V(A). Planned Program (Summary)

Program # 3

1. Name of the Planned Program

Sustainable Energy

☑ 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
102	Soil, Plant, Water, Nutrient Relationships	10%		10%	
131	Alternative Uses of Land	5%		5%	
201	Plant Genome, Genetics, and Genetic Mechanisms	10%		10%	
204	Plant Product Quality and Utility (Preharvest)	15%		15%	
213	Weeds Affecting Plants	5%		5%	
216	Integrated Pest Management Systems	5%		5%	
402	Engineering Systems and Equipment	10%		10%	
511	New and Improved Non-Food Products and Processes	10%		10%	
605	Natural Resource and Environmental Economics	20%		20%	
610	Domestic Policy Analysis	10%		10%	
	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	11.1	0.0	35.2	0.0
Actual Paid	6.7	0.0	16.8	0.0
Actual Volunteer	0.0	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**
1155830	0	366784	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
2613480	0	2765314	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
318780	0	1272464	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

- Conduct meetings, conferences, workshops, seminars
- Conduct research projects
- Publish research and extension publications
- Publish newsletters
- Establish web sites
- Organize field days and demonstrations
- Consultations
- Work with mass media

2. Brief description of the target audience

- Producers
- Consumers
- Youth
- Professionals related to energy
- Agribusiness
- Elected officials and public policy decision makers

3. How was eXtension used?

eXtension was not used in this program

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	1098	0	29	0

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

Patent Applications Submitted

Year:	2014
Actual:	2

Patents listed
US 8,921,648; US 8,790,904

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	36	75	111

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of Extension publications written, new or revised

Year	Actual
2014	0

Output #2

Output Measure

- Number of research publications

Year	Actual
2014	75

Output #3

Output Measure

- Number of research projects

Year	Actual
2014	20

Output #4

Output Measure

- Number of consultations

Year	Actual
2014	57

Output #5

Output Measure

- Number of educational workshops or seminars conducted

Year	Actual
2014	26

Output #6

Output Measure

- Number of volunteers

Year	Actual
2014	0

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of energy producers, farmers, and consumers who increase their knowledge of the technical and economic implications of various Indiana crops being used for biofuels
2	Number of technologies developed and disseminated that will increase the efficiency of bio-fuel production
3	Number of participants who increased their knowledge of policy issues related to sustainable energy
4	Number of research-based studies, publications, and reports for policy organization members and legislators on sustainable energy
5	An impact of new knowledge on plant productivity from alternative energy sources in closed environments.
6	An impact on agricultural machines related to new knowledge about green technology.

Outcome #1

1. Outcome Measures

Number of energy producers, farmers, and consumers who increase their knowledge of the technical and economic implications of various Indiana crops being used for biofuels

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	75

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
There is need to evaluate renewable resource materials as alternatives to fossil sources for fuel production. Corn grain has been effectively used as a renewable bioenergy feedstock for ethanol. Other bioenergy sources high in fiber and low in starch, unlike corn grain, able to be grown on soils not conducive to corn production need to be evaluated for yield and composition content. Tall perennial warm-season grasses, switch grass, big bluestem and Indian grass, dominated the landscape of much of the US' current Corn Belt 150 years ago. These grasses protect the soil from being eroded, improve water quality, and may be an important renewable bioenergy resource.

What has been done
Field demonstration plots of two switch grass varieties, Shawnee and Liberty, and a mixture of big bluestem, Indian grass and side oats grama have been established on private landowner farms at two sites less than optimum for corn and soybean production in Indiana. Shawnee is a forage-type variety of switch grass, whereas Liberty was developed for the purpose of bioenergy production. Plots were randomized and replicated twice. Three rates of nitrogen, 0, 60 and 120 pounds per acre, were applied in the spring to the grasses. Each plot was measured for plant density in the spring and fall, and monthly assessments were made during summer and early fall for plant height, canopy closure, and yield. Sample collected for yield determination was processed to measure compositional content. Demonstration sites were used for field training.

