

Penn State **Extension**

On-Farm Production of Biomass Grass Pellets



A Case Study of **Wood Crest Farm**
in Wapwallopen, Pennsylvania



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College of Agricultural Sciences



Summary

Farm-based production of grass pellets for energy is an interesting new opportunity for farmers in the Northeast United States. Perennial grasses, such as switchgrass, can be grown on marginal land and made into biomass pellets on the farm. These pellets can be used as heating fuel for homes and other purposes. This case study analyzes the operation at Wood Crest Farm in Wapwallopen, Pennsylvania, where switchgrass is grown and pelletized. The analysis covers all aspects of the operation, from crop establishment through marketing the crop, and provides a detailed analysis of costs as well as tips from the farmer on successful operation.



Production of grass-based pellets has proved to be challenging but feasible at Wood Crest Farm. It takes time to learn how to grow, harvest, and pelletize switchgrass, and there are things about the crop that are different from traditional crops. After the crop is harvested, pelletizing switchgrass successfully is a significant challenge, and many details must be carefully controlled if one is to produce pellets.

The total cost of production for pellets at Wood Crest Farm is \$88 per ton. However, labor costs are not included in this amount, equipment purchase costs are not accounted for, no profit is included, and land costs are only equal to the taxes due on the land. Space in the barn for operating the pelletizer is also used without cost. As such, this represents a “bare bones” operating cost. If these resources were not available, the cost of producing pellets would be much higher. This highlights an important point: the available resources at a farm can have a big impact on the viability of a pelleting operation.

Marketing is also a big challenge for grass pellets. The pellets are not suitable for most wood pellet stoves, so it may take quite a bit of effort to develop a market for the product. In addition to pellets, Wood Crest Farm sells baled and ground switchgrass for a variety of uses as a way of diversifying its market and increasing income.

This case study describes the experiences of one farmer/pellet maker in the Northeast United States, but it also serves as a useful guide to others who may be interested in trying something similar.

Contents

Introduction 4

- Pellet Use Today 4
- Switchgrass for Pellets 5
- Wood Crest Farm 6
- Applying this Case Study to Your Farm 6

Growing and Establishment 7

- Seed Variety 7
- Site Selection and Preparation 7
- Planting 8
- Establishment 9

Harvesting 10

- Mowing 10
- Raking and Baling 11
- Yield 11

Storage 13

Pellet Production 14

Cost Summary 16

- Fixed Costs 16
- Variable Costs 16
- Grants and Assistance 17
- Total Costs 18

Markets for Switchgrass, Pelletized or Not 18

- Mulch Markets 19
- Animal Bedding 19
- Absorbents 19
- Large Customers 19

Conclusions 19

References 20

Appendixes 21

- A. Pellet Press Diagram 21
- B. Schedule of Operations at Wood Crest Farm 22
- C. Equipment List for Wood Crest Farm 23
- D. Acknowledgments and Contact Information 23

Figures and Tables

Figures

- Figure 1. Local renewable energy from grass pellets on the farm. 4
- Figure 2. Switchgrass pellets. 5
- Figure 3. Switchgrass in the field. 5
- Figure 4. Will Brandau, owner of Wood Crest Farm. 6
- Figure 5. Wood Crest Farm map. 6
- Figure 6. Switchgrass at the end of the first year. 10
- Figure 7. Mowing the crop. 11
- Figure 8. Clearing chaff from the round baler. 11
- Figure 9. A freshly made round bale. 11
- Figure 10. Old unused bales, and newer, tarped bales in storage. 13
- Figure 11. Equipment used for making pellets at Wood Crest Farm. 14
- Figure 12. Cost savings from switching to grass pellets. 18
- Figure 13. Switchgrass—baled, ground, or pelletized—an excellent mulch. 19

Tables

- Table 1. Site preparation costs. 7
- Table 2. Seed application rates. 8
- Table 3. Planting costs. 9
- Table 4. Establishment costs. 10
- Table 5. Harvesting costs. 12
- Table 6. Time of field operations. 12
- Table 7. Cost of storage. 13
- Table 8. Pelletizer performance. 14
- Table 9. Pellet production costs. 15
- Table 10. Fixed startup costs—equipment. 16
- Table 11. Variable one-time startup costs. 17
- Table 12. Variable operating costs (per year). 17
- Table 13. Variable operating costs by category (per year). 17
- Table 14. Funding support. 17
- Table 15. Total costs. 18

Introduction

On-farm production of grass pellets is a relatively new opportunity for farm energy production in the Northeast United States. Some farmers have already taken the initiative to grow, harvest, and pelletize perennial grasses to either use on the farm or sell to others. The processes and equipment that were developed for wood pellets and feed pellets can also be used to manufacture grass pellets, even at a smaller “farm scale.” In the Northeast, many farms and homes use expensive fuel oil or other nonrenewable energy sources for heat. There is a real opportunity for grass pellets to be used instead, providing affordable, renewable heat to homes and businesses. However, the on-farm pelleting opportunity is still in its infancy, and very few people use them today as a fuel.

Many farms are well suited for producing grass pellets, especially those that have haying equipment and abandoned, marginal fields that are not suitable for food crops. In many parts of the Northeast United States, this is especially true given the shift away from grazing and the availability of degraded or low-quality land that is not suitable for food crop production. While hay equipment is widely available in the region and can be used to harvest and handle biomass grasses, specialized pelleting equipment is also needed, and the costs and the know-how related to those systems need to be understood in advance if farmers are to know whether or not grass pelleting

will work for them. Early experiences have shown that pelleting is not an “automatic” process, and there are many tricks to making the process work well. Also, the economics of the operation are not always clear.

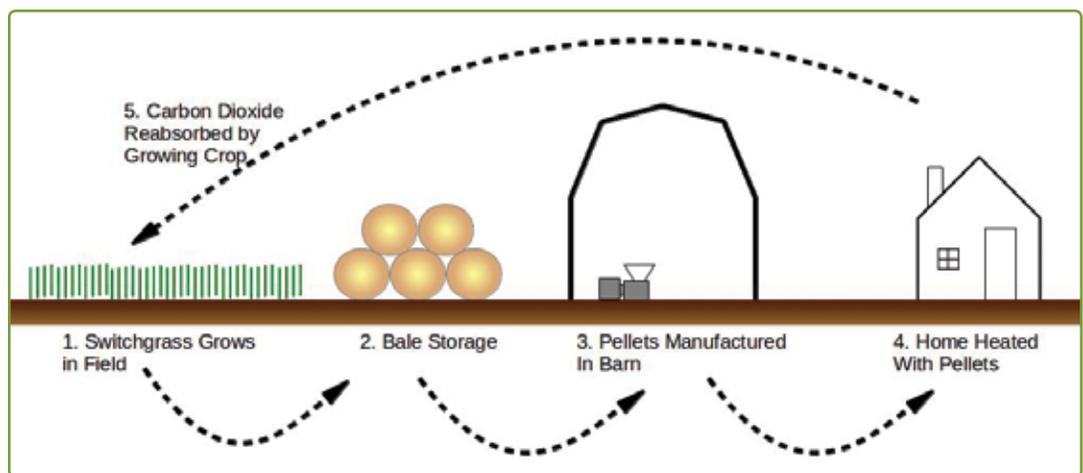
Pellet Use Today

Most pellets in use today are made from wood. They first became popular as a response to the fuel crises in the 1970s and early '80s as an industrial and residential fuel (Lisle 2013). The wood pellet market has recently seen some fluctuations due to the housing market crash in 2008, as well as the growth of the export market and variations in production capacity as new plants are built.

