T H E G R A S S E N E R G Y C O L L A B O R A T I V E

A Scenario for Grass Energy

Combined Heat & Power

The Convergence of Microprocessors, Sensors, Communications & CHP
Distributed Solutions for Distributed Problems

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The Grass Energy Collaborative,Inc.

The Grass Energy Collaborative, Inc. is registered in the state of Vermont as a not for profit organization. This working paper will be the foundation for future plans, projects, and proposals.

Mission:

To create a grass energy sector producing renewable biofuels and land stewardship tools that will promote economic development, a healthy environment and energy independence.

Problem Statement

- The American economy, is currently importing on the order of $677,000 per minute of foreign fossil carbon energy, and is threatened by rapidly rising fossil fuel prices that are being driven upwards by a growing divergence between demand and supply, possibly complicated by "Peak Oil";

- 350,000 mid-sized farmers in America, who work 40% of our agricultural lands, are at risk and require new income streams to improve their long term economic viability;

- Non-point source (NPS) pollution of streams, lakes, and reservoirs from sediment, fertilizers, and pesticides is a significant threat to water supplies, waterways, and wildlife habitats in many parts of the country.

- Reliance on insecure and vulnerable foreign fossil fuel supplies constrains U.S. foreign policy options and exposes the U.S. economy to risky disruptions and distortions;

- Burning fossil fuels releases sequestered carbon into the atmosphere and is destabilizing the biosphere;

- Centralized generating plants create single points of failure - a Homeland Security issue;

- The U.S. economy can no longer afford centralized power plants operating below 67% efficiency - 49% of US electricity is made by burning coal at less than 35% efficiency;

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The Benefits of a Grass Energy Program

Grass is a dedicated energy crop we can use in a modern energy strategy that would have these beneficial characteristics:

- Lower cost per million BTUs: 1 ton of grass pellets = 100 gallons of #2 oil;
- Offers a sustainable economic activity to farmers;
- Mitigation for Non-point source (NPS) pollution of water ways;
- Creates a new stewardship tool for Conservation Land Managers;
- Creates local new jobs in a smokeless light industry;
- Keeps cash spent for energy in the local economy;
- Is a superior feed stock for the production of ethanol for transportation fuel;
- Complements use of green wood chips - creates an integrated strategy;
- Keeps fields open for scenic preservation & tourist industry;
- Late harvesting provides improved bird and other wildlife habitat ;
- Has a net energy gain higher than ethanol or biodiesel;
- Nearly carbon neutral and good candidate for Green House Gas credits;
- Perennial crop with a 10 - 15 year cycle;
- Has low fertilizing requirement;
- Is drought and flood resistant;
- Has an energy content that is 88% - 95% of that of wood pellets;
- Low particulate emissions;

19th Century Kansas History

“Our great grandmothers did all of their cooking and baking in "grassburner ovens". Wood and coal were scarce and expensive in that prairie country, so the new immigrants built a combination brick oven-fireplace that burned loose wheat straw, which was plentiful.

Located in the center of the house, this stove provided warmth for two sitting rooms and ample heat for cooking. ... According to an article in The Newton Kansan, December 9, 1875, "it took only four good sized armloads of straw to provide heat twenty-four hours a day, even in coldest weather." Grassburner ovens measured seven feet high, seven feet long and two feet wide.

The Kansan writer commented further: "We can but look upon these ovens as among the grandest things in use for this country and might with a sense of economy, neatness, and practicability be adopted into every house where it is possible to do so."

From: Peppernuts Plain and Fancy: A Christmas Tradition from Grandmother's Oven

By: Norma Jost Voth

Preamble

> "Sharp increases in oil, natural gas, propane, and some regional electricity prices during the last ten years have demonstrated consumer vulnerability to fluctuations in energy supply. Farmers are particularly vulnerable because as primary producers they are often expected to swallow higher energy costs. These high energy prices combined with low food commodity prices represent a double threat to the prosperity of farmers worldwide.
>
> One solution to resolve these problems would be to commercialize renewable biofuel crops. By doing this, it would help diversify the farm economy, as well as allow farmers to increase their energy self-reliance and control their energy costs." R.E.A.P. Canada

In 2004, the Center for American Progress wrote:

> "America now spends more than $200,000 a minute on foreign oil imports. Nearly 60 percent of our oil is imported. Even if we drained every last drop of U.S. supply, the nation has just 2 percent of the world's remaining oil reserves [which can not] accommodate what amounts to a quarter of global demand. The Department of Energy (DOE) predicts that by 2025, domestic petroleum sources will be meeting less than a third of our oil needs."

In July of 2006, the dollars per minute value used above has to to be revised sharply upwards to $677,000 per minute [13 MBD @ $75/barrel] or over $11,200 per second!

Today, there is an exciting opportunity to create a new energy business based upon grass, and other biomass crops, as a dedicated energy crops. Grass captures more BTUs in the least amount of time than any other biomass crop. Today, there is also an exceptional opportunity available to entrepreneurs as there are currently no known dedicated grass for energy crop sites in all of New England. The scenario under development in this document begins to explore this possibility.

There were, as of 2003, on the order of 350 operating power plants using biomass fuels in the United States. Further, the U.S. Department of Energy asserts that the potential exists for biomass power to grow to an industry with 30,000 megawatts (MW) of capacity, employing 150,000 persons in mainly rural areas, and producing 150-200 billion kilowatt-hours (kWh) of electricity by the year 2020.

There is also, in other parts of the world, significant innovations, driven by in part by the Kyoto Accords, in the area of Combined Heat & Power [CHP], as well as Micro-CHP. Take, for example, the WhisperGen Micro-CHP unit from New Zeland's Wisper Tech < http://www.whispergen.com/>. The WisperGen makes innovative use of Stirling Engine technology to produce 1000W AC at 220-240V and heat output from 7.5-13kW. It was announced in Oct. 2004 that WhisperGen Micro-CHP units, priced at about $5,300, would be installed in 550 family homes, part of a new residential development in East Manchester, England.

The vision in this document is also about increasing the choices we have as to how we heat and light our buildings and heat our domestic hot water. A benefit of the scenario is that it describes ways to significantly improve the efficiencies of extracting energy from fuel stocks. It is also about creating renewable, close to carbon neutral energy that will reduce reliance on increasingly expensive and unreliable fossil carbon fuels. When this vision is realized, a net gain in rural economic development is an expected outcome. For example, a smokeless light industry providing year round employment for heating and local electrical generation plant operators, pellet stove and boiler support teams, transportation workers delivering bales, pellet delivery services, etc. The concepts presented here also create seasonal work for custom biomass croppers.

Within the national context, the scenario will support the goal that, by the year 2025, agriculture will provide twenty five percent of the energy consumed in the United States. See < http://agenergy.info/home.htm> for more on the national level goals for biofuels

In the future, it is expect that Grass Energy projects will benefit from Green House Gas [GHG] carbon trading credits, Open Space preservation incentives, such as are to be found already in NH, animal waste management and non point source pollution abatement credits as well.

It is expected that the demand for solid biomass fuels will also benefit as Combined Heat and Power [CHP] applications are broadly adopted, possibly in combination with plugin, biofueled, hybird vehicles.

These developments will be built upon the currently emerging convergence of energy, microprocessors, sensors and communications to create networks of cooperating, high efficiency, low carbon and low impact solutions: Distributed solutions to Distributed Problems. Already, today's best pellet fuel boilers for light industry rely on microprocessors and sensors for their operation. We can anticipate that sites at which next generation of pellet boilers will be installed will also already be part of the Internet.

If Grass Energy successfully contributes to reaching the goal of 25% by '25, a principle benefit will be the development of a proven a model for an additional income stream for the 350,000 mid-sized farmers in America who work 40% of our agricultural lands, while improving national security, the reliability of our energy supplies, and reducing the impact of our activities on the environment.

A potential result of this convergence of technologies will be a new Internet-like, distributed, electricity generation paradigm. This new approach would replace the conventional view of power as being naturally created at large, isolated power plants. In today's new energy and security environment, however, the old model, dating from the late 19th century, is too inefficient. We can no longer afford to waste 67% of the input energy for a system that also creates too many risky points of failure.

The Grass Energy vision supports a new model that defines a new paradigm: smart, connected, active, communicating and cooperating points at the edge of the network. It is here that the future of innovation, creation, distribution as well as consumption will be located. What are these points at the edge? They are our offices, farms, public places and our homes.

It is sobering indeed to consider where we would be today as a nation if we had invested 2 trillion dollars in a Grand Challenge to shift our nation to a 100% renewable, carbon neutral, economy. Instead, we chose to pour the lives to 10s of thousands, and trillions of our national treasure, into the sands of the Middle East.

Is Biomass Energy a Viable and Proven Option?

In July of 2005, at the Micropower conference, Ian Stares, Business Development Manager, Baxi Group gave a 37 slide overview of the current outlook for MicroCHP in Europe. The range of products and options he presents is quite amazing for an American living in a political culture which opted out of the Kyoto Accords and denies the existence of any environmental problems resulting from all time record high levels of CO_2 in the atmosphere.

