Economic Development Incentive Grant 2014-15 Final Report

Please submit the final report as a **Word document via email** to gkitchen@uwsa.edu (no hard copies please). The annual report is due by **Monday, January 11, 2016 at noon**. The following information must be provided:

Institution Name(s): **University of Wisconsin-Stevens Point**	**Project Title:** **Collaborative Research Facility for Development and Commercialization of Biorefinery Technologies: Cellulose Pilot & Processing Lab**
Principal Investigator: Eric Singsaas	**Person submitting Report: Katherine Jore**
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Grant Award Amount: $2,837,596	**Report Date: January 11, 2016**
Grant Funding Spent (to date): $2,837,596	**Date project began: January 1, 2014**
	Date project ends (projected): December 31, 2015

I. Status Report

The Cellulose Pilot and Processing Lab (CPPL) was established to accelerate the development of the renewable materials, paper, green chemicals and biofuels industries through collaborative research and piloting facilities made available to major manufacturers, small startups, biotechnology entrepreneurs and academics with an idea of how to convert cellulose, the most abundant natural material on Earth, into the sustainable and renewable products of the future. The CPPL includes pilot production facilities located in Wausau, Wisconsin and analytical technology development laboratories located at University of Wisconsin-Stevens Point.

Summary of Objectives

This project comprised initially an 18-month, now 24-month, effort resulting in the development of a pilot biorefinery to support a portfolio of sustainable, renewable, and affordable alternative energy and biorefinery technologies. The supported research and development will utilize and modify existing state of the art technologies, as well as develop new technologies, and facilitate collaboration between industry and academia.

Personnel and hiring

In order to establish the fermentation and digester laboratories at UW-Stevens Point and establish initial projects, the recruitment of two researchers with specialized knowledge and experience was required.
Status: COMPLETE. WIST hired two postdoctoral research associates: Dr. Raghu Nandan Gurram, research associate in chemical engineering and Dr. Alex S. Rajangam, research associate in microbiology. Both candidates have been continuously employed developing cellulose processing and fermentation technologies. An extension of the grant period was approved that enabled maintenance of both positions through December 31, 2015.

Businesses assisted

A total of eight businesses were anticipated to be assisted as a result of this project.
Status: EXCEEDED GOAL. Cellulose center staff and students completed a comprehensive analysis of cellulose residuals (sludge) from four regional paper mills in collaboration with Akzo Nobel chemicals. This

project has been completed and we are in the process of disseminating the information through scientific publications, presentations and social media.

WIST staff completed a market analysis of bio-based products for Cosmo Specialty Fibers, Cosmopolis, WA. The report was delivered to their investors, Gores Group in Los Angeles, CA on April 10, 2014. Gores Group approved piloting of a preferred process and has created a committee to study further investment in a paper mill-located biorefinery. The principal investigator supervised the pilot and process development in cooperation with Lafayette, Indiana-based Bio-Process Innovations Inc. The work was successfully concluded September 30, 2015.

In addition to the five paper companies and the chemical company served as above, the CPPL has ongoing research projects with several companies including, but not limited to, Kimberly Clark, Neenah WI and Kimberly Clark, Atlanta GA. The CPPL has also provided technical assistance and bio-based chemical samples to research teams from the following academic institutions: Massachusetts Institute of Technology, Cambridge, Massachusetts; University of Wisconsin-Platteville; Montana State University Northern – Havre; Mississippi State University; Washington State University; and the University of Minnesota. By serving this combination of private and academic institutions, the CPPL is gaining a reputation as a go-to facility for biomass and bio-based chemical research and development. We expect to build on our reputation in the coming years to help this new industry develop in the upper Midwest.

WIST/UW-Stevens Point team has signed nondisclosure agreements with 22 companies in the agriculture, forest products, biotechnology and paper industries.

Fermentation laboratory, including equipment purchase and installation

Fermentation facilities at UW-Stevens Point will be modified to improve capacity.
Status: COMPLETE. UW-Stevens Point Facility Services and WIST laboratory staff completed renovations in room D005 of the Science Building for a fermentation laboratory and prepared it for biosafety level 1 certification. Six vendors of fermentation equipment were evaluated based on price, performance and delivery status. WIST ordered and installed six 0.5L off-the-shelf fermenters (Mini Bio Bundle) and one 20L pilot fermenter (20 L Bio Bench) from Applikon Biotechnology, NJ.

Scheduled fermentation experiments

Fermentation experiments will be undertaken at the 0.5 liter and 20 liter scale sto convert biomass to chemicals.
Status: COMPLETE. The fermentation and biotechnology laboratory has been used to support research in conversion of pulp mill residuals in collaboration with Wisconsin-based paper companies as well as to support internal research into bio-based products. This facility has demonstrated its usefulness by allowing for a scale-up and demonstration project for one customer to produce 10 gallons of pure cellulosic ethanol. This project demonstrated the feasibility of converting cellulose-based biomass into fuel-grade ethanol at the pilot scale.

Marketing and communications

Promote and market the CPPL to potential industry users
Status: COMPLETE. American Science and Technology (AST) and WIST are promoting the combined assets of the pilot plant, analytical laboratory and fermentation scale-up laboratory to commercial users under the Cellulose Pilot and Processing Laboratory (CPPL). Promotion has been through attendance at industry conferences, brochures and fliers and a full-page advertisement in the January 2015 edition of Biofuels Digest. WIST hosted a booth at the International Biomass Symposium, Minneapolis, Minnesota, in April 2015. All brochures, advertising and presentations direct users to a landing page at http://www.cppl-pilotplant.com/. The CPPL participates in further networking opportunities through participation in the Biorenewable Deployment Consortium http://www.bioenergydc.org, an industry group aimed at commercializing biomass to fuels and chemicals technologies.

WIST has developed a cost and pricing model and marketing documents for fermentation and biomass laboratories.

In addition, researchers associated with this project published a number of papers and other material, as shown in the following list:

1. Runge T, Zauche T, Baxter C, Singsaas E and Alkasrawi M (2014) Classroom Materials for Bioenergy Education. Wisconsin Energy Institute. https://energy.wisc.edu/education/classroom-materials.
2. Gurram RN, Lecher NJ, Duncan SM, Singsaas EL, Al-Shannag M and Alkasrawi M (2015) Bioconversion of paper mill sludge to bioethanol in the presence of accelerants and hydrogen peroxide pretreatment. Bioresource Technology 192, 529-539.
3. Gurram R, Al-Shannag M, Knapp S, Das T, Singsaas E and Alkasrawi M (2015) Technical possibilities of biofuel production from coffee pulp: a renewable feedstock. Clean Technologies and Environmental Policy. 01/2015.
4. Duncan S, Gorzek B, Lecher N, Gurram R Alkasrawi M & Singsaas E (2015) Pulp and Paper Mill sludge as a source of sugars for the production of renewable fuels and chemicals. TAPPI Journal. Submitted manuscript.
5. Alkasrawi M, Al-Hamamre Z, Al-Shannag M, Abedin MdJ and Singsaas E (2016) Conversion of Paper Mill Residuals to Fermentable Sugars. BioResources 11 (in press).

Pilot digester laboratory, including design and construction, laboratory preparation and digestor installation

The overall goal of this task was to design and install a functioning biorefinery.
Status: American Science and Technology (AST), under contract from UW-Stevens Point, was assigned to build upon its past experiences and expand its current pilot biorefinery. In particular, AST was contracted to scale up its pilot plant by designing, building, assembling and operating a scale up pilot fractionation reactor that can process two tons of biomass per day. This 15-month task started on April 1, 2014.

Prior to the period of this EDI grant, AST and UW-Stevens Point collaborated on the development of technologies to fractionate various lignocellulosic biomass sources into their ingredients and then explore production of valuable products such as fiber, sugar, and pure lignin. During this period of collaboration, AST developed and built a pilot production plant and UW-Stevens Point added the required equipment to establish laboratories for technology development and analytical support. The CPPL is a continuation of the ongoing collaboration and expansion of the pilot plant and analytical services facilities, capabilities, and shared resources.

Task One - Design

This task was to design a new, larger unit to increase AST's capacity of biomass treatment from its level at the start of the project of 200 kg to approximately two tons per day. For this task, AST used its past experiences in operating its pilot plant to design a new process flow diagram (PFD), process instrumentation diagram (PID), floor plan (FP), and materials flow diagram (MFD). To minimize costs, AST sought to capitalize on most of its existing equipment. This task was expected to take about two persons and three months to complete.
Status: COMPLETE. AST completed the design of its process flow diagram (PFD) and initial quote package. To further improve its capabilities, AST hired Baisch Engineering. The team of AST/Baisch Engineering completed and submitted a general specification to various vendors to obtain their formal quote as the major output of this task.

