilities and independent power producers consumed 143 million MWh of bioenergy in 2003 (17 percent of total consumption). Much of this consumption is attributed to co-firing a small percentage (typically not more than 5 percent) of wood residues, wood chips, straw, or switchgrass in large power plants designed originally to burn only coal.

Ethanol production, using corn with few exceptions, accounted for 64.5 million MWh (8 percent) of bioenergy consumption in 2003. According to the U.S. Department of Energy, ethanol production from corn totaled 2.81 billion gallons in 2003, up sharply from the 1.7 billion gallons produced in 2001. The rapid growth is largely due to aggressive government incentives designed to help the ethanol industry meet the demand for gasoline oxygenates to reduce emissions. The use of methyl tertiary butyl ether (MTBE), the only other oxygenate used in the U.S., is declining due to its propensity to contaminate groundwater.

Residential heating accounted for 105 million MWh of bioenergy consumption in 2003 (13 percent of total consumption). Roughly 1.84 million U.S. households (1.5 percent of total households) heat with wood, predominantly by burning “cord wood” logs in wood stoves and fireplaces. Pellet stoves and boilers are gaining popularity, with an estimated 48,500 sold in 2003. There are at least 26 pellet-fuel manufacturers in the U.S., with combined annual shipments of 793,000 tons (719,400 metric tons) in 2003. Based on this data, only an estimated 3.8 percent of homes heated with wood use pellets.

Commercial heating and electricity are the smallest bioenergy consumptive sectors, consuming a combined 32.2 million MWh (4 percent of total consumption) in 2003. The majority of this energy was used for space heating in businesses and schools, and in federal, state, and local government buildings.

Potential to Expand U.S. Bioenergy

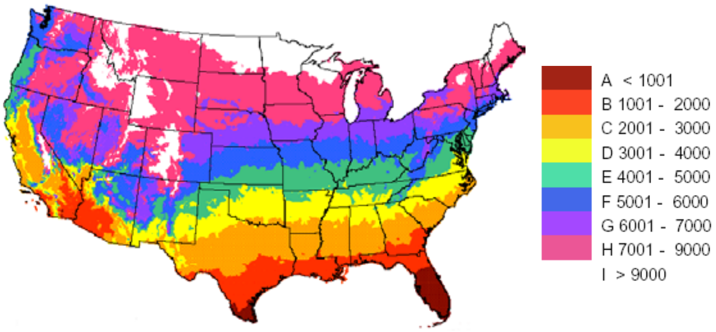
Several national resource assessments and federal programs aimed at increasing U.S. bioenergy production have been carried out recently. The Oak Ridge National Laboratory (ORNL) estimates the total standing vegetation in the U.S. to be 65-90 billion dry metric tonnes, containing 14-19 years of the country’s energy use at present consumption levels. A 1999 study by ORNL and others [7] cites a 1997 USDA estimate that the country has 559 million acres (226 million hectares) of publicly and privately held forestlands and 337 million acres (136 million hectares) of agricultural cropland. The location of forest biomass resources, and their proximity to cold climates, can be seen by comparing Figures 7 and 8.

The ORNL study [7] also looked at other biomass sources, and estimated that at a market price of US$40 per delivered dry ton, the availability of biomass from urban wood waste, mill waste, and forest thinning residues could produce 559 million MWh annually.

Figure 7: Forest Cover in the U.S.
(green, orange, and yellow areas are forested)

Source: U.S. Geological Survey

Figure 8: Mean Total Annual Heating Degree Days, °F



Source: U.S. National Oceanic and Atmospheric Administration

The University of Tennessee developed a computer model called POLYSYS that uses agricultural and economic data to determine locations and conditions under which energy crops can be produced at the same or higher profit margins than conventional crops. A 2003 report on the model [8] estimated that at a farmgate price of US$1.83 per gigajoule (US$1.73 per MMBTU), 7.9 million hectares (19.5 million acres) of agricultural land could be economically converted to bioenergy production (switchgrass, hybrid poplar, and willow), producing 60 million dry tons (54.4 million metric tonnes) of biomass. At a higher price of US$2.44 per gigajoule (US$2.31 per MMBTU), the model estimated that 17 million hectares (41 million acres) of agricultural land could be economically converted to bioenergy production, producing 188 million dry tons (170.6 million metric tonnes) of biomass. Based on ORNL's energy density factor of 65 million dry tons per quad, and converting to SI units, energy from crops grown on the converted land areas for the two cases would yield 271 million MWh and 847 million MWh, respectively.

