Agricultural/Renewable Contributions to U.S. Electricity Usage

Otto Doering
Purdue University

Energy From Agriculture: New Technologies, Innovative Programs & Success Stories

December 14-15, 2005

St. Louis, Missouri

Agricultural/Renewable Contributions to U.S. Electricity Usage

Otto Doering, Purdue University*

Introduction

Agriculture's contribution to U.S. electricity usage is most often expressed in terms of renewable biomass sources that are to be used in combustion to generate heat/steam for traditional electric generation technology. There is also discussion about the generating methane which can be used for electricity generation. Electricity generation from wind is sometimes considered as a contribution from agriculture due to the potential location of such systems on land that was in or relates to agricultural use. However, such electricity generation does not involve any activity which is agricultural. So, we will concentrate here on biomass materials resulting from agricultural activities and the use of those materials for electricity generation in conventional steam modes. Forest biomass utilization for electricity generation will not be considered here, but some contrasts will be drawn with agricultural biomass utilization. It will be clear as we examine this that biomass materials from agriculture are not necessarily low cost in and of themselves or in use. There are competing uses for such materials other than electricity generation and there are also substitute fuels for electricity generation that have cost and logistical advantages.

The opportunity cost of biomass is an important factor in the availability of biomass and in the way we need to think about its use and its future. If biomass were not produced or harvested, what else could be done with the same resources, and would this alternative be more profitable to those involved? Projections of biomass availability and costs for any use make important assumptions about such things as alternative uses of

*Otto Doering is public policy specialist and professor of agricultural economics at Purdue University. He has served as Director of Indiana's State Utility Forecasting Group, Director of Purdue's Energy Policy Research and Information Program, and as a National Science Foundation evaluator for the Industry/University Cooperative Research Power Systems Engineering Research Center. This paper was presented at the USDA/DOE conference Energy from Agriculture, Dec. 14-15, 2005, St. Louis MO.

land, labor, and capitol; costs of various inputs; and prices for biomass and alternative products that might have been produced instead. Especially in a farming situation, alternatives for management time are many and its opportunity cost can be very high. Changes in any of these factors have the potential to change the availability and cost of biomass materials. The users of biomass face the same opportunity cost decisions. They can use, design appropriate facilities, and pay for biomass or do the same for competing energy inputs. So, from both the supply and demand side there are always going to be calculated decisions about using biomass that reflect its opportunity cost for production and for its use.

Material Characteristics Affecting Usage

Materials have specific characteristics that help determine their value. Especially important are those characteristics that relate to their economic and technical performance in comparison to other materials. Agricultural Biomass materials that are going to be used for combustion generally have low energy density. That is, they have a large amount of weight and often bulk for a given amount of net energy that they provide. Biomass such as agricultural byproducts has an average heat content of 8.248 million BTU per dry ton. This compares with paper pellets at 13.029 million BTU and auto tires at 26.865 million BTUs (EIA, 2004). In contrast, Bituminous coal, most commonly used for electricity generation, can average about 25 million BTU per ton and sub-bituminous coal like Western low sulfur coal may average 15 to 20 percent less. The heat content relative to weight and density determine how a fuel material can be transported, stored, and used economically. Biomass, by its nature, can hold substantial amounts of moisture, rewets easily, but must be in a dry form to be most efficient for combustion. It thus needs be stored in a way to keep it dry. Its relatively high bulk determines its storage, handling, and transportation requirements.

The value of a product in relation to its transportability determines where the product can be used and produced. The first spatial economist, Von Thunen, described this relationship in 1826 using low weight, non-bulky, high value examples and contrasted these with heavy, bulky, low value examples like firewood in his book The Isolated State. In his example, if one looked at a central market town of his day one would have to produce firewood not too far from the town given the cost of wagon transportation. A valuable good, like diamonds could come from long distances, even in a merchant's pocket – having very high value relative to its weight and density. This situation is changed if the product can transport itself, like cattle in the days of cattle drives. It also changes if a river runs through the town because then low cost water transportation can move bulky low value goods relatively cheaply over longer distances. The river bank miles from town becomes a viable point of origin. Distance to the river becomes most critical, not distance to town. Such was the intent and the brilliance of the building of the Erie Canal to boost the economy of New York City. It effectively opened up the area surrounding the Great Lakes for shipping the nations grain out through the port of New York.

