Wheat Straw for Ethanol Production in Washington: A Resource, Technical, and Economic Assessment

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Executive Summary

Washington State is one of the major wheat producing states in the country. The open field burning of straw is being reduced and possibly eliminated. Concurrently, the interest in using cellulosic materials for the production of ethanol fuels increases as the conversion technologies improves, the price of crude oil increases, the national dependence on imported oil increases, and the need for an oxygenate replacement for methyl tertiary butyl ether (MTBE) grows.

The purpose of this report is to assess the availability of wheat straw, the status of the conversion technologies, and the economics of ethanol production from wheat straw.

This report quantified the availability of wheat straw at the county level using five-year averages of crop yields. Biomass supply curves were developed to show the cost of delivering a specific quantity of biomass to a hypothetical facility in Moses Lake. In general, the marginal cost increases, as the quantity needed increases. An overview of the available conversion technologies is presented as well as their developmental status. The National Renewable Energy Laboratory ran their economic model for the hypothetical plant and developed capital and operating costs for a model facility. Oregon State University analyzed the economic impact on the region surrounding Moses Lake and for the state. Recommendations are presented on actions Washington State could take to promote the development and deployment of a biomass-to-ethanol facility.

Findings

1. The quantity of straw available for removal from a field is highly sensitive to the amount that must be left to insure long-term sustainable crop production. If the limit is 3,000 pound per acre than 3 million tons of straw are available. If the limit is 5,000 pounds per acre the availability drops to 680 thousand tons. The average price for delivering straw to a 20 million gallon per year plant also increases from $32/ton to $54 per ton as the straw availability decreases.

2. Currently, there are no biomass to ethanol plants in commercial operation, although at least five are in an advanced planning stage or actively seeking financing. The industry is very young and the real or perceived risks will only be addressed when several plants are in successful operation. To date, the cost of making ethanol from biomass is substantially greater than ethanol made from corn ($1.70 versus $1.10/gallon). As the technology matures, however, producing ethanol from cellulose will become more competitive with corn based ethanol. An expanding ethanol market will also result in increasing costs of corn, further narrowing the price difference between the fuels.

3. A straw based industry in eastern Washington would have a significant positive economic impact on the region. Just one 40 million gallons per year facility would create about 104 direct long-term jobs and 335 additional indirect and induced jobs. The counties of Adams, Franklin, Grant, and Lincoln counties would see an economic value-added of $19.6 million. In addition, there are energy and environmental advantages to using wheat straw to produce ethanol. The use of ethanol fuels offer air quality benefits to the region and could help soften petroleum price increases or supply disruptions.

Recommendations

1. The Washington Department of Agriculture, Office of Trade and Economic Development and Washington State University Cooperative Extension/College of Agriculture and Home Economics should convene an advisory committee that would represent the various stakeholders. This committee would explore in more detail the questions about straw availability and work towards guidelines that would be useful to the resource agencies, the landowners, and developers.

2. Washington State and the agricultural community should actively encourage the Federal government to commit more dollars to the full-scale demonstrations of technologies as they are proven in the laboratory. Only through actual experience with commercial scale operations can the engineering improvements be made that will move the industry from infancy to maturity. Because wheat straw is the most promising feedstock for Washington State, efforts should be made to establish a commercial facility within the state.

3. The Governor, as a member of the Governors Ethanol Coalition, and Washington State Congressional representatives should advocate for Federal financial incentives to help establish a cellulose-to-ethanol industry. Currently, there are bills in front of Congress that, if supported, would help to jumpstart this industry. Washington State should follow Minnesota's lead and begin developing a set of incentives and policies that support the production and use of ethanol fuel made from agricultural waste products. While it may be premature to institute an incentives program at this time, debating the pros and cons of various state incentives, including a renewable fuels standard, should begin.