<http://www.iee.org/oncomms/pn/powertrading/Ian%20Stares.pdf>

A further source of information is the Combined Heat and Power Association web site. <http://www.chpa.co.uk/> Clean and efficient Combined Heat and Power (CHP) is already in use on close to 1,400 locations around the UK.

Read the "Prime Minister's support for CHP"

The United Kingdom Parliament, Select Committee on Science and Technology, offers a government perspective lacking in the United States:
<http://www.parliament.the-stationery-office.co.uk/pa/ld200506/ldselect/ldsctech/21/2111.htm>

Biomass Task Force, Report to the Government [British], October 2005
<http://www.defra.gov.uk/farm/acu/energy/biomass-taskforce/btf-finalreport.pdf>

In Europe, there is now an establish biomass energy market that is experiencing strong growth driven by: The price of fossil fuels; Government policies informed by both national self interest and the Kyoto Accords; and, Citizens' desire to be part of the solution. The US is now adding some pressure to the demand side of the biofuels market, but this demand can be expected to increase rapidly in 2006 or 2008. All these factors will keep pressure on prices for biomass pellets of all sorts - no matter how their distribution is manipulated. They will go to the highest bidder, regardless of location. Already, the demand for wood pellets has exceeded the existing supply of sawdust in some locations. Currently, at least one manufacturer has been forced to make wood pellets from green wood chips. In 2006, grass clearly has an important role in balancing the supply side of the demand for renewable energy.

In contrast, the US Department of Energy reports: "year-to-date through September 2005, 49.3 percent of the Nation's electric power was generated at coal-fired plants (Figure 1). Nuclear plants contributed 19.0 percent, 19.4 percent was generated by natural gas-fired plants, and 2.5 percent was generated at petroleum liquid-fired plants. Conventional hydroelectric power provided 6.7 percent of the total, while other renewables (primarily wind, but also geothermal, solar, and biomass) and other miscellaneous energy sources generated the remaining electric power [3.1%]."

<http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html>

Three Grasses: Reed Canary, Switch & Miscanthus

Dedicated Energy Crops

Prof. Jerry Cherney of Cornell University, an expert on forage production, management and quality, writes: Both switchgrass and reed canarygrass (RCG) are native to the Northeast and VT. Reed canarygrass is the only cool-season perennial forage grass commonly used in the Northeast that is native to North America (timothy, orchardgrass, smooth bromegrass, tall fescue etc. are not native).

<http://grassbioenergy.org/>

The Union of Concerned Scientists has a useful web site: Growing Energy on the Farm: Biomass Energy and Agriculture

<http://www.ucsusa.org/clean_energy/renewable_energy_basics/growing-energy-on-the-farm-biomass-and-agriculture.html>

Reed Canary Grass (*Phalaris arundinacea Linnaeus*)

Prof. Jerry Cherney of Cornell University continues: There is essentially no land in New York State that is unsuitable for reed canarygrass, which is one of the most drought tolerant perennial grasses, as well as the one that takes the wettest conditions. If you can't grow reed canarygrass you probably can't grow any agricultural crop.

We have collected wild reed canarygrass from Iowa to New Hampshire and have planted about 80 collections in 5 locations in 2005. This study is being conducted cooperatively with biomass grass breeders in Iowa and Wisconsin. We hope to generate a reed canarygrass variety that yields as well or better than switchgrass and is adapted to all agricultural soils. This was done in Sweden, producing a biomass variety of reed canarygrass (Bamse) that is over 20% higher yielding than normal varieties. This is a major improvement in a very short time period.

In a 2005 research project titled "Evaluating Strategies for Biomass Fuel Production in New York State" P. B. Woodbury *, J. H. Cherney, J. Wightman, J. M. Duxbury, W.J. Cox, C. L. Mohler, S. D. DeGloria concluded that Reed Canary would offer the best greenhouse gas emissions mitigation benefits.

" For maximal greenhouse gas mitigation potential, the best agricultural strategy is producing reed canary grass for heat and the best forest strategy is timber stand improvement cuts. Together, these strategies could reduce total New York State emissions by 3.7%. These options provide 30-fold greater greenhouse gas mitigation potential than corn for ethanol and 24-fold greater potential than soybean for bio-diesel.”

<http://soilcarboncenter.k-state.edu/conference/Technical_Sessions_Oral_Presentations.htm >

More on RCG from Finland

<http://www.hightechfinland.com/2004/energyenvironment/vapo.html>

"Reed canary grass provides a better energy yield than any other grass grown for this purpose. It yields 6 - 8 metric tonnes of dry matter per hectare and has a thermal value of 4.5 MWh per tonne dry matter. The yield from one hectare is sufficient to cover the annual energy requirements of two private homes.

Trials have been run at industrial sites and municipal heating plants to test the grass in energy production. It can be used in conjunction with peat and wood fuels in heating plants equipped with a multi-fuel boiler – in Finland there are already many suitable plants in use. Compression and combustion tests have also confirmed that the grass can be used in fuel pellets, either on its own or with wood. Vapo currently has around 1100 ha of reed canary grass under cultivation, with some 120 ha being harvested in 2002."

Note: 1 acre = .4047 hectares. Thus 2.8 tonnes of RCG per acre.

1 tonne = 1.1 US tons. Or 3.1 tons RCG per acre.

Characteristics of reed canary grass:

harvest approx. 6-8 tonnes dry matter/hectare
calorific value 4.5 MWh/per tonne of dry matter
energy up to in excess of 30 MWh/hectare
produces harvest for 10-12 years
low fertilizing requirement

Switchgrass (*Panicum virgatum*)

Switchgrass as a biomass fuel feed stock has been well studied, as a Google search on “switchgrass” will clearly show. A major research center with studies and pilot projects on switchgrass is R.E.A.P.-Canada.

From the R.E.A.P. site:

'Growing Interest in Grass Biofuels: An ecological response to energy concerns'

Sharp increases in oil, natural gas, propane, and some regional electricity prices during the last ten years have demonstrated consumer vulnerability to fluctuations in energy supply. Farmers are particularly vulnerable because as primary producers they are often expected to swallow higher energy costs. These high energy prices combined with low food commodity prices represent a double threat to the prosperity of farmers worldwide.

One solution to resolve these problems would be to commercialize renewable biofuel crops. By doing this, it would help diversify the farm economy, as well as allow farmers to increase their energy self-reliance and control their energy costs.

The need to find alternatives to fossil fuels and reduce Greenhouse Gas emissions has peaked interest in biofuels by energy specialists around the world. REAP-Canada has pioneered the research and development of biofuel pellets made from switchgrass (*Panicum virgatum*) for use in space heating applications. Switchgrass, when pelletized, has considerable potential to displace oil, natural gas, and electricity used for heating fuel. This development can significantly reduce greenhouse gases and heating costs and sustainably assist the development of rural communities. Fast growing warm season perennial grasses have been identified as ideal candidates for biomass fuel production due to their high net energy yield per hectare and low cost of production. Switchgrass is one type of warm season perennial grass native to the Great Plains and eastern North America. It is favourably viewed as it easily adapts to marginal soils and arid climates with minimal fertility and management requirements.

Converting switchgrass into a viable energy option suitable for widespread application requires an energetically efficient, economical, and convenient energy transformation pathway to meet consumer energy needs. The recent development of gasifier pellet stoves and furnaces (see www.pelletstove.com) provides a practical pathway for grass biofuel pellets to be converted into heating energy. These appliances are capable of burning moderately high ash pelleted agricultural fuels at 81-87% efficiency. In this system, switchgrass pellets are used much like wood pellets and provide fuel conversion efficiencies and particulate emissions in the same range as modern oil furnaces. When burned in the gasifier stoves and furnaces, pelleted switchgrass provides fuel conversion efficiencies and particulate emissions in the same range as modern oil furnaces. Each GJ of grass pellet energy directly substitutes for one GJ of oil, and can be utilized on a large scale without significant air pollution. The pelletized grass biofuel systems builds on, and is likely to overtake, the existing wood pellet heating industry which is rapidly developing without any significant level of government intervention. Pelletized grass biofuel is poised to become a major fuel source because it is capable of meeting some heating requirements at less cost than all available alternatives.

The cost-effectiveness of pelletized grass as a fuel results from:

- efficient use of low cost marginal farmland for solar energy collection
- minimal fossil fuel input in field production and energy conversion
- replacement of expensive high-grade energy forms in space and water heating
- minimal biomass quality upgrading which limits energy loss from the feedstock
- efficient combustion in advanced, affordable, and user-friendly devices

Source: <http://www.reap-canada.com/bio_and_climate_3_2.htm>

Giant Miscanthus (*Miscanthus x giganteus*)

University of Illinois at Urbana-Champaign Professor Stephen Long, crop sciences and plant biology, and his graduate students, have been researching Giant Miscanthus as a dedicated energy crop.

