

# **Advancing Bio-Based Chemicals and Next-Generation Fuels from Montana's Agricultural Crops**

*Second Quarterly Report, FY 2017*

**Randy Maglinao, PhD**  
*Lead Principal Investigator*  
Advanced Fuels Center  
Montana State University Northern

March 2017



## ***Introduction***

This collaborative research effort between the Advanced Fuels Center, Montana State University Northern (AFC-MSUN) and Montana State University Billings (MSUB) City College aims to establishing and maintaining a biorefinery utilizing Montana-grown industrial oilseed crops. The team continues to gather essential data in producing sustainable, renewable fuels from Montana-grown camelina and create partnerships with academia and industry. This report covers all activities performed from December 1, 2016 to February 28, 2017. It includes a summary of the progress for each task, brief biographies of staff hired, and project expenditures.

## ***Progress Towards Meeting Milestones***

**Task 1: Life Cycle Analysis (LCA) and Techno-Economic Assessment of Green Diesel and Bio-jet Fuel** (Lead: E.P. Resurreccion, [eleazer.resurreccion@msun.edu](mailto:eleazer.resurreccion@msun.edu)). Evaluate the environmental life cycle impacts and techno-economic feasibility of green diesel and bio-jet fuel (next-generation fuels) and high-value added chemicals (bio-based chemicals).

### *Key Milestones:*

- a) Development of a thorough unit process analysis and life cycle inventory of the entire camelina-to-next-generation fuels/bio-based chemicals process chain. (Timeline: July 1, 2015 to July 2016)
- b) Comparative assessment of "cradle-to-gate" life cycle impacts of camelina-to-next-generation fuels/bio-based chemicals. (Timeline: July 1, 2016 to January 1, 2017)
- c) Evaluation of techno-economic feasibility of camelina-to-next generation fuels/bio-based chemicals via life cycle costing (LCC). (Timeline: January 1 to July 1, 2017)

### *Key Activities for January-March 2017*

The entire life cycle model has been established and developed. Critical model parameters directly linked to the results of Task 2 are still being optimized and will be incorporated in the life cycle inventory. Technoeconomic assessment is currently being performed. Manuscript for a paper is being prepared and has working title, "**Sustainable Biofuels and Biochemicals Production from Camelina: A Biorefinery Approach.**" This is to be submitted to *Environmental Science and Technology* by May 2017. Results of this task has also been selected to be presented at the 2017 Association of Environmental Engineering & Science Professors (AEESP) Research and Education Conference at the University of Michigan, Ann Arbor, MI on June 21-22, 2017.

Five researchers are currently working on this task under the supervision of CET assistant professor Dr. Eleazer Resurreccion. (1) Mason Martin, a graduate intern/researcher with a background in CET, is starting his Masters and PhD in environmental sustainability analysis this coming Fall 2017. He hopes to utilize his experience from this research in his academic career; (2) Paul Jeffrey, a biology junior at MSUN, hopes to pursue graduate education in Environmental Engineering when he graduates; (3) Lane Urick, a graduating CET student, is starting a Civil Engineering job May 2017; (4) Benjamin Rice, a professional cartographer and a graduate of MSU Bozeman, is finalizing his GIS-based analysis on camelina cultivation and has developed a query system for relevant growth parameters related to yield and land availability; and (5) Javad Roostaei, an Environmental Engineering PhD student from Wayne State University under the supervision of Dr. Yongli Zhang, is assisting Ben in data acquisition and GIS modeling.

Through this task and through collaboration with universities/industries such as Old Dominion University (Norfolk, VA), Virginia Commonwealth University (Richmond, VA), South Dakota School of Mines and Technology (Rapid City, SD), University of Minnesota Twin Cities (Minneapolis, MN), USDA Extension Office in St. Paul, MN, Omega Grains, LLC (Buenos Aires, Argentina), Virginia Coastal Energy Research Consortium (Norfolk, VA), and Calumet Refining, LLC (Great Falls, MT), Resurreccion has established a solid research team/collaboration that focuses on oilseed-based research. Within the first quarter of 2017, Resurreccion has submitted research proposals to the National Science Foundation (Innovations at the Nexus of Food, Energy, and Water Systems, MBRCT), US Department of Energy

(Energy Efficiency and Renewable Energy, EERE), and the Montana Board of Research and Commercialization Technology (MBRCT).

**Task 2: Production of Camelina-Derived Alkylated Aromatics as a Blend Component to Aviation Gasoline** (Lead: R.L. Maglinao, [randy.maglinao@msun.edu](mailto:randy.maglinao@msun.edu)). Propose and validate the mechanism of producing high-octane number chemicals (e.g., alkylated aromatics) from camelina.

*Key Milestones:*

- a) Validation of the mechanism of producing high-octane number chemicals from camelina. (Timeline: July 1 to December 1, 2015)
- b) Identification of optimum ratio of camelina-derived alkylated aromatics and unleaded avgas with desired anti-knock value identified. (Timeline: December 1, 2015 to October 1, 2016)
- c) Certification of the newly-formulated unleaded avgas. (October 1, 2016 to June 30, 2017)

*Key Activities for December 2016-February 2016 period:*

During this period, the team used the program the team developed in Quarter 1 of Year 2 of the project. The program predicts a fuel's Research Octane Number (RON) and Motor Octane Number (MON) based on its molecular composition. Different formulations of high-octane unleaded avgas with alkylbenzenes derived from camelina were identified. Unfortunately, the Center's automated vacuum distillation unit broke. The team would not be able to produce camelina-derived alkylbenzenes until the distillation unit is repaired. It is anticipated that the instrument will be fixed in April. As a substitute, alkylbenzenes equivalent to the ones derived from camelina were bought from chemical retailers instead. Several formulations of unleaded avgas containing alkylbenzenes were prepared and would be sent to an independent lab for fuel performance testing (e.g. RON, MON, and vapor pressure). Calumet Montana Refining (Great Falls, MT) is assisting the team in the analysis of the samples.

**Task 3: Development of Heterogeneous Grubbs Catalyst for Biomass Conversion** (Lead: A.K. Jones, [alexandra.jones@msun.edu](mailto:alexandra.jones@msun.edu)). Develop a novel and robust heterogeneous Grubbs catalyst that achieves efficient conversion of natural oils to next-generation fuels and bio-based chemicals.

*Key Milestones:*

- a) Synthesis of a silica-supported polymeric Grubbs catalyst for olefin metathesis of natural oils. (Timeline: July 1, 2015 to June 30, 2016)
- b) Synthesis of a novel silica-supported Grubbs catalyst for olefin metathesis of natural oils. (Timeline: July 1 to December 31, 2016)
- c) Comparative analysis of the two heterogeneous Grubbs catalysts. (January 1 to June 30, 2017)

*Key Activities for December 2016-February 2017 period:*

A precursor to the catalyst previously proposed had been confirmed through characterization analysis. These results will be presented in a poster presentation at the 253<sup>rd</sup> American Chemical Society National Meeting & Exposition in San Francisco, CA on April 4<sup>th</sup>. The catalyst proposed in milestone *b* has also been synthesized and is being characterized and undergoing preliminary activity tests.

**Task 4: Design of an Optimum Process Configuration and Economic Analysis for Medium- and Large-Scale Pelletizing Plants for Camelina Meal** (Lead: A. Sullivan, [andrew.sullivan3@msubillings.edu](mailto:andrew.sullivan3@msubillings.edu)). Develop and prepare a design study documenting an optimum process configuration and economic analysis for medium- and large-scale pelletizing plants for camelina meal (next-generation fuels).

*Key Milestones:*

- a) Development of an optimized process for fuel pellet production from camelina meal and manufacturing of a range of pellet compositions to verify producibility. (Timeline: Summer 2016)
- b) Testing of products in a range of commercially-available multi-fuel pellet stoves and identification of potential markets to determine product price including a fish food for export. (Timeline: Winter 2016)
- c) Preparation of study design for 40,000 to 500,000 ton per year pelletizing plant with economic analysis. (Timeline: Summer 2017)

*Key Activities for December 2016-February 2017 period:*

The grant has allowed MSUB to develop its facilities and offer independent researches to its students. Fifteen first and second year students in the Process Plant Technology program have joined to partake on the following research projects:

1. Design and fabrication of an oil press alarm and auto-shutdown system.
2. Preparation of soap derived from Montana-grown oilseeds and glycerin from biodiesel production.
3. Development of an efficient pellet furnace to lower carbon dioxide emissions and reduce operating costs.
4. Optimization of fuel and feed pellet production from Montana's agricultural crops.
5. Development of an industrial control system using a Delta V system.
6. Investigation of constraint busting, distillation optimization, and economic maximization for bio-energy/biofuels production.

The results of these studies will be presented at the MSUB Research and Creativity Conference and Process Plant Technology Open House. The Phillips 66 Citizens Advisory Council will be attending the open house which will be in April of this year.