Introduction

Ethanol production from cellulosic materials may offer a solution to some of the recent environmental, economic, and energy problems facing Washington State's agricultural sector. Nationally, energy costs are on the rise and forecasts of petroleum supply disruptions are once again making news. Washington State farmers are not immune to these events and feel the impact of rising energy prices every time they purchase gasoline, diesel or other petroleum products.

Changes in how agricultural field residues are managed further complicate farming economies in Washington State. In the past, disposal of wheat straw by burning was an accepted practice. This practice is now being challenged due to concern over the health effects of smoke from burning fields. These smoke emissions contain harmful air pollutants including particulate matter, carbon monoxide, and volatile organic compounds. In aggregate, agricultural burning in Washington State is responsible for as much as 40,000 tons of emissions annually.

The elimination of field burning is forcing growers to examine alternative management practices. Converting wheat straw, or other agricultural residues, to ethanol may provide an acceptable alternative to burning. The use of local feedstocks produced in Washington would enhance both the grower's and the state's economy by partially offsetting fuel imports and by using products which currently have little or no value. In addition, ethanol fuel offers air quality benefits to the region for both regulated emissions such as carbon monoxide, as well as carbon dioxide or greenhouse gas emissions. In the future, these emission offsets may provide added value to an ethanol operation.

While converting wheat straw to ethanol may offer some promising benefits, a number of questions need to be answered to determine the viability of a cellulosic ethanol industry in Washington State. First, is there a sufficient quantity of wheat straw available at a competitive cost? Second, is the technology for converting wheat straw to ethanol mature enough to compete with the current corn-based ethanol industry? Third, how robust is the ethanol market, and what added value does ethanol offer to the region? Finally, what are the existing barriers to establishing a cellulosic ethanol industry in Washington State and what type of incentives may be necessary to support this industry?

Converting waste agricultural residues to a high quality fuel may provide an economic opportunity for Washington State. This report examines the viability of establishing a wheat straw-to-ethanol facility in Washington, and proposes recommendations for moving this industry forward.

Wheat Straw Availability and Conversion Technologies

Wheat straw can be converted to ethanol fuel. Determining the volume of fuel that could be produced depends on both the quantities of available straw and the technology used to convert the straw-to-ethanol. The amount of straw available depends on how much is produced each year, how much can be recovered while maintaining soil fertility, and how much someone is willing to pay. The technologies for converting straw to ethanol have all been demonstrated in pilot plants. The particular technology or combinations of technologies that are chosen are mainly driven by economics. This section of the report presents the results on the availability of wheat straw, the technologies and their stage of development.