Below is the opening of a paper from 2003 by Emily A. Heaton, a doctoral student, et al:

MISCANTHUS FOR RENEWABLE ENERGY GENERATION:

EUROPEAN UNION EXPERIENCE AND PROJECTIONS FOR ILLINOIS

"When considering renewable energy from plants, corn ethanol and reforestation have been widely promoted. Herbaceous perennials, which produce an annual crop of above ground shoots, may have some important advantages over both of these systems. Herbaceous perennials require far fewer energy and financial inputs than annual arable crops. They can be higher yielding than forestry crops and utilize existing farm equipment. Perennial energy crops can sequester carbon into soil previously under annual arable crops, providing potential additional income in carbon credits. The advantages and disadvantages of different plant types are explained to show herbaceous perennials hold special promise as bioenergy crops. C4 photosynthesis allows greater efficiencies in the conversion of sunlight energy to biomass energy, and of nitrogen and water use. However, few plants in temperate climates use this more efficient process. One exception is the rhizomatous perennial grass Miscanthus, which is a C4 plant and exceptionally cold tolerant. Miscanthus is now being grown commercially in the European Union (EU) for direct combustion in local-area power stations. It may also have longer-term potential as a feedstock for other bio-based industry. The lessons learned from trials of this crop in the EU are summarized, potential yields in Illinois predicted and a tentative comparison of the economics of growing Miscanthus versus traditional row crops developed. Overall, the results suggest that Miscanthus could yield an average of 33 t of dry matter per hectare [14.7 tons per acre] in Illinois. At current energy prices the crop would be profitable, if grown for 4 or more years, even without subsidy.

Heaton et al. University of illinois. 2003

<http://www.springerlink.com/(1vvc05qfdnodfe55qrrbn145)/app/home/contribution.asp?referrer=parent&backto=issue,8,14;journal,9,43;linkingpublicationresults,1:102962,1>

For more on the work of Prof Long, see: <http://www.news.uiuc.edu/NEWS/05/0927miscanthus.html>

And a very good over-view slide presentation:

<http://www.sustainablebioenergy.uiuc.edu/Presentations/Long.pdf>

Herbaceous Energy Crops & Water Quality

Richard Nelson, Kansas State University, has done significant research on another benefit provided by Switchgrass (*panicum virgatum*), "a native perennial grass, has been shown to control erosion on Conservation Reserve Program acres, river banks, and in buffer strips. Additionally, switchgrass has a massive root system that adds carbon to the soil, thereby helping mitigate the greenhouse effect."

Background

Non-point source (NPS) pollution of streams, lakes, and reservoirs from sediment, fertilizers, and pesticides is a significant threat to water supplies, waterways, and wildlife habitats in many parts of the country. The United States Environmental Protection

Agency (EPA) 2000 National Water Quality Inventory (United States Environmental Protection Agency, 2000) found that sedimentation remains one of the most widespread pollutants affecting assessed rivers and streams, impairing 84,503 river and stream miles (12% of the assessed river and stream miles and 31% of the impaired river and stream miles). Sedimentation alters aquatic habitat and can interfere with drinking water treatment processes and recreational use of a river and downstream watersheds. The United States Department of Agriculture-Agricultural Research Service (USDA-ARS) considers sediment the primary contaminant in rivers, lakes, and reservoirs.

Most NPS pollution problems are attributable to production agriculture as intense agricultural land use is leading to rapid sedimentation in many Kansas reservoirs, including Perry reservoir in the Delaware Basin in northeast Kansas. Sources of non-point source pollution include sediment from runoff on agricultural lands, nutrients such as nitrogen (N) and phosphorus (P), and pesticides. The state of Kansas performed an assessment that prioritized 72 watersheds/reservoirs into three separate severity categories for meeting state water quality standards regarding sediment and nutrient loadings with Category 1 watersheds being most in need of immediate restoration and protection. Over 77% of the state's watersheds were classified as Category 1 including the Delaware Basin.

Environment

Transported sediment contains remnants of fertilizers, and herbicides and pesticides which can cause eutrophication in reservoirs. Switchgrass (*panicum virgatum*), a native perennial grass, has been shown to control erosion on Conservation Reserve Program acres, river banks, and in buffer strips. Additionally, switchgrass has a massive root system that adds carbon to the soil, thereby helping mitigate the greenhouse effect. In two recent analyses, Kansas investigators found switchgrass production resulted in reductions of over 90% in rainfall-induced soil erosion, sediment transfer into streams and reservoirs, and major reductions in nutrient loss in runoff and subsurface flow versus rotations comprised of corn, soybeans, wheat, and grain sorghum. In general and historically, energy crops can not compete with conventional sources of energy, such as coal.

One strategy for reducing the cost of energy crops is to determine the extent of surface water quality benefits associated with their production and use through a reduction in soil erosion (sediment transport) and nutrient runoff compared to conventional commodity crop production, and place a monetary value on these benefits. The actual monetary value could potentially be in the form of a payment to either the landowner or other entity based on the amount of soil (sediment) saved or a percent reduction in N and P transported from the field in sediment or surface runoff. By planting switchgrass in selected locations throughout a watershed, it may be possible to add decades to the physical and economic life of such reservoirs.

Economics

In order for switchgrass to potentially provide water quality benefits, it must be able to compete with both conventional commodity crop production and have a delivered price competitive as an alternative energy source. A "switchgrass water quality payment" is defined as a monetary payment, on a per hectare or per Mg basis of switchgrass produced, that local, state and/or the federal governments would need to pay to the farmer/landowner for switchgrass to achieve a "target" market price.

The economics were concerned with determining the break-even price for switchgrass at which farmers/landowners would be indifferent to producing switchgrass in place of conventional commodity crop rotations. Farmers will want have at least the same potential income from switchgrass production (as an alternative energy source), versus what they currently are producing and what they feel they will be profitable in future years. In either case, (conventional commodity crop or switchgrass production) as is true with agricultural production in general, some element of risk is always involved.

The switchgrass production break-even price per hectare was determined and converted into an analogous payment per Mg of switchgrass by dividing by the average annual switchgrass yields attainable over the areas upon which each cropping rotation was produced. These payments ($\$ Mg^{-1}$ of switchgrass produced) were then converted to an edge-of-field energy payment ($\$ GJ^{-1}$) by dividing them by a switchgrass energy conversion factor of 18.4 $GJ\ Mg^{-1}$. In the case of employing switchgrass as an alternative energy source, all costs associated with converting it into a useable energy source (e.g., transportation, loading, processing, and conversion) must be considered when making a valid comparison to the competing alternative fossil-based fuel source. To accomplish this, the net return to land and management per hectare associated with each commodity crop production rotation was estimated within the Delaware Basin watershed and these returns were used to set the edge-of-field switchgrass break-even price ($\$ ha^{-1}$ and $\$ Mg^{-1}$).

Project Conclusions

Switchgrass production has been shown, when produced on conventional agricultural cropland in northeast Kansas, to have distinct environmental advantages versus the traditional cropping rotations of corn-soybean, corn-soybean-wheat, grain sorghum-soybean, and grain sorghum-soybean-wheat. Model simulations showed that sediment yield, surface runoff, NO_3-N in surface runoff, and edge-of-field erosion were reduced by an average of 99%, 55%, 34%, and 98% respectively over the range (0-224 kg N ha^{-1}) of N application levels.

In nearly every scenario concerning switchgrass production, at least 50% of the environmental savings in sediment yield, surface runoff, NO_3-N in surface runoff, and edge-of-field erosion could be attained at an edge-of-field switchgrass prices of $22-$27.49 Mg^{-1} or less. In some instances, a much greater percentage of environmental savings could be attained within this price range. The conversion to switchgrass from any conventional commodity crop production scenario requires that farmers be fairly confident in the price they will receive for the crops (commodity or alternative energy), which in turn dictates the expense of converting to energy crop production. Hence, the real conversion expense is fairly variable with an inherent element of risk. In general, only farmers that believe they can sustainably produce energy crops at fairly higher yields, coupled with a potential long-term demand for their crops with a utility or energy service provider, would substantially reduce their expense. The magnitude of "switchgrass water quality payments" needed to achieve delivered energy costs of $5.68 GJ^{-1} were determined and ranged from a low of $11.07 Mg^{-1} to a high of $27.18 Mg^{-1} depending upon switchgrass yield level. Results will potentially vary from these across the country (both positively and negatively) due to variation in yield, commodity crop price , and land use.

Net Energy Realized

The key metrics for biofuels are the net energy gain and energy output:input ratios. Net energy gain is the amount of useful energy provided to the consumer from a given area of land minus the production inputs to produce that energy. The energy output to input ratio measures the total production of energy returned for the investment in fossil energy inputs to produce them. The higher the better.

Grass Pellets appear to offer the best return on fossil energy invested as it has a 14:1 energy output to input ratio according to R.E.A.P. Canada. Biodiesel has been rated as high 3.2:1 but is now generally rated closer to 2:1 . On the other hand, ethanol made from corn in North America, according to the Wikipedia (Minnesota Department of Agriculture), offers 1.34:1 return on the fossil energy investment. This raises a question as to why research on ethanol from corn is currently receiving the lion's share of U.S. Government research dollars for dedicated energy crops.

By way of comparison, gasoline made from fossil oil is reported to have a net energy value of only .85:1. This shows that the return on the investment of the total energy inputs required to deliver gasoline to the retail pump is negative.