For the first research project, materials needed to fabricate the oil press alarm and auto-shutdown system has been ordered. A working design has also been developed. If successful, this research project will help Story Mills Oils in Laurel Montana, an industrial partner established through this grant. Story Mill Oils is a small business that produces specialty safflower cooking oil from locally grown crops. The owner reported similar issues the MSUB team observed in the investigation of pressing camelina. Mills stalled and presses disrupted due to overheating during unattended operations. If not shut down immediately, stalled mill could damage parts due to wear and tear at high temperatures. This is a significant problem especially for small businesses that cannot afford staff to oversee a 24-hour a day operation. Other industrial partners will also benefit from this research project as the results and designs will be shared to them.

The second research project came about from Story Mill Oils need to find an economic and environmental way to manage its glycerol residue from biodiesel production. As per report period, MSUB students developed recipes following industrial practices and have produced the first batch of bar soap from camelina oil. A soap calculation tool using Microsoft Excel was also developed. The calculation tool includes a database of fatty acid profiles of different oilseeds, a guide in developing soap recipes, and a calculator that estimates the amount of glycerin produced from processing oil to biodiesel.

In developing an efficient pellet furnace, students at MSUB are installing a 52,000 Btu/h multi-fuel stove from the United States Stove Company and a M55 Steel Freestanding Multi-Fuel Pellet Stove from a local vendor. A sturdy steel mobile pedestals to facilitate outside operation for lower cost and more flexibility were installed. An instrumented stack has been constructed to measure stack flow, temperature, and composition for efficiency calculations. A Microsoft Excel spreadsheet has been developed to simplify the calculation of a multi-fuel furnace efficiency. The spreadsheet includes an orifice flow simulation to assist in designing and calibrating an orifice meter for continuous flow of a furnace stack and a rigorous efficiency model to measure combustion efficiency for multi-fuel furnaces.

MSUB students recommissioned the pelletizing plant which includes the hammer mill, cyclonic separator, conveyor, agitated feed hopper, conditioner, pellet mill, and particle size screener. The mill was

not used in the fall of 2016 due to other demands on resources. The process unit has a capacity of 3,600 lbs/day or 657 tons/year, the appropriate size to investigate and demonstrate a pelletizing plant. For the next quarter, the focus will be in determining the optimum operating conditions such as hammer mill particle size, hopper feed rates, moisture content, and pellet mill speed and clearance. The objective of these activities is to minimize operator involvement and reduce overall operating costs.

### ***Personnel Recruitment and Employment***

#### **Advanced Fuels Center, Montana State University Northern**

Six (6) undergraduate research assistants were hired to assist the leads with their respective tasks. The following are brief biographies for all AFC-MSUN researchers and staff supporting the project activities.

<p><b><i>Randy Maglinao, PhD</i></b> <i>Lead Principal Investigator (AFC-MSUN)</i> Dr. Randy Maglinao earned his degree of Doctor of Philosophy in Biological and Agricultural Engineering at University of Idaho in 2011. His research interests are converting industrial oilseed crops and glycerol to value-added chemicals and next-generation fuels, scaling chemical processes to pilot-scale production, and heavy-duty engine emissions and performance of different fuels and additives.</p>	
<p><b><i>Eleazer P. Resurreccion, PhD</i></b> <i>Principal Investigator (AFC-MSUN)</i> Dr. Eleazer Resurreccion obtained his Doctor of Philosophy degree in Civil Engineering (Environmental focus) from the University of Virginia in 2013. His interest is on the area of renewable energy and environmental sustainability, particularly in the nexus of energy-water systems. He utilizes an interdisciplinary systems approach that combines novel technology, environmental restoration, and economics to address challenges pertinent to these systems in an innovative manner. The application of these areas in industrial ecology allows him: (1) to perform both lab-scale investigations and multi-scale modeling of environmentally-conscious processes and (2) to implement environmental-economic modeling for policy analyses.</p>	
<p><b><i>Alexandra Jones</i></b> <i>Research Associate (Catalyst Development)</i> Alexandra Jones graduated from Washington and Lee University in May of 2015 with the degree of Bachelor of Science in Chemistry. She began her work at AFC-MSUN in August of 2015 as a Montana State Energy Corps Service Member. She plays a key role in the catalyst development research and as much of the science, technology, engineering, and mathematics (STEM) outreach activities.</p>	

**Keith Richardson***Performance Engineer*

Keith Richardson has over 40 years of experience in automotive, aircraft, motorcycle, agriculture, construction, and mining equipment repair maintenance and design. Keith designed and supervised the building and assembly of tractors for Big Bud Tractors starting in 1975. Keith has extensive experience in designing tractors, prototype power trains, hydraulic systems, and electrical systems. He also designed earth moving scrapers as well as several other equipment for railroads.