Government Support for Bioenergy

In 1999, President William J. Clinton signed Executive Order 13134, ordering the development of "a comprehensive national strategy, including research, development, and private sector incentives, to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in large national and international markets." The next year, Congress passed the *Biomass Research and Development Act of 2000* with the stated purpose to "promote research and development leading to the production of biobased industrial products. The Act furthermore called for the creation of a technical advisory committee and board to guide and oversee the process, and a funding initiative to provide grants, contracts, and financial assistance to help carry out the objectives.

In October, 2002, the technical advisory committee established by the Act published a vision paper which set long-term goals for bioenergy development. The goals stated in the vision paper can be summarized as:

- *Biomass consumption in the industrial sector will increase by 2 percent per year through 2030*
- *Biomass consumption in electric power will double every 10 years through 2030*
- *Increase biomass-derived transportation fuels from the current 0.5 percent of U.S. transportation fuel consumption to 20% in 2030*
- *Increase production of chemicals and materials from biobased products from the current 5% of target U.S. chemical commodities to 25% in 2030*

Calculations of actual increases in bioenergy if the technical committee's stated energy-based goals are met are shown in Table 2 below.

Table 2: Potential Increases in Bioenergy Consumption based on Governmental Goals

End Use Sector	2001 Consumption (million MWh)	Vision for 2030 (million MWh)	Net Increase (million MWh)	Annual Effective Rate of Increase
Industrial	791	1,405	614	2.0%
Electric Utilities	6	42	36	7.2%
Transport Fuels	43	2,344	2,301	14.8%
Totals:	**840**	**3,790**	**2,951**	

Source: Data have been converted to SI units, but are taken from "Vision for Bioenergy and Biobased Products in the United States 2002" a report from the Biomass Technical Advisory Committee established by the Biomass R&D Act of 2000.

Grant awards made through the funding initiative established under the Act have totaled US$144 million over three rounds of funding. Awards in the first round were US$96 million and went to just six companies, all focused on the conversion of energy crops (primarily corn) into liquids (primarily ethanol). Second-year funding was more diverse, giving 19 awards valued at US$23 million to companies and universities seeking to advance research into liquid fuels (ethanol, biodiesel), hydrogen, biogas, and chemicals. Two of the 19 awards, one of them to Local Energy for the project that produced this paper, were for economic and environmental assessments of biomass potential. The third round awarded US$25 million to corporations, universities, and research institutes for a total of 22 projects including research and development on corn-stover biomass, black-liquor gasification, ethanol production, liquid fuels for fuel cells, and hydrogen from farm-animal waste. The projects also included two for education, one for rural development, one for sustainable forestry and one to investigate incentives. See Table 3.

Table 3: Grant Award Funding through the National Biomass Initiative

Biomass Research and Development Initiative	Number of Awards	Total Funding US$	Recipients	Projects
Round 1 (FY 2002)	6	$96 million	Corporations	conversion of energy crops (corn) into liquid fuels (ethanol)
Round 2 (FY 2003)	19	$23 million	Corporations, Universities, Nonprofits	liquid fuels (ethanol, biodiesel), hydrogen, biogas, chemicals, economic and environmental assessments of biomass potential
Round 3 (FY 2004)	22	$25 million	Corporations, Universities, Nonprofits	corn-stover biomass, black-liquor gasification, ethanol production, liquid fuels for fuel cells, hydrogen from farm-animal waste, education, rural development, sustainable forestry, incentives

Appropriate Bioenergy Development

Determining what is appropriate in terms of bioenergy development requires first an assessment of what various bioenergy technologies can and cannot do relative to the fossil-energy source problem, followed by refinement of methods for deploying those technologies in ways that best produce economic benefits and security. Obviously that will be an enormous undertaking. An overview of some factors to consider and some first case studies are presented below.