Results
Shawnee had better plant stands than Liberty switch grass the year of establishment. Liberty switch grass tiller density improved to acceptable stands. Within the big bluestem, Indian grass

and side oats grama mixture, big bluestem was the dominant plant type at the sandy locations, but Indian grass was most prolific on the droughty ones. Weed control with herbicide use was helpful in establishment. Nitrogen application beginning the second year of production improved yield, although the 120 pound per acre rate produces similar yield as the 60 pound per acre rate. Higher nitrogen rate at the sandy soil sites caused grasses to fall over (lodging) mid-summer. Grasses were well established on the droughty soil and the poorly drained sections of the sites. Engaging local Extension Educators in field day planning, stand assessment and data gathering has been helpful to the project and a positive experience to campus-based personnel. At one site which is the location of the Indiana FFA Leadership Center, an eight-station walking tour exhibit was developed and available for individual or group education.

4. Associated Knowledge Areas

KA Code	Knowledge Area
102	Soil, Plant, Water, Nutrient Relationships
605	Natural Resource and Environmental Economics

Outcome #2

1. Outcome Measures

Number of technologies developed and disseminated that will increase the efficiency of bio-fuel production

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Cost and feasibility are important considerations for the production of biomass for biofuels. Poplar trees are gaining importance as a source of biomass for many uses including biofuels due to their consistent quality and growth patterns. They are harvestable every 6 years, so regardless of how the biomass is used, accurate growth estimates are needed to make realistic projections for buyers and growers. To complete an economic and financial feasibility analysis of the entire value Wood-to-Wheels pathway, all costs and benefits associated with producing a biofuel from woody

biomass need to be incorporated into an economic model. For this model to be of use to potential growers in Indiana, relevant growth data are needed to assemble a yield component.

What has been done
The overarching goal of this research was to assess the silvicultural and economic viability of dedicated poplar (species within the genus Populus) energy plantations in Indiana. More than 60 genotypes of poplar were evaluated at three locations. The output from this project was relevant growth data needed to assemble a yield component for an economic model that estimates all of the costs and benefits associated with producing a biofuel from poplar bioenergy plantations.

Results
From the collected growth data, the team was able to develop yield equations that accurately predict whole-tree, dry-weight biomass using diameter at breast height (DBH) as the sole input variable. This allows growers to make more effective harvesting decisions based on market price.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
204	Plant Product Quality and Utility (Preharvest)
402	Engineering Systems and Equipment
511	New and Improved Non-Food Products and Processes
605	Natural Resource and Environmental Economics

Outcome #3

1. Outcome Measures

Number of participants who increased their knowledge of policy issues related to sustainable energy

Not Reporting on this Outcome Measure

Outcome #4

1. Outcome Measures

Number of research-based studies, publications, and reports for policy organization members and legislators on sustainable energy

Not Reporting on this Outcome Measure

Outcome #5

1. Outcome Measures

An impact of new knowledge on plant productivity from alternative energy sources in closed environments.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Lack of sunlight severely limits crop and plant production in protected cultivation in northern climates. Energy for heating and lighting to grow vegetables and ornamentals in greenhouses during the off-season is costly. Traditional lamps used for supplemental lighting in horticulture are electrically inefficient, blisteringly hot, spectrally challenged, have limited lifetimes, are fragile, and have disposal restrictions due to mercury content.

What has been done
Research studies on tomatoes and on flowering plants were conducted to determine which environmental factors can overcome the growth-limiting conditions and minimize the energy required to grow plants and crops productively and affordably in controlled and semi-controlled environments. Light-emitting diodes (LEDs) were used as the source of plant-growth lighting. LEDs have extremely long lifetimes, are robust due to their solid-state nature, have color emissions that can be custom selected for specific crop requirements, are cool in temperature and can be placed close to leaf surfaces, and do not require high electrical power.