**William Cochran***Senior Biology Student*

William Cochran was raised on the Fort Belknap Indian reservation, where he attended Hayes Lodge Pole High School. William is currently planning to commission into the Navy after graduation. William is currently assisting the Research Associate in the development of a sustainable heterogeneous catalyst that will be employed in AFC-MSUN's biorefinery process.

**Brody Dahlman***Senior Ag Operations Technology Student*

Brody Dahlman was born and raised southeast of Dutton Montana on his family farm and ranch. He graduated from Dutton/Brady High School in 2013 as class salutatorian. He is attending Montana State University Northern pursuing a bachelor's degree in Agriculture Operations Technology with a minor in Farm Mechanics. Brody plans on graduating in 2017 from MSUN and returning to the family farm and ranch to continue the family tradition as he is a 5th generation Dahlman and has already begun to build his own cattle herd.

**Chazley Hulett***Senior Biology Student*

Chazley Hulett was born and raised in Havre, Montana. He graduated from Havre High school in 2011 and started attending MSUN in 2014 where he is currently studying Biology. After graduation, he plans to pursue higher education in healthcare professions. He is critical in AFC-MSUN's lab-scale investigations, particularly with experiments related to production of bio-based chemicals and bio-based fuels.



**Mason Martin**

*Senior Civil Engineering Technology Student*

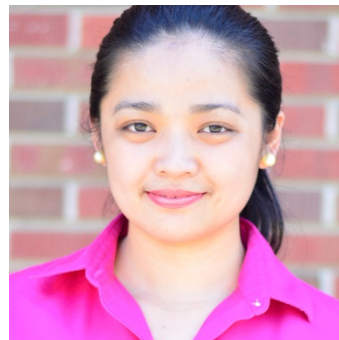
Mason grew up in Miles City, Montana, a farming and ranching community very similar to Havre. He is in his final semester at MSU-Northern, completing his Civil Engineering Technology degree. His plan is to continue his education and pursue a Master's degree in Environmental and Sustainable Engineering. Mason is assisting the leads in gathering data and running simulations in the life cycle assessment (LCA) of bio-based fuels.



**Maria Christina Resurreccion**

*Education Graduate Student (Master of Science in Education: Instruction and Learning)*

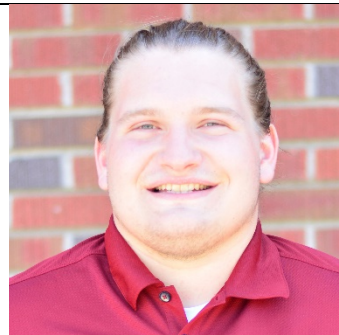
Christina is a vital component in AFC-MSUN's daily administration operations and outreach activities. Prior to coming to MSUN, she holds a Masters degree in Science Teaching from Laguna State Polytechnic University and a Bachelor of Science degree in Zoology from the University of the Philippines Los Baños. She also holds a degree in Special Education from Singapore. While an undergraduate student, Christina performed wildlife research and her work was featured at National Geographic Society Magazine. She worked as a finance and administration manager at Olive Green, Singapore for five years.



**Lane Urick**

*Senior Civil Engineering Technology Student*

Lane Urick attended high school in Great Falls, Montana. He is currently entering his senior year at MSUN as a Civil Engineering Technology major. He plays football for the Northern Lights and hopes to pursue a graduate degree in Environmental Engineering. Lane is involved in the life cycle assessment (LCA) and techno-economic modeling of bio-based fuels and chemicals. His knowledge in modeling and laboratory will undoubtedly prepare him for a future in research and academe.



**Montana State University Billings City College**

Two new undergraduate researchers, who majors in Process Plant Technology, were added to the seven undergraduate students who were employed in support of the project. Tyler Shanley is employed as a part-time undergraduate researcher while Samuel Sailors is paid through the Work-Study program with a fraction of his time devoted to the grant activities.

A total of 13 students contributed to this project. Four students participated through the independent research which the results of which were presented at the competitive 4<sup>th</sup> Annual Student Research Day for Montana's Two-Year Colleges in Helena and at last year's MSUB Research and Creativity Conference. The remaining nine students either worked for credit or were paid by this grant. Below are their brief bios.

**Andrew D. Sullivan**

*Principal Investigator (MSUB City College)*

Andy is the Process Plant Technology Instructor at MSUB City College. He holds a Bachelor of Science degree in Chemical Engineering from MIT, and has 20 years of operations and technical experience in refining at ExxonMobil. His research interests focus on process operations excellence, operator training, and renewable fuels process design and optimization.



