Environment and Natural Resources Trust Fund
2010 Request for Proposals (RFP)

LCCMR ID: 051-B1

Project Title:

Dimethyl Ether A Renewable Biofuel Meeting Minnesota Needs

LCCMR 2010 Funding Priority:

B. Renewable Energy Related to Climate Change

Total Project Budget: $ $230,000

Proposed Project Time Period for the Funding Requested: 2 years, 2010 - 2012

Other Non-State Funds: $ $0

Summary:

Dimethyl ether, a second generation biofuel, has the highest well-to-wheel energy efficiency and lowest greenhouse gas emissions of any biomass-based fuel. Combustion-related engineering issues will be addressed.

Name: David Kittelson

Sponsoring Organization: U of MN

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Minneapolis MN 55455

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Email: watts012@umn.edu

Fax: (612) 625-1578

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

_____ Knowledge Base _____ Broad App. _____ Innovation

_____ Leverage _____ Outcomes

_____ Partnerships _____ Urgency _____ TOTAL

MAIN PROPOSAL

PROJECT TITLE: **Dimethyl Ether** – A Renewable Biofuel Meeting Minnesota Needs

I. PROJECT STATEMENT: **Dimethyl Ether** (**DME**) is a second generation, renewable biofuel that **meets the needs of Minnesota**.

- DME has the *highest well-to-wheel energy efficiency*, 25% better than synthetic diesel fuel, and the *lowest greenhouse gas emissions* of any biomass-based fuel (see graphic).
    - DME combustion produces less black carbon. Black carbon is estimated to produce 18% of the planet's warming, compared to 40% for carbon dioxide.
- The Department of Energy's National Renewable Energy Laboratory estimates that MN could produce all of the gasoline and diesel fuel required to meet MN transportation needs if DME was produced from existing biomass resources in MN.
    - DME is produced from renewable cellulosic biomass such as pulp mill residue, corn stover, prairie grass, and forestry waste by gasification.
- Infrastructure exists to distribute DME as a bottled gas, propane replacement fuel.
- DME has excellent combustion properties, produces low exhaust emissions, is non-toxic and is biodegradable.

An example illustrates the potential of DME. DME can be produced by the gasification of black liquor, a waste stream produced by pulp mills (see graphic). A typical pulp mill produces 1000-1200 tons dry pulp per day, and processes 1800-2100 tons of black liquor dry solids per day ((ton ds)/day). A small black liquor gasifier can process 400 (ton ds)/day (about 20% of the pulp mill capacity) and over an entire year produce 7 million gallons of DME. Seven million gallons is enough to fuel 700 buses or about *2/3 of the current Metro Transit fleet*. If DME were produced from every MN pulp mill, 10-15% of the state's diesel fuel requirements would be met. If DME was also produced from all other sources of cellulosic biomass in MN then *all of the gasoline and diesel fuel required to meet MN transportation needs could be produced*. Rational Energies' proposed pilot-scale gasification plant in Rosemount, MN is an example of a small biomass gasifier.

While the potential of DME is great, it has received little attention in the U.S, because of technical barriers, lack of public awareness, lack of preferred tax status, and high capital costs associated with start-up production. DME cannot be blended with petroleum-based fuel, because the physical properties of DME are similar to those of propane. Engine and fuel system modifications are also required. *The purpose of the proposed research is to address DME engineering issues, evaluate DME emissions, and raise the profile of DME within MN.* We will demonstrate that DME is a clean, renewable biomass-based fuel that is a suitable propane replacement, and that it could immediately be used with gas grills, space heaters and furnaces given sufficient production capacity.

II. DESCRIPTION OF PROJECT RESULTS

Result 1: Address engineering issues and evaluate emissions in a diesel engine

a. Install a DME fuel distribution system.
b. Measure gaseous and particulate matter emissions from a small diesel engine operated on diesel fuel.
c. Install DME fuel injectors in the diesel engine.
d. Determine the best operating regimes for DME in the diesel engine.
e. Measure gaseous and particulate matter emissions from the diesel engine using DME as the fuel and compare them to the same engine fueled with diesel fuel.