Wood pellets are an essential fuel for many Americans. The Pellet Fuels Institute approximates that there are 1,000,000 homes in the United States that rely on wood pellets for residential heating (Pellet Fuels Institute 2014). Wood pellets are burned in pellet stoves or boilers, providing hot air or hot water heat. Pellets in the United States are almost exclusively used for home heating, although some commercial and institutional facilities have recently switched to pellet heat. Overseas, a large market for pellets exists, especially in Europe where they are being used to co-fire with coal in power plants. However, worldwide use of pellets is almost exclusively of wood pellets, with very little grass pellet production to date. Nonetheless, boilers and stoves that are designed to use grass pellets as fuel are available on the market.

Figure 1.

Local renewable energy from grass pellets on the farm.



Switchgrass for Pellets

Switchgrass (*Panicum virgatum*) is probably the top candidate for making grass pellets in the Northeast United States. Originally native to the prairies and grassy areas of the eastern United States, the warm-season grass can be grown throughout most of the country. The crop has been planted for low-grade forage in some places, but it is more commonly used for soil and wildlife conservation efforts because of its ability to control erosion, add soil organic matter, improve rainfall infiltration, and provide habitat for wildlife. In the Northeast, about 300,000 acres are enrolled in the USDA Conservation Reserve Program, with much of that being planted in switchgrass as an ecological measure (USDA Farm Service Agency 2014). Some farmers even grow switchgrass to improve habitat for hunting.

Switchgrass easily adapts to and yields well in marginal lands; therefore, it does not need to compete with food crops requiring fertile soils for establishment. Switchgrass can have extremely deep root systems, which can make it suitable for many different soil types, including “droughty” soils that do not remain moist enough at the surface to support typical crops. Switchgrass also has very modest nutrient requirements. Because of these characteristics, switchgrass generally does not have to displace primary crops that need more fertile soils. The crop can grow up to 6 feet (1.8 meters) tall and yield 4 to 6 dry tons per acre (9 to 13 tonnes per hectare) annually, although typical yields are often lower (Jacobson 2013). Switchgrass also has relatively low costs associated with establishment and maintenance, making it economically feasible to grow.

Invasiveness/spreading is usually not a big issue for



DANIEL CIOLKOSZ

Figure 2. Switchgrass pellets.

switchgrass because of its tendency to establish itself slowly. Once it is established, it competes very well with weeds and other plants; however, it does not naturally spread easily because seedlings tend to be sensitive to weed pressure, and as a result, it does not readily “take over” a field without help.

Pellets or Briquettes?

If you densify grass into cylindrical pieces less than about 20 millimeters ($\frac{3}{4}$ inch) in diameter, it is typically called a “pellet.” If it is larger, it is typically called a “briquette.” While people are usually more familiar with pellets, briquettes may have potential as well. Briquettes are usually less expensive to manufacture, but they require heavier duty handling equipment (augers, etc.). Because of this, briquettes are probably best suited for larger scale commercial and industrial uses.

There are many different cultivars of switchgrass, which are divided into upland and lowland species. Upland species of switchgrass are naturally more accustomed to drier and colder conditions found in the northern parts of the country, while lowland species originate in floodplain regions in the South (Jacobson 2013). Both types of species can flourish in the Northeast United States

depending on the specific site. When buying switchgrass seeds, it is best to check with the local seed provider to find cultivars that will work well with your property. Some of the common types of switchgrass include ‘Blackwell’, ‘Cave-In-Rock’, ‘Timber’, and ‘Kanlow’ (Ernst Conservation Seeds 2014).



DANIEL CIOLKOSZ

Figure 3. Switchgrass in the field.

“I love the way it heats my home. If I am looking for quick heat, I throw a few shovels of switchgrass pellets into my boiler.”

WILL BRANDAU

Wood Crest Farm

This case study takes a look at a farm that grows switchgrass and manufactures pellets on the farm for sale to the local community. The farm evaluated for the case study is Wood Crest Farm in Wapwallopen, Pennsylvania, which lies on the banks of the Susquehanna River in northeastern Pennsylvania (see Figure 5). Wood Crest farm is located on stony silty loam soils, 93 percent of those soils belonging to hydrological soil group C. The farm soils consist of Atherton, Braceville, and Chenango soils. Owned and operated by Will Brandau, the farm dates back to the mid-1800s when Will's ancestors established the farm as a dairy operation with some hay fields toward the river. Will Brandau planted seven fields, for a total of 40 acres, with switchgrass in 2006 with the dream of growing and processing his own fuel source, which



DANIEL CIOLKOSZ

Figure 4. Will Brandau, owner of Wood Crest Farm.

he could then sell to people and businesses in his community. Switchgrass farming was a way for Will to spend his days as a retired teacher making fuel for his house and his community

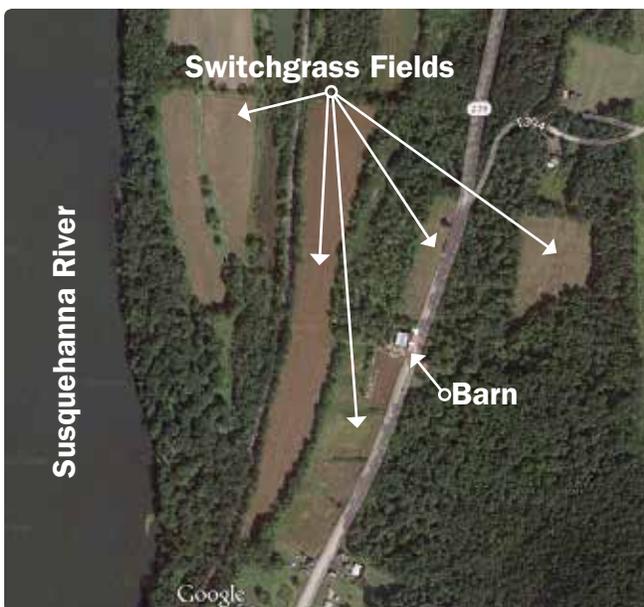
while also earning a supplemental income. Will has experience with not only growing switchgrass but also processing it into a usable form. He has worked with briquetters as well as pelletizers, and runs his own pelletizer in the lower level of the barn. His expertise and experience with switchgrass growing and pelletizing make this farm a great example of farm-based grass pellet production.

The sections that follow give details of the operation at Wood Crest Farm, including equipment use, estimated costs, and miscellaneous tips on successful operation that the farmer has learned over the course of establishing the crop and manufacturing pellets on the farm.

Applying this Case Study to Your Farm

This case study is intended to provide practical guidance to farmers interested in growing switchgrass and producing pellets on the farm. Keep in mind, however, that every farm is different, and costs and labor can vary considerably from farm to farm. Not only that, but productivity of fields and pelleting equipment can also vary a great deal. Lastly, a farmer's experience and skill can have a big impact on costs and performance. However, the information in this report does provide some practical, experience-based information that should be very useful for farmers planning to try pellet production as a business venture.

The following sections of the report are organized according to the main phases of production: establishment, harvest, storage, and pellet production. In each section, a table lists operating costs for that step. Labor requirements are listed, but no cost value is included (we assume that the labor is "free"). Equipment purchase costs (cost of a tractor, mower, etc.) are treated as fixed startup costs and only listed in the "Costs Summary" section at the end of the report. Land purchase costs are zero (the farmer already owned the land) and yearly costs for land are assumed to equal the annual property tax rate for the land. Equipment lubrication costs are assumed to equal 15 percent of fuel costs, and equipment maintenance costs are calculated based on guidelines from the American Society of Agricultural and Biological Engineers (2011).



GOOGLE 2014

Figure 5. Wood Crest Farm map.

Growing and Establishment

Switchgrass is an attractive energy crop because of its high yields and easy maintenance. The crop's productivity throughout its multiple growing seasons relies on the successful establishment of this perennial warm-season grass. Described below are the strategies used at Wood Crest Farms to ensure the successful establishment of switchgrass.

