## V(A). Planned Program (Summary)

**Program # 15**

**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 |
|---|---|---|---|---|---|
| 112 | Watershed Protection and Management | 10% | 10% | 10% | 0% |
| 124 | Urban Forestry | 10% | 10% | 10% | 0% |
| 132 | Weather and Climate | 10% | 10% | 10% | 0% |
| 206 | Basic Plant Biology | 10% | 10% | 10% | 20% |
| 402 | Engineering Systems and Equipment | 10% | 10% | 10% | 20% |
| 403 | Waste Disposal, Recycling, and Reuse | 10% | 10% | 10% | 0% |
| 511 | New and Improved Non-Food Products and Processes | 10% | 10% | 10% | 60% |
| 601 | Economics of Agricultural Production and Farm Management | 10% | 10% | 10% | 0% |
| 605 | Natural Resource and Environmental Economics | 10% | 10% | 10% | 0% |
| 610 | Domestic Policy Analysis | 10% | 10% | 10% | 0% |
| | **Total** | 100% | 100% | 100% | 100% |

## V(C). Planned Program (Inputs)

**1. Actual amount of FTE/SYs expended this Program**

| Year: 2012 | Extension | | Research | |
|---|---|---|---|---|
| | 1862 | 1890 | 1862 | 1890 |
| Plan | 1.7 | 0.0 | 1.6 | 1.0 |
| Actual Paid Professional | 1.6 | 0.0 | 1.8 | 0.0 |
| Actual Volunteer | 13.0 | 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** |
| 32354 | 0 | 32378 | 23131 |
| **1862 Matching** | **1890 Matching** | **1862 Matching** | **1890 Matching** |
| 45777 | 0 | 72812 | 23733 |
| **1862 All Other** | **1890 All Other** | **1862 All Other** | **1890 All Other** |
| 135859 | 0 | 401081 | 0 |

## V(D). Planned Program (Activity)

### 1. Brief description of the Activity

The Sustainable Energy program includes laboratory research, development of pilot scale projects in the field, educating clientele on the merits of particular energy practices and conversion technologies, and engaging the private sector to spur the commercialization and economic development of innovative and efficient energy systems. Specific examples of activity areas of this program are listed below:

* Develop biomass use for biofuels
* Designing optimum forestry and crops for bioenergy production.
* Produce value-added bio-based industrial products.
* Logistics/material handling
* Processing and management of end use waste products and byproducts
* Analysis of the global impacts of new generation biofuels
* Demonstration and commercialization of technologies that increase US energy independence
* Development of programs to train students and current county educators (in-service) to meet the new sustainable energy challenges.
* Energy conservation
* Alternative energy
* Understanding agricultural energy use and opportunities for conservation
* Smart and sustainable energy systems for communities
* Understanding the cost differences of energy usage
* Public outreach and engagement around energy public policy development
* Youth development programs to teach energy conservation, alternative energy sources, electricity and recycling.

- Clean energy project analysis via RETScreen

### 2. Brief description of the target audience

- Farmers
- Citizens
- Agency personnel
- Economic developers
- Regional planners
- Commercial Producers
- Land Owners

- 4-H Youth
- K-12 Youth
- State and Federal Agency Personnel
- Extension Educators
- Policy Makers
- Consumers
- Ag Related Businesses
- Energy Service Companies (ESCOs)

**3. How was eXtension used?**

eXtension was not used in this program

**V(E). Planned Program (Outputs)**

**1. Standard output measures**

| 2012 | Direct Contacts Adults | Indirect Contacts Adults | Direct Contacts Youth | Indirect Contacts Youth |
|---|---|---|---|---|
| **Actual** | 683 | 325 | 205 | 0 |

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

**Patent Applications Submitted**

Year: 2012

Actual: 0

**Patents listed**

**3. Publications (Standard General Output Measure)**

**Number of Peer Reviewed Publications**

| 2012 | Extension | Research | Total |
|---|---|---|---|
| **Actual** | 16 | 27 | 43 |