Task Two - Reactor Fabrication

This task was contracted to a fabrication shop, due to the size, pressure, and temperature requirements of the reactor. This task was expected to take about nine months to complete with the forecast requirement of one full time engineer from AST, plus materials and fabrication costs.
Status: COMPLETE. Through Baisch Engineering, AST sent technical specifications to eight vendors. The equipment was procured and installed at AST's Wausau pilot plant.

Task Three - Installation

The equipment built by the fabrication shops was to be delivered to the AST plant in Wausau and installed by AST's experts. The AST team has the necessary experiences to assemble this biorefinery. This task was anticipated to take approximately one year and three engineers and technicians to complete. This task was also expected to sustain two jobs and allow AST to hire one new full time employee.
Status: COMPLETE. Building modifications were completed and the pressure vessel and associated tanks and plumbing installed on concrete footings in a new explosion-proof room at AST's Wausau facility.

These pictures show installation of the 992-pound (450kg) capacity biodigester at the AST facility. The digester can process approximately two tons per day of biomass in multiple batches.

Task Four - Marketing

For this task AST planned to utilize a range of outlets, including hiring nationally known experts, web-based advertising, and social media to publicize CPPL's capabilities and services. In particular AST proposed to undertake the following marketing activities:

Direct Marketing: While the new pilot plant was being built, AST would hire a marketing specialist to introduce CPPL to big biorefineries, biomass producers, and biomass users.
Status: COMPLETE..

Web-based and social media marketing: In addition to direct introduction, AST would use web-based marketing and social media to disseminate information about the new cellulose R&D center. The messaging was intended to focus on how the collaboration between state, university, and private industries could implement new technologies to expand their market share or to maintain their current business.
Status: COMPLETE..

Task Five - Other Equipment

While the new pilot reactor was being built, as time and funds permitted, AST staff undertook to either identify vendors or design and fabricate the required equipment necessary to complete the biorefinery. In particular, AST undertook to perform the following subtasks:

Solvent recovery: To match the pulp production, AST would identify and purchase a screw press or a horizontal centrifuge to remove as much solvent as possible from the digested pulp. This subtask was expected to take about one month to identify and purchase the necessary equipment and six months to install and prepare them for use.
Status: IN PROGRESS. To match the pulp production, AST has identified a wipe film dryer necessary to remove lignin / recover solvent from the organic solvent as well as to remove water-soluble inorganic salts from the aqueous layer.

Pulp washing system: To match the pulp production, AST undertook to purchase an additional horizontal centrifuge to remove water from the washed pulp. This task was expected to take about one month to identify and purchase the necessary equipment and six months to install and commission.
Status: COMPLETE: To match the pulp production, AST has purchased a horizontal screw press to remove solvent from the pulp. In addition, AST purchased and installed a pulp de-flaker to further process its pulp. Also, AST has identified the main problem in pulp washing to be the water recovery. As of now, AST has not found an economically viable solution to separate the volatiles from the wash water. Currently, AST is studying the possibility of using its distillation tower to purify water to 99% and use some type of resins to remove the rest of the volatiles and produce clean water for recycling.

Pulp drying: To match its new production capabilities, AST undertook to design and build a drying chamber that can dry two tons of pulp up to 90% solids content in three to four days.
Status: COMPLETE. To match its new production capabilities, AST has designed and built a drying room that can dry about one ton of pulp up to 90% solid content in three to four days.

Hydrolysis: To match the pulp production, AST undertook to purchase and install enzymic hydrolysis reactors with approximately 12,000 gallons capacity to hydrolyze about one ton of pulp to glucose per day. This process would be followed by the separation of any unreacted fibers from the resulting digestate and then dehydration of the digestate. This task was forecast to take approximately nine months to complete.
Status: COMPLETE. AST has repurposed two available horizontal tanks about 3600 gallon enzyme hydrolysis capacity.

