Multidisciplinary Academic Demonstration of a Biomass Alliance with Natural Gas

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***Abstract* –** *Recent increases in prices and imports of natural gas are posing threats to university budgets as well as to the U.S. economy and trade balance. In the near term, biomass in various forms is the most available renewable energy source in the USA, particularly in the wild land -urban interface. The possibility of gasifying biomass and developing a local Biomass Alliance with Natural Gas (BANG) so that the biomass gas (BG) can supplement natural gas (NG) could have many campus, local, regional, national and international benefits. An analytic cost estimation (ACE) method is used to facilitate assessments of various BANG systems and to determine NG prices at which BG systems can deliver electricity at competitive costs. ACE is based upon the approximate linear relationship between cost of electricity (COE), Y, and cost of fuel (COF), X, i.e., Y = K + SX, as seen in detailed cost analyses of many electrical generating systems. This paper focuses on the development of a multidisciplinary academic demonstration (MAD) platform for a campus educational and research effort. It is directed towards minimizing the cost of electricity and heat on campus while conducting research and development on both agricultural and engineering aspects of green fuel technologies that use biomass to supplement or replace natural gas. Biomass stores are abundant, particularly at the wild land -urban interface represented in north Florida. Engineering's R&D focuses on the many thermo -chemical factors that can reduce S and K of BG systems at NG facilities. A Biomass Focused Forest Management Training (BFFMT) program is also underway with the participation of the USDA Forest Service, the University of Florida (UF), the Southern Regional Extension Forester and the Southern States Energy Board. Its purpose is to develop a training program to encourage the use of woody biomass for bio -energy production in southern communities at the wild land -urban interface. This BFFMT program will help the development of multidisciplinary student and faculty teams to investigate and resolve obstacles for the successful implementation of campus and community BANG programs. As the state's land grant university UF is well positioned to develop new knowledge that could be extended to interested stakeholders throughout the Southern United States. Developing knowledge and training engineering and agricultural students to apply the technologies of local biomass production, delivery, processing, gasification and use with gas turbine facilities will lower greenhouse gas emissions, provide jobs, stabilize local economies and reduce our dependence on imported fuels.*

***Index Terms* –** *Biomass gasification, wild land -urban interface, forest management training, cost of electricity*

INTRODUCTION

After the oil crises of 1973 and 1979 co-utilization of coal with natural gas (NG) in boilers designed for oil was considered as an alternative to $35/barrel oil [1]. A successful demonstration at an industrial scale was achieved in late 1985 [2]. When to regain market share the OPEC cartel in 1986 abruptly lowered their price of oil to the $10 level, US interest in oil alternatives quickly disappeared, as did funds for research and development on energy alternatives. Oil has recently risen to the $45/barrel level, the highest it has ever been (even after correcting for inflation). Interest in alternative fuels is again at a high level. and to a large extent we must start from were we left off in 1986.

Last year the University of Florida hosted the first International Conference on Co-utilization of Domestic Fuels (CDF). Its purpose was to examine various CDF technologies and the energy, environmental, and economic (EEE) benefits of blending available domestic fuels in eco-friendly thermo-chemical reactors for electrical generation, waste disposal, and production of gaseous fuels, liquid fuels, and chemicals [3]. Most of the CDF presentations covered technologies for co-using coal with various forms of biomass. Biomass, a renewable CO_2 neutral fuel, is currently considered to include forest residues, agriculture residues, energy crops, municipal solid waste (MSW), refuse derived fuel (RDF), construction and deconstruction (hurricanes!) debris and human and animal solid waste (bio-solids).

Looking back some half million years, the use of biomass as a fuel is human-kind's oldest technology. With the industrial revolution, biomass was displaced by fossil fuels which have become the primary source of energy in developed countries. However, with the 1973 and 1979 energy crises, the use of biomass was re-considered as a supplementary fuel for Florida [4, 5]. The co-utilization of domestic fuels (CDF) strategy [3] by focusing on the use of biomass in small percentages in existing fossil fuel facilities is somewhat different in that it requires a reconciliation of fuel communities that traditionally compete. The biomass-coal co-firing form of CDF requires a much smaller renewable subsidy than windmills or solar photo-voltaics [6] to compete with a coal or natural gas based electric generation. The biomass-coal co-firing option is somewhat tainted among environmentalists because of coal's mercury, SO_2 and CO_2 emissions. Biomass-natural gas co-utilization is obviously more eco-friendly.

In the last two decades, natural gas (NG) combined cycle (CC) electrical generating systems have been the main additions to the national electrical generating fleet. The low capital cost of NGCC plants, the low price of natural gas, and the low carbon intensity of NG have been the drivers of this trend. Unfortunately, because of a massive drain on our domestic NG resources, USA imports have reached about 20% of consumption and NG prices have increased from the $2/MMBtu level to the current $6/MMBtu level. In view of the relative ease of converting biomass into liquid or gaseous fuels, it is now timely to consider seriously biomass alliances with natural gas (BANG).