Consider the location of production facilities today that use large amounts of bulky and relatively low value materials like coal and iron ore. Historically we built these facilities near water transportation and then near rail transportation. The efficiency of these transportation forms holds today (even as we transport an increasingly higher proportion of U.S. goods by truck at higher energy costs). Large scale electric power plants today are located at mine mouth, within reach of water transportation, or within reach of rail transportation where unit trains can bring large volumes of coal at relatively low cost. Location of generation also gets locked in as electric transmission systems are built. This locational imperative is increasingly important today with the difficulty and cost of siting new transmission and distribution lines.

Bulk density as it affects the ease or difficulty of handling is also important. Mine mouth power plants can often move coal by conveyor belt to be pulverized and then to the furnace for burning. No separate handling or stacking is required. Handling cost differences are real and important. Natural gas, by comparison, makes the transition from interstate pipeline to boiler almost seamless. This is one of the reasons for the low capital cost of natural gas power plants. Wood chips also can provide a somewhat homogeneous feedstock which may have reasonable flow characteristics.

Availability

A great deal of attention has been paid to the current and potential availability of biomass materials, either as biomass crops or as crop residues (Gallagher et. al, 2003, Ugarte et. al., 2003, and Haq, 2002 as examples). The critical question today is not physical availability but production cost, utilization cost, and physical capacity to utilize the biomass. One suspects that these will be the most important concerns for a long time before we hit up against physical availability concerns. The other question is which potential use of biomass will be able to pay the highest price and have the fewest other options so as to effectively draw in the bulk of biomass produced.

Estimates of annual biomass resource potential from agricultural resources approach a billion dry tons a year (U.S. DOE &USDA, 2005). This would include crop residues, grains used for bio-products, perennial grasses, and perennial woody crops (excluding the forest sector) as primary sources. Secondary sources would be animal manures and food/feed processing residues. If one looks at the current sustainable availability of biomass from agriculture, corn stover is the 800 pound gorilla at 75 million dry tons a year followed by crop and other residues at 52 million tons, manures at 35 million dry tons, small grain residues and wheat straw at 17 million and grains to biofuels at 15 million dry tons, for a total of 194 million dry tons per year (US DOE&USDA, 2005, p. 21). One important limitation is the development of harvesting systems for something like corn stover that would not require a second pass or make contract harvesting on a second pass basis practicable (Atchison, 2003).

A variety of different scenarios could potentially bring production to a range of 500 million to almost a billion tons annually and be able to do this on what might be defined as a sustainable basis. (The billion ton estimate includes the addition of perennial biomass crops.) This scenario includes 446 million dry tons of crop residues, 377 million tons of perennial energy crops (like switch grass), 87 million tons of process residues, and 87 million tons of grains to be converted to bio-fuels (US DOE&USDA, 2005, p.32). There are a number of concerns that go along with such scenarios of high production including; the necessary technological development and its adoption, the concerns about over-removal of biomass that would diminish long run productivity, nutrient replacement, variability in yield from year to year, the challenge of redirecting animal manure to bioenergy, and the question whether markets would be there for such levels of production.

Likely Utilization

Projections for the growth in biomass production do not tend to consider electricity generation as the major use that will develop. The future is seen in terms of bio-fuels and bio-products. Bio-power, i.e. the biomass share of electricity and heat demand in utilities and industry is seen as growing from 2.7 quads in 2001 to 5 quads in 2030. Bio-fuels – the biomass share of demand for transportation fuels is seen as growing from 0.15 quads in 2001 to 9.5 quads in 2030. Bio-products, the share of target chemicals that are bio-based, are seen as growing from 5 percent in 2001 to 25 percent in 2030 (USDA&U.S. DOE, 2005, p.4). This relates to the higher value of fuel and chemical end products and the high costs of their current petroleum or gas based feed-stocks relative to combustion fuel alternatives like coal. (Energetics, Inc, 2003, sections on prices of possible bio-product derivatives).