It is suggested by some that Net Energy must be balanced with the Application Value of the biofuel produced. It should be further noted that agricultural subsidies have distorted the choice of input stocks for making biofuels. A further distortion is caused by our failure to realistically price the consequences of releasing sequestered carbon into the biosphere. In general, we have ignored the limits of the biosphere in terms of supplies and and ability to handle waste streams. It has been conventional economic orthodoxy to assume that there were no limits and no consequences. Consequently we have not priced them and the price of fossil fuel, sequestered carbon, does not today reflect the price of very real and dangerous limits and consequences.

A second metric for biofuels is the utility of the feedstock used. New research at UC Berkeley has identify switchgrass as a feed stock for ethanol production with a much better portfolio of benefits than corn.

A third metric is the environmental impact of the production of the biomass feedstock itself. Modern row cropping has one set of characteristics, modern hay production another. Which has the best portfolio of benefits?

Roger Samson of R.E.A.P. Canada writes about data in their recent review paper: R. Samson et al. 2005. The potential of C4 perennial grasses for developing a global bioheat industry. Critical reviews in plant science 24:461-495.

"We estimated dry corn to consume 2.9 GJ/tonne in Ontario and switchgrass 0.9 GJ/tonne. The energy in a dry tonne we estimated at 19.0 GJ for switchgrass and 18.8 GJ for corn for an oven dry tonne (ODT) of each. The energy output:input ratio for the switchgrass is 23.8:1 (unprocessed but delivered to a pellet plant) and grain corn would be 6.4:1. In the US it would be lower because of irrigation. Also the actual energy recovery is also a bit lower in the combustion process because of the higher moisture content of corn kernels (14% moisture) than grass pellets (7% moisture).

You would be safe to say a 14:1 energy output:input ratio for Switchgrass pellets and 6:1 for corn kernels for combustion based on our analysis in that paper. For corn ethanol, they normally talk about a 1.2-1.5:1 energy output to input ratio. The net energy gain per ha is also distinctly different and another useful comparison".

According to R.E.A.P., "Switchgrass has a net energy gain of about 11 barrels of oil energy equivalent per acre. This compares favourably to other commercial biofuel alternatives. Corn ethanol, for example, only produces enough net energy on one acre to replace 1.5 barrels of oil. Corn also requires moderate to high quality farmland for its production; switch grass can be grown on lower quality lands."

Grass Growing Assumptions

2006: 10,000 tons of biomass input stock [2,000 acres of land yielding 5 tons per acre. Biomass yields of 5 tons per acre is used as a baseline figure in this document. The goal is to develop crops that can yield 8 - 10 tons per acre in Vermont.]

[Note: Pelletizing plants must be operated three shifts per day to achieve the most effective economic benefits. A 100 thousand tons per year plant could require a grass catchment area as large as 20,000 acres. As higher yielding plants are identified and planted, the required acreage to support a plant will decline substantially. A further reduction will be achieved by blending in other materials.]

In the first few years, as the production of grass as a dedicated energy crop ramps up to production levels required to support a fixed pelletizing plant, a portable pelletizer, developed by GEC co-founder Averill Cook, may be used. This unit, on a 45 ft trailer, is expected to be able to produce 2 - 3 tons of 1/2 inch grass pellets per hour.

In 2004, Cornell University prof. Jerry Cherney contracted with VIFAM in Canada to pelletize grass from a number of fields ranging from pure timothy to mixed meadow to weeds. When Cherney compared these grass pellets to wood pellets, "he found they were about two to five per cent lower in energy than premium wood pellets and some were almost the same."

It is reported that VIFAM charges on the order of $65 per ton to pelletize with their portable unit. At this price, VIFAM, however, does not provide trained and skilled operators for their machine.

The first two to three years will also be required to revitalize long dormant fields and to establish viable plantings of appropriate high yield biomass types. Studies from the University of Illinois suggest that it may cost as much as $640 per acre in the first two years to establish high yielding Miscanthus variants.

Four Source Model

Operational grass production, once reached, could be based on a four source model such as:

1] **Farms within 25 miles of the pellet plant**, each producing 100 tons of grass in bales = 5 tractor trailer loads per farm [20 acres of dedicated energy crop land per farm @ yields of 5 tons per acre], stored at the farm until taken to the pelletizer.

A 200 animal farm will produce the equivalent of about 1,000 tons of 20% moisture crops. Thus the grass for pelletizing is about a 10% increase.

2] **Landowners** each producing 70 tons [requires 14 acres of dedicated energy crops per owner]

3] **Conservations lands** will be a significant source of land for growing dedicated energy crops. Hither to fore, the effort to preserve fields as open landscapes has been a financial liability and a drain on scarce assets for non profit organizations and foundations. If this scenario works, these fields will become assets that produce income for their stewards and thus increase their financial stability and well being.

4] **Agricultural set aside lands** could be restored to active production of dedicated bio-energy crops. This have the added advantage of eliminating a cost that must be covered by general tax revenues.

Note: Starting in Vermont, we need to inventory the Energy Sheds around the state.

Cost to Produce Grass

For estimates of harvesting cost for hay, please see <http://www.nass.usda.gov/pa/>

The 2005 Machinery Custom Rates for PA estimates mowing and conditioning costs @ $13.50 per acre + raking @ 7.80 per acre + $6.60 each for large round bales at 940 lb. This suggests a cost of about $92 per acre yielding 5 tons, or just over $18 per ton. Labor, land costs, fertilizer, fuel, depreciation, interests costs and profit factors will increase this to a $45 - $60 per ton farm gate price for a low risk crop that is cut only once, late in the year when it is convenient.

This compares favorably to mulch hay that can be sold for about $1.00 per 40 lbs bale or about $50 dollars per ton. This amount may only just cover the production and handling costs. Note that mulch hay is only produced by accident and is not an intentional economic activity.

A Wisconsin haylage economic analysis says haylage making cost is $36/acre. Shelburne Farms reports that their cost for making hay is closer to $30 per acre.

By way of comparison, a farmer in Danville, VT reports that he sells bales of top grade feed hay, averaging 35 lb., to local horse owners for an average price of $3.50 per bale. This yields him a gross $200 per ton or $600 - $800 per acre from top grade crop land. If the same costs factors are accounted for, what is his net profit per acre?

The land owner who has been renting crop land for $30 per acre per year now has some interesting new choices to consider.

Pelletizing Plant Location and Buildings

A facility for a pelletizing operation, bale buster to bagger, with a storage buffer of one weeks worth of input materials, about 2,000 tons in 1,000 lb. bales, and storage for bulk pellets as well as bagged pellets, will require on the order of 24,000 sq. feet. $100 per sq foot would have to be allowed for the construction of a new metal building on a 8" thick concrete slab.

The better, and more affordable, solution is to repurpose existing, under utilized, or empty, industrial facilities. These can be found up and down Vermont's Interstates and rail lines. These structures, already zoned for industrial business operations, and with good access to major transportation infrastructure, could be "Triple Net" leased for very attractive terms at far less cost than new construction.

Basic Pellet Plant Equipment

CPM provided these rough numbers for a facility with an estimated capacity of 4 tons per hour.

- Hammermill, Feeder....................$40,644
- Air assist discharge system....................$20,373
- Pellet Mill, Conditioner, Feeder.................... $119,613
- Cooler, Air system....................$45,949
- Rotex Screener.................... $7,831
- Bagger system.................... not quoted
- Bulk storage....................not quoted
- Rough equipment expense:.................... $345,000

A more detailed estimate form CPM remains to be analyzed in detail.

On the other hand, Bliss has a work sheet with 25 items that suggest the comprehensive price of a mill with a 4 - 6 tons per hour capacity would be on the order of: $784,200.

Wood Pelleting Plant

Budgetary Cost , 4-6 TPH, Bliss Industries, Inc., Ponca City, OK

- 1) Raw Material In-feed Bin....................$28,000.00
- 2) Raw Material Transfer Conveyor & VFD....................$9,000.00
- 3) Suspended Magnet....................$2,000.00
- 4) Hammer Mill.................... $53,000.00
- 5) Pneumatic System (Hammer mill take-away)....................$35,000.00
- 6) Mixing/Live Bottom Pellet Mill Surge Bin.................... $36,000.00
- 7) Bindicators for Surge Bin....................$600.00
- 8) Pellet Mill, Conditioner & Motors....................$209,000.00
- 9) Dies for Pellet Mill.................... $6,000.00
- 10) Spare Rollers for Pellet Mill....................$15,000.00
- 11) Counter Flow Cooler....................$27,000.00
- 12) Cooler Air System....................$16,000.00
- 13) Drag Conveyor for Cooler....................$6,000.00
- 14) Bucket Elevator for Cooler Discharge....................$17,000.00
- 15) Pellet Screener.................... $20,000.00
- 16) Bagging Bin....................$8,000.00
- 17) Bagging Bin Bindicators....................$600.00
- 18) Bagging Scale....................$13,000.00
- 19) Bag Hot Air Sealer.................... $12,000.00
- 20) Bagging Conveyor....................$6,000.00
- 21) Structural Steel.................... $85,000.00
- 22) Electrical Service & Controls....................$95,000.00
- 23) Engineering....................$35,000.00
- 24) Boiler & Hardware....................$25,000.00
- 25) Miscellaneous Spare Parts.................... $25,000.00
- Budget....................$784,200.00

Other Cost Considerations:

- 26) Front End Loader
- 27) Fork Lift
- 28) Buildings
- 29) Site & Driveway Work
- 30) Fire Protection System
- 31) Bulk Storage Bins
- 32) Bags, Slip-Covers & Pallets
- 33) Start-up Costs

- 34) Operating Capital
- 35) Rotary Drum Dryer (if needed)

Note: If a dryer is required, the equipment cost of the plant about doubles.