**V(F). State Defined Outputs**

**Output Target**

**Output #1**

**Output Measure**

- Number of Train the Trainer and In-service Energy Workshops

**Year** **Actual**

| | |
|---|---|
| 2012 | 10 |

**Output #2**

**Output Measure**

- Number of On-farm Demonstrations

| Year | Actual |
|---|---|
| 2012 | 0 |

**Output #3**

**Output Measure**

- Bioenergy Featured Case Studies

| Year | Actual |
|---|---|
| 2012 | 0 |

**Output #4**

**Output Measure**

- Number of educational meetings, workshops, conferences, training sessions, and field days

| Year | Actual |
|---|---|
| 2012 | 46 |

**Output #5**

**Output Measure**

- Number of fact sheets, publications, newsletters, and other print resources

| Year | Actual |
|---|---|
| 2012 | 43 |

**V(G). State Defined Outcomes**

## V. State Defined Outcomes Table of Content

| O. No. | OUTCOME NAME |
|---|---|
| 1 | Increase farm profitability due to more energy efficient practices |
| 2 | Increase the number of individuals using energy more sustainably |
| 3 | Increase the number of sustainable energy products |
| 4 | Percent increase in the optimization of logistics management for sustainable energy systems |
| 5 | Increase number of enterprise budgets related to sustainable energy development |
| 6 | Characterization of Genes that Regulate Wood Formation and Biomass Accumulation. |
| 7 | Energy sensing in plants. |
| 8 | Genome-scale model-guided alterations of the cellulose pathway in plants. |
| 9 | Virgina Bioenergy Systems |
| 10 | A Systems Biology Approach to Cellular Regulation of Seed Filling |
| 11 | Balancing bioenergy benefits with the risk of invasiveness. |
| 12 | Developing New Tools for Exploring Bioenergy Project Opportunities in the Commonwealth of Virginia: GIS-based Assessments of Bioresidues, Dedicated Energy Crops, Existing Boilers, and Policy Drivers |
| 13 | The Bioenergy Engineering Education Program (BEEP), Department of Biological Systems Engineering, Virginia Tech |
| 14 | Biological CO2 fixation for the production of formic acid powered by sugars |
| 15 | Redox control of anaerobic metabolism - implications in biofuel production and infectious disease control |

**Outcome #1**

**1. Outcome Measures**

Increase farm profitability due to more energy efficient practices

**2. Associated Institution Types**

- 1862 Extension
- 1890 Extension

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
Dairy and poultry operations, greenhouse facilities, and flue-cured tobacco farms in Southside and Southwest Virginia are significant consumers of energy. Rising fuel and electricity expenses increase the cost of production and reduce already tight operating margins. Fluctuations in energy costs make budgeting more difficult. Inquiries to Virginia Cooperative Extension regarding farm energy audits and energy conservation cost-share programs illustrated the immediate demand by agricultural producers for resources and programs to address energy efficiency issues.

**What has been done**
The Virginia Tobacco Indemnification and Revitalization Commission awarded Virginia Cooperative Extension a $248,842 grant to develop a pilot farm energy efficiency program. An energy firm was selected to train data collectors for energy audits, and a Virginia firm focusing specifically on the energy usage of agricultural enterprises was launched. The program addresses VCE focus area ?enhancing the value of Virginia's agriculture," and provides a strategy to achieve Goal 1: increase the profitability and sustainability of Virginia's commercial food, fiber, animal, recreation, and green industry.

