A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

National Renewable Energy Laboratory

Innovation for Our Energy Future

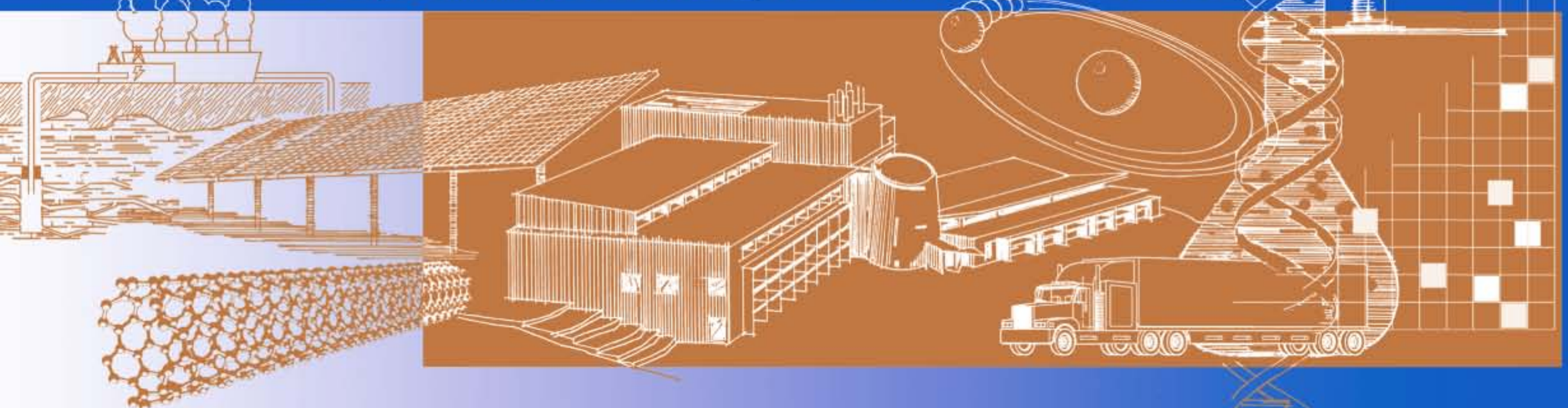
Assessment of Biomass Pelletization Options for Greensburg, Kansas

Executive Summary

S. Haase

Technical Report
NREL/TP-7A2-45843
November 2009

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC   Contract No. DE-AC36-08-GO28308



Assessment of Biomass Pelletization Options for Greensburg, Kansas

Executive Summary

S. Haase

Technical Report
NREL/TP-7A2-45843
November 2009

Prepared under Task No. IDKS.1070

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Contract No. DE-AC36-08-GO28308

NOTICE

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

NREL Contacts

Laboratory Point of Contact:	**Scott Haase** **Phone: 303-275-3057** scott.haase@nrel.gov
Project Team:	**Scott Haase** **Lynn Billman** **Anelia Milbrandt** **Dave Peterson** **Chris Gaul** **Rachel Gelman** **Alexander Dane**
Project Name:	Assessment of Biomass Pelletization Options for Greensburg, Kansas: Executive Summary

Acknowledgments

This work was conducted by the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) to provide input on the potential to establish a biomass pelletization or briquetting plant in or around the community of Greensburg, Kansas.

A number of organizations and individuals contributed information that was useful in the analysis. The authors wish to thank the following persons and organizations for their assistance with this project (listed alphabetically):

- Bob Dickson, Mayor of Greensburg, Kansas
- Kelly Estes, BTI Industries
- Mike Estes, BTI Industries
- Josh Harden, Biomass Energy Development Company
- Steve Hewitt, Greensburg City Administrator
- Brian Hoffman, Pratt Area Chamber of Commerce
- Roger Masenthin, USDA, Sunflower Resource Conservation and Development (RC&D) Program
- Mike Mayberry, USDA, Sunflower RC&D Program
- Don Queal, Queal Enterprises
- Jeanette Siemens, Kiowa County Economic Development
- Terry Studer, Local Agricultural Producer.

At NREL, staff who contributed to the effort in addition to the main author include: Lynn Billman, Alexander Dane, Chris Gaul, Rachel Gelman, Anelia Milbrandt, and Dave Peterson.

Executive Summary

In May 2007, the town of Greensburg, Kansas, was struck by a large tornado that destroyed more than 90% of the buildings and infrastructure of the town. After this devastating event, the citizens of Greensburg decided to rebuild their town in a green manner, incorporating the most efficient energy technologies possible in the reconstruction effort. The U.S. Department of Energy, through the National Renewable Energy Laboratory (NREL), has been providing technical assistance to Greensburg to help facilitate the various efforts. As part of this support, NREL conducted an assessment of potential opportunities to develop a biomass pelletization or briquetting plant in the region.

Major activities conducted for this assessment include the following:

- Detailed analysis of the biomass resource base in the region, including quantity, physical and chemical properties, availability, cost, and collection potential
- Assessment of demand for thermal energy in the region, and opportunities for biomass to be utilized to meet some of that demand
- Overview of the pellet manufacturing process, including equipment needs, capital costs, and manufacturing costs
- Overview of briquette and bripell manufacturing technologies and costs
- Discussion of end-use conversion technologies
- Conclusions and recommendations for next steps.

