# *The Role of Extension in Energy*

*Proceedings of a conference June 30-July 1, 2009, in Little Rock, Arkansas*

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# Executive Summary
# Transition to a Bioeconomy: The Role of Extension in Energy

Burton C. English, Jamey Menard, and Kim Jensen

On June 30-July 1, 2009, the Farm Foundation held the final conference in the Transition to a Bioeconomy series titled The Role of Extension in Energy at the Doubletree Hotel, Little Rock, Arkansas. This day and one-half conference was designed to provide Extension educators with timely, practical information they can use for developing programming in their own state or locale. This conference was a collaboration of USDA's Office Energy Policy and New Uses; Farm Foundation; USDA's Cooperative State Research, Education and Extension Service; and the University of Arkansas.

The Farm Foundation's Steve Halbrook (now located at the University of Arkansas) and Mary Thompson, along with Peggy Caswell, Jim Duffield, Vernon Eidman, Burton English, Jim Fischer, Janie Hipp, Steve Klose, Suchada Langley, John Miranowski, Joe Outlaw, Laila Racevskis, Felix Spinelli, Wallace Tyner, and David Zilberman, were on the planning team for a series of conferences on the transition to a bioeconomy. The five conferences were to focus on:

1. Integration of Agriculture and Energy Systems
2. Risk, Infrastructure and Industry Evolution
3. Environmental and Rural Development Impacts
4. Implications of a Global Bioeconomy, and
5. Extension Education for a Bioeconomy.

This Executive Summary focuses on the fifth and final conference of the series. The conference program featured experts working in renewable energy, biofuels, energy efficiency and new energy technologies. Presenters include industry leaders, staff from USDA and the U.S. Department of Energy, and researchers working in energy efficiency, renewable energy and new energy technologies. The planning committee for this conference consisted of Michael Popp and Burton English Co-chairs, Mary Thompson, Steve Halbrook, Joe Outlaw, Janie Hipp, James Fischer, Pat Hipple, Don Day, and Tom Riley.

Each participant at the conference received an information toolkit containing handouts and papers from conference presentations. The materials were designed to assist Extension educators in developing education materials for their state and local energy programming efforts.

The conference had four plenary sessions, six workshops, and a luncheon speaker. Each plenary session had between three and five papers presented and incorporated discussion between the conference attendees and the panel members. The agenda and titles of the presentations for both the plenary session and workshops are listed below.

**Plenary Sessions**

**Plenary Session I**: The Role of Extension in Energy chaired by Neil Conklin of the Farm Foundation

*Presentation 1*: The Leadership Charge presented by John Ferrell, U.S. Department of Energy

*Presentation 2*: Expectations for Extension presented by Duane Acker, 25 x '25

*Presentation 3*: Extension, Energy and Public Policy presented by Charles Stenholm, Olsson Frank Weeda Terman Bode Matz PC

**Plenary Session II**: Renewable Energy Technology Outlook chaired by James Fischer, Fischer and Associates

*Presentation 1*: Wind: Technology Trends, Costs & Contracts by Marguerite Kelly, National Renewable Energy Laboratory

*Presentation 2*: Geothermal Applications, Costs and Feasibility by Roy Mink, Mink Geohydro, Inc.

*Presentation 3*: Solar Technology, Trends and Costs by John Thornton, Thornton Solar Consulting, LLC, NREL Emeritus

*Presentation 4*: Digester Technology Trends and Costs by Bill Lazarus, University of Minnesota

*Presentation 5*: Biomass: Producer Choices, Production Costs and Potential by Francis Epplin, Oklahoma State University

**Lunch Session** chaired by Milo Shult, University of Arkansas with the lunch presentation titled "Extension Strategies Targeting Energy Conservation and Efficiency" delivered by Stanley Johnson, University of Nevada.

**Plenary Session III**: Anticipated Extension Program Needs chaired by Steve Halbrook, University of Arkansas

*Presentation 1*: Green House Gas and Indirect Land Use by Wallace Tyner, Purdue University

*Presentation 2*: Legal Issues with Bioeconomy Development by Harrison Pittman, University of Arkansas

*Presentation 3*: Community Development Issues by Mark Edelman, Iowa State University

**Plenary Session IV**: Role of Extension in Bioeconomy chaired by Steve Halbrook, University of Arkansas

*Presentation 1*: Effectiveness of Extension Efforts on Energy by David Anderson, Texas A&M University

*Presentation 2*: Extension Administration Perspective on Funding Energy Efforts by Tim Cross, University of Tennessee

Presentation 3: Strengths, Weaknesses, Resources, Opportunities and Challenges by Dan Dooley, University of California

## Workshops

**Workshop I**: Risk Management for Energy Investments chaired by Clark Garland, University of Tennessee

*Presentation 1*: Establishing a Dedicated Energy Crop by Kenny Hamilton, Tennessee farmer

*Presentation 2*: Biomass from a Plant Perspective by Kyle Althoff, DuPont Danisco

*Presentation 3*: Agricultural Policy and Extension Recommendations by Jim Larson and Burton English, University of Tennessee

**Workshop II**: Making Energy Efficiency Choices chaired by Stanley Johnson, University of Nevada

*Presentation 1*: Extension Resource Efficiency Programs for Residential Housing by Pierce Jones, University of Florida

*Presentation 2*: How State Energy Offices Can Work with Extension by David Sjoding, Washington State University

*Presentation 3*: Energy Conservation and Great Lakes Agriculture by William Johnson, Alliant Energy

*Presentation* 4: Weatherization by Tom Potter, Southwest Energy Efficiency Project

**Workshop III**: Energy Crop Agronomics chaired by Michael Popp, University of Arkansas

*Presentation 1*: BMPs for Establishing and Maintaining Perennial Energy Crops by Chuck West, University of Arkansas

*Presentation 2*: Hybrid Energy Crop BMPs (Annuals) by Bill Rooney, Texas A&M University

*Presentation 3*: Economics of Crop Residues by Daniel Petrolia, Mississippi State University

**Workshop IV**: Forestry chaired by David Anderson, Texas A&M University

*Presentation 1*: Potential for a Sustainable Supply by Daniel De La Torre Ugarte, University of Tennessee

*Presentation 2*: Technological Trends and Production Costs for Forestry Biomass by Mathew Pelkki, University of Arkansas

*Presentation 3*: Coproducts and Byproducts of Biorefinery Processing by Eric Taylor, Texas A&M University

**Workshop V**: Harvest, Storage, and Logistics chaired by Shahabaddine Sokhansanj, Oak Ridge National Laboratory

*Presentation 1*: Developing a Uniform-Format Feedstock Supply System by Chris Wright, Idaho National Lab

*Presentation 2*: Logistics Challenges and Size Reduction by John Cundiff, Virginia Tech

*Presentation 3*: Economics of the Supply Chain by Burton English and Daniel Mooney, University of Tennessee

**Workshop VI**: eXtension and Other Delivery Methods chaired by Harrison Pittman, University of Arkansas

*Presentation 1*: eXtension Overview, Purpose and Direction by Craig Wood, University of Kentucky

*Presentation 2*: Farms as Producers and Consumers of Sustainable Ag Energy: Strategies for Improving Energy Efficiency by Sue Hawkins, University of Vermont

*Presentation 3*: The Case of High Plains Wind Consortium by Cole Gustafson, North Dakota State University

The papers and handouts for many of these presentations can be found in these proceedings. The presentations can be found on the Farm Foundation web site.

The authors and paper titles included in this book are:

- Francis Epplin: Biomass: Producer Choices, Production Costs and Potential;
- James Larson and Burton English: Risk Management for Energy Investments: Agricultural Policy and Extension Recommendations;
- Daniel Mooney and Burton English: Economics of the Switchgrass Supply Chain: Enterprise Budgets and Production Cost Analyses;
- Harrison Pittman: Anticipated Extension Program Needs: Legal Issues with Bioeconomy Development; and
- Mark Edelman: Bioeconomy Transitions and Community Issues;

The authors and handout titles included in this book are:

- Roy Mink: Geothermal Energy's Role in Agriculture;
- John Thornton: Solar Technology Trends and Costs;
- William Lazarus: Anaerobic Digester Technology;
- Pierce Jones: Extension Resource Efficiency Programs for Residential Housing;
- Bill Johnson: Farm-Electrical Energy Efficiency Technologies;
- Bill Johnson: Biomass-Direct Combustion-Renewable Energy;
- Tom Potter: Weatherization, Efficiency, and Carbon Opportunities;
- Chuck West: Establishing and Maintaining Perennial Grass Crops for Energy: Emphasis on Switchgrass;
- William Rooney: Annual Hybrid Energy Crops: Sorghum;
- Daniel Petrolia: Economics of Crop Residues: Corn Stover;
- Mathew Pelkki: Technological Trends and Production Costs for Forestry Biomass;
- Eric Taylor: Coproducts and Byproducts of Woody Biorefinery Processing;
- Eric Taylor: Biomass Chemical Products;
- Christopher Wright: The Uniform Formal Solution;
- John Cundiff: Biomass Logistics in the Southeast;
- Craig Wood: eXtension;
- Susan Hawkins: Sustainable Agricultural Energy Systems -- Farm Energy Community of Practice (CoP); and
- Cole Gustafson: The Case of the High Plains Consortium Wind Energy Handout.

# Biomass: Producer Choices, Production Costs and Potential

Francis M. Epplin[1]

## Introduction

The U.S. fuel ethanol program is a result of a series of government policies enacted over more than three decades that have provided subsidies, tax incentives, and mandates. Corn ethanol is frequently described as a first generation biofuel. When the original policies were implemented, a primary goal was to find an alternative use for corn grain that was often in "surplus". Critics of the corn ethanol program have posited concerns about the economics, welfare implications, sustainability, and environmental consequences of using grain for fuel (deGorter and Just, 2008; Fargione *et al*., 2008; Hahn and Cecot, 2009; Searchinger *et al*., 2008; and US-DOE, 2008).

The U.S. Energy Independence and Security Act of 2007 (EISA) included a provision that by 2022, 36 billion gallons of biofuel be produced annually (Congressional Research Service, 2007). The mandates provided for a limit to first generation biofuel (primarily ethanol from corn) at 15 billion gallons. The U.S. Environmental Protection Agency (US-EPA) proposed rules (as of May 2009) to facilitate fulfillment of the congressional mandate would require an annual production by 2022 of 15 billion gallons of conventional biofuels (primarily grain-ethanol); 16 billion gallons of cellulosic biofuels (primarily cellulosic ethanol); 4 billion gallons of advanced biofuels; and 1 billion gallons of biomass-based diesel (US-EPA, 2009a, 2009b).

Research and development is ongoing in an attempt to develop economically competitive and environmentally sound methods to produce ethanol from lignocellulosic biomass. More frequently the terms cellulosic biomass and cellulosic ethanol are used. For policy purposes, ethanol produced from cellulosic biomass is classified as a second generation biofuel. (This classification is made under the assumption that the resulting product will meet a greenhouse gas reduction threshold of 60 percent). Examples of technologies under evaluation for converting biomass to ethanol include acid hydrolysis, enzymatic hydrolysis, gasification, gasification-fermentation, liquefaction, and mixalco (Aden *et al*., 2002; Boateng, Anderson, and Phillips, 2007; Caputo *et al*., 2005; Klasson *et al*., 1990; McKendry, 2002; Mosier *et al*., 2005; Rajagopalan, Datar, and Lewis, 2002; Service, 2007; and Wyman, 1994).

The energy content of ethanol used as transportation fuel, when no attempt is made to extract useful work from hot exhaust gases, is 75,700 Btu per gallon. The energy content of unleaded gasoline is 115,000 Btu per gallon (US-DOE, 2009). By this measure, when used as an energy substitute, ethanol contains 66 percent as much energy as gasoline. For a gasoline price of $2.05 per gallon (as projected) the economically competitive breakeven price for ethanol would be $1.35 per gallon (in 2006 dollars). The US-EPA estimates that if feedstock can be delivered for $73 per ton, by 2022, cellulosic ethanol could be produced for $1.31 per gallon (US-EPA, 2009a, p. 550). By this measure, unsubsidized cellulosic ethanol produced from cellulosic biomass is expected to be economically competitive with unleaded gasoline. Cellulosic ethanol is also expected to be less costly to produce than corn ethanol. These cost estimates are sensitive to the cost to deliver a steady flow of cellulosic biomass to biorefineries.

An April 2009 assessment found 25 pilot and demonstration-size cellulosic ethanol plants operating in the United States, with nine producing measurable volumes of ethanol (US-EPA, 2009a, 2009b). What remains to be determined is which of the competing technologies is the most efficient, and if they can compete economically with gasoline. An economically competitive business model based on any of these technologies is expected to require a steady flow of massive quantities of cellulosic biomass.

The US-EPA proposes that the 2022 EISA goals for the 16 billion gallons of cellulosic ethanol can be met as follows: 9 billion gallons from agricultural crop residues, including corn stover, wheat straw, sugarcane bagasse, and sweet sorghum pulp (7.8 of the 9 billion gallons is expected to be processed from corn stover); 3.9 billion gallons from forestry biomass; 2.1 billion gallons from urban waste; and 0.9 billion gallons

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[1] Epplin is Charles A. Breedlove Professor of Agriculture Economics at Oklahoma State University, Stillwater, Oklahoma.

from switchgrass (or other dedicated energy crop). Table 1 includes the US-EPA estimates by state for each of the four feedstock categories.

Corn stover and switchgrass are the two most frequently cited potential agricultural cellulosic biomass feedstocks. The purpose of this paper is to discuss the potential and the challenges that the 2007 EISA legislation provides for U.S. agriculture. Corn stover and switchgrass issues and farm gate cost estimates are reviewed.

## Potential Market for Biofuels

The chart included in Figure 1 enables a comparison of total 2007 U.S. energy consumption and net 2007 U.S. energy imports with energy from ethanol. In 2007, the United States consumed more than 100 quadrillion Btus (quads) of energy. This total includes energy from all hydrocarbon (such as coal, oil, and natural gas), nuclear, and renewable (such as ethanol, geothermal, hydroelectric, solar, and wind) sources. Of this total, 29.2 quads were imported. In 2007, approximately 2.4 billion bushels of U.S. corn grain were converted into ethanol that contained 0.49 quads of energy. The gross energy in this ethanol was equivalent to the energy contained in about 1.7 percent of the net imports. Since some energy was used to fertilize, till, plant, harvest, and transport the corn grain and the ethanol, the net gain in energy was substantially less than 1.7 percent of the net imports.

If the entire 2007 U.S. corn crop of 13.1 billion bushels had been converted, the resulting ethanol would have contained about 2.68 quads. This figure would have been equivalent to about 9.2 percent of net 2007 energy imports. The final bar in Figure 1 illustrates that if the 2022 goal of producing 21 billion gallons of second generation biofuel is achieved, the gross energy in the resulting biofuel would be equivalent to 5.5 percent of 2007 net U.S. energy imports. The market for energy in the United States is immense. The challenge is to produce and deliver very large quantities of an alternative fuel that is economically competitive and environmentally sound.

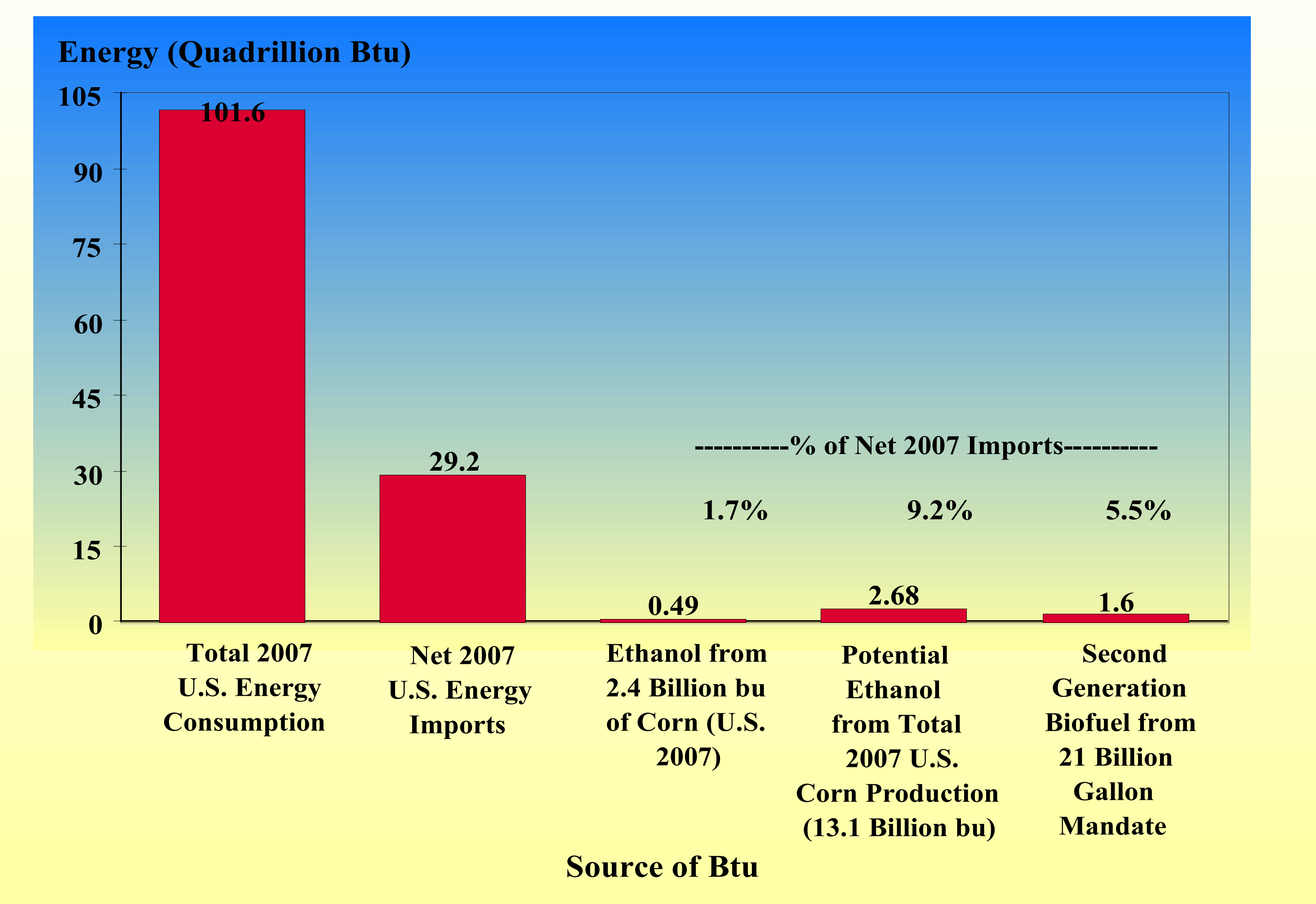

**Figure 1.** U.S. Energy Consumption, Net Energy Imports, Energy in Ethanol, and Potential Energy in Second Generation biofuels Mandated for 2022. (Based on the actual energy yield from use in motor vehicles; gasoline estimated at 115,000 Btu per gallon and ethanol at 75,700 Btu per gallon (US-DOE, 2009))

**Table 1. U.S. Environmental Protection Agency's Projected Cellulosic Ethanol Feedstock Production by State (Measured in Million Gallons of Ethanol in 2022)**

| State | Total Volume | Crop Residue Volume | Energy Crop Volume | Urban Waste Volume | Forestry Volume |
|---|---|---|---|---|---|
| Alabama | 532 | 0 | 0 | 140 | 392 |
| Arkansas | 298 | 0 | 0 | 0 | 298 |
| California | 450 | 0 | 0 | 221 | 229 |
| Colorado | 28 | 0 | 0 | 28 | 0 |
| Florida | 421 | 390 | 0 | 31 | 0 |
| Georgia | 437 | 0 | 0 | 67 | 370 |
| Illinois | 1,525 | 1,270 | 0 | 198 | 58 |
| Indiana | 1,109 | 948 | 0 | 101 | 60 |
| Iowa | 1,697 | 1,635 | 0 | 32 | 30 |
| Kansas | 310 | 250 | 0 | 29 | 32 |
| Kentucky | 70 | 70 | 0 | 0 | 0 |
| Louisiana | 1,001 | 590 | 0 | 103 | 308 |
| Maine | 191 | 0 | 0 | 2 | 189 |
| Michigan | 505 | 283 | 0 | 171 | 51 |
| Minnesota | 876 | 750 | 0 | 50 | 76 |
| Mississippi | 214 | 0 | 0 | 22 | 192 |
| Missouri | 654 | 504 | 0 | 78 | 72 |
| Montana | 92 | 0 | 0 | 9 | 83 |
| Nebraska | 956 | 851 | 0 | 31 | 75 |
| Nevada | 17 | 0 | 0 | 17 | 0 |
| New Hampshire | 171 | 0 | 35 | 29 | 107 |
| New York | 72 | 0 | 0 | 72 | 0 |
| North Carolina | 315 | 0 | 0 | 98 | 217 |
| Ohio | 598 | 410 | 0 | 156 | 32 |
| Oklahoma | 793 | 0 | 777 | 0 | 16 |
| Oregon | 244 | 0 | 0 | 44 | 200 |
| Pennsylvania | 42 | 0 | 0 | 42 | 0 |
| South Carolina | 213 | 0 | 0 | 57 | 156 |
| South Dakota | 434 | 350 | 0 | 6 | 78 |
| Tennessee | 97 | 0 | 0 | 19 | 78 |
| Texas | 576 | 300 | 0 | 131 | 145 |
| Virginia | 197 | 0 | 0 | 95 | 102 |
| Washington | 175 | 0 | 0 | 17 | 158 |
| West Virginia | 149 | 0 | 101 | 0 | 48 |
| Wisconsin | 581 | 432 | 0 | 43 | 106 |
| Total Volume | 16,039 | 9,034 | 913 | 2,139 | 3,955 |

Source: US-EPA, 2009a, p. 193; US-EPA, 2009b, p. 24996.

In 2008 the United States consumed 138 billion gallons of gasoline and 9 billion gallons of ethanol (Figure 2). A gallon of the common E-10 blend (10 percent ethanol and 90 percent gasoline) contains 96.6 percent as much energy as a gallon of gasoline. In 2007, the ethanol consumed by U.S. vehicles contained about 2.9 percent as much energy as that contained in U.S. gasoline (Figure 3). If the 2022 goal of producing 36 billion gallons of first and second generation biofuels is achieved, the gross energy equivalent of the biofuels will be approximately 16.2 percent of the energy contained in 2007 U.S. gasoline and ethanol consumption. In terms of energy, achieving the 2022 goal of 36 billion gallons of biofuel would be equivalent to increasing U.S. automobile fleet mileage from 25 to 29 miles per gallon. If an economically competitive and environmentally sound conversion technology is developed, the size of the potential market for cellulosic biomass is enormous.

## Corn Stover and Switchgrass Production Potential

Perlack *et al*. (2005) estimated that 256 million dry tons of corn stover could be sustainably removed annually from U.S. cropland, and that 368 million dry tons of perennial grass could be produced annually on 55 million U.S. acres of cropland, idle cropland, and cropland pasture. These projections are based on the assumption that the United States could continue to meet food, feed, and export demands. Perlack *et al*. (2005) did not provide estimates of the cost to produce, harvest, store, and deliver the cellulosic biomass.

The U.S. Department of Energy's National Renewable Energy Laboratory established an ethanol from cellulosic biomass conversion goal of 90 gallons per dry ton (Pacheco, 2006). (The US-EPA uses a conversion ratio of 94 gallons per dry ton (US-EPA, 2009a, 2009b)). If the 90 gallons per ton conversion goal is met, the 256 million tons of stover could be converted to 23 billion gallons of ethanol. The 368 million tons of cellulosic biomass from perennial grasses could be converted to 33 billion gallons of ethanol. By this measure, either of the feedstocks, corn stover or switchgrass, could be used independently to fulfill the 21 billion gallons of second generation biofuels mandate included in the 2007 legislation.

For a conversion rate of 90 gallons per ton and the mandate of 21 billion gallons, 233 million tons will be required. If switchgrass was the single source of feedstock, for a yield of three (seven) dry tons per acre, a total of 78 (33) million acres would be required. In 2007, U.S. farmers planted 94 million acres to corn, 64 million acres to soybeans, 60 million acres to wheat, and 11 million acres to cotton. Landowners had about 35 million acres enrolled in the Conservation Reserve Program (CRP). If an economically competitive business model is developed, the potential impact of a cellulosic biomass biofuels program on the use of U.S. agricultural lands is mammoth. However, as noted in Table 1, the US-EPA projects that fewer than two million acres of switchgrass will be used to fulfill the 2022 mandate. Switchgrass is not expected to play a major role by 2022.

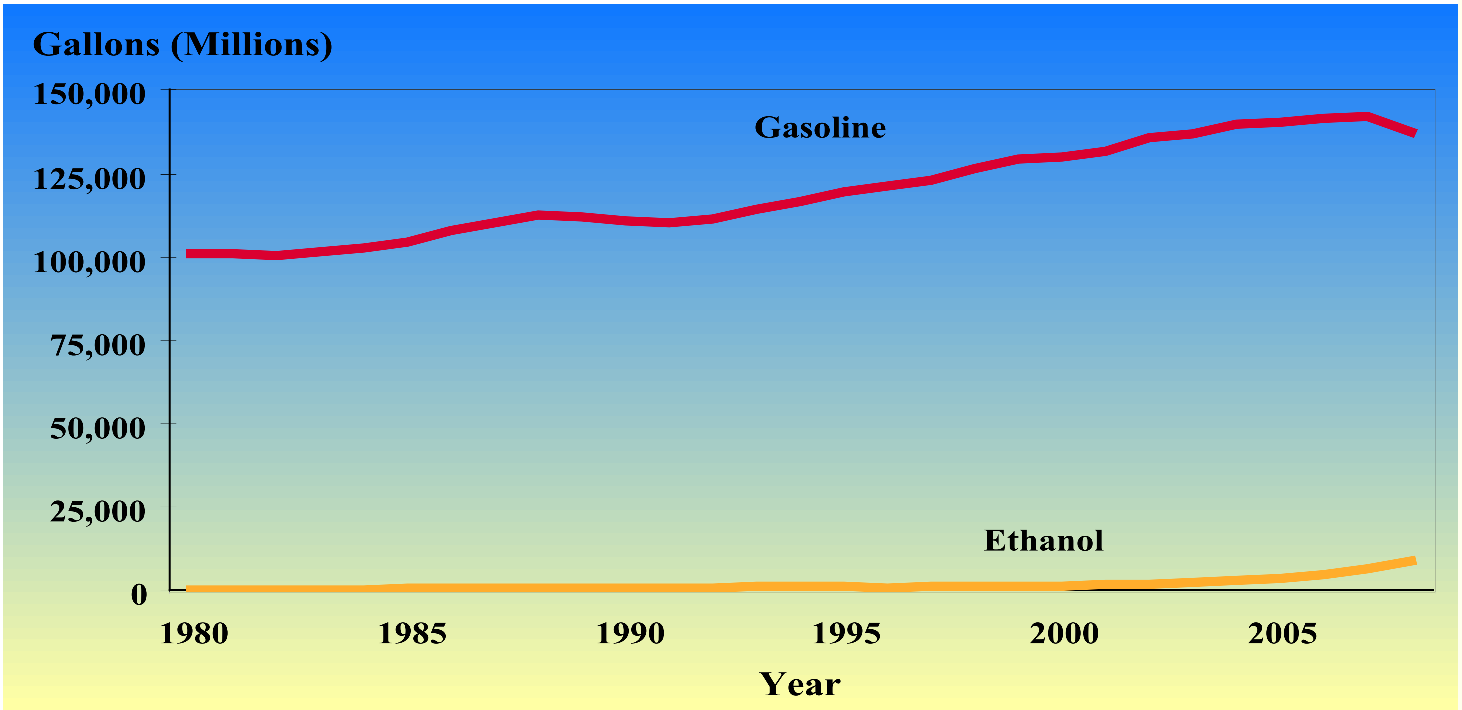

**Figure 2.** U.S. Gasoline Consumption and Ethanol Production, 1980-2008. (U.S. gasoline comsunption in 2008 was 138 billion gallons. U.S. ethanol production in 2008 was approximately 9 billion gallons)

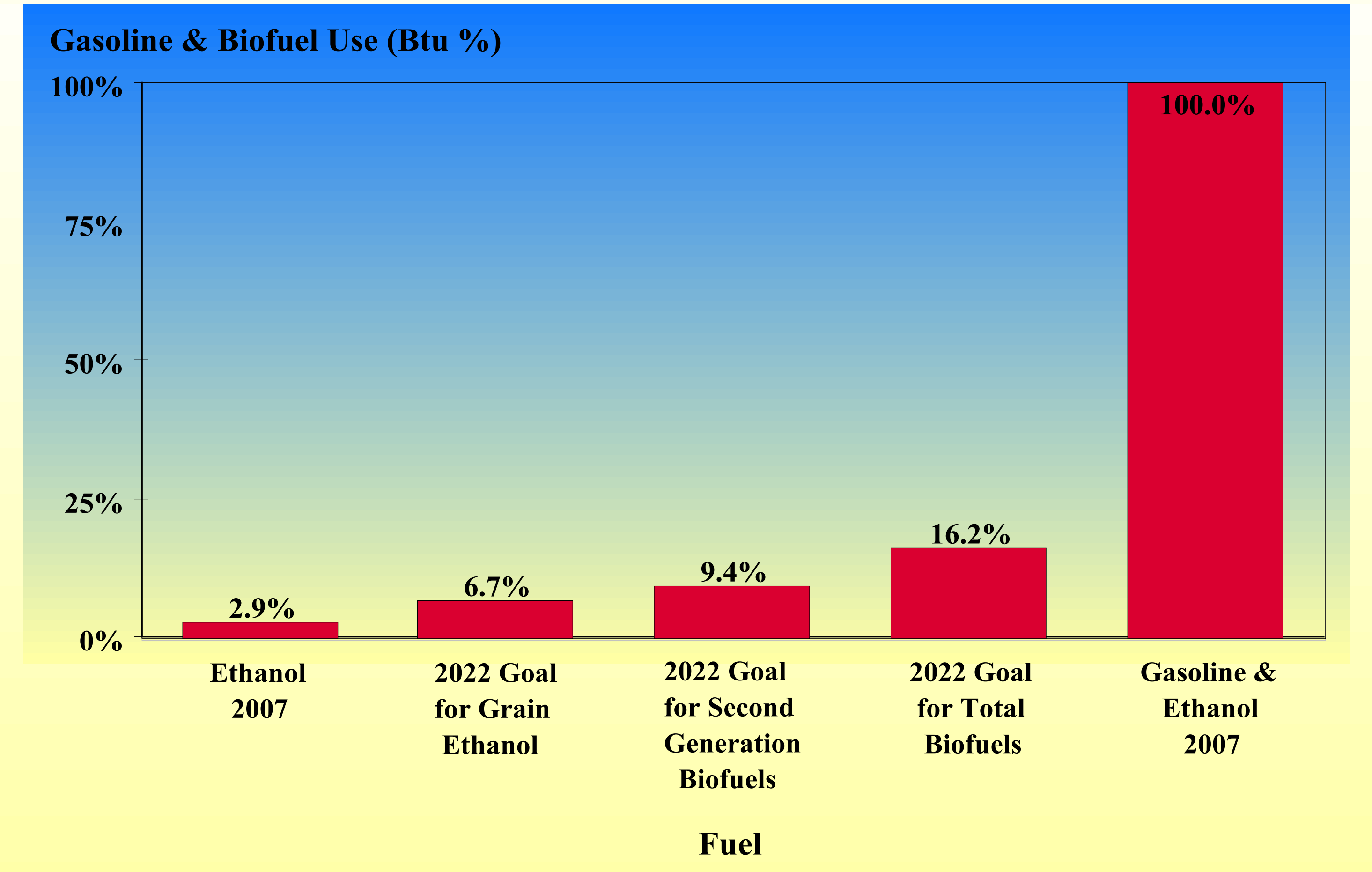

**Figure 3.** Energy Content in Ethanol Produced in 2007 and Biofuel Goals in the 2007 U.S. Energy Independence and Security Act Relative to Total Energy in Gasoline and Ethanol Consumed in 2007.