Budget: $ 112,766
Deliverables:
1. Operate a diesel engine on DME.
2. Demonstrate the environmental benefits of DME compared to a diesel-fueled engine by quantifying emission reductions.

Completion Date: 06/30/2011 (assuming a 07/1/2010 start date)

Result 2: Evaluate DME as a propane replacement for gas grill/burner
a. Determine design changes necessary to operate a propane gas grill, space heater and/or furnace on DME.
b. Measure changes in performance and emissions when switching from propane to DME.
Budget: $ 108,431
Deliverables:
1. Establish guidelines for the use of DME as a propane replacement that will serve as a basis for introduction into the marketplace including:
    a. Design changes that are required to use DME as a propane replacement.
    b. Safe and stable operating parameters.

Completion Date: 5/31/2012

Result 3: Raise awareness of DME within the state of MN and nationally
Budget: $ 8,803
Deliverables: The results of this project must be shared with interested parties within the state of MN to ensure the widest possible public and private sector awareness. Greater awareness will help DME fulfill its potential as a second generation renewable fuel.
1. Post findings on the Center for Diesel Research web site http://www.me.umn.edu/centers/cdr/.
2. Share results with colleagues at the University Center for Transportation Studies and the Institute on the Environment by making conference presentations.
3. Publish findings in a scientific journal.

Completion Date: 6/30/2012

III. PROJECT STRATEGY

A. Project Team/Partners: Prof David Kittelson is the principal investigator and Director of the Center for Diesel research at UMN. He will work closely with Dr. Winthrop Watts and graduate research assistants to complete this project.
B. Timeline Requirements: During the first 12 months we will address engineering issues associated with DME used as fuel for a small diesel engine. During the next 12 months we will evaluate and establish guidelines for the use of DME as a propane replacement for use in gas grills, burners, and furnaces. We will also champion the use of DME by sharing our findings at public meetings, symposia, on the web and in scientific publications.
C. Long-Term Strategy: This project is a first step to introduce DME to MN. MN has had little if any previous experience with DME research. We envision that it will be necessary to partner with other organizations in the long-term to ensure successful technology transfer. We will use this project as a platform demonstrating our capabilities so that we may seek funding from other organizations such as the Department of Energy's National Renewable Energy Laboratory. We envision this project as the first step that will demonstrate our capability to carry out DME research. It will also enhance our capability to prepare engineers to consider second-generation, biomass-based renewable fuels as viable alternatives in the future.

