

POTENTIAL FOR ON-FARM CONVERSION OF STRAW TO BIOENERGY IN SEED PRODUCING OPERATIONS

G.M. Banowetz, J.J. Steiner, A. Boateng and H. El-Nashaar

Introduction

National support for developing renewable fuel sources has rekindled interest in bioenergy production from agricultural products. As a part of the USDA Agricultural Research Service national mission, the Bioenergy and Bioproducts National Program was established to create jobs and economic activity in America and reduce the Nation's dependence on foreign oil. As a part of this national effort, the National Forage Seed Production Research Center and Eastern Regional Research Center have initiated a research partnership with Taylor Energy in Irvine, California and the Western Research Institute in Laramie, Wyoming to develop a farm-scale gasification reactor to convert straw to energy products as a way to provide value-added revenue for Pacific Northwest seed producers.

The concept of local-grown transportation fuels is not new. Efforts during the 1980s to find alternative uses for straw without open field burning included the conversion of straw to energy (Conklin, Young and Youngberg, 1989; CH₂M Hill, 1991). At that time, available technologies could not produce energy from straw at costs competitive with existing energy sources so much of that work was abandoned.

Since that time, demand has increased for electrical generation capacity and transportation fuels with regional population growth and the rise in energy prices. These two factors have made straw-to-energy conversion an attractive strategy for value-added revenue because there are existing markets for energy, and the value of energy from existing sources has risen so alternative energy production is becoming more competitive.

Based on our current research, we discuss the potential for using straw biomass as feedstock for production of electricity or liquid fuel, the current limitations in conversion technologies when using straw, and our research to develop an affordable gasification reactor for on-farm use. Our business model for on-farm energy product production is based on the assumption that a suitable farm-scale gasification reactor will be developed that converts straw to a mixture of carbon monoxide and hydrogen gases called synthesis gas. Our analyses assume that revenues from seed sales will continue to provide the primary income source for farmers and treat bioenergy as a value-added revenue source when using straw already produced from existing profitable seed production enterprises.

Available straw feedstock

The current prevalent use of Willamette Valley straw from seed fields is as animal feed to Pacific Rim export markets valued at \$25-million. Assuming straw worth \$45-50 per ton, these receipts are spread among straw brokers, straw storage,

compression, and transportation enterprises. In most cases, seed producers receive minimal if any payment for straw from their fields. Limited markets are available for Kentucky bluegrass straw produced east of the Cascades in Oregon, Washington and Idaho.

The value of energy products produced on the farm will be dependent upon the amount of straw available, the efficiency of conversion to energy, and end product market value. Our conservative estimate of available straw for energy conversion is 1 ton of straw per acre after leaving a minimal 1-ton per acre to meet the NRCS conservation requirement. ARS research in western Oregon determining straw production amounts from three grass species over a 10-year period showed that this assumption is very conservative (Table 1). Extending the 1-ton per acre estimate to include straw from the approximate 486,000 acres of grass seed production in Oregon and 100,000 acres in Washington and Idaho provides a total of 586,000 tons of straw. The energy content of straw is approximately 12,000,000 BTU/ton (NREL, 2005 a). Converting straw to electricity using gasification technology for synthesis gas production and using an internal combustion engine to power an electrical generator provides 350 kWh per ton at 10% conversion efficiency. Assuming a market value of \$0.04 per kWh, electricity production from PNW straw has an apparent gross value of \$8.2-million that translates to \$14 per ton of straw.

An alternative straw-to-energy conversion strategy would be to produce liquid fuels. Assuming a conservative yield liquid fuel yield of 60 gallons per ton of straw (NREL, 2005 b) with a wholesale value of \$1 per gallon provides gross regional revenues in excess of \$35-million at \$60 per straw ton. Electricity production could provide producers more value if used as on-farm replacement power since retail prices are greater than wholesale prices and for enterprises that consume large amounts of electricity.

Limitations to straw-based bioenergy production

Despite a long-term interest and efforts to convert straw into value-added energy products, two factors have proven to be major obstacles to success. First, the cost of transporting low-density straw to an energy conversion facility usually exceeds the value of the energy produced (Graf and Koehler, 2000; Kerstetter and Lyons, 2001). Therefore, farmers need to nearly give the straw away for energy producers to make a profit. Second, previous kinds gasification reactor technologies based on air-blown designs were not suitable for use with straw because of slagging and durability of the reactors due to corrosive constituents found in straw (Miles et al., 1996). Air-blown designs also introduce large quantities of atmospheric nitrogen that dilute the quality of the synthesis gas which reduces its

heating value and decreases the efficiency of synthesis gas conversion to liquid fuel.