Wheat Straw Availability

Overview

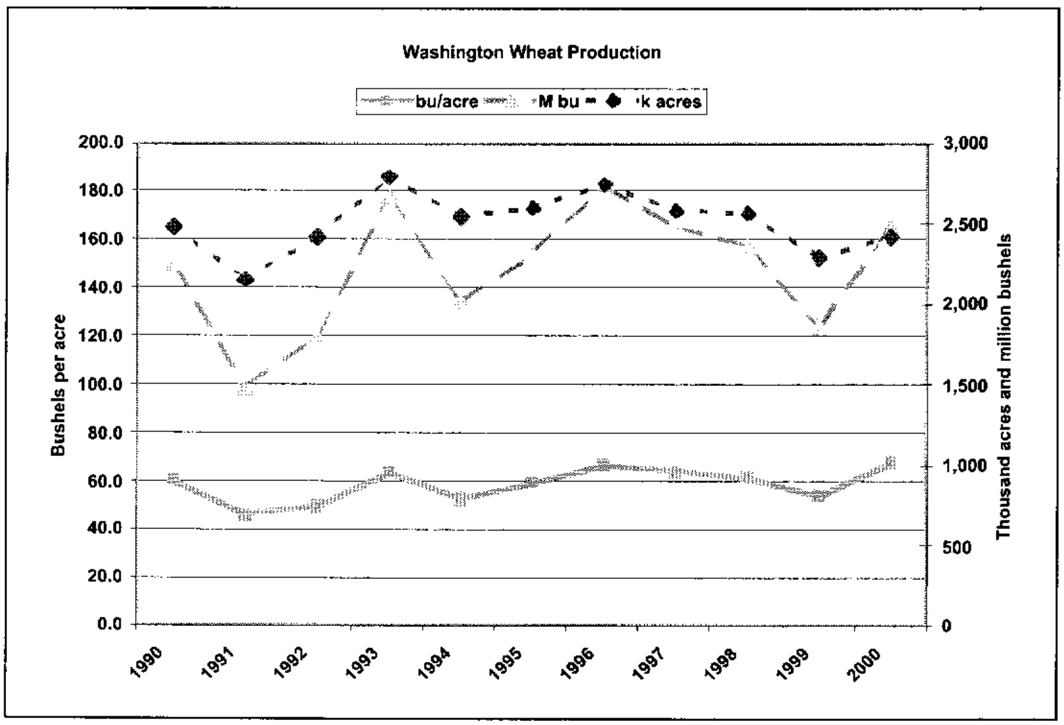
Wheat is an annual agricultural crop grown for the grain portion of the plant that is a valuable food product. The rest of the wheat plant is in the wheat straw consisting of stems and leaves, chaff that is a protective cover over the grain, and the underground root system. After the grain is harvested the fields are prepared for the next crop. The straw is burned, removed, left on the field or plowed back into the soil. The choices made by the landowner depend on a variety of factors including the quantity of material, the next crop to be planted, the weather conditions, the soil erodibility and nutrient needs, the slope of the land, and any markets that may be available for the straw.

The procedure to determine the quantity and cost of straw available for conversion to ethanol fuel is relatively straightforward. The procedure is: 1) determine the quantity of straw generated as the result of producing the wheat grain, 2) determine the quantity of straw that should be left on the field for erosion control and soil fertility, 3) determine the physical accessibility of the straw, slope of the land being the critical issue, 4) determine the cost of collecting and removing the straw, 5) determine the location and cost of storing the straw, 6) determine the cost of transporting the straw to the conversion facility, and 7) determine any other costs involved such as payment to the landowner for the straw or the nutrient value of the straw that is removed. While the procedure is well understood, the "devil is in the details". Besides getting quantitative data for many of the factors, the question of how the landowner values their land is important. Finally, crop yields and hence straw production are subject to the annual variation in weather, and the acres planted depend on world market conditions and federal farm legislation. Figure 1 shows the acres harvested, yield, and production from Washington wheat over the past decade. The yields are influenced by rainfall as illustrated by the drought years of 1991-92. The production can change drastically from year to year. Over the past five years production and acres harvested have tended to decline.

Quantity of straw generated

The National Agricultural Statistical Service of the U.S Department of Agricultural annually publishes the acres harvested and the yields by practice (irrigated and non-irrigated) and county (1). The most recent five years (1995-2000) of data was used to determine the average yields and quantity of straw generated. Some counties do not always have a wheat harvest because landowners try different crops and rotations. Therefore, we only included counties and/or practices that harvested wheat over the past three years or more. Sixteen counties in Washington have harvested some wheat over the past five years. For this study we are only including the 13 largest producers in the state, and they account for 97 percent of the total production.

Figure 1.
Historical Wheat Production



The yields of grain and straw are a strong function of the amount of moisture available for the crop. Irrigated lands have very high yields while the dry land yields closely follow the amount of rainfall.