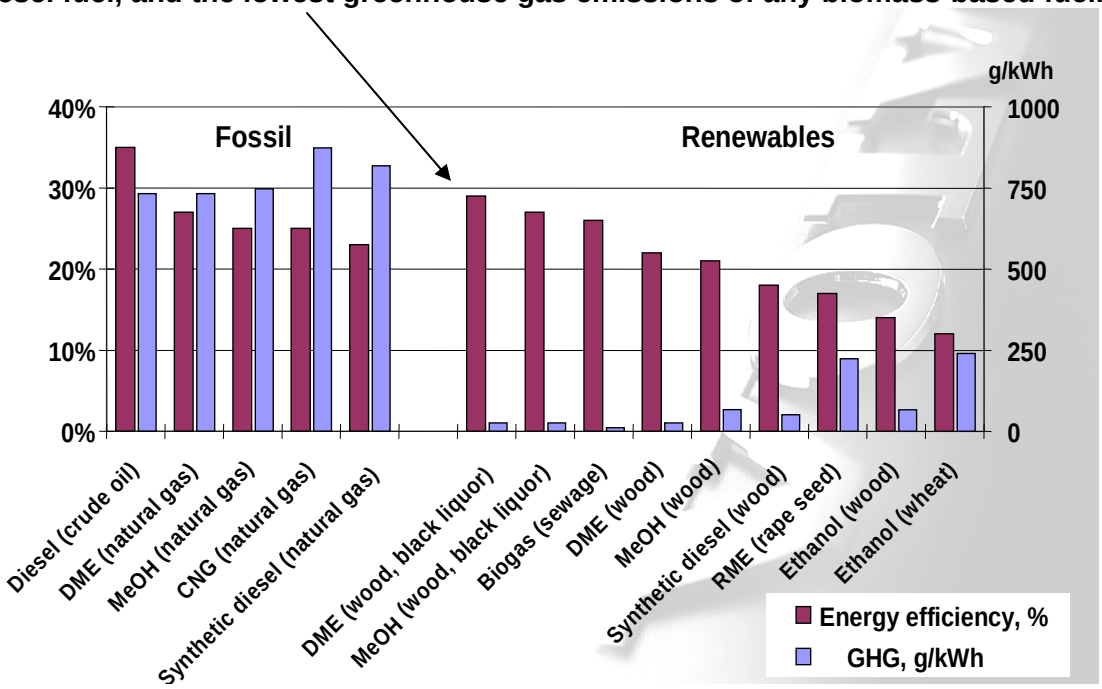
Project Budget

IV. TOTAL PROJECT REQUEST BUDGET (2 year project)

BUDGET ITEM	**AMOUNT**
Personnel: (rates incremented 3.5% for year 2)	
Prof. Kittelson, PI, 7.7% time, 75.6% salary, 24.4% fringe, 2 yr	$ 45,662
9-month academic appointment	
Dr. Watts, Res Assoc., 13.5% time, 75.6% salary, 24.4% fringe, 2 yr	$ 35,476
Dr. Watts is paid entirely from research funds	
Mr. Zarling, Mechanical Engineer, 6.3% time, 73.0% salary, 27.0% fringe, 2 yr	$ 11,960
Mr. Zarling is paid entirely from research funds	
Graduate Research Assistant (GRA) 50% time, 57.4% salary, 42.6% fringe, 2 yr	$ 84,537
GRA Fringe benefit 16.84 % of salary, Tuition benefit $14.32 * hrs	
Contracts:	N/A
Equipment/Tools/Supplies:	
Dimethy ether fuel @~$400 per bottle of DME	$ 6,000
Fuel storage and delivery system	$ 16,365
Fuel inection systems	$ 10,000
Test stand development and modification	$ 15,000
Calibration gases (NO, CO, NOx)	$ 400
Factory calibration of flow meters, particle analyzers	$ 2,500
Swagelock fittings, tubing, miscellaneous parts	$ 1,500
Acquisition (Fee Title or Permanent Easements):	
Travel:	
Presentation and publication of results at biofuels meetins in MN	$ 600
Additional Budget Items:	NA
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$ 230,000

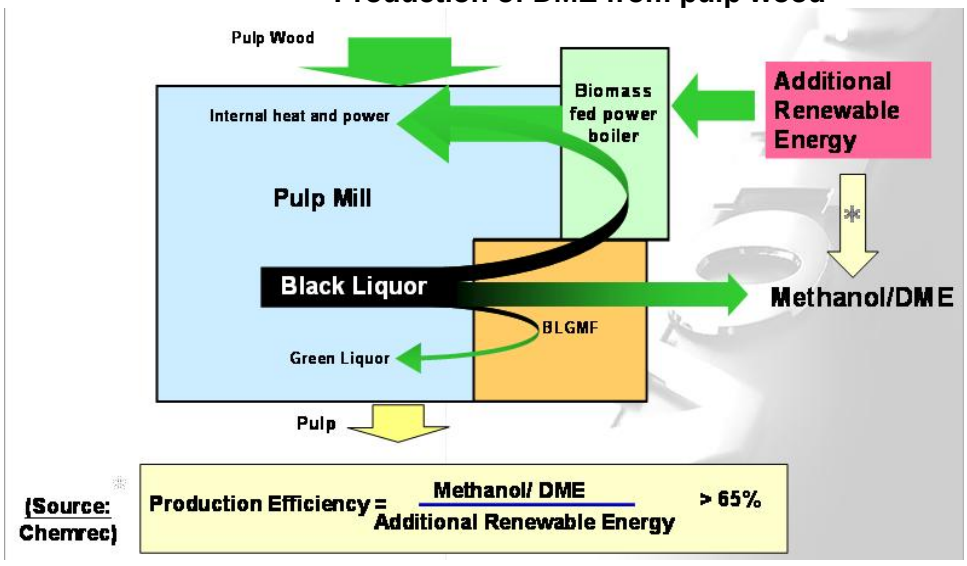
V. OTHER FUNDS N/A

DME has the highest well-to-wheel energy efficiency, 25% better than synthetic diesel fuel, and the lowest greenhouse gas emissions of any biomass-based fuel.