### Cellulosic Biomass is not Grain

Many of the early policy discussions regarding a cellulosic biomass ethanol industry were framed from experiences in the corn-ethanol business. However, harvesting, storing, and transporting corn stover, and producing, harvesting, storing, and delivering cellulosic biomass, is fundamentally different than producing and marketing corn grain. The infrastructure for production, harvest, storage, transportation, and price risk management of corn grain was well developed prior to implementation of the public policies designed to increase the production of fuel ethanol.

Initially, the corn fuel ethanol industry used a relatively small quantity of total corn production. A well capitalized firm could build a corn-ethanol plant almost anywhere in the Midwest and not be overly concerned about obtaining feedstock. They could post a corn price a cent per bushel higher than the nearest grain elevator, and the existing marketing system would deliver corn. They could adjust price as necessary to obtain a flow of corn grain to the facility throughout the year. They could hedge feedstock price. Limited corn grain storage (perhaps as little as three weeks) capacity was sufficient for an orderly corn gain to corn ethanol production system. A similar infrastructure does not exist for cellulosic biomass (corn stover or switchgrass).

Corn is an annual crop with established spot markets and futures markets. Efficient systems for seed production, planting, fertilizing, harvesting, transportation, and storage of corn grain developed in market economies over decades. Corn has many alternative uses and requires many farming activities. Switchgrass is a perennial, with zero spot markets, zero futures markets, and no infrastructure. Mature harvested switchgrass is of limited value for anything other than biomass feedstock. After the grass is established, switchgrass involves very little “farming”. In most U.S. environments for established switchgrass, a single trip across the field per year to apply fertilizer may be sufficient to maintain healthy thriving stands.

Investors in a cellulosic ethanol biorefinery will come to expect the business plan to contain careful detailed attention to feedstock procurement. Optimal cellulosic biorefinery size is unknown. However, corn ethanol plants with capacity in excess of 50 million gallons per year are common. For a conversion rate of 90 gallons per ton, a 50 million gallons per year facility would require about 1,600 dry tons per day to operate 350 days per year. To achieve economies of size, a moderately sized cellulosic biorefinery may require 2,000 dry tons per day or 700,000 tons per year. If feedstock is delivered in 20 ton truck loads (at 85 percent dry matter, 17 dry tons per truck), a single facility could require 118 loads per day, 24 hours per day, or 4.9 trucks per hour (Tembo, Epplin, and Huhnke, 2003). For a corn stover removal rate of two dry tons per acre, 350,000 acres of corn stover would be required to supply a single biorefinery.

## Corn Stover Issues: The Trouble with Stubble

For decades corn stover has been viewed as the "low hanging fruit" of agricultural cellulosic biomass. In 1981, English, Short, and Heady (1981) published a feasibility study of using crop residues to supplement coal in coal-fired electric generating plants. They concluded that "…under the rapid upward trend in energy prices, the use of corn residues may indeed be feasible…". However, they cautioned that additional research would be warranted to determine "willingness to harvest" and "opportunity cost" (English, Short, and Heady, 1981, p. 644).

Table 2 includes a summary of findings of several studies that have been conducted to determine the cost of removing corn stover. Most of the studies reported in Table 2 are based on economic engineering estimates with one exception. Glassner, Hettenhaus, and Schechinger (1998) evaluated a corn stover collection project conducted near Harlan, Iowa and reported actual cost (in 1997 dollars). They collected more than 50,000 tons from 30,000 acres from the 1997 crop. The 50,000 tons would provide 25 days of feedstock for a 2,000 tons per day biorefinery. They reported an average harvest cost of $14.60 per ton, a harvestable yield from 1.5 to 3.0 tons per acre and a payment to farmer-land owners of $3 to $15 per ton. The farm gate payment varied from $18 to $30 per ton depending on distance from the use facility.

In another discussion of the same project, Schechinger (2000) described the transportation of corn stover as a "logistical nightmare" that included problems with rain, snow, ice, mud, fire, and stalk moisture retention. For much of the U.S. Corn Belt the narrow harvest window is likely to be a major factor. For example, Nielsen (1995) estimated that the average harvest window for corn stover in the upper Midwest is 40 days. Petrolia (2008) estimated a 21-day harvest window for Minnesota. The US-EPA assumed a 50-day harvest for Indiana (US-EPA, 2009a, 2009b). Based on historical weather patterns, Abengoa Bioenergy concluded that in one of seven years, corn stover harvest in the Eastern Corn Belt is likely to be limited by weather (Robb, 2007). They plan to build a hybrid (grain and cellulose) biofuel facility near Hugoton, Kansas and use a combination of feedstocks, including wheat straw, corn stover, grain sorghum stubble, switchgrass, and

**Table 2. Estimates of Corn Stover Farm Gate Costs**

| Source | Year | Location | Harvest | Fertility Replacement | Payment to Landowner/ Farmer | Harvestable Yield | Farm Gate Cost |
|---|---|---|---|---|---|---|---|
| | | | ($/ton) | ($/ton) | ($/ton) | (tons/acre) | ($/ton) |
| Brechbill & Tyner | 2008 | IN | $7 to $11 | $15.64 | N/A | 1.6 to 3.0 | $23 to $26 |
| English, Short, & Heady | 1981 | IA | $7.30 | $4.38 | N/A | N/A | $12.00 |
| Gallagher *et al.* | 2003 | IA | $6.27 | $6.46 | N/A | 3.13 | $13.00 |
| Gallagher *et al.* | 2003 | KS | $5.96 | $6.47 | N/A | 3.33 | $12.00 |
| Graham *et al.* | 2007 | US | $18 to $33 | $6.50 | N/A | 1.4 to 2.3 | $25 to $40 |
| Glassner, Hettenhaus, & Schechinger | 1998 | IA | $14.60 | N/A | $3 to $15 | 1.5 to 3.0 | $18 to $30 |
| Khanna | 2008 | IL | $35.05 | $8.27 | $24.00 | 1.85 | $67.00 |
| Petrolia | 2008 | MN | N/A | $4.21 | N/A | N/A | $40[a] |
| US-EPA | 2009 | IN | $23.73 | $11.81 | $10.00 | 2.0 | $43 to $46[b] |

[a] Calculated by subtracting average estimates of storage, transportation, and loading costs from reported marginal feedstock costs of $60 per ton.

[b] These estimates include a charge of $3.39 to haul fromthe field to the farm edge.

Note: In cases where multiple values or a range of values were provided, the value reported is assumed to be averaged over those provided.

Sources: Brechbill and Tyner, 2008; English, Short, and Heady, 1981; Gallagher *et al*., 2003; Graham *et al*., 2007; Glassner, Hettenhaus, and Schechinger, 1998; Khanna, 2008; Petrolia, 2008; and US-EPA, 2009a and 2009b.

grasses harvested from CRP acres (Mapemba *et al.*, 2007; Robb, 2009).

Given the investment required in harvest machines, and the need to provide a continuous flow of biomass to a biorefinery throughout the year, a highly coordinated harvest system would likely develop (Thorsell *et al.*, 2004). For example, a substantial quantity of the grain produced in the Great Plains is harvested by custom harvest companies that can perform the operations in a timely, cost efficient manner (Kastens and Dhuyvetter, 2007). Decisions regarding switchgrass harvest could well be made external to the "farm". Modeling of switchgrass harvest has found that the estimated cost to lease the land and produce, harvest, and store the switchgrass would be $16 more per ton if harvest was restricted to a two-month versus an eight-month harvest window (Epplin *et al.*, 2007).

If corn stover were used as a single feedstock, a rather substantial investment would be required in harvest machines and storage. Several dual (stover plus grain) harvest systems are in various stages of development. However, several problems likely to be encountered in the U.S. Corn Belt must be overcome before dual harvest systems are economically viable. Under some weather conditions a dual harvest system would delay harvest of the primary product, corn grain. Delayed corn grain harvest is likely to result in a decrease in expected harvestable yield and a potential reduction in grain quality with a corresponding reduction in net price per unit. If the producer is faced with the possibility of lower expected grain yields and lower expected grain prices, an incentive would be required to enable corn stover harvest. None of the budget estimates included in Table 2 include a compensation to offset the potential risk of a decrease in corn grain yield or a decrease in corn grain price and, hence, a lower price likely to be required by a dual harvest system. A payment to the corn producer may be needed as an incentive to insure against a loss of revenue in the event that stover harvest reduces the expected revenue of the primary product, corn grain.

The corn grain may, at times, be sufficiently dry for harvest. However, the moisture content of the stalks may be too high for safe baling. One alternative is to chop rather than bale the stover. However, storage and handling for chopped material is not without problems. Transportation of water is expensive. The market for corn silage is local for a reason.

### Corn Stover Removal Cost Estimates

The more recent economic engineering estimates of the farm gate cost of corn stover vary from $12 per ton (Gallagher *et al.*, 2003) to $67 per ton (Khanna, 2008) (Table 2). Estimated harvest costs vary from $5.96 per ton (Gallagher *et al.*, 2003, KS) to $35.05 per ton (Khanna, 2008). Fertility replacement costs vary from $4.21 per ton (Petrolia, 2008) to $8.27 per ton (Khanna, 2008). Petrolia's costs are lower in part because he assumes that soybeans will follow the corn and that the nitrogen removed in the corn stover does not need to be replaced.

Even though English, Short, and Heady (1981) concluded that additional research would be warranted to determine "willingness to harvest" and "opportunity cost", many of the studies do not report a payment to the landowner-farmer other than a payment for fertility replacement. Khanna (2008) does include a $24 per ton payment in addition to the $8.27 per ton fertility replacement cost for the opportunity to remove the stover. The US-EPA (2009a, 2009b) includes a payment of $10 per ton to compensate the farmer and/or land owner.

Abengoa Bioenergy plans to offer four alternative types of 10-year contracts to include a payment of $1 per acre paid only in the first year as a commitment fee, and $0.50 per year per acre contracted as a reservation payment in subsequent years (Robb, 2009). The proposed contracts are for acres rather than for a specific crop. Farmers/landowners are free to plant wheat, grain sorghum, or corn. The contracts grant Abengoa Bioenergy the option to either purchase or to refuse to purchase crop residue biomass available after grain harvest on contracted acres. Abengoa will be responsible for harvest, transport, and storage. Farmers/landowners may elect from one of four payment alternatives: (1) $15 per dry ton; (2) $7 plus nutrient replacement cost per dry ton; (3) $10 plus revenue share per dry ton (revenue share = 2.5 * Chicago Board of Trade EtOH futures (capped at $10 per ton)); and (4) $2 plus revenue sharing plus nutrient replacement per dry ton. CRP land (subject to USDA approval) and acres in perennial grass such as switchgrass may be contracted as well (Robb, 2009).

What price would be required to entice farmers and landowners of 350,000 acres of corn to permit the removal of corn stover to fulfill the needs of a single biorefinery remains to be determined. However, it does not seem reasonable to assume that merely compensating by covering harvest costs and cost of fertility replacement would be sufficient. As one corn producer told a newspaper reporter: "…Our main concern is $4-per-bushel corn (worth $750 to $800 an acre)…," "…$30 per acre for biomass is a minor concern …" (Hord, 2007). A corn stover harvest system that does not have provisions for offsetting the potential risk of reducing expected revenue from corn grain is not likely to procure much biomass.

### Switchgrass Production

In 1978, more than 26 million acres of U.S. cropland was classified as idle (Lubowski *et al.*, 2006). Much of this idle land was diverted from crop production as a result of various federal programs. Development of energy crops was envisioned as a way to convert this idle land to productive use and, at the same time, reduce the cost of government commodity and conservation programs that were funded to entice land owners to set aside the land from the production of traditional crops. "…The rationale for developing lignocellulosic crops for energy is that …poorer quality land can be used for these crops, thereby avoiding competition with food production on better quality land…." (McLaughlin *et al*., 1999, p. 293).

Research sponsored by the Bioenergy Feedstock Development Program at the Oak Ridge National Laboratory evaluated more than 30 species in research plots on a wide range of soil types in more than 30 sites across seven states (Wright, 2007). Based on these trials, switchgrass was selected as a model species. It is an indigenous noninvasive widely adapted endemic species of the tall grass prairies, has high water use efficiency, has a large and deep root system, and has demonstrated a capacity for high yields on relatively poor quality sites (Wright, 2007). Switchgrass also has a significant capacity to improve soil quality by sequestering carbon below ground (Lewandowski *et al*., 2003; Wright, 2007).

### Switchgrass Production Cost Estimates

Table 3 includes a summary of switchgrass production cost estimates from nine studies. Two factors are critically important: the opportunity cost of land and the expected yield. Mature yield estimates range from 2.23 tons per acre reported by Perrin *et al*. (2008) obtained from field trials in the northern plains to 6.45 tons per acre budgeted by Garland (2008) for Tennessee. Switchgrass yield depends on a number of factors including variety. Fuentes and Taliaferro (2002) reported yields from variety trials conducted over seven years at two locations in Oklahoma. They found an average annual yield of 7.2 tons per acre from stands that included a combination of varieties, Alamo and Summer, but a yield of only 4.4 tons per acre from stands of variety Cave-in-Rock.

The lowest switchgrass farm gate cost estimate of the post 2007 studies of $37 per ton is from an Oklahoma study that depends critically on the assumption that harvest could extend over at least eight months (Epplin *et al*., 2007). The estimated costs are relatively low because the extended harvest season allows for a substantially lower investment in harvest machines resulting in lower fixed costs per harvested ton (Mapemba *et al*., 2008). This result also provides lower storage costs and lower storage losses. However, if harvest is extended into December, January, February, and March, the harvestable yields are also lower. The highest farm gate cost estimates of $113 per ton are from Khanna (2008). Khanna's estimates are relatively high because they assume an estimated yield of only 2.4 tons per acre from Illinois cropland.

Most of the costs estimates in Table 3 are based on information obtained from small research plots. However, the estimate provided by Perrin *et al*. (2008) of $54 per ton is based on field level studies. The cost estimates suggests the likelihood is low that switchgrass could be economically competitive on land capable of supporting a corn-soybean rotation. The US-EPA estimate of $44 per ton is based on the assumption that switchgrass would only be produced on low quality cropland in New Hampshire, Oklahoma, and West Virginia.

As noted, US-EPA proposed regulations are based on the assumption that 7.8 billion gallons (49 percent) of the EISA 2022 mandated level of 16 billion gallons of cellulosic biofuels (primarily cellulosic ethanol) can be produced from corn stover. Only only 0.9 billion gallons (6 percent) are expected to be produced from dedicated energy crops (switchgrass). Dedicated energy crop production is expected only in the states of New Hampshire, Oklahoma, and West Virginia. The US-EPA estimates that the average cost to deliver a dry ton of corn stover in 2022 (in 2006 dollars) will be $89 (US-EPA, 2009a, p. 532). This compares with $77 per ton for switchgrass (US-EPA, 2009a, p. 536).

## Discussion

The market for energy in the United States is huge. If economically competitive and environmentally sound business models are developed to enable conversion of agricultural residues, such as corn stover and dedicated energy crops, that can be produced on marginal lands, such as switchgrass, are developed, the landscapes of rural America could be radically changed.

Distinctions between land owners and farmers are not made in the studies of cost estimates for corn stover and switchgrass. In some regions of the United States, more than 50 percent of cropland is not owned by people who till, plant, and harvest crops (USDA, 2007). Access to collection and acquisition of corn stover is likely to be controlled by corn farmers rather than land owners. On the other hand, switchgrass production is much more likely to involve the land owner, similar to the Conservation Reserve Program. Similar to CRP lands, in post establishment years, switchgrass is not expected to require many farming activities. Every privately owned U.S. acre is used for some purpose. If a biorefinery wants to use it to produce feedstock they will be required to bid it from existing use.

A biorefinery with intentions to use corn stover is likely to engage in business dealings with corn farmers and to have little need for interaction with land owners. However, a biorefinery designed to process switchgrass biomass will likely be required to deal with land owners. This interaction may be similar to that of the government with CRP. In the case of switchgrass, or any other perennial dedicated energy crop, the biorefinery may be in competition with farmers for land. Extension educators may have a role in educating the public regarding resource values and contracts and may be called on to mediate potential conflicts.

Historically, when traditional extractive mining industries discovered deposits of minerals and hydrocarbons, owners of mineral rights realized an unanticipated windfall. In

**Table 3. Estimates of Switchgrass Farm Gate Production Costs**

| Source | Year | Location | Nitrogen | Land Charge | Mature Yield | Farm Gate Cost |
|---|---|---|---|---|---|---|
| | | (State) | (lb/acre) | ($/acre) | (tons/acre) | ($/ton) |
| Brechbill & Tyner | 2008 | IN | 80 | $70 | 5.00 | $45 |
| Duffy | 2007 | IA | 100 | $80 | 4.00 | $82 |
| Epplin | 1996 | OK | 50 | $30 | 4.00 | $23 |
| Epplin *et al.* | 2007 | OK | 80 | $60 | 3.75 to 6.50 | $37 to $53 |
| Garland | 2008 | TN | 60 | N/A | 6.45 | $62 + Land |
| Khanna | 2008 | IL | N/A[a] | $77[b] | 2.40 | $113[c] |
| Khanna, Dhungana, & Clifton-Brown | 2008 | IL | 100 | $78 | 2.58 | $82 |
| Perrin *et al.* | 2008 | ND, SD, & NE | 67 | $60 | 2.23 | $54[d] |
| Vadas, Barnett, & Undersander | 2008 | WI | 125 | $80 | 4.84 | $53 |
| US EPA | 2009 | | N/A[e] | $62[f] | 6.17[g] | $44 |

[a] $66.70 per acre listed as fertilizer cost.

[b] The $77 per ton estimated is based on the assumption that in the article contains a typographical error. The value specified as 179.40 to $189.00 ($/t dm) is assumed to be $/acre, which when divided by the average yield of 2.4 tons per acre would provide an estimated land cost of $77 per dry ton.

[c] The units error as described in footnote b is also assumed for total farmgate costs.

[d] The five year observed costs are reported as $60 per ton. The $54 per ton estimate is based on extrapolated costs over a ten year stand life.

[e] The nitrogen level is not specified but a charge of $11.81 per ton is assessed for nutrient replacement, p. 536.

[f] Cost are estimated on a per ton rather than per acre bases. A charge of $10 per ton is assessed at an assumed yield of 6.17 tons per acre (see g).

[g] A specific yield is not specified. However, an expected ethanol yield of 580 gallons per acre is reported. This, at a conversion rate of 94 gallons of ethanol per ton as used by the US EPA would translate into an assumed yield of 6.17 tons per acre.

Sources: Brechbill and Tyner, 2008; Duffy, 2007; Epplin, 1996; Epplin *et al.*, 2007; Garland, 2008; Khanna, 2008; Khanna, Dhungana, and Clifton-Brown, 2008; Perrin *et al.*, 2008; US Environmental Protection Agency, 2009a, 2009b; and Vadas, Barnett, and Undersander, 2008.

Note: In cases where multiple values or a range of values were provided, the value reported is assumed to be averaged over those provided. These are nominal dollar values.

some locations, wind energy may provide a small unexpected windfall to land owners. However, major windfalls are not likely from corn stover and switchgrass. Biorefineries will be required to pay the opportunity cost to acquire feedstocks. However, neither farmers or land owners are likely to receive a Jed Clampett windfall from the biofuels business. If switchgrass provides a greater return to marginal lands than current use, values of marginal lands will increase. Existing landowners may benefit. However, land rent, a major cost of doing business for tenant farmers, would be expected to increase.

Perennial crops that require a substantial investment for establishment, such as switchgrass, that are expected to produce for more than a decade also carry another potential problem for land owners. If the biorefinery goes bankrupt, and if no other biorefineries are operating within a reasonable distance, the land owner may suffer the switchgrass establishment investment loss. After the grass is established, if the land owner has access to only one biorefinery, the company may choose to exercise monopsony power and pay less than the marginal value of the feedstock. Landowners are likely to anticipate both of these risks and be reluctant to establish switchgrass. One potential role for government that could facilitate the policy goal of establishing dedicated energy crops on millions of acres would be to guarantee or insure payment over the expected life of the crop. Perhaps the most efficient way to entice land owners to establish dedicated perennial energy crops would be to use the existing CRP infrastructure.

The Conservation Reserve Program was established in 1985. USDA provided CRP participants (farm owners or operators) with an annual per acre rent and half the cost of establishing a permanent land cover (usually grass or trees) in exchange for retiring highly erodible or environmentally sensitive cropland for 10 years. Farmers and land owners began enrolling land in 1986. During the first three enrollment periods in March, May, and August of 1986, more than 8 million acres were enrolled. An additional 13.9 million acres were enrolled in February and July of 1987. More than 22 million acres were enrolled in the two years after the 1985 legislation (Osborn, Llacuna, and Linsenbigler, 1995).

Given the rather substantial cost economies associated with harvest machines, given that the costs of harvest may account for 45 to 65 percent of the total farm gate costs of production, and given that a biorefinery is expected to require a continuous flow of feedstock, if switchgrass, or some other perennial grass is established on millions of acres, it is likely that a highly coordinated harvest system will develop. Established stands of an indigenous perennial grass such as switchgrass are expected to require little management, perhaps one trip across the field for fertilization per year, followed later in the year by harvest. Except for the activities associated with harvest, established stands of switchgrass are not likely to require much activity.

The structure of a mature cellulosic feedstock production and delivery system remains to be determined. However, production characteristics and harvest cost economies could result in a structure for perennial grass production for use as a dedicated energy that more nearly resembles the structure of U.S. timber production rather than the atomistic system that we observe for U.S. grain and oilseed production. If the low-cost feedstock is a perennial, such as switchgrass, with a long stand life and wide harvest window, market forces may drive the structure toward vertical integration. For a mature industry, feedstock production, harvest, and transportation may be centrally managed and coordinated.

A number of additional issues remain. A system to manage the risk associated with feedstock yield variability and the risk of fire of standing and stored biomass will be required. How a biorefinery would respond to short crops or weather issues that interfere with corn stover harvest is unclear. In years of above average yields, not all acres would have to be harvested. However, in years of below average yields, the biorefinery may not have sufficient feedstock to operate throughout the year. Finally, the ultimate challenge is to discover, develop, design, and demonstrate an economically competitive biorefinery technology necessary for a profitable business model.

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# Risk Management for Energy Investments: Agricultural Policy and Extension Recommendations

James A. Larson and Burton C. English[1]

## Introduction

The Renewable Fuel Standard set forth by The Energy Independence and Security Act of 2007 requires a minimum of 36 billion gallons of renewable fuels to be produced by 2022 (U.S. Congress, 2007). Other currently proposed renewable fuels goals would require even higher production levels. For example, the 25x'25 Initiative calls for 25 percent of energy use to come from renewable sources by 2025 (English *et al*., 2006), the 30x'30 proposal calls for replacing 30 percent of petroleum consumption with biofuels by 2030 (Perlack *et al*., 2005), and the Bush Administration's "Twenty in Ten" goal is to reduce gasoline consumption by 20 percent over the next 10 years (US-EPA, 2007). The implications of meeting such goals on cellulosic feedstock production are immense. For example, both De La Torre *et al*. (2007) and Perlack *et al*. (2005) estimate that up to 10 percent of the U.S. agricultural land base could be converted into dedicated energy crop production depending on market conditions.

In 2007, the State of Tennessee invested $70 million over 5 years for the University of Tennessee (UT) Biofuels Initiative (UT, 2008a and 2008b). Of the $70 million devoted to biofuels research and development, $40.7 million was to be paid for construction of a pilot biorefinery and $8.25 million was allocated for research, farmer incentives, and operating expenses. DuPont Danisco and UT are jointly planning to operate a pilot biorefinery in the town of Vonore in Monroe County in East Tennessee starting January 2010. The plant will use corn cobs initially followed by switchgrass as feedstocks. The Initiative contracted with 16 farmers in Monroe and surrounding counties in spring 2008 to plant 723 acres of switchgrass to provide feedstock to the plant. An additional 1,954 acres of switchgrass were planted in spring of 2009 and another 3,000 acres are scheduled to be planted in spring of 2010. In advance of a mature market, these farmers are paid on a per-acre basis. Farmers received high quality switchgrass seed for planting, as well as research and technical support from UT Extension. Depending on market conditions and the success with the pilot-plant in Vonore, switchgrass planted area in east Tennessee may expand to 25,000 acres or more to support a 25 million gallons per year or more biorefinery.

Research and Extension personnel at the UT Institute of Agriculture (UTIA) have extensive experience with switchgrass as a dedicated energy crop. In 2004, the UT Switchgrass Project established 32 acres of switchgrass at the Milan Research and Education Center, Milan, TN, to study optimal agronomic practices for switchgrass, including weed control, nitrogen and seed management, harvesting alternatives, post-harvest logistics and storage, enhanced variety evaluation, and production potential on different land qualities constrained by different drainage and slope conditions. An additional 92 acres of switchgrass were established by farmers in west Tennessee under contract with the UT Switchgrass Project to evaluate production under actual farming conditions. In early 2008, 16 acres of switchgrass were established at the Dairy Research and Education Center, Lewisburg, TN, to determine switchgrass yield and economic potential relative to corn on different qualities of marginal land as defined by soil depth and water availability. Early findings provided information for Extension recommendations and crop enterprise budgets for switchgrass establishment and annual maintenance.