Seed Variety

Wood Crest Farms uses a combination of grasses to promote biodiversity, wildlife habitat, and crop health. In addition to switchgrass, Will uses a mixture of big bluestem, Indian grass, and wildflower seeds. It is also a good idea to add legumes into the seed mixture to provide nutrients and increase productivity. Other common species to incorporate are coastal panic grass,

cordgrass, showy tick trefoil, wild sienna, and partridge pea (Ernst Conservation Seeds 2014). At Wood Crest Farm, some of the fields remained a mix of species after planting and establishment, whereas others tended to become dominated by switchgrass after a few years.

Site Selection and Preparation

Switchgrass can grow on a wide variety of soil types, including marginal lands, but different varieties may be better adapted to different conditions, depending on the local climate, soil fertility, and soil moisture characteristics. Speak to your seed supplier before settling on a variety for your farm. Generally, it makes more sense to grow switchgrass on marginal ground instead of good land—returns from food crops on good land are usually much higher.

The most important step in site preparation is the elimination of competing grasses and weeds. Weed

▼ **Table 1.** Site preparation costs.

ITEM	UNIT	NUMBER PER ACRE	UNIT COST	ACRES	COST PER ACRE	TOTAL COST FOR 40 ACRES
Spraying in the Fall						
Tractor Operation	hours	0.375	\$0.75	40	\$0.28	\$11.25
Sprayer Operation	hours	0.375	\$0.21	40	\$0.08	\$3.15
Herbicide	per acre	1.000	\$30.00	40	\$30.00	\$1,200.00
Fuel	gallons	0.375	\$3.75	40	\$1.41	\$56.25
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.21	\$8.44
Labor	hours	0.375	\$0.00	40	\$0.00	\$0.00
				Total:	\$31.98	\$1,279.09
Spraying in the Spring						
Tractor Operation	hours	0.375	\$0.75	40	\$0.28	\$11.25
Sprayer Operation	hours	0.375	\$0.21	40	\$0.08	\$3.15
Herbicide	per acre	1.000	\$30.00	40	\$30.00	\$1,200.00
Fuel	gallons	0.375	\$3.75	40	\$1.41	\$56.25
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.21	\$8.44
Labor	hours	0.375	\$0.00	40	\$0.00	\$0.00
				Total:	\$31.98	\$1,279.09
Selective Disking (approx. 3 acres)						
Tractor Operation	hours	0.50	\$7.34	3	\$3.67	\$11.01
Disk Operation	hours	0.50	\$0.95	3	\$0.48	\$1.43
Fuel	gallons	0.93	\$3.75	3	\$3.49	\$10.46
Lube (15% of fuel cost)	n/a	n/a	n/a	3	\$0.52	\$1.57
Labor	hours	0.50	\$0.00	3	\$0.00	\$0.00
				Total:	\$8.16	\$24.47

Notes: Fuel use for herbicide spray is based on farmer measurements. Fuel use for other operations is based on typical fuel use rates from Helsen and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of purchasing land and/or equipment is not included in this table; however, those costs are discussed in the "Cost Summary" section of this report.

What Counts as Marginal Land?

Switchgrass is often touted as being a great crop for use on “marginal land.” So, what counts as marginal land? It turns out that many things could make a field “marginal,” but it generally comes down to whether or not the land is suitable for production of traditional food or feed crops. It could be that the soil has low fertility. It could be that the land is wet, droughty, steep, or highly erodible. However, it could also be that the owner’s situation makes the fields unsuitable for food production. In the case of Wood Crest Farm, the fields are in most respects quite good, but the farmer, being semi-retired, was not in a position to put intensive effort into the operation. That is what made this farm unsuitable for food or feed production, but suitable for switchgrass.

competition is the main enemy of healthy establishment in switchgrass. Therefore, it is important to minimize the presence of inhibiting plants. At Wood Crest Farm, Will applies glyphosate and 2,4-D herbicide in the fall season before planting and then again 2 weeks before planting in the spring. Will begins planting in the early spring, usually in April, once the risk of frost has passed. Immediately before planting, Will used a disk to selectively smooth out the soil in the few spots that had ruts. He did disc one of his smaller fields entirely—this was probably not necessary, and it seemed that the weeds were much more vigorous in that field, probably because the disking allowed more weed seeds to contact the soil and germinate.

Planting

One of the fields (13.5 acres) was thick with corn stubble, so Will had to mow it down before the no-till drill would work well in that field. Will also obtained a permit and burned two of the fields (10 acres) prior to planting. A no-till drill was then used to apply seed to the fields. It seemed that once the planter was

running well, the biggest time waste was when the machine had to be turned around to start a new row. From a planting point-of-view, fields that are long and narrow would probably be the most efficient.

Will uses a mixture of native grasses and wildflowers, not just switchgrass, to provide biodiversity in the field. The no-till drill is calibrated to the specific application rate of each species, which is listed in the table below. The seeds are planted in rows ¼ inch deep and with 7 inches between rows.

Table 2. Seed application rates.

SEED	APPLICATION RATE (POUNDS PER ACRE)
Switchgrass	7
Big Blue Stem	1
Indian Grass	1
Native Wildflowers	¼

Twenty-five acres of the fields were treated with a cultipacker after seeding. (A cultipacker is a ridged or textured roller that is pulled behind a tractor, pressing down the top layer of soil and improving seed-to-soil contact. Cultipackers are normally not needed for fields planted with a no-till drill, but if the drill is not planting seeds at a uniform depth, the cultipacker could conceivably help.) Will’s impression is that the cultipacked fields had better germination rates than the noncultipacked fields, but this was not carefully measured. Will was also impressed with how vigorously the switchgrass started in the fields that were burned prior to planting. However, those fields probably have the most fertile soils on the farm, so the good growth may be due to more than the initial burndown of the fields. Costs for planting include the cost of equipment maintenance, seed, labor, and fuel. In this case, the planter was provided free of charge by Pheasants Forever, a local conservation organization. As a result, Will’s maintenance cost for that equipment was zero.

Table 3. *Planting costs.*

ITEM	UNIT	NUMBER PER ACRE	UNIT COST	ACRES	COST PER ACRE	TOTAL COST FOR ALL ACRES
Mowing of One Field (13.5 acres)						
Tractor Operation	hours	0.50	\$2.06	13.5	\$1.03	\$13.91
Mower Operation	hours	0.50	\$2.48	13.5	\$1.24	\$16.74
Fuel	gallons	0.66	\$3.75	13.5	\$2.48	\$33.41
Lube (15% of fuel cost)	n/a	n/a	n/a	13.5	\$0.37	\$5.01
Labor	hours	0.50	\$0.00	13.5	\$0.00	\$0.00
				Total:	\$5.12	\$69.07
Burning of Two Fields (10 acres)						
Labor	hours	0.40	\$0.00	10	\$0.00	\$0.00
				Total:	\$0.00	\$0.00
Planting						
Tractor Operation	hours	0.30	\$2.06	40	\$0.62	\$24.72
No-till Drill Operation	hours	0.14	\$0.00	40	\$0.00	\$0.00
Switchgrass Seed	pounds	7.00	\$6.00	40	\$42.00	\$1,680.00
Bluestem Seed	pounds	1.00	\$1.00	40	\$1.00	\$40.00
Indian Grass Seed	pounds	1.00	\$1.00	40	\$1.00	\$40.00
Wildflower Seed	pounds	0.25	\$25.00	40	\$6.25	\$250.00
Fuel	gallons	0.43	\$3.75	40	\$1.61	\$64.50
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.24	\$9.68
Labor	hours	0.50	\$0.00	40	\$0.00	\$0.00
				Total:	\$52.72	\$2,108.90
Cultipacking (25 acres)						
Tractor Operation	hours	0.30	\$2.06	25	\$0.62	\$15.45
Cultipacker Operation	hours	0.30	\$0.18	25	\$0.05	\$1.35
Fuel	gallons	0.43	\$3.75	25	\$1.61	\$40.31
Lube (15% of fuel cost)	n/a	n/a	n/a	25	\$0.24	\$6.05
Labor	hours	0.30	\$0.00	25	\$0.00	\$0.00
				Total:	\$2.53	\$63.16

Notes: Operating time is based on farmer measurements. Fuel use is based on typical fuel use rates from Hessel and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs are based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of land use and/or equipment purchase is not included in this table; however, those costs are discussed in the “Cost Summary” section of this report.