THE NEED FOR BIOMASS ALLIANCES WITH NATURAL GAS (BANG)

Table 1 gives the gross properties of various fuels that are most relevant to investigation of CDF combinations. Corrections to dry, ash, nitrogen, and sulfur free (DANSF) conditions have been made. Natural gas (NG), consisting mostly of methane, is by far the premium fossil fuel, having the lowest carbon intensity and the lowest trace pollutants and toxic emissions.

	Ultimate Analysis (wt%)				Emission properties			
Name	C	H	O	FC	VT	HHV MJ/kg	CarbonEF mmTC/EJ	E/vol relative
Natural gas	75	25	0		100	54	14	
Oil	88	12	0		100	43	20	
Hard coal	85	5	10	49	33	30	28	50
Soft Coal	70	5	25	42	58	27	26	27
Wood	49	7	44	19	81	18	27 (0*)	11
Cellulose	44	6	50	12	88	10	44 (0*)	9

* allowing for CO_2 absorption during biomass growth

TABLE 1
PROPERTIES OF FUELS FOR CO-UTILIZATION

A generation ago, national policy discouraged utilities from using NG, a premium fuel, so as to make it more available for residential heating and cooking. However, with the development of high efficiency, low capital cost natural gas combined cycle (NGCC) systems, this tradition was abandoned. To alleviate recent high natural gas cost problems countries with abundant natural gas resources have been encouraged to develop liquefied natural gas (LNG) plants. Greater competition on the supply side could restore prices towards earlier levels. On the other hand, some industry officials believe "the costs and complexities of importing LNG to the US are so enormous that only a handful of large companies will succeed- and only if a combination of key ingredients falls into place. Furthermore, with the rising demand for natural gas in industrial countries in the European Union, Japan, and in populous countries such as China, India, Malaysia , Indonesia, and others, competition on the demand side could maintain current high levels or even higher.

Another way of alleviating high NG prices would be to convert local biomass into gas (BG), which is much simpler to accomplish than gasifying coal. If the BG product is non-condensable at room temperatures it is here called bio-gas (BG). If it is condensable it can be called bio-oil (BO). Both can be co-utilized with NG at a nearby NG facility. Essentially, the construction of a biomass gasifier or liquefier and cleaning system, matched to the nearby biomass supply, can deliver supplementary bio-gas or bio-oil to NGCC systems. If the combustion turbine is robust, the retrofitting cost of the NGCC facility should be modest. The BG might also be used as a supplementary fuel for the heat recovery steam generator (HRSG) or simple NG boiler- steam turbine system.

THE ANALYTICAL COST ESTIMATION (ACE) METHOD

This effort began as a short term exploratory assessment of the possibility of retrofitting a typical NGCC system to accommodate some biomass syngas [7]. A simplified analytic cost estimation (ACE) method was used to compare the cost of electricity (COE) for a NGCC system vs. a BIGCC system at various costs of fuel (COF). The current method of relying on complex accounting type analyses not only requires expensive programs, but often gets lost in details and assumptions as to uncertain inflation rates, interest rates, facility lifetimes, fuel costs, etc. Of course, once a promising technology has been identified by the ACE method, a detailed cost analysis would be appropriate before initiating the project.

The Analytical Cost Estimation (ACE) method has been used in two recent papers [7, 8] to explore the competitiveness of BGCC systems vs. NGCC systems at various natural gas and biomass fuel prices. The ACE method is based on the linear relationship seen in many detailed cost analyses of the cost of electricity (COE), or Y, vs. cost of fuel (COF), or X, i.e.

$Y = K + SX$ (1)

Here, Y (COE) is usually given is in cents/kwh, and X (COF) is usually given in \$/MMBtu (M when in association with Btu means thousand). In (1) S is the slope of the Y(X) line in cents/kwh/\$/MMBtu or 10,000 Btu/kwh. As discussed in [7], we can relate S to the net plant heat rate (NPHR) [9, 10] or to the efficiency via

$S = NPHR/10{,}000$ (2) or

$S = 34.12/Eff$ (3)

The constant K (in cents/kwh) mainly reflects the capital investment, the normal rate of owner return and operation and maintenance (O&M) expenses. Lowering K and S as much as possible so to lower the cost of electricity is the goal of true competition (and deregulation!). For each fuel type fuel competition is intended to lower X= COF..

In [7] K and S for both the NGCC system and the BGCC system were related to the power level (P in MW) by

$K = K1/P^{\alpha}$ (4) () and

$S = S1/P^{\beta}$ (5))

A study led by a United Technology Research Center (UTRC) [11] gave graphical Yn(Xn) relations for NGCC plants of 70 MW and 500 MW. Using the slopes and intercepts of these two straight lines, it is simple to evaluate the four parameters in (4) and (5). The results approximately are $K_1 = 4.8$, $\alpha = 0.20$, , $S_1 = 1.11$, and $\beta = 0.1$. This provides reference COEs for NGCC systems at any power level and cost of NG. The solid lines in Figure (1) show the NGCC Y(X) lines for 10, 100, and 500 MW calculated from this equation. The dotted and dashed lines are for 40% efficient BGCC systems with K values of 2.6 for the lower line and 4.2 for the upper line, a reasonable range for current technology. Focusing on the 100 MW NGCC case one sees that at \$2 MM/Btu the NG COE is 3.3ct. kWh. This price can be matched by the BGCC cases at about 0.8 and -1.2 ct/kWh respectively. On the other hand if NG is at \$6/MMBtu the COE would be 6ct/kwh. For the high NG biomass at \$4/MMBtu could match the NG COEs, a good price for the biomass supplier. For the low NG biomass at 2\$/MMBtu could match, which might be an adequate price for an efficient biomass supplier.