The experience gained from the UT Switchgrass Project since 2004 and the UT Biofuels Initiative in the first year of contracting with farmers has brought forth many observations regarding the establishment and production of switchgrass on large fields. In particular, UT AgResearch and Extension personnel have identified risk management issues that require further research. The objectives of this paper are: 1) to describe issues related to the management and risk of producing switchgrass that have been identified by the UT Switchgrass Project and the UT Biofuels Initiative, and 2) to recommend possible Extension programming efforts for risk management of perennial cellulosic crops such as switchgrass.

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## UT Biofuels Initiative Extension Programming

An 18-member multidisciplinary Biofuels Farmer Education Team (BFET) provides leadership to overall educational programming for the UT Biofuels Initiative (Table 1). The BFET has developed and published a series of seven fact sheets ranging from "Growing and Harvesting Switchgrass for Ethanol Production in Tennessee" (Garland, 2008a and 2008b) to "Biofuels 101" (Wilcox, Lambert, and Tiller, 2008). The BFET also developed guidelines for establishing switchgrass, annual production budgets for various planning horizons (Garland, 2008a and 2008b), and switchgrass contracting documents.

In the Fall of 2007, six listening sessions and focus group meetings were conducted to obtain input from farmers on desirable features to include in a switchgrass production and harvesting contract. The initial round of contracting occurred with 16 small-to-mid-sized farmers. These farmers planted a total of 723 acres of switchgrass in the spring of 2008. The acreage of switchgrass per farm ranged from 15 to 136 acres. Because of the topography of East Tennessee, the fields tend to be small, irregularly shaped, and on slopes. In 2009, meetings were again held to solicit more farmers to grow switchgrass for the UT Biofuels Initiative. An additional 1,954 acres with a similar range of sizes of switchgrass area on each farm was contracted and planted in the spring of 2009. Some of the farmers who planted switchgrass in 2008 contracted additional area in 2009. Twenty-three new farmers planted switchgrass in 2009.

For the first round of contracts in 2008, major efforts were taken to teach farmers how to manage risks associated with this new Tennessee crop. During the farmer focus group meetings and contracting sessions, farmers expressed concerns about production, price and financial risks. These concerns during the first year of the Initiative were exacerbated by higher fuel, seed, and other variable input costs between October 2007 and January 2008. Total variable costs associated with switchgrass production and harvesting increased by more than 25 percent.

The contract between the Tennessee Biofuels Initiative and switchgrass producers is dynamic and can change as new information emerges. These contract changes will be guided by experience with what works and what does not work with existing contracts and on going research (e.g. Larson, English, and He, 2007; Griffith, 2009). The current contract for the 2008 and 2009 establishment years that is being offered by the University of Tennessee Biofuels Initiative compensates the contractor with an annual $450 per acre payment for a three year contract term. In order to receive full payment, producers must document and follow established production practices. To help farmers manage input price risk, budgeted energy costs were converted to diesel fuel equivalents and contract payments for switchgrass production were tied to the change in the diesel fuel price based on the last week of October 2007 US-DOE's Energy Information Agency (2007)

**Table 1. Biofuels Farmer Education Team (BFET)**

| | |
|---|---|
| 1. Ken Goddard | Biofuels Specialist |
| 2. John Goddard | Loudon County Extension Director |
| 3. Laura Howard | Area Farm Management Specialist |
| 4. David Perrin | Eastern Regional Agriculture Program Leader |
| 5. Clark Garland | Agricultural Economist, Chair Biofuels Farmer Education Team |
| 6. Delton Gerloff | Department Head, Agricultural Economics, Agricultural Economist, Farm Management & Financial Planning |
| 7. Chris Clark | Agricultural Economist & Attorney |
| 8. Michael Wilcox | Agricultural Economist, Economic Development |
| 9. Melvin Newman | Plant Pathologist |
| 10. Pat Keyser | Forestry, Wildlife & Fisheries, Warm Season Grass Specialist |
| 11. Gary Bates | Plant Scientist, Forages |
| 12. Larry Steckel | Plant Scientist, Weed Control |
| 13. Don Tyler | Soil Scientist, Biomass |
| 14. Jim Wills | Agricultural Engineer, Machinery |
| 15. Finis Stribling | Small Farm Specialist, Tennessee State University |
| 16. Anne Dalton | Communications Specialist |
| 17. Jon Walton | Area Specialist in Biofuels |
| 18. Andrew Griffith | Area Specialist in Biofuels |

published price levels. The price will be adjusted annually based on the change in the U.S. Gulf Coast No.2 Diesel Low Sulfur average price in the first week in October of 2007 which was $2.24 per gallon. The first year adjustment will be based on 40.65 gallons per acre of diesel fuel while years two and three will be adjusted based on 32.4 gallons per acre of diesel fuel. The current contract has the energy company being responsible for loading and hauling the switchgrass from the contractor's property to the biorefinery but the producer is responsible for harvest and staging. The contract also provides that the University of Tennessee supplies the seed for all acres contracted to help offset establishment costs (University of Tennessee, 2008a). The University of Tennessee Extension administers the terms of the contract and provides technical assistance to producers through a Biofuels Specialist and two Area Specialists in Biofuels (Table 1). Thus, the relationship between farmers and Extension is very different under the UT Biofuels Initiative than under the typical education programming efforts provided by Extension. The Initiative not only provides education programming about switchgrass production but also mandates the set of management practices that farmers must follow to be eligible for production payments from the Initiative.

## Risk Management Issues Identified by the UT Switchgrass Project and Biofuels Initiative

### General Risk Management Issues

One of the issues for the UT Biofuels Initiative in the development of a commercial scale biorefinery and feedstock supply operation is that many of the contracts are with small part-time operations. Some land owners lack equipment for establishment and for harvest operations and also lack basic production and equipment experience and management skills. Extension personnel spent time educating some switchgrass producers about basic machinery safety and agricultural production practices. Another potential issue is that many of the fields on which switchgrass would be grown in East Tennessee are small, irregularly shaped, and are on marginal soils. Aggregating production from these dispersed and small fields will likely be more expensive than from larger less dispersed fields.

Wang (2009), using a simulation and mixed-integer programming model of feedstock supply for a biorefinery near Vonore, TN, found the delivered cost per dry ton of switchgrass feedstock rises as the plant size is increased from 2 million to 50 million gallons of ethanol processed per year. The model simulates switchgrass production and costs for 77 soil types on agricultural lands within a 50-mile radius of Vonore, TN. In addition, Wang (2009) also found that a refinery in East Tennessee with the objective of minimizing delivered cost per dry ton of switchgrass feedstock would choose more productive soil types rather than marginal lands. The cost per dry ton of delivered feedstock was higher on the marginal soils in East Tennessee, which are in much greater abundance than more productive soil types. The more productive soils are located near the Vonore, TN, plant site while the marginal soils that the plant must depend on to expand production are further away. Thus, the increasing cost feedstock supply chain structure with expanding ethanol production may be a source of risk for a biorefinery in this location.

On the other hand, Griffith (2009) found that a livestock and crop farmer in East Tennessee would choose to produce switchgrass on less productive soils. The primary farm enterprise that switchgrass must compete against in terms of risk and return on marginal soils in East Tennessee is beef cattle production. For the more productive agricultural soils in East Tennessee, corn production is the primary enterprise that switchgrass must compete against in terms of risk and return.

Switchgrass is a perennial that takes several years to establish and has lower yields during the establishment period (Walsh, 2007). Thus, farmers may not be willing to grow switchgrass without financial incentives to over-come the up-front costs of establishment and the lower income for the first few years after establishment. For example, Griffin (2009) found that contracts that paid producers based on expected switchgrass yield over the life of the contract were risk preferred over contracts that paid based on actual yield in each year of production. Nevertheless, it is likely that a biorefinery would prefer to pay based on actual production in each year of the contract and would prefer annual or short-term contracts rather than long-term contracts. Farmers will likely prefer longer term contracts because of the lack of alternative uses for switchgrass. Thus, the UT Biofuels Initiative and Extension will need to determine ways to reconcile the potentially conflicting objectives of farmers and the biorefinery when establishing switchgrass and negotiating production contracts. In addition, the Initiative should consider the potential impacts of displacing beef production with switchgrass production. Beef cattle have historically been an important enterprise in East Tennessee.

The Food, Conservation and Energy Act of 2008 (U.S. Congress, House of Representatives, 2008) established the Biomass Crop Assistance Program (BCAP) to encourage farmers to produce annual or perennial biomass crops in areas around biorefineries. Producers can contract with the USDA to receive biomass crop payments of up to 75 percent of establishment costs during the first year. Subsequent annual payments then offset the so-called "lost opportunity costs" until the dedicated energy crops are fully established and begin to provide farmers with revenue. In addition, the BCAP program provides for cost-share payments up to $45 per dry ton for the harvest, storage, and transport of biomass crops to a processing plant. Larson (2008) found that switchgrass production was more risky on the marginal soils in East Tennessee because of a higher frequency of low yields. Generally smaller yields over which to spread production costs contributed to the lower probability of having a lower cost per dry ton on marginal soils. Thus, policymakers and other decision makers may want to target BCAP payments to more marginal lands to maximize the potential reductions in soil erosion, improvements in water quality, and other benefits of growing switchgrass and overcome the cost disadvantage. Because of the on-the-ground experience that Extension has with farmers and production conditions in East Tennessee, it could play an important role in identifying soils and fields in Tennessee to maximize the benefits of BCAP payments to both farmers and the processor as production scales up from the pilot plant level to a commercial scale level.

### Establishment Risk Management Issues

Typically, it takes three years for switchgrass, a native warm-season perennial, to reach its full yield potential after establishment (Walsh, 2007). Harvest can still be conducted in the first two years after establishment, though some experts recommend not harvesting the crop in the first year to allow more root establishment. The current recommendation for Tennessee is to harvest switchgrass in the first year of establishment provided that sufficient biomass exists. In addition, switchgrass exhibits a high degree of seed dormancy, low seedling vigor and slow seedling growth (Beckman *et al*., 1993; Minelli *et al*., 2004). Because of these characteristics, plantings of switchgrass and numerous other perennial grasses are slow to establish, making them vulnerable to drought and weed competition. This can result in reduced yields or a complete stand failure (Fermanian, Huffine, and Morrison, 1980; Lee, 1965; Martin, Moomaw, and Vogel, 1982; Masters *et al*., 1990; and Rhodes, Steckel, and Mueller, 2008).

Of the 723 acres of switchgrass planted spring 2008 by the UT Biofuels Initiative, 164 acres (23 percent) were replanted in 2008 because of poor germination and emergence due to drought conditions. Soil moisture problems may have been particularly acute where switchgrass was planted after winter wheat harvested for grain. About half of the replanted area was due to a complete stand failure where the whole field was reseeded. Most of the replanted area involved sections of fields being reseeded because of a poor plant stand. In addition, with the anticipated expansion in area devoted to switchgrass production in East Tennessee, the potential also exists for the occurrence of weed, insect, and disease problems that may have significant risk effects due to the potential negative impacts on biomass yield and quality and dramatic reductions in biodiversity (Andow, 1991; Reay-Jones *et al*., 2008). For example, new fields of switchgrass are often planted in fallow or pastureland where several soil insects (e.g., wireworms and white-grubs) may play a role in poor stand establishment. These pests may continue to feed on roots and reduce biomass production throughout the life of switchgrass fields. Preliminary investigations in Tennessee by Dr. Scott Stewart, Extension entomologist, indicated that insect pests can dramatically reduce switchgrass establishment and yield. In addition, several species of root-knot nematodes -- parasites of grasses -- have been shown experimentally to be pathogenic on forage species (Bernard, Gwinn, and Griffin, 1998; Griffin *et al*., 1996). Lesion nematodes were associated with poor persistence of upland genotypes in Arkansas and Louisiana (Cassida *et al*., 2005a; Cassida *et al*., 2005b).

Currently, Alamo is the only variety that is being planted by the UT Biofuels Initiative. Given that perennial switchgrass stand is a durable asset that lasts more than one year, it may be subject to technological risk due to newer, higher yielding varieties may be developed before the end of the useful life of the stand (Larson, 2008). There is likely to be varietal improvement of switchgrass with traits geared toward producing ethanol (i.e., maximizing dry matter production and enhancing conversion-to-ethanol properties) rather than traditional uses. In addition, the lack of diversity in varieties may be an issue as switchgrass area expands in East Tennessee and the potential for increased outbreaks of weeds, insect pests, and diseases typical of monoculture systems. The UT Biofuels Initiative and Extension will need to develop research and education programs to minimize the risk of pest damage in switchgrass while maintaining the crop as a sustainable low input production system capable of providing valuable ecosystems services such as carbon sequestration and the enhancement of soil quality.

### Harvest and Storage Risk Management Issues

The logistics of harvest and storage of switchgrass may present the largest challenges in terms of the cost of production and risk in Tennessee and the southeast (Larson, 2008). The projected harvest time for switchgrass is once in the fall or early winter after a killing freeze (Rinehart, 2006). After a freeze, nutrients move into the root system, minimizing the harvest of nutrients and their replacement, and maximizing the lignocellulosic material for conversion to ethanol. Another important factor that will influence switchgrass production costs and risk in the southeast and in Tennessee is weather. With a once-a-year harvest in the fall or winter, storage of switchgrass bales for a year or more may be required to keep a biorefinery supplied with feedstock to operate at capacity year round. Precipitation tends to be higher year-round and the available daylight hours for drying and harvest are less during the late fall and winter in Tennessee and the southeastern United States. High annual precipitation may affect the quality and dry matter losses of bales during storage and thus the yield of ethanol from a dry ton of switchgrass (Wiselogel *et al*., 1996).

Switchgrass can be harvested using conventional hay equipment (Jensen *et al*., 2007). It is likely that conventional hay equipment will be used for the foreseeable future until specialized harvest equipment is developed. As indicated in Figure 1, large rectangular bales may have economies of size advantages over large round bales even though a large rectangular baler has an initial investment cost more than three times that of a large round baler. English, Larson and Mooney (2008) (unpublished data) estimate that a large rectangular baler may be able to package 11 to 12 dry tons of switchgrass per hour compared with 5 to 6 dry tons per hour for a large round baler. Thus, under Tennessee weather conditions, one large rectangular baler may be able to harvest 600 or more acres over a four-month harvest season between November and February (Table 2). By comparison, one large round baler might be able to harvest about 300 acres over the four month period. Thus, using rectangular balers to harvest rather than round balers may reduce the risk of being able to successfully harvest large acreages of switchgrass under Tennessee weather conditions.

There also may be cost advantages with the handling and transportation of large rectangular bales. Assuming an average switchgrass yield of 6 dry tons per acre, Wang (2009) estimated that the cost of feedstock delivered immediately after harvest to a biorefinery plant gate (i.e., no storage costs incurred) is $78 per dry ton for large rectangular bales compared with $81 per dry ton for large round bales under Tennessee conditions. The delivered costs drop to $60 and $64 per dry ton, respectively, for rectangular and round bales when the average harvested yield is increased to 9 tons per acre. In addition, the costs of protected storage for large rectangular bales may be less than the costs of storing large round bales under cover because more tonnage can be placed within a given area. Wang (2009) estimated that the annual cost of storing large round bales on wooden pallets with a tarp cover in a 3-2-1 pyramid design is $15 per harvested dry ton. This storage cost assumes a 6 dry ton average yield and a 5 year contract period and a zero salvage value for materials for the purpose of calculating annual materials costs. By comparison, the annual cost of storing rectangular bales on wooden pallets with a tarp cover in a 2-2-1 pyramid is $11 per dry ton. Notwithstanding the potential cost advantages of large rectangular bales, the potential dry matter losses during storage were not considered in the calculation of the delivered costs of dry matter and the costs of storage. In addition, large round balers are the predominant type of harvest equipment available in Tennessee (Jensen *et al*., 2007).

Data from an ongoing switchgrass harvest and storage study at the Milan Research and Education Center at Milan, TN, indicate that weathering and dry matter losses during storage may be substantial under Tennessee weather conditions. As shown in Figure 2, unprotected round bales after 111 days (January 25, 2008 to May 15, 2008) typically showed 5 to 10 inches of weathering along the bale's outer edge. About 16 inches of precipitation was recorded during that period. By comparison, round bales stored individually on wooden pallets with a tarp top cover typically showed little signs of

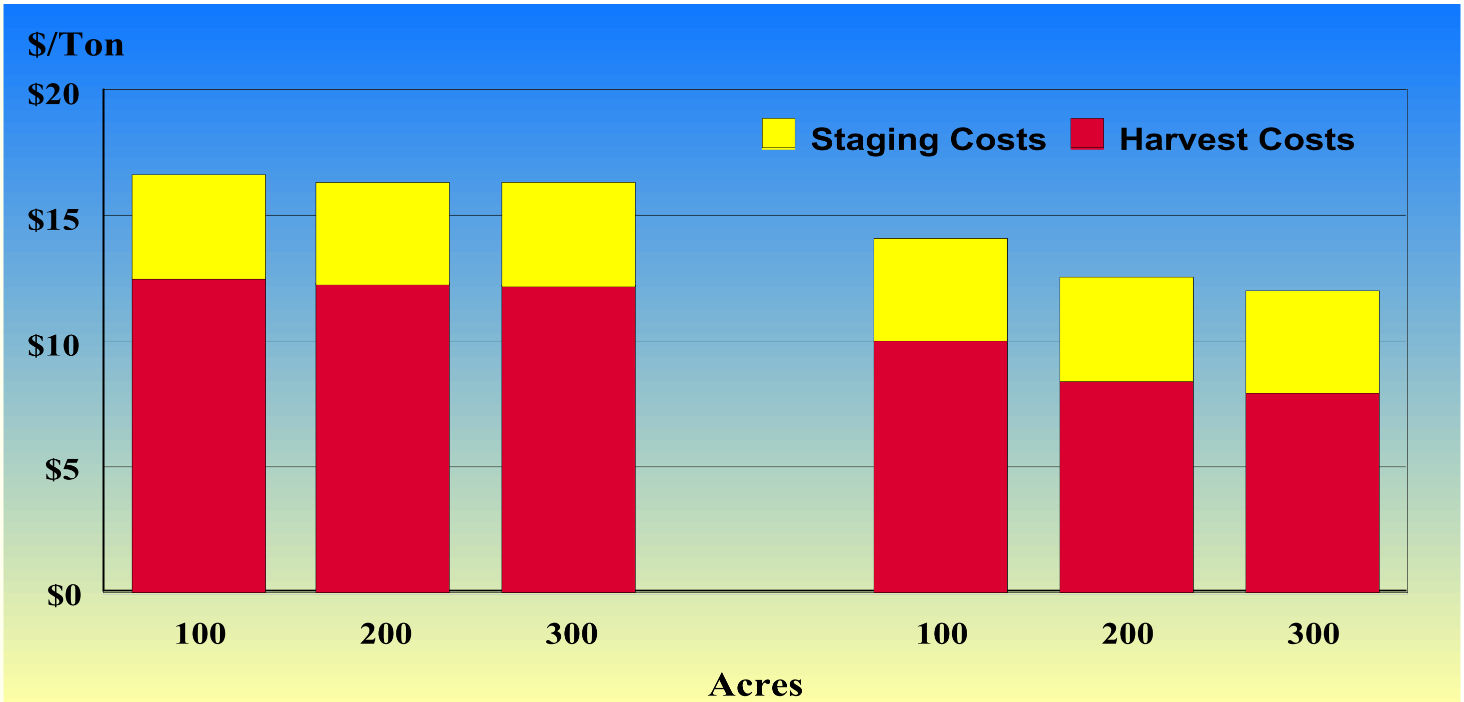

**Figure 1.** Large Round and Large Rectangular Bale Harvest and Staging Costs as a Function of Average Annual Harvested Area.

**Table 2. Estimated Available Harvest Time and Land Area Covered for Switchgrass in East Tennessee**

| | Month | | | | |
|---|---|---|---|---|---|
| Item | November | December | January | February | Total |
| Available Harvest Time[a] | Days/Hours | | | | |
| Days | 14 | 14 | 13 | 12 | 53 |
| Hours | 84 | 84 | 78 | 72 | 318 |
| Land Area Covered[b] | Acres | | | | |
| Rectangular Baler | 168 | 168 | 156 | 144 | 636 |
| Round Baler | 77 | 77 | 72 | 66 | 292 |

[a] Estimated harvest days assuming that 70 percent of the days per month when precipitation was less than 0.01 inches were available for harvest operations (Knoxville, TN, precipitation data). Available harvest hours assume an average of 6 hours of harvest time per available harvest day.

[b] Assumes an average switchgrass yield of 6 dry tons per acre and a throughput of 12 dry tons per hour for the large rectangular baler and 5.5 dry tons per hour for the large round baler.

Source: Wang, 2009

weathering after 111 days in storage. Regardless of storage surface, uncovered rectangular bales tended to become waterlogged and exhibited signs of mold. In addition, the individually covered rectangular bales tended to show more weathering than the individually covered round bales. Early experimental results clearly indicate that rectangular bales would always need to be covered under Tennessee weather conditions. In addition, the large round bales in the Milan harvest and storage experiment were bound using twine. While not used in the experiment, it is likely that mesh wrapped bales would be more dense than twine wrapped bales and would better shed water. Bales wrapped with mesh appear to have a more uniform shape that may facilitate handling and storage.

Preliminary dry matter loss results over about 400 days from the storage experiment in Milan, TN, were as follows (Table 3). First, storage dry matter losses for individually covered rectangular bales were greater than for individually covered round bales. Second, while the data have some problems with consistency over time because individual bales for each treatment were destroyed at each sampling point, the switchgrass dry matter losses tended to increase at a decreasing rate with time and cumulative precipitation. This is consistent with Savoie *et al.* (2006) who indicated that dry matter losses for biomass materials would diminish over time and eventually stop at some point when there is no organic matter left to oxidize. Finally, the quality of dry matter and thus the yield of ethanol may also be influenced by storage method. Data from the Milan harvest and storage experiment are currently being analyzed to estimate the potential storage effects on ethanol yield from a ton of switchgrass dry matter.

Dry matter losses during storage increase the cost of feedstock. Wang (2009) found that dry matter losses for uncovered switchgrass round bales after approximately 200 days in storage increased the delivered cost per dry ton at the plant gate by 13 percent over feedstock that was delivered to the biorefinery immediately after harvest. Thus, a biorefinery may require that stored bales be protected from precipitation and weathering. Who is going to pay for the protection and storage of the crop—the farmer or the biorefinery? In addition, how might premiums and discounts be determined for the quality of dry matter that is delivered to the biorefinery? Testing individual bales for dry matter quality would likely be a labor intensive operation. Based on preliminary results from the Milan harvest and storage experiment (Figure 2), one simple method of preserving switchgrass dry matter might be to pay a premium if farmers store switchgrass on farm using a documented set of protective storage practices. This might be the most cost effective way to ensure uniformity of product given the large amount of material that would need to be handled by a biorefinery.

Cost differences due to harvest and storage method also may have implications for a biorefinery in terms of a delivery schedule. Wang (2009) evaluated the costs of delivering switchgrass to a refinery sited near Vonore, TN, as influenced by harvest and storage method using a simulation and mixed integer mathematical programming model. The assumed harvest window was from November to February. Estimated dry matter losses for different storage methods and times were from the Milan, TN, harvest and storage experiment by English, Larson and Tyler (2009) (see Table 3). Assuming the plant could process more than one bale type, a mixture of bale types and storage methods would minimize the cost of switchgrass feedstock. From November to January, switchgrass would be harvested only using large rectangular balers and transported to the plant immediately after harvest. In February, both larger round and large rectangular bales of switchgrass would be harvested, but only the rectangular bales would be transported to the plant. The round bales of switchgrass would be put into storage using tarps and wooden

Unprotected Round Bale

Protected Round Bale on Wooden Pallet With Tarp Cover

Unprotected Rectangualar Bale

Protected Rectangular Bale on Wooden Pallet With Tarp Cover

Source: English, Larson and Mooney, 2008, Unpublished Data

**Figure 2.** Weathering of Individually Stored Large Round and Rectangular Switchgrass Bales With and Without Protection over 111 Days of Storage at Milan, Tennessee, 2008.

**Table 3. Switchgrass Dry Matter Loss (DML) During Outside Storage at Milan, TN, 2008-2009**

|  |  | Days in Storage |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Shape | Cover System | 100 |  | 200 |  | 300 |  | 400 |  |
|  |  | N | % DML | N | % DML | N | % DML | N | % DML |
| Round | None | 3 | 6.0 | 8 | 15.7 | 9 | 14.0 | 9 | 9.7 |
|  | Tarp | 3 | 0.0 | 8 | 6.1 | 9 | 4.6 | 8 | 7.0 |
| Rectangular | None | 2 | 27.2 | 6 | 52.5 | 5 | 52.1 | 2 | 64.8 |
|  | Tarp | 2 | 25.7 | 6 | 20.8 | 5 | 12.5 | 4 | 13.7 |

Notes: Bales were placed into storage on 24 January 2008. N = number of replications sampled.
Source: English, Larson and Tyler, 2009, Unpublished Data.

pallets for protection or without any protection. For March through April, the round bales stored without protection would be transported to the biorefinery. During the following months of the year, the round bales stored with tarps and pallets would be transported to the biorefinery. The optimal solution assumes no constraints on available harvest equipment. The optimal delivery schedule also suggests that someone would need to coordinate the harvest, storage, and delivery activities to the plant. Thus, the UT Biofuels Initiative and extension may have a role in facilitating a relationship between farmers and the biorefinery to coordination of the feedstock supply chain.

### Risk Programming Needs

The Tennessee experience with the on-going development of a switchgrass feedstock supply chain and pilot biorefinery in East Tennessee suggests that Extension has an important role to play in the development of a biomass supply chain. The management expertise provided by Extension was instrumental in the administration of production contracts and the selection of fields to establish over 2,600 acres of switchgrass in East Tennessee in 2008 and 2009 and likely reduced the risk involved in the development of the supply chain for the pilot biorefinery. Thus, Extension has the potential to provide risk management services to farmers but also to the biorefinery during the development of the supply chain. As the supply chain continues to develop, Extension will need to develop education programming for pest (weed, insect, and disease) and storage management as acreage in the UT biofuels Initiative expands to a commercial scale of 25,000 or more acres in the region. Extension may also have a role in identifying soils and fields in Tennessee to maximize the benefits of BCAP payments and facilitate logistics for the plant as production scales up from the pilot plant level to a commercial scale level. Another possible role for Extension is to facilitate the development of a farmer cooperative to handle the coordination of harvest, storage, and transportation activities. The feedstock handling cooperative may allow farmers to capture a greater proportion of value in the feedstock supply chain which would potentially promote rural economic development. Farmers could jointly purchase and share the use of harvest machinery and storage materials such as large rectangular balers and tarps and thereby lower capital cost outlays and risk for small and medium size farmers. In addition, the cooperative could coordinate the aggregation of feedstocks from farmer fields and negotiate a premium schedule for switchgrass produced and stored using a specified set of production and storage management practices.

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# Economics of the Switchgrass Supply Chain: Enterprise Budgets and Production Cost Analyses

Daniel F. Mooney and Burton C. English[1]

## Introduction

Successful transition of the U.S. economy from a primarily fossil fuel energy base to one based in large part on renewable sources stands to revitalize rural America, where the anticipated economic benefits are thought to be substantial. For instance, recent analysis indicates that the introduction of a dedicated energy crop on 22.8 million acres of cropland, pasture, and fallow areas in the U.S. southeast by 2025 could increase farm income by $37.5 billion per year, add one million jobs for the construction and operation of conversion facilities, and increase overall annual economic activity by $99 billion (English *et al*., 2006). These figures are impressive, and don't yet take into account other potential benefits of increased domestic energy production from renewable resources such as enhanced national security or improved environmental amenities such as water quality, wildlife habitat, and decreased greenhouse gas emissions.

The drive to meet an increasing share of our electricity, fuel, and other energy needs from renewable resources found within the United States is guided by a set of renewable energy goals at the federal and state levels; chief among them being the Renewable Fuels Standard which establishes a production mandate of at least 36 billion gallons of ethanol by the year 2022 (USDA., 2008), the 25x'25 Initiative which calls for 25 percent of energy use to come from renewable sources by 2025 (English *et al*., 2006), the 30x'30 proposal which seeks to replace 30 percent of petroleum consumption with biofuels by 2030 (Perlack *et al*., 2005), and the "twenty in ten" goal to reduce gasoline consumption by 20 percent over the next 10 years (US-EPA, 2007).

If these goals are to be met, massive quantities of high quality, low cost dedicated energy feedstock will need to be produced, harvested, stored, and delivered to conversion facilities on a consistent, daily basis throughout the calendar year (De La Torre Ugarte, English, and Jensen, 2007; Perlack *et al*., 2005). Due in part to government mandates, and in part to volatile petroleum prices, decreasing conversion costs and new policy incentives, demonstration-scale pilot projects using switchgrass as feedstock have recently proliferated. Tennessee's legislature led by Governor Bredesen passed the Tennessee Biofuel Initiative in 2007 committing over $40 million to capitalize the establishment of a cellulosic ethanol facility, along with another $30 million to provide farmer incentives, research, and operating expenses. Additional biomass provisions at the Federal level such as the Biomass Crop Assistance Program (BCAP) found in the 2008 Farm Bill (USDA, 2008) and the $400 million in funding for integrated biomass conversion facilities found in the American Recovery and Reinvestment Act of 2009 (US-DOE, 2009), may further accelerate the initiation of similar projects and expand those already in progress.

In this article we examine the economics of the supply chain for perennial dedicated energy crops, specifically switchgrass (*Panicum Virgatum*). For switchgrass cropping systems to become commercially viable, the price paid to producers per ton of biomass must be high enough to bid land away from traditional farm enterprises in quantities necessary to ensure a constant, year-round supply of biomass to the biorefinery doorstep. A precondition for this to occur is that the biomass price must also exceed the cost to produce, harvest, store, and deliver the biomass, as well as cover the opportunity costs involved in land conversion. Because markets for biomass are currently absent for much of the United States, most economic analyses of switchgrass production have focused on the later precondition, reporting their findings on a unit production cost basis (i.e. cost per ton) rather than on net return, or profitability, basis. In completing the study, existing university enterprise budgets and cost of production economic analyses are reviewed, key economic concepts that arise along the switchgrass supply chain are identified, and important issues and shortcomings are highlighted for future analyses.

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### Switchgrass Enterprise Budgets

Enterprise budgets allow farm managers to compare costs and returns of alternative crop or livestock activities and evaluate the technology, resources, and management abilities required for each option. They typically include a revenue statement and variable costs for a fixed enterprise size (e.g. per acre or per head), and a machinery and labor schedule. With the exception of land, fixed and overhead costs are rarely included. Thus net returns are interpreted with respect to the costs considered and generally don't account for management or risk. Activities whose production cycle extends beyond a single calendar year and whose cost or benefit streams vary require separate enterprise budgets for each stage of production.

Nascent efforts by U.S. land grant universities and affiliated institutions to develop switchgrass enterprise budgets are underway. An informal survey of 26 universities and institutions in the Southeast and Midwestern United States found that seven (23 percent) had developed enterprise budgets or informational bulletins oriented towards potential producers of switchgrass for bioenergy. The general structure and type of costs included varied widely across the studies analyzed (Table 1). Five of the seven studies provided separate budgets for switchgrass establishment and annual production (i.e. fertilization and harvesting). Of these, two (IA and TN) also included a reseeding budget; and one (IA) went further to include budgets for storage and delivery.

### Cost of Production Analyses

A growing number of articles estimate the full economic cost to produce and harvest switchgrass. While crop enterprise budgets are intended to provide information about the cost and returns of various farm activities, the large variation in cost categories included and parameter assumptions used limited the ability to determine final production cost estimates on a per-ton basis. Because biomass pricing regimes will likely be structured on a per-ton basis, it is important that cost estimates also be obtained on a per ton basis. A summary of six economic analyses whose objective was to determine switchgrass cost of production on a per ton basis is provided in Table 2. Two of these studies report production costs at the farm gate, while the others report farm gate and delivered costs.

### Economics of the Switchgrass Supply Chain

#### *Stand Establishment*

Establishment typically includes land preparation, seed, chemical weed control, and fertilizer costs in addition to labor and machinery costs for the required field operations and interest on variable operating costs. Seed costs have increased considerably in recent years due to increased demand and are likely to remain high as seed production becomes commercialized and improved breeding lines, some with genetically modified input traits, are introduced. Previous research suggested that, beyond a certain plant density threshold, switchgrass yield is unresponsive to increased plant population density (Schmer *et al*., 2005; Vogel and Masters, 2001). This finding is likely explained by increased tillering or above ground growth in stands with low initial plant densities, such that full yield compensation occurs. As a result, continued seed cost pressures may result in producers reducing seed rates below the range of 6-10 lbs per acre pure live seed currently recommended. Figure 1 illustrates this concept graphically, showing the relationship between yield, seeding rate, and net return to seed costs using data from an experiment conducted in Milan, TN. A maximum cumulative yield of 14.2 tons per acre with an associated net return of $478 per acre was achieved at a seeding rate of 5.7 lbs per acre pure live seed. However, reducing the seeding rate from 5.7 to 3.8 lbs per acre would decrease yield by an estimated 0.3 ton per acre but increase the net return to seed cost by $23 per acre.

Weeds are primarily a factor during the establishment phase. In the first year following planting, most switchgrass growth occurs below ground in the root structure. Stands generally look poor during the first years of production and weed infestations may appear high. Annual grass weeds are potentially more problematic than broadleaf weeds because they more easily canopy the emerging switchgrass seedlings and because current chemical controls may damage the switchgrass in addition to the weeds. However, the economics of weed control in switchgrass are poorly understood. In multiple field experiments conducted by the University of Tennessee Switchgrass Project, strong stands have emerged by the third year of production even where severe weed infestations occurred during the first two years of production and weed control was absent. The question of whether the benefits of chemical control during establishment, in terms of yield losses avoided, are sufficient to pay for their expense remains to be answered.

A final establishment issue concerns foregone revenue from alternative enterprises. Switchgrass yields typically reach full maturity during the third year of production (Parrish and Fike, 2005). Consequently, a lag period exists between when costs are first incurred and when benefits begin to accrue. Nevertheless, such opportunity costs must be recognized since the foregone revenue will likely impact a farmer's decision on whether to adopt a perennial dedicated energy crop. Of the enterprise budgets reviewed, only Bangsund, DeVuyst, and Leistritz (2008) included foregone revenue as an opportunity cost in the establishment budget. Though well-designed production incentives, such as those found in the BCAP provisions of the 2008 U.S. Farm Bill, may help to overcome this issue by providing annual payments to producers during establishment to offset the initial decrease in revenue.

**Table 1. Summary of Eight University Extension Budgets/Bulletins that Estimate the Cost to Produce Switchgrass as a Dedicated Energy Crop**

| Budget/ Study | State | Budgets Included | Yield Level(s) Assumed | Stand Lifespan(s) | Land Cost | Seeding Rate | Annual Herbicide Cost | Harvest Method | Estimated Cost of Production |
|---|---|---|---|---|---|---|---|---|---|
| | | | *tons/acre* | *Years* | *$/acre* | *lbs/acre* | *$/acre* | *Type* | *$/ton* |
| Ferland (2001) | GA | P† | 6 | NS‡ | $20 | NS | $7 | NS | $60 |
| Whitten (2007) | MS | E, P | NS | NS | NS | 8 | $18 | NS | NS |
| Green & Bension (2008a/b) | NC | E, P | 6 | 15 to 25 | None | 6 | $0 | Round Bales | $61, not including establishment costs |
| Garland (2008) | TN | E, R, P | NS | 3.6 | NS | 6 | $13 | Round Bales | NS |
| Virginia Cooperative Extension (2007) | VA | E, P | NS | NS | None | 10 | $0 | NS | NS |
| Duffy (2008) | IA | E, R, P, S, T | 4 | 10 | $80 | 6 | $8 | Square Bales | $114 |
| Carpenter & Brees (2008) | MO | P | 4.5 | NS | $33 | NS | $0 | NS | $86 |
| Bangsund, DeVuyst, & Leistritz (2008) | ND | P | 2.7 to 3.5 | 10 | None | NS | NS | NS | $47 to $76 |

Notes: E=Establishment, R=Reseeding, P=Production, S=Storage, T=Transportation;
†Production budgets include fertilization, weed control, and harvesting costs; ‡NS = Not specified

### *Stand Failure and Reseeding*

Separate reseeding budgets were included in two of enterprise budgets reviewed. In both cases, reseeding budgets were developed to estimate the increase in production costs that result due to stand failure. However, similar to the establishment budgets, they do not account for the opportunity cost of foregone production. That is, stand failure in the first year not only increases costs but also further delays the revenue stream by one year for those areas requiring reseeding. Scant data from large plantings on multiple fields exist. In establishing 92 acres of switchgrass in middle Tennessee in 2005, 12 percent of the acres required replanting. This reseeding resulted because of several factors including weed competition, planting depth of seed, or farmer error in chemical application in adjacent fields. Additional experience in Tennessee has been gained through the Tennessee Biofuels Initiative where establishment of 720 acres in a drought year required approximately 25 percent of acres to be reseeded. From an economic perspective, this may become a major issue for short-term contracts (e.g. 3-5 years) where the period for cost recovery is shorter.

### *Annual Production Budgets*

Annual production budgets for the maintenance and harvesting of switchgrass biomass typically include fertilizer, chemical weed control, and harvest costs (Table 3). Fertilizer applications are an important cost and environmental consideration in switchgrass production. Nitrogen fertilizer represents the primary nutrient for switchgrass produced as a bioenergy crop (Parrish and Fike, 2005). In most cases, the Extension budgets reviewed recommend that no nitrogen be applied in the initial year as the nitrogen will stimulate weed growth and thus increase competition for water, mois-

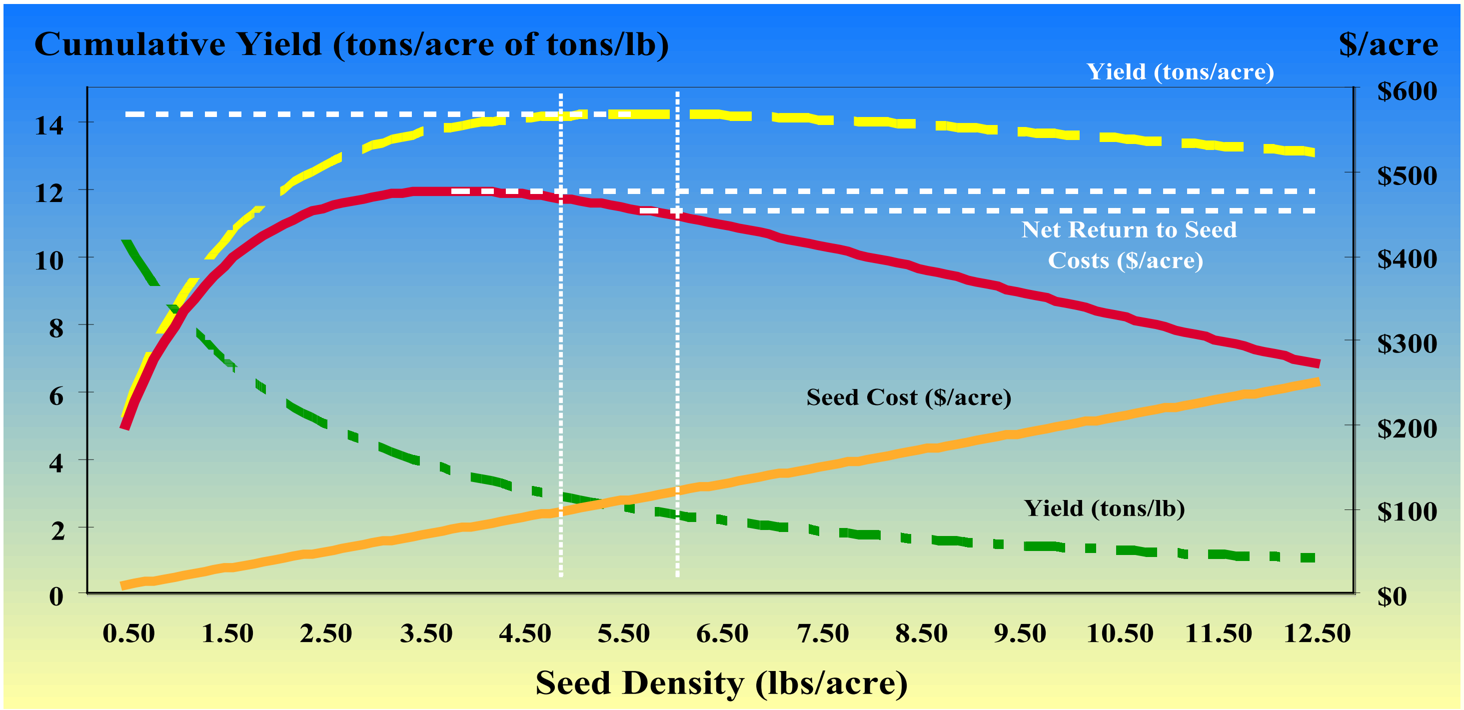

**Figure 1.** Relationship between Cumulative Yield, Seed Density, and Net Return to Seed Cost for a Moderately Drained Sloping Upland Location in West Tennessee 2004-2006.
Source: Mooney *et al.*, 2008

ture, nutrients, and sunlight. The range of recommended nitrogen levels in annual production budgets ranged from 0 to 200 pounds per acre. Current recommended phosphorus and potassium applications rates differ widely. In Tennessee, current recommendations are based on data contained in Parrish *et al.* (2003) where P and K applications are not recommended unless soil levels are low in these nutrients. Even when no P and K are applied, it may be appropriate to include

**Table 2. Summary of Four Economic Analyses that Estimate the Full Economic Cost to Produce Switchgrass as a Dedicated Energy Crop**

| Study | State | Yield Level(s) Assumed | Stand Lifespan(s) | Land Cost | Harvest Method | Estimated Cost of Production |
|---|---|---|---|---|---|---|
| | | *tons/acre* | *Years* | *$/acre* | *Type* | *$/ton* |
| Khanna, Dhungana, & Clifton-Brown (2008) | IL | 4.2 | 10 | $78 | Rectangular Bales | $44 (farm gate, w/o land cost); $89 (delivered) |
| Mooney *et al.*, (2009) | TN | 6.2 to 7.9 | 5 & 10 | $68 | Round Bales | $42 to $63 (farm gate, 10-year lifespan) |
| Perrin *et al.*, (2008) | ND, SD, NE | 2.6 to 3.5 | 5 & 10 | Various | Mixed | $42 to $71 (farm gate, 10-year lifespan) |
| Epplin *et al.*, (2007) | OK | NS‡ | NS | $60 | Rectangular Bales | $36 to $52 (farm gate); $49 to $65 (delivered) |
| Lazarus (2008) | MN | 4 | 10 | $40 | Round Bales | $77 (delivered) |
| Wang (2009) | TN | 6.0 to 7.8 | NS | Varied by Productivity | Mixed | $66 to $77 (delivered) |

‡NS = Not specified

an opportunity cost for the P and K removed in the harvested biomass. Possible approaches may include an annual cost based on removal rates or an amortized annual cost representing maintenance applications every few years. A final option may be to include no costs during production but charge a fixed cost in the final year of production that would cover the expense of building fertility levels back to initial levels.

Harvest costs typically represent the largest cost component for switchgrass produced as a bioenergy crop. Recommended switchgrass harvest procedures for maximum biomass production include one harvest following senescence to allow for translocation of nutrients to the soil, which minimizes the amounts of nutrients removed and maximizes the amount of lignocelluloses. Harvests costs will vary by yield level and method (i.e., round bales, square bales). While switchgrass can be harvested with conventional hay equipment, the coarse and fibrous nature of the switchgrass plus the large yields may impact equipment cost (e.g. repair and maintenance) and performance (e.g. throughput, field speed). In this case, reliance on average engineering performance standards developed for other feedstock characteristics and/or feedstocks with much lower yields may significantly misrepresent the actual costs of harvesting switchgrass. Large square balers will generally result in the lowest per-ton harvest costs, but are more expensive and require a larger tractor for their operation. Round balers may be better adapted to the marginal landscapes (e.g. small/irregular fields, sloping hillsides) that are likely to be abundant in areas where switchgrass is grown.

### *Determination of Unit Production Costs*

The production of perennial dedicated energy crops such as switchgrass results in a flow of annual yield benefits and production costs across a stand's expected lifespan. To determine the cost per ton of switchgrass produced, the approach followed in most university extension budgets assumes that yield and production costs remain constant and amortizes establishment costs across the stand lifespan. Calculated in this manner, cost estimates may provide a fair approximation of production costs for the purpose of comparing the cost and return of alternative farm enterprises for a particular producer. However, while the assumption of constant production costs adjusts for inflation if costs are considered real costs, it does not account for discounting issues associated with the time value of money.

The time value of money requires benefit and cost flows to be valued at the same point in time using net present value (AAEA, 2000). This is the typical approach followed in most full economic analyses of switchgrass production costs. An example of determining unit production costs for switchgrass with a 5-year stand lifespan is given in Table 3 (Mooney *et al*., 2008). First, all maintenance, land, and harvesting costs incurred over the estimated lifespan of the switchgrass stand are discounted to their establishment year dollar value using a standard net present value (NPV) formula. Second, annualized production costs are calculated by summing establishment year costs with the present values of maintenance and harvest costs, and then amortizing this value across the stand's lifespan. Finally, per-ton production costs for each treatment combination are obtained by dividing amortized annual costs by amortized annual yields.

**Table 3. Example Calculations to Determine the Cost Per Ton of Switchgrass Produced on a Moderately Drained Sloping Upland Environment, West Tennessee**

| | Year (time period) | | | | | 5-Year Stand Lifespan (2004 USD) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | NPV of Productions Costs (@ 8% discount rate) | | Annualized Total Production Cost | |
| Item | 2004 (t=1) | 2005 (t=2) | 2006 (t=3) | 2007 (t=4) | 2008 (t=5) | $/acre | % | $/year | $/ton |
| Yield (dry tons/acre) | 1.08 | 4.18 | 8.83 | 8.83 | 8.83 | | | | |
| Establishment Costs | $222 | $0 | $0 | $0 | $0 | $222 | 15% | $51 | $8.11 |
| Maintenance Costs† | $0 | $40 | $40 | $40 | $40 | $132 | 9% | $31 | $4.82 |
| Harvest Costs | $46 | $114 | $216 | $216 | $216 | $666 | 46% | $154 | $24.32 |
| Land Costs | $100 | $100 | $100 | $100 | $100 | $431 | 30% | $100 | $15.74 |
| Total Production Costs | $368 | $254 | $356 | $356 | $356 | $1,452 | 100% | $337 | $53.03 |

†Weed control and fertilizers
Source: Mooney *et al*., 2008

## Integration of Harvest, Storage, and Delivery Systems

While enterprise budgets and cost analyses are useful for on-farm decision making, they do not provide insight into the optimal design of biomass systems as production scales up. For example, harvest costs will vary by method (i.e., round bales, square bales) and may differentially impact costs of other supply chain elements (e.g., handling, storage, pre-processing), indicating a need to evaluate different harvest methods within the context of the entire system. Precipitation and weathering may also result in quality and dry matter losses in bales delivered to the plant (Larson, English, and He, 2008; Sanderson, Egg, and Wiselogel, 1997; and Wiselogel *et al*., 1996). Higher precipitation in the fall and winter months may also limit field days and increase harvest times and biomass losses relative to other potential harvest periods (Hwang and Epplin, 2007). Previous harvest and storage cost analyses have focused on various aspects of integrating harvest, storage, and deliver systems (Bhat, English, and Ojo, 1992; Cundiff, 1996; Cundiff and Marsh, 1996; Cundiff, Dias, and Sherali, 1997; Sokhansanj, Kumar, and Turhollow, 2006; and Thorsell *et al*., 2004).

Preliminary analysis using limited data (individual bales rather than bales in large stacks necessary for commercial operations) from an experiment in Milan, TN indicates that large rectangular bales reduce harvest and transportation costs, but dry matter losses due to weathering increase more rapidly over time relative to round bale systems (Wang, 2009). When harvest and transportation costs are included with dry matter losses a mixture of harvest and storage solutions becomes optimal. Wang (2009) reports that costs are lowest for rectangular bales processed immediately after harvest, for round bales stored without protection and processed within three months of harvest, and for round bales stored with protection if stored for more than three months.

Given this, a proposed harvest, storage, and transportation system might be described as follows: harvest is initiated after the first frost and continues until initial greening up in the spring. The material that is harvested and transported to the plant for immediate use would be done using the large rectangular bale system. Any bales that are not to be used during this window would be harvested using a round bale system. Bales to be stored for a period of time less than 90 days would not require protection and those bales harvested and stored for a period of more than 90 days would require protection (e.g. tarp and stored on wood pallets).

## Summary and Conclusions

To meet the need for increased U.S. domestic energy production from renewable sources, large quantities of high quality, low cost dedicated energy feedstock will need to be produced, harvested, stored, and delivered to biorefineries on large scale. Evaluation of such integrated systems will require sound economic analysis along the supply chain. To date, most economic analyses of production, harvest, and storage systems for dedicated energy crops such as switchgrass have focused on cost accounting because biomass markets are yet to develop.

For switchgrass production systems to become commercially viable, biomass prices must first be sufficiently high to bid land away from current farm enterprises. Before deciding to convert acres to switchgrass production, producers will require information about switchgrass cost and return estimates to compare with alternative farm enterprises. In a survey of 26 land grant universities, we found that seven had produced an enterprise budget or related informational bulletin containing production cost information. The budgets reviewed contained a large variation in cost structure and individual cost items included. In many cases not enough information was provided to determine the net return per acre, nor per ton production costs. To accurately determine the cost of production at the farm-level, full economic cost analyses will be needed that clearly state the assumptions used with respect to assumed yield level, stand lifespan, opportunity costs, and the discounting of cost and revenue streams.

Second, integrated harvest, storage, and delivery systems must be developed to ensure a flow of high quality, low cost biomass to conversion facilities year round. Harvest and storage costs will vary by method (i.e., round bales, square bales) and may differentially impact costs of other supply chain elements (e.g., handling, pre-processing), indicating a need to evaluate separate supply chain components within a systems framework. Optimal systems that minimize the cost of biomass delivered to the biorefinery gate will likely consist of a mix of harvest/storage solutions that will vary as a function of harvest method, precipitation, time in storage, and refinery capacity.

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# Anticipated Extension Program Needs: Legal Issues With Bioeconomy Development

## Harrison M. Pittman[1]

## Introduction

A county extension agent in Georgia is approached by a landowner in rural Georgia with questions about whether he should enter into a particular wind farm lease. The agent listens carefully to a series of questions, mostly legal in nature, wanting to help the farmer as much as possible. As the farmer continues, the agent asks himself, "How can I help this person? Where do I turn for help in this situation?"

A similar scenario occurs on the same day in Oregon, but this time a landowner has questions about whether he has ownership rights in the geothermal energy beneath his land and about what issues he should consider regarding a possible contract to sell carbon credits to an aggregator in another state. Somewhere else across the country, leaders within a rural community approach their local extension agent to seek information on federal and state biofuels program funds that may be available to it as part of its economic development planning. Again, the agent considers how to approach addressing these and other questions, not knowing exactly where to turn.

These scenarios illustrate some of the legal issues that arise, and will continue to arise, in the complex and evolving bioeconomy arena. Further, they demonstrate the technical knowledge gap that must be anticipated by the cooperative extension service in order to effectively interact with farmers, landowners, communities, citizens, and others impacted by continued bioeconomy development.

The bioeconomy is multi-faceted and diverse. It is comprised of several parts, fundamentally including but not limited to wind, solar, geothermal energy; crop and forestry biomass for the development for ethanol and biodiesel; and other areas such as ecosystem services, carbon credit markets, and water credit markets. It also incorporates areas, some of which are not directly agricultural, such as energy efficiency in residential housing and commercial buildings and other technology-based issues. Each component possesses its own set of unique issues, challenges, and opportunities that must be addressed in a comprehensive, interdisciplinary fashion.

The cooperative extension service community must address and, at times, navigate, legal issues associated with each evolving component of the bioeconomy. This is a difficult task and one that will necessarily evolve over time. The task is further complicated by the fact that federal, state, and local laws can apply in varying ways from state to state.

Historically, the extension service has had relatively limited access to the legal expertise needed to handle federal, state, and local legal issues that arose. This is especially true for those states that have not had an attorney within their respective cooperative extension service units. Currently, however, the extension service has two very unique resources available to it to address and navigate agricultural legal issues, including those issues integrated with the transition to a bioeconomy.

The primary resource available to the cooperative extension service is the National Agricultural Law Center at the University of Arkansas, www.nationalaglawcenter.org. The Center is a federally funded, nonpartisan research and information entity that serves as the nation's leading source of agricultural and food law research and information. The Center serves the nation's agricultural community, which includes attorneys, policymakers, producers, agribusinesses, consumers, and extension personnel. The Center is the only institution of its kind in the United States.

The Center was created in 1987 and has evolved considerably since that time. In 2007, USDA Secretary Mike Johanns visited and spoke about the National Agricultural Law Center, noting that:

> "The decision to create the Center, now more than twenty years ago, was certainly the right decision. As agriculture has evolved over the last quarter century, legal issues have gotten bigger and their impact

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> has gotten broader…. Your work can bring predictability and equity in every day dealings in unchartered areas where agriculture is moving."

The Center provides an extensive amount of agricultural and food law research and information relevant to many aspects of the extension service via its website at www.nationaglawcenter.org. In addition, the degree to which the Center is currently coordinating with the cooperative extension service is unparalleled in the Center's nearly twenty-year history. For example, the Center has devoted resources necessary to create and fill a full-time position specifically devoted to coordinating the Center's research and information activities with the cooperative extension service.

A direct outgrowth of these efforts, and another unique tool available to the nation's extension community, is the eXtension Community of Practice (CoP) for Agricultural Law. The National Agricultural Law Center is the lead institution for the newly established CoP and is coordinating with more than 40 land grant faculty and state, regional and county Extension professionals, and nonprofit organizations representing 25 states to develop the Agricultural Law CoP.

The primary focus of this article rests upon the question of how the cooperative extension service must fill the knowledge gaps relative to legal issues in the transition to a bioeconomy rather than a comprehensive rendition of the various legal issues to be addressed. In so doing, the article emphasizes the role of the National Agricultural Law Center and the eXtension Community of Practice for Agricultural Law, both of which provide historically significant tools to the extension community.

## Discussion

In the past, the extension community has had limited access to legal resources, research and information. This situation, simply put, is no longer true. Extension personnel in every county of every state can now turn to the National Agricultural Law Center at the University of Arkansas for any legal research and information assistance they may need on a variety of areas, including bioeconomy development issues. In addition, the extension community can leverage the newly developed eXtension Community of Practice for Agricultural Law, of which the Center is the lead institution.

The information set out below describes the Center and the eXtension CoP for Agricultural Law. Also, it highlights some other legal resources available to the extension community, including the Agricultural Law Resource and Reference Center at Penn State University and the Center for Agricultural Law and Taxation at Iowa State University. It bears noting that each of these entities participates in the eXtension CoP for Agricultural Law.

**Legal Resources for the Extension Community**

The National Agricultural Law Center, www.nationalaglawcenter.org, is the nation's leading source of agricultural and food law research and information. The Center is a federally funded, nonpartisan research and information entity that serves the nation's agricultural community, including farmers, attorneys, policymakers, academics, students, consumers, extension personnel, and others.

The Center is funded by Congress through the USDA Agricultural Research Service, National Agricultural Library (NAL), and supports NAL's mission of "advancing access to global information for agriculture." In addition to its formal relationship with USDA, the Center works collaboratively with the USDA CSREES and other USDA agencies such as the Risk Management Agency, the Office of the Chief Economist, the Agricultural Marketing Service, and the USDA Office of the General Counsel.

The Center's website is the primary means by which it fulfills its mission and serves the nation's vast agricultural community. The main aspects of the Center's extensive website and its application to the extension service are described below.

Over the past year, the Center has significantly expanded its emphasis on coordinating with the cooperative extension service. This expansion has occurred in three principal ways. First, the Center is coordinating with the extension personnel throughout the United States to assist with the publication of extension materials on subjects such as the National Organic Program, insurance, and water issues. Second, the Center has engaged with eXtension on a number of fronts, not the least of which is the establishment of the eXtension Community of Practice for Agricultural Law. It bears noting that the Center has devoted resources to maintain a full-time position for an attorney to handle its extension activities. Finally, the Center will soon create a six member National Advisory Board that will include one representative of the cooperative extension service.