Biomass Resource Assessment

Biomass Quantity and Geographic Distribution. NREL conducted a detailed, county-level assessment of the biomass residues found in the region. The primary agricultural biomass types located in the region include corn stover, corn cobs, sorghum residue, and wheat straw. There is also significant potential to collect woody biomass in the form of eastern red cedar. Eastern red cedar is considered an invasive species, and it is spreading rapidly from Oklahoma into southwestern Kansas. Cedar trees are being aggressively cut and removed to prevent its continued spread into agricultural lands.

Counties were included in the analysis if all or most of the county boundary is located within a 50-mile radius of either Pratt or Greensburg, Kansas. Using data available from the U.S. Department of Agriculture National Agricultural Statistics Service (NASS), NREL estimated the quantities of residues that are produced in the region. NREL used a 10-year average of values to account for potential year-to-year fluctuations in market conditions, weather patterns, and harvest. Based on total residue produced, NREL then used standard factors to estimate the amount of biomass that could safely be removed from agricultural lands while still maintaining nutrient cycling, soil health, and erosion mitigation. We estimated the quantity of eastern red cedar available through interviews with a local cedar clearing company. The full methodology is documented in Appendix A of this report.

Table ES-1 shows the total residues available in the study area, by county. A total of 1.7 million bone dry tons per year (bdt/yr) are available within counties that intersect 50 miles of Pratt and Greensburg. The value under "other forestry removals" for Pratt County is an estimate of the quantity of eastern red cedar available in the area. Even though this material is collected from many counties in the region, this quantity has been assigned to Pratt County because it is the location of the contractor's business. It should also be noted that the values for corn are based only on residues available from irrigated acres. We found that non-irrigated corn is in a net-deficit situation, meaning that more residue should be left on the land than is actually being produced.

Table ES-1. Summary of Biomass Residues

	Residues Available (bdt/yr)									
County	Wheat	Corn	Sorghum	Soybean	Sunflower	Cotton	Logging Residues	Other Forestry Removals	Corn Cobs	Total
Barber	25,283	407	4,004	1,337	46	210	161	2,818	623	34,888
Barton	74,604	17,556	47,399	14,320	222	-	22		14,760	168,882
Clark	469		9,681	345	-	-	-		218	10,713
Comanche	3,835	285	5,357	627	-	-	-		450	10,554
Edwards	31,955	39,921	18,599	21,961	60	-	-		31,913	144,409
Ford	55,368	22,632	53,883	10,214	136	-	-		21,533	163,765
Harper	96,815	146	9,270	1,821	65	436	0		135	108,687
Hodgeman	21,536	2,228	18,130	1,287	-	-	-		4,200	47,380
Kingman	78,586	5,270	8,869	6,458	185	-	-		3,810	103,177
Kiowa	17,281	15,562	12,205	12,255	24	-	-		15,113	72,438
Pawnee	59,127	21,710	35,327	16,494	52	-	-		18,915	151,626
Pratt	58,679	38,472	19,270	17,711	377	1,122		12,500	33,533	181,663
Reno	89,693	13,495	51,240	22,829	1,253	-	15		13,118	191,642
Rice	111,254	14,194	50,816	15,130	931	-	24		8,190	200,539
Stafford	35,258	18,182	20,366	14,845	85	-	-		31,935	120,670
Total	**759,742**	**210,058**	**364,416**	**157,632**	**3,435**	**1,768**	**222**	**15,318**	**198,443**	**1,711,034**

Figure ES-1 shows the geographic distribution of the residues in the study area. Notice that, in general, greater quantities of residues are produced in the eastern counties of the region.