ANTARES GROUP INC. REPORT (AGIR) AND ACE

Two technical papers [7, 8] were published using the ACE method on BGCC vs. NGCC systems that essentially encouraged green alliances of natural gas with biomass for utilities' total emission reduction (GANGBUSTER). Subsequently, one of us (AG) gained access to a massive Antares Group Inc. report (AGIR) entitled, "Assessment of Power Production at Rural Utilities Using Forest Thinnings and Commercially Available Biomass Power Technologies" [14]. This study gave quantitative results for eleven technologies that might be applied in the wild lands-urban interface. The AGIR eleven COE vs. COF tables were based upon standard methods of utility cost analyses. We used these tables as quantitative "data" to determine the magnitudes of K and S for the eleven biomass fueled or co-fueled electrical generating technologies. At the same time, we found that our ACE method could usefully serve to interpolate and extrapolate the AGIR results to power levels and fuel supply costs not specifically investigated in the AGIR. Applying the ACE methodology to the results of eleven economic technologies, Green and Jie [15] found that all COE vs. COF could be fit by regression (R> 0.95) with the 3 parameter Y(X) relation

$Y = K_o + K_1/P^{1/2} + S_1X/P^{1/4}$ (6)

The parameters are given in Table (2). The first column identifies the table in the AGIR report, containing the results of the economic analysis. The second column identifies the biomass fueled or biomass-natural gas fueled technology. The next three give the parameters, and the last column presents the power levels chosen for economic analysis in the AGIR

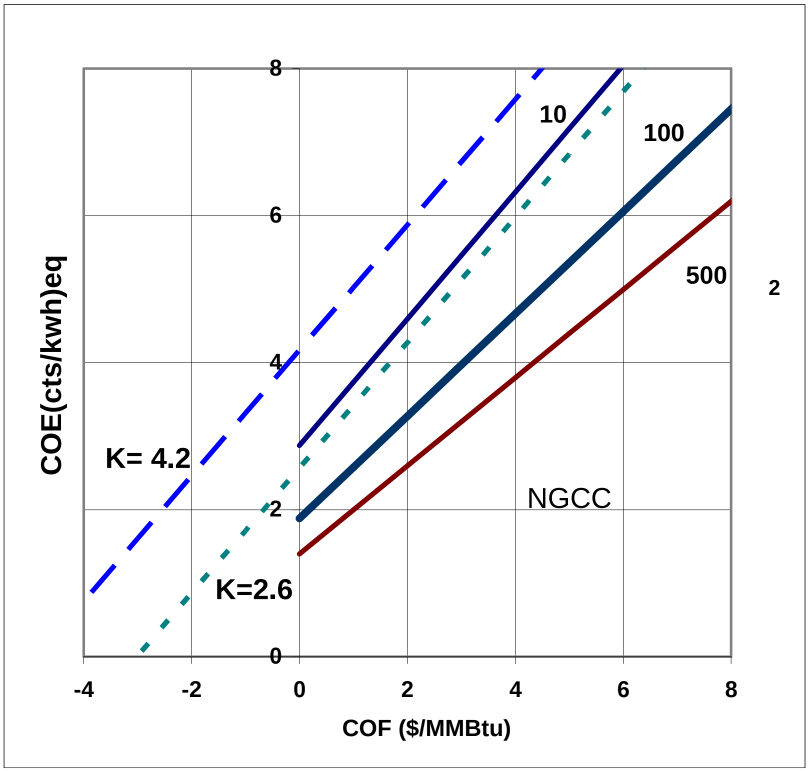

FIGURE 1
COST OF ELECTRICITY VS. COST OF FUEL FOR BGCC AND NGCC SYSTEMS

Antares Group Inc. Report (AGIR)		COE = K0 +K1/P1/2 + S1 COF /P1/4			
Table	Technology	K0	K1	S1	P (MW)
14-29	BIG CCblend	0.08	31.2	1.94	10, 15, 25
14-30	BIG CCsyn	-2.82	45.2	3.51	10, 15, 25
14-31	BIG SCblend	1.76	27.3	2.10	2, 10, 15
14-32	BIG SCsyn	0.33	34.1	2.06	2, 10, 15
14-33	BIG IC blend	3.36	14.9	0.38	2, 10, 15
14-34	BIG ICsyn	3.74	16.4	2.06	2, 10, 15
14-16	Solid Fuel Cofiring	1.27	1.9	2.17	2, 10, 15
14-17	BIG-coal Cofiring	2.02	7.1	2.34	2, 10, 15
14-18	FWHR	0.29	10.7	2.38	3.13.20
14-28	SBST	-4.44	39.1	4.50	0.7, 10, 15
App.D	CHP	-26.6	48.0	7.41	0.5, 4, 6