The Center's website is a comprehensive clearinghouse for legal research and information that spans nearly four dozen agricultural and food law topics both in the United States and around the world. Topics covered by the Center include:

- Animal Welfare;
- Renewable Energy;
- Biotechnology;
- Conservation Programs;
- Local Food Systems;
- Agritourism;
- Climate Change;
- Food Safety;

- Agriculture and Urbanization;
- Estate Planning and Taxation; and
- Environmental Law.

As such, the website incorporates unique components that cannot be found elsewhere and provides an invaluable resource to those needing information on legal issues surrounding food and agriculture.

As noted, the Center serves the nation's agricultural community, which includes attorneys and non-attorneys. Consequently, the Center's website is constructed in a manner that is suitable for use by this broad constituency. The website is provided free of charge to the public.

As a nonpartisan entity, the Center takes no position on the views expressed in any articles or writings published on the website. All such articles and writings are included for their legal or practical discussions of agricultural and food law topics rather than any particular viewpoint. Furthermore, while every effort is made to supply accurate and up-to-date information, the website is not meant as a source of legal advice, nor is it a substitute for the use of a competent legal professional.

One of the most important services provided by the Center website is the construction and maintenance of its Reading Rooms. A Reading Room is a compilation of electronic resources that provides readers with an excellent place to research a particular area of agricultural law. Reading Room subjects include:

- Agritourism;
- Environmental Law;
- Renewable Energy;
- National Organic Program;
- Water Law
- Business Organizations;
- Food Safety;
- Labor Law;
- Animal Welfare;
- Local Food Systems; and
- Sustainable Agriculture.

For a full listing of the more than 40 Reading Rooms published by the Center, please visit the Index of Reading Rooms at http://www.nationalaglawcenter.orglreadingroomsl. The Reading Rooms are constantly monitored and regularly updated in order to reflect new developments.

At the beginning of each Reading Room is an "Overview" article designed to familiarize the reader with the specific subject area for that Reading Room. The Overview article is most helpful for those researchers in need of background information on a particular subject area, rather than for someone who has extensive experience with the subject area. A typical Overview article presents background information, identifies legal and policy issues, and provides pertinent terminology for the subject area at issue. For example, the Overview article for the Environmental Law Reading Room provides, among other items, a brief discussion of federal laws applicable to agriculture as well as legal and policy issues.

Each Reading Room also provides a listing of all major federal statutes affecting the area, links to any federal regulations on point, and a case law index of citations to recent common-law authority. In some instances, the Reading Room will also list relevant state laws to the particular subject area. For example, in the Animal Welfare Reading Room, the Center provides a link to all federal statutes such as the Animal Welfare Act and a digital compilation of each state's animal cruelty law. Another example is the comprehensive list of federal and state biofuels laws the Center provides in the Renewable Energy Reading Room.

Each Reading Room also provides numerous secondary resources in an organized, user friendly format. These secondary resources include Center research publications, Congressional Research Service reports, USDA resources organized on an agency-by-agency basis, other governmental and non-governmental reference resources, and publications.

An example of a Reading Room directly related to the development of the bioeconomy is the Renewable Energy Reading Room. The Overview article provides a brief discussion of the various components of the renewable energy subject area and a description of the major laws pertinent to renewable energy. Following the Overview, is an extensive listing (and links to) of the federal and state laws applicable to renewable energy. Following the list of statutes, there is provided a listing of applicable regulations. Finally, there is a comprehensive listing of secondary research and information resources directly related to the various components of the renewable energy equation, including wind, solar, and biofuels.

Another extension-appropriate resource offered by the Center's website is the "Glossary of Agricultural Production, Programs, and Policies." This is a very extensive resource that contains thousands of terms and definitions used throughout the food system with a heavy emphasis on programs and policy terms arising under various farm bills. The printed version of the Glossary is more than 700 pages in length. The glossary is appropriate for use by attorneys and non-attorneys, including extension personnel.

The author of the Glossary, Chuck Culver, Director for Development for the Division of Agriculture at the University of Arkansas, has compiled this extensive list of legal and non-legal definitions of terms and acronyms used in the food and agricultural fields. Recent additions to the Glossary have included many terms and definitions pertinent to the burgeoning energy issues impacting agriculture, particularly in the biofuels arena.

The Center website also provides the nations only free of charge database of agricultural and food law related Congressional Research Service (CRS) Reports. The Congressional Research Service is a part of the Library of Congress and exists to provide support to members of Congress. CRS Reports are especially useful resources, often providing a succinct but thorough discussion of legislative issues and developments, discussions of farm bill provisions, and many other areas of agricultural law and policy.

Professor Drew Kershen, Earl Sneed Centennial Professor of Law at the University of Oklahoma College of Law, publishes the "Agricultural Law Bibliography." The Bibliography spans over 50 years of law journals, law reviews, and legal periodicals that publish articles, comments, notes, and developments. The Bibliography is organized into 48 main categories of agricultural and food law, many of which contains sub-categories. Simply stated, the Bibliography represents the nucleus of agricultural and food legal literature over the past several decades in the United States. The Bibliography is updated quarterly, and the entire compilation is provided free of charge on the National Agricultural Law Center web site.

In order to enhance the ability of researchers to access these materials, the Center is in the process of digitizing the full text of each of the entries contained in the Bibliography. Currently, the Center has digitized more than 1,000 articles and will continue this project for the foreseeable future. When completed, the Bibliography will be a free, internet-based "library" of agricultural and food law literature.

In addition to legal research and information, the National Agricultural Law Center also provides access to the national network of agricultural and food law practitioners throughout the United States. In particular, the Center collaborates closely with the American Agricultural Law Association (AALA), the national professional association of agricultural law practitioners.

The Center has partnered with the AALA to provide "The United States Agricultural & Food Law and Policy Blog", a source of agricultural-related news, research, and information that is updated daily. In addition, the Center helps sponsor the AALA List serve, which is heavily used by AALA members. As a result of this relationship, the Center is capable of leveraging AALA membership to help resolve legal issues and questions confronted by the extension service community, when appropriate.

## eXtension Community of Practice for Agriculture Law

As noted, the Center devotes considerable resources to facilitate coordination with the cooperative extension service throughout the United States. While the Center has provided research and information to extension in the past, its current focus far surpasses any effort previously made by the Center. One area of strategic and long-term focus is the eXtension Community of Practice for Agricultural Law.

The National Agricultural Law Center is the lead institution for the eXtension CoP for Agricultural Law. The Center's application for the CoP was approved in late December of 2008. Implementation of the CoP is a high priority for the Center and current plans are to have conducted all internal preparations to have the CoP available for public view by September 2009.

The CoP for Agricultural Law is a direct outgrowth of the Center's emphasis on supporting and coordinating the cooperative extension service. The pursuit and creation of the CoP for Agricultural Law is a testament to the Center's permanent institutional commitment to providing legal research and information to the cooperative extension service.

The CoP is comprised of over 40 land grant faculty and state, regional and county Extension professionals, and nonprofit organizations representing 25 states. Members will be added to this list as the CoP develops, including representatives from other institutions, businesses, agencies and organizations as appropriate. Currently, the Agricultural Law CoP is comprised of six subgroups:

- Environmental and Natural Resources;
- Labor Issues;
- Ag Diversification;
- Taxation and Business Organizations;
- Estate Planning and Farm Succession; and
- Renewable Energy.

New subgroups will be added in the months and years ahead as needs and priorities are identified. Ultimately, the subgroups contained in the CoP will reflect the Reading Room subjects published on the Center's web site, www.nationalaglawcenter.org.

Current and recent activities in this area have focused on preparing the CoP for publication to the public component of the eXtension site. The Center has conducted several teleconferences and webinars for CoP leadership to facilitate content development for each of the subgroups.

While the primary focus of the Agricultural Law CoP will be to develop general content to populate its site, the CoP will also focus on working with existing and newly developed communities. For example, the Agricultural Law CoP is currently partnering with the Horse Quest CoP to address legal issues that arise in the equine industry such as boarding stable contracts and premise liability.

Additionally, the Renewable Energy subgroup is working hand-in-hand with the Sustainable Agricultural Energy Community of Practice to identify legal issues relevant to renewable energy and create resources to address those issues. As new communities are created within the eXtension system, the Agricultural Law CoP will continue to look for potential partners in filling the knowledge gap.

The Agricultural Law CoP will offer various resouces, including:

- Fact sheet "articles";
- Ask and Expert and FAQ;
- "Best of the Best" resources relative to each subgroup;
- Webinars and phone conferences with experts from around the country; and
- Special research projects with other CoPs or institutions.

For more information about the eXtension CoP for Agricultural Law, or for any extension related legal inquiries with which the National Agricultural Law Center may be of assistance, please contact Center Attorney Shannon Mirus at srnirus@uark.edu or (479) 575-7646.

## Additional Legal Resources Available to Extension Community

In addition to the National Agricultural Law Center, there are at least two other Centers available to the extension community that should be highlighted. One resource is The Agricultural Law Resource and Reference Center, http://www.dsl.psu.edu/centers/aglaw.cfm, which is collaboration between The Penn State Dickinson School of Law, The Penn State College of Agricultural Sciences, and The Pennsylvania Department of Agriculture. Located at both the University Park and Carlisle campuses of Penn State Dickinson, the Center is designed to provide the highest quality educational programs, information, and materials to those involved or interested in agricultural law and policy.

The other resource is the Center for Agricultural Law and Taxation at Iowa State University, http://www.calt.iastate.edu/. According to the Center's web site, The Center for Agricultural Law and Taxation at Iowa State University, created by the Iowa Board of Regents in 2006, provides timely, objective information to producers, professionals and agribusinesses concerning the application of important developments in the law (federal and state legal opinions of relevance, as well as critical legislative developments), and is a primary source of professional educational training in agricultural law and taxation. Each of these institutions participates in the eXtension Community of Practice for Agricultural Law.

## Anticipated Needs

The cooperative extension service is confronted with any number of legal questions and issues involving the development of a bioeconomy in the United States. The types and scope of these legal issues will necessarily evolve along with the continued bioeconomy development. Consequently, it is imperative that legal resources, research, and information be made available in a manner that is reliable and adaptable to evolving circumstances.

The provision of legal research and information that actually fills the knowledge gap between the cooperative extension service and the citizens, communities, families, farmers and others that it serves is a significant challenge. Meeting this challenge fundamentally requires the following: (1) a substantive, comprehensive platform of legal research and information such as what is provided and maintained on the National Agricultural Law Center web site; and (2) an information and curriculum delivery system such as eXtension and its various Communities of Practice, of which the CoP for Agricultural Law is a central component.

For example, the Center has partnered with the USDA Office of the Chief Economist, Office of Energy Policy and New Uses, to develop a digital database of federal and state biofuel and climate change statutes that will be maintained, updated, and expanded for years to come. This comprehensive work product constitutes part of the "platform" of bioeconomy-related legal research and information that the Center will leverage to help fill the knowledge gap between the cooperative extension service and its constituents. The Center will then leverage this platform to deliver information and curriculum in any number of ways - factsheets, Frequently Asked Questions, webinars, videos, etc - through the eXtension CoP for Agricultural Law and often in collaboration with other CoPs.

The anticipated needs of the extension service in addressing the transition to a bioeconomy are extensive. While the focus of this article is not to delve into the substance of the types of legal issues that will arise, the following examples are illustrative.

One issue is determining the treatment of legal ownership of geothermal sources. In other words, how do various states treat the ownership of geothermal sources, if at all? This is a matter of state law, which means that the answer may be different from one state to another. However, the issue itself has a direct bearing on bioeconomy development throughout the United States. Some states consider geothermal sources to be mineral rights. In other states, they are considered water rights, and in others, surface rights. In some states the question in not answered conclusively.

Building out from the preceding hypothetical, let us assume that a landowner in a particular state has approaches his local extension agent about how his state treats geothermal sources. The agent could either refer the landowner to the National Agricultural Law Center, or consult with the eXtension CoP for Agricultural Law to locate an answer.

Under the same hypothetical, let us assume that a state legislator has similar questions after determining that the law is unclear in his state. The legislator is interested in developing proposed legislation and would like to know what his likely options are for developing proposed legislation. The National Agricultural Law Center could refer the legislator to a digitized compilation of states' laws pertaining to the ownership of geothermal sources. In addition, the Center could coordinate with the legislator to discuss the tradeoffs associated with various provisions as well as any relevant case law that may impact the situation in his state. Any research and information produced in the course of this activity would be published on the Center's web site but also transported into the eXtension CoP for Agricultural Law and cross-linked to other relevant CoPs.

Another possible hypothetical would be working with an extension agent who needs to have a better understanding of zoning laws and their application in his state in order to assist a constituent with a particular problem. The agent could utilize the "Frequently Asked Questions" and the "Ask an Expert" feature of the eXtension CoP for Agricultural Law regarding his questions. Alternatively, the agent could also work with Center staff in identifying a legal practitioner in the agent's state who could also assist with understanding zoning laws in the agent's state.

In another scenario, a question arises as to what are the major pitfalls to anticipate in discussing a possible wind lease with a developer. What questions should the landowner ask the developer? What particular contractual provisions should be the owner be wary of? Are there any recent judicial developments that should be considered in discussing the contract? Again, the Center and the eXtension CoP for Agricultural Law is an excellent resource to help address these and other questions.

## Conclusion

The bioeconomy is diverse, complex, and comprised of several major components that includes wind, solar, geothermal energy, and biogas; crop and forestry biomass for the development for ethanol and biodiesel; and other areas such as ecosystem services, carbon credit markets, and water credit markets. In addition, the bioeconomy incorporates areas, some of which are not directly agricultural, such as energy efficiency in residential housing and commercial buildings and other technology-based issues. Each component possesses its own set of unique issues, challenges, and opportunities that must be addressed in a comprehensive, interdisciplinary fashion. Many of these issues are legal in nature, which present unique challenges.

The question is not whether the cooperative extension service addresses these issues, especially the legal issues, but rather how it must address them. For the first time, the cooperative extension service community has direct access to legal research and information dealing with bioeconomy-related issues. The National Agricultural Law Center is the only institution of its kind in the United States and is an integral resource, research, and information platform that can be leveraged by the national extension community. In addition, the Center has significantly strengthened its capacity to serve the extension community, including but not limited to the establishment of the eXtension Community of Practice for Agricultural Law.

# Bioeconomy Transition and Community Issues

## Mark A. Edelman[1]

## Discussion

My assignment today is to comment on Community Issues that are likely to emerge during the transition to a bioeconomy. There are many issues and some myths that are drivers of change in this transition. World hunger, biotechnology, food versus fuel, and indirect land use; organic, natural, local foods, obesity, nutrition, and food safety; housing, healthcare, credit institutions, and economic recovery; and others are among the issues being discussed. But today I would like to focus on two of the key drivers that underlie much of the discussion at this conference and they are not likely to go away.

**Issues Discussed:**

***What, if anything, should our Community do regarding the dual priorities of Reducing Dependence on Imported Oil and emerging incentives being written into Climate Change policy?***

**Background:** Relying on oil imports from nations that are vulnerable to terrorism for a majority of our domestic transportation fuel supply has become a national security issue. Historical accounts suggest a major factor in the outcome of World War II was the Axis Powers basically ran out of oil and synthetic transportation fuels. Today, not only does the United States rely on imported oil, but the world economy relies heavily on OPEC nations to supply the international demand as well. Historically, the United States relied on imported oil for only a fraction of our transportation fuels. However, with the economic growth and development of China, India, and other nations, it is clear that the United States can no longer rely on energy prices and international availability that the United States has enjoyed for most of the past century. So a key issue for public deliberation is: What, if anything, should our community do to reduce our dependence on imported oil?

Scientists and political leaders from around the world have reached a high level of consensus regarding man's contributions toward global warming and the potential longer term impacts on our environment and quality of life should nothing be done. While initially deciding against participation in the global treaty (Kyoto Accord) designed to establish a global framework for reducing the effects of carbon and other greenhouse gas (GHG) emissions, the United States is now on track toward reconsidering its global participation in the Copenhagen Climate Conference in December 2009, as well as considering major domestic policy initiatives for limiting and/or reducing domestic emissions of carbon and green house gases. The problem is that almost all human and economic activities have carbon and GHG emission impacts, therefore incentives that reduce harmful emissions or cause adjustments toward low carbon technologies and activities that sequester carbon are likely to impose costs on those of us who directly or indirectly use the old technologies. In addition, the incentives for adjusting to low carbon technologies and carbon sequestration activities may require active decisions to change the way business is done and perhaps some additional capital investment for which the returns are not fully known or recovered in the short run. This is also a key issue for public deliberation: What, if anything, should our community do to address climate change policy.

The second issue is even more intractable then the first because it is likely to be of a longer term nature. Brazil became independent from imported oil in about a decade. On climate change, while scientists can now say that man has an impact, we are less certain about the probable consequences of the alternative corrective actions.

My perceptions are informed by two nontraditional experiences involving rural communities. First, I had the opportunity to serve as an elected city council member for a rural community of 12,500 during the 1990s. Secondly, I have had good fortune to participate in several business related experiences. One such experience allowed me to participate as part of a business decision-making team that evaluated over 20 proposals from communities in a region that were interested in being selected for an ethanol plant in the earlier part of this decade. That process taught me how important community

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resource factors sometimes become that most of us take for granted. It makes a difference if your community is at the end of a natural gas pipeline and your existing industry is using all of the current capacity. It makes a difference if your community is on the right rail road that will agree to service your new industry. It makes a difference whether your community owns its own municipal electric utility, is served by a rural electric cooperative, or is served by a large external investor owned utility because they are regulated by different bodies and have different incentives.

The opportunities for rural America are wide open. One often quoted study suggests that agriculture provides 7 percent of the carbon and GHG emissions, but provides 20 percent of the potential offsets. Conventional ethanol capacity has nearly tapped out the first 15 billion gallons per year Renewable Fuel Standard (RFS) mandate, and we are poised for the second RFS wave of cellulosic and advanced biofuels that will get us to 30 billion gallons per year of renewables. Wind farms are cropping up all over the country thanks to a federal production tax credit. Iowa has become number two in wind turbine farms because of an added state production tax credit. Thin film solar technologies are putting solar power in places that were once unheard of in the past. With the right economic incentives, community digesters might spike industrial processing and animal wastes, with corn stalks, or wood chips to supply the smart grids during peak power demand or gaps when the wind doesn't blow the wind turbines. Or land fill methane collectors and community digester biogas might replace a locally short supply of natural gas capacity. Local food systems might save transportation fuel as well as reduce obesity and save on health costs. One innovative Kellogg funded project in a Northeast Iowa community is looking directly at that kind of project. Farm organizations have been facilitating carbon credits for farmers who use no-till crop farming practices, rangeland offsets, methane digesters, and tree plantings. Why not make these opportunities more widely available to all who live in rural America just like the insurance products?

Agriculture and rural America can stand pat and watch the policy debates pass by or they can figure out how to make the policy change opportunities work for rural America. It makes a difference how the policy incentives are written. Minnesota has a lot more wind turbines owned by farmers and local investors, whereas in Iowa the farmers receive a lease payment. In Iowa, most of the wind farms are owned by the investor-owned utilities. As Governor, Secretary Vilsack looked for ways to create new engines for economic growth in rural Iowa and was a big supporter of renewable fuels, biotechnology, and empowerment boards. Perhaps we are near a conclusion that too many scarce USDA Rural Development stimulus dollars are buying squad cars and emergency vehicles that can be purchased with local funds, when the critical focus ought to be on positioning agriculture and rural America to be competitive in the new global economic and policy environment. But government agencies will only fund what local community interests and agriculture ask for. If they ask for squad cars that is what they will get until the funds run out or are shifted elsewhere. The sustaining and growing communities in rural America will be led by leaders who figure out how to get things done to position themselves for the future and who don't take "no" for an answer.

The span of local decision-making influence varies from community to community depending on institutional history, local assets, and decision-making culture. The range of approaches will be as varied as there are community numbers. Some will do nothing unless they have to. Some will take the time to understand the direction of the new incentives and organize innovative initiatives designed to capitalize on any opportunities for creating new income streams for the local economic base. A vast majority of communities will follow the early adopters once the verdict comes in from the initial lessons learned and best practices.

Based on these perceptions, it appears that there are at least four circles of local decisions and decision-makers that are in play for a typical rural community. These are: (1) local citizens, consumers, and household decisions, (2) local private business, industry, and nonprofit sector decisions, (3) local government, public sector, and community-wide decisions, and (4) external decisions made by regional entities or by a higher level of government. In Iowa we have 950 communities and all but those in the 12 metro areas are rural. Many decisions are made externally with some input from local decision-makers, but others are totally under local control and influence. An illustration that supports reducing dependence on imported oil and reducing GHG emissions are provided for each alternative.

**I. Create local community research and education initiatives to measure impacts and inform the public.**

A. Identify the local transportation fuels consumption trends and mix (direct and indirect) such as availability of various alternative fuels, purchase of flexfuel, hybrid and electric vehicles, and provide education initiatives to inform citizens, business, agriculture, and community leaders about the probable consequences of the alternatives, as well as facilitate effective participation in solutions.

B. Identify local carbon and GHG emissions (direct and indirect) and provide educational initiatives to inform citizens, business, agriculture, and community leaders about the alternatives, the probable consequences of the alternatives, and to facilitate effective participation in solutions.

**II. Provide incentives and regulations that move local citizens and private sector leaders to make informed decisions and to act locally as individuals and the private sector.**

A. Provide incentives and regulations favorable for initiatives to develop plans and conduct due diligence on individual and private sector approaches for stimulating conservation, deploying new renewable energy resources, and other technologies locally that would reduce dependence on imported oil. Examples might include local tax incentives for making alternative fuels available to local consumers and the private sector and/or tax incentives for purchase of flexfuel and hybrid vehicles by local citizens and businesses.

B. Provide incentives and regulations favorable for local citizens and private sector leaders to reduce carbon and GHG emissions by encouraging plans, approaches, and due diligence on incentives for deployment of new technologies to clean up local emissions, deploy new low-carbon and low-GHG technologies, and implement sequestration activities that may generate new income streams or reduce costs for local individuals and the local private sector.

**III. Create local government-led or public-private sector partnership initiatives to gather research, develop plans, conduct due diligence, make informed decisions, and implement actions in a manner that addresses community-wide and/or local government activities that can influence outcomes.**

A. Create community-based initiatives that develop plans for shifting local government and the community toward purchase of renewable fuels and other technologies that reduce the dependence on imported oil. Examples might be purchase of flex fuel or hybrid vehicles for local government and local mandates for government to purchase alternative fuels.

B. Create community-based initiatives that develop plans for local public sector entities to deploy technologies to clean up emissions, deploy low-carbon and low-GHG technologies, and implement carbon sequestration activities that may generate new sources of income or reduce costs for the community.

**IV. Identify local leaders with expertise and linkages to external regional entities and higher levels of government so as to inform and influence them regarding likely strategies, outcomes, unintended consequences, and/or promotion of approaches that would in turn benefit the local community.**

A. Participate in regional entities and higher government decisions that encourage external distribution systems to make fuel choice locally available through vehicle distribution, blender pumps, and fuel distribution networks.

B. Participate in regional and statewide initiatives that encourage external enterprises to deploy technologies that clean up emissions, that deploy new low-carbon and low-GHG technologies, and that provide incentives for local sequestration activities to reduce local costs and generate new sources of income in the community. For example, incentives provided by investor-owned utilities that deploy coal plants may be critical for creation of community digesters or methane land fills that cash flow long term.

**Now that we have the basic alternatives and consequences framework down,** there are some elements that apply across the framework. It is important to recognize that signals and culture are important to the public. After working with entrepreneurial communities and communities that want to create an entrepreneurial culture for the past decade, I am always amazed and please at the accomplishments that communities can get for simply lifting up successful examples of what they would like to see others emulate. Media success stories, awards, competitions, and educational tours are low cost methods that have been used by Extension for years in stimulating opportunities to educate and provide lessons learned and best practices. I have wondered what would happen if Iowa were to provide a million dollar award for the community or county that would win a statewide competition for highest percentage renewable energy consumption per capita or least carbon and GHG emissions/most sequestration per capita. Such incentives provide clear signals, examples, success stories, rewards, and models for others to learn from.

It is also important to recognize that the four generic approaches above represent the beginnings of an Issue Map along the lines of a typical National Issues Forum template. As is the case with most public policy issues, the local decisions deal with only part of the picture that is related to the policy issues at that national and international level. In some cases, understanding the larger issue choices helps to understand the context for the local community decisions. For example, understanding the facts and fiction in the food versus fuel debate and the indirect land use debate might contribute to clearing up the political choices involved and the local stake in these issues.

Finally, it is important to recognize that the four alternative approaches are not mutually exclusive. A fifth option is to implement a "Combination Approach" involving two or more of the first four approaches outlined, and, a sixth option is to "Continue the Status Quo" policy or to make no change. The status quo is the option that local leaders often prefer until there is sufficient rationale for change. Unfortunately for the two policy issues discussed herein, the cost of inaction may be that local citizens and taxpayers experience higher costs longer term. So local leaders and decision-makers are "boxed-in" with only a limited number of pathways toward the future.

**In summary,** the media coverage given to these topics in recent years and months, many statewide trade associations with local community representatives are seeing a rapid growth in new vendors at their trade shows promoting “green streets”, “green buildings”, “green roofs”, “green construction", "green homes", "green energy", "green vehicles", "green light bulbs", "green food", and the list goes on. At some point, there is a role for a disinterested third-party research-based adult education oriented institution to develop decision tools and provide objective information regarding the choices consumers, businesses, and communities make, so that they are enabled to make informed decisions, and to avoid waste and unintended consequences. These issues are nearly too big for one person, one discipline, or one institution, but maybe a coordinated national extension effort with some capable leadership might make some sense and have an impact on the outcomes.

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# Geothermal Energy's Role in Agriculture

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Geothermal energy is a key factor in agriculture operations in many states, especially in the west. Historic use was focused on use of springs for irrigation water because the thermal water heated the ground where applied. This resulted in gaining a few days of additional growth in the spring and fall. Agricultural producers, realizing the importance of thermal energy, started locating facilities in areas of geothermal potential for heating of greenhouses, heating buildings, drying crops or raising fish. Today there are facilities in many states taking advantage of thermal energy from the earth.

Facilities using geothermal energy in an agriculture operation include onion dehydration in Nevada; algae growing in California; and aquiculture operations in California, New Mexico, Colorado, Utah, Oregon, and Idaho. These operations raise catfish, talapia, and tropical fish in some operations. Two aquiculture operations, one in Idaho and the other in Colorado, also raise alligators. These unique operations are raising alligators in climates considerably north of their natural habitat.

Green house operators who traditionally use natural gas or other fossil fuel for energy supplies are viewing options for re-location to areas with geothermal potential.

Bernie Carl at Chena Hot Springs, Alaska, has developed a complete system for his resort from production of power to greenhouses raising herbs, lettuce, tomatoes and other crops for his resort. He also heats all of the buildings at the resort with geothermal water.

New binary technology has been developed to allow power production at temperatures well below the boiling point. This new technology provides potential for on farm power production which was not feasible a few years ago.

Geothermal energy though enhanced geothermal systems (EGS) technology has resulted in potential energy development anywhere in the United States. This, together with geothermal heat pump technology, allows geothermal energy possibilities any where in the United States.

# Solar Technology Trends and Costs

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Advances in technology as well as decreases in prices as a result of mass production have made solar technologies a viable option in meeting our nation's current and future energy needs. Solar technologies have entered the marketplace fully able to compete competitively in many business sectors, including agriculture.

There are two major types of solar systems in use today: solar thermal and photovoltaics (PV). Each type has many variants and advantages. Solar thermal and photovoltaic systems have many attributes in common. Both can be deployed in a wide range of capacities, from small sizes used on residences and small buildings or in fields, to large centralized utility plants for the generation of electricity. Both are silent generators of energy and produce no emissions or pollution during operation. Both demonstrate very high reliability and are capable of being integrated with the grid or with storage systems to provide continuous operation when the sun is not available. Solar systems provide their greatest energy during the midday hours, a time when agricultural needs for irrigation and other uses are often the greatest.