**Paul Bledsoe**

*1<sup>st</sup> Year Process Plant Technology Student*

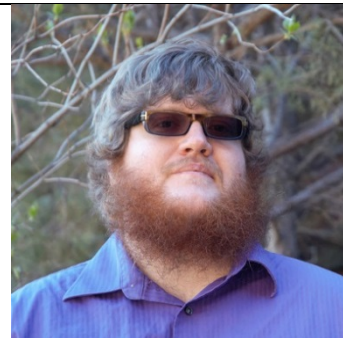
Paul is serving as a Process Plant Laboratory Technician under the Federal Work Study program. He has worked in hard rock mining and brings considerable computer experience to his work at MSUB City College. He has interest in renewable fuels, and is designing and retrofitting a vehicle to operate on 100% vegetable oil.



**Cody Dayley**

*2<sup>nd</sup> Year Process Plant Technology Student*

Cody is the 2016 Student Employee of the Year for his service as the Process Plant Laboratory Technician, a position he has held since fall 2015 under the Federal Work Study program. He has an entrepreneurial spirit and brings a high level of enthusiasm and skill to everything he does. He has interest in starting a biofuels business and in developing advanced training tools for processing industries.



**Adam Goodburn**

*2<sup>nd</sup> Year Process Plant Technology Student*

Adam plans on pursuing an Engineering Degree after completing his AAS in Process Plant Technology. He works as a machinist and brings a high level of knowledge and practical skills to his work at MSUB City College. He has interest in advanced process control and was selected to present his work on a self-balancing robotic platform at the 2016 Research and Creativity Conference at MSUB City College.





**Greg Howick**

*1<sup>st</sup> Year Process Plant Technology Student*

Greg has served in the Navy and in the Air National Guard as an Avionics Technician. He plans to use his skills in the Refining sector when he graduates with an AAS in Process Plant Technology.



**Jason Kills Pretty Enemy**

*1<sup>st</sup> Year Process Plant Technology Student*

Jason is an enrolled Crow tribal member. He is a member of the Whistling Water Clan and a child of the Greasy Mouth. He graduated from Plenty Coup High School and has spent a few semesters at Haskell Indian Nations University located in Lawrence, KS and Little Big Horn College located in Crow Agency, Montana. Jason has experience in wild land fire-fighting as a crew and engine boss. He plans on working as a Process Plant Technician in the Billings, Montana area.



**Samuel Sailors**

*1st Year Process Plant Technology Student*

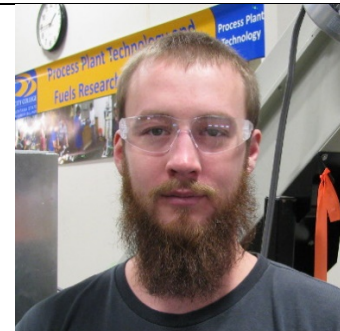
Sam is serving as a Process Plant Laboratory Technician under the Federal Work Study program. He enjoys many ties to processing plants with four family members that work in the industry. Sam uses his knowledge of process operations and background in carpentry to bring a practical approach to problem solving that benefits our work on the project.



**Tyler Shanley**

*1<sup>st</sup> Year Process Plant Technology Student*

Tyler has worked in an oil refinery, paper mill, and has some Chemical Engineering course work completed. His work experience and education gives Tyler a great foundation to continue developing and improving our pelletizing process.



**Garth Webster**

*2<sup>nd</sup> Year Process Plant Technology Student*

Garth plans to work in the refining sector when he graduates with an AAS in Process Plant Technology. He brings a background in agriculture that benefits his research at MSUB City College.

**Expenditures**

<b>MSU Northern</b>	<b>Expenditures to Date</b>
Personnel Services	\$477,713. <sup>30</sup>
Operations	\$108,031. <sup>70</sup>
Equipment	\$14,935. <sup>85</sup>
<b>MSU Billings</b>	
Personnel Services	\$22,471. <sup>00</sup>
Operations	\$5,304. <sup>00</sup>
Equipment	\$30,991. <sup>00</sup>
<b>TOTAL</b>	<b>\$659,446.<sup>85</sup></b>
Percent Spent	82.43%

**Equipment Purchased**

MSU Billings City College has received the following equipment:

- Buskirk Engineering PM605 pellet mill
- 12' pellet cooling conveyor
- 10" wide vibratory screener
- 60" paddle mixing auger
- 10 cubic foot surge tank