(BIG-biomass integrated gasification, blend-syngas - NG, CC-combined cycle, SC- single cycle, IC internal combustion engine, FWHR-feed-water hat re-powering, SBST-stoker boiler steam turbine, CHP combined heat and power)

TABLE 2

PARAMETERS FOR COE (CT/KWH) VS. COF ($/MMBTU) EQUATION

As an example of the application of Table 1, Figure 2 illustrates COE vs. COF as projected for various power level with (6) for the BGCC and BG-NG CC cases. The NG is assumed to provide 36% of heat at $4/MMBtu.

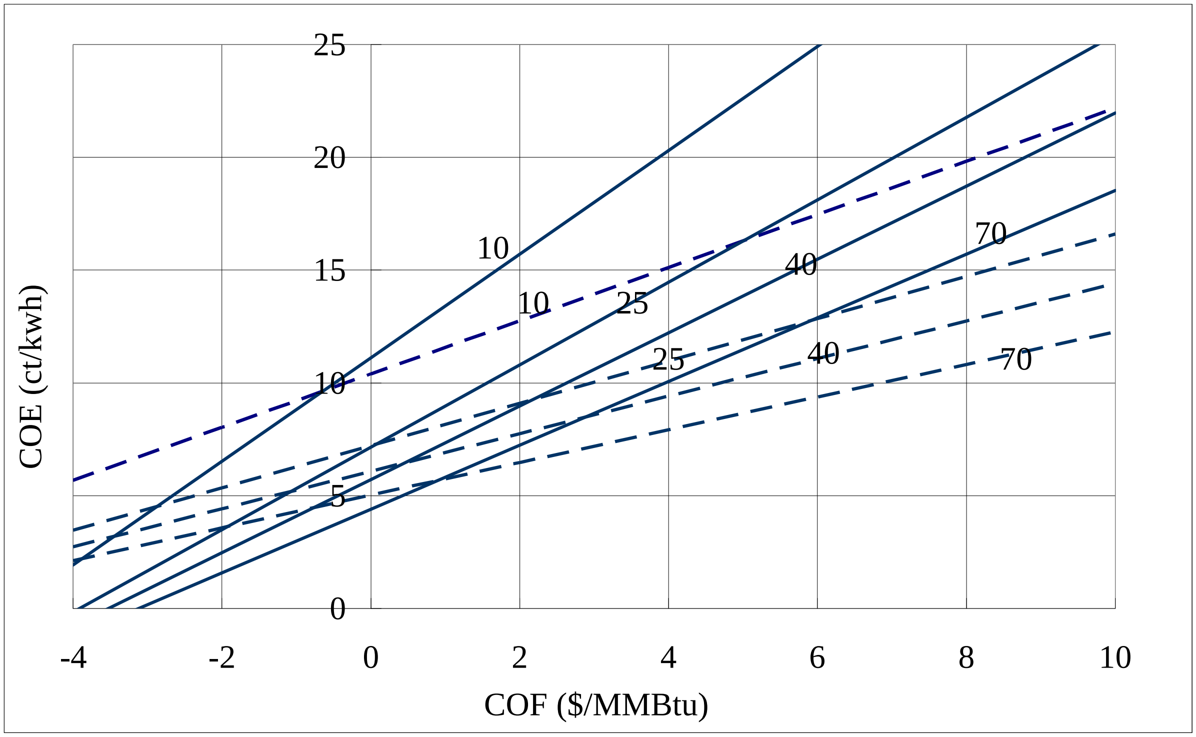

FIGURE 2
COST OF ELECTRICITY VS. COST OF FUEL FOR VARIOUS POWERS IN BIGSC SYSTEM (SYNGAS SOLID LINE, BLEND DASHES)

IMPLICATIONS OF THE ACE-AGIR ANALYSES

In the spirit of the scientific method, the large body of economic "data" given in the AGIR has been represented quite accurately by an empirical equation (6) that uses a limited number of adjusted parameters. The equation seems reasonable in that it confirms the economic and efficiency advantages of scale (power level) usually seen by utilities. Furthermore the equation can extend the usefulness of the AGIR report to examine the influence of electricity prices or power levels and fuel costs that were not considered in the AGIR that was carried out mainly in 2002, when fuel prices were low.

The major conclusion of the Antares Study, as confirmed by the ACE analysis, is that solid fuel co-firing (biomass- coal) and CHP have the best potential for delivering cost competitive electricity at the small scale of rural facilities that are suitable for generating electrical energy from 100 tons per day of forest thinnings. In the solid fuel co-firing case, the low COEs follow from the low values of K_o, K_1, and S_1. Essentially, when adding biomass to an existing coal boiler, the incremental capital costs are small. Furthermore, the good efficiency of the coal plant due to the economy of scale is not significantly degraded as implicit in the small value of $S_1/P^{1/4}$, the multiplier of the X (COF). Since the biomass fuel cost X is not heavily weighted in the COE from an economic standpoint, the coal-biomass co-firing option rates highly. From a perception standpoint it is tainted by the negative image that coal has for many environmental and biomass enthusiasts.

