V(A). Planned Program (Summary)

Program # 2

1. Name of the Planned Program

Biologically Based Materials and Products

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
101	Appraisal of Soil Resources	0%		2%	
102	Soil, Plant, Water, Nutrient Relationships	5%		3%	
112	Watershed Protection and Management	4%		3%	
123	Management and Sustainability of Forest Resources	6%		12%	
131	Alternative Uses of Land	2%		4%	
201	Plant Genome, Genetics, and Genetic Mechanisms	3%		7%	
205	Plant Management Systems	7%		4%	
211	Insects, Mites, and Other Arthropods Affecting Plants	6%		3%	
213	Weeds Affecting Plants	6%		3%	
216	Integrated Pest Management Systems	9%		4%	
302	Nutrient Utilization in Animals	4%		2%	
307	Animal Management Systems	8%		4%	
315	Animal Welfare/Well-Being and Protection	6%		3%	
402	Engineering Systems and Equipment	3%		9%	
404	Instrumentation and Control Systems	3%		5%	
511	New and Improved Non-Food Products and Processes	4%		13%	
512	Quality Maintenance in Storing and Marketing Non-Food Products	2%		5%	
601	Economics of Agricultural Production and Farm Management	9%		4%	
602	Business Management, Finance, and Taxation	7%		5%	
608	Community Resource Planning and Development	6%		5%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	{NO DATA ENTERED}	{NO DATA ENTERED}	{NO DATA ENTERED}	{NO DATA ENTERED}
Actual Paid	12.6	0.0	1.9	0.0
Actual Volunteer	25.6	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
1951697	0	319698	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
2721933	0	684487	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
2084890	0	1130200	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research into biologically based materials and products includes work toward the formation of a more durable biofeedstock through better understanding of the microscale mechanics of pelletizing materials common to the Northeast. Researchers also examined the effect of time of harvest of switchgrass on amount of energy consumed in baling, and analyzed 200 site-years of field data to determine the average sustainable removal rates for bioenergy corn stover across the country, as well as associated rates of N, P, and K removal. Other scientists are investigating and developing sustainable technologies to convert biomass resources into chemicals, energy, materials, and other value-added products.

This planned program also includes research into nascent technologies that are farther from commercial-ready, such as semicontinous bacterial cellulose production in a rotating disk biofilm bioreactor. Over the long term, research such as this may help us transition from sequestered-carbon energy sources such as oil, natural gas, and coal, to more renewable energy systems.

Extension work included support for the first commercial energy willow harvest ever in PA; making specialized willow planting and harvesting equipment available for use by farmers; facilitating a switchgrass energy purchase agreement for a Pennsylvania farmer to supply the first known commercial "bale burner" in the region; facilitating the sale of $120,000 of alternative energy credits for PA renewable energy producers; and organizing and hosting on-site field days, demonstration site tours, individual site visits, and other on-site educational opportunities, as well as webinars, newsletters, and other online outreach programs.

2. Brief description of the target audience

Agricultural Producers/Farmers/Landowners
Agriculture Services/Businesses
Nonprofit Associations/Organizations
Business/Industry
Community Groups
Education
General Public
Government Personnel
Local, Regional, State, and Federal agencies
Military
Policy Makers

3. How was eXtension used?

The bioenergy extension team worked with the Farm Energy COP to deliver materials, especially for regional efforts. They used eXtension materials for referrals and resource material, and provided peer review of eXtension materials.

Penn State Cooperative Extension supports faculty and staff use of eXtension and promotes communities of practice as a way of broadening sources of information and outreach. Penn State Cooperative Extension supports the professional development offered through eXtension.org.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	34282	759106	9718	3214

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year: 2014
Actual: 0

Patents listed

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	31	19	50

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of participants in extension education classes and workshops.

Year	Actual
2014	38191

Output #2

Output Measure

- Number of technology disclosures involving college faculty, staff, extension educators, or students.

Year	Actual
2014	0

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Work toward better understanding of the microscale mechanics of pelletizing biofeedstock materials common to the Northeast, with the goal of forming a durable pellet.
2	Finding that fall-harvested switchgrass consumes less energy to compress into bales than does spring-harvested switchgrass due to changes in properties of switchgrass over winter.
3	Supported the first commercial energy willow harvest ever in Pennsylvania.
4	Quantified average sustainable bioenergy corn stover removal rates for 36 sites across the country using 200 site-years of field research data.