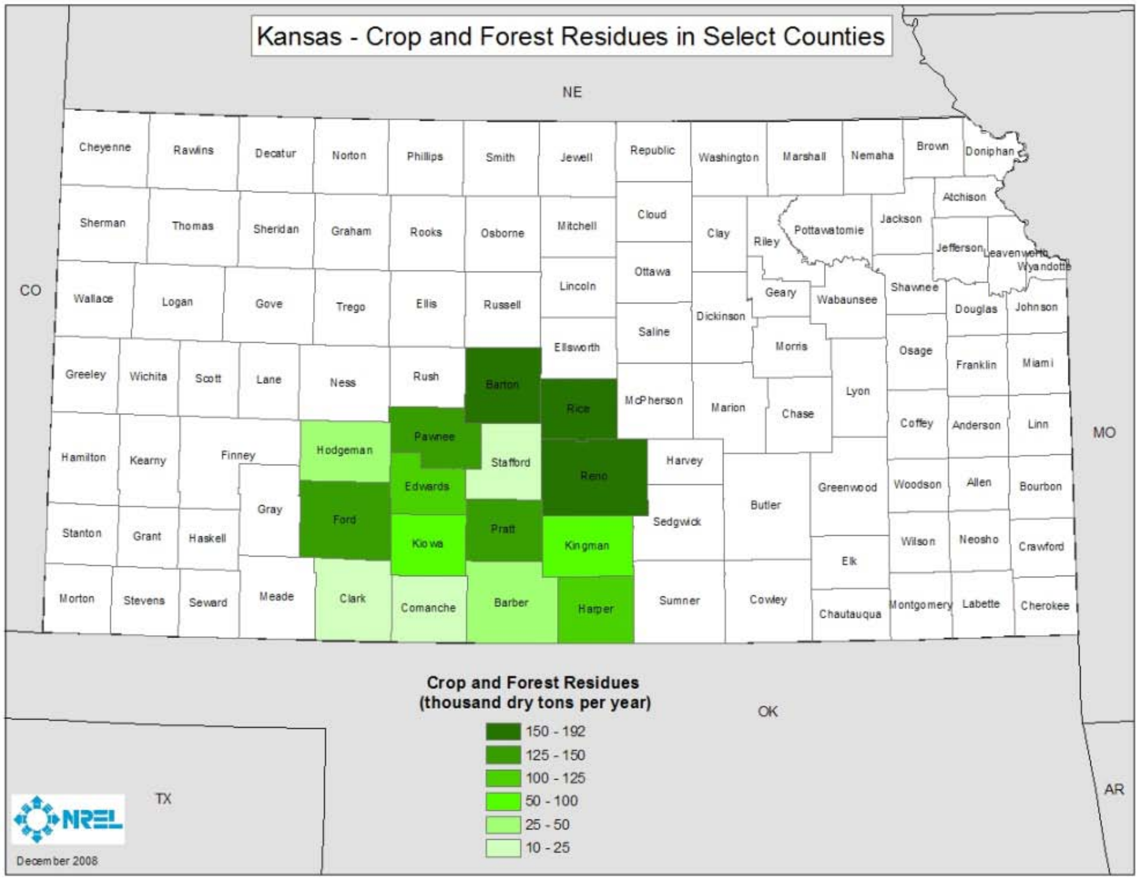


Figure ES-1. Biomass residue distribution

Looking in greater detail at the production of agricultural residues, we present in Table ES-2 the yields of biomass per acre of land harvested. The values for corn are only from irrigated acres. The table indicates that irrigated sorghum and irrigated corn will yield the greatest amount of biomass per acre. Thus, if one is interested in collecting agricultural residues, these two feedstocks should be considered as the top priority, as fewer acres will be needed to collect the most material.

Table ES-2. Yields of Biomass per Acre of Crop Land (bdt/acre/yr)

County	Wheat (bdt/acre)			Sorghum Residues (bdt/acre)			Corn (bdt/acre)
	Wheat Irrigated	Wheat Non-irrigated	Wheat Total	Sorghum Irrigated	Sorghum Non-irrigated	Sorghum Total	Corn Stover and Cobs
Barber	0.52	0.22	0.22			0.50	1.24
Barton	0.67	0.46	0.46	1.35	0.80	0.86	1.64
Clark	0.27	-	0.01	1.22	0.70	0.65	0.75
Comanche	0.44	0.05	0.06	1.23	0.37	0.55	1.23
Edwards	0.70	0.27	0.33	1.13	0.60	0.71	1.69
Ford	0.57	0.31	0.33	1.28	0.71	0.80	1.54
Harper	0.61	0.44	0.44			0.57	1.56
Hodgeman	0.64	0.17	0.21	1.09	0.64	0.69	1.15
Kingman	0.69	0.40	0.41	1.20	0.54	0.59	1.79
Kiowa	0.47	0.22	0.25	1.27	0.63	0.73	1.52
Pawnee	0.74	0.42	0.45	1.29	0.73	0.83	1.61
Pratt	0.58	0.39	0.40	1.25	0.64	0.70	1.61
Reno	0.68	0.37	0.38	1.17	0.67	0.71	1.52
Rice	0.57	0.75	0.75	1.07	0.63	0.85	2.05
Stafford	0.56	0.23	0.26	1.24	0.69	0.75	1.18
Average	**0.51**	**0.26**	**0.28**	**1.05**	**0.52**	**0.58**	**1.47**

Biomass Physical and Chemical Properties. Table ES-3 shows the results of lab tests for some of the feedstocks in the region. The column labeled SMEC pellets shows the results of tests performed on a 50-50 blend of wood and agricultural residues made by Show Me Energy Cooperative (SMEC) of Centerview, Missouri. These pellets have moderate Btu value, high percentage of ash, and high alkalis. Most pellet-burning appliances are designed to handle low-ash (< 1%) fuels and low-alkali fuels. Values higher than 0.4 pounds of alkali per million British thermal units (lb/Mbtu) are likely to cause slagging or clinker formation during the combustion process. Pellets made from wood and agricultural residues in Greensburg would exhibit similar characteristics if similar blend ratios are used. In general, the SMEC pellets are better suited for use in large-scale utility plants (mixed with coal) or in large industrial- or commercial-scale biomass combustors designed to handle high-ash, high-alkali fuels. Appendix B contains the detailed lab results of the analysis of these samples, and of samples of corn stover, corn cobs, and sorghum residue.

Potential end users of biomass pellets in the region would likely want a price concession on the cost of the product in order to offset the higher operations and maintenance costs associated with using a high-ash, high-alkali fuel.