The CHP case need not have this problem since it can rely entirely on biomass or a combination of biomass and natural gas that is generally viewed as more eco-friendly than coal. The Y(X) generated in the AGIR economic analysis for 4 and 6 MW CHP power levels have large slopes (S) but small or negative intercepts (K). The origin of the negative intercepts can be understood in terms of the regression parameters $K_o = -26.6$ and $K_1 = 48.0$, whereas in all other cases the K_o has relatively small positive or negative values. This result can be understood using an extension of some simple equations given in the AGIR. Thus when the return to the utility is reflected both in their COE (really their charge for electricity!) and the sale of the steam, their expression for the effective burner tip price (Btp) can be generalized to

Btp = {(C/L) + Oma – QstaCst + Fca }/ Ha in $/MMBtu (7)

Here, C is the effective total capital cost, L is the nominal lifetime of the facility, Oma is the annual operating and maintenance cost, Qst is the quantity of steam sold at the cost to consumer Cst, Fca is the annual fuel cost, and Ha is the annual heat input. This heat input is given by [14]

Ha = Tpd*2000*365*Cf*Hv = 0.73*10 6*Tpd*Cf*Hv* (8)

where Hv is the heating value of the fuel in Btu/lb, Cf is the capacity factor, and Tpd is the average tons per day of fuel used by the plant. The burner tip price relates to the cost of electricity, Y (COE), and the net plant heat rate or efficiency via

Y = COE = SBtp = SC/LHa + SOma/Ha - SQstCst/Ha + SFca/Ha (9)

It is obvious that SFca/Ha, the fourth term, is simply SX in (1), where here X = COF averaged over a year. The other three terms in (8) thus can be interpreted as components of the net K, the zero fuel cost intercept of the Y(X) relationship. Accordingly we can write

Y=Kc + Kom - Kst + SX (10) where,

Kc=SC/LHa , Kom=SOma/Ha and Kst = SQstaCst/Ha (11)

As an oversimplified decomposition of the results of the AGIR analysis, one might say that the capital and operating costs contributions to the net K are reflected in the positive $K_1/P^{1/2}$ and the steam return is reflected mainly in the subtractive K_o. This points clearly to the benefits of combining electrical generation with a second cash generating output or service.

The AGIR economic analysis gives good positive net present values (NPVs) at low power levels for CHP systems. Tables of NPV's dependence upon power level and cost of electricity for all systems are accurately represented by another analytic formula [15]. The unique aspect of CHP again can be understood in terms of the additional income source generated via steam. The NPV analysis also points towards multiple outputs, in which utilities serve as fuel or chemical factories, that has long been discussed, but thus far rarely implemented. Clearly, biomass suppliers should encourage the pursuit of technologies with all potential beneficial outputs that can be derived from biomass in high temperature processing, such as familiar to utility and industrial boiler operators.

MARKET BASED SYSTEMS AND ACE

Market-based "cap and trade" programs have been used to lower NOx and SOx emissions from coal fired power plants and have recently been proposed to lower mercury emissions. The concept is to setting tight emission limits but let utilities that go under sell their underage. This could provide a secondary income stream for biomass use. It effectively raises the costs of electricity from coal with respect to biomass that usually has little mercury. This approach would give utilities the flexibility and incentive to install the most cost effective technologies. Integrated Gasification Combined Cycle (IGCC) systems for solid fuels provide the greatest combination of near term environmental, energy, and economic (EEE) benefits. BG-CHP, is a more advanced form of combined heat and power technology than that considered in the AGIR It is also emerging in response to environmental drivers such as CO2, mercury, and other toxic emission concerns, as well as the high cost of natural gas. With judicious application of market based systems, decision makers could help biomass generated electricity become competitive even with coal and nuclear generated electricity. Essentially, biomass can become competitive when

- Local sources of waste wood, agricultural residues and/or energy crops are available in the wild lands-urban interface; and natural gas prices range above $4/MMbtu
- Co-use of biomass with natural gas simplifies the gasifier and lowers capital costs
- When local biomass gas can help power a NGCG or CHP system and local markets are available for the steam, waste heat, and waste heat desalinated water
- Converting local biomass to transportable bio-oil or valuable chemicals can overcome the need for local markets
- Conversion of biomass to syngas or bio-oil uses less energy than the conversion of coal or petroleum coke
- Favorable conditions arise in re-powering an existing facility, i.e. major parts of the old facility and modular new components are available to keep retrofit costs low
- Re-powering an old facility with BG and gas turbines adds valuable capacity, service capability and emission reduction
- When appropriate market values are assigned to public health and welfare externalities such as: a) enhanced local employment for biomass collection and processing and BG operations, b) local MSW and bio-solids disposal services, c) CO2, NOx, and SOx emission reduction, d) reduced mercury and other toxic emissions, e) reduced home risks from forest fires, f) disposal of contaminated biomass, g) mitigation of NG prices.