Outcome #1

1. Outcome Measures

Work toward better understanding of the microscale mechanics of pelletizing biofeedstock materials common to the Northeast, with the goal of forming a durable pellet.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Agriculture is the second largest producer and user of products in particulate form. The U.S. particulate industry is valued at over $1 trillion and growing. Plants that handle and process solids generally operate at average efficiency of 64% vs. 90% for liquid/gas plants. For the bioenergy sector to compete effectively with other fuel sources, every stage of biomass processing must be at efficiencies comparable to currently dominant fossil fuels.

What has been done
Three Northeast bioenergy crops--corn stover, switchgrass, and willow--were ground to two sizes (3.175 mm and 6.35 mm) and were conditioned at two levels of moisture content (17.5% and 20%). Various tests of pellet durability were run on the three materials.

Results
Pellet durability for the three materials was more than 80%. The pelletization process compressed the loose material nearly 12- to 14-fold for corn stover, 7- to 9-fold for switchgrass, and 5- to 7-fold for willow. The achieved relative pellet densities were 96-98% for corn stover, 67-88% for switchgrass, and 91-98% for willow. Diametral tensile strength of pellets was 4-5.8 MPa for corn stover, 0.9-3.8 MPa for switchgrass, and 0.8-5.7 MPa for willow. Axial compressive strength was 8-11.5 MPa MPa for corn stover, 0.8-5.7 MPa for switchgrass, and 1.5-8.5 MPa for willow. These results improve our understanding of how to make a durable pellet using these three bioenergy materials, and point to issues needing further research and development.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
511	New and Improved Non-Food Products and Processes

Outcome #2

1. Outcome Measures

Finding that fall-harvested switchgrass consumes less energy to compress into bales than does spring-harvested switchgrass due to changes in properties of switchgrass over winter.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The greatest challenges in biomass logistics are transportation and storage costs. Current transportation costs are as high as $0.18-$0.40 per km/Mg for truck, rail, pipeline, and barge transport. Storage costs are usually greater than $15/Mg. These costs become substantial when massive quantities of biomass must be transported and stored. Maximizing the transportation and storage efficiencies through densification is critical.

What has been done
Switchgrass may be harvested in fall or early spring, depending on weather conditions and other issues. To reduce storage space demand and increase transportation efficiency, harvested switchgrass should be densified. Research was conducted to examine energy consumption of compressing switchgrass collected from different harvesting seasons. Lab compression tests quantified the energy requirements needed for switchgrass compression. The work appeared in American Journal of Plant Sciences.

Results
Switchgrass moisture content had no effect on energy required to compress switchgrass when only dry matter bulk density was accounted for. Wetter switchgrass could be compressed to higher wet bulk density for any given pressure. When baling switchgrass, moisture content did not influence dry matter bulk density of bales. Bales with higher moisture content have higher wet

bulk density.

Time of year of switchgrass harvest greatly affects biomass characteristics. Compression testing showed that decreased leaf matter caused the spring-harvested switchgrass to be much harder to compress than fall-harvested. Switchgrass fields harvested in fall yield more dry matter, and the material can be formed into denser, large square bales, indicating higher quality over long-term storage.

Specific energy requirements calculated from the lab compression tests showed that the energy consumed by large square balers and bale compressors will be much less if harvest and baling is done in fall than in spring.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
511	New and Improved Non-Food Products and Processes
601	Economics of Agricultural Production and Farm Management

Outcome #3

1. Outcome Measures

Supported the first commercial energy willow harvest ever in Pennsylvania.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Renewable energy resources, especially biomass sources, are gaining a foothold in Pennsylvania, and the bioenergy extension team is supporting these efforts on several fronts.

What has been done

The team is supporting biomass crop farmers with equipment, knowledge, and connections to renewable energy producers. For example, they organized a field tour and provided technical support for the first ever commercial energy willow harvest in PA. Interested people came from all over the Mid-Atlantic to see how the harvest was done and to learn more about how a school uses biomass energy for heating.