Table ES-3. Biomass Physical and Chemical Properties

Value	Wheat Straw	Freshly Cut Cedar	Seasoned Cedar	SMEC Pellets
Btu content as received HHV (Btu/lb)	7,125	8,143	8,056	7,059
Btu content bone dry (Btu/lb)	7,709	8,827	8,976	7,680
Moisture content as received (%)	7.57	7.75	10.25	8.09
Percentage Ash (%)	7.83	1.63	0.88	9.04
Lb Alkali/Mbtu	1.3	0.08	0.05	1.44
Lb ash/Mbtu	10.99	2.00	1.09	12.81
Potassium in ash as K2O (%)	11.4	3.25	4.55	10.8

The values for cedar shown in Table ES-3 indicate that this material would make an excellent feedstock for a biomass system. A product made of only cedar, or mostly cedar, is going to have much better combustion properties than a 50-50 blend of agricultural residues and cedar. For this reason, entrepreneurs wishing to develop a plant in the region may want to use either 100% cedar or a small blend percentage of agricultural residues. Test batches of various blend percentages would need to be made in order to test for ash content and alkali values before any full-scale production begins. The size of any potential pellet enterprise may be limited by the quantity of cedar that can economically be collected in the region.

Biomass Cost. Biomass collection cost is one of the major factors influencing the final cost of pellets. One of the challenges of using agricultural residues for feedstock is that the resource is dispersed on the land and relatively expensive to collect. Remember, too, that biomass pellets are competing against fossil fuels–primarily natural gas and propane. In recent months, the wholesale price of natural gas has fallen from $14/Mbtu to less than $4/Mbtu.

Figure ES-2 shows the cost of biomass in $/Mbtu versus various costs to collect and deliver a ton of agricultural residues. Based on results of this and other studies referenced herein, we estimate that biomass collection costs will be in the range of $55-$60 per field-dried ton for agricultural residues. Note that at $60 per ton, the fuel cost alone is equivalent to $4.29/Mbtu. When pellet manufacturing costs (labor, energy, packaging, debt, transportation) are added to this, it is clear that pellets will have a difficult time competing with fossil fuels at today's prices.

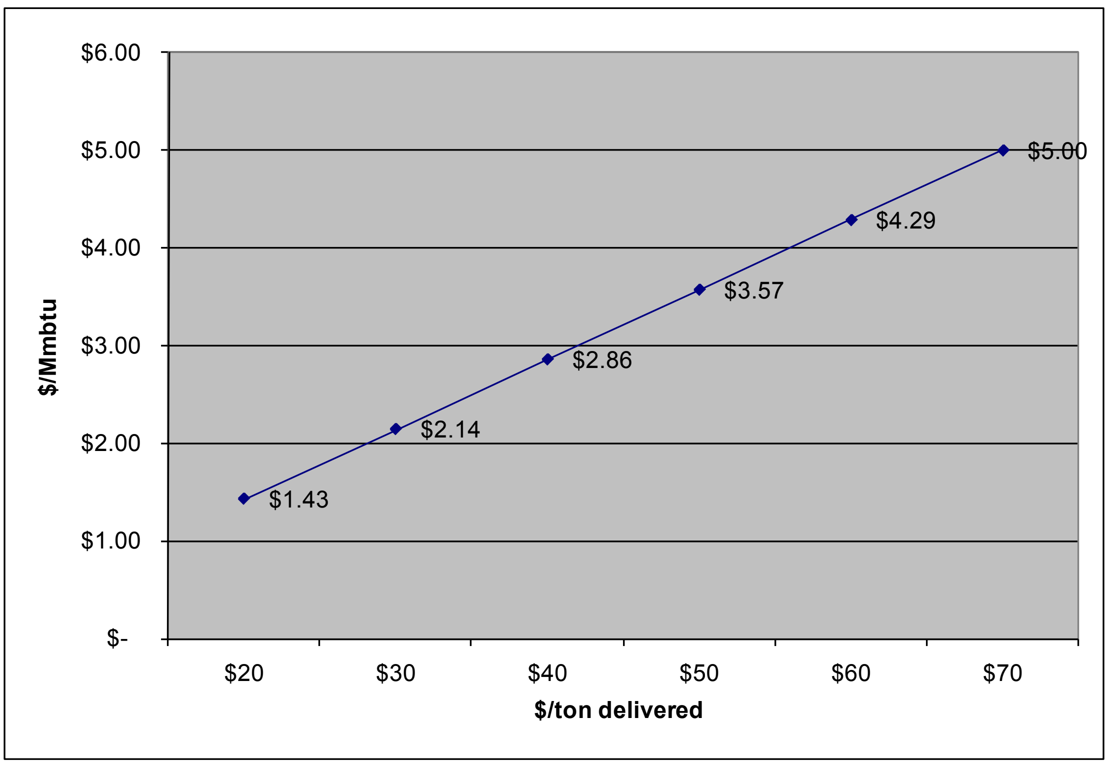


Figure ES-2. Fuel costs of agricultural residues ($/Mbtu versus $/delivered ton)

The delivered cost of cedar biomass is likely to be somewhat lower than that of agricultural residues. We estimate that cedar can be delivered to a regional pellet manufacturing plant for about $35/green ton. Assuming 8,800 Btu per dry pound and 40% moisture, this equates to

$3.31/Mbtu. Cedar is an important feedstock in the region, as it is likely to be the lowest cost resource; at the same time it has the best physical and chemical qualities of all the regional biomass sources.

Regional Demand for Thermal Energy and Competing Fuel Costs

Comparison of Fuel Prices. Table ES-4 shows the delivered costs of energy from various fuels used in the region. The delivered cost of energy takes into account appliance efficiency and thus represents the cost to deliver a therm of useful energy to the building space. The natural gas prices used in the table are based on statewide averages for Kansas for the months of April through December 2008. Although the natural gas prices are based on average values for the period, note that the most recent prices for November and December 2008 were considerably lower than the averages. So while the commercial cost per therm is listed as $1.57 in table ES-4, the value for December 2008 was $1.00 per therm, which would make the delivered cost of energy $12.00/Mbtu as compared to the $19.63 shown in Table ES-4.