**Results**
As a result of the pilot farm energy efficiency program, farm energy audits identified potential annual energy savings including: 1,258,086 (kWh) in electrical usage, 603,315 (gallons) propane fuel, and 19,336 (gallons) fuel oil. Farm audits projected annual savings of $1.2 million with installation costs to be approximately $4.9 million. Approximately 76% of the recommended energy conservation measures have a payback period shorter than five years. Twenty-one (21) farms implemented the cost saving projects identified in the audits. Fourteen (14) farms applied for USDA REAP energy conservation grants and 11 of these were successful. The farm energy audit program has focused the attention of agricultural producers on the cost of energy that they

use, energy conservation options, and opportunities to cost-share projects to reduce farm energy consumption.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 402 | Engineering Systems and Equipment |
| 601 | Economics of Agricultural Production and Farm Management |

**Outcome #2**

**1. Outcome Measures**

Increase the number of individuals using energy more sustainably

Not Reporting on this Outcome Measure

**Outcome #3**

**1. Outcome Measures**

Increase the number of sustainable energy products

Not Reporting on this Outcome Measure

**Outcome #4**

**1. Outcome Measures**

Percent increase in the optimization of logistics management for sustainable energy systems

Not Reporting on this Outcome Measure

**Outcome #5**

**1. Outcome Measures**

Increase number of enterprise budgets related to sustainable energy development

Not Reporting on this Outcome Measure

## Outcome #6

### 1. Outcome Measures

Characterization of Genes that Regulate Wood Formation and Biomass Accumulation.

### 2. Associated Institution Types

- 1862 Research

### 3a. Outcome Type:

Change in Knowledge Outcome Measure

### 3b. Quantitative Outcome

| Year | Actual |
|---|---|
| 2012 | 0 |

### 3c. Qualitative Outcome or Impact Statement

**Issue (Who cares and Why)**
"The U.S. forest products industry employs over 1 million people and produces thousands of paper, fiberboard, lumber and engineered wood products with an estimated value, in 2004, of $243 billion in U.S. sales (DOE, Industrial Technologies Program, Fiscal Year 2004 Report). Xylem is the wood-forming tissue in plants and hence is the raw material for the forest products industry. It is the structure, arrangement and relative proportions of the xylem cell types, that determines the physical properties of woods and hence their suitability for specific applications. Remarkably little is known about the genetic mechanisms that regulate wood formation.

**What has been done**
My laboratory uses Arabidopsis and poplar to study wood formation. Arabidopsis is a good choice for such studies because its genome has been fully sequenced and several unique resources have been developed for facilitating rapid characterization of genetic mechanisms. By exploiting these resources, we recently identified all of the Arabidopsis genes expressed in xylem and we are now in the process of determining the function of selected regulatory genes. Additionally, we are translating our findings with Arabidopsis to poplar, a model for forest products research that was the subject of a recently completed genome sequencing effort. For the poplar work, we are supported by a feedstocks genomics grant from the DOE to study poplar protein-protein interactions relevant to wood formation.

**Results**
We are characterizing Arabidopsis and poplar genes controlling a variety of activities that contribute to wood formation and overall biomass accumulation, including a gene that negatively regulates lignocellulose production and programmed cell death in xylem, genes that are putative components of a signaling pathway that regulates cell cell fate in the xylem, and genes involved

in novel protein-protein interaction networks relevant to wood formation. We have cloned over 400 genes associated with wood formation in poplar. These are being used to identify protein-protein interactions important to wood formation http://xylome.vbi.vt.edu/. Results from these investigations can be incorporated into bioengineering and breeding strategies for manipulating economically important aspects of the structure of wood.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |

**Outcome #7**

**1. Outcome Measures**

Energy sensing in plants.

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
A better understanding of how energy is sensed by living organisms will help us better utilize organisms like plants to meet our increasing energy demands.

**What has been done**
"To analyze molecular controls of energy-sensing in plants the Gillaspy laboratory continues to investigate a network of protein factors involved in nutrient and energy sensing. The protein network was delineated starting with a group

of plant genes that are used in the response to drought and cold. One of these genes was used in an assay that

can detect interacting gene products. This assay identified a gene that encodes an energy/nutrient/stress sensor

we call SnRK1. There are two SnRK1 genes in plants, so we have been examining the regulation of these two

different genes and the impact of altering their expression in plants. "

**Results**
The work on this project has shown that this energy sensor can alter plant lifespan and biomass when greater amounts of it are produced in plants. The work characterized how genes for this sensor are expressed in a model plant throughout development, and where they each located within the cell. In addition, the work delineated a new separate gene that controls the stability of the energy sensor. Together, the sensor and its controller represent one way to potentially alter plant fitness, lifespan and/or biomass. The impact of our work is that it has delineated important genes for sensing energy levels. These important processes may be a valid target for genetic engineering to increase plant fitness and/or biomass.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |

**Outcome #8**

**1. Outcome Measures**

Genome-scale model-guided alterations of the cellulose pathway in plants.