The vision goals set by government's technical advisory committee would increase biomass consumption to nearly 3800 million MWh by 2030, which is about 12 percent of current U.S. energy consumption and less than 10 percent of expected 2030 consumption based on EIA projections. Even replanting the entire cropland of the U.S. with energy crops would yield, using the ORNL factors for biomass energy per unit land area [7], about 6800 million MWh – which is 15 percent less than the energy consumed annually by the transportation sector. Analyses such as this are not only folly (where would we grow our food?), they are erroneous because they use gross, rather than net, energy production. If producing biofuel is more energy intensive than producing gasoline (and all indications are that it is, regardless of which study you believe), then the gap between supply and demand would be even worse.

Appropriate Project Criteria

Since bioenergy cannot replace fossil-fuel energy, rather than setting targets for increased national consumption of bioenergy, it may be more appropriate to set goals for the combined thermodynamic and economic efficiency of bioenergy projects. This would help ensure that the limited supply of bioenergy is used for projects that produce the greatest amount of useful work and economic benefits possible. In this way, the economic hardships of fossil energy decline are optimally addressed. The criteria for evaluating projects would be based on the following:

> ***Production Efficiency:*** *Calculation of the energy profit ratio, defined as the ratio of produced fuel energy to process energy, must be calculated by a neutral third-party using standardized protocols.*
>
> ***Utilization Efficiency:*** *The amount of useful work done per unit of fuel consumed must be calculated by a neutral third-party using standardized protocols.*
>
> ***Economic Efficiency:*** *The value to consumers must be calculated not only based on changes in current and projected energy expenditures, but more importantly based on local multiplier impacts. The local character of capital costs, fuel costs, and operating costs must be evaluated over the life of the project to determine the net long-term benefits to the community hosting the project.*

First Case-Study Projects

The efficiency criteria above are being used to develop biomass projects in Santa Fe, New Mexico, USA. The projects are currently under development by Local Energy (Santa Fe, New Mexico, USA) in cooperation with BIOS BIOENERGIESYSTEME GmbH (Graz, Austria) and with several economists, including local-economic specialist Michael Shuman (Washington D.C., USA).

The main project is a district-energy system designed to provide space heating and domestic hot water to about 550 commercial and residential customers in downtown Santa Fe using woodchip biomass from forest and woodland thinning projects surrounding the community. A variety of scenarios are under investigation, including two proposed locations for the heating plant, and a cogeneration option. For brevity, only one option (the most likely one) is presented here, which is the heat-only scenario with the heating plant located 2 miles (3.2 km) from downtown.

Four smaller micro-grid systems are being studied simultaneously with the main project in order to begin demonstrating the technology within the community and to develop the local capacity to provide biomass fuel for larger projects. The four sites of the micro-grid projects are an apartment complex, a government office complex, a private college, and a community college. This last project, at the Santa Fe Community College, is expected to go to construction in summer 2005 in order to be operational for the 2005-06 heating season.

Fuel Production Efficiency

Sources of biomass fuels within a 50-mile radius were investigated, including sawmills and other commercial operations, municipal green-waste stations, and forest-thinning projects. Conservative estimates from that investigation found a 53 percent surplus of fuel available on a sustainable basis for the main project, with most of the fuel coming from commercial sawmills. This bodes well under the *Production Efficiency* criterion given above, since mill wastes have been shown to have a 50:1 energy profit ratio in studies conducted in Austria [9]. Wood chips from forest projects in the same study showed a 20:1 energy profit ratio. The many different methods used in life-cycle analyses limits the usefulness of comparisons with other studies, but with that limitation in mind, biodiesel from soybeans has been shown to have an energy profit ratio of 3.2:1 [10], and ethanol from corn has a reported energy profit ratio of between 0.6:1 [11] and 1.3:1 [12]. Since relatively little processing is required for woodchip biomass, it is expected that the energy profit ratio should be higher than for liquid fuels, at least for cases in which the transport distance is small.