Pellet Production assumptions: Co-Op model

A key to the economics of growing grass for pelletizing, and extracting profits from the resultant pellets, is to never pay retail for the raw materials. It is important to flatten the value chain and eliminate as many middle men as possible. For this reason, a producer owned Co-Op is proposed as a logical organizing principle.

It is assumed that producers deliver their grass to their Co-Op at 1] no charge if they will use the pellets themselves to displace fuel oil and KWH from the grid; or 2] in expectation that their share of the profits realized from sales of pellets by the Co-Op will generate sufficient profits. The question is: What are sufficient profits? It is assumed that the profit per acre from dedicated energy crops must equal to, or be greater than, the profits from other crops that could be planted on the same prime crop lands.

For example, a top farmer will get 50 bushels of soy beans an acre from prime land. At $6 per bushel, he will gross just $300 per acre. A UVM study in the mid 1990s reported costs of $200 per acre for soy beans. In 2006, this cost factor will have increased, as costs for seeds, fertilizer and chemicals have all gone up significantly. Thus, in 2006, the net per acre for 1,100 acres of soy beans will be less than $100.

The Co-Op pelletizes bales of grass hay at a cost of operations of $80 - $85 per ton paid to a custom pelletizer. The pellets are then returned to the coop for eventual resale within the Co-Op's energy shed. If the Co-Op can establish and maintain an energy services and supply business, it might sell the pellets for $165 per ton. As a ton of pellets has the same heating energy as about 100 gallons of #2 oil, this would make the coop's energy pellets the equivalent of heating oil at $1.65 per gallon. In this model, the Co-Op would recover the cost of pelletizing and realize approximately another $82.50 with which to cover operating costs and make payments to farmers for their hay.

Given 5 ton yields, a farmer needs $20 per ton profit to make energy crops a better business choice than soybeans. If costs are in the $35 - $40 range, this suggests a farm gate price of $55 - $60 per ton.

Three Applications For Grass Energy

Application: Grass Pellets for Heating

> Energy is the most significant driving force of our economy. All commercial, institutional and industrial facilities need electric power for lighting and operating equipment and appliances. One of the major consumers of energy in these facilities is the equipment for space conditioning.

Prospective markets: Light Industry, small businesses, public buildings such as schools, town halls, town garages, post offices, libraries and, in the future, residential.

Note: On January 18, 2006, **Business Week** wrote:

> Only a month ago chances seemed good that 2006 would break the streak of five consecutive years of rising oil prices. But not anymore. Less than three weeks into the new year, the prospect that the average price per barrel for light, sweet U.S. crude in 2006 would fall below last year's nearly $57 per barrel look considerably diminished.
>
> ... On Jan. 17 prices jumped more than $2 per barrel to nearly $67. In trading on Jan. 18, oil held onto most of its gains: The price for U.S. benchmark futures contracts for February delivery fell slightly from the previous day's close, to $65.78 per barrel.
>
> In July of 2006, the price had already increased another 12% to $75 per barrel.

Economics: A **Light Industrial consumer** might consume 5,000 gallons of #2 heating oil per year. Such a customer might qualify for a 10% discount from the Net 30 day price per gallon. On January 19, 2006, Northern Petroleum's Net 30 Day price per gallon was $2.519. A typical residential customer, at 1,000 gallons per year, who paid cash within 10 days of delivery, would qualify for a 10 cents per gallon discount.

The chart below assumes a **Light Industrial customer** who burns 5,000 gallons per year w/ a 10% discount. This represents 690K gross BTUs which yields 483K net BTUs. The annual cost at January's prices is $11,335.

Fuel Costs per Million BTU Delivered by the Appliance

Fuel	Unit	Btu/unit	Cost/unit	Heat efficiency	Cost for 1,000,000 btu's
Fuel Oil	gallon	138,000	$2.429	80.00%	$22.00
Propane	gallon	91,000	$2.35	90.00%	$28.69
Electricity	KWH	3,413	$0.1356	100.00%	$39.73

Wood Chips	Ton	11,000,000	$47	50.00%	$8.55
Wood pellets	ton in bulk	16,400,000	$211.00	75.00%	17.15
Dry shell corn	ton in bulk	13,000,000 @ 15.5% H20	$122	75.00%	$12.51
Co-op grass	ton	14,700,000 @ 8% H20	$185.00	75.00%	$16.78
BCC blend #1	ton	14,700,000	$200.00	75.00%	$18.14

See: http://publicservice.vermont.gov/pub/fuel-price-report/06may.pdf

The above model was sent to me from Cornell University by Prof. Jerry Cherney, an expert in Forage Production, Management, and Quality, and was developed by Jim Grace, Cornell University Cooperative Extension of Steuben Co., NY. It has been modified and extended, and updated for this scenario.

Note 1: We expect the availability of premium hard wood pellets to remain tight, and thus the prices high, for at least another three to five years. Factors driving this are: A] European buyers offer 5 - 10 year delivery contracts which are more attractive to producers than the very short term contracts offered by big box stores in the U.S.; B] It takes up to two years to bring a new wood pellet plant on line. It is currently the case that many dealers have very low stocks of hard wood pellets.

Note 2: Hypothetically, grass pellets made by a Co-Op might be priced to Co-Op members at a point well below retail mark-ups - see page 21.

Note 3: A key comparison is between the cost per million net BTUs from heating oil, cash that leaves the local economy, and the cost per million net BTUs from Co-Op grass pellets purchased in bulk by a Co-Op member, with the cash retained in the local economy.

Currently, for a Light Industrial customer, #2 oil costs about $22 per million net BTU vs bulk grass pellets @ $18.14 per million net BTU [delivered price]. On a cash out of pocket basis, the grass pellet option appears to offer an 17.5% advantage over #2 heating oil.

The above discussion assumes that all of the fuels are burned in "basement appliances", not in consumer room heaters.

Note 4: Historically, American policy heavily subsidizes the costs of burning fossil fuels, largely through tax policy, while totally ignoring the consequence of releasing sequestered carbon into the biosphere. If we eliminated all subsidizes for fossil fuels and fairly price the costs of destabilizing the biosphere caused by burning fossil fuels, then the cost of carbon neutral biomass energy could be evaluated on a level playing field.

Until that time, biomass systems will appear to be several times more costly than fossil fuel systems.

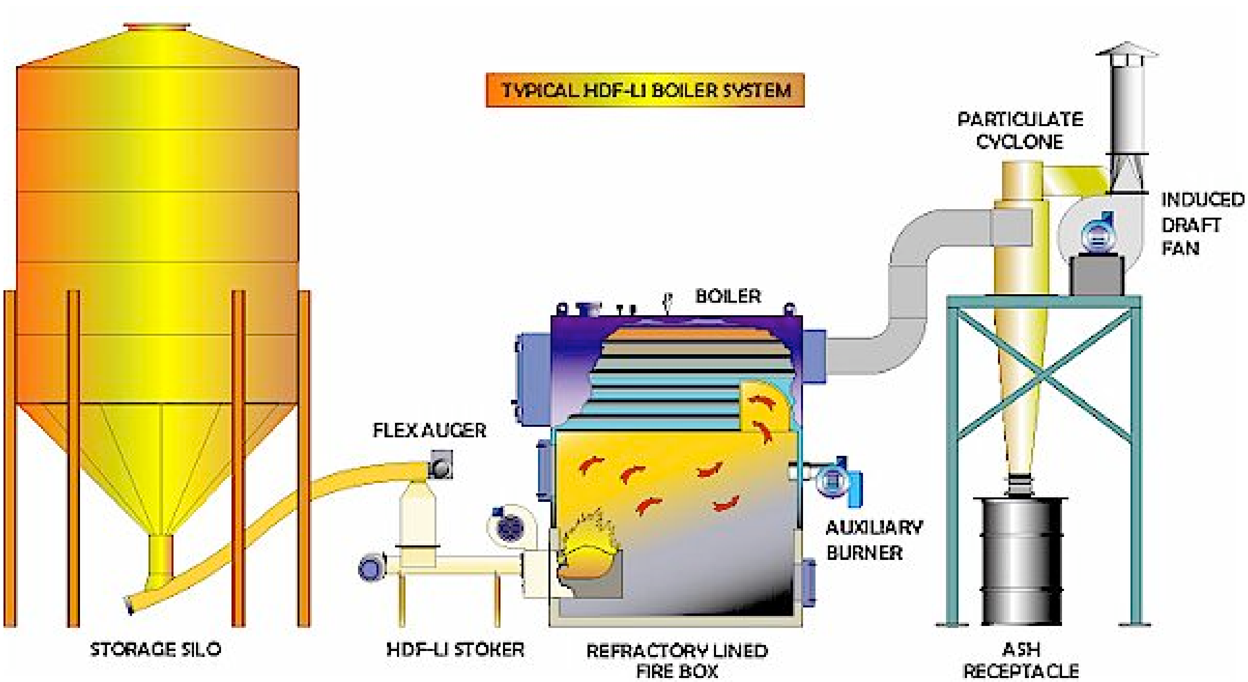
A Note on Feed Corn

The careful reader will have noticed that readily available bulk feed corn delivers a million net BTUs for less than pelletized grass. Burning corn, however, has its peculiarities and requires some additional end user intervention. The operational cost differentials of biomass fuels, as of this writing, has yet to be determined. Biomass fuels that are made from conventional annual row crops also have non point source pollution problems that need to be taken into account [See page: 13, above]. From a net energy perspective, whole kernel corn offers about a 7:1 net energy advantage, while grass pellets offer about a 14:1 net energy advantage [See the chart on page 17, above]. Today, as in ethanol production, whole kernel corn is an attractive pathway fuel that can usefully act as a bridge to other alternatives currently being developed and proven out.