Establishment

Switchgrass takes at least two years to establish, and activity during this time consists primarily of mowing for weed control. During this period, the switchgrass crop is spending most of its effort developing its deep and complex root structure, which can be 6 to 8 feet deep. As a result, there may not be a lot of visible growth above the surface. Switchgrass seeds are relatively small and known to germinate slowly. This leads to a slow and long establishment (Foster et al. 2013). In

fact, farmers who are growing switchgrass for the first time often think that they have a failed crop at the end of the first year since so little growth is visible.

Switchgrass’s slow initial growth makes weed interference a large inhibitor of switchgrass establishment. It is crucial to reduce weed competition during this growth phase. If the plant cannot establish its root system early on, it will yield less biomass in the early years of harvest. At Wood Crest Farm, the fields are mowed three times during the summer

of the first year (June, July, and August) with a rotary blade mower to reduce the amount of weed interference. Each time, Will is careful to set the height of the mower just above the height of the growing switchgrass. The mowing reduces competition for nutrients and moisture, and allows the switchgrass to receive more light during the day. Will strongly encourages farmers to use mowing as a weed control tool during the establishment of the crop. Usually by the second year the switchgrass is able to crowd out most weeds, but mowing during the first year makes a big difference.



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Figure 6. Switchgrass at the end of the first year.

Harvesting

The switchgrass is not harvested until its second year because it is developing its root zone during that first year, so there will not be enough growth to result in a reasonable harvest. At Wood Crest Farm, Will gets a reduced yield (only about one-third of the normal yield) in the second year and full harvests in following years. Harvesting at Wood Crest Farm is always done in the spring before new growth begins. This allows the switchgrass to transport nutrients from the leaves back down to the root zone while it is standing in the fields over winter. This process allows Wood Crest Farm to not apply fertilizers to the fields.

Mowing

The switchgrass is harvested with a flail chopper at Wood Crest Farms. There are a few reasons for this. First, it chops the switchgrass into 12- to 14-inch pieces as opposed to the full 6- to 8-foot length of the

Table 4. Establishment costs.

ITEM	UNIT	NUMBER PER ACRE	UNIT COST	ACRES	COST PER ACRE	TOTAL COST FOR ALL ACRES
Mowing (3 x 40 acres)						
Tractor Operation	hours	0.50	\$2.06	40	\$3.09	\$123.60
Mower Operation	hours	0.50	\$2.48	40	\$3.72	\$148.80
Fuel	gallons	0.66	\$3.75	40	\$7.43	\$297.00
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$1.11	\$44.55
Labor	hours	0.50	\$0.00	40	\$0.00	\$0.00
				Total:	\$15.35	\$613.95
Selective Spraying (18.5 acres)						
Tractor Operation	hours	0.375	\$0.75	18.5	\$0.28	\$5.20
Sprayer Operation	hours	0.375	\$0.21	18.5	\$0.08	\$1.46
Herbicide	per acre	1.000	\$30.00	18.5	\$30.00	\$555.00
Fuel	gallons	0.375	\$3.75	18.5	\$1.41	\$26.02
Lube (15% of fuel cost)	n/a	n/a	n/a	18.5	\$0.21	\$3.90
Labor	hours	0.375	\$0.00	18.5	\$0.00	\$0.00
				Total:	\$31.98	\$591.58
Land Cost, Year 1						
Taxes	per acre	1	\$25.00	40	\$25.00	\$1,000.00
				Total:	\$25.00	\$1,000.00

Notes: Operating time is based on farmer measurements. Fuel use is based on typical fuel use rates from Hiesel and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs are based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of land use and/or equipment purchase is not included in this table; however, those costs are discussed in the “Cost Summary” section of this report.

grass. This allows for easy baling. Second, the flail chopper tends to “draw up” stems that were pushed over by snow in the winter rather than leaving them on the ground unmowed. Third, the flail chopper tends to cut some very small pieces of leaf and stem that don’t get picked up by the baler, thus leaving some biomass behind on the field to be composted for next year’s crop.

The final reason is that the flail chopper is adjusted to leave 6 to 8 inches of the switchgrass on the plant instead of cutting it very close to the surface.

This protects the switchgrass plant from damage and helps ensure that the switchgrass stub will bend over during mowing to reduce the chance of tire puncture. Other types of mower (e.g., sickle bar, disc, rotary) have been used by other farmers and may be suitable depending on your particular situation.

Regardless of your mower type, be on guard against sparks or heat that could start a fire in the field. Switchgrass fields are dense, and when they are harvested dry, they are definitely flammable. The other safety issue to keep in mind is that dry switchgrass can kick up quite a bit of dust when harvested—using a dust mask or enclosed cabin could be a very good idea.



DANIEL CIOLKOSZ

Figure 7. Mowing the crop.

Raking and Baling

Once the switchgrass is cut, it is then raked into windrows for baling. Will uses both a round baler and a square baler. It was noted that the switchgrass has the tendency to clog the belts in the round baler. Because of this, you need to plan to stop periodically to clean the belts during harvesting to prevent clog-



DANIEL CIOLKOSZ

Figure 8. Clearing chaff from the round baler.



DANIEL CIOLKOSZ

Figure 9. A freshly made round bale.

ging. The round bales are good for storing large quantities of the grass. However, small square bales are easier to manage. The square bales are also preferred by some of Will’s customers who buy bales for use as mulch or bedding.

On April 17–18, 2014, measurements were made of the harvesting operations at Wood Crest Farm, includ-

ing the time and

labor required to rake and bale the crop. The results of this operation, displayed in Table 6, are normalized to show the amount of time Will spends per acre.

Fall or Spring Harvest?

Some farmers harvest their switchgrass in spring, while others harvest in the fall. Which is best? Fall harvest allows a more complete harvest (higher yield) and eliminates the problem of heavy snows pushing down (“lodging”) the crop. Spring harvest, however, usually results in the driest crop and gives extra time for nutrients to be leached out of the crop, back into the root zone. Some farmers try a combination approach—mowing in the fall, then leaving the biomass over winter to be baled in the spring. It’s hard to say which approach is best, and it might depend on available markets, the specifics of your farm, and how you choose to manage it.

Yield

Some researchers have reported switchgrass yields of up to and over 5 dry tons per acre. This may be possible in some locations, but experience at Wood Crest Farm has been that the actual yield from switchgrass is much lower—more like 3 dry tons per acre, with some fields producing more and some producing less. Three dry tons per acre corresponds to about 11 large round bales or 160 small square bales per acre.

Table 5. Harvesting costs.