Results
For propagation of tomato seedlings in the greenhouse, supplemental lighting enhanced seedling production during months of the year having low ambient solar light levels. Effects of different red to blue ratios of supplemental lighting from LEDs were season specific, but stimulation of seedling growth from LEDs generally responded linearly to total daily light interval. Adding blue light to supplemental lighting stimulated seedling growth. For tomatoes, overall, 5% blue to 95% red light gave the best growth responses across seasons. The greatest growth benefits of supplemental light occurred during periods of low ambient lighting. Energy for lighting definitely was saved. Also, because greenhouse tomatoes have a stigma of poor quality and flavor relative to garden-

grown tomatoes, and because greenhouse glass does not allow solar UVB radiation to transmit into the greenhouse, a greenhouse was equipped with UV-emitting lamps with and without a transparent Mylar barrier. Analysis of fruits indicated that broad-band UV treatment reduced fruit mass 20% but stimulated ascorbic acid content 31%.

For bedding plant species, impatiens, marigold, petunia, vinca and geranium, red and blue LEDs were used as supplement to sunlight. Also, studied was sole-source LED lighting to grow plant seedlings in multilayer production when plants are stacked on top of each other on shelves where this is no sunlight. Resulting quality of seedlings grown with LEDs as supplement to sunlight was similar to, and in some cases better than, those grown in greenhouses with high-pressure sodium lamps to supplement sunlight. Seedlings produced indoors with no sunlight but with LEDs as the sole source of light were high-quality and uniform, compact and sturdy.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
204	Plant Product Quality and Utility (Preharvest)
511	New and Improved Non-Food Products and Processes

Outcome #6

1. Outcome Measures

An impact on agricultural machines related to new knowledge about green technology.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Power transmission using hydraulics and hydrostatic pump and motor systems are used for most machines from robots to construction, agricultural and marine machines. But they are not without issues. Hydraulics include undesired dynamic behaviors from resonances, limiting productivity of many applications, and can cause safety hazards. Current methods to reduce oscillations may introduce system slow-downs. Noise emission levels of fluid power system limits application of

this technology to many fields, especially for machines working closely to humans. Current fluid power machines are energy inefficient, their fuel consumption is excessive. Current power transmission systems and agricultural machines are most often based on old-fashioned technology for the hydraulic system using petroleum-based fluid with energy inefficient system configurations. These is a need for new and environmentally friendly agricultural machines with low fuel consumption and zero-leakage risk.

What has been done
A series of research studies were conducted to develop new approaches and designs for hydraulic systems: 1) A pressure feedback method was developed forming an auto-tuning strategy to control applications of the machine itself (mechanical arms) but also of the payload in real time. 2) A thermal-fluid structure interaction model was created on external gear pumps with direct film thickness measurements to analyze main sources of energy dissipation inside hydrostatic units in internal lubricating gaps. 3) A new design was created for variable delivery flow on external gear machines, preserving advantages of cost, reliability and flexibility. 4) Novel experimental approaches were designed to address noise emission sources in pumps. 5) New designs were created for green, high efficient agricultural machines powered by high-pressure water hydraulic technology.

Results
These new approaches developed for hydraulic systems are being put to use by industry partners in consideration for future commercialization and in their research and development departments. Industry partners are using the numerical models to study for more efficient solutions and using the four new designs formulated for pumps. Current testing also is occurring on the feasibility of the new technology created for using water in hydraulic systems.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Public priorities
- Competing Programmatic Challenges
- Populations changes (immigration, new cultural groupings, etc.)

Brief Explanation

{No Data Entered}

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Outcome 1 - field plots of switch grass on diverse soil conditions for biomass
Outcome 2 - field test of plots of poplars
Outcome 5 - greenhouse studies of LED lighting for enhancing plant growth
Outcome 6 - mechanical testing of engine designs for improved efficiency and fuel use

Key Items of Evaluation

Outcome 1 - Switch grasses were well established in droughty soil and in poorly drained sites making them great candidates for growing in marginal land areas for biomass; use of nitrogen application at 60 pound per acre rate improved yield.
Outcome 2 - Able to determine that there is only measure (diameter breast height) needed to calculate volume of poplar biomass for use in biofuel production.
Outcome 5 - Tomatoes thrived with red and blue LED combination as supplemental lighting with inclusion of UVB light to enhance taste. Ornamentals thrived with red and blue LED combination either as supplemental or sole-source of lighting.
Outcome 6 - New hydraulic designs improved efficiency without increasing cost or losing power