Larger Industrial Applications

For light industrial applications demanding over several hundred thousand BTUs, units from **Solagen** might be used. For example, a 500K BTU, a HDF-LI Stoker unit from Solagen can be fully installed for around $100,000.

This is significantly less expensive to install than a similar size green wood chip boiler. The cost of the handling operations required by the green wood chips is the principal reason for the cost advantage of the Solagen unit. How much less expensive? 1/2 to 1/3 the cost. It is estimated that a 500 BTU Solagen unit, running seasonally for heat only, would require 80 - 100 tons of pellets per year. This would could be accomplished with 4 - 5 deliveries of bulk pellets in the equivalent of a Blue Seal Feed truck with a 20 ton capacity.



It should be noted, however, that when demand for space conditioning energy requires boilers of 1 million Btu/hr. size and larger, the total life cycle economic advantage starts to swing back towards wood chip systems. The bigger the heating system, the more significant a factor the difference in the fuel costs between chips and pellets ($35-$45/ ton) vs. ($165 - $250 ton) makes in the life-cycle cost analysis. Grass pellets in bulk might be sold to a large customer for approximately the cost of feed corn in bulk, currently about $165 a ton. This would tend to push the cross over point to some what larger installations.

Taken together, it can be seen that grass pellets, used in systems below 500K BTUs are complimentary to and synergistic with a strategy of using green wood chips in installations of over 1 million BTUS. This "and both" strategy is more economical for the smaller installations and allows the wood chips distribution system to focus more efficiently on the larger customers. This "and both" strategy also allows us to have appropriate tools for managing both open lands and wood lands. Neither asset is neglected, or abused, at the expense of the other.

Application: Grass Pellets for Generating Electricity

[A GEC Research project for 2006]

A study from March, 2003, Prepared for the CONEG Policy Research Center, Inc. Northeast Regional Biomass Program, provides this quote:

> From a technology standpoint, the utilization of biomass [primarily from the forest products industries] for power production is a commercially proven option for electricity generation. Biomass currently provides about four percent (7,500 megawatts) of all the electricity produced in the U.S. The vast majority of this electricity production comes from approximately 350 existing biomass power plants that utilize established direct combustion boiler/steam turbine designs. [4]
>
> In addition to traditional biomass energy conversion technologies, a number of advanced technologies, such as biomass gasification, pyrolysis, and micro-scale biomass units, are in development, but are not ready to be deployed on a commercial scale. Accordingly, the U.S. Department of Energy asserts that the potential exists for biomass power to grow to an industry with 30,000 megawatts (MW) of capacity, employing 150,000 persons in mainly rural areas, and producing 150-200 billion kilowatt-hours (kWh) of electricity by the year 2020. [5]
>
> <http://www.nrbp.org/pdfs/nrbp_final_report.pdf>

One example of a small, pre-commercial, biopower system that has converted grass pellets to heat and power is the BioMax®, being prepared for commercial market entry by Community Power Corporation of Colorado. The following link describes this testing and shows a picture of the biopower system that gasified and compared Timothy hay pellets to wood pellets and wood chips. <http://grassbioenergy.org/res/pellet_stove_demo.asp#cpc>

CPC has been developing its modular biopower systems since 2000, and has become a leader in the field. The company has developed a 15 kW system several of which were placed in the field for Product Validation trials starting in 2002. Based on that experience the company developed a 50 kW system for placement at Mt. Wachusett Community College in early 2006 as part of a combined heat and power demonstration. CPC has also adapted the BioMax® 50 technology to the BioMax®15 and produced a prototype BioMax® 25 that began initial testing in December 2005.

As a rule of thumb, CPC's systems convert 2 pounds of biomass to 1 kWh of electricity and 2 kWh [6,826 BTUs] of thermal energy. Electrical efficiencies of 25% have been measured. As new, more efficient, gas-based prime movers come to the market (solid oxide fuel cells for example) electrical efficiencies should increase. In a combined heat and power application (when both heat and power are generated) the BioMax® can achieve efficiencies greater than 70%. It is estimated that grass pellets on average will have about 14% less energy than a wood pellets, therefore, it will take 14% more grass pellets by weight to obtain the same energy as from wood pellets.

BioMax® units have already demonstrated the ability to successfully gasify wood chips, wood pellets, grass pellets and grass cubes, as well as corn. Gasifiers, such as the CPC BioMax® units, work better if their fuel supply is consistent in character: size, moisture content, energy content etc. Standardized grass pellets and cubes for use in a modular biopower system would eliminate the labor and machinery costs required to chip, sort, dry, and remove tramp materials from green wood.

The BioMax® 25 and 50 have both been designed for continuous operation. This will greatly improve the economics of modular biopower since more energy will be delivered annually. A BioMax® 50 has already demonstrated six days of continuous operation. Automation is another important factor governing economics, since a highly automated system will reduce the labor required for operation. The BioMax® 25 and 50 are fully automated from startup to shutdown, and can even be operated remotely via the internet.

Another major contributor to economic performance in the BioMax® is the cost of feedstock. Thus, it is of interest to understand the benefits of low cost grass grown and gasified in Vermont.

Today, BioMax® units make the most economic sense when used in a combined heat and power mode where maximum efficiency can be achieved. The BioMax® 25, producing about 170,000 BTUs of thermal energy, has been developed to capture the waste heat in water, a very convenient medium for thermal transfer. The heated water can be used for space heating, water heating, or it can be stored in a tank for later use.

The BioMax® has been demonstrated in both off-grid and on-grid applications. Off-grid prices can be very high; therefore, the BioMax® is immediately competitive in most of these applications. For grid connected applications the key is to locate a system in areas with high utility prices such as in areas served by Green Mountain Power where the average is $0.129 per kWh or in the Boston area where National Grid is charging $0.1353 per kWh.

The capital cost for a BioMax® is a function of many variables --- the application, location, access, interconnection expense, and biomass type to name a few. Currently the systems are made in small quantity at CPC's Colorado facility. But even with these limitations a 25 kW system could be installed currently for ~ $150,000 and a 50 kW for ~$250,000. These prices are expected to decrease significantly with volume manufacture.

From the point of view of how much demand for grass pellets or cubes the BioMax® units will create per year, consider that a BioMax® 50 operating for 6,480 hrs/yr would use about 324 tons of wood pellets or 370 tons of grass pellets having slightly lower energy content. In the process it would generate 324,000 kWh of electricity and over 600,000 kWh of thermal energy. [Data from CPC]

If the target price for production units of the above BioMax® 50 unit were to be $175,000 - FOB their factory in Colorado. This is about $75,000 more than a Solagen boiler that is rated at 500K BTUs. Perhaps $100,000 more than a Solagen unit if shipping and installation is included. The question is whether the Biomass 50 will produce enough kWe per year to displace a sufficient value of grid electricity to justify the premium. In part, this will be determined by the future price of electricity from the grid, which is not expected to decline.

In the example above, assuming a future electricity price of $0.14 per kWh, the power would be worth ~ $45,000 per year if it could be used to displace grid electricity at its retail rate. If we assume that both the BioMax® and Solagen units produce the same amount of thermal energy per year using comparable amounts of feedstock, then the incremental value of the electricity can be used to recover the additional capital cost of the BioMax®. On that basis, a simple break-even would occur in a little over 2 years.

From the above, we can see that a mix of BioMax® units into the customer base for pellets/cubes might be a future market for grass pellets. Only three such BioMax® 50 units would account for 18% of the production of a pellet mill producing 6,000 tons per year.

Robb Walt, co-founder of Community Power Corporation, has expressed strong interest in working with a pilot project in Vermont that would be based on grass cubes or pellets.

Sample of CHP Research in Europe:

Research in CHP and Stirling engine-based CHP, fueled by wood chips with 40% moisture content, has been done in Denmark, See:

<http://www.videncenter.dk/exportcat/combined_heat_and_power.pdf>

This research has now be taken to a second stage in Austria:

<http://bios-bioenergy.at/bios01/biomass/en/stirling.html>

> Within the scope of a R+D&D (research, development and demonstration) co-operation of the BIOS BIOENERGIESYSTEME GmbH, MAWERA Holzfeuerungsanlagen GesmbH and the TECHNICAL UNIVERSITY OF DENMARK, a small-scale CHP technology with a 35 kWel and a 75 kWel Stirling engine for biomass fuels has been designed. The CHP technology with a 35 kWel Stirling engine has been successfully tested for more than 7,000 operating hours (status March 2004). A commercial project has already been realised (**Project Oberlech**). A pilot plant with a 75 kWel Stirling engine has been put into operation in autumn 2003 and has been operated for more than 2,000 hours (until march 2004).

BIOS BIOENERGIESYSTEME GmbH has also developed an bio-mass fired CHP plant based on an ORC process (Organic Rankine Cycle) with "a newly developed Fuzzy Logic control system." This unit produces 400kW and 8 million BTUs of thermal energy for space conditioning or other uses. Grass pellets or green wood chips may be used to fuel this ORC CHP system. Bios Bioenergiesysteme reports that 30 of these units have already been installed in Europe.

Combined Heat & Power Summary:

While densified biomass for generating electricity, or a Combination of Heat and Power [CHP], is still in the early stages of commercialization in the United States, smart, networked and distributed power generation will offer many advantages in terms of: total efficiencies more than twice those of existing coal fired plants; security created by redundancy; fuel independence with reliable domestic supply; and reduction in transmission line losses. It will also create incentives for community cooperation for robust and reliable electricity supplies.

This new model would enable us to look at the generation of electricity from the point of view of the first mile out from the home, rather than the last mile in from some remote, centralized power plant. The distributed solution will make possible local, self healing, cooperating mesh networks of many small, local, micro-processor and sensor managed generators for secure provisioning of electricity.

Application: Feed-stock for Ethanol Production

Ethanol from grass produces twice as much energy as ethanol from corn and there is a “95 percent emission reduction from producing cellulosic ethanol over gasoline production in all three production phases—farming, refining, and use.” Corn based ethanol appears to only offer about a 13% reduction on green house gas emissions.

The Los Angeles Times writes on January 27, 2006, a “new study, to be published today in the journal Science, lead author Alex Farrell and five other UC Berkeley researchers ... Farrell said the new study found that corn-based ethanol only reduces greenhouse gas emissions by 13%, but the fuel's effects on emissions varies depending on what it's made from. The study found that ethanol made from plants such as willow trees and switchgrass "offers large reductions in greenhouse gas emissions."

Source:
<http://www.latimes.com/business/la-fi-ethanol27jan27,1,4442662.story?coll=la-headlines-business>

Live Science also reviewed the new research from UC Berkely:

“... corn-based ethanol gas reduce petroleum use by 95 percent, it also reduces greenhouse gas emissions about 13 percent, although that decrease is within a range of uncertainty for the imprecise data involved.

"Making ethanol from corn is a good thing if you want to offset fossil fuels from overseas," Kammen told *LiveScience*. "On the greenhouse gas side of things, it is not clear if corn, as grown today, is a good thing. We just don't know yet, but it appears to be a mildly good thing."

A woody solution?

While corn-based ethanol is an improvement over gasoline, ethanol from woody, fibrous plants would pack even more energy. Willow trees, switch grass, farm waste and specially grown crops are all feasible sources.

The main energy components of these plants are cellulose and lignin, which produce more energy per unit—in the form of breaking hydrogen bonds—than the starches from corn.

"It looks to be that you can get just about twice the amount of energy by going the cellulose route, and greenhouse emissions are very small," Kammen said.

Assuming replant rates equal harvests, there is a 95 percent emission reduction from producing cellulosic ethanol over gasoline production in all three production phases—farming, refining, and use.

Source: http://www.livescience.com/environment/060126_ethanol_better.html

Market for Grass Pellets:

To develop a market for many tens of thousands of tons of grass pellets for heating and CHP applications will require some very creative seeding and leasing of pellet burning boilers and CHP systems. At worst, this should be a revenue neutral program, at best it is a segment of a vertically integrated market solution: grow grass, make pellets, installing equipment, training, maintain heating units, deliver pellets, etc. As a business design consideration, this integration is probably best presented to the end-user as an all inclusive service contract.

The comprehensive and integrated service contract approach as already been developed, implemented and matured successfully in Europe.

A further requirement is that the government and private sector must work together to help create the market by creating demand for the fuel. All new government construction programs, for example, should be required to include at least a component of biomass energy use.

A Personal, Prospective, Case Study:

I might retire to a large, old, plank house, with no insulation, that probably has at least a 180 day [4320 hours] heating season in Northern Vermont. This property also has 18 acres of crop land that currently yield $30 per acre in rental income, $540 per year. Alternatively, this land could be put into grass as a dedicated energy crop for pellet production.

What story do the numbers tell us?

If my pellet heating system, perhaps one of the new Mount Vernon units with state of the art combustion technology from Quadrafire, averaged 5 pounds of pellets per hour, it would burn about 11 tons of pellets per season. I might expect the fuel made from my own grass to cost on the order of $165 per ton in bulk from my local Coop My annual pellet cost might be $1,815. From this we subtract the $110 per acre I earned selling my 18 acres of grass to the Coop. This leaves me with a net positive $165 income after paying for a year's worth of heat. I might even earn a small bonus from the Coop at the end of the year.

The 11 tons of grass would represent about 100 million net BTUs delivered. It would take about 1035 gallons of #2 heating oil to deliver the same net benefit, at a cost of about $2,700. Thus, if I only burned grass, I would save the entire $2,700 and have another $165 in my pocket.

Clearly, I am better off as a producer of dedicated energy crops on my 18 acres than I am if I rent it out: $110 per acre vs $30 per acre. Producing offers a 3.7:1 advantage over renting.

The scenario would be even more favorable if a reasonable CHP solution scaled for a residence could be found or developed. Again, if we are able to establish a robust new energy business sector based upon grass biomass, it will be much more likely that private sector companies will invest in R&D in order to participate and compete in this new business domain.

Pellet Boilers:

Dennis Buffington, professor of agricultural engineering at Penn State, has created a list of systems for Commercial applications (100,000 TO 500,000 BTU/HOUR):

This Commercial list is at:

<http://energy.cas.psu.edu/EnergySelector/commercial.html >

Other Considerations

All of the above not with standing, Jerry Cherney, Cornell University's E.V. Baker Professor of Agriculture, points out that the context in which biomass pellet plants will operate is about to change in some very important and advantageous ways. Prof. Cherney writes:

1. The Green House Gas Credit Scenario

The basic principle, being practiced to some degree by all countries that signed the Kyoto Accord (not including the USA), is to manage national and international climate change risk using emissions trading schemes. Climate change risk is transferred to companies and organizations, requiring them to develop a framework to manage their greenhouse gas exposures. Carbon trading and tax credits provide a means to give monetary value to the superior environmental characteristics of biomass fuels, such as grass pellets. If countries are required to reduce GHG emissions, they have to provide some powerful incentives to organizations. The USA has so far chosen to deal with global warming by pretending that it does not exist, contrary to the opinions of most all scientists around the world.

The emergence of the Chicago Climate Exchange, the collaborative of Eastern states addressing carbon emissions, and the Green Tags market are further evidence of additional incentives.

2. "Open Spaces" plans

At one time the Northeast was mostly forest land and it is slowly reverting back to forest. A certain amount of open spaces are required to maximize biodiversity from an ecological standpoint, and to maintain a proper mix for aesthetic purposes. Recently outside advisory groups to Cornell University ranked "Maintaining Open Spaces" as their number one concern in NY state. Cornell University set aside significant funding to address this issue in NY state. This is more of a Northeast USA issue than a national issue, but it will continue to increase in importance here.

3. Grass lands for animal waste management

All large farms with animals in the country now (or very soon) will need to generate CAFO (confined animal feeding operations) plans for whole farm nutrient management. Probably all farms will eventually need to do so. The problem is usually too much manure relative to the acreage where it can be safely spread. Most nutrient management planners now see the benefit of having a grass acreage for safe management of excess manure. Grass acreage appears to be increasing in NY, no stats to prove this. [Don Davis reports that this is already becoming a substantial issue for him and his 200 animal operation in Peacham, VT -- JPG]

While it is difficult to put a price on any of the above three factors, any one of these three issues could easily evolve into sufficient justification to substantially 'subsidize' a grass pellet industry in some fashion, such that it would be quite profitable. The likely future offsets the present government (state and federal) attitude towards grass.

Why divert resources to grow grass for energy?

There are, for example, at least 1.5 million acres of idle land in NY state. As a result, most farmers in NY have an acreage that is growing some type of grass that is just sitting there. Even in the rainiest summer on record there would still be no problem making hay for biomass (unless it was in a swamp, and you could still do that in a normal year). You can cut grass for pelletizing whenever it is convenient, and harvest it when it has dried to 14% and you have the time. The issue with grass biomass is not will it compete significantly for time/labor resources. It is much more about wether or not there is a market for it. Five possible market opportunities to consider:

1] Heating - pellets and cubes
2] Electricity generation - pellets and cubes
3] Animal bedding - absorbs up to 7 times its weight in water
4] Seed bed with seeds and fertilizers pre-mixed in the pellets
5] mulch - one truck load of pellets = two of conventional mulch.