Well-to-wheel analysis for energy efficiency and greenhouse gases (Courtesy – A. Röj, Volvo Technology Corporation). These estimates include production, transport, and end use GHG emissions. KEY: DME dimethyl ether; MeOH methanol; CNG compressed natural gas; RME rapeseed methyl ester; GHG greenhouse gas.

Production of DME from pulp wood



KEY: BLGMF Black Liquor Gas to Motor Fuels

DAVID B. KITTELSON (Currently on sabbatical at University of Cambridge, England until June 2009)

Frank B. Rowley Distinguished Professor of Mechanical Engineering and Director, Center for Diesel Research, University of Minnesota

Education

B.S. and M.S. in Mechanical Engineering, University of Minnesota, 1964 and 1966, Ph.D. in Chemical Engineering, University of Cambridge, England, 1972

Work Experience

1970-76, Assistant Professor, 1976-80, Associate Professor, 1980-present, Professor, Department of Mechanical Engineering, University of Minnesota; 1996-present, Director, Center for Diesel Research, University of Minnesota

Other Related Experience

Visiting Scientist, IRCA Centre de Recherche, Vert le Petit, France (spring 1977) Visiting Professor, University of Vienna, Institute of Applied Physics (spring 1981); Overseas Fellow, Engineering Department, Cambridge University, Cambridge, UK (1985-86 and 2003-04 academic years); Instructor, Short Course (3-4 lectures), "Diesel Particulate and NO_x Emissions," Leeds University, Leeds, UK, (April 1988-annually); Consultant, European Commission “Particulates” program (2000-03); Health Effects Institute (2005-); Army Aberdeen Proving Grounds (2005-06); California Air Resources Board (2006-).

Selected Awards

Overseas Fellowship Churchill College, Cambridge University, 2003-04, Frank B. Rowley Endowed Professorship in Mechanical Engineering (December 2002 -), Center for Transportation Studies 2000 Braun Distinguished Service Award; SAE 1998 Arch T. Colwell Outstanding Paper Merit Award: Graskow, B.R., D.B. Kittelson, I.S. Abdul-Khalek , M.R. Ahmadi, and J.E. Morris, “Characterization of Exhaust Particulate Emissions from a Spark Ignition Engine,” SAE Paper No. 980528; SAE 1995 Arch T. Colwell Outstanding Paper Merit Award: Simons, G.R. and D.B. Kittelson, "Reducing Utility Engine Exhaust Emissions with a Thermal Reactor," SAE Paper No. 951762; Fellow, Society of Automotive Engineers, 1992

Current Research Interests

Sampling and characterization of ultrafine and nanoparticles from engines and other combustion systems; development of advanced engine exhaust aftertreatment systems, production and use of biofuels including biodiesel, butanol, DME, Fischer-Tropsch liquids, ethanol, and biocrudes; use of hydrogen produced on-board to modify conventional and low temperature combustion in engines; reduction of greenhouse gas emissions from transportation, and development of fast response sensors for engine control.

Recent Refereed Publications

Johnson, Kent C., Thomas D. Durbin, Heejung Jung, Ajay Chaudhary, David R. Cocker III, Jorn D. Herner, William H. Robertson, Tao Huai, Alberto Ayala, and David Kittelson, 2008. Evaluation of the European PMP Methodologies during On-Road and Chassis Dynamometer Testing for DPF Equipped Heavy Duty Diesel Vehicles, submitted Aerosol Science and Technology.

Swanson, J. J., D. B. Kittelson, W. F. Watts, D. D. Gladis, and M. V. Twigg, 2008. Influence of Storage and Release on Particle Emissions from New and Used CRTs, submitted to Atmospheric Environment.

Boies, Adam; J. Lucke, D. Kittelson, J. Marshall, L. McGinnis, P. Nussbaum, T. Patterson, W. Watts, and E. Wilson 2008. Reