2010 Environment and Natural Resources Trust Fund (ENRTF) Work Program

Date of Report: December 15, 2009
Date of Next Progress Report: December 31, 2010
Date of Work Program Approval:
Project Completion Date: June 30, 2013

I. PROJECT TITLE: **Algae for Fuels Pilot Project**

Project Manager: Roger Ruan
Affiliation: University of Minnesota
Mailing Address: 1390 Eckles Ave.
City / State / Zip: St. Paul, MN 55108
Telephone Number: 612-625-1710
E-mail Address: ruanx001@umn.edu
Fax Number: 612-624-3005
Web Site address: http://biorefining.cfans.umn.edu.

Location: St. Paul, Ramsey County, Minnesota

Total ENRTF Project Budget:	**ENRTF Appropriation**	**$**	**900,000**
	Minus Amount Spent:	**$**	**0**
	Equal Balance:	**$**	**900,000**

Legal Citation: M.L. 2010, Chp. 362, Sec. 2, Subd. 7a

Appropriation Language:
$900,000 is from the trust fund to the Board of Regents of the University of Minnesota to demonstrate an innovative microalgae production system utilizing and treating sanitary wastewater to produce biofuels from algae. This appropriation is available until June 30, 2013, by which time the project must be completed and final products delivered.

II. PROJECT SUMMARY AND RESULTS:
Biomass energy is a viable alternative to fossil based energy supplies. However, significant advances in biomass energy technologies have encountered economic, ecological, and policy concerns, including feed stock procurement, energy balance, carbon footprint, competition for food and fuel, water use, etc. The University of Minnesota will partner with the Metropolitan Council Environment Services (MCES) to demonstrate "Algae to Fuels" technology. This project advances our existing collaborative R&D partnership, and will ***demonstrate an innovative photosynthetic algae production system*** which simultaneously produces high lipid oil for bio-diesel production, captures and recycles N and P from waste water, and sequester CO_2. The **GOAL** of the project is to develop, build, and test a pilot scale algae production system that will treat concentrated wastewater and animal facility wastewater and generate algal biomass. The facility will be located at the UMN St. Paul campus greenhouse facilities (alternative sites are U MN Rosemount Research and Outreach Center or MCES Metro waste water treatment facility, pending on the additional funding we are seeking from MCES and UMN). The harvested algae will be converted into biofuels. The project is expected to improve water quality, minimizing freshwater and land use, reducing carbon

emission, capture and recycling of plant nutrients, and producing clean, green energy. With further R&D efforts, the technology can potentially be implemented at other wastewater treatment facilities, and adapted to other waste streams (livestock waste, food production wastes) in the long term. The knowledge gained will be documented and disseminated to the public and academic communities. The system will also be used for field demonstration and publicized through various educational outreach and communication activities.

III. PROGRESS SUMMARY AS OF:

IV. OUTLINE OF PROJECT RESULTS*:*

RESULT/ACTIVITY 1: *Pilot Scale System for Production of Algae on Wastewater*

Description:
The objective of this project result is to develop, design, and construct a pilot scale algae production facility for process testing and improvement, and demonstration. This facility will consist of our proprietary multi-level continuous flow enclosed photobioreactors (PBRs) housed inside a simple structured greenhouse and will be operational about 10 out of 12 months in Minnesota weather conditions. Concentrated wastewater, diluted or undiluted, will be used as culture media. The facility will be capable of utilizing CO_2 from sludge burning and other sources. The growth of algae will simultaneously remove nitrogen, phosphorus, COD, and other nutrients in the wastewater, sequester carbons in organic matters and flue gas. Algae will be harvested on a continuous or semi-continuous basis. The harvested algae will be processed to produce fuels and high value materials as described in the next result. The specific activities for this result include: (1) conduct preparatory research to determine and optimize process parameters for a large pilot scale algae production system, (2) design the pilot scale algae production and harvest system, (3) construct the system, and (4) test and improve the system and process parameters.

Summary Budget Information for Result/Activity 1:

ENRTF Budget:	**$330,065**
Amount Spent:	**$ 0**
Balance:	**$330,065**

Deliverable/Outcome	**Completion Date**	**Budget**
1. Optimized process parameters necessary for the design of a large pilot scale algae production system	*12/31/2010*	$56,108
2. Production and harvest system development	*12/31/2011*	$111,443
3. System construction and installation	*06/30/2012*	$106,807
4. System testing and improvement	*12/31/2012*	$55,707

Result Completion Date: *12/31/2012*

Result Status as of December 31, 2010
Result Status as of *June 30, 2011*
Result Status as of *December 31, 2011*

Result Status as of *June 30, 2012*
Result Status as of *December 31, 2012*

Final Report Summary:

RESULT/ACTIVITY 2: *Lab Scale Algae to Fuel Conversion Technology*

Description:
Processing is another important factor in the algae-to-fuel equation. The processing costs may be reduced by improving the processing efficiency and generating multiple value-added by-products. The objective of this project result is to develop cost effective conversion processes and a product portfolio for best economic returns. Figure 1 shows the possible product streams from algae.

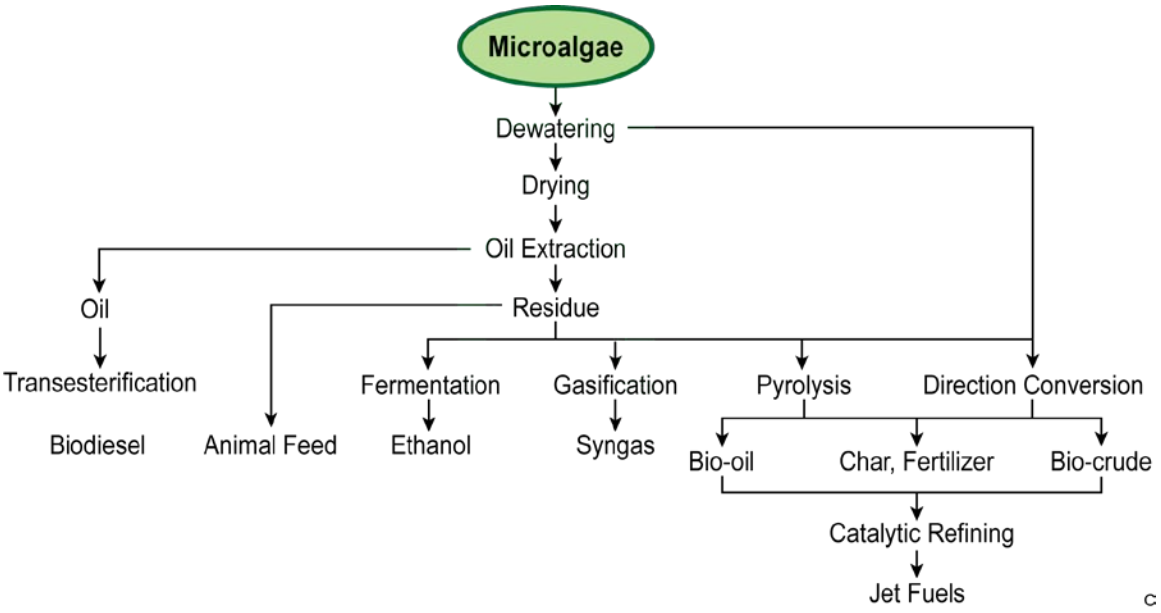

Figure 1. Product possibilities from algae.

The planned activities for this project result include development and demonstration of technologies for converting algal biomass to a range of products. We will advance research on direct conversion processes which either extract lipids from wet algae or convert wet algae directly to fuels without the expensive drying process. In this project, we will (1) optimize direct conversion and catalytic upgrading processes, (2) design and construct large lab scale systems, (3) develop P and N recovery process through algae processing, and (4) test and demonstrate the systems.

Summary Budget Information for Result/Activity 2:

ENRTF Budget:	**$414,010**
Amount Spent:	**$ 0**
Balance:	**$414,010**

Deliverable/Outcome	**Completion Date**	**Budget**

1. Optimize direct conversion and catalytic upgrading processes	*06/30/2011*	$57,508
2. Design and construction of the conversion systems	*06/30/2012*	$253,315
3. Develop P and N recover process	*06/30/2013*	$44,980
4. Evaluation data and demonstration	*06/30/2013*	$58,207

Result Completion Date: *06/30/2013*

Result Status as of December 31, 2010
Result Status as of *June 30, 2011*
Result Status as of *December 31, 2011*
Result Status as of *June 30, 2012*
Result Status as of *December 31, 2012*
Result Status as of *June 30, 2013*

Final Report Summary:

RESULT/ACTIVITY 3: *Evaluation, Demonstration, and Outreach*

Description:
We will evaluate and demonstrate the systems and present our results to the general public, in scientific and trade journals, and to funding agencies. Specifically, we will (1) evaluate the systems against designed technical specifications; (2) evaluate and quantify the green impacts and benefits with respect to pollutant removal, water usage and quality, carbon sequestration, energy balance, and fuel quantity and quality, and conduct economic and environmental life-cycle analysis; (3) demonstrate the systems and processes to stakeholders; and (4) present the project data to funding agencies, academic community, and the general public through reports, seminars, meetings, and journal publications.

Summary Budget Information for Result/Activity 3:

ENRTF Budget:	**$155,925**
Amount Spent:	**$ 0**
Balance:	**$155,925**

Deliverable/Outcome	**Completion Date**	**Budget**
1. Technical evaluation data	*12/31/2012*	$54,435
2. Environmental, ecological, and techno-economic evaluation, and life-cycle analysis data	*06/30/2013*	$25,296
3. Demonstrations	*06/30/2013*	$63,353
4. Project report and presentations	*06/30/2013*	$12,841

Result Completion Date: *06/30/2013*

Result Status as of December 31, 2010
Result Status as of *June 30, 2011*

Result Status as of *December 31, 2011*
Result Status as of *June 30, 2012*
Result Status as of *December 31, 2012*
Result Status as of *June 30, 2013*

Final Report Summary:

V. TOTAL ENRTF PROJECT BUDGET: $900,000

Personnel: $609,854

Paul Chen, co-PI, 30%, 3yrs, including 32.3% benefits, project coordination, conducting R&D, project evaluation, progress report	$86,724
Dean Current, co-PI, 15%, 3yrs, including 32.3% benefits, conducting R&D, economic and environmental life-cycle analysis	$43,365
2 Postdocs, 100%, 3yrs, including 19.75% benefits, conducting R&D, operations, demonstration, data analysis	$299,053
2 Graduate Research Assistants, 50%, 3yrs, including 16.84% benefits and tuitions, conducting R&D, operating, demonstration	$180,712

Equipment/Tools/Supplies: $*276,000*

Non-capital Equipment / Tools: pumps, hoses, valves, control components, lights, tanks, mixers, for maintenance, repair and replacement	$14,000
Algal biomass conversion equipment including hydrothermal reactor system, oil extraction system, and catalytic upgrading reactors.	$200,000
Lab and operation supplies: materials for making lab scale reactors for testing, nutrients, cultures, chemicals for analysis, lab supplies, consumables for analytical instruments, external analysis services	$62,000

Travel: $*10,145*

In-state travel: daily usage of University and personal vehicles for researchers to travel between campus and research and demonstration sites	$10,145

Additional Budget Items: $*4,000*

Copying and printing of project materials for demonstration, extension, and education activities	$4,000

Explanation of Capital Expenditures Greater Than $3,500:
We requested $200,000 for custom-manufacturing of an algal biomass conversion system. We will develop a basic design through our research for the system. The requested budget is to cover the costs associated with engineering design and manufacturing of the system by a local company. The system will be used for this ENRTF project and for similar work throughout its useful life time for process development, demonstration, education, and pilot scale trials.

VI. PROJECT STRATEGY:

A. Project Partners:

The project will be carried out by a team of researchers and engineers from UMN and MCES.

Dr. Roger Ruan, Professor, Director, Center for Biorefining, Department of Bioproducts and Biosystems Engineering (BBE), UMN, will be the PI & project director. He will be responsible for overall project planning and budget control, development, design and evaluation of enclosed photobioreactors, development and evaluation of processes and lab scale systems for conversion of algae to fuels. He will also lead demonstrations and present project results. Dr. Ruan's salary will not be covered by this project.

Dr. Robert Polta, Director of Research, Metropolitan Council Environmental Services (MCES), a registered professional engineer in Minnesota, will be a co-PI of the project. He will be responsible for demonstration site preparation and coordinate construction, installation and operation of the production system. He will also lead efforts in evaluating the environmental and ecological benefits of the project. Dr. Polta's salary will not be covered by this project.

Dr. Paul Chen, Program Director, Center for Biorefining, Dept of BBE, UMN, will be a co-PI. He will be responsible for experiment design and coordination, monitoring and documentation of project progress and results, and publicizing the project. He will also be involved in development of conversion processes.

Dr. Dean Current, Program Director, Center for Integrated Natural Resources and Agricultural Management, UMN, will be a co-PI and will be responsible for conducting the economic and environmental life-cycle analysis.

B. Project Impact and Long-term Strategy:

The proposed project, built on our existing R & D efforts, does not need additional investment other than the requested financial support to be completed. However, further R & D leading to eventual technology transfer and commercialization will be our long-term goal and will require additional funding. Next level scale-up pilot facilities must be demonstrated with federal, state, and private funding before the technology can be commercialized.

C. Other Funds Proposed to be Spent during the Project Period:

The expected LCCMR funding level for this project was lower than initially requested. Therefore, we are planning to build and expand a scaled-down demo system in our current small pilot reactor site in the St Paul campus greenhouse facilities. However, we are actively seeking additional funding to build other large pilot demo systems. The University of Minnesota IREE is considering providing $250,000 for us to build the pilot demo system in The *Rosemount* Research and Outreach Center where there is wastewater treatment facility. And MCES intends to come up with $653,845 to $979,045 to support building and operating a pilot demo system in the MCES St. Paul wastewater treatment plant.

Additional information about these proposed funds can be found in the attached spreadsheet.

D. Spending History:

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period: private gift funds will be used for algal biomass conversion research	$100,000	*secured*
Other State $ Being Applied to Project During Project Period:	$	*N/A*
In-kind Services During Project Period: spaces and utility donated by MCES and PI Dr. Ruan's 8% time and co-PI Dr. Bob Polta's 20% time.	$40,000	secured
Remaining $ from Current Trust Fund Appropriation (if applicable):		*N/A*
Funding History:	$	
Xcel Energy (2007-2008): Development of mass algae culture systems	$150,000	secured
MCES (2006-2009): Mass Culture of Algae as an Energy Crop for Biofuel Production by Utilizing Wastewater and Flue Gas from Wastewater Plant	$540,000	secured
MCES (7/1/2009-6/30/2010): Mass Culture of Algae as an Energy Crop for Biofuel Production by Utilizing Wastewater and Flue Gas from Wastewater Plant	$55,000	secured
IREE (2006-6/30/2010): Mass Culture of Algae as an Energy Crop for Biofuel Production by Utilizing Wastewater and Flue Gas from Wastewater Plant	$540,000	secured
Other related private gift supports	$100,000	secured

VII. DISSEMINATION:
The objective of the dissemination activities is to inform Minnesota stakeholders and general scientific community of our project results, benefits, and potential for commercialization of this environment and ecology conscious technology. We will disseminate our project results through multiple channels and in different material formats.

1) We will submit progress reports twice a year to LCCMR, who may in turn pass the information to stakeholders through various channels.
2) We will present our project and findings at local workshops and national and international meetings.
3) We will demonstrate the technology developed through the project to the stakeholders.
4) An educational brochure will be developed to provide general information of the project and the technology developed.
5) We will have our technical and scientific findings published on peer reviewed journals. We anticipated at least 3 papers will be produced from this project.
6) We will update the project progress on our website (http://biorefining.cfans.umn.edu).
7) We will publicize our project and findings through public media.

VIII. REPORTING REQUIREMENTS: Periodic Work Program progress reports will be submitted not later than 6/30 and 12/31 of each year. A final Work Program report and associated products will be submitted between June 30 and August 1, 2013 as requested by the LCCMR.

Attachment A: Budget Detail for 2010 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: *Algae for Fuels Pilot Project*

Project Manager Name: *Roger Ruan*

Trust Fund Appropriation: $ *900,000*

1) See list of non-eligible expenses, do not include any of these items in your budget sheet

2) Remove any budget item lines not applicable

2010 Trust Fund Budget	**Result 1 Budget:**	**Amount Spent** *(7/1/10)*	**Balance** *(7/1/10)*	**Result 2 Budget:**	**Amount Spent** *(7/1/10)*	**Balance** *(7/1/10)*	**Result 3 Budget:**	**Amount Spent** *(7/1/10)*	**Balance** *(7/1/10)*	**TOTAL BUDGET**	**TOTAL BALANCE**
	Pilot Scale System for Production of Algae on Wastewater			*Lab Scale Algae to Fuel Conversion Technology*			*Evaluation, Demonstration, and Outreach*				
BUDGET ITEM											
PERSONNEL: wages and benefits	243,265	0	243,265	228,810	0	228,810	137,780	0	137,780	609,855	609,855
Paul Chen, co-PI, 30%, 3yrs, including 32.3% benefits, project coordination, conducting R&D, project evaluation, progress report											
Dean Current, co-PI, 15%, 3yrs, including 32.3% benefits, conducting R&D, economic and environmental life-cycle analysis											
Postdoc 1, 100%, 3yrs, including 19.75% benefits, conducting R&D, operations, demonstration, data analysis											
Postdoc 2, 100%, 3yrs, including 19.75% benefits, conducting R&D, operations, demonstration, data analysis											
Graduate Research Assistant 1, 50%, 3yrs, including 16.84% benefits and tuitions, conducting R&D, operationg, demonstration											
Graduate Research Assistant 2, 50%, 3yrs, including 16.84% benefits and tuitions, conducting R&D, operationg, demonstration											
Non-capital Equipment / Tools *(pumps, hoses, valves, control components, lights, tanks, mixers, for maintenance, repair and replacement)*	9,800	0	9,800	4,200	0	4,200				14,000	14,000
Capital equipment over $3,500 *(Algal biomass conversion equipment including hydrothermal reactor system, oil extraction system, and catalytic upgrading reactors.)*	50,000	0	50,000	150,000	0	150,000				200,000	200,000
Printing	1,000	0	1,000	1,000	0	1,000	2,000	0	2,000	4,000	4,000
Supplies *(materials for making lab scale reactors for testing, nutrients, cultures, chemicals for analysis, lab supplies, consumables for analytical instruments, external analysis services)*	22,000		22,000	30,000	0	30,000	10,000	0	10,000	62,000	62,000
Travel expenses in Minnesota	4,000		4,000				6,145	0	6,145	10,145	10,145
Other *(Describe the activity and cost) be specific*											
COLUMN TOTAL	**$330,065**	**$0**	**$330,065**	**$414,010**	**$0**	**$414,010**	**$155,925**	**$0**	**$155,925**	**$900,000**	**$900,000**