These projections were made prior to the recent increase in natural gas and petroleum prices. The increases in these prices are likely to make the economics of utilizing biomass for conversion rather than for direct combustion even stronger. Consider that the most versatile and valuable petrochemical feedstock is natural gas. Natural gas prices have gone from a $2 to $4 range several years ago to over $12 per million BTUs in November 2005. Oil prices have increased almost as much. Biomass used as a combustion fuel is not competing against oil or gas but against coal. Unita basin coal, which is low sulfur, has gone from about $17 per ton in 2003 to $29 on the spot market in early 2005 and $37 in mid November 2005 on the spot market – a virtual doubling (EIA, Nov.23 2005). However, most coal is burned on long term contracts at much lower prices. As there is increased demand for coal consumption, new mines will be opened and new long term contracts will be signed at rates closer to the 2003 prices – in the $20 a ton range. For both oil and natural gas, the North American continent is no longer self sufficient in these fuels. A scarcity can no longer be relieved domestically. While oil and gas prices are not expected to remain at late 2005 levels, their decline will still keep them well ahead of the heat cost of coal. US DOE 2005 median price projections had oil prices declining gradually to $31 per barrel in 2010 and then increasing gradually to $35 a barrel in 2025, in 2003 dollars (EIA, July 2005). The end 2005 projection has oil at $47 a barrel in 2014 and $54 per barrel in 2025, in 2004 dollars

(EIA, December 2005). The cost of solid fuel combustion thus remains low while the cost of liquid transportation fuels and petroleum based feed-stocks remains high. Natural gas prices are projected to decline to the $5 per million BTU range by 2016. The question is how successfully and how soon new North American gas sources actually can be brought on line given the difficulty of importing natural gas from overseas. This may be an optimistic price decline forecast.

Utilizing Biomass as a Direct Combustion Fuel

Much of the direct combustion of biomass for electricity generation has been done on a co-firing basis with coal. Several full biomass direct firing systems are in Denmark (IEA, OECD 1998). There are good reasons for this. Danish Government policy is very favorable to biomass utilization – both biogas and biomass. The geography of Denmark, especially the density of population centers, allows a number of things to happen more economically than in other places. The biomass based direct burning systems in Denmark are relatively small in scale, but tied to users who are relatively close by. This also allows the operations to sell waste heat as well as electricity. This is important to aid the economics of the electricity generation which may even be secondary to the heat production. In the case of straw burning, the supply is clustered close to and dedicated to the plant. The tight geography itself makes possible the utilization of lower density energy sources on a small scale and the easier distribution to users. The lack of domestic alternative fuel sources also enhances the opportunity for domestic biomass utilization and a willingness to pay higher costs for this energy which is competing with higher priced oil and gas. Danish policy has thus reacted to both various petroleum price shocks and to initiatives for reducing greenhouse gasses (EREC, May 2004). Environmental benefits of biomass use are fully recognized in the provision of subsidies and regulations to promote biomass use for electricity generation and heat.

A recent commentary on a co-firing experience in the U.S. with switch grass gives a useful perspective on biomass use for combustion in electricity generation (Walling, March 2005). Some of the over-arching issues identified here are as follows:

- U.S. Public policy is focused on broad, universal solutions while biomass in local.
- Low bulk-density of the material constrains the economics of transport.

- Biomass is not homogeneously distributed and is often dispersed and small scale by nature (i.e. not amenable to large scale solutions).
- Past agricultural research has not focused on energy value enhancement.
- Production of electricity is a low value commodity – biomass resources may require a high value product to be economically feasible.

The first three points here emphasize that utilization of biomass is very dependent upon local conditions – both the locational geography, the type of material, and the productivity that can be achieved. The transport issue also is a major one. Seasonality is not mentioned here but is critical in its importance for the provision of a secure and continuous even flow of dry combustion material.

There are several ways to approach these first three issues. One is the siting of generating plants on the basis of optimization of biomass availability and transport (Fruin, 1998). There are some critical trade-offs here. One would like, for scale reasons, to have as large a plant as possible. This would then require a location surrounded by the most dense biomass source potential possible to keep transportation costs within bounds and gain as much biomass material as possible. (Here forest waste/biomass can have a great advantage.) The other concern is access to electric transmission. The two may not coincide, and, even if they do, the transmission at that point may not be viable for feeding new source power into the grid.