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
Increasing the amount of plant celluose and biomass could positively impact our ability to produce bioenergy. It is difficult to predict which genes should be altered to increase production of cellulose or other desired plant compounds.

**What has been done**
A genome-scale model for the model plant Arabidopsis is being modified and used to make predictions of gens useful for genetic engineering of this pathway.

**Results**
Computational approaches have allowed for gene predictions to be made. Transgenic plants have been constructed and are being used to test the model and predictions. Information from these plants will be used to refine the model.If successful, the methods developed in this project can be applied to other plants and pathways to produce useful compounds.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |

**Outcome #9**

**1. Outcome Measures**

Virgina Bioenergy Systems

**2. Associated Institution Types**

- 1862 Extension

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
The bioenergy industry in Virginia is nascent, being only about 5 years old. Energy systems - particularly using herbaceous crops - are slowly gaining traction in Virginia, but agents (and producers) need more information and better understanding of how these systems will be put in place, how they will work, and how they are likely to affect existing producers and agricultural and forest systems. There are many thousands of acres in Virginia that currently receive little or no management, and these acres represent lost opportunities for Virginia land owners who could be getting rental (or better) returns if their land were put into energy crops.

**What has been done**
I have begun putting together a set of in-service training sessions to make agents aware of the scope of the energy efforts and what this may mean to the producers in their region.

**Results**
"Our first field day was held in December and attended by about 10 agents/specialists, including: Cynthia Gregg, Bob Jones, Kelly Liddington, Haley McCann, Scott Reiter, Todd Scott, Laura Siegle, David Smith, Lindy Tucker, and Martha Walker. A retired faculty member and two graduate students also attended.

We had sponsorship from the industry for the day's activities and the agents and industry alike appreciated the session. Following the event the sponsor sent the following email:

""a big thank you for arranging the tour. As we told you @ the Processing Facility --this was one of the best ---if not the best meeting we have had over the past 4-5 years in terms of interest, question and enthusiasm about our project. We look forward to working with you and the Agents in the future as we continue to develop this industry.""

Although we are on the cusp of this activity, there is high likelihood that these efforts - and the interactions they lead to - will have broad impact in Virginia."

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |
| 511 | New and Improved Non-Food Products and Processes |
| 601 | Economics of Agricultural Production and Farm Management |

**Outcome #10**

**1. Outcome Measures**

A Systems Biology Approach to Cellular Regulation of Seed Filling

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
Plants as ?green factories? offer a solution to growing food and energy needs. From an agronomic perspective, seeds are the lowest cost/highest volume biological producers of protein and oils, which are valuable sources of food and chemicals. Approximately 19B lbs of vegetable oil are currently produced annually in the U.S., which represents 70% of total fats and oil produced. Over 700M gallons of biodiesel was produced from soybean alone in 2009. The production of biodiesel keeps increasing each year and in 2009, it was 350 fold higher than in 2000. To obtain high oil content in seeds, rational metabolic engineering strategies are needed based on the knowledge of the corresponding regulatory mechanisms. Systems biology approaches such as metabolic flux analysis (MFA) allow better understanding of metabolic regulation by globally investigating cellular interactions in seed composition. At VT, this interdisciplinary research falls within 3 key College of Agriculture and Life Sciences initiatives: Agricultural and Environmental Sustainability, Biodesign and Bioprocessing, and the Green Industry.

