V(A). Planned Program (Summary)

Program # 13

1. Name of the Planned Program

Integrated Bioenergy and BioBased Products Development

☑ 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
511	New and Improved Non-Food Products and Processes	100%		100%	
	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	2.0	0.0	4.0	0.0
Actual Paid	0.5	0.0	5.8	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**
25000	0	292255	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
25000	0	292255	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
189000	0	1448503	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

· Partnerships with universities, industry, and federal laboratories:

- University: **7**

Brigham Young University, Ohio State University, University of Oklahoma, Arkansas State University, Texas A& M University, Kansas State University, University of Arkansas

- Industry: **7**

C-Tech; Byogy Renewables, Inc.; AGCO; Stinger, Inc.; Forest Concepts, LLC; Compact Membrane Systems, Inc.; CMS Inc.; PFI Biotechnology in Pirmasens, Germany

- Federal Laboratories: **1**

Idaho National Laboratory (INL)

- Others: **2**

The Samuel Roberts Noble Foundation; ICRISAT, India

· Project proposals: **26**

· Technical papers, including posters: **63**

· Journal articles (indicate which are Extension or Research)

- Research: **51**
- Extension: **0**

· Licenses awarded (List complete citation of awarded patents.)

None

· Patent applications submitted and/or awarded (List complete citation of awarded patents.)

- Awarded: **1**
  - Patil, K.N., R.L. Huhnke, and D.D. Bellmer. 2014. Downdraft Gasifier with Internal Cyclonic Combustion Chamber, U.S. Patent 8,657,892 issued 02/25/2014.
- Patent Applications: **2**

See Section V(E).

- Provisional Patent Applications: **2**

See Section V(E).

- Provisional Patent Applications: **2**
  - Atiyeh, H. K., J. R. Phillips and R. L. Huhnke. Fermentation Control for Optimization of Syngas Utilization. US Provisional Patent Application, Filed: 11/13/2014.
  - Kumar, A., K. Qian, D. D. Bellmer, H. Zhang, and K. N. Patil. Biomass-derived catalyst for conditioning syngas and other applications. Provisional Patent filed to US Patent Office - May 28, 2014.

· New and/or improved products to pre-commercialization

Technology Briefs-Marketing of Inventions: 3

- Atiyeh, H. K., J. R. Phillips and R. L. Huhnke. Methods to Sustain Culture Activity, Gas Uptake and Improve Selectivity for Alcohol Production During Syngas or Producer Gas Fermentation in Bioreactors. Oklahoma State University-Technology Development Center, OSU Inventions 2013.026 & 2013.52.
- Atiyeh, H. K., J. R. Phillips and R. L. Huhnke. Feedback Control Algorithm for Alcohol Production via Syngas Fermentation. Oklahoma State University-Technology Development Center, OSU Invention 2013.51.
- Craige, C. and Buser, M.D. Geospatial Logistics and Agricultural Decision Integration System (GLADIS). Beta released December 2014.

· Educational materials developed: 3

Peer-Reviewed Book Chapters in 2014

- Epplin, Francis M., Andrew P. Griffith, and Mohua Haque. 2014. Economics of Switchgrass Feedstock Production for the Emerging Cellulosic Biofuel Industry. In: H. Luo, Y. Wu and C. Kole (eds.). Compendium of Bioenergy Plants - Switchgrass. CRC Press, Taylor & Francis Group, Boca Raton, FL.
- Kumar, A. and R. Huhnke. 2014. Biomass thermochemical conversion technologies for production of fuels, power and chemicals. In: H. Luo, Y. Wu and C. Kole (eds.). Compendium of Bioenergy Plants - Switchgrass. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Peer-Reviewed Book Chapter in Review in 2014

- Wilkins, M. R., H. K. Atiyeh and S. K. Khanal, "Syngas Fermentation", in "Bioenergy: Principles and Applications", Y. Li and S. K. Khanal, Eds., Wiley-Blackwell, IW, USA. In review. Expected publication date is in 2015.

· Meetings and workshops held: 1

- Dani Bellmer hosted Summer Camp for 25 Middle School students for one week in June, 2014. Focus of the camp was 'Biology and Engineering for a Sustainable Tomorrow'.

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2. Brief description of the target audience

Other scientists, industry, agricultural producers, commercial developers

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	51	0	0	0

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

Patent Applications Submitted

Year:	2014
Actual:	4

Patents listed
?Patent Applications: 2
oAtiyeh, H. K., R. S. Lewis, J. R. Phillips and R. L. Huhnke. Method Improving Producer Gas Fermentation. International Patent Application No. PCT/US2014/049608, Filed: 08/04/2014.
oMueller, M., M.R. Wilkins, R. Prade. 2014. System and method for continuous enzyme production using a filamentous fungus with inhibited growth. United States Patent Application 61/839,973. Filed June 27, 2014.
?Provisional Patent Applications: 2
oAtiyeh, H. K., J. R. Phillips and R. L. Huhnke. Fermentation Control for Optimization of Syngas Utilization. US Provisional Patent Application, Filed: 11/13/2014.
oKumar, A., K. Qian, D. D. Bellmer, H. Zhang, and K. N. Patil. Biomass-derived catalyst for conditioning syngas and other applications. Provisional Patent filed to US Patent Office ? May 28, 2014.

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	51	51

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Technical papers and presentations

Year	Actual
2014	51

Output #2

Output Measure

- New processes or products developed
  Not reporting on this Output for this Annual Report

Output #3

Output Measure

- Technology demonstrations conducted

Year	Actual
2014	0

Output #4

Output Measure

- Educational Publications

Year	Actual
2014	0

Output #5

Output Measure

- Extension programs developed

Year	Actual
2014	0

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Release and commercialization of new feedstocks varieties
2	Best management practices identified for sustainable feedstock production
3	Fundamental knowledge of engineering or science gained in developing biobased products
4	Number of students graduated (masters and doctoral)
5	New processes or products developed
6	Products/processes taken to pre-commercialization

Outcome #1

1. Outcome Measures

Release and commercialization of new feedstocks varieties

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Most current ethanol plants in the U.S. are corn-based, but in the state of Oklahoma corn production is not a major agricultural activity. Switchgrass, a plant native to Oklahoma, has been deemed one of the best options as a sustainable feedstock to support a biorefinery. Switchgrass, other native perennial grasses and annual forage species can be grown on marginal soils for producing large amounts of feedstocks in Oklahoma. The production potential, if realized, will likely bring in huge economic benefits to the rural communities in the state.

What has been done
Switchgrass (Panicum virgatum L.) is a naturally allogamous species. However, efficient and reliable bagging methods are unavailable for inbred development. Four northern lowland (NL) inbreds, four NL non-inbreds, two southern lowland (SL) non-inbreds, and 16 upland-lowland (interecotypic) F1 hybrids were self-pollinated by enclosing their inflorescences in polyester bags in the field, and on 14 F1 interecotypic hybrid plants potted in a greenhouse. The reliability of the bags was determined using 8-10 SSR markers that distinguished the genetic parentage of the pollen. Contaminants were identified in two groups: outcrossing contaminants (OCs) and physical contaminants (PCs) based on amplified alleles of progeny and their seed parents.

Results
Of 39 polyester bags tested in 2012 in the field, 35 bags showed 100 % selfed progeny, four showed PCs and no OCs were identified. Similarly, of 61 bags tested in 2013 in two field plots, 50 bags produced 100% selfed progeny, while four bags produced OCs, five produced PCs and the other two produced both OCs and PCs. No contaminants were identified from the progeny of 18 bags used in the greenhouse, suggesting that high wind speed, physical damage or handling errors may have resulted in the contaminations of bagged progeny in the field. The result of this experiment establishes the increased reliability of the polyester bagging method over previously

tested methods for selfing switchgrass under field and greenhouse conditions. Additionally, the S1, S2 and S3 inbreds produced in this study will contribute to developing completely or near completely homozygous inbred lines in the future.

4. Associated Knowledge Areas

KA Code	Knowledge Area
511	New and Improved Non-Food Products and Processes

Outcome #2

1. Outcome Measures

Best management practices identified for sustainable feedstock production

2. Associated Institution Types

- 1862 Extension
- 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)
Logistics is a critical issue and can make or break a sustainable bioenergy and/or biobased products system. Logistical systems are highly dependent on the type of feedstock material and the biorefinery or biobased products industry material specifications. Currently one of the major logistics issues is the lack of industry material specifications. Another critical issue is the current cellulosic feedstock value of $45 per delivered ton. Delivering feedstocks to the biorefinery at $45/ton is virtually impossible with traditional harvesting, packaging and storage practices unless the feedstocks being delivered are residues such as corn stover. Even delivering feedstocks such as corn stover at $45/ton using conventional practices is challenging

What has been done
Large scale harvesting and storage studies on forage sorghum, switchgrass and mixed grasses from CRP lands have been conducted over the last 3 years. The harvesting component included 6 harvesting locations; 4 harvesting dates; 3 years of harvesting data; use of commercial size equipment; 3 biomass feedstocks that included about 1074, 498 and 130 acres of switchgrass, perennial grasses and forage sorghum, respectively. The storage studies include: 4 locations; 4

harvest dates; 3 storage treatments; and 5 storage times. A total of 117 stacks were included and more than 23,000 core samples were pulled during the study. To date all the field work has been completed and the team is focused on data analyses and developing manuscripts.

Results
It was demonstrated that a common set of commercially available equipment could be used in a production scale biomass collection system in Oklahoma
We are solidifying the economic data in the logistics components of the cellulosic bioenergy supply chain
We are developing best management practices for Oklahoma producers
This research will be used in developing the best management practices for storing switchgrass, forage sorghum and mixed grass as a bioenergy feedstock.
This research will be used in determining the expected accuracy of moisture content measurements taken in large format square bale switchgrass, forage sorghum and mixed grass bales.
This research will provided the basis for a just-in-time delivery and logistics system
38 outreach YouTube videos that were developed to share the status of current bioenergy logistics research with Oklahoma producers, potential biorefinery venture capitalists and other researchers across the country.

4. Associated Knowledge Areas

KA Code	Knowledge Area
511	New and Improved Non-Food Products and Processes

Outcome #3

1. Outcome Measures

Fundamental knowledge of engineering or science gained in developing biobased products

Not Reporting on this Outcome Measure

Outcome #4

1. Outcome Measures

Number of students graduated (masters and doctoral)

Not Reporting on this Outcome Measure

Outcome #5

1. Outcome Measures

New processes or products developed

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)
The development and production of biofuels and biobased chemicals from readily available renewable resources is essential to minimize the cost of shifting from a petroleum-based economy to a more environmentally sustainable biobased economy and improve energy security of the U.S. The Renewable Fuels Standard (RFS2) mandates production of 16 billion gallons per year (GPY) renewable cellulosic biofuels by 2022, without significantly affecting our current agricultural production. Besides being an energy-producing state, Oklahoma is well-positioned to take a leading role in the biobased economy to meet part of the demand for cellulosic biofuels to enhance rural farm economy and attract capital ventures.
Thermochemical, biochemical and hybrid conversion technologies for the production of biofuels and biobased products are in early stages of development. These technologies can be employed in different parts of the U.S. and abroad, based on the type of feedstock used and availability of other resources to sustain the biorefinery. Currently, high capital costs and technological obstacles hinder the development of a viable biorefinery industry. As such, advancing the knowledge base in various aspects of the conversion processes to make this industry profitable is critical for sustainable biorefineries.

What has been done
The DASNR biomass conversion team is actively developing solutions to these challenges to make cellulosic biofuel and biobased chemical production a reality in Oklahoma and elsewhere. Technologies being developed include hybrid conversion, which is the conversion of biomass syngas components (carbon monoxide, carbon dioxide and hydrogen) into liquid biofuels and chemicals, syngas cleanup using biochar catalysts, biomass pretreatments to improve gasification, fungal pretreatments to improve enzymatic hydrolysis of biomass, and biochemical conversion of biomass to biofuels. Cellulosic feedstocks being converted are switchgrass,

sorghum and Eastern redcedar.

Results
Current research efforts will impact conversion efficiency, cost of production, reactor design, and process development of the hybrid conversion technology for implementation in sustainable biorefineries in Oklahoma, the nation, and the world. The developed tools represent a break-through characterization of the production mechanisms that underline the commercially deployed hybrid conversion process, and can be implemented in industrial control systems for process operation. These tools can be used on an industrial scale to maintain high conversion of syngas components to alcohols, which also requires moderately skilled operators and potentially reduce capital and operating costs.

4. Associated Knowledge Areas

KA Code	Knowledge Area
511	New and Improved Non-Food Products and Processes

Outcome #6

1. Outcome Measures

Products/processes taken to pre-commercialization

Not Reporting on this Outcome Measure

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Public priorities
- Competing Programmatic Challenges

Brief Explanation

External factors which affected outcomes

- Low funding levels.
- Accounting issues within departments and division.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Studies are planned but has not been conducted.

Key Items of Evaluation

- Numerous breeding lines were bred and evaluated for their potential in the development of new cultivars in switchgrass for the south central states.
- Organized Symposium-- "Plants Helping Plants: Bioenergy Feedstock Based Systems for Sustainable Production Environments" at our International Annual Meeting held on November 2-5, 2014 in Long Beach, CA.