Table ES-4. Delivered Cost of Thermal Energy for Various Fuels ($/Mbtu)

Source	Units	Cost to User ($)	Efficiency (%)	Btu/unit	$/Mbtu
Chipped Cedar	$/green ton	50.00	75	13,200,000	5.05
Wheat straw bales	$/ton	55.00	70	14,000,000	5.61
Natural gas (industrial)	$/therm	0.69	80	100,000	8.63
Wood/ag pellets ($130/ton)	$/ton	130.00	80	15,000,000	10.83
Wood/ag pellets ($160/ton)	$/ton	160.00	80	15,000,000	13.33
Hardwood pellets	$/ton	185.00	80	16,600,000	13.93
Natural gas (commercial)	$/therm	1.50	80	100,000	18.75
Fuel oil	$/gallon	2.17	85	135,000	18.91
Natural gas (residential)	$/therm	2.10	80	100,000	26.25
Propane	$/gallon	2.13	85	91,600	27.36
Electricity	$/kWh	0.10	100	3,413	29.30

When assessing the market for pellets, it is important to remember that fossil fuel prices fluctuate considerably, and while prices are low, end users may not be as interested in alternative fuels as they would be when prices are high. One of the selling points of biomass should be that biomass prices typically remain stable and seldom exhibit the wild price swings evident with fossil fuels.

Chipped cedar at $50 per ton has the lowest delivered cost, followed by straw bales. However, the use of these fuels will require additional on-site labor and higher up-front capital costs when compared with systems that burn pellets or other densified fuels. Notice that wood/ag pellets at $130 per ton are about $0.67 less per Mbtu than the cost of energy at the average industrial rate for gas in Kansas. It is difficult to compete with natural gas if your fuel is just slightly less expensive yet takes more labor and maintenance and requires an up-front purchase of a new appliance. Ag pellets at $130 per ton compare nicely, however, with hardwood pellets at $185 per ton, fuel oil at $2.17 per gallon, propane at $2.13 per gallon, and electrical resistance heat at $0.10 per kilowatt-hour (kWh). Ag pellets also compare well with commercial natural gas rates of $19.63/Mbtu. Ag pellets at $160 per ton compare favorably with fuel oil, commercial and residential gas, propane, and electricity. Note that it may be a challenge for a pellet plant to deliver wood/ag pellets to its customers at $130 per ton, even when using bulk shipments instead of plastic bags. A cost of $160 per ton for bulk pellets delivered to a regional customer may be more likely.

Table ES-5 shows the average natural gas rates in Kansas by customer type. Data are shown through October 2008. It is likely that in the near term these rates will show a continued downward trend. The value for “electric power price” is the rate paid for gas used to generate electricity. The Energy Information Administration reports the data in terms of dollars per thousand cubic feet ($/Mcf). We have reported these values in $/Mbtu to be consistent with the other units used in this report.

Table ES-5. Average 2008 Monthly Natural Gas Prices in Kansas, by Customer Type ($/Mbtu)

Sector	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Average
Residential	15.29	17.14	22.41	23.81	24.90	21.82	18.73	12.71	10.41	18.58
Commercial	14.57	15.71	18.61	19.11	19.32	17.54	15.15	11.64	10.06	15.75
Industrial	9.30	9.64	10.09	11.09	10.11	8.35	6.95	7.84	9.25	9.18
Electric Power	10.22	10.98	11.65	10.85	8.97	6.67	4.50	4.88		8.59

Figure ES-3 shows historic wholesale prices of Kansas natural gas, adjusted to 2008 dollars. Prices have experienced significant volatility over the 36-year period. From the early1990s until about 2000, prices were around or below $4/Mbtu and relatively stable. Since the year 2000, prices had been on a steady upward trend until the fall of 2008. With the recent economic downturn, prices have fallen significantly. On January 22, 2009, the Henry Hub natural gas prices closed at $4.72/Mbtu. Although prices have fallen precipitously over the last few months, the long-term trend line is still upward, at least for now.