Our approach is to significantly reduce straw transportation costs by developing a farm-scale gasification reactor suitable for economic production of on-farm energy. Technology already exists to produce liquid fuel from synthesis gas, but currently is scaled and priced for large centralized conversion centers. Alternative processes based on fermentation also are available to produce liquid fuel from straw, but these rely on large-scale, high-capitalized centralized plants to which straw must be transported. Idaho Biorefinery Corp., a subsidiary of Iogen (Ottawa, Ontario, Canada) is planning construction of a plant near Idaho Falls to convert wheat straw to ethanol (Cavener, 2005). This centralized straw conversion approach is different than our small-scale, on-farm conversion concept.

Progress in gasification-based energy production from straw

Through a cooperative research agreement with Western Research Institute, we are evaluating the suitability of a new concept dual-stage gasification unit (Figure 1) for producing synthesis gas suited for fueling an internal combustion engine to power an electrical generator or be used in a thermal catalytic reactor to produce liquid fuel. Our research gasification reactor is based on a design that separates the pyrolysis and combustion reactions into two stages (Pletka et al., 2001). The reactor has been constructed at Western Research Institute and is being tested for thermal stability and gas quality using Kentucky bluegrass straw as feedstock. Because the unit is currently utilizing air to circulate heat transfer media, preliminary gas analyses show relatively high nitrogen content (Table 2). The nitrogen content of the synthesis gas will be reduced in the next phase of testing by injecting steam instead of air into the combustion stage of the reactor.

After our initial research is complete and has shown that the reactor design is suited for further testing, Farm Power, a Washington State non-profit organization will conduct on-farm trials using the experimental technology to evaluate the feasibility of on-farm electrical generation from synthesis gas produced from straw.

As shown in our estimates above, synthesis gas used to power a generator for electricity production will provide value-added revenue, but it is likely that conversion of synthesis gas-to-liquid fuels will significantly increase the value of the straw. Western Research Institute is conducting research to develop catalytic conversion reactors that would be suited for use with a farm-scale gasification reactor. The next phase of this research will evaluate the feasibility of farm-scale liquid fuel production utilizing these new technologies.

Conclusions

There is great potential to convert straw produced by already profitable seed producing operations into energy products and provide value-added revenue directly to seed producers. To

make this feasible, we are doing research to develop gasification reactor technology scaled for on-farm use to reduce the costs of transporting the straw and make farmers energy producers. New dual-stage gasification technologies have promise utilizing straw as feedstock, although more testing is needed to evaluate the amounts of slagging and corrosion associated with straw that occur in our reactor compared to other technologies. Emerging thermo-catalytic technology for conversion of synthesis gas to liquid fuels promises the greatest economic returns at this time.

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Table 1. Comparison of straw yield for three grasses during establishment and three harvest years in direct seeded and tilled fields. Yields presented for harvest years represent combined data from direct seeded and tilled fields because there were no significant differences between establishment methods.

Straw phytomass	pounds/acre		<i>P</i>	Harvest year (pounds/acre)			<i>P</i>
	Direct	Tillage		1	2	3	
Perennial ryegrass	7259	7548	NS ¹	6640 b	8214 a	7405	ab *** ²
Tall fescue	10956	10958	NS	11851a	10662 b	8265	c ***
Creeping red fescue	5472	6398	***	4654 b	6563 a	6748	a ***

¹NS Not significant at $P \leq 0.05$.

²*** Significant at $P \leq 0.001$.

Table 2. Preliminary analysis of synthesis gas produced by dual stage gasification of Kentucky bluegrass straw at 900 F. Numbers represent volume % of total gas at specified time points following start-up of gasification operation.

Sample #	Time	H ₂	N ₂	O ₂	CO	CH ₄	CO ₂
B	215	0.5	54.4	0.0	10.5	0.9	32.8
C	235	0.9	59.5	0.5	9.5	1.6	28.0
D	255	2.7	31.1	2.1	17.0	4.7	42.9
E	275	3.5	44.4	2.7	11.8	5.7	32.3
F	300	1.6	37.3	3.0	15.5	3.6	39.4



Figure 1. Taylor/WRI dual stage gasification unit used to convert straw to synthesis gas.