BIOMASS FOCUSED FOREST MANAGEMENT TRAINING (BFFMT)

Throughout the United States, a wide variety of efforts are underway to develop economically sound and environmentally sustainable bio-energy production systems. Federal policy, for instance through the Healthy Forest Restoration Act of 2003, supports the establishment of biomass systems. Scientists in government and non-governmental agencies are taking the initiative to improve biomass production, processing, and conversion. Entrepreneurs are developing and marketing bio-based products for use as bio-energy. Consumers are creating a demand for alternative forms of fuel and power generation. Yet, in order to advance biomass-based production, there is still a need to educate concerned citizens, community leaders, and those who can supply and use biomass fuels about the potential uses, sources of raw material, and requirements to make practical use of bio-fuels. Training is needed to increase the awareness of the possibilities of utilizing biomass, knowledge to put bio-energy production systems in place, and coordination among the different groups that would need to be involved.

This MADBANG effort to establish a demonstration program that fosters the near term development of biomass to energy fits synergistically with a Biomass Focused Forest Management Training (BFFMT) program. Its goal is to develop a training program to encourage the use of woody biomass for bio-energy production in southern communities at the wild land-urban interface (WUI). The Southern United States produces nearly sixty percent of the Nation's wood and projections show that it will continue to be the leader into the future. The climate is well suited for fast-growing pines and hardwoods, and as a result the timber industry has played a large role in the economic development of the region. Many of these southern forests are located in the WUI, where increased human influence and land use conversion are changing natural resource goods, services, and management [16]. Population is increasing faster in the South than any other region of the U.S. As urban centers spread, large areas of once primarily contiguous forestland are increasingly influenced by humans and surrounded by or intermixed with urban development. Consequently, the South already has more cities with forests within 50 miles than any other part of the United States [17].

Because of the proximity of forests to expanding urban areas, the South is a prime location for producing woody biomass for energy production. This is due to a continuous source of biomass fuels without exorbitant shipping costs. While the demand for large diameter trees remains strong in this region, small diameter trees in many areas need a new market since the pulp and paper market is moving offshore where fiber can be produced at a lower cost. Furthermore, although federal policy previously encouraged farmers to convert agricultural lands to forest plantations and family forest owners to replant trees immediately upon harvest, this policy developed many forests that were planted too densely. With a reduced fiber market, there has been a build up of un-thinned trees, standing dead and downed wood that poses a serious fire hazard. Using the deadwood and small diameter trees for woody biomass for fuel production provides a new market for forest landowners, reduces fire risk, and provides an incentive for landowners to keep their property in forests. Forests provide valuable green space, which in turn improves air and water quality and provides many other environmental benefits, especially to nearby communities experiencing environmental pressures from urbanization.

While energy from biomass is not yet economically competitive with coal, the rising cost of natural gas is making biomass an attractive energy. Public utilities that burn natural gas in combined cycle generators could retrofit their facilities to utilize wood waste, cellulose, and other woody feedstock. In communities where there are barriers to the adoption of this gasification process, direct combustion of biomass alone or with coal is also possible. On a smaller scale, industries and other commercial complexes can generate their own energy with wood and recycled cellulose fuel. When the price of natural gas is above $4/MBU, there are selected opportunities for energy from biomass gasification to be economically competitive [7]. Displacing some fossil fuels with biomass fuels will provide positive economic multiplier effects and multiple environmental services locally and globally, that will contribute to long-term energy security.

Better management of forests in the WUI and an organized effort to harvest forest residues could generate a steady supply of biomass fuel that could supplement and replace a portion of the fossil fuels used to generate energy. But forests [18] are only a part of the potential biomass supply in the WUI. For this reason we do not solely focus on biomass forest management in this training proposal. Several other options already exist that would provide a large portion of the quantity necessary to provide biomass for energy on a sustainable basis. Gainesville, Florida is an example of a medium-sized city in the South that can provide over 1,000 tons of biomass/day from harvesting debris and unused stumps within 30 miles of Gainesville Regional Utilities (GRU) [20]. Urban tree debris from tree trimmings, land clearing for development purposes (i.e. residential, urban, and transportation corridors), and pre-commercial thinning is a significant source of potential fuel that is currently difficult to dispose of in many communities and is largely wasted if sent to landfills. Short rotation woody crops, particularly those grown for phytoremediation, windbreaks, or riparian buffers, have potential to supplement existing woody biomass sources if needed. Forest landowners growing trees for saw logs must be able to thin densely planted young stands; this wood can also be factored into the potential biomass stream.