ITEM	UNIT	NUMBER PER ACRE	UNIT COST	ACRES	COST PER ACRE	TOTAL COST FOR ALL ACRES
Mowing						
Tractor Operation	hours	0.50	\$2.06	40	\$1.03	\$41.20
Mower Operation	hours	0.50	\$2.48	40	\$1.24	\$49.60
Fuel	gallons	0.66	\$3.75	40	\$2.48	\$99.00
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.37	\$14.85
Labor	hours	0.5	\$0.00	40	\$0.00	\$0.00
				Total:	\$5.12	\$204.65
Raking						
Tractor Operation	hours	0.20	\$0.75	40	\$0.15	\$6.00
Rake Operation	hours	0.20	\$0.09	40	\$0.02	\$0.72
Fuel	gallons	0.24	\$3.75	40	\$0.90	\$36.00
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.14	\$5.40
Labor	hours	0.20	\$0.00	40	\$0.00	\$0.00
				Total:	\$1.20	\$48.12
Baling						
Tractor Operation	hours	0.55	\$4.04	40	\$2.22	\$88.88
Baler Operation	hours	0.55	\$7.70	40	\$4.24	\$169.40
Fuel	gallons	0.80	\$3.75	40	\$3.00	\$120.00
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.45	\$18.00
Labor	hours	0.55	\$0.00	40	\$0.00	\$0.00
				Total:	\$9.91	\$396.28
Land Cost						
Taxes	per acre	1.00	\$25.00	40	\$25.00	\$1,000.00
				Total:	\$25.00	\$1,000.00

Notes: Operating time is based on farmer measurements. Fuel use is based on typical fuel use rates from Hiesel and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs are based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of land use and/or equipment purchase is not included in this table; however, those costs are discussed in the “Costs Summary” section at the end of this report. Land tax is based on farmer experience and a survey of similar properties in the area.

Table 6. Time of field operations.

	TIME TO MOW (MINUTES/ACRE)	TIME TO RAKE (MINUTES/ACRE)	TIME TO BALE (MINUTES/ACRE) ¹	COMMENTS
Measured Values	46	17	54	Field shows lodging. Stems lying on the ground from previous winter.
Textbook Values ²	10	8	14	These numbers are pretty quick and probably only apply to very large fields, highly experienced operators, and equipment that is in perfect condition
Values Used for This Case Study	30	12	33	These numbers are a compromise between the very slow going measured in 2014 and the book values. They represent a reasonable estimate of how quickly operations usually proceed at the farm.

Notes:

1. The bale chain broke during operation, so the baling process was finished for the day after. In 16 minutes two round bales were made weighing 560 and 630 pounds each.
2. Data for mower conditioner, rake, and rectangular baler, and 12-foot swath from the American Society of Agricultural and Biological Engineers (2011).

Storage

After harvest, the baled grass is stored until ready for pellet production. Will uses a tractor with a bale spear to move the bales to a storage area near the barn. One purpose for this is that the optimal moisture content for switchgrass pellets is between 12 and 15 percent and the bales

come off the fields at a moisture content of 6 to 8 percent. As they sit in the open air, the bales tend to absorb a bit of moisture, bringing them closer to the optimum

level for pellet production. Will stores most of the switchgrass outside. According to Will, indoor storage does not affect the moisture content as much as outdoor storage. Will has stored bales on the ground under the open air, but he now prefers to use old pal-



DANIEL CIOLKOSZ



DANIEL CIOLKOSZ

Figure 10. Old unused bales (left) and newer tarped bales in storage (right).

lets or steel siding to keep the bales off the ground, and he obtained some reclaimed rubber roofing to use as tarps to keep the bales from getting too wet. The rubber roofing is heavy enough that it doesn't have to be tied down in the wind.

When the bales are stored outside there is some loss to spoilage, but Will reports that it is minimal. The

outmost layer of the round bail gets wet and soggy, but the interior remains in good condition. Will has found that, even after a few years, round bales that are stored outside still pelletize well

with limited losses from rotting. Limited indoor storage space is one reason Will stores the bales of switchgrass outside; it is much more cost effective to store the switchgrass outdoors. We have assumed a 10 percent mass loss in this study.

Table 7. Cost of storage.

ITEM	UNIT	NUMBER PER ACRE	UNIT COST	ACRES	COST PER ACRE	TOTAL COST FOR ALL ACRES
<i>Handling/Storage</i>						
Tractor Operation	hours	0.25	\$2.06	40	\$0.52	\$20.60
Fuel	gallons	0.66	\$3.75	40	\$2.48	\$99.00
Lube (15% of fuel cost)	n/a	n/a	n/a	40	\$0.37	\$14.85
Labor	hours	0.25	\$0.00	40	\$0.00	\$0.00
				Total:	\$3.36	\$134.45

Notes: Operating time is based on farmer measurements. Fuel use is based on typical fuel use rates from Hessel and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs are based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of land use and/or equipment purchase is not included in this table; however, those costs are discussed in the "Cost Summary" section at the end of this report.

“I love to repurpose things. If I can find a way to reuse something in a different way, that excites me.”

WILL BRANDAU

Pellet Production

Once it is time to begin producing pellets, Will first takes the switchgrass bales and grinds them in a bale buster, which rotates and chops the bales, producing a coarse-ground material. From there, the switchgrass goes into a ¼-inch-screen hammer mill. The switchgrass is then placed in super sacks for storage. Wood Crest Farm uses a 55-horsepower diesel pellet mill to form the pellets. (See Appendix A for more information about the pellet mill.) Will suggests that a three-phase electric pellet press would be more cost effective than his diesel pellet press, but three-phase power was not available at the farm. The machine at Wood Crest Farm has produced at most 400 pounds (182 kg) of switchgrass pellets in one hour, although its rated capacity is 1,500 pounds per hour.

Table 8. Pelletizer performance.

PERFORMANCE RATING	PRODUCTION RATE (KG HR ⁻¹)
Poor	16.8
Typical	90
Best	182
Machine Rating	682

At Wood Crest Farm, Will adds switchgrass material as soon as he turns the machine on. Pellets may not form immediately while the machine is warming up. Will takes the unpelletized “fines” and re-adds them to the feeder until he starts getting pellets. The heat needed to form the pellets comes from the friction of the material running through the system, so it may take a little while before the machine begins to produce pellets. It takes about 10 minutes for Will’s machine to start producing pellets. He can tell it is ready when the machine starts to produce steam.

During June 2013, a team of students measured the pelleting process at Wood Crest Farm. Their findings were that the pelletizer produced only 16.8 kilograms of pellets per hour. That is quite slow—only 9 percent of the peak rate that Will has achieved in the past, and a mere 2.5 percent of the rated output of the machine. This slow production rate was due to the time needed to warm up the machine and to adjust the operating conditions until the pelletizer started working properly. This illustrates a vital point that farm pellet manufacturers need to understand: it is very difficult to get high output from pelletizers, and you will probably never come close to achieving the machine’s rated output. Keep that in mind so that you are not sorely disappointed when you find out how much time it takes to make pellets.

How Do Pellets Form?

Most pelletizers work by using a steel roller to force ground biomass through holes in a thick metal die. But why does this cause the ground material to turn into a pellet? Well, the ground biomass is compressed when this happens, and a great deal of heat is also produced. If it gets hot enough (~80°C), the lignin in the biomass will start to get soft and tacky, and serves as a natural “binder” to hold the ground particles together in its dense pellet shape. If all goes well, by the time the biomass is pushed out the far end of the die, it will have formed a dense pellet.

All naturally occurring wood and grasses contain lignin, but wood tends to have a higher fraction of lignin—about 22 to 24 percent by mass (switchgrass is typically 12 to 15 percent). However, even though grasses are lower in lignin, experiments have shown that they still form high-quality pellets without the use of extra binders.



DANIEL CIOLKOSZ

Figure 11. Equipment used for making pellets at Wood Crest Farm: (a) bale grinder and hammer mill, (b) ground switchgrass for pelleting, (c) pelletizer, (d) cooling rack.