Results
Several years ago, Hughesville High School in East Lycoming School District planted 40 acres of shrub willow hybrid for use as fuel for the heating system. Now about one-third of this area can be harvested each year. Biomass provides approximately one-third of the school's annual heating needs. About $30,000 per year is saved by heating with biomass. Many other schools and organizations have inquired about growing and heating with shrub willow, and Penn State Extension often links interested parties and organizes tours.

The team also facilitated:
-the sale of $120,000 of alternative energy credits for PA renewable energy producers. Energy corporations nationwide purchased credits to meet their commitments for renewable energy generation.

-a switchgrass energy purchase agreement for a Pennsylvania farmer to supply the first known commercial "bale burner" in the region, in New Jersey.

4. Associated Knowledge Areas

KA Code	Knowledge Area
131	Alternative Uses of Land
205	Plant Management Systems
402	Engineering Systems and Equipment

Outcome #4

1. Outcome Measures

Quantified average sustainable bioenergy corn stover removal rates for 36 sites across the country using 200 site-years of field research data.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The need for information regarding potential effects of harvesting crop biomass as feedstock to meet mandated Renewable Fuel Standard (RFS) requirements for advanced biofuels is increasing exponentially as the 15 billion gallon ceiling for grain-based fuels in 2022 deadline approach. Corn (Zea mays, L.) stover was identified as an important feedstock for cellulosic bioenergy production because of the extensive area upon which the crop is already grown.

What has been done
A regional partnership collected replicated field data quantifying grain and stover (aboveground plant parts remaining after harvesting the grain) yields, as well as the amount of nitrogen (N), phosphorus (P), and potassium (K) removed when harvesting a moderate or high amount of the stover at 36 locations across the U.S. The team summarized more than 200 site-years of field research conducted across the country to determine quantities and locations where stover could be sustainably harvested.

Results
New and existing research studies provide extensive field validation data sets to confirm the sustainable amount of corn stover available for advanced biofuel production. Average corn grain yields ranged from 5.0 to 12.0 Mg ha-1 (80 to 192 bushels per acre) and were highest in the center of the Corn Belt. Stover removal rates averaged 3.9 and 7.2 metric tons per hectare (1.7 and 3.2 tons per acre). Harvesting stover increased N, P, and K removal by 24, 2.7, and 31 kilograms per hectare (22, 2.4, and 28 pounds per acre) at the moderate harvest rate or 47, 5.5, and 62 kilograms per hectare (42, 4.9, and 55 pounds per acre) at the high harvest rate. This information will be useful to scientists, conservationists, farmers, and industries planning to use corn stover for producing bioenergy or other bioproducts. This data should be used to verify simulation modeling and available corn stover feedstock projections, but not for site-specific stover harvest decisions.

4. Associated Knowledge Areas

KA Code	Knowledge Area
101	Appraisal of Soil Resources
102	Soil, Plant, Water, Nutrient Relationships
131	Alternative Uses of Land
205	Plant Management Systems

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Public priorities
- Other (Extramural Funding)

Brief Explanation

Economy

- Strong markets for food and feed crops, coupled with a sluggish economy and falling fuel prices, dulled interest in renewable energy.

Appropriations

- Losses of county-level funding for renewable energy programming reduced the team's ability to deliver programming.

Public Policy

- Wavering public policy regarding biofuels increased risk for renewable energy producers.

Government Regulations

- Public Utility Commission rule changes regarding renewable power increased risk for renewable energy producers.

Competing Public Priorities

- Extension educators were drawn away from energy extension work by demands for programming in other areas.

Extramural Funding

- Some of our programs are affected by extramural funding, either by adding resources to promote them or by shaping the content of the product.
- Extramural funding has allowed some teams to conduct practical applied research projects that include integrated extension/educational components.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

The generation of outcomes from existing programs and the development of new programs require improved evaluation that identifies pre- and post- responses to information and monitoring for long-term behavioral changes that result in improved outcomes. More statewide extension programs are using retrospective evaluation to gather information about the number of participants who actually put into practice lessons learned through extension programs. Measuring costs averted or profit increased can show powerful, tangible benefits of our programming--the type of feedback that keeps people coming back for more information. Customer satisfaction and needs assessment instruments (Salesforce and Atlas) are scheduled to be implemented in fall 2015 to provide feedback on the quality and value of our programs.

Key Items of Evaluation

See highlights of state-defined outcomes in this planned program.