## Solar Thermal Systems

Solar thermal systems depend upon collecting the sun's energy with either flat-plate or concentrating collectors and using that energy to heat air or liquid. The hot air or liquid can be used for a wide range of heating applications. For example, low temperature heat can be collected and used for space heating or grain drying. Higher temperature heat can be used for producing hot water or steam. Very high temperatures can be used to generate steam for large-scale generation of electricity by utilities.

Although they do not receive as much publicity as PV, solar hot water systems are very popular and cost-effective for home, farm and ranch application. As of 2007, nearly 130 gigawatts (GW) of electrical capacity are still in operation today, producing electricity at a cost of 12 to 14 cents per kilowatt-hour (kWh). In 2007, the Solar One plant near Boulder City, Nevada, began operation and is expected to produce 134 million kWh annually at a cost of 15 to 17 cents per kWh.

The potential cost (not necessarily selling price) of utility-scale solar thermal electricity is projected to reach 8.5 cents per kWh by 2010 and to be as low as 6 cents per kWh by 2015.

## PV Systems

PV systems use combinations of semiconductor materials to convert the sun's energy to direct-current (DC) electricity. The DC electricity can be utilized directly or inverted to produce alternating current (AC) electricity. PV is used over an enormous range of sizes, from milliwatts to gigawatts.

In grid-connected applications, electricity generated by PV during daylight hours is used to offset electricity that would need to be imported from the local utility. PV-generated electricity often displaces high-cost utility electricity for air conditioning or irrigation uses during daylight hours. PV can also be used to minimize expensive demand charges. Grid-connected applications are compatible with applications of any size and are the lowest cost PV systems available.

Several centralized utility-scale PV plants are in operation in the United States today, the largest being a 14 MW plant located at Nellis Air Force Base in Nevada.  Even larger U.S. PV plants are currently on the drawing boards.

PV is often used in grid-independent applications where the capital cost of the PV system can be substantially less than those associated with extending a power line or disrupting infrastructure.  Combined with battery storage, PV systems can provide very high reliability and are often preferred over other energy sources for high-value applications, such as telecommunications.  Many business sectors today, such as the financial or communication sectors, require electrical availabilities far in excess of what utilities are capable of supplying on their own.

The current cost of PV in the United States ranges from 18 to 23 cents per kWh, with the expectation that it will decrease to 11 to 18 cents per kWh by 2010 and 5 to 10 per kWh by 2015.

## Incentives

There are many incentives, grants and loans for solar applications available from federal, state and local governments.  The DSIRE website listed below is the most comprehensive source available.

## The Importance of Energy Efficiency

To obtain the lowest cost as well as the most cost-effective solar thermal or PV system, it is essential that energy efficient practices be considered first in any application.  If the energy isn't needed in the first place, it won't have to be purchased or generated.  The time to consider energy efficiency is in the planning stages. Through careful planning, an application's energy consumption can often be reduced by 1/3 or even half. This reduces both the size and cost of the solar necessary to meet the remaining use, often making a project affordable.

It is now possible to construct energy efficient buildings utilizing solar energy, that supply as much or more of their annual energy use.  Known as "zero energy buildings", these buildings are the wave of the future.

## Resources

The following websites will be informative to homeowners, business owners and city staff interested in energy efficiency and using solar:

1. National Renewable Energy Laboratory (NREL) - Valuable information for the homeowner, business owner, and farmer or rancher.   www.nrel.gov/learning.html
2. Database of State Incentives for Renewable Energy (DSIRE) - A comprehensive source providing information on state, local, utility, and selected federal incentives that promote renewable energy.  www.dsireusa.org
3. Solar How Water and Space Heating and Cooling - Solar water heating is among the most practical, affordable, and durable renewable energy technologies available.  Visit this site to find out more:  www.eere.energy.gov/RE/solar_hotwater.html
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy - An excellent source for the layperson with information about all aspects of renewable energy.  http//www1.eere.energy.gov/solar

# Anaerobic Digester Technology

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Anaerobic digestion converts volatile acids in livestock manure into biogas consisting of 55-70 percent methane along with carbon dioxide, small amounts of water, and other compounds. While the main feedstock for farm-based digesters is manure, any organic matter ("digestate") can be processed in a digester. Food industry wastes and crop residues are other materials that are sometimes processed in farm digesters. These materials increase biogas output and provide tipping fees. In Europe, digesters are referred to as "biogas plants".

At most farm digesters, the biogas supplies an engine that generates electricity. A few digesters purify the biogas into a marketable, natural gas-grade biomethane suitable for household and industrial use. In addition to generating renewable energy, anaerobic digestion leads to reduced odor pollution, fewer pathogens, and reduced biochemical oxygen demand. Digestion stabilizes the volatile organic compounds that remain in the manure so that they can be land-applied with fewer objectionable odors; so many farm digesters have been installed to address neighbors' complaints. Methane is a potent greenhouse gas (21 times the warming potential of carbon dioxide) so combustion of the methane can be a source of carbon credits whose value may increase in the future if more stringent climate policies were to be enacted. Where odor control and/or carbon credits are the main concern, the biogas may be simply flared rather than used as an energy source, thereby eliminating the considerable maintenance requirements of the engine. There is little change in the nutrient value of the manure and organic matter that passes through the process, which can then be used as fertilizer.

The main farm digester designs on farms are covered lagoons, plug-flow digesters, and mixed or stirred designs (Figure 1). At least 125 farm digesters are currently operating in the United States, 98 of them on dairy farms and most of the rest on swine operations[1]. The biogas is being used to generate electrical power on 113 of those operational systems, with 35 megawatts (MW) of generating capacity. While the focus here is on farm digesters, many municipal sewage treatment plants also include digesters. They are designed more to destroy volatile solids than for energy. The energy they do produce is usually used to help power the plant itself. Landfills also often collect gas that is similar to the biogas from farm-based digesters.

**Figure 1.** Plug-Flow Digester (left), Complete Mix Digester (center), and Covered Lagoon Digester.

**Costs and Profitability:** The Mason-Dixon Farms digester in Pennsylvania is the oldest in the United States, operating for 30 years[2]. Eight other 1980s-era digesters are still operating. Half of all currently operational digesters have gone in since the start of 2005. Feasibility analyses often use a projected useful life of 20 years.

While costs vary widely, a regression of investments made versus herd size at sixteen recent dairy farm plug-flow digesters gave a result of $678,064 + $563 per cow[3]. Ancillary items that may be incurred are charges for connecting to the utility grid and equipment to remove hydrogen sulfide, which could add 13 percent to the base amount. This works out to $1.2 million for a 700-cow dairy operation, going up to $2.5 million for 2,800 cows. A similar regression for ten mixed digesters gave $354,866 + $615 per cow. A solids separator would add another 8 percent to these amounts.

Since digester engine-generator sets operate continuously, the engines typically require major overhauls every 3-5 years depending on the quality of maintenance and whether gas cleanup equipment is installed (Figure 2). Flexible covers, pumps, and other components will likely require periodic replacement. The digester vessel itself may also require periodic cleanouts to remove sludge. A ballpark planning number for operation and maintenance (O&M) of a digester with electrical generation is five percent of the initial investment per year, or 14 percent per year to cover both O&M and capital cost.

**Figure 2.** Internal Combustion Engine and Generator.

Achieving expected biogas output has been an issue for some digesters. Measured output at six New York plug-flow digesters and one mixed digester ranged from 25 to 135 feet$^3$/cow/day[4]. A mid-range 70 feet$^3$/cow/day of gas at 60 percent methane, thermal conversion of 27 percent, and 90 percent engine runtime works out to electricity output of 1,000 kilowatt-hours (KWH)/cow/year. If there are no other sources of value from the digester and no subsidies, then, the breakeven cost of electricity for these two farm sizes is 22 cents/KWH for the 700-cow farm and 12 cents/KWH for the 2,800-cow size.

What will this electricity contribute to farm profitability? A digester can be much more profitable where the electricity can offset retail purchases rather than being sold at the utility's avoided generation cost. However, many farms do not need as much energy as a digester would provide so much of the electricity gets valued at the lower price unless ancillary enterprises are present such as farm-based cheese plants that need a lot of energy. Net metering regulations vary by state and can affect the price received. The average U.S. retail price of electricity for all uses is around 10 cents/KWH[5]. The United States avoided generation cost is likely around 5 cents/KWH, but is not reported publicly. When the 12 to 22-cent/KWH breakeven cost is compared to the likely 5 to 10-cent market value of the electricity, it is clear that electricity sales alone are usually not enough to allow unsubsidized farm digesters to operate profitably.

Still, digesters are going in at an increasing rate. Twenty-one digesters became operational in 2008 and nine more in 2009, at last count. Seventeen more are in the construction or planning phases[2]. What is driving this growth?

Most digester installations that have been described in the literature recently have also received subsidies or incentives of various kinds. Available incentives are too numerous to list fully here, but they include programs such as the USDA Rural Energy for America Program (REAP) which provides grants of up to 25 percent and guaranteed loans of up to 50 percent of project costs[6]. A 25 percent REAP grant to the two farms described above would bring the breakeven costs down to 18 cents/KWH for the 700-cow farm and 10 cents for the 2,800-cow size.

Digester growth in some states is being driven by high electricity prices such as New York's 15.5-cent average price (as of January 2009), or renewable electricity credits linked to utility renewable portfolio standards[7]. Many digesters are also coupled with solids separators that supply fiber that can be used for bedding or sold as a soil amendment (Figure 3).

**Figure 3.** Manure Solids Separator.

These separated manure solids are generally regarded as another important source of value. Many dairy farms use sand as bedding, and must switch to an alternative bedding source when installing a digester because the sand would plug up the digester. Wood shavings for bedding are also in short supply in some areas. Bedding with manure solids requires careful management to minimize bacteria buildup that might contribute to mastitis problems in the dairy herd. Dairy farms in Minnesota spent $50/cow on bedding in 2007[8]. If manure solids could eliminate that cost, net of what the separation equipment would cost, that would reduce the (subsidized) electricity breakeven cost to 14 cents/KWH for the 500-cow farm or to 6 cents/KWH for the 2,800-cow size.

Not considered in the above cost numbers are tipping fees for accepting offsite food processing wastes, which have also contributed significant value for a few digesters. Carbon credit sales are not much of a factor so far, but anticipation of higher carbon values in the future may be driving some digester installation activity. Odor control has also been an important motivation for many digesters, but is difficult to value in financial terms.

**Ability to Mass Produce:** Digester operational scale has been increasing. Only three digesters had generating capacity of over one MW by 2007, while six with that much capacity were installed in 2008 and 2009[2]. Digesters are made of conventional equipment and materials such as concrete and engines designed for natural gas or diesel fuel, so there are no obvious barriers to rapid implementation if the economics are there. If half of the large (500+ cows) dairy and (2,000+ pigs) swine operations in the United States were to install digesters, the 6,500 systems could potentially provide 802 MW (0.1 percent of the U.S. total)[9]. Germany is regarded as the world leader in digesters, with over 3,700 in operation and with a combined capacity of 1,270 MW, around one percent of Germany's electricity needs[10]. Germany has roughly half as many dairy cows and pigs as the United States, so the projection of 6,500 systems would put us where Germany is now in terms of animals per digester.

**Environmental Impact:** One impediment to future digester growth is tightening limits on digester engine NOx emissions, especially in air quality non-attainment areas such as southern California. While accepting off-site food processing wastes can add revenue, the extra nutrients can exceed the fertilizer needs of available cropland and can trigger more extensive scrutiny from regulators.

**Expected Technological Innovations:** New digester designs and pre-treatment techniques may increase conversion rates of the manure solids to biogas and/or may reduce the size and cost of the digester vessel required. Cheaper systems for removing hydrogen sulfide and other impurities may become available. Rather than using the biogas to generate electricity, a few digester systems are beginning to upgrade the biogas to natural gas standards and trucking or piping it to off-site industrial users. One U.S. digester operator is following Sweden's lead by powering milk trucks with compressed biogas[11].

More stringent water quality regulations are pressuring livestock operations to minimize nonpoint nutrient losses and may also offer nutrient credit trading opportunities to generate additional revenue. Digestion itself has little effect on the nutrient content of manure, but integrated nutrient removal systems have been proposed that would use digester energy to power other equipment that would divert nutrients away from land application to other uses that have less impact on water quality.

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# Extension Resource Efficiency Programs for Residential Housing

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***Situation/Policy Question:*** Residential construction directly associated with population growth is the primary driver of Florida's economy. In 2005 over 208,000 building permits were issued statewide for new, single-family, detached homes. Direct consequences of this growth include a steadily increasing demand for energy, water and land for urban uses. This rapid growth is coming at a steep cost to the state's natural environment, which is most directly felt in our depleted water supply and degraded water quality. This situation has created numerous policy questions that all revolve directly around growth management.

***Extension's Role:*** Most of Florida's new homes are constructed in master planned community developments. These community planning efforts require cross disciplinary collaboration between built-environmental professionals (engineers, landscape architects, planners, environmental consultants, attorneys and others), local governments, water management districts, and other agencies. The Program for Resource Efficient Communities (PREC) was established in 2004 to more effectively bring University of Florida resources into the growth management discussion.

PREC was organized on the premise that its success depends on building and maintaining an inclusive, multi-disciplinary faculty team focused on the adoption of best design, construction and management practices that measurably reduce energy and water consumption and environmental degradation in new residential community developments. The group's interests extend from lot level through site development to surrounding lands and ecological systems. PREC promotes implementation of resource efficient practices by:

- Providing direct training, education and counseling services;
- Conducting applied research projects and case studies;
- Supporting graduate student projects and internships; and
- Partnering with "green" certification programs.

It is important to note the Program for Resource Efficient Communities was a bottom-up initiative with no recurring personnel or programmatic funding. PREC generates its own revenues primarily through registration fees, for sale publications, contracts and billable hour consulting (developers).

***Policy Alternatives:*** Simply stated, the policy alternatives fall into two camps: increase supply and decrease demand. Steadily increasing supply ("growth") is Florida's default (status quo) position while recognizing and accommodating the state's carrying capacity (conservation) is the minority view. Unfortunately, when "policy alternatives" become closely linked to financial interests and political positions, objective data and analysis can get lost in the shuffle.

***Misconception:*** With respect to growth management a primary misconception is that the choice is between jobs and the environment. Florida's 2008 housing starts have plummeted to 20 percent of where they were in 2005 and the state's economic downturn could be interpreted to confirm the view. However, Florida's agricultural economy remains relatively strong. Ironically, land development is a primary threat to agriculture.

***Stakeholders:*** If growth management is defined along the lines described in the "Policy Alternatives" section above, then developers, large landowners, built environmental professionals and the real estate industry are generally in favor of reduced regulation and increasing the supply of needed development resources (energy, water and land) while conservation groups, regulatory agency staff and the general public are generally in favor of slowing growth.

***Consequences:*** There's little doubt that continuing to increase the supply of developmental resources and reducing the constraints on growth will increase economic activity. Likewise, there's little doubt that the costs of producing additional energy and water will rise sharply. In the Tampa Bay area surface water (the Hillsborough and Alafia Rivers) and ground water are at their limit. After more than a year of delays due to technical failures, a desalinization plant began functioning in 2007 and is producing about 10 percent of the region's water supply. More desalinization plants could be built, but producing potable water by "desal" requires 15 times as much energy as surface or ground water. The majority of increased demand for water is for residential landscape irrigation.

Water quality is degrading in the state's rivers, lakes and springs to such an extent that many bodies of water in the state have been declared to be impaired as defined by the Federal Clean Water Act of 1972. This has triggered the establishment of Total Maximum Daily Loads (TMDLs). In the Lower St. Johns River TMDLs for nitrogen are requiring local jurisdictions to implement expensive treatments to reduce loading. A primary source of nitrogen is fertilizer and in many watersheds, the majority of the fertilizers applied are for non-farm uses with residential landscapes being a major user.

The other major users of water and fertilizer in Florida is agriculture, which will be directly affected by the shortages and regulations created to respond to water supply and quality problems.

***Avoiding the "Policy Alternative" Trap:*** The phrase "Policy Alternative" can create the illusion that the real world is a simple place. Growth management is complicated. The Program for Resource Efficient Communities avoids being categorized by staying focused on readily and publically available data. Essentially, data on population, building permits, energy use, water demand, and fertilizer consumption tell the story; while case studies that compare and contrast measured impacts inform policy choices. Master planned community development projects can take 30 years from inception to completion. Consequently, developers must be very strategic in their decision making; for long-term success, they must design their communities in anticipation of future water shortages and more stringent requirements to reduce pollution loading. PREC avoids the trap by staying clearly focused on design and management solutions that directly address the strategic challenges that developers and the State of Florida face.

# Farm-Electrical Energy Efficiency Technologies

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1. **Name of Technologies:** Energy efficient technologies for lighting, water heating-heat recovery system, milk cooling-pre-cooling, VSD vacuum pump motors, and livestock ventilation fans and grain drying.
2. **Capital Costs:** Cost of dairy related equipment depends on herd size and application of technology, grain drying and handling technology costs vary depending on the volume of grain being processed. Targeted cost savings payback should be five years or less to be eligible for some grants and loans.
3. **Expected Output:** Energy saving technologies can significantly reduce electrical energy costs depending on the technology selected. **Long day lighting** can reduce energy costs and increase milk production with paybacks from six months to two years. **Refrigeration heat recovery** systems payback period is dependent on current water heating energy source, amount of water used and amount of milk produced, can reduce water heating costs up to 50 percent. **Plate pre-cooler**, potential energy savings up to 60 percent of milk cooling costs. **Variable speed vacuum pump** can reduce electrical use 30 to 80 percent. **High volume low speed ventilation fans** can increase cow comfort and decrease energy costs over high speed box fans, payback can be long, up to seven years. **Grain drying** offers many technologies that reduce cost of handling and drying grain, from heat recovery to grain drying system design using gravity flow versus mechanical transfer of grain.
4. **Ability to Mass Produce:** All the technologies referred to are manufactured or offered by most dairy equipment companies and grain dryer manufacturers as optional equipment and are readily available today.
5. **Externalities:** Technologies like energy efficient lighting, ventilation and automatic milking machine take-offs will save energy compared to conventional technologies and have the potential to increase animal productivity by enhancing milk production physiology, increasing animal comfort and decreasing injury to mammary tissue.
6. **Electrical Technology:** Innovation is improving rapidly, energy management systems can also reduce energy load when equipment is not being optimally utilized, digital technology reduces energy losses through heating, and proper on-farm wiring can more safely and efficiently serve on-farm electrical load requirements.
7. Web site links for energy efficiency assessment tool: The USDA has energy self-assessment tool accessed through: [www.ruralenergy.wisc.edu/esa](http://www.ruralenergy.wisc.edu/esa)

# Biomass-Direct Combustion-Renewable Energy

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1. **Name of Herbaceous/Woody Crop or Residue:** High yield perennial grasses and woody crops, corn stover and non-merchantable forest residues.

2. **Land Footprint (Yield Per Acre):** Upper mid-west non-irrigated dedicated perennial herbaceous crops such as switchgrass can average 5 tons per acre, crops like miscanthus offer potential for greater yields. Sustainable corn stover yields vary depending on prescribed removal rates based on soil type, soil slope and grain yield. An average 144 bushels per acre field yields 1,200 pounds of stover per acre while 246 bushels per acre yields 7.2 tons of stover per acre using the Soil Conditioning Index and RUSL2 Management file to determine sustainable corn stover removal rates. Corn stover can be a problem to harvest and store due to high moisture content at time of traditional grain harvest.

   Perennial grasses and crop residues are preferred after the plant senescence's and is seasonably available in the late fall and early winter. Spring harvest is possible, improving biomass chemistry, but decreases crop yield and increases biomass inorganic matter (ash) content. Multiple harvests per year yields more per acre but have not shown to be profitable and often results in decrease plant survival, greater input costs and loss in plant vigor in subsequent years.

   Test harvest of wood materials in southwest Wisconsin in woodlots result in harvests of 6 to 68 tons per acre depending on prescribed forest management plant.

3. **Expected Conversion Technology:** The conversion technology discussed is the co-firing of biomass with coal or using it in a stand alone biomass combustion boiler. The biomass capacity of the boiler is partially determined by the availability of fuel within an economic transportation distance from the plant. Currently the minimal capacities we've considered are 300,000 tons per year boiler, which is equivalent to approximately 30 MW of electrical generation.

4. **Ability to Mass Produce:** Currently there are several challenges to commercialization of the biofuel industry:

   - The industry awaits an energy bill that outlines whether there will be a national renewable portfolio standard (RPS), carbon cap and trade, carbon tax, etc.
   - Crop yield optimization
   - Biofuel standards allowing marketing and quality control
   - Efficient means of biomass harvest and densification
   - Methods of long term biomass storage that maintains its fuel quality
   - Biomass supply chain business structure

5. **Environmental Impact:** The impact of stover removal to soil carbon, soil fertility and soil erosion could be negative if the crop is inadequately managed. Best soil stewardship management practice must be required to sustainably remove corn stover for biofuel production.

   Herbaceous perennial crops grown for biofuel production can provide environmental benefits similar to the USDA CRP program while providing greater income potential for the land operator. Some research indicates that planting diverse plant varieties will increase land productivity and improve wildlife habitat over the production of monoculture crops.

   Using forest best management practices the harvest of wood material through Timber Stand Improvement (TSI) and removal of slash from logged forests can increase carbon sequestration, improve watershed water quality, improve quality of merchantable trees and improve wildlife habitat.

   Dedicated biomass herbaceous and woody crops can increase the economic value of marginal lands, improve wildlife habitat, increase carbon sequestration and improve water quality.

6. **Expected Cost of Production:** Cost of production varies widely depending on special grown, plant cultural requirements, best management practices and harvest methods used

7. **Web-Links:**

   National Renewable Energy Lab -- www.nrel.gov/biomass/

   Midwest Rural Energy Council -- www.mrec.org

   Biomass Magazine -- www.biomassmagazine.com

   Switchgrass -- www.iowaswitchgrass.com

   Miscanthus -- www.miscanthus.illinois.edu

   National Food & Energy Council -- www.nfec.org

# Weatherization, Efficiency, and Carbon Opportunities

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### 1. Brief Technology Description

- The CEDAR approach to energy investment (i.e., Conservation, before Efficiency, before Demand peak reduction, before Adders of non-utility energy/carbon reductions, before Renewables) reduces energy input costs for ag/rural businesses and homes, and introduces new forms of rural income, rural jobs, and rural career options.
- Demonstrations now under way show reductions in home-related and small business energy use greater than 50 percent, costs paid out of future energy savings.
- By emphasizing the primacy of human factors in energy use, CEDAR offers rural residents the first truly cost-effective approach to large energy savings.

### 2. Capital and Operational Costs, Useful Life and Expected Payback of CEDAR

- Capital costs to achieve 50 percent total energy savings by a rural resident will average $8,000 to $10,000, with payback to a revolving loan fund in less than 10 years on the utility bill, and overall energy costs reduced from Day One.
- About half the reductions will be with low-cost/no-cost practices and measures, the majority of which will outlive the 10-year combined payback period. The balance of 50 percent of the savings will be achieved with improvements in materials (e.g., attic insulation) and hardware (e.g., space heating systems), with an average useful life longer than 20 years.
- The CEDAR approach can be applied to homes and small businesses at small, medium and large operational scales.

### 3. Cost Competitiveness of the CEDAR Technologies

- The advantage of the CEDAR Approach, which amounts to a comprehensive, integrated check for fit of each of the elements (C-E-D-A-R) in every home, is that it allows a significantly larger home retrofit package within the payback criterion, thereby achieving total cost savings of 50 percent or more.
- The disadvantage of the CEDAR Approach, if any, is that the allowable measures will range in cost competitiveness from zero cost (with immediate savings over any conventional supply source; e.g., reducing the thermostat set-point in winter and raising it in summer) to relatively high costs and only long-term savings expectations (e.g., solar electric panels with a lifetime of 30 to 50 years, paying off even with rebates in 10 years). With such a comprehensive, integrated approach, of course, the faster payoff measures essentially "balance" the savings of the longer payoff measures to meet the selected package payoff criterion.
- Cost competitiveness must include the critical rural factors of distance and lack of efficiency/renewable infrastructure. One very good reason that rural homes constitute the largest stock of homes in the United States (14 million) that have not received a comprehensive energy retrofit is that the distances render

unworkable the audit-bid-install energy savings model used in urban areas. The CEDAR Approach addresses this problem by combining homeowner action partnership with reduced visit requirements and economies of scale.

### 4. Logistics of the CEDAR Technologies

- The CEDAR Approach can begin immediately at pilot scale with standard off-the-shelf technologies, if program information and assistance effectively can be provided by rural institutional partners like Extension and the local utility, each of which have a stake in true rural sustainability.
- Successful pilot programs, describing very large and profitable rural markets for CEDAR products and services, will rapidly grow training and entrepreneurial opportunities for new and existing rural energy businesses.

### 5. Externalities or Environmental Impact of the CEDAR Technologies

- Environmental impacts, e.g.,
  - Reduced use of water directly (through less domestic use) and indirectly (through less electricity use),
  - Reduced use of fossil fuels (solid, liquid, gas) and associated environmental carbon burden,
  - Increased carbon sequestration at all scales,
  - Increased wildlife habitat through greater use of trees and other landscaping features around homes,
  - Improved soil conditions through reduced production/use/disposal of toxic materials, including heavy metals produced in power generation, and
  - Improved indoor air quality through improved ventilation and reduced production and use of toxic materials.
- Other externalities, e.g.,
  - Positive rural economic impacts in terms of new rural jobs, new forms of rural income, and new rural career options,
  - Improved standard of living for rural residents,
  - Improved home health and safety,
  - Reduced out-migration from rural areas,
  - Increased viability of rural communities,
  - Improved survivability of rural electric cooperatives, and
  - Increased relevance of the Cooperative Extension function.

### 6. Long-term Outlook for CEDAR

- Massively distributed efficiency and local renewables (e.g., solar, wind, geothermal, biofuels) in rural America will yield a broad range of long-term jobs in new CEDAR technology.
- Good energy-related jobs and improved reliability of the infrastructure will encourage the transformation of rural America back into the economically thriving communities and extended families that made the rural lifestyle so desirable not so long ago.

### 7. Further Information

"Rural Electric Efficiency Prospects," 135pp, 252 endnotes, March, 2008, Southwest Energy Efficiency Project (SWEEP) report posted at [www.swenergy.org/pubs/reep/index](www.swenergy.org/pubs/reep/index)

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# Establishing and Maintaining Perennial Grass Crops for Energy: Emphasis on Switchgrass

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***Species and Varieties*** **--** Several perennial grass species are regarded as potential bioenergy crops. They include the temperate species switchgrass (*Panicum virgatum*), reed canarygrass (*Phalaris arundinacea*), and giant (or hybrid) miscanthus (*Miscanthus* x *giganteus*); and the subtropical to tropical species energy cane (*Saccharum* spp.), giant reed (*Arundo donax*), guineagrass (*Panicum maximum*), elephantgrass (*Pennisetum purpureum*), and bamboo (*Bambusa* spp.). This fact sheet emphasizes agronomic practices for establishment and early stand maintenance of switchgrass because it is widely adapted in the United States, seed is readily available, and it has received the most research attention. Giant miscanthus is gaining increased attention in the United States because of its very high yield potential.

Several varieties (cultivars) of switchgrass are commercially available because of earlier breeding efforts for its use as forage. 'Cave-in-Rock', originating in Illinois, is an example of a variety that performs well in the northern half of the United States, and represents the upland type of germplasm. 'Alamo' and 'Kanlow', originating in Texas, represent the lowland germplasm, which produce thicker, taller stems than the lowland types, and are preferred for biomass plantings in the southern states. The upland types possess greater winterhardiness, and are thus more reliable in northern states. Public and private breeding efforts are currently underway to develop high-biomass-yielding types specifically for biofuel production. For some traits, the objectives in breeding bioenergy varieties run counter to those for forage in that high stem proportion, low crude protein (nitrogen), and low mineral concentrations are preferred.

***Establishment*** **--** Three factors work against rapid, even, stand establishment of switchgrass: 1) dormancy of seeds, 2) weed competition, and 3) small, slow-growing seedlings (Figure 1). Freshly harvested seed generally has high dormancy, i.e. alive but will not germinate until aged several months or subjected to artificial stratification (wetting followed by cold storage). Switchgrass seed is harvested in late summer. New seed can be planted in late autumn or winter when naturally cold, moist soil conditions break dormancy so that seedlings can emerge the following spring. This is an uncommon practice because weed control is difficult. More commonly, seed harvested the previous summer is planted in the subsequent spring. Confirm with the seed company that dormancy is low when spring planting.