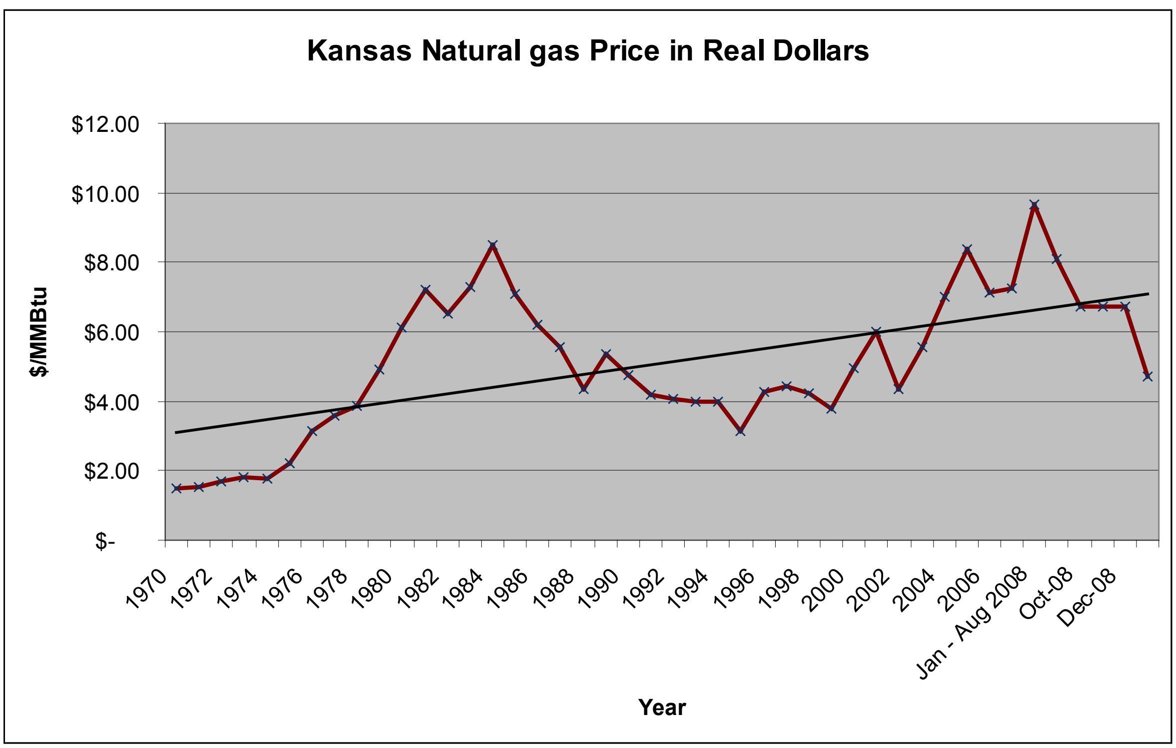


Figure ES-3. Industrial customer natural gas prices (1970-January 2009)

Regional Demand for Natural Gas. NREL contacted regional natural gas providers to request aggregate data on natural gas sales by zip code or town/city place name. NREL staff then aggregated these data to the county level. Table ES-6 shows the estimated regional demand for thermal energy based on natural gas consumption. These numbers do not account for customers heating with propane, fuel oil, or other sources such as electricity, corn, or wood pellets, or customers on well-head gas. Overall, nearly 235 million therms of natural gas are consumed each year by more than 225,000 customers in the study area. The largest county in terms of both consumption and users is Sedgwick, which contains the city of Wichita. Reno and Ford counties also consume significant quantities of natural gas. While it is clear that it is not possible for pellets to replace 100% of regional natural gas use, the annual consumption of natural gas in the region is equivalent to approximately 1.6 million tons of pellets, assuming 7,000 Btu/lb for the pellets. This is tied very closely to the potential supply in the region of 1.8 million bdt/yr.

Table ES-6. Regional Demand for Natural Gas by Customer Type

	RESIDENTIAL			COMMERCIAL			INDUSTRIAL			Total	
County	Therms	# of Users	Average Use	Therms	# of Users	Average Use	Therms	# of Users	Average Use	Therms	# of Users
Barber	1,040,442	1,481	702	391,788	256	1,532	0	0	0	1,432,230	1,737
Clark	576,868	777	743	181,722	133	1,366	233,991	7	33,427	992,581	917
Comanche	457,942	626	732	266,810	128	2,089	0	0	0	724,752	753
Edwards	691,173	911	758	500,976	188	2,660	142,831	16	8,927	1,334,980	1,116
Ford	6,609,854	10,616	623	4,433,399	1,071	4,139	14,841,118	189	78,524	25,884,371	11,876
Kingman	1,354,386	1,990	680	588,138	306	1,919	180,679	5	35,543	2,123,203	2,302
Kiowa	634,912	689	922	285,830	135	2,111	408,839	37	11,050	1,329,581	861
Pawnee	1,528,536	2,029	753	529,844	256	2,069	169,351	8	21,169	2,227,731	2,293
Prattt	2,386,993	3,201	746	1,498,291	487	3,074	234,771	18	13,043	4,120,055	3,706
Reno	13,864,507	20,655	671	4,683,720	1,907	2,457	23,068,579	27	854,392	41,616,806	22,588
Sedgwick	106,217,438	162,805	652	34,022,082	12,565	2,708	11,267,245	75	150,230	151,506,766	175,445
Stafford	1,032,418	1,348	766	398,222	257	1,549	84,910	9	9,434	1,515,550	1,615
Total	**136,395,468**	**207,128**		**47,780,823**	**17,690**		**50,632,314**	**391**		**234,808,605**	**225,209**

Adding the pellet potential across the commercial and industrial sectors yields 700,000 tons per year maximum potential. Assuming pellets can capture 5% of this market, we get a total of about 35,000 tons per year local potential in these sectors. This is not to suggest that the market in the area is limited to 35,000 tons. It may be possible to identify several larger customers that alone could consume more than 35,000 tons at a single facility. These large potential users should be contacted directly to discuss their possible interest in biomass pellets. It is also possible to develop markets outside of the local area, either by truck or rail.