Utilization Efficiency

The heating plant design for the main project is a moving-grate furnace with a horizontal pressurized hot-water boiler. Based on chemical analyses of the locally available biomass and their past experience with optimizing biomass combustion performance using computational fluid dynamics modeling, BIOS BIOENERGIESYSTEME projects an overall efficiency at the heating plant of 91.6 percent. The design of the 30,000 meter delivery network is similarly optimized using software designed by BIOS and calibrated with empirical data from their database, and has a projected overall efficiency of 84.1 percent. The overall efficiency of the heating system is therefore 77 percent or, if the electricity needed to run the pumps is considered, 75 percent.

Similar utilization efficiency calculations for the micro-grid at the Santa Fe Community College show overall system efficiencies of 87 percent without considering the pumping energy, and 85 percent if the pumping energy is considered.

Economic Performance

Most of the target customers for the main system currently use natural gas-fired boilers, for which fuel prices have tripled over the past six years. (The net increase to the consumer has been smaller, since the fuel is only one component of the bill.) The January, 2005 price for delivered gas to commercial customers in Santa Fe is US$8.20 per million BTU (US$0.028 per kWh), making the actual price for heat (considering an average 75% utilization rate) US$10.92 per million BTU (US$0.037 per kWh).

Capital costs for the main project are estimated by BIOS at US$23.7 million, and annual operating costs total about $2.9 million per year. This translates to a specific energy production costs of $17.91 per million BTU, 64 percent above current heating costs. Superficially, the project does not appear economic unless natural gas costs increase. Such an increase is certainly expected, but the timeframe for it is not known. A similar analysis for the project at the Santa Fe Community College predicts an energy production cost of US$8.53, 22 percent below current costs. This project appears to be economic immediately.

Economist Michael Shuman designed an ownership model for the main project with the objective of localizing the economic benefits. He furthermore calculated that under the current scenario, only about 20 cents of every dollar spent by Santa Fe residents on their natural-gas utility bills gets re-spent within the community, while the other 80 cents leaks out. Under his proposed community-ownership model, preliminary results show that the reverse is true, with 80 cents of every dollar remaining in the community. Using the RIMS-II economic model, he calculates that every dollar not spent on a utility bill with the investor-owned utility creates US$0.35 in output for Santa Fe County.

Under Shuman's ownership model for the project, the project would be built by a for-profit corporation with residency requirements on the stock to ensure local ownership. The County would agree to subsidize the project as needed to bring the price of heat from the system down to the equivalent price of natural gas. At some point the price of gas is expected to rise such that no further subsidy is needed. To determine the total subsidy required, Shuman took historical data for consumer prices of natural gas dating to 1987, and determined three possible price-rise scenarios, ranging from 1.09 percent per year to 13.84 percent per year. Preliminary results showing the subsidy required under each scenario and the respective multiplier benefit to the county over the fifty-year life of the project are shown below in Table 4.

Table 4: Preliminary Results of Local Economic Benefits of the Main District Heating Project

Gas Price-Rise Scenario (annual percent increase)	Subsidy Required (million US$)	Multiplier Benefit to County (million US$)	Net Benefit to County (million US$)
1.09% (1987-2004)	19.5	34.2	14.7
4.16% (1995-2004)	5.5	116.3	110.8
13.84% (2002-2004)	2.1	4,070	4,068

There are limitations to this type of analysis, of course. No community could withstand the perpetual 14 percent annual rise in energy costs on which the resulting US$4 billion benefit is based. That's part of the point, however: no one knows how high gas costs will go as the resource depletes, and a significant benefit of this project is that it limits the community's exposure to the very real threat of runaway energy costs.

Summary

It is acknowledged that the work presented here, in its current state, may pose more questions than it answers. The process of determining the steps that are most “appropriate” with regard to bioenergy development is just that – a process. The hope is that this work will inspire the right questions, and that further work to answer those questions will ensure that we continue in the right direction. The fossil-energy supply problem facing us is serious, and its consequences are likely to be severe. Bioenergy alone cannot solve the problem, but strategic and appropriate bioenergy projects that emphasize high efficiency and local economic benefits can serve as models of sustainability for communities seeking to protect and improve the quality of life for their citizens now and in the future.

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