Wildfire mitigation in the WUI could also provide a woody biomass source for energy. As more homes and businesses are built in forested areas, risk of wildfire increases. This is particularly of concern in parts of the country, like the South, that have fire-dependent ecosystems. The use of prescribed fire, the preferred fire-hazard reduction tool, is increasingly limited in the

WUI due to liability and air quality issues. Mechanical fuel reduction is a viable alternative to prescribed fire that generates large amounts of biomass in the South where rapid re-growth of vegetation necessitates a continuous fuel reduction effort. Reducing fuel loads makes communities safer by reducing overall wildfire risk. Thinning small diameter trees and dense thickets of vegetation can improve overall forest health and stand structure. The Healthy Forest Restoration Act broadly addresses over-stocked forests with high fuel loads, which are often exacerbated by forest pest problems that leave dead, highly flammable trees. Specifically, the Act recognizes the extreme danger in the WUI. Some have placed an estimate of $1000 per acre to mitigate fire hazard in the WUI. Capturing and using this fuel for energy could go far in reducing these costs while reducing the threat of wildfire to communities, structures, and standing forests.

Establishing a biomass system can give forestland increased value in the WUI. Forest landowners worry about the high cost of staying in business due to tax pressures, lack of public acceptance of traditional management tools, and the low value of pulpwood [19] Creating a local market for trees may help some landowners keep their land in forest rather than selling to commercial development. The community at large will gain by retaining nearby open space, which contributes to groundwater infiltration, water quality, wildlife habitat, climate stability, etc. [16]

In these WUI communities where both the necessary technology and adequate supplies of biomass are available, the limiting factors to immediate implementation of this commercial application utilizing biomass are awareness of the possibility, knowledge to put the system in place, and coordination among the suppliers and users that would need to be involved. Potential woody fuel users (utilities, industries, etc), urban tree care industries, and the local forest landowners must work together to make this system successful. Support from local environmental organizations and community leaders will also be necessary to remove barriers and ease the transition to a new source of energy. All of these players can be educated and supported by their forestry agency and extension educators, provided these key players have the resources and materials to advocate biomass fuel systems. Thus the key barriers to using woody biomass for energy production can be reduced through a "Wood to Energy" community workshop program designed to distribute current information and examples, support networking, and enable forest owners, managers, utility operators, and other potential wood energy users to begin to plan jointly this novel energy system for their community.

RURAL ECONOMIC DEVELOPMENT, ENVIRONMENTAL BENEFITS, MANAGEMENT

The utilization of bio-based renewables can enhance the environmental sustainability of southern forestry. The proposed training program will stimulate a shift in energy consumption patterns toward bio-based products. Converting to bio-energy in WUI and rural areas can ultimately improve the economy, ecosystems, and human health. With increased knowledge and skills, land managers and community developers can expand their management options to include removal of hazardous small diameter material, reducing the risk of wildfire and increasing the health of forest stands. Economic and environmental impacts of using bio-energy are many. While quantifying the dollar values is complex, overwhelming evidence suggests that economic and environmental characteristics associated with using bio-energy are positive.

The implementation of biomass-based training programs can improve overall community well-being by promoting a safer and healthier environment. Forest fuel reduction activities decrease the risk of catastrophic wildfire, which also improves overall forest health. Biomass fuels have lower CO_2, NOx, and SOx emissions than most fossil fuel emissions, contributing to cleaner air. By keeping rural lands in biomass production, interface and rural communities would have more green space, which helps provide cleaner air and water and many other environmental benefits.

This training program also encourages increased cooperative interaction among diverse and often conflicting stakeholders. Bio-based renewables are a potential rallying point for people with divergent political perspectives. The training program envisioned will bring different stakeholders together to provide a forum for joint ventures for biomass focused forest management. The proposed project will encourage partnerships among private citizens, small businesses, community developers, policy makers, industries, nongovernmental and government agencies, which will in turn make their community a better place to live and work.

This project will utilize the existing capacity of two research work units in the USDA Forest Service's Southern Research Station: the Southern Center for WUI Research and Information (SCWUIRI) (RWU-4951) and the Disturbance and Management of Southern Ecosystems (RWU-4104). The project also includes expertise on biomass, economics, behavior change, forestry, air quality, engineering, extension, and education from the School of Forest Resources and Conservation and the Department of Food and Resource Economics at the University of Florida, the Southern Region Cooperative Extension Service, and the Southern States Bio-based Alliance of the Southern States Energy Board. The unique partnership that already exists between the USDA Forest Service, the University of Florida, and the Southern Group of State Foresters (who all worked together to form SCWUIRI) will be utilized in this project. An advisory council, which consists of members from State Forestry

Agencies, the USDA Forest Service, Academia, Cooperative Extension, and non-government organizations, already guides SCWUIRI's technology transfer efforts. A subcommittee of this advisory council would be created and expanded to include potential woody biomass users, biomass specialists, and other identified stakeholders to advise the development and delivery of this proposed "Wood to Energy" training program. The Southern Region Cooperative Extension Service is a network of land grant universities in the 13 Southern states, coordinated through the Southern Regional Forester. This network enables new extension products and information to be efficiently disseminated throughout the region. Satellite-based training programs have been successfully used to share information and answer questions throughout the entire region.