The location and state of the grid becomes an important factor if biomass is to be a source for generating electricity in a scale beyond that which could be used by the biomass generator. Since the beginning of deregulation, a decade ago, the major incentive for electric utilities has been to utilize the existing capital stock of transmission as fully as possible – i.e. to bring down extra capacity margins. There has been little or no financial incentive to keep the transmission system as redundant and reliable as it was or to build new transmission. This remains the case today. So, we are facing a grid which has less flexibility to receive new power and is potentially less reliable than it was a decade or two ago.

One alternative to deal with this is to go with small scale plants – distributed generation - fed by biomass. The first concern here is one of tying into some distribution system effectively and without causing problems with existing power quality or reliability. This is to some extent a controls problem, and substantial headway has been made in this respect in recent years – but it also relates to the character and flexibility of the existing distribution system. In addition, the problem is one of scale of operation. We do not have a great deal of experience with smaller dedicated biomass units. If the Danish experience is transferable, one needs to be able to sell the waste heat effectively as well and also needs sufficient subsidies to ensure reliable supplies of biomass on a year round or stored basis. In summary, we have important trade-offs with respect to location for effective biomass production and delivery, with respect to scale, and with respect to the ability to move the electricity generated to customers. We may also have to sell the heat as well as the electricity and be able to maintain a continuous long term dedicated supply of biomass for the life of the plant.

One of the more realistic approaches to successful co-firing was a study of options for the Northeastern U.S. The objective was to find existing power plants that would have the ability technically to co-fire a modest amount of biomass where these plants were already located within reasonable transportation distance from biomass sources (Antaras Group, et. al. 1996). This appears to be a more cost effective and sensible way to go if one is to expand biomass utilization for electricity generation. Among other things, it obviates the transmission concern. However, investments for biomass handling, storage, and processing are still very substantial for the user of the biomass fuel. This is in addition to the cost necessary to attract the biomass.

The notion that past research has not focused on energy value or on increased production of residues is certainly true. Increases in grain production in many cases, taking wheat and rice as examples, have focused on getting the plant to put more energy into grain and less into stalk. While there has been some work on this (Lewandowski et. al. 2003) the focus of such development may be something different from contemplated earlier. This is not just a question of production volume and material density, but also may be a question of chemical composition and burning character to make a biomass combustion fuel material more acceptable.

Especially in a cofiring situation there are a number of important parameters that relate to success. In these situations there is also the concern how the biofuel reacts relative to the coal. This affects the efficiency of the biomass use in terms of heat production and also with respect to the environmental benefits and boiler conditions (Tillman, 2000). Existing utility coal boilers do not optimize the characteristics of a biomass fuel. Combustion characteristics are different and particle size and density will be different. Combustion may have to be redesigned to take advantage of the different volatility of biomass. The higher moisture content and low heat content of biomass may limit cofiring in boilers designed for bituminous coal – this may be less of a problem with the lower heat value western coal. In pulverized coal boilers, the ability of biomass to reduce NOx emissions will relate to these biomass characteristics. The alkali in the biomass will have its own reactions with the combustion products of the coal. This and the P&K associated with fertilization may cause slagging in the boiler. The abundant ash from biomass may also affect the Selective Catalytic Reduction catalysts. The addition of biomass ash may also affect the marketability of coal fly ash to the cement industry. Cofiring in fluidized bed boilers and spreader-stoker boilers appears to be more favorable. The chlorine content of biomass may still be a problem. Success in reducing fossil CO2 emissions, SO2 emissions and trace metal emissions are largely due to the proportion of the biomass fuel that does not have these problems. There is no magic that biomass causes in the boiler to reduce these pollutants in the cofired coal.

When considering either cofiring or sole biomass burning, material handling becomes a major challenge. This is a material, in its dry state, that is dusty and often more flammable than coal. If one is dealing with a baled product, there will be a number of pre process steps such as pulverizing required prior to combustion. Logistics of handling and queuing will be important considerations. For something like forest waste and wood biomass, the forest product industry already has such equipment and protocols in use that can be adopted, but this is not the case for agricultural biomass.