**Figure 1.** Switchgrass Seedlings.

**Figure 2.** No-till Planting of Switchgrass.

**Figure 3.** Miscanthus Transplanted.

Switchgrass seeds are very small <1/8 in.; <3 mm), and one pound contains around 400,000 seeds. Seeding rates are generally recommended at 6-7 lbs/acre of pure live seed (PLS), and commercial seed can have PLS values of 40-85 percent. Calculate the seeding rate as the desired seeding rate of PLS (exa. 6 lbs/acre) divided by the fraction of PLS (exa. 75 percent = 0.75). In this example, 6 lbs/acre divided by 0.75 PLS is 8 lbs/acre of purchased seed. Since establishment of switchgrass is so risky, a higher seeding rate is often recommended, such as 8-10 lbs/acre, especially when establishing small acreages for demonstration or trial purposes.

Soil area should be sampled six months before planting to apply recommended amounts of lime, phosphorus, and potassium fertilizer. Soil pH should be at least 5.0, and P and K should be applied to attain medium soil test levels. Do not apply nitrogen during the seeding year to avoid excessive weed growth. Preparing a seedbed with tillage assures good incorporation of the lime and fertilizer before planting. Perennial plants should be killed with glyphosate (Roundup®), disked or rototilled as necessary to reduce clods and to achieve a fine, firm seedbed. Seed is planted from a small seed box attachment on a grain drill or a no-till drill (Figure 2). There is high seedling mortality during the first year. An excellent density of vigorous plants having multiple tillers at the end of the first year would be at least 2/$ft^2$, with few gaps exceeding 4 $ft^2$. By the beginning of the third year, plant density of at least one plant per 2 $ft^2$ would be excellent, and one plant per 4 $ft^2$ would be acceptable if uniform. A single plant of the lowland variety, Alamo, can tiller out to a crown diameter of more than 1 ft.

Seed can also be no-till drilled into a sod (pasture) or crop stubble. For a sod, make sure the pre-existing grass has been heavily grazed or closely mowed the previous late summer and fall to minimize surface plant residue. Allow regrowth to 4-6 inches in the fall and apply glyphosate, and then reapply glyphosate again in the spring before planting. If fall preparation is not done and dead residue is fairly thick, conduct a burn in the spring before there is new green growth, allow 6 inches of regrowth, and apply glyphosate to kill the perennial vegetation. Switchgrasss can be no-till drilled into the stubble of cropland that is not bedded after a burn-down application of paraquat to kill annual weeds or with an application of glyphosate for perennial weeds. Depth of planting should be between ¼ to ½ inch. Seed should be planted when soil temperature reaches 60ºF.

***__Weed Control__*** -- Tillage, burning, and chemical burn-down can help in weed control, but pre- and post-emergence herbicides are also useful. Follow label recommendations for your state. After planting, apply the herbicide imazethapyr (Pursuit® or Newpath®) at 1.0 oz of a.i./acre for preemergence control of grass weeds. If broadleaf weeds are a postemergent problem when switchgrass is at the 3-leaf stage, apply a herbicide containing metsulfuron (e.g. Cimarron®). The presence of johnsongrass may be a major obstruction to converting pasture to switchgrass. Experience in Arkansas has shown that planting at the earliest date to satisfy the soil temperature requirement can lead to serious problems with summer grass weeds. Delaying planting of switchgrass until after a chemical burn-down of the first flush of summer weed seedlings eases the weed pressure and lends flexibility in planting time. A second flush and burn-down is recommended in very weedy sites. A very good stand of switchgrass at the end of the first year should recover in the spring of the second year with enough density to not need herbicides in subsequent years.

***__Production Years__*** -- At the beginning of the growing season of the second and subsequent years, apply 60 lb/acre of nitrogen to maximize energy efficiency at low cost. The first biomass harvest of switchgrass can be taken at the end of the second growing season. During and after seedset, the leaves and stems retranslocate some nutrients to the roots for storage and the plant turns brown and dry. After a killing frost, the biomass can be harvested to a stubble height of no less than 6 inches. Two harvests per year will increase costs without increasing yield and could reduce stand longevity.

***__Miscanthus__*** -- Giant miscanthus is a hybrid whose flowers are sterile, and therefore does not produce viable seeds. This has the advantage of reducing the risk of this plant becoming a noxious invader, but it also drives up the cost of establishment. Planting consists of transplanting small plants or rhizome cuttings into the field, in 30-inch wide rows (Figure 3). Vegetable seedling transplanters have been modified for this purpose. This requires more labor, and fewer acres per day can be planted. Miscanthus is not as drought and heat tolerance as switchgrass, therefore in southern states, planting on heavy textured or river bottom soils is preferred; whereas switchgrass can produce well on upland, well-drained soils, even the so-called lowland types. After transplants exhibit new growth, nitrogen can be sidedressed at 30 lbs/acre.  Miscanthus can grow over 12 ft tall, so heavy-duty harvesting equipment will be needed.

Agronomy/Forestry

# Annual Hybrid Energy Crops: Sorghums

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Second generation biofuel production will be based on crops grown specifically for the purpose of biofuel production. These dedicated energy crops provide the only economic and logical means for the production of biofuel on a commercial scale. Most of the research emphasis has focused on perennial grass species such as switchgrass and miscanthus, and these perennial crops will be critical for second generation bioenergy fuel production.

Regardless of which perennial bioenergy crops are grown in each location, there will be a need for annual lignocellulosic bioenergy crops for several reasons. First, they are needed to fill production gaps due to establishment lags in perennial crops. Second, they are the only means available to rapidly replace lost production due to weather or other unpredicted factors. Finally, in many productions systems, annual crops are required for the crop rotation patterns practiced by producers.

For lignocellulosic biomass production, sorghum is the logical annual bioenergy crop. In describing sorghum as a dedicated bioenergy, there are two distinct types to consider. Sweet sorghums are tall sorghums that accumulate sugar in the stalk as well as lignocellulosic biomass. Photoperiod sensitive energy sorghums are types that do not flower in temperate climates; they are tall and accumulate large amounts of lignocellulosic biomass.

Energy sorghums have high yield potential in favorable environments. Studies in Iowa, compare perennial grasses with annual row crops and found that sorghum had the highest yield potential, averaging over 35 Mg ha$^{-1}$ (dry weight basis), and also performed well when intercropping with legume species. More recent data in multiple locations across the country have demonstrated that sorghum will consistently produce between 18 to 35 Mg ha$^{-1}$ (dry weight basis) in rain-fed environments in the Eastern United States, with total yield directly correlated with available moisture. The potential to increase these yields through genetic improvement is high; adopting hybrids (sweet sorghum) and selection for highly heritable traits such as height, maturity and disease resistance. Longer term gains from marker-assisted breeding and transgenic approaches can be expected as well.

The biochemical composition of sorghum is highly dependent on the type that is produced; i.e., grain sorghum, sweet sorghum, forage and cellulosic (high biomass) sorghum. Sorghum grain is high in starch, with lower levels of protein, fat and ash. Juice extracted from sweet sorghum stalks is high in fermentable sugars, predominantly sucrose with variable levels of glucose and fructose, and in some genotypes, small amounts of starch. In photoperiod sensitive energy sorghums, the predominant compounds that are produced are structural carbohydrates (lignin, cellulose and hemi-cellulose). Our lab recently screened an array of different sorghum types, glucan content ranged from 20-40 percent; xylan content ranged from 8-21 percent; lignin content ranged from 9-20 percent and soluble extractive content ranged from 17-43 percent. The range in variation indicates that sorghum has substantial variation within the species from which to either increase or decrease a component, depending on the end-users desired raw material. There remains a need to assess the relative magnitude of environment in composition.

Of all the potential bioenergy crops, sorghum is unique in that is has been cultivated in many regions of the United States as either a grain or forage crop. Producers are familiar with the crop and the agronomic infrastructure for growing the crop is essentially identical to other row crops such as corn. This reduces the need for additional equipment or the development of alternative production practices. There remains the need to develop agronomic management plans for energy sorghum production (as opposed to forage or grain sorghum production), but there are several groups actively researching the topic now. Production of sorghum as an energy crop will be initially similar to that of forage sorghum; the crop will required a good seed bed, early season weed control and suitable moisture to establish the crop.

While nitrogen fertilization requirements are not yet established, the crop will require nitrogen for maximum productivity and it is expected to be at a level somewhat lower than that required for optimum forage production, primarily because forage crops require and remove higher levels of nitrogen at harvest. It is our assertion that irrigation of bioenergy crops will be very limited; primarily to those that will produce a sugar component: i.e., sugar or energycane or sweet sorghum. In these situations, the water requirements of sweet sorghum are approximately 1/2 to 3/4 that of sugarcane. For photoperiod sensitive energy sorghums, they have been bred specifically for rainfall production and the absence of reproductive growth allows them a much greater level of drought tolerance than seen in other crops where reproduction is a required phase of growth. Consequently, these crops will be rain-fed; yields will be a function of available moisture.

Because of its history as cultivated crop in the United States, much of the infrastructure to establish sorghum as a viable energy crop already exists. There remains an active sorghum improvement industry that is producing new grain, and forage sorghum hybrid seed. These production and processing facilities have been used for over fifty years and are completely adaptable to the production of energy sorghum hybrid seed. Commercially acceptable sorghum hybrids are available for energy sorghum production at this time; new hybrids developed specifically for energy production will be available in the next couple of years. Sweet sorghum cultivars are currently available, but sweet sorghum hybrids are needed to provide seed quantities at scale; these should be available within two years.

With excessive storage, it is unrealistic to expect a single crop species to supply biomass to a large (>30MGY) throughout the year. Sorghum is one crop in a portfolio that will be used to provide biomass to the plant across a wide range of the United States. Energy sorghums can be harvested as early as two to three months after planting, if planting in staggered schedules it can be continuously harvested until past a killing frost. Composition over that time will change depending on hybrid and environment so management is important. If storage is required there is the potential to dry on ensile it. For sweet sorghum, like sugarcane, processing immediately is critical, so production in most of the United States is limited by available growing season. Application of sweet sorghum in initial development will be limited to regions that also produce sugarcane and can use the crop in a complementary fashion.

# Economics of Crop Residues: Corn Stover

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***Corn stover refers to the cobs, stalks, and leaves of the corn plant, i.e., it typically implies the material left over in the field after grain harvest.***

***Land Footprint:*** The ratio of corn stover to grain is typically assumed to be 1:1; thus, there is 56 pounds of corn stover produced for every 56 pound bushel of grain harvested. Thus, stover production estimates are typically based on grain harvest figures (this assumes ~ 15 percent moisture). Table 1 below shows some estimates of stover produced at various corn yields. Current estimates indicate that existing technology allows for only 30-40 percent of the stover produced to be harvestable.

**Table 1. Stover Yield at Various Corn Yields**

| Corn Yield (bu/ac) | 125 | 150 | 175 |
|---|---|---|---|
| Stover Yield (dry tons/ac) | 2.9 | 3.5 | 4.1 |
| Harvestable Stover (dry tons/ac) | 1.0 | 1.2 | 1.4 |

***Expected Conversion Technologies:*** A recent study by Eidman *et al*. (2009) gives a detailed account of the profitability of a corn-stover-to-ethanol conversion facility under various conversion rates, plant sizes, internal rates of return, and ethanol and electricity prices. Please see reference at the end of this document for details on the study.

***Harvest Methods:*** Harvest time is limited to roughly a three month period in the fall just after corn is harvested. Existing farm equipment can be used to harvest corn stover, although collection at a larger scale could be a challenge due to the short harvest window which falls during the harvest time for the primary crop (corn), when weather may also cause delays, etc. Please see Petrolia (2008a) for a detailed discussion on harvest, storage, and delivery issues and costs. It is reasonable to assume that if harvest of corn stover becomes widespread that alternative harvest methods would be developed such that the entire corn plant could be harvested at once, then separated off-farm. This would likely have the effect of substantially reducing harvest cost of the overall operation.

***Environmental Impact:*** Because this crop is a residue, i.e., already being produced, the change in environmental impact with regard to carbon sequestration/emission is negligible. However, theoretically speaking increased use of stover-based fuels may reduce the use of non-renewable petroleum-based fuels, resulting in a net reduction in carbon emissions. The immediate environmental concern is soil erosion. Corn stover has historically been left in the field as cover to reduce erosion and for nutrient content. Use of stover for energy production, if harvested in excess of recommended levels, could produce erosion problems in some steeply sloped production areas. The harvest and cost estimates reported in Petrolia (2008a) assume that sufficient stover is left unharvested to satisfy tolerable soil-loss levels. There is some evidence that the economic incentive to harvest beyond tolerable soil-loss levels is small (Petrolia, 2008b).

***Expected Cost of Production Per Acre:*** Cost of production is expected to be between $76-$90 per dry ton, depending on yield and transport distance. Assuming a conversion rate of 70 gallons per dry ton, feedstock production and delivery would account for $1.09 to $1.29 of the cost of a gallon of ethanol produced. Sensitivity analysis indicates that cost estimates are most sensitive to assumptions on bale moisture content, harvest efficiency, and producer participation rate (availability).

***Storage:*** Because all of the stover would be harvested in a three month period, a considerable amount of storage for year-round ethanol production would be necessary. Storage adds between $7 and $13 per dry ton to feedstock cost. The ideal situation would be to identify other feedstocks that could be used throughout the year to reduce or eliminate the need for long-term storage, such as winter wheat straw during the winter and switchgrass during the summer.

***Potential of Other Crops of Interest:*** Also of interest are residues from sorghum and wheat production. Table 2 shows a comparison of these with corn stover and the potential for ethanol production (Kim and Dale, 2004). Carbohydrates, which include starch, sugar, cellulose, and hemicellulose, are the main potential sources for producing ethanol, whereas lignin can be used to generated electricity and/or steam.

**Table 2. Comparison of Corn Stover to Other Residue Feedstocks of Interest**

| Residue | Residue/Crop Ratio | Dry Matter (%) | Carbohydrates (%) | Lignin (%) | Ethanol Yield (gal/dry ton) |
|---|---|---|---|---|---|
| Corn Stover | 1.0 | 79 | 58 | 19 | 69.5 |
| Sorghum Straw | 1.3 | 88 | 61 | 15 | 64.7 |
| Wheat Straw | 1.3 | 90 | 54 | 16 | 69.5 |

Source: Kim and Dale, 2004

***Useful Web Links for Further Information:***

Department of Energy's Biomass Program - Information Resources

http://www1.eere.energy.gov/biomass/information_resources.html

Biomass Feedstock Composition and Property Database

http://www1.eere.energy.gov/biomass/information_resources.html

***Key References:***

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# Technological Trends and Production Costs for Forestry Biomass

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## What is "forestry biomass" and how much is available?

Forestry biomass can be defined as logging residues from conventional timber harvests, direct fuel wood harvests from forests, mill residues (including black liquor from paper mills), forest health biomass removals, and urban wood waste. Nationwide, an annual supply of 368 million dry tons per year of forest biomass has been made, with 17 percent from logging residues, 14 percent from fuel wood harvests, 40 percent from mill residues, 16 percent from forest health removals, and 13 percent from urban wood waste collection.

In terms of understanding the supply costs of forestry biomass, it is important to note that mill residues are largely spoken for by the wood products industry. The wood products industry generates approximately 50 percent of its own energy needs from burning mill residues, and yet it is still the third largest consumer of fossil energy amount all U.S. manufacturing sectors. Any diversion of mill residues to other energy production will quickly raise the price of those residues as mills would need to buy electricity and natural gas to replace them.

## Technologies being used to collect forestry biomass

Aside from mill residues, all forestry biomass has three characteristics that are important to the technologies that are used to collect them. They are bulky, dirty, and have high moisture content. In order to deal with the relatively low bulk density, forestry biomass, be it logging residues, urban wood waste, fuel wood or forest health harvests, must be comminuted, or condensed by chipping, grinding, or baling/bundling (Figure 1). Chipping is the most efficient of these processes, but knife blades used are very sensitive to dirt and foreign objects, so chipping logging slash so the preferred technology for this material is grinders. Both chipped and ground wood material can be stored for several weeks, but are subject to decay and degradation over time. This is where baling and bundling technologies can provide a solution as bundles stored even as long as nine months can retail 90 percent of their energy value.


**Figure 1.** Whole-tree Chippiing (top), Grinding Logging Slash After a Clearcut (middle), and Bundling Slash (bottom).

## Production rates and costs of forestry biomass

Observed recovery rates from conventional logging operations indicate that 15-25 percent additional logging slash can be recovered from pine stands and 20-40 percent from hardwood stands. That is to say, if a conventional operation in pine removes 60 tons per acre of stem wood volume, then 9-15 tons of additional logging slash will be recovered. Table 1 below provides some general estimates of production rates and costs per green ton of processing forestry biomass. The costs do not include hauling from production locations to a mill or biorefinery, these costs run $0.13 to $0.20 per loaded ton/mile. In general, biomass production rates will be highest, and costs lowest, when working in pine stands; hardwood biomass will cost more per ton to produce.

**Table 1. Production Rates and Costs Per Green Ton of Processing Forestry Biomass**

| Technology | Production Rates | Cost per green ton (wood side) |
|---|---|---|
| Chipping | 300-400 tons/day | $8-$12 |
| Grinding | 250-325 tons/day | $10-$15 |
| Bundling/Baling | 100-200 tons/day | $12-$20 |

It should be noted that most logging operations are not equipped to harvest in-forest residues or very small diameter woody biomass. Typical capital investment required for a forestry biomass operation is $800,000 to $1,200,000.

## Economic benefits and ecological concerns for forest landowners

Forest biomass most likely occupies a market position and price below that of pulpwood, at least for the near future (5-10 years). As such, landowners should expect nominal payments of $1 to $5 per green ton for forestry biomass. At present, delivered pulpwood is bringing $25-$30 per green ton, if forestry biomass costs exceed or come close to this amount, logging operations will likely increase production of pulpwood material and deliver this material to biorefineries, rather than harvest in-forest residues and urban wood waste.

If we assume an average payment of $2 per green ton for forestry biomass to landowners, and recovery of an additional 20 percent of biomass from conventional operations, this would provide an additional $50 to $100 per acre over a rotation or crop of trees. In addition, reforestation costs would likely be reduced because the biomass harvesting would leave sites in a more suitable condition for planting.

Current forestry biomass recovery assumes that approximately 30-40 percent of in-forest residues from any harvest will be left on site. Whole-tree removal will affect site productivity and would require supplemental nutrient additions to maintain productivity. Use of biorefinery residual materials such as char and ash as fertilizers might be one method of reducing productivity impacts from collecting forestry biomass. Other ecological considerations pertaining to small mammals and bird populations, as well as soil and water quality, are not well understood under forestry production systems that include biomass harvesting.

## Useful web-site links for further information

Forest biomass supply

http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

http://essmextension.tamu.edu/publications/files/forestry/ForestBioenergy/2-2.pdf

http://www.eia.doe.gov/emeu/mecs/iab98/forest/energy_use.html

# Coproducts and Byproducts of Woody Biorefinery Processing

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U.S. forests produce nearly 370 million dry tons annually from harvest residues, fuel treatments, small diameter trees, urban wood waste, and mill residues. Millions of tons of woody biomass are also produced from insect, disease, and extreme weather conditions each year. All of these forest resources (except for mill residues) are not currently utilized, do not significantly compete with other uses, and are available on a sustainable, environmentally sound basis. Currently, these resources are currently burned, left in the field to decay, or sent to landfills. Using this woody biomass from the source listed above will actually alleviate environmental and economic pressures. Utilization of woody biomass for bioenergy, for example, can help mitigate greenhouse gases; contribute to healthier forests; significantly reduce or eliminate loss from catastrophic wildfires, insects and disease and the concomitant degradation to watersheds; reduce GHG emissions; help control invasive species; and bolster rural economies.

Woody biomass is converted into useful forms of energy (solid, liquid, or gaseous fuels) as well as useful products (polymers, bioplastics, char, pellets, and acids) at a biorefinery. A biorefinery is a facility that uses biomass conversion technologies to convert biomass into fuels, power, and value-added chemicals. Each biorefinery process yields different amounts and types of coproducts and by-products. Coproducts describe the useful and marketable by-products, other than energy, that are produced simultaneously during biomass conversion. Many of today's coproducts may have traditionally been defined as waste or by-products. Biorefinery process technologies include thermochemical (gasification, pyrolysis), biochemical (fermentation), or chemical (chemical synthesis) pathways (Figure 1). Each route is currently being developed by many different entities. The main challenge is to determine or discover processing technologies that can collect and convert currently under-utilized woody biomass into products with higher value.

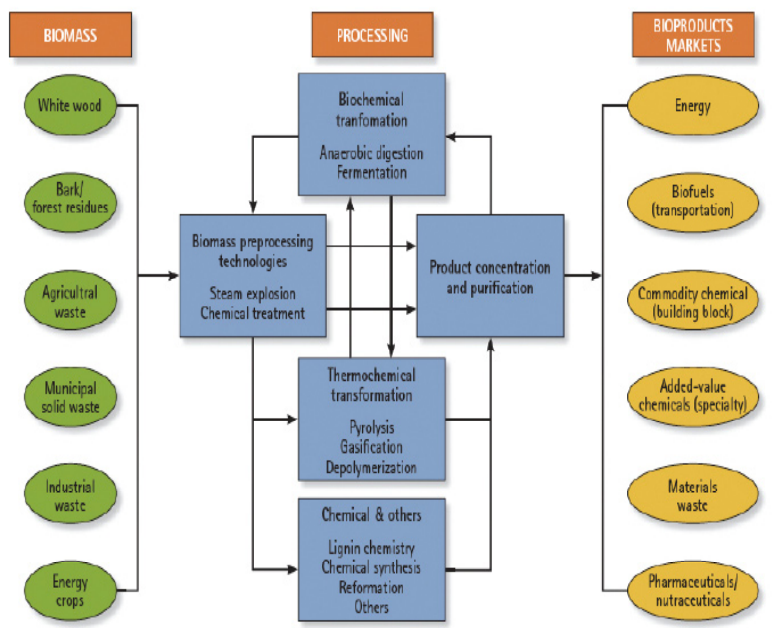

**Figure 1.** This Illustration Exemplifies the Number of and Complexities of Biomass Process Technologies.

***Gasification.*** Thermochemical processes, such as gasification, depend on the relationship between heat and chemical action as a means of extracting and creating products and energy. Gasification is a special combustion process, occurring between 700-900°C. Main product of gasification is a synthetic gas, or syngas. Syngas is primarily composed of $CO$, $CO_2$, $H_2$, and $H_2O$. In addition, the gasification process produces by-products of ash, char, tars, methane, and other hydrocarbons. Products of gasification cannot be stored easily. Consequently, the system is often integrated with other conversion processes. Studies have shown that gasification systems are as much as 20 percent more efficient than direct combustion systems, potentially making them more economical for power production. One particularly attractive gasification route is to reform the syngas into methanol, a high value commodity chemical with the relatively high energy density or 17.9 GJ/m (Figure 2). Methanol can easily be reformed to produce hydrogen for use in a fuel cell. Syngas must first be cleansed of the by-products before it can be processed further. This step is one of the most challenging aspects of gasification technology. Tar, for example, fouls equipment and reduce catalysts efficiencies and economic removal of tars remains problematic. Research is ongoing in this area and breakthroughs are hopeful. The composition of the wood influences gasification process. Consequently, some types of woody biomass may prove more costly to gasify than others. For example, wood residues high in sodium or potassium will require pre-cleaning prior to utilization. The mobilization and use of gasification in the field, near the point of feedstock collection, is technically challenging because it require significant infrastructure.

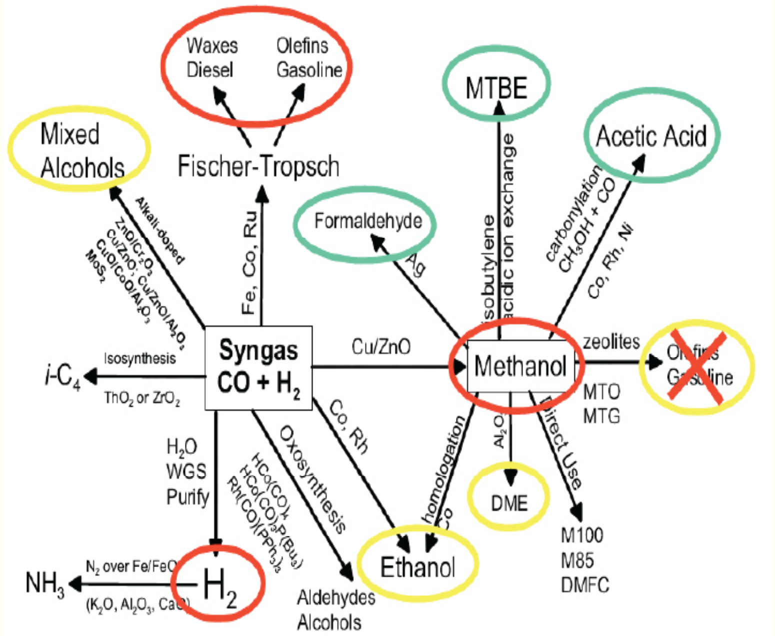

**Figure 2**. Illustration of the Main Products (red), Coproducts (yellow) and Byproducts (red) of Syngas.

***Pyrolysis.*** Pyrolysis is the process of rapid thermal decomposition (500°C) of biomass in the absence of oxygen. It produces energy, liquids, gases, and char. The primary products are pyrolytic bio-oils, a combustible mixture of oxygenated hydrocarbons, and char. Bio-oil may be burned in a furnace or combusted in industrial turbines for power generation. Bio-oil may be further upgraded in a biorefinery to produce highly valuable chemicals. Bio-oil has a low pH (2.5), a moderate heating value (18 MJ/kg), and a high water content (15-30 percent). For reference, heavy fuel oil, the nearest petroleum fuel, has very low water content (0.1 percent) and substantially higher heating value (40 MJ/kg). Due to its high water content it cannot be easily blended with other petroleum fuels. Feedstock moisture must not exceed 10-15 percent by weight. Additional grinding and filtration is also necessary to reduce feedstock to an amenable size. Unlike gasification, reactors best suited for pyrolysis use are currently under development. However, again unlike gasification, mobilization for small-scale use at the collection site appears to be rather feasible. At 10 percent moisture content, pyrolysis will yield about 150 gallons of bio-oil per ton. The non-condensable, combustible gas (CO, H, $CH_4$) is recycled into the reactor for process heating.

While it may not be economic to produce methanol and bio-oil at the collection site, an intermediate processing point, that allows for an optimization between increased transportation costs and decreased equipment costs due to scale effects, may be economically attractive. Today's bio-based products include both commodity and specialty chemicals. Some of these products result from the direct physical or chemical processing of biomass—cellulose, starch, oils, protein, lignin, and terpenes. Others are indirectly processed from carbohydrates by biotechnologies such as microbial and enzymatic processing. The gross annual sales are in the billions of dollars and continue to grow each year. For more information, please refer to the Encyclopedia of Southern Bioenergy at http://www.forestencyclopedia.com/Encyclopedia/bioenergy.

# Biomass Chemical Products

## Taken from Fact Sheet 5.9 of Sustainable Forestry for Bioenergy and Biobased Products

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***Introduction*** -- Numerous opportunities are emerging to expand industrial needs through the production and processing of biological materials. Biological feedstocks can be used as a substitute for petroleum-based feedstocks to make a variety of bulk, intermediate, and specialty chemicals. Biomass-related chemical products typically fall into three general categories: biobased acids, biobased oils, and specialty chemicals. This fact sheet highlights some of the more important biobased chemicals derived from biological feedstocks.

***Biobased Acids*** -- Acids are a vital component of industrial production. They play an important role in everything from the production of food preservatives and plastics to medical advances. Increasing the feedstock supply for the production of acids is vital if the United States is to stay economically competitive in the global market. As technology advances and the understanding of acid production become clearer, the use of woody biomass to produce specific acids will become a more economically attractive solution than the current petroleum-based and energy intense methods.

Several important biobased acids recovered from forest residues include acetic acid, fatty acid, and lactic acid.

Acetic or ethanoic acid is acid produced from the fermentation of lignocellulosic material. Uses include foodstuffs, solvents, and fungicides. It is a key component in the production of pharmaceuticals like aspirin. Esters derived from the acid are used to produce vinyl acetate used in paints, glues, and wallboard and cellulose acetate used mainly for rayon and photographic films. Vinegar is 4 to 8 percent acetic acid by volume. PETET or polyethylene terephthalate, a thermoforming polymer commonly used for food and beverage containers, is also produced using acetic acid.