Lignin recovery: Since lignin is potentially one of the most important products arising from the biorefinery, it is necessary to be able to recover and dry it to at least 95% solids content. For this task, a new reactor was to be designed and built. This task was forecast to take about three months for conceptualization, six months for building, and two months for installation.
Status: COMPLETE. AST performed R&D to propose a potential design for a lignin recovery and drying system. One of the more successful processes identified involves continuously grinding the lignin clumps into smaller pieces and blowing dry air through them. AST has purchased a grinder to break lignin into small particles and has been using its air dryer unit to dry the lignin. The process includes two or three steps to remove most of the solvent from the lignin. The end product is an odor free lignin.

Other Equipment: In addition to the equipment mentioned, as funds and time permitted, AST undertook to design and build other required parts, equipment, and systems to further enhance the biorefinery for CPPL usage.
Status: IN PROGRESS. New equipment, e.g., pulp washing and lignin/solvent recovery systems were not purchased due to extra costs incurred for building modifications. AST will continue this work using current equipment for both old and new reactors.

Task Six - Integration
As the equipment was purchased/built and installed, it was intended that the system be tested and debugged to ensure all the equipment, piping, valves, and instruments were working properly. This task was expected to require the efforts of two technicians for one year.
Status: COMPLETE. All tanks and pressure vessels have been fitted and connected with stainless steel piping and explosion-proof wiring..

Task Seven - Operation
Upon completion of all equipment installation and commissioning, AST would operate the integrated system to provide R&D services for customers as well as for internal R&D. For this task, the operation costs will be provided by the customers (biomass owners and users who want diversify their product portfolios). To operate the larger biorefinery, AST expected to hire and train one additional employee. Altogether, this task was expected to sustain six employees in Wausau, WI.
Status: START UP is expected during first quarter 2016. After system completion and initial commissioning, AST decided to add a remote control system for operator safety. AST will incur all costs associated with this addition.

Task Eight - Reporting
On a quarterly basis, AST reported all of its activities and progress for each task. AST reports included the number of hours worked on the various tasks, potential customers contacted or worked with, and up to date expenses for the reporting period.

Issues / Recommendations
AST is slightly behind the planning schedule due to unanticipated building safety and environmental compliance modifications, as noted above in tasks 5, 6, 7. Despite these unanticipated events AST is committed to investing its own funds as necessary to complete the pilot plant build and commissioning in 2016.

Future Work
AST continues pre-pilot work for two major customers, a major international brand owner and a major paper company located in Wisconsin. Contracts are being serviced currently through the pre-pilot scale processor with plans for expansion after the pilot-scale processor is operational. AST and WIST are in discussions with additional users, including a major Central Wisconsin agricultural processing company.

II. Updated Goals/Performance Metrics and Assessment Plans
The attached Excel spreadsheet and this document report the current status of project goals/performance metrics, anticipated completion date(s), actual completion date(s), and assessment plans.

Number of jobs created: Five jobs were forecast for creation and eight have been created. One additional technical staff was hired at AST in first quarter 2014. Two postdoctoral associates and one laboratory chemist were hired in the WIST laboratory. The WIST biorefinery laboratory has employed three student researchers since January 2014.

Number of jobs retained: Four jobs were projected to be retained and five have been retained. AST retained four technical positions. WIST laboratory retained one postdoctoral associate position, Dr. Shona Duncan.

Number of businesses assisted: Four businesses were forecast to be assisted in the first full project year and eight businesses were projected to be assisted overall; nine have been assisted.

III. Project/Program Budget and Expenditures

Expenditure report for the complete project

Budget Item	Original ($)	Actual ($)	Remaining ($)
Salary	497,972	476,186	21,786
Fringe	208,067	146,442	61,625
Travel	22,350	31,781	–9,431
Supplies	53,500	118,092	–64,592
Equipment	290,955	303,582	–12,627
Subcontracting	1,495,000	1,495,000	0
Indirect Costs	269,752	266,513	3,239
TOTAL	2,837,596	2,837,596	**0**

IV. Changes

UW System granted a project extension to December 31, 2015. System startup and operation will occur in the first quarter of 2016.

Project lead, Dr. Eric Singsaas, has accepted a new position as Forest Products Group leader at the University of Minnesota Natural Resources Research Institute, and will bring with him expertise in biomass processing and bio-based chemical research and development. We hope to develop a cooperative research agreement between the University of Minnesota and the CPPL partners - AST, WIST and UW System - as a cooperative platform for advanced bio-economy research and development aimed at improving the rural Northwoods economy in the upper Great Lakes region.