Entrepreneurs interested in starting a pellet facility should be prepared to spend significant amounts of time educating potential end users and developing the market before constructing any facility. One of the biggest challenges associated with building a facility to make pellets in the region is that there are no existing customers beyond perhaps some residential or farm users of pellet or corn appliances. This is the proverbial “chicken and egg” problem—end users will only be willing to invest in conversion technologies to burn pellets if there is a reliable, affordable, high-quality product available, and the builders of a pellet mill must have a reliable, credit-worthy customer base to ensure that the product they make can be sold. Under present market conditions, there are few compelling reasons for potential end-users to be early adopter adapter.

Possible Local Commercial Customers. A successful biomass fuel production facility would need to develop off-take contracts with customers in order to obtain financing. Two industrial plants in the area, Orion Ethanol in Pratt and National Gypsum in Medicine Lodge, may be potential customers. The Pratt ethanol plant is not operating at this writing but presumably could be reactivated when more favorable business conditions return. There are many other potential customers in Dodge City and Wichita that could be identified and contacted.

As an example of a potential customer, the National Gypsum drywall manufacturing plant in Medicine Lodge could utilize biomass fuel. The plant presently consumes about 900,000 Mbtu per year of natural gas in its dryers. Offsetting 75% of this load would require on the order of 45,000 tons of biomass pellets (or 50,000 tons of 25% moisture content cedar chips) per year. As of February 2009, National Gypsum is interested in exploring the economics of switching from gas to biomass.

National Gypsum currently purchases natural gas for the NYMEX price, plus about 45 cents for delivery. Biomass costs must compete with those of natural gas. National Gypsum's delivered cost of gas is presently about $5.00/Mbtu, although this price fluctuates daily. We do not believe that biomass pellets can be delivered to National Gypsum for $5per million Btu. If a ton of biomass pellets has 15 Mbtu, then the delivered cost would need to be $75 per ton to meet $5/Mbtu gas. The only biomass feedstock that can come close to meeting this cost at present is cedar chips.

It is interesting to consider emissions of carbon dioxide. Consumption of 675,000 Mbtu/yr of natural gas (75% of National Gypsum's estimated use) emits 39,500 tons of CO_2 per year. Since biomass is considered CO_2 neutral by the U.N. International Panel on Climate Change, conversion to biomass could potentially free up carbon credits for National Gypsum under a cap and trade system. Some of these credits may need to be given to the biomass supply company to offset the emissions of the biomass pellet operation (from field to customer). Alternatively, the price of natural gas would go up by about $1.20/Mbtu if CO_2 is taxed at $20 per ton. This would make biomass pellets more attractive to the plant.

Abengoa Ethanol Plant, Hugoton, Kansas. Abengoa is presently moving forward with plans to construct a 100 million gallon per year combination corn/cellulosic ethanol plant in Hugoton, Kansas. As of the writing of this report, Abengoa is in the process of conducting its environmental studies and developing its feedstock supply infrastructure. Abengoa has stated that the plant will require nearly 500,000 "as is" tons of biomass—primarily wheat straw and corn stover—as inputs for the cellulosic ethanol process, as well as to provide thermal energy for the plant. At this time, Abengoa has stated that it plans to collect feedstocks from within 50 miles of Hugoton, which would keep transportation costs as low as possible. At this time, we are unsure if Abengoa will need to go beyond this 50-mile radius and obtain feedstocks from closer to the Greensburg/Pratt areas. However, interested entrepreneurs should contact Abengoa to discuss the potential for supplying the ethanol plant with densified biomass feedstocks.

Summary of Local Market Potential. For any densified biomass product to be commercially viable, it must be at least as cost-competitive and somewhat as convenient as competing fuels. This includes wood pellets as well as fossil fuels. In most cases, pellets are truly a commodity product. A lower cost producer can ship farther and thus compete with smaller, higher production cost pellet mills, even in the smaller mill's own backyard. Agricultural residue pellets are generally lower in grade than wood pellets. If agricultural residue pellets are available in the same market as wood pellets, they would have to sell at a lower price to compete with both wood pellets and natural gas. Biomass pellets are likely to compete very favorably with propane, fuel oil, commercial natural gas rates and electricity, but so will wood pellets. Any entrepreneur who seeks to develop a biomass pelletization facility in the Greensburg/Pratt region should be prepared to spend considerable time and effort on educating potential consumers and developing the market.

Densification Options

We evaluated three potential densified products that could be made from local biomass: pellets, briquettes, and bripells. All three options represent commercial technologies that would create viable market products, and all three can be used in commercial boiler systems to produce heat, power, or combined heat and power. We estimate that a 24,000-ton-per-year plant is the minimum size that should be built to take advantage of economies of scale, labor requirements, and infrastructure. It may be possible, however, to start with a smaller briquette or bripell production level, and scale up as the market develops.

Of the three products, pellets are associated with the most acceptance and consumer awareness, especially in the residential and small commercial sectors. However, the pellet market is still dominated by demand for premium, bagged pellets (less than 1% ash, high Btu) for the residential sector. Most pellet-burning appliances being sold to the residential market today are designed to handle low-ash fuels. Based on the feedstocks available in the Greensburg region, pellets made from a mixture of wood and agricultural residues will be high in alkalis, produce high ash, and contain medium Btu content (see the chemical analysis of the biomass sample pellets located in Appendix A). Without changes to pellet stove technology, there is not likely to be a high demand for this type of pellet from the residential sector. If pellets are the desired product, we suggest they be made either from 100% wood or perhaps a blend of 85%–90% wood with the remainder coming from agricultural residues. The exact blend could be determined through lab tests of various mixture percentages.