One of the main reasons the production rate is so low relative to the rated output has to do with the feedstock—switchgrass is known to be slow to pelletize. It could also be that the rated output of the machines is somewhat overly optimistic. Regardless of the reason, the low production rate and the variable production rate from day to day can be a real challenge. Will has not tried to automate his system yet, in large part due to the variability in pelletizer performance. He often needs to be on hand to tweak the system to keep things running. Another important point to stress is that it takes time and practice to learn how to operate a pelletizer well. You will probably spend

quite a while making mistakes before you finally start making pellets, and it will be a while after that before you get good at it. A hammer and punch is handy to have for those times when the die gets clogged.

Will suggests that having the right moisture content yields the best results. If the switchgrass is too dry, Will adds water to it until he reaches the desired moisture content. He hasn't carefully controlled moisture content yet, but the bales, which are about 4 to 7 percent moisture, are definitely too dry. Most recommendations state that feedstock moisture content should be in the 12 to 18 percent range. In addition to water, Will has tried adding lime, but that didn't seem to help.

Table 9. Pellet production costs.

ITEM	UNIT	UNITS PER TON OF FEEDSTOCK	UNIT COST	TONS PER YEAR	TOTAL COST PER TON OF FEEDSTOCK	TOTAL COST
Barn Use	n/a	n/a	\$0.00	108	\$0.00	\$0.00
				Total:	\$0.00	\$0.00
Grinding						
Tractor PTO for Grinder	hours	1.12	\$2.06	108	\$2.31	\$249.18
Fuel	gallons	1.48	\$3.75	108	\$5.55	\$599.40
Lube (15% of fuel cost)	n/a	n/a	n/a	108	\$0.83	\$89.91
Grinder Operation	hours	1.12	\$3.60	108	\$4.03	\$435.46
Labor	hours	1.12	\$0.00	108	\$0.00	\$0.00
				Total:	\$12.72	\$1,373.94
Hammer Milling						
Hammer Mill Operation	hours	1.12	\$0.22	108	\$0.25	\$26.61
Fuel	gallons	0.59	\$3.75	108	\$2.21	\$238.95
Lube	n/a	n/a	n/a	108	\$0.33	\$35.84
Labor	hours	included in grinding task	\$0.00	108	\$0.00	\$0.00
				Total:	\$2.79	\$301.40
Pellet Making						
Pellet Mill Operation	hours	10.0	\$0.05	108	\$0.51	\$55.08
Die Replacement	hours	10.0	\$0.40	108	\$4.00	\$432.00
Fuel	gallons	12.1	\$3.75	108	\$45.38	\$4,900.50
Lube	n/a	n/a	n/a	108	\$6.81	\$735.08
Labor	hours	10.0	\$0.00	108	\$0.00	\$0.00
				Total:	\$56.69	\$6,122.66
Drying and Bagging						
Sacks for Pellets	number of super sacks	5.0	\$0.00	108	\$0.00	\$0.00
Labor	hours	1.0	\$0.00	108	\$0.00	\$0.00
				Total:	\$0.00	\$0.00

Notes: Operating time is based on farmer measurements. Fuel use is based on typical fuel use rates from Hiesel and Oguntunde (1985) and published in Grisso et al. (2010). Equipment used for each operation is listed in the appendix. Lube cost is assumed to equal 15 percent of fuel cost per Edwards (2009). Maintenance costs are based on the American Society of Agricultural and Biological Engineers (2011) and reported in Edwards (2009). The cost of land use and/or equipment purchase is not included in this table; however, those costs are discussed in the "Cost Summary" section at the end of this report.

Having the rollers and the die at the right tightness is another important element. This setting will vary from machine to machine. After some experimentation, Will found that if he puts three sheets of thin cardboard (from a case of soda cans) between the die and roller and then tightens the rollers down with a wrench, the resulting spacing is perfect for his machine.

Another thing that helps is to have some “soft” biomass on hand for when you are ready to shut down; add a scoop of ground soybeans or dried distillers grains to the machine and let it run through the die. That way, switchgrass won’t be in the die to cool, harden, and form a very hard plug.

The pellets they are very warm and soft once they come out of the press, so they are placed on screen racks to cool and harden. They are stored in super sacks and bagged as needed for shipping. Will receives the super sacks from a local pet store, which receives pet food in the super sacks and then gives them to Will to reuse instead of throwing them away. This saves Will about \$15 per bag.

Cost Summary

The cost of a switchgrass operation will vary from farm to farm because some of the equipment may already be readily accessible without the need for purchase. This section summarizes costs for Wood Crest Farm and provides a typical range of costs that other farmers might encounter depending on their situation. The costs associated with switchgrass growth and pellet production are classified here as either a fixed cost or variable cost that depends on the size of operation. The grant and assistance programs that Wood Crest Farms received will also be considered in the total cost.

Fixed Costs

Fixed costs are the amounts paid for equipment, material, etc. It does not depend on farm size, within reason. The tractors and field implements were mostly purchased used, which helped keep costs down.

The barn and land are already owned, so there were no fixed costs for purchasing the farm or building the barn. If the farm were not already owned, the purchase cost of the land (or rental cost, if rented) would have to be factored in as well. In the region, land costs of \$1,000 to \$2,000 per acre for tillable land are not uncommon, and land rental rates as high as \$150 per acre per year have been seen.

Table 10. Fixed startup costs—equipment.

EQUIPMENT	BRAND	COST AT WOOD CREST FARM
Tractors		
Discing, Planting, Baling	International 1086	\$9,000
Mowing	International Super C	\$4,000
Spraying, Raking	Ford 1300	\$6,500
Bale Grinding	NorTrack Diesel	\$4,000
	Total:	\$23,500
Field Implements		
Sprayer		\$625
No-Till Drill	Loaned by Pheasants Forever	\$0
Flail Mower	AVCO/New Idea Cut/ditioner	\$600
Wheel Rake	Tonutti P4/94 on a Ford 1300 tractor	\$900
Round Baler	Gehl bale1500	\$1,500
Square Baler	Sperry New Holland 273	\$900
	Total:	\$4,525
Pelleting Equipment		
Barn	Wood Post Frame Traditional Barn	n/a
Bale grinder	Kidd Bale Chopper 5-4	\$4,000
Hammer Mill		\$1,600
Pellet Mill	55-hp Diesel Unit	\$5,200
Augers and Conveyors	For automating pellet process	\$2,600
Spare Parts		\$700
Shipping		\$2,000
	Total:	\$16,100

Variable Costs

Here, variable costs are assumed to be the expenses that change depending on the size of the operation. Variable costs can be part of the startup or part of regular operations. Keep in mind that fuel rates will change from region to region and also labor prices will vary. The costs listed here are scaled “per acre” as well as the total for the farm.

Table 11. Variable one-time startup costs.

	PER ACRE	TOTAL
Site Prep	\$72.11	\$2,582.64
Planting	\$60.37	\$2,241.12
Establishment	\$72.33	\$2,205.53
Total:	\$204.80	\$7,029.29

Table 12. Variable operating costs (per year).

	PER ACRE	TOTAL
Harvest	\$41.23	\$1,649.05
Storage	\$3.36	\$134.45
Pelleting	\$194.95	\$7,798.00
Total:	\$239.54	\$9,581.50

Table 13. Variable operating costs by category (per year).

ITEM	PER ACRE	TOTAL
Fuel and Lube (Tractors, Mills)	\$175.17	\$7,006.78
Equipment Upkeep	\$39.37	\$1,574.72
Labor	\$0.00	\$0.00
Land Cost	\$25.00	\$1,000.00
Buildings, Packaging	\$0.00	\$0.00
Total:	\$239.54	\$9,581.50

Grants and Assistance

Starting up a new farm operation can be very expensive, so Will tapped into some funding resources to help offset the cost of his operation. Specifically, Will received grant money through the REAP, EQIP, and WHIP grants. These grants were received at the beginning of the project at Wood Crest Farms. Will does not receive any type of yearly funding; these grants have aided in the startup funding, but farm production has had to be self-sustaining since.