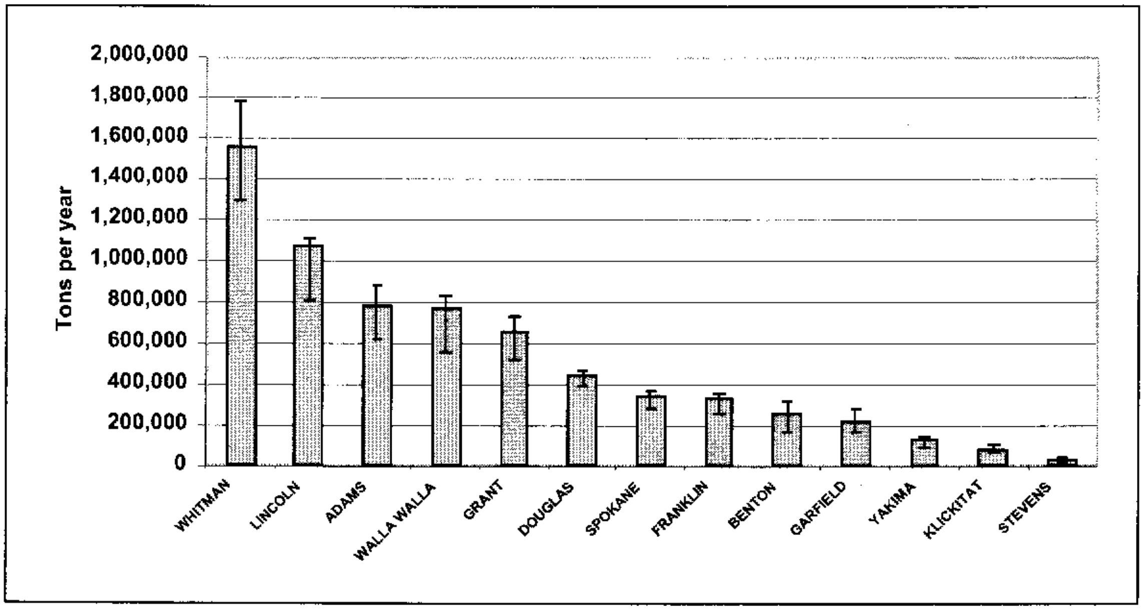
The total quantity of grain produced is the product of the yield and the number of acres harvested. Thus, counties with large acreage in wheat production and in high yield areas will produce the greatest quantity of grain and straw. The quantity of straw generated per acre depends mainly on the variety of wheat grown and the yield of the grain product. Agricultural scientists in Washington have developed a linear correlation to permit computation of the quantity of straw generated if the wheat yields are known (2). The least squares relationship is: pounds of wheat straw per acre = 69.76 x yield (bushels/acre) + 1067.7.

The quantity of wheat straw generated each year was computed using the relationships given above. The results are shown in Table 1 and Figure 2. The error bars in figure 2 represent the range of values observed over the past five years. Average volumes are typically used for resource assessments but the minimums must be considered in any decision making. The top five counties generating wheat straw during the last five years have had minimum straw volumes twenty five percent less than the average. Nevertheless, the volume is large. For example, over 100 million gallons of ethanol could be produced from just the straw generated in Whitman and Lincoln counties. However, the most important data is how much straw can be delivered to a conversion facility at a cost that permits economic operation of the facility.

Table 1
Wheat Straw Production 1996-2000

	Average, tons	Minimum, tons	Maximum, tons
STATE TOTAL	6,866,094	5,552,520	7,836,948
WHITMAN	1,562,280	1,289,261	1,787,518
LINCOLN	1,074,139	803,639	1,110,061
ADAMS	787,684	618,085	879,652
WALLA WALLA	766,083	558,145	833,560
GRANT	650,379	517,262	735,266
DOUGLAS	437,550	389,472	466,873
SPOKANE	341,954	285,324	369,045
FRANKLIN	329,360	255,392	353,891
BENTON	253,912	172,281	320,513
GARFIELD	220,318	166,692	282,263
YAKIMA	126,796	93,761	140,867
KLICKITAT	83,330	72,510	107,139
STEVENS	22,935	14,309	37,534