**What has been done**
In 2012, Collakova?s ?Seed Metabolic Regulation? lab was fully functional, producing results using the extramural funding for basic research regarding the regulation of the oil and protein formation in Arabidopsis and legume seeds, such that the resulting knowledge will be used in engineering oil-based products in soybean and peanuts. To elucidate regulatory mechanism underlying seed filling, we focused on transcriptomic and metabolomic aspects to identify major genetic and metabolic regulators. NSF-MCB-1052145 funds ($880,000) were used for work in Arabidopsis, while internal Bioprocess and Bioengineering (BBRC) seed funds ($102,803) were used for the sub-projects relevant to soybean work.

**Results**
Arabidopsis seeds accumulate up to 40% of each oil and protein in their seeds, while soybean seeds contain 20% of oil and 40% protein. Building blocks (metabolites such as fatty and amino acids) of oil and protein, respectively, can be made by different metabolic pathways and we can determine how these metabolites are formed by assessing changes in metabolite levels and quantifying flow of carbon in metabolic network in developing seeds. The soybean projects generated detailed transcriptomic and metabolomic data that are currently being mined for meaningful biological information. The NSF project involving exploration of regulation of Arabidopsis thaliana seed metabolism was launched in spring 2011. We are taking advantage of

combining experimental and computational approaches to identify regulators of seed metabolism. We are nearly done screening about 200 Arabidopsis seed transcription factor mutants potentially affected in seed composition. The ongoing phenotypic screens have identified 15 potential mutants with significantly altered seed protein levels that will be further investigated. The computational approach has yielded a preliminary gene-interaction network, from which we can identify potential regulators of seed metabolism and composition. The flux modeling results of the testing of an Arabidopsis flux balance model that will be adapted for Arabidopsis and soybean seeds were published in Plant Science.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |

**Outcome #11**

**1. Outcome Measures**

Balancing bioenergy benefits with the risk of invasiveness.

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Action Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
The nascent bioenergy industry is growing at a tremendous pace as they identify new crops, improve existing crops, and target specific growing regions. Virginia will play an important role in this industry as we adopt new crops to replace the dwindling tobacco fields. However, as the industry develops there is a growing concern that the crops we use could escape the cultivated environment and become harmful invasive species.

**What has been done**
"One component of my research program is to evaluate the threat posed by a multitude of crops throughout the Southeast, and identify mitigating strategies to reduce the threat. The concern over the invasive potential of bioenergy crops

has been expressed by state and federal officials, environmental organizations, academics, and the bioenergy industry. Thus, my research program aims to present an unbiased evaluation of the invasion risk. We are conducting field, greenhouse, laboratory, and modeling studies to meet our goals. "

**Results**
Results are being disseminated via peer-reviewed publications, presentations, and extension documents.

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 206 | Basic Plant Biology |
| 610 | Domestic Policy Analysis |

**Outcome #12**

**1. Outcome Measures**

Developing New Tools for Exploring Bioenergy Project Opportunities in the Commonwealth of Virginia: GIS-based Assessments of Bioresidues, Dedicated Energy Crops, Existing Boilers, and Policy Drivers

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
In 2011, Virginia was selected as the ?Top State for Business? by CNBC, indicating efficient infrastructure, talented workforce, lower costs of doing business, among other factors. To remain competitive Virginia businesses must explore all options to minimize production costs and to increase the marketability and value of their products and services. Energy prices are often volatile and energy-intensive industries are often exposed to energy price fluctuations. Furthermore, many consumers are placing a greater emphasis on the ?greenness? or sustainability of certain products. Often fuel switching, from a fossil fuel to biomass, represents one opportunity to reduce energy costs while enhancing the overall sustainability, and often

marketability, of the production process. To maintain this competitive advantage and spur economic growth how can Virginia institutions, agencies, and businesses identify opportunities to lower their operating costs?"