Economics from Cofiring Experience

Walling gives his estimate on biomass economic elements from their experience in cofiring as follows:

Economic Element	$/dry ton
Producer ownership costs	$13
Production costs to edge of field	$30
Collection and Transport	$10

Handling and Grinding (at the plant)	$16
Process facility ownership costs (at the plant)	$10
Total	$79 per dry ton

When compared with existing contract coal costs, even current spot contract costs, there is no contest. If there were a cost of $30 per ton of biomass delivered to the plant, this amounts to $3.64 per million BTU (given 8.248 million BTU per ton). At a more realistic price of $53 per delivered ton of biomass, this would amount to $6.43 per million BTUs. (We still have not dealt with the added costs at the plant.) By comparison, for Uinta Basin coal (23.4 million BTUs per ton) at today's high spot prices of $37 per ton, this amounts to $1.58 per million BTUs. At a long term contract price of $20 per ton this is $0.85 per million BTUs (transportation cost would have to be added).

Challenges for Using Agricultural Biomass as Fuel for Electricity Generation

Utilizing agricultural biomass, either perennial crops or crop residues for electricity generation is a technical and economic challenge. Some of the key components of the challenge are

- The very nature of the biomass itself. This is a bulky, low energy density material.
- The high transportation costs relative to its heat value that severely limits the economic distance from its point of use.
- The competition with a product that has multiple times higher heat value and lower density, i.e. coal.
- The fact that coal is not in short supply in the US and its market price can be stabile over the long term due to its great abundance.
- The likelihood that the most efficient burning of biomass will take place in a furnace specifically designed for that application as in Denmark. (This will likely limit the size of the facility on the basis of a transportable supply radius below that considered economic for coal electricity generation. We don't yet know enough about the scale trade-offs here.)
- The fact that it has not proved easy to cofire small amounts (5-10 percent) of agricultural biomass products in conventional coal plants for a variety of reasons that relate mostly to the nature of the biomass itself.

- The low price paid for electricity that might be generated from agricultural biomass when sold to the grid in small quantities.
- The existence of other opportunities for utilizing biomass for replacements for such things as petrochemicals that will likely command much higher prices.

What we see is the opportunity cost of firing or cofiring agricultural biomass for electricity generation is rather high when compared with current coal systems.

How Might We Use More Biomass as A Fuel for Electricity Generation?

- Be willing to place a high dollar value on the potential environmental amenities that utilizing agricultural biomass might provide. These would include; closing the greenhouse gas loop and lower emissions of SO2 and NOx.
- Expand industrial use of biomass to provide heat and possibly electricity where there is agricultural biomass generated as a waste product.
- Develop technologies that give good economies for smaller scale biomass heat electricity generation and solve access to transmission and distribution lines.
- Provide high levels of subsidies for such biomass electricity generation.
- Ensure A high price for such power when purchased for the grid.
- Be forced to pay a high cost for clean coal technology to meet increasingly stringent clean air standards

Using agricultural biomass as a heat source for electricity generation is only one option. Today forest related biomass consumption is greater than that derived from agricultural biomass by far. The forest product industry is already utilizing large amounts of forest waste products as fuel and generating electricity. One reason is the higher energy and physical density of these products. Another is that the harvesting and gathering systems in the forest industry have evolved over time to transport and utilize increasingly high proportions of each tree as an economic imperative. The resource potential from forest resources is estimated at 368 million dry tons annually as compared with the agricultural sector estimate of 998 million dry tons (U.S. DOE&USDA 2005, Summary). The critical question here for biomass use for electricity generation is not just availability but the character of the material that best suites combustion for producing electricity. In this respect, forest biomass is usually far superior to agricultural biomass. If we are going to see biomass power generation increase, it is likely to be more prevalent, as it is today, in the forest sector.

There is also interest in using biogas to generate electricity. Farm level biogas production has been most viable in the past when the gas can be directly used as a heat source on the farm. Its use in large dairy operations is a good example of this. There are some very large dairy operations that are able to supply large volumes of manure and invest in appropriate equipment and management to produce consistently large amounts of gas and some generate electricity as well. Beyond the primary use for heat, they find that the buy-back rate for electricity is low enough in most cases such that a specialized operation to provide reliable electricity for the grid is not worthwhile. Farm level biogas production is a little like farm level ethanol production. Farmers were enthusiastic about this 25 years ago, but learned that the management demands were beyond those that could be combined with full time management of agricultural production (Fulhage, 2003). We are beginning to see consultant/management arrangements, however, that make this more possible.