Fatty acids, readily available from plant oils, are used to make soaps, lubricants, and chemical intermediates such as esters, ethoxylates, and amides. These three classes of intermediates are used to manufacture surfactants, cosmetics, alkyd resins, nylon-6, plasticizers, lubricants and greases, paper, and pharmaceuticals.

Lactic acid is produced by the fermentation of starch-derived glucose. In the United States, nearly 72 million pounds are used yearly, mainly in food and beverage service. Chemical companies have invested substantially in identifying potential derivatives of lactic acid that can serve as biobased alternatives to chemicals currently produced from petroleum. Currently the largest source of lactic acid results from the fermentation of corn.

***Biobased Oils*** -- Raw liquefaction oil is a free-flowing dark liquid produced by thermochemical liquefaction. A light liquefaction oil, known as TDTDP-40, is used as refined biodiesel. Some types of liquefaction oil are used as solvents. An example is Cyclohexane, a paint remover also used in making nylon. Another example is Methylethyl benzene, used in the production of rubber and waxes. Liquefaction oil is also blended with gasoline. Toluene, also derived from liquefaction oils, is used in the manufacturing of explosives and added to jet fuel to improve octane.

Pyrolytic bio-oil is a complex, combustible mixture. Pyrolytic bio-oil has been used commercially for industrial heat since the early 1930s. It is currently being tested as a fuel for diesel transportation and stationary turbine and diesel power. Pyrolytic bio-oil fuel is a free-flowing, dark brown liquid that can be stored and transported easily. The wood industry relies on petroleum based phenol-formaldehyde resins to produce plywood, oriented strand board, and other wood composites. In addition, extracted additives from bio-oil during the fast pyrolysis process can be used to infuse "smoked", "roasted", or "grilled" flavors in food.

***Specialty Chemicals*** -- Specialty chemicals, which are chemicals produced in small volumes for specific end uses, often mixtures or formulations of different chemicals, play an important role in the economy of the United States. Currently, organic chemicals are primarily synthesized from a petroleum base and used in the production of paints, solvents, fibers, and plastics. Specialty chemical markets represent a wide range of high-value products. These chemicals generally sell for more than $2.00 a pound and their market is steadily growing.

Several important specialty chemicals that are produced from woody biomass are enzymes, 3-HP, biobased fuel gas, syngas, butanol, and glycerin.

The primary source of current and future enzymes is the fermentation of biological materials. Enzymes function as catalysts in industrial systems to produce feed additives and chemicals. In addition, they function as detergents, reagents, diagnostics, and health aids. Expectations are that enzyme sales will increase 10 percent annually as new markets and needs emerge. Enzyme-derived products have replaced water-polluting phosphate detergents and allowed wash waters to be cooler. They are used to coagulate milk proteins for cheese production, as sweeteners for sodas, and in lactose-free milk. Xylanase enzymes are beginning to replace chlorine in the pulp and paper industry and cellulase in the textile industry.

3-HP is perhaps the most well known intermediate chemical produced by lignocellulosic fermentation behind lactic acid. Research has shown that the intermediate chemical can be produced at a theoretical yield of 100 percent from glucose. With the addition of chemical processing, 3-HP is transformed into a variety of marketable chemicals such as PDODO, acrylic acid, acrylonitrile, and acrylamide. When transformed into acrylic acid, the polymer is used in coating, adhesive, super absorbent, and detergent. In addition, it is used to make acrylic fibers for carpets and clothing, pipes, furniture, automobiles, nitrile rubber and the resin in latex.

Butanol is an organic chemical that can be broken down into several large-volume derivatives. Butanol could be used as a biobased oxygenated fuel for blending with gasoline, although it is not in use currently. Butanol has several advantages over methanol and ethanol, such as having energy content closer to that of gasoline with few to no mechanical and chemical compatibility issues. In 1999, about 925,000 tons of butanol were used domestically. Projections are that the usage will increase 3 percent per year, expanding demand significantly when blended with gasoline.

Glycerin is a sweet, viscous alcohol that is produced as a byproduct of the manufacturing of biodiesel. The ratio of glycerin to biodiesel produced is one to 10. Selling for $600 to $900 per ton, glycerin is used in soaps, solvents, and industrial lubricants that perform on par with or better than petroleum-derived relatives.

In 2006, an estimated 220,000 tons of glycerin were used in the United States. Small home-based soap companies use glycerin in their products. The glycerin market in the United States is currently for more "boutique" products, but glycerin is also used as a humectant, a food additive that keeps foodstuff moist in packaging.

***Summary and Conclusions --*** Today's biobased products include both commodity and specialty chemicals. Some of these products result from the direct physical or chemical processing of biomass—cellulose, starch, oils, protein, lignin, and terpenes. Others are indirectly processed from carbohydrates by technologies such as microbial and enzymatic processing. The gross annual sales are in the billions of dollars and continue to grow each year.

Visit http://www.forestbioenergy.net to download this and other publications related to woody biomass.

# The Uniform Format Solution

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While national assessments identify sufficient biomass resource to supply the 1 billion tons required to meet national fuel production goals, much of that resource is inaccessible using current biomass supply systems because of unfavorable economics. Increasing the demand for lignocellulosic biomass introduces many logistical challenges to providing an economic, efficient, and reliable supply of quality feedstock to the biorefineries.

One strategy to address these logistic challenges is the gradual transition from existing biomass supply systems to an economic and reliable commodity-scale supply system that provides uniform, aerobically stable, quality-controlled feedstocks to biorefineries. This strategy is outlined in a report recently released from the Idaho National Laboratory (INL), a U.S. Department of Energy lab (available at www.inl.gov/bioenergy/uniform-feedstock), and takes advantage of the highly efficient, scalable, and economic bulk solids handling infrastructure that is used today for grain.

The INL report details two feedstock supply system designs: the Conventional Bale Feedstock Supply System Design ("Conventional Bale") that reflects current practice, and the Uniform-Format Supply System Design ("Uniform-Format") that moves the preprocessing unit operation as early in the supply system as practically possible, minimizing logistical issues with transporting and handling dispersed, low-density, often aerobically unstable biomass. The Uniform-Format system is presented in two implementations: (1) a Pioneer Uniform system that uses current or very near-term technologies and offers incremental improvements over the Conventional Bale system and (2) an Advanced Uniform system that meets all cost and supply targets and requires some conceptual equipment, such as advanced processing systems, to provide a commodity-scale bulk solid feedstock. The Advanced system is demonstrated using a pellet format, however there are many possible bulk solid formats that could be applied (for example, granules, powder, briquettes, etc.).

The Pioneer Uniform design enables the transition from the Conventional Bale to the Advanced Uniform supply system by developing the supply chain infrastructure required for forward-deployed preprocessing. The Advanced Uniform system formats biomass of various types (i.e., corn stover, switchgrass, etc.) and physical characteristics (i.e., bulk densities, moisture content, etc.) into a standardized format early in the supply chain. This uniform material format allows biomass to be handled as a commodity that can be bought and sold in a market, vastly increasing its availability to the biorefinery and enabling large-scale facilities to operate with a continuous, consistent, and economic feedstock supply. The commodity-scale system also removes the obligation for local farmers to contract directly with the biorefineries for biomass feedstocks.

Biomass commodities are storable, transportable, and have many end uses. Implementing a commodity-based feedstock supply system promotes cropping options beyond local markets, which in turn promotes crop diversity and enhances crop rotation practices. Figure 1 shows a schematic of the end-state commodity supply system.

The supply system represented in Figure 1 incorporates many species and types of biomass that can be formatted at specialized biomass depots. The preprocessed biomass is transported from the depots to a central blending terminal, where it may be blended to end-use specifications to form a consistent, uniformly formatted and aerobically stable product. The aggregate biomass is then managed as a commodity to be distributed to the biorefinery.

Only the Uniform-Format design can overcome the physical and equipment barriers inherent in working with biomass. This is accomplished by increasing the material dry matter bulk density through size reduction, reducing moisture content through drying, improving equipment performance to minimize dry matter losses, and taking advantage of biomass material properties to facilitate material deconstruction. The Uniform-Format system produces a commodity product, reduces plant handling costs, and is conducive to long-term biomass supply sustainability required to meet the annual biofuel production goals of 60 billion gallons by 2030. This commodity system promotes cropping options beyond local markets by providing access to diverse markets, and increasing cropping options to promote enhanced sustainable crop rotation practices.

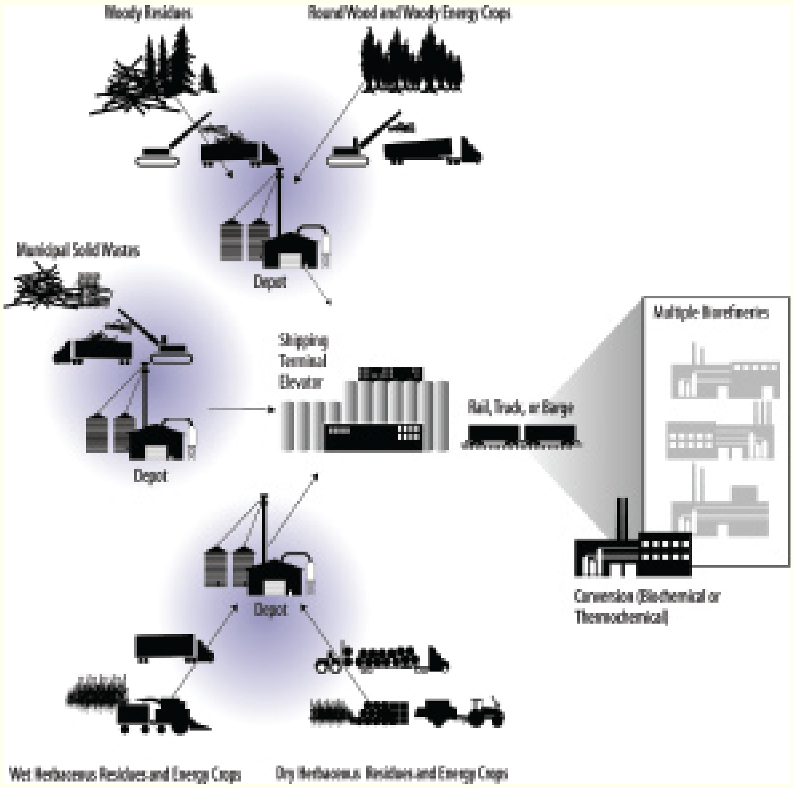

**Figure 1.** The Advanced Uniform-Format Feedstock Supply System (Advanced Uniform) Design Emulates the Current Grain Commodity Supply System, which Manages Crop Diversity at the Point of Harvest and at the Biomass Depot/Elevator, Allowing Subsequent Supply System Infrastructure to be Similar for all Biomass Resources.

Ethanol import restrictions are the same as those encountered when developing a commodity-based biomass supply system:

- Standardized product
- Efficient transport
- Sustainability of production
- Integration with existing distribution infrastructure
- Environmentally conscious production from all sources
- Net every balance when importing is considered.

Source: http://www.bioenergytrade.org/downloads/finalreportethanolmarkets.pdf

A challenge of using biomass as an energy resource is securing long term availability of the biomass, and the ability to sustainability supply a consistent biomass quantity and quality. There are four components of establishing this consistent supply:

1) facilitating diversity in regional cropping options;
2) enabling access to remote resources;
3) allowing efficient transport of biomass beyond 200 miles; and
4) addressing supply risks associated with weather, competition, pests, and other local issues.

# Biomass Logistics in the Southeast

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***Year-Round Operation*** -- A bioenergy plant must operate year-round. It is different than a sugar mill, cotton gin, or other seasonal plant. A bioenergy plant must have a continuous supply of size-reduced material for a 24-7 operation, 47 weeks/year.

***Storage*** -- Woody biomass is "stored on the stump" meaning that it is left in the forest and harvested when needed. In the Southeast, wood is harvested year-round.

Herbaceous biomass must be stored. Studies in Virginia have shown that switchgrass can be harvested 8 months. Certain fields can be harvested in August and other fields can be harvested through the fall and winter. The switchgrass is left to dry in the field and harvested when needed, a concept known as "delayed harvest". In the Upper Southeast, harvests must be completed before the end of March. Because of an earlier start of regrowth, harvests must be completed before the end of February in the Lower Southeast.

An energy crop, like switchgrass, has a significant advantage over a crop residue like corn stover. In the Upper Midwest, the corn stover must be collected after the grain is harvested and before the fields are covered with snow. In a typical year, the period for the collection of all the stover for year-round operation is about 5 weeks, which compares to about 30 weeks for switchgrass in the Southeast using the delayed harvest strategy.

***Round Bale*** -- The round bale, because the rounded top sheds water, will protect itself in ambient storage. Round bales can be formed, left in the field, and hauled later. Uncoupling the harvest and in-field hauling operations offers a significant advantage.

Bales placed in single-layer ambient storage in satellite storage locations (SSLs) can be stored up to six months with less than 5 percent storage, handling loss. Cost for this storage is about $2/ton as compared to about $8/ton for big square bales stacked 4-high in a hay shed.

The big square bale has a significant advantage in highway hauling which offsets some of the higher storage cost. If a system can be put in place to solve the highway hauling problem of the round bale, it can be the best choice for the Southeast. Summarizing...

1. The round bale protects itself in single-layer ambient storage thus avoiding the cost of tarping a stack or building a hay shed to provide the storage (up to 6 months) required to supply a bioenergy plant year-round.
2. The self- protection feature of the round bale means that it protects itself in the field, even if it rains the day of baling. It is a significant advantage to be able to uncouple the baling and in-field hauling. Hauling can be done the next day, week, or month.
3. The round baler is a less expensive machine than the big square baler, requires a lower-power tractor, and it is therefore a more economic harvest unit for small, irregular-shaped fields.

***Multi-Bale Handling Unit*** -- The container shipping industry achieves high labor productivity (ton/h) with their rapid load, rapid unload capability. Load time and unload time are the two key variables in the loads-per-day an individual truck can haul. Travel speed on the roads is, of course, constrained by the traffic laws.

There is a system proposed where 16 5-ft diameter round bales are loaded into a rack with dimensions that emulate the 20-ft ISO container. Plans are to have loaded racks ready when the truck arrives. The driver sets off two empties and loads two fulls. The goal is to load and leave in 10 minutes. The sequence is reversed at the bioenergy plant. Two loaded racks are removed and replaced with two empties for return to the SSL.

***Receiving Facility*** -- The term "receiving facility" is used to describe the organization of resources at the bioenergy plant to receive raw biomass and place it in at-plant storage, or deliver it directly into the plant. Flow of material into, and out of, at-plant storage is a key issue in Receiving Facility operations, because no one expects just-in-time delivery to be a practical option. Handling the raw materials can be expensive. No one envisions individual bale handling, thus the 16-bale rack provides a benefit in Receiving Facility operations.

***Labor Productivity*** -- It is interesting to compare the labor productivity of several unit operations in the logistic chain.

1. Baling - we assume that the baler operator averages a bale every two minutes and the bales weight 900 pounds *(0.5 bale/minute x 60 minutes/hour x 900 pounds/bale) ÷ 2000 pounds/ton = 13.5 ton/hour*
2. In field-hauling - suppose the bales are hauled with a self-propelled bale wagon that self-loads 10 bales in the field and unloads these bales by tilting the bed and allowing the bales to roll off in position (single-layer ambient storage). The load time averages 30 seconds/bale, travel speed in the field is 4 mph, and travel speed over the road to the SSL is 30 mph. Unload time is 2 minutes. If the operator of the bale wagon is to haul 13.5 tons/hour and load is *(10 bales x 900 pounds/bale) ÷ 2000 pounds/ton = 4.5 tons/load*. Then the operator must haul *13.5 tons/hours ÷ 4.5 tons/load = 3 loads/hour or 20 minutes/load*. This means the SSL must be located no more than 2 miles from the field.
3. Rack loading - *(16 bales/rack x 900 pounds/bale) ÷ 2000 pounds/ton = 7.2 tons/rack*. Two workers are required for the work crew loading racks at the SSL. Their productivity must be *2 workers x 13.5 tons/hour = 27 tons/hour; 27 tons/hour ÷ 7.2 tons/rack = 3.75 racks/hour; 3.75 racks/hour x 10 hours/work day = 37.5 racks/day; 37.5 racks/day x 16 bales/rack = 600 bales/day*. Is it reasonable to expect a 2-person crew to load 600 bales in a 10-hour workday? A consortium of three companies and three universities has formed to develop the equipment and management plan for the rack system. The goal set by the Consortium is 30 racks per day, which equals 480 bales in a 10-hour workday for a crew of 2 workers. Labor productivity equals *(30 racks/day x 7.2 tons/rack) ÷ 2 workers x 10 hours/day = 10.8 tons/hour/worker*, or 20 percent less than the bale operator.
4. Hauling - the truck hauls two racks per load. How many loads does a driver have to make in an 8-hour shift to have the same labor productivity as the bale operator? *(7.2 tons/rack x 2 racks/load = 14.4 tons/load)* Required hauling rate is *13.5 tons/hour x 8 hours/shift = 108 tons/shift; 108 tons/shift ÷ 14.4 tons/load = 7.5 loads/shift*. Time allowed for each load is *8 hours/shift ÷ 7.5 loads/shift = 1.067 hours/load or about 64 minutes/load*. Suppose it takes 10 minutes to load, 10 minutes to unload, and 45 mph average travel speed. How far can the trucker haul? *64 minutes - 10 minutes (load) - 10 minutes (unload) = 44 minutes total travel time; 44 minutes/2 = 22 minutes = 0.367 hours travel time one way; 45 miles/hour x 0.367 hours = 16.5 miles*. Under ideal conditions, the trucker can only haul 16.5 miles and average the same labor productivity as the bale operator. In summary, the bale operator averages a bale every 2 minutes = 13.5 tons/hour, the bale wagon operator hauls 2 miles to the SSL and averages 13.5 tons/hour, two rack loaders load 480 bales in a 10-hour workday and average 10.8 tons/hour/worker, the truck driver hauls 16.5 miles and averages 13.5 tons/hour.

# eXtension

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**Commitment to Success --** eXtension, in its commitment to meet the needs of online customers, will ensure the greatest possible success of the entire Cooperative Extension System. We do this by:

- *Building the Cooperative Extension Service Network:* eXtension represents the organization's subject matter interests and expertise joined together in Communities of Practice and charged with supporting the information and educational needs of customers in new ways.
- *Producing Effective Content:* eXtension supports an appealing and easy-to-use workspace that attracts Communities of Practice, encourages collaboration, and yields interactive, high-quality information, useful in answering questions, solving life issues and stimulating interaction.
- *Increasing Visibility:* eXtension by providing relevant and timely access to high quality contents and services, enhances the visibility of Cooperative Extension. We work with member institutions to increase content discoverability, while reducing duplicative and/or borrowed content. We will create as many link and references as possible so that CES is ranked higher in common search engine listings.
- *Increasing Local Use and Value:* Cooperative Extension employees derive value from eXtension in many ways. People can share programmatic loads and expertise with colleagues, add breadth and depth to content offerings and know that programs will be maintained over time. Local officers are able to direct local customers to a complementary information source for questions and answers, as well as use, repackage, and brand content to support local programming. This saves local offices time and resources to be reinvested in other transformative educational efforts. eXtension also supports customers interested in linking to local offices and related resources and refers customers to local offices for more in-depth and/or precise local information.

- *Reach More Customers:* eXtension reaches more customers because of greater choice, greater convenience, and availability.

**eXtension Tools**

- **Public Site** (trusted, reliable source of information) http://www.extension.org
- **People** *(eXtensionID required) (Manage your eXtension profile and find colleagues)* http://people.extension.org
- **eXtension Training** *(select 'Professional Development', attend/review trainings)* http://about extension.org/wiki/
- **About eXtension Blog** *(learn more about eXtension)* http://about.extension.org
- **About eXtension Wiki** *(Organizational information, resources and updates)* http://about.extension.org/wiki
- **Communities of Practice Wiki** *(eXtensionID required) (Member create content for public site)* http://cop.extension.org
- **Events Application** *(eXtensionID required) (Application to post events on the public site)* http://events.extension.org
- **Frequently Asked Questions Applications** *(eXtensionID required) (Tools to find, submit, and produce answers and questions database that is published on the public site)* http://faq.extension.org
- **Cooperative Extension Collaboration Wiki** *(A wiki for professionals from the land-grant universities to topics of interest)* http://collaborate.extension.org
- **Moodle Learning Management System** http://campus.extension.org - public; http://pdc.extension.org - professional development collaborate on tool to compare/offer learning lessons

# Sustainable Agricultural Energy Systems -- Farm Energy Community of Practice (CoP)

**Susan Hawkins, University of Vermont**
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**Farm Energy** is a national, extension-driven web resource designed to provide timely and practical energy information for agricultural producers and service providers that enhances profitability, conserves natural resources, and promotes vibrant local communities. Topics will provide information about on-farm energy production and use, to include: energy conservation, sustainability dimensions, biofuels, solar and wind.

**Our Goals**

- To provide relevant resources that are research based and peer reviewed.
- To develop educational materials and learning opportunities focused on the energy needs of farmers.
- To create collaboration among energy specialists.
- To link users to local and national experts and resources.
- To "launch" Farm Energy resources on www.extension.org in January 2010.

**Works in Progress**

We have a collaborative (wiki) web site, http://cop.extension.org/wiki/Sustainable_Ag_Energy_Content, where we are collecting and creating resources. This "virtual community" includes members from across the United States. Resources are both national and regional in scope.

*Active Content Work Teams:*

- Sustainability Dimensions
- Energy Conservation and Efficiency
- Biofuel Feedstocks -- Energy Crops
- Biodiesel
- Biogas/Anaerobic Digestion
- Combustion

*Next Priorities:*

- Wind
- Solar
- Ethanol
- Curriculum material for "Master Energy Educator Training programs
- Your Topic?

*Team Members Collaborate to:*

- Identify existing materials and link them to our eXtension web site.
- Develop new content (written and multi-media information) for our eXtension web site.
- Review content material prior to 'live' publication.
- Prepare FAQs and be available as specialists for "Ask the Expert".

**What is eXtension?** It is an interactive, web-based learning environment, delivering researched knowledge from land-grant universities and cooperating organizations to the public. To find out more, visit http://www.extension.org/main/about.

## Access Information & Links to Get Involved with eXtension Farm Energy Community

We hope you will join in this new venture at whatever level you are able!

- Public Site www.extension.org
- "Live Links" of this page - http://cop.extension.org/wiki/Farm_Energy_CoP_Wiki_Bookmarks

All the rest of the information relates to the collaborative working wiki site! It is a work in progress which includes finished material, rough drafts and blank pages. Please enter with an open mind and, perhaps, a willingness to collaborate with a Content Team.

- This is what our site would look like if it was launched today: http://preview.extension.org/ag%20energy
- Obtain an eXtension ID at http://people.eXtension.org/account/signup. If your e-mail address is not a ".edu", contact us with a brief bio, so that we may offer you an invitation. This is required to be able to access the wiki site, and will not generate any junk mail.
- Contact us for 'training session' conference calls that will explain our CoP and how to 'work in the wiki'.
- Main eXtension wiki Page for all Communities - http://cop.extension.org/wiki/Main_Page
- Farm Energy Content - http://cop.extension.org/wiki/Sustainable_Ag_Energy_Content. From here, access the Basic Information pages where you can:
  1. Join the Content Work Teams to create resources.
  2. Add to the outline of pages to be developed.
  3. Create links to existing Resources and Publications.
  4. Contact us if you have interest in helping to organize or lead a Content Work Team.
- Sustainable Ag Energy People Page - https://people.extension.org/communities/25. Join the CoP, see Members, see Leaders
- Content Chart for conceptual thinkers: http://cop.extension.org/wiki/Ag_Energy_Content_Chart
- Community home page – Where organizational information about the CoP is stored http://cop.extension.org/wiki/Sustainable_Ag_Energy_Community_of_Practice
- Additional Linked Resources - http://cop.extension.org/wiki/Sustainable_Ag_Energy_Resource_and_Publication_Inventories
- Case Studies - http://cop.extension.org/wiki/Farm_Energy_Case_Studies
- Research Summaries - http://cop.extension.org/wiki/Ag_Energy_Research_Summaries
- Decision Tools - http://cop.extension.org/wiki/Farm_Energy_Decision_Tools
- Legal Issues - http://cop.extension.org/wiki/Legal_Issues_about_Agricultural_Energy
- eXtension Categories. Ours are all prefaced by 'ag energy' - http://cop.extension.org/mediawiki/index.php?title=Special:Categories&limit=500
- Invite a colleague to eXtension- https://people.extension.org/invitations/new
- Sand box for Farm Energy – trial and error area to learn wiki skills - http://cop.extension.org/wiki/Sustainable_Ag_Energy_Sandbox

# The Case of the High Plains Consortium Wind Energy Handout

**Dr. Cole R. Gustafson, North Dakota State University**
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1. **What is the policy issue? What factors led you to frame the issue this way?**

   In most regions and applications, wind energy and transmission are not economically viable without federal and state tax credits. Many areas have high wind potential but transmission infrastructure is lacking and too expensive for a single firm or entity to construct. What is the appropriate public versus private sharing of risk when developing this new renewable energy resource?

   A second policy issue is that wind investors have diverse goals and lack needed investment information. Some seek profit while others simply want to aid struggling rural economies. A third group is often enamored with creation of a new renewable energy resource. Regardless, wind investors face several hurdles in addition to turbulent national financial markets. Power companies typically sell consumers electricity at one rate but only buy power back at a lower rate. Confidentially clauses prevent potential investors from learning prevailing terms being offered in a region. The long investment period complicates financial analysis for people in differing financial positions.

   I frame the issues this way because these are the most common questions I receive.

2. **What value can Extension provide to policy discussions on this issue?**

   The High Plains Extension Consortium has developed a wiki space (http://sustainablegreatplains.wikispaces.com/Energy) three webcasts targeted to both Extension educators and lay audiences, and a discussion forum (www.plainswind.org) in an effort to provide educational resources so potential investors are more informed of economic opportunities, environmental effects, investment risks, and externalities.

3. **What are the policy alternatives?** *There are usually several including the status quo.*

   Policy alternatives revolve around degree of public support for wind education, infrastructure development, reduction of ongoing operating costs, and environmental constraints placed on growth.

4. **What are the myths/urban legends surrounding the issue that need to be put into context?**

   a) *Wind Energy is Free* -- Naive wind investors often fail to consider total economic costs of a potential wind investment. Costs that are typically overlooked are full investment costs and on-going repair costs.

   b) *My Utility Will Buy Power Back At The Same Rate I Pay* -- In most cases, utilities only pay a fraction of what consumers pay for power.

   c) *Wind Provides Constant Power* -- Electricity is only generated when the wind blows. Moreover, turbines are designed to operate in a range of relatively narrow wind speeds. Unless the tower is located in an ideal wind area, the turbine will only provide power about 25 percent of the time. A second complication is that farm and home energy demand varies considerably within a day -- rarely highest midday when wind is strongest. Other energy sources must be utilized for storage or as backup.

d) *Wind Turbines Last Forever* -- Wind turbine technology is constantly changing and wind turbines do wear out. Consequently, their economic life if finite. Investors often fail to budget for removal costs.

e) *A Wind Tower Only Affects Me* -- While a wind tower may be on your property and considerable distance from neighbors, they will most likely still be affected by sight of the tower, noise, or restrictions placed upon them. Often overlooked is aerial crop spraying. If the tower is closer than 2,000 feet to a neighbor, pilots may resist spraying a portion of their crop.

f) *If A Wind Investment Is Good For My Neighbor, It Is Good For Me* -- People have differing investment goals, time horizons, risk preferences, and discount rates. Everyone needs to perform individual financial analyses.

5. **What groups/stakeholders are promoting the various policy alternatives? *Need to use neutral language.***

   Key stakeholders are individual investors seeking profit, community developers who are striving to raise economic activity in rural areas, environmentalists who are concerned about the impact of growing wind energy industry, and people who seek to develop wind energy as a new renewable source. Each group prefers unique federal policy action.

6. **What are the consequences of each policy alternative? *Economic analysis.***

   While several groups may have general agreement on policy development, their individual self-interests result in diverging views when implementation occurs. Current federal policy initiatives (Renewable Electricity Standard, Renewable Electricity Credits, Stimulus Funding, and Carbon Cap/Trade) could result in significant industry expansion or decline.

7. **How to avoid taking sides.**

   Provide financial decision aides so investors can gauge returns and risks themselves. Urge wind investors to review resources listed in High Plain's wiki sites so they are fully informed of externalities.