This scenario only considers the first two of these potential markets. Grass grown as a dedicated energy crop may simply be too valuable for the bedding, seeding or mulch.

Acres owned by non-farmers and summer residents, land in agricultural set aside programs, and acres in the stewardship of conservation trusts, who are looking for ways to convert land operating at a loss to land generating a profit, are prime candidates for growing grass as a dedicated energy crop. A land owner/manager could earn money from what once was idle land, rather than pay taxes and $50 per hour for brush hogging just to keep the land open.

Clearly, if a farmer can raise top quality feed hay for the horse trade, and sell it for between $200 per ton [$3.50 per 35 lb. average bale w 3 tons per acre] and $430 per ton, less shipping, she should do so. This, after all, is a yield of between $600 and $1,290 per acre. Pellet grass lands yielding $300 per acre do not compete with the bottom range of high quality feed hay.

Obstacles

Tim McKay writes:

There are enormous obstacles to achieving this scenario. I will comment only on the grass production side of the equation.

I work with virtually all dairy farmers in 2 counties, and a large number of other landowners, and have for 28 years. There will be only a handful of dairy farmers willing to try this. After several years, if other people are successful in this enterprise, a few more would slowly convert. Production of grass would rely on non-farm, or part time farm landowners. Custom operators would have to be integral to the scheme (middleman). Custom operators would develop as soon as the market firmed up.

Bringing 2000 acres into RCG production within 30 miles of here is virtually impossible. You would find only a few acres here and there already in RCG, and the cost of re-seeding land will be a huge obstacle. Using the existing low value grasses and forbs in the fields you are envisioning would be do-able, but yields will be 1 ton per acre or less to begin with. Fields not being cropped now are not cropped for a reason - either they are remote, or they are tiny, or they are rocky, or they are droughty, or they are acidic, or they are infertile.

Cooperative ventures used to be a part of our agrarian culture, but no longer. Vermonters are very independent people. There are periodic attempts at cooperatives of all types in the dairy business, with precious little success. Dairy cooperatives today are cooperative in name only. For instance, it makes total economic sense to buy grain cooperatively by the railcar load. It doesn't happen. It makes sense for milk to be trucked cooperatively, but milk trucks from different companies pass each other constantly on all our back roads, one going to Joe Blow, the other to his neighbor. Both truck away partial loads. Cooperative trucking doesn't happen.

Grass Energy in 2006

The conditions for a well integrated grass energy business supporting heating applications and ethanol production exist today. Grass energy supporting a CHP strategy looks favorable in the future. The opportunities for grass energy will yield improved benefits as the convergence of microprocessors, sensors, communications and CHP enable us to move to a new, distributed, energy strategy.

The analysis above suggests the need for a vertically integrated solution, or strong partnerships, with businesses selling boilers and CHP solutions. The value of this integrated equipment, energy and services strategy has already been proven in Europe.

If we are successful in implementing our mission, we can anticipate, in the sense intended by Buckminster Fuller, that 1] we will have improved the economic options for 350,000 mid-sized farmers; 2] we will have contributed to the formation of a low impact and low carbon economy with better security; 3] new tools for sustaining a healthier environment will have been developed; and 4] a grass energy sector will have been created along with the necessary culture to support it.

We can do this. We put a man on the moon in less than 10 years 36 years ago for 135 billion in 2005 dollars. We can certainly chose to embrace a Grand National Challenge to a shift to a 100% green and renewable carbon neutral economy. If we do not wish to experience the biosphere destabilizing into very unfavorable conditions, it is imperative that we work to eliminate the release of sequestered carbon into the atmosphere. Grass energy can power us to these remarkable and ambitious goals.

Supporters

In 2005, The Grass Energy Collaborative, Inc. received an initial enabling grant from the Vermont Community Loan Fund, with additional support and resources provided by The Wendling Foundation.

The Grass Energy Collaborative has the enthusiastic support of two large farms on Lake Champlain in Shelburne, VT: Shelburne Farms and The Meach Cove Trust. These two farms, along with some neighboring land, can provide enough acres of grass to supply the pilot project during 2006. In addition, existing unused grain silos at Meach Cove can be utilized for grass pellet storage, significantly reducing capital needs for the first year of operation.

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Editor's note

Clearly, many details remain to be developed and obstacles over come. The Grass Energy Pellet Project of 2006, to be hosted by Shelburne Farms and The Meach Cove Trust, will provide an opportunity to further explore the challenges and benefits associated with this vision for grass. The Grass Energy Collaborative is actively seeking donors who wish to support this effort.

Book

Rick Darke's The Color Encyclopedia of Ornamental Grasses, Timber Press - 1999, is a fine coffee table book on grass.

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Additional Material

Terms

Biomass

<http://en.wikipedia.org/wiki/Biomass>

There is a link at the bottom of this page to "Biomass as Feedstock for a Bioenergy and Bioproducts Industry", [The Technical Feasability of a Billion-Ton Annual Supply] an April 2005 joint study sponsored by the United States Department of Energy and Department of Agriculture: [78 pages].

Combined Heat and Power

<http://en.wikipedia.org/wiki/Combined_heat_and_power>

<http://www.chpcentermw.org/03-00_chp.html>

Stirling engine

<http://en.wikipedia.org/wiki/Sterling_engine>

This Wiki entry uses a picture of a $65,000 (w/o biomass system) 50kW, CHP unit produce in Michigan by STM Power, Inc. This unit does not require fossil fuels as it can be fueled by a number of renewable energy sources. Seven of these units are presently being installed in New Jersey. <http://www.stmpower.com/. For the foreseeable future, Stirling engines are unlikely to be fueled by grass.

Evidence for need to reduce carbon in the atmosphere

November 25, 2005
An ice core about two miles long — the oldest frozen sample ever drilled from the underbelly of Antarctica — shows that at no time in the last 650,000 years have levels of the greenhouse gases carbon dioxide and methane been as high as they are today.

<http://www.latimes.com/news/nationworld/nation/la-na-ice25nov25,0,2141135.story?track=tothtml>

Also see the 2006 film "An Inconvenient Truth" by Al Gore.
<http://www.climatecrisis.net/>

Biomax: Additional information

The FAQ linked to on CPC's home page is an excellent resource:

<http://www.gocpc.com/>

In March 2005, Richard Bergman, Research Chemical Engineer, USDA, created a very informative 20 slide Power Point presentation on the BioMax® family of products:

Small Modular and Distributed BioPower Systems

Applications and Demonstrations in California

<http://biomass.ucdavis.edu/pages/forum/2nd/Bergman.pdf>

CHP as an Alternative to Nuclear Power

In the UK, it is estimated that half of the homes are suitable for micro-CHP installations. Together, it is estimated that they would generate as much electricity as all of the UK's nuclear power plants combined.

In 1997, the US Dept. of Housing & Urban Development reported: The composition of the 112 million housing units of the American housing stock is presented in Table 1. Of these housing units about 3 percent are seasonal units and nearly 9 percent are vacant. Of the nearly 100 million occupied units in 1997, nearly 66 percent are owner occupied.

<http://www.huduser.org/periodicals/ushmc/Fall99/summary-2.html>

If half of the US housing stock, 50 million residences, operated 2 kWh micro-CHP units for 10 hours per day, in aggregate they would produce 1 billion kWhs per day, or 365 billion kWhs per year. This would be approximately 8.9% of total annual US demand of 4.1 terrawatt hours. The total power produced by all of the nuclear power plants in the US is about 800 billion kWs, or 19% of total demand. An installed base of micro-CHP units in 50% of US homes would equal about 46% of all of the electricity produced by all of the nuclear plants currently operating in the US. This would have a significant impact on future radioactive waste storage costs and risks as well as decommissioning costs of nuclear plants that would not have to be built. Similarly, we could establish policies to encourage much larger scale CHP units in industrial plants and business office buildings.

We put a man on the moon in less than 10 years 36 years ago for 135 billion in 2005 dollars. We can certainly chose a policy to make a similar investment in our future for a renewable micro-CHP option for the security and independence of our homes.

Sources:

<http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html>

<http://en.wikipedia.org/wiki/Apollo_program>

Background

I first joined the ranks of those expressing these ideas in 1997. At that time, I saw fuel cells as the key component in the CHP strategy. It is now clear that boilers and electrical generators burning biomass fuels will be an earlier catalyst for the convergence of communications, microprocessors and sensors that will produce the first examples of what will become the Intelligent House story. For more on my thoughts in 1997, please see:

<http://www.penfield-gill.com/presentations/highland.htm>

<http://www.penfield-gill.com/presentations/aug97/intellihouse.html>

About the editor

<http://public.xdi.org/=Jock>

A word about links

Some of the hyper-links to newspaper web sites may require either registration or a payment to view the referenced documents.