Again, the Danish government has encouraged cooperative biogas generation at a larger than single farm scale with adequate technology and management. They are also facing extreme concerns about animal waste disposal that puts a very high value on utilizing manure as a value producing product while combating some of its negative characteristics. Also, in the Danish case, the value of the heat is again an important part of economics of the production of electricity.

One of the trends in the American livestock industry is increasing concentration. This should increasingly allow large scale utilization of centrally located manure for methane production where adequate capital and management can be brought to bear. Again, it is likely to be most economical if this gas can be used as directly as possible for heat in some part of the livestock process. The additional capital expense for a gas engine and generator to provide electricity is not warranted in many cases because of the low cost of electricity from the grid and the lower buy-back price - except in those states mandating higher buy-back rates like California and Maine. The increasing summer electric peak may facilitate methane generation. It can be used for heat in the winter and potentially fuel electric generation in the summer if it can receive peak prices.

In all of these considerations we come back to the hard fact of opportunity cost. Any biomass use for electricity generation is facing a tough challenge against proven existing fuels and systems. Biomass materials will also likely face higher profit opportunities in other uses which will draw these materials to these uses.

References:

Antares Group and Parsons Power (1996) Utility Coal-Biomass Co-firing Plant Opportunities and Conceptual Assessments, U.S. DOE, Northeast Regional Biomass Program, Washington D.C.

Atchison, J. and J. Hettenhaus (2003) "Innovative Methods for Corn Stover Collecting, Handling, Storing and Transporting," National Renewable Energy Lab, Golden.

Energetics, Inc (July 2003) Industrial By-products Today and Tomorrow, U.S. DOE, Office of the Biomass Program, Washington, D.C.

EIA (Energy Information Administration) (July 2004) Renewable Energy Trends 2003, US DOE, Washington, D.C., p.21.

EIA (Energy Information Administration) (July 2005) International Energy Outlook 2005, U.S. DOE, Washington, D.C.

EIA (Energy Information Administration) (November 2005) Coal News and Markets; November 20, 2005, U.S. DOE, Washington, D.C.

EIA (Energy Information Administration) (December 2005) Annual Energy Outlook 2006 with Projections to 2030 (Early Release) – Overview, U.S. DOE, Washington, D.C.

EREC (European Renewable Energy Council) (May 2004) Renewable Energy Policy Review: Denmark, EREC, Brussels.

Fruin, Jerry (1998) "An Application of Geographic Information Systems to Alfalfa Biomass Energy and Marketing Coops" Sixth Joint Conference on Food, Agriculture and the Environment, Dept. of Applied Economics, Univ. of Minnesota, Minneapolis.

Fulhage, Charles, Dennis Sievers, and James Fischer (2003) Generating Methane Gas from Manure, University of Missouri Extension Bulletin, Columbia.

Gallagher, Paul W., Mark Dikeman, John Fritz, Eric Wailes, Wayne Gauthier, and Hosein Shapouri (2003) "Supply and Social Cost Estimates for Biomass from Crop Residues in the United States," Environmental and Resource Economics, 24: 335-358.

Haq, Z. (2002) “Biomass for Electricity Generation.” U.S. DOE, EIA, Washington, D.C.

IEA, OECD (1998) The World’s First Straw-fired CHP Plant Offers Environmental Benefits” Technical Brochure No. 96, CADDET, Harwell, UK.

Lewandowski, I, J. Scurlock, E. Lindvall, M. Christou (2003) “The Development and Current Status of Perennial Rhizomatous Grasses as Energy Crops in the US and Europe,” Biomass and Bioenergy, 25, 335-361

Tillman, D.A. (2000) “Biomass Cofiring: the Technology, the Experience, the Combustion Consequences,” Biomass and Bioenergy 19 365-384.

Ugarte, Daniel G. De La Torre, Marie Walsh, Hosein Shapouri, and Stephen Slinsky (2003) The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture, USDA Agricultural Economic Report Number 816, Washington, D.C.

USDA&U.S. DOE (February 2005) Annual Report to Congress on the Biomass Research and Development Initiative for FY 2003, USDA, Washington, D.C.

U.S. DOE&USDA (April 2005) Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. U.S. DOE, OSTI, Oak Ridge.

Walling, Gary, (March 15/16, 2005 Global Climate and Energy Project, Advanced Coal Workshop, Alliant Energy.