The Rural Energy for America Program (REAP) is a financial assistance program supported by the United States Department of Agriculture (USDA) to help agricultural producers and rural small businesses purchase, install, and construct renewable energy systems. This grant provided Will with 25 percent of the pelleting equipment cost. According to Will, the process

of filing for this program was the lengthiest of all the programs with the final application consisting of 25 pages. After Will's application was processed, a member of the Conservation Commission came out to do a field inspection.

The second grant Will received for Wood Crest Farms was the Environmental Quality Incentives Program (EQIP) grant, which is a conservation grant promoted through the USDA's Natural Resources Conservation Service (NRCS). EQIP provides financial and technical assistance to farmers and other landowners to help them improve wildlife habitat, air quality, and water quality. This program provided the funds to allow Will to plant 25 acres of grass. In order to receive this funding, Will had to create a conservation plan, also known as the EQIP plan of operations. With the help of a biologist from the NRCS, they were able to put this document together.

Table 14. Funding support.

GRANT SOURCE	AMOUNT PER ACRE	NUMBER OF ACRES	TOTAL
EQIP, Year 1	\$350	25	\$8,750
EQIP, Year 2	\$180	25	\$4,500
EQIP, Year 3	\$180	25	\$4,500
WHIP	\$380	15	\$5,700
REAP	n/a	n/a	\$4,000
		Total:	\$27,450

The final grant Will utilized for his operations was the Wildlife Habitat Incentive Program (WHIP). This grant provided funding for Will to plant 15 acres of grass. However, this program was merged with the EQIP grant after the latest Farm Bill. Funding for this type of conservation effort can be received through the EQIP program.

In conclusion to this section, Will recommends that farmers consider the timeline from application to collection of funds. In the case of Wood Crest Farms, it took a long time for Will to hear back about his applications. The granting agencies took as much as two to three years to clear the system and send the funds to Will.

“Switchgrass can be a substitute for almost any application of baled hay.”

WILL BRANDAU

Total Costs

The total cost of the pelleting operation (broken down according to fixed costs) and operating costs for each of the major steps in the process is shown below.

Table 15. Total costs.

	AMOUNT PER ACRE	TOTAL COST
Startup Costs		
Fixed: Equipment	\$863.13	\$44,125.00
Variable: Site Prep	\$72.11	\$2,582.64
Variable: Planting	\$60.37	\$2,241.12
Variable: Establishment	\$72.33	\$2,205.53
<hr/>		
Grant Support	-\$686.25	-\$27,450.00
Net Total		\$23,704.29
<hr/>		
Ongoing Costs (per year)		
Variable Costs		
Harvest	\$41.23	\$1,649.05
Storage	\$3.36	\$134.45
Pelleting	\$194.95	\$7,798.00
Total	\$239.54	\$9,581.50

Cost per Ton

If we consider that the yield is 3 tons per acre, with 10 percent storage loss, and a final moisture content in the pellet similar to that of the original feedstock, we end up with a total production of 2.7 tons of pellets per acre, which corresponds to \$88.72 per ton. (Remember that this cost does not include any labor, does not account for paying back equipment or land costs, has zero profit margin, and assumes that 100 percent of pellets are sold.) Most of the cost (about 80 percent) is due to the pelleting operation itself, with the remainder due to field operations. If you break down the costs according to the type of expense, you find that most of Will’s expenses (over 70 percent) are for fuel and lube costs.

This calculation assumes no labor costs, no cost for using the barn, and land costs only equal to the annual tax rate for the land. Will is fortunate to have those resources available for his operation. If not, the costs would be much higher. For example, a labor cost of \$10 per hour would increase production costs to \$215 per ton. A land cost of \$150 per acre (but no labor

costs) would increase production costs to \$135 per ton. Combining the \$10 per hour for labor and the \$150 per acre for land would result in a production cost of \$261 per ton. As you can see, the availability of low-cost land, labor, and other facilities can make a huge difference to the bottom line.

This calculation also assumes that all of the switchgrass is harvested and pelletized. If all of the switchgrass is harvested but only half is pelletized, the production cost rises to \$105 per ton of pellets. Since the market for grass pellets is still somewhat limited, it makes sense to think about potential markets for the baled and ground material as well as the pellets.

Markets for Switchgrass, Pelletized or Not

The intended end market for switchgrass is in pellets or briquettes to be used as residential or industrial heating fuel. Pellet stoves can provide very efficient heating that is much less expensive for the owner than a petroleum-based product. People’s actual cost savings when switching to pellets will vary depending on the fuel they are currently using and the price they are paying, but in most cases, the savings is significant. Figure 12 shows how much savings people can expect when switching from fuel oil or propane to grass pellets. Fuel oil and propane are two common heating fuels in the Northeast United States, especially in rural areas.

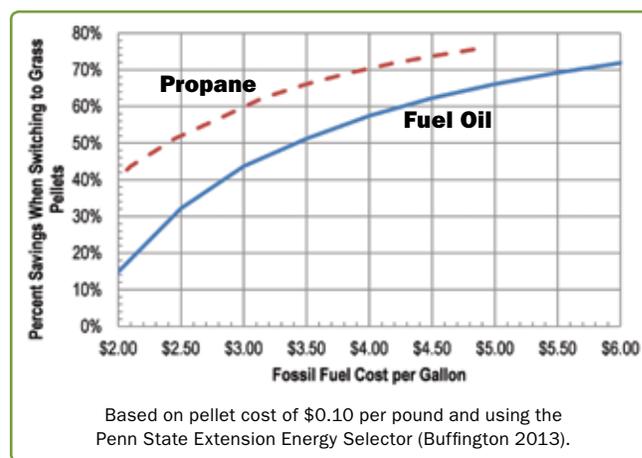


Figure 12. Cost savings from switching to grass pellets.

The industry is relatively new, so it will take time to convince people that grass pellets are a good replacement for wood and petroleum. So far, Will has been his own best customer for home heating with grass pellets. Since he is able to make much more than he needs for himself, Will has looked to other market opportunities in order to maximize sales and profits from his switchgrass production operation. This includes both energy and nonenergy uses of the material.

Mulch Markets

Will sells the baled or shredded switchgrass to local businesses and farms. Ground switchgrass is a great product for mulching lawns and as a wood mulch substitute in gardens. Will sells the switchgrass to a local landscaper and a hardware and garden store. According to his customers, they enjoy the switchgrass because it's cheaper than the products they were previously using on lawns and gardens and works just as well if not better. Will also mentioned that the square bales of switchgrass sell better than the round bales for landscaping applications because it is easier to handle in that form. People are often unsure about using switchgrass for mulch, but once they have tried it and see how it performs, they tend to become great enthusiasts and promote it to others.



DANIEL CIOLKOSZ

Figure 13. *Switchgrass—baled, ground, or pelletized—makes an excellent mulch.*

Animal Bedding

Another market for ground switchgrass is animal bedding. Will sells his product to a few beef cattle farms in the area. He also sells quite a large amount of the ground grass to chicken farmers to be used as coop bedding. Farmers have reported back to Will that they need to change their bedding less often, and have better performance than with other bedding materials.

Absorbents

Other switchgrass growers have found that switchgrass pellets can be made purposely loose and sold as an absorbent. Switchgrass can be used on construction sites that require erosion control. It can also be used

for municipal purposes to direct rainfall runoff. It seems the needs of switchgrass will vary by region and what markets flourish there. Creativity and persistence have allowed Will to find buyers for his product.

Large Customers

One of the upcoming ideas in switchgrass pelleting is switchgrass co-ops for large-scale fueling. If multiple growers and producers collaborate and combine their efforts, they could serve large clients such as schools, hospitals, industries, etc. Proceeds would be divided among all the farmers and they would have a steady client base and a consistent revenue stream. Will has attempted this type of model, but unfortunately, problems with briquetter performance prevented that effort from succeeding.