Figure 2
Wheat Straw Production 1996-2000



Availability

The quantity of straw generated is an easy task compared to determining the quantity of material available for recovery. We use the term "available" in a broad sense to mean the materials available after accounting for how much must be left to insure the long-term fertility of the land. This is not an easy number to quantify. The quantity that must be left depends on the weather, the crop rotation, the existing soil fertility, the slope of the land, the wind patterns, the rainfall patterns and tillage practices. We talked to several agricultural and soil scientists about this issue (3-6). They all acknowledged the difficulty of coming up with generalities that could be applied at the county level and still give a meaningful number. Some used rules of thumb such as; don't take any straw off of lands with yield of less than 60-70 bushels per acre; leave 8-10 inches of straw; and leave 5,000 pounds of residue per acre.

The US Department of Agriculture has regulatory authority in addressing this question. Landowners that want to participate in federal commodity programs must prepare a soil conservation plan for their farms if the land is classified as highly erodible. In 1997, forty percent of Washington's cropland was classified as highly erodible (7). The quantity that must be left depends on the factors addressed above: slope, soil type, crop rotations, tillage practices, wind patterns, and rainfall patterns.

The Conservation Technology Information Center (CTIC) is an off-site branch of the National Association of Conservation Districts and promotes the adoption of conservation tillage and residue management. They developed a program called CORE 4 that aims to protect and improve the land while addressing on-farm profits. They set the criteria of 30 percent residue requirement (water erosion) or 1,000 pounds of small grain residue (wind erosion) on the field per acre after the field is cultivated and replanted as the standard for conservation tillage (8). The Natural Resources Conservation Service (NRCS) supports the CTIC/CORE4 marketing plan. The quantity remaining after replanting depends on the quantity generated and on the tillage practices. For example, disk plowing removes 80-90 percent of the straw from the surface (8). This practice would essentially preclude the removal of any residue for energy purposes and still maintain soil value. Other tillage practices are much less disruptive such as a rodweeder that only removes 10-20 percent (8). The trend is to use conservation tillage practices that are much less disruptive to the soil. In 1998 about 25 percent of Washington's winter wheat had residue management classified a conservation tillage (9).

The NRCS suggested we use a value of 5,000 pounds per acre. A study done in Oregon used values from 2,685 to 7,298 based on the Lightly soil conditioning index program (10). The Fibre Futures group makes the general assumption that you can remove 25 percent of the crop residue (11).

The overall objective is to maintain soil fertility, which involves nutrient and organic management and minimizing erosion. The suggested values, such as 10 inches of stubble or 3,000 pounds per acre pertain to the quantity of residue left after any straw would be removed. The more critical number is the quantity of residue left on the field after the field is cultivated and replanted. As discussed above the quantity remaining after the cultivating and replanting field operations depend on the tillage practices. These practices are changing as more conservation tillage is practiced and as direct seeding is more widely adopted. Today's practices are not likely to be what we will see in the future. We looked at the situations of leaving 3,000 pounds/acre and 5,000 pounds per acre after straw removal and assuming that cultivation and planting practices would result in leaving enough residue on the field to meet the conservation tillage guidelines. The choices of 3-5,000 pounds/acre capture the other suggested values of 60 bushels/acre or 10 inches of stubble.

Figure 3 and Table 2 show the five-year average and range by county for the quantity of straw generated and available for removal at the 3,000 and 5,000 pound per acre limits. The choice of either 3,000 or 5,000 pounds has a dramatic effect on the quantity of straw that is available. For example, the average availability of straw from Lincoln county drops from 495,000 tons to 109,000 tons when the going from 3,000 to 5,000 lbs./acre respectively. Even more dramatic are the minimum available quantities that result when crop yields are low. Again for Lincoln county, the minimum available drops from 327,000 tons to 8,000 tons. This makes planning the supply for an ethanol facility very difficult and points out the need for conservative supply estimates and/or contingency options for years with low crop yields. Such a contingency could be carrying an inventory of straw from one year to the next.