For the large commercial or industrial sectors, there are a number of boilers or furnaces on the market that are capable of handling higher ash pellets. Briquettes and bripells are also well-suited for commercial use. Appendix E contains a list of manufacturers of technologies that could burn any of these products in larger applications.

Table ES-7 shows the estimated costs of pellets, briquettes, and bripells. It must be stressed that these numbers are estimates only, and interested entrepreneurs are encouraged to develop their own detailed cost analyses before selecting one technology over another. The numbers below are sensitive to many factors, and changing one assumption can change any value. All of the numbers below were developed assuming a biomass feedstock cost of $65/bdt delivered to the plant.

Table ES-7. Summary of Manufacturing Costs

Product	Plant Capacity (tons/year)	Capital Costs ($)	Employees (FTEs)	Estimated Cost Bagged ($/ton)	Estimated Cost Bulk ($/ton)	Cost for 100% Cedar ($/Mbtu Bulk)	Cost for 50/50 Ag-Cedar Blend ($/Mbtu Bulk)
Pellets	24,000	5,500,000	15	159	135	8.42	8.98
Briquettes	25,000	4,700,000	6	143	123	7.66	8.17
Bripells	24,000	3,000,000	10	154	134	8.36	8.92

Conclusions

There is sufficient biomass located in the region to supply at least one plant creating pellets, briquettes, or bripells. Because cedar represents the highest quality feedstock in the region, the interested entrepreneur may wish to consider sizing a plant based on the quantity of cedar available. Agricultural residues can be added into the product mix at a later date as markets mature. We estimate that 12,500 bdt of cedar can be collected easily, although to get to a minimum sized plant (24,000 tons per year), additional cedar will need to be collected, or ag residues will need to be added. Due to the dry climatic conditions in the region, only agricultural residues from irrigated lands should be considered. Potential target feedstocks include corn stover, corn cobs, sorghum residue. and wheat straw.

There is also sufficient demand for thermal energy in the region. Given the current price of natural gas, it may be more difficult than it was a year ago to convince large commercial or industrial users to switch heating fuels. They could be reminded, however, that fossil fuel prices fluctuate considerably, and it is only a matter of time before prices begin to increase again. But while fossil fuel prices are low, considerable market conditioning and educational efforts will still be needed to persuade current natural gas customers to consider installing a biomass heating system. Biomass fuel will compete better with fuel oil or propane, as these two fuels are more expensive on a $/Mbtu basis.

A pellet, briquette, or bripell plant in the region will create six to 15 jobs, depending upon the technology selected.

Suggestions for Next Steps

This report has confirmed that there is a potential business opportunity in the region to develop some form of densified biomass business, be it pellets, bripells, or briquettes. The following actions are suggested as potential next steps for interested parties:

- Product Development
  - Make sample blends of various feedstock combinations (e.g., cedar/corn stover, cedar/sorghum) in various percentage mixtures
  - Send samples to the lab for chemical analysis, especially to asses ash percentages, Btu content, and alkali content
  - If possible, conduct test burns of products in candidate appliances to assess ash, feed handling, slagging, and odor.

- Feedstock Procurement
    - Identify producers interested in biomass supply options
    - Develop contract mechanisms for biomass supply
    - Assess potential for planting Conservation Reserve Program (CRP) land in switchgrass, mixed grass prairie, or other biomass for specific production of biomass for pellets or bricks. Some sample questions to answer would be:

      What is the best mix of plants for the local region?

      What are the yields and economics versus alternative CRP options?

      What is the best mix of plants in terms of energy content and use?
- Market Development
    - Perform additional market development efforts and educate potential end users about biomass energy
    - Seek state support to organize a local biomass heating workshop in the region
    - Contact large commercial energy users to analyze their actual energy usage and costs. For example, potential regional targets in Kansas could include National Gypsum in Medicine Lodge; the Robert J. Dole VA Medical Center in Wichita; the new Kiowa County Memorial Hospital in Greensburg; Pratt Community College in Pratt; agricultural processing plants in Dodge City; and any federal facilities
    - Continue to identify end use technologies that are commercially available and can be deployed at customer sites.
- Business Analysis
    - Conduct detailed pro forma analyses for bripells, briquettes, and pellets
    - Develop a business plan and conduct a detailed plant design.

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*
November 2009

2. REPORT TYPE
Technical Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Assessment of Biomass Pelletization Options for Greensburg, Kansas: Executive Summary

5a. CONTRACT NUMBER
DE-AC36-08-GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
S. Haase

5d. PROJECT NUMBER
NREL/TP-7A2-45843

5e. TASK NUMBER
IDKS1070

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/TP-7A2-45843

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
This executive summary provides an overview of a technical report on an assessment NREL conducted in Greensburg, Kansas, to identify potential opportunities to develop a biomass pelletization or briquetting plant in the region.

15. SUBJECT TERMS
National Renewable Energy Laboratory; NREL; DOE; U.S. Department of Energy; Greensburg; executive summary; TP-7A2-45843; technical report; technical assistance; Greensburg tornado; Kansas; tornado; tornado damage; EF-5 tornado; severe weather; green communities; green buildings; green community development; sustainable development; rebuilding green; energy efficiency; biomass; pelletization; briquetting; eastern red cedar

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER (*Include area code*)

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1147-E(10/2008)