Conclusions

In conclusion, starting up a new switchgrass pellet operation can be a way to generate income using marginal lands to create sustainable biomass energy. Switchgrass will require a bit of land, but it only needs to be planted one time, and then once the crop becomes established, it will continue to grow and require relatively little maintenance. It can be harvested yearly and used in a variety of markets. The switchgrass can be pelletized using some specialized equipment to be used as a heating fuel or it can be sold as a mulching material in baled or ground form.

Switchgrass has the ability to create an entirely new revenue stream for a crop that requires a relatively small amount of input. There are many uses for the crop. For example, it can be grown as a buffer alongside traditional crops, such as soybeans or corn. There are many energy and nonenergy uses for switchgrass, but it's a matter of finding the local markets. Will Brandau has taken the risk of beginning a switchgrass farm in order to heat his own home with a renewable energy source, provide others with this clean source of energy, and be a pioneer so others can learn from his experiences to grow and make switchgrass pellets themselves.

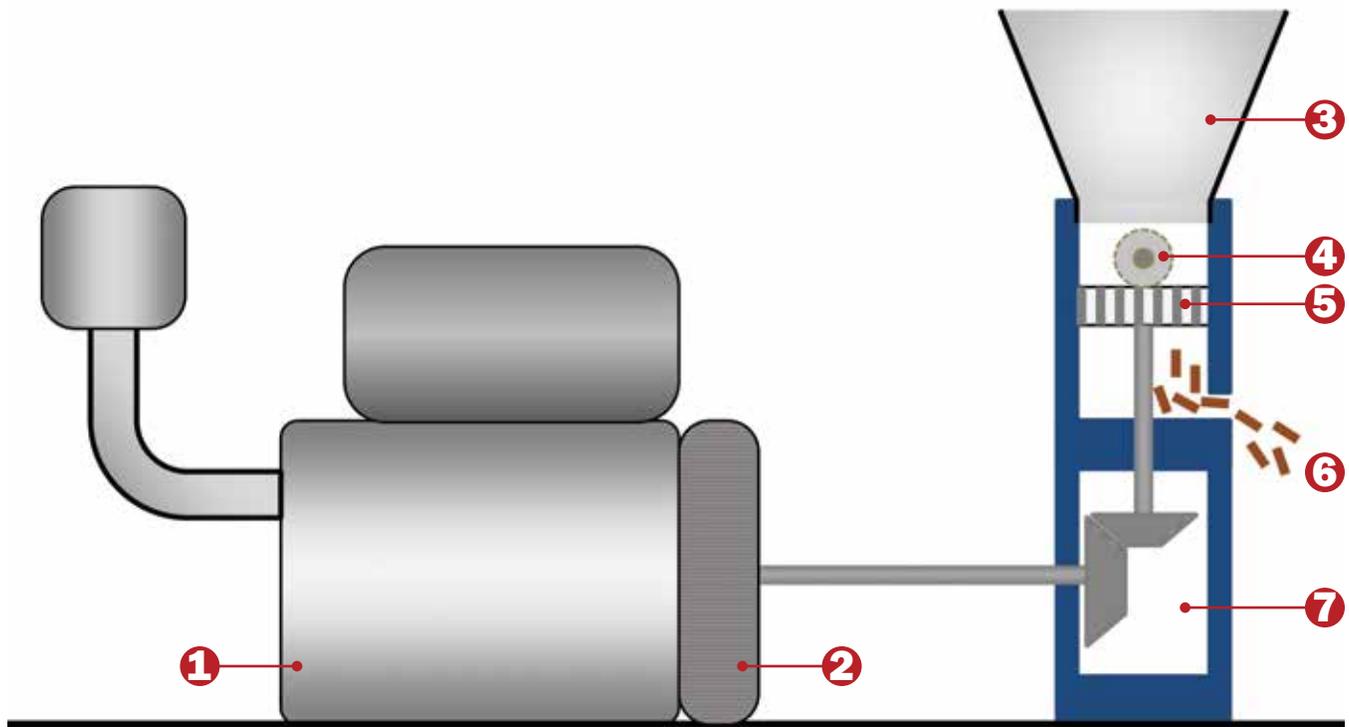
The cost of growing and making switchgrass pellets at Wood Crest Farm is about \$89 per ton. However, this does not include any labor costs or count the significant startup costs that Will is paying off over time. Other farmers may find their costs to be higher or lower depending on the specifics of their situation.

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Appendixes

Appendix A: Pellet Press Diagram



- 1** diesel engine
- 2** clutch
- 3** infeed hopper
- 4** rollers

- 5** die
- 6** pellets exiting pelletizer
- 7** gear box

The feedstock is loaded into the infeed hopper and forced through to the die, where the heat and pressure of the machine press the switchgrass into a cylindrical shape and the natural lignin of the switchgrass starts to melt. This acts as the glue that holds the pellets together.

Appendix B: Schedule of Operations at Wood Crest Farm

	Field Operations	Storage	Pellet Production	
Year 1	SEP	Spray		
	OCT			
	NOV			
	DEC			
	JAN			
	FEB			
	MAR			
	APR	Spray, disc if needed		
	MAY	Plant		
	JUN	Mow weeds		
	JUL	Mow weeds		
	AUG	Mow weeds		
SEP				
OCT				
NOV				
DEC				
Year 2	JAN			
	FEB			
	MAR			
	APR			
	MAY			
	JUN			
	JUL			
	AUG			
	SEP			
	OCT	Admire the fine fields		
	NOV			
	DEC			
Year 3	JAN			
	FEB			
	MAR			
	APR	Partial harvest		
	MAY	Spray, if needed	Store bales on site	Make Pellets
	JUN			
	JUL			
	AUG			
	SEP			
	OCT			
	NOV			
	DEC			
Years 4-20	JAN			
	FEB			
	MAR			
	APR	Harvest	Store bales on site	
	MAY			
	JUN			
	JUL			
	AUG			
	SEP			
	OCT			
	NOV			
	DEC			

Appendix C: Equipment List for Wood Crest Farm

The following list shows which pieces of major equipment are used for the different operations at the farm. Note that some tractors are used for multiple tasks.

<i>Spraying Operations</i>	
Tractor	Ford 1300, 160-hp Diesel 2WD
Sprayer	NorthStar 3-Pt. Broadcast and Spot Sprayer (55 Gallon)
<i>Discing Operations</i>	
Tractor	International 1086, 131-hp Diesel 2WD
Discer	(not recommended by farmer for use)
<i>Planting Operations</i>	
Tractor	International 1086, 131-hp Diesel 2WD
Planter	No-till drill
<i>Mowing Operations</i>	
Tractor	International Super C 24-hp 2WD
Mower	New Idea/ Avco Cut-ditioner
<i>Raking Operations</i>	
Tractor	Ford 1300, 16 hp Diesel 2WD
Rake	Tonutti P4/94
<i>Baling Operations</i>	
Tractor	International 1086, 131-hp Diesel 2WD
Baler	Gehl Gehlbale 1500
<i>Bale Handling Operations</i>	
Tractor	International Industrial 2410 w/bale spear
<i>Pelleting Operations</i>	
Tractor (to run bale grinder)	Nortrac 25XT 25-hp Diesel 4WD
Bale Grinder	Kidd Bale Chopper 4-5
Hammer Mill	22-hp Diesel Hammer Mill
Pelletizer	55-hp Diesel Pellet Mill

Appendix D: Acknowledgments and Contact Information

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On-Farm Production of Biomass Grass Pellets

A Case Study of **Wood Crest Farm** in Wapwallopen, Pennsylvania

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