PYROLYSIS AND GASIFICATION OF BIOMASS

There is tremendous background literature on pyrolysis/gasification of solid fuels going back to Clayton's first production of coal gas in 1694. Yet, at this time, no technology has emerged as an off-the shelf leader ready to be used with combustion turbines at a small or large scale. As applied to biomass in the form of waste, the latest literature is well summarized in a 2004 review article entitled "Novel and innovative pyrolysis and gasification technologies for energy efficient and environmentally sound MSW disposal," [21], a summary that has over 300 references. The 73 chapters in the recent book Pyrolysis and Gasification of Biomass and Waste [22] have a thousand references on these topics, the vast majority coming from the European Union. Since bio-energy has the highest renewable energy potential, the European Union (EU) is supporting many advanced thermo-chemical technology projects. Several assessments in this book point to the urgent need for more demonstration projects to establish the reliability of the most advanced conversion technologies. The subject has also become a "hot" topic at Coal, Biomass and Alternative Fuels (CBAF) sessions of the International Gas Turbine Institute meetings and it appears that a few promising systems are finally emerging. However, we are mostly at the first of its kind (FOK) stage and far from having reached the 2nd or 3rd successful proof of concept and performance stage. Thus there is a need to accompany agricultural and engineering training program with research, development, and demonstration (RD&D) programs lest the students are trained with technologies that are soon outmoded.

Finally, at the high current costs of natural gas and some successful FOK examples of biomass conversion technologies, it appears promising that biomass generation can now, or soon, compete economically with natural gas. However, on a strict COE basis, it is still difficult to beat the price of grid electricity generated at existing coal or nuclear fueled plants. In this regard, the most promising advanced biomass converter systems are those that have dual marketable products. Such systems are under rapid development particularly in Europe and Canada.

MADBANG SCOPING STUDIES

In seeking a multidisciplinary academic demonstration (MAD) as a platform for a campus educational and research effort, a decision was made to focus first on campus sites so that students can easily participate. The program is intended to demonstrate appropriate green fuel technologies based upon the use of biomass to supplement or replace natural gas, and to foster investigations on campus directed towards the conversion of various forms of available biomass into useful electricity, heat, fuels, chemicals or activated carbon.

An Institute of Food and Agriculture (IFAS) team is undertaking

- to estimate energy demands of the overall campus and specific building complexes with stand-alone energy systems to determine suitable applications for biomass gasification
- to estimate volumes of all potential biomass resources, both on campus and within the surrounding community, including forest harvest residue, landscape debris, waste paper, sewage sludge (bio-solids), animal bedding, etc.
- to characterize the quality of various biomass resources regarding their suitability for gasification, including parameters such as moisture, density, particle size, and processing requirements

With the BFFMT project, the IFAS team should be able to carry out these studies much more comprehensively.

The Engineering team will consider the technology options to be pursued if the campus demonstration is at the 10 KW, 100 KW, 1 MW or 40 MW power levels in light of the current state of gasification technology. The team is now examining the space and service feasibility of placing the demonstration gasifier at one of the following locations: a) the campus steam plant with its 1 megawatt steam turbine generator (near the 42 MW Co-Generation plant of the Florida Power Corp), b) the new Genetics Building, c) the new Orthopedics Building, d) a new building planned for the Florida Museum of Natural History, e) the campus sewage treatment plant, and f) a gas fired cat crematoria in the new Veterinary School complex

Engineering will also investigate technical and location options for a facility to prepare the feedstock for gasification at the campus facility. The Engineering and IFAS teams will collaborate in developing a list of companies with near term gasification technologies to be requested for bids for final installation when and if project funds become available. While the first priority has been given to a demonstration gasifier on campus, we will also consider collaborative demonstrations at nearby Gainesville Regional Utilities and the Florida Power Corporation sites should funds become available.

CONCLUSIONS

This is a progress report on the development of a multidisciplinary academic demonstration (MAD) program directed towards the energy conversion of campus and nearby forestry residues and cellulosic campus waste. The program is intended to foster student and faculty team investigations of advanced technologies that can improve the cost effectiveness of Biomass Alliances with Natural Gas (BANG) campus projects. MADBANG could hasten the approach of the University of Florida to Energy Sustainability and provide a platform for the general advancement of biomass gasification projects. Campus projects could be developed as part of a curriculum on biomass production and use as a renewable energy feedstock for co-generation, conversion to a syngas, production of liquid fuel, chemicals, activated carbon, and other valuable products. MADBANG's goal is to advance Biomass to Energy technologies, particularly biomass gasification. It is a natural companion or component of the just awarded USDA Forest Service BFFMT (Biomass Focused Forest Management Training) program. MADBANG and BFFMT together should be particularly helpful to Southern communities at the wild land-urban interface (WUI) where some sixty percent of the Nation's wood is produced. The University of Florida as the state's land grant university is well positioned to develop new knowledge that could be extended to interested stakeholders throughout the Southern United States. Developing knowledge and training agricultural and engineering students to apply the technologies of local biomass production, delivery, processing, gasification and use in gas turbine facilities can lower greenhouse emissions, provide jobs, stabilize local economies and reduce our dependence on imported fuels.

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