**What has been done**

"In 2011 the Virginia Tech team began the initial assessment work for Virginia locations. The first step was to assess facilities with permitted boilers throughout Virginia. The Virginia Department of Labor and Industry (DLI) performs inspections of industrial boilers used in many large and small establishments, including hospitals, small offices, and large factories. Work focused on accessing, organizing, standardizing, and assessing boiler record information maintained by the DLI. The data was then be used to identify specific facilities that could be well suited for conversion to a biomass fired boiler. The metrics of the assessment consist of many factors, some of which are current fuel type, boiler size, boiler age, facility location, and any organizational policies promoting the use of renewable fuels. The second step was to identify Virginia businesses with Corporate Social Responsibility goals related to energy and greenhouse gasses. The third step was to begin the biomass resource assessments for the identified facilities. The feedstock assessment includes biomass sources appropriate for the given energy conversion technology, and typically includes sources of residual biomass, dedicated energy crops, and certain forest material.

**Results**

To date, 25,300 boiler records have been geocoded and entered into a Geographic Information System, and

7,874 Virginia business locations have been identified to have CSR goals related to energy and greenhouse gases. Biomass assessment reports are near completion for eight facilities (Three locations for biofuel developer OptaFuel, three locations for the New River Highlands Resource Conservation District, one location at Ferrum College, and one location for Barnes Biofuel).

While work is still underway, initial feedback has been very positive, with one business client indicating??From what you have shared, I expect that your output will be excellent support for our planning?.By all indications, you are definitely on the right track, and we could not be more appreciative.?  A summary of the project was presented at the US Department of Energy's ""Biomass 2012"" conference."

## 4. Associated Knowledge Areas

| KA Code | Knowledge Area |
|---|---|
| 402 | Engineering Systems and Equipment |
| 403 | Waste Disposal, Recycling, and Reuse |
| 511 | New and Improved Non-Food Products and Processes |
| 601 | Economics of Agricultural Production and Farm Management |
| 605 | Natural Resource and Environmental Economics |
| 610 | Domestic Policy Analysis |

## Outcome #13

### 1. Outcome Measures

The Bioenergy Engineering Education Program (BEEP), Department of Biological Systems Engineering, Virginia Tech

### 2. Associated Institution Types

- 1862 Extension

### 3a. Outcome Type:

Change in Knowledge Outcome Measure

### 3b. Quantitative Outcome

| Year | Actual |
|---|---|
| 2012 | 0 |

### 3c. Qualitative Outcome or Impact Statement

**Issue (Who cares and Why)**
Whether due to worries of rising energy prices, climate change, or energy security issues, many citizens are concerned that our nation has become too dependent on foreign sources of petroleum and are troubled by the impacts that this dependence has created. The federal government signed into law the Renewable Fuels, Consumer Protection, and Energy Efficiency Act of 2007 which seeks greater energy independence and security and promote the production of renewable fuels. Additionally, the commonwealth announced in the 2010 Virginia Energy Plan a target of making Virginia the energy capital of the east coast by increasing in-state production of energy by 20 percent over the next 10 years. These policies are indicative of a broader interest to sustainably increase our energy independence while spurring economic growth. The 2007 Energy Act received considerable attention in April 2012 when gasoline was well over $3.93/gallon and livestock/poultry industries were challenged by high feed prices. Policy makers, farmers, and citizens of Virginia are facing new economic development opportunities and making difficult decisions related to bioenergy project and policy development. However, it is often difficult for the citizenry to fully understand the complex terminology, and energy conversion processes, related to bioenergy. As a result, decision making and opinion forming often occurs with incomplete, misunderstood, or inaccurate information."

**What has been done**
Virginia Tech's Department of Biological Systems Engineering developed the Bioenergy Engineering Education Program (BEEP). The primary goal of this extension program is to increase participant's knowledge and awareness of the basics of bioenergy. Specifically, the program seeks to inform participants on the many different forms of bioenergy, discuss the feedstocks typically used for the generation of bioenergy, and explain how the bioenergy conversion technologies actually work."

**Results**
Over the course of 2012, the materials from the BEEP program were presented to different and diverse audiences through presentations, workshops and field tours. Last year the BEEP program focused primarily on biomass utilization, poultry litter-to-energy technologies, and energy project analysis. These sessions were targeted to community leaders, entrepreneurs, farmers, K-12, and interested citizens alike. The common thread was to give participants basic information on bioenergy and to enable them to make informed decisions on the opportunities created through these bioenergy technologies. As a direct result of these educational efforts, several Virginia farmers are exploring manure to energy pilot projects for their farm in order to enhance their competitive advantage via the generation of renewable electrical and thermal energy and reduced bedding and fertilizer expenses. This represents the potential adoption of innovative bioenergy technology to help sustain Virginia farms, often while also addressing nutrient management concerns, which are vital component of Virginia?s rural heritage and economy.

Collaborators: BEEP is a collaborative extension program executed with the cooperation of: Dr. Jactone Arogo Ogejo and John Ignosh."

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 112 | Watershed Protection and Management |
| 132 | Weather and Climate |
| 402 | Engineering Systems and Equipment |
| 403 | Waste Disposal, Recycling, and Reuse |
| 601 | Economics of Agricultural Production and Farm Management |

**Outcome #14**

**1. Outcome Measures**

Biological CO2 fixation for the production of formic acid powered by sugars

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

### 3c. Qualitative Outcome or Impact Statement

**Issue (Who cares and Why)**

"Efficient utilization of carbon dioxide (CO2) has become an important global issue due to the continuous rise in atmospheric CO2 concentrations, the growth in the consumption of fossil energy, and the depletion of fissile fuel resources. The cost-effective catalytic reduction of CO2 has inspired many sustainable energy and ?clean tech? applications.

formic acid can be produced from a variety of approaches. The annual production of FA is approximately 720,000 tonnes (Wolfel et al. 2011). On industrial scales, formic acid is mostly produced through carbonylation of methanol plus carbon monoxide. Both methanol and carbon monoxide are produced from fossil fuels, such as methane, coal, and crude oil. Also, this production process requires high-pressure reactors, consumes a large amount of water, and generates ammonia sulfate as a byproduct. "

**What has been done**

"The goal of this project (Phase I) is to validate the technological feasibility of enzymatic conversion of CO2 and starch to formic acid by putting 13 enzymes together under modest reaction conditions (e.g., ~30-40oC and ~1 atm). To accelerated CO2 reduction rate, we will construct the synthetic enzyme complexes including formate dehydrogenase and NADH-generating enzymes [e.g., glucose-6-phosphate dehydrogenase (G6PDH), and 6-phosphogluconate dehydrogenase (6PGDH)], which enzyme complexes are believed to accelerate reaction rate greatly due to substrate channeling among proximate cascade enzymes and circumvent unfavorable equilibrium. Also, we will attempt to engineer the cofactor preference of FDH from a costly and labile NAD to a low-cost and stable biomimetic cofactor by rational protein design.

In the Phase II project, we will (i) utilize less costly cellulosic materials as an energy input for CO2 fixation, (ii) replace NAD by using a low-cost biomimetic cofactor and engineer three redox enzymes (i.e., FDH, G6PDH and 6PGDH) that can work well with the biomimic, (iii) further enhance all enzyme stability with total turn-over number (TTN) values of more than 108 mol per mol enzyme and (iv) decrease their enzyme production costs to $100 per kg protein. With these four advances, biological CO2 fixation for FA production will be economically competitive.

"

**Results**

"The production of FA from high-concentration CO2 released by power stations and renewable sugars would bring numerous benefits: (i) utilize CO2 for the production of a value-added chemical, which is produced from fossil fuels, (ii) decrease net CO2 emissions, (iii) create high-paying biomanufacturing jobs and promote rural economy, (iv) utilize abundant domestic renewable resources, (v) enhance national energy security, and (vi) enhance technology export in the future.

The combination of unique features of the USA (e.g., sufficient arable and marginal lands with modest temperatures and ample rainfall in most areas) and cell-free systems developed here could help the USA re-gain No.1 manufacturing leadership based on its renewable biomass resource and decrease net CO2 emissions. The production of renewable building block chemicals, such as formic acid or its derived biofuels (e.g., butanol) (Li et al. 2012), would be a

key component of future sustainable biomanufacturing industry. "

**4. Associated Knowledge Areas**

| KA Code | Knowledge Area |
|---|---|
| 132 | Weather and Climate |
| 206 | Basic Plant Biology |
| 511 | New and Improved Non-Food Products and Processes |
| 610 | Domestic Policy Analysis |

**Outcome #15**

**1. Outcome Measures**

Redox control of anaerobic metabolism - implications in biofuel production and infectious disease control

**2. Associated Institution Types**

- 1862 Research

**3a. Outcome Type:**

Change in Knowledge Outcome Measure

**3b. Quantitative Outcome**

| Year | Actual |
|---|---|
| 2012 | 0 |

**3c. Qualitative Outcome or Impact Statement**

**Issue (Who cares and Why)**
There are many beneficial uses of microbes. For example, they are used in the production of antibiotics, vitamins, and fuels such as ethanol and methane (main component of natural gas), and in sewage treatment. Numerous microbes that inhabit human body help us to remain healthy. Yet we know about only a fraction of their metabolic capabilities. Consequently, we are not in a best position to utilize their potentials to our benefit and to combat the harmful actions of a few of them on our health and environment. The research in my laboratory is focused on following such poorly or incompletely understood areas of microbial metabolism. 1. The full capabilities of microbial hemes, which are iron-containing compound: A type of heme provides oxygen transport capabilities to our red blood cells. 2. The mechanisms that anaerobic microorganisms employ to face changes in the supply of low potential electrons: This is relevant in the biofuel production processes and microbial metabolism in our gut that determines whether we would be lean or obese. 3. The role of coenzyme F420 in the pathogenesis of Mycobacterium tuberculosis (Mtb), the causative agent of tuberculosis, and Mycobacterium avium (Mav), which causes disease in immunocompromised individuals, such as elderly and AIDS and cystic fibrosis patients. Mtb and Mav possess F420, a deazaflavin coenzyme. This is bit surprising, as F420 is

rare in bacteria that grow under air. Mycobacterium species grow under air.

**What has been done**

"1.The laboratory has recently discovered a group of potentially heme-containing proteins (DsrLPs) in a group of microorganisms called methanogenic archaea. Comuptaional analysis has identified these as sulfite reductases. But these proteins do not exhibit this predicted function, and therefore, could serve as platform for the discovery of new roles of heme proteins.

2.Our Computational studies have led to the hypothesis that anaerobic microorganisms modulate their metabolism in response to changes in the supply of low potential electrons by use of a thioredoxin system. We are testing this hypothesis via a proteomics approach.

3.Our preliminary studies indicated that the mycobacteria could employ F420 in deriving energy and cell building blocks and for evading human immune system while lying dormant within human body or causing overt disease. We are testing this hypothesis via genetics analysis and biochemistry studies."

**Results**

"The following are our current results.

1. he DsrLPs seem to have unusual electron transfer roles and these could exist in organisms belonging to all domains of life

2. Thioredoxin system could control both energy metabolism and cell synthesis in strictly anaerobic methanogenic archaea

3. Our preliminary results support the above-described hypothesis about the role of F420 in mycobacteria. The hypothesis is under further testing in a NIH funded project.

We have developed collaboration with a vaccine manufacturer to take some of our basic science findings from item 3 to applications (vaccine development).

**4. Associated Knowledge Areas**

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

**V(H). Planned Program (External Factors)**

**External factors which affected outcomes**

- Competing Public priorities

**Brief Explanation**

No external factors affected the Sustainable Energy planned program outcomes.

## V(I). Planned Program (Evaluation Studies)

### Evaluation Results

The program is progressing and many more opportunities exist.

### Key Items of Evaluation

The program is progressing and many more opportunities exist. The program is comprehensive building from a base of energy efficieny then with grwoing tools, techniques and collaborators to facilitate understanding, and the appropraite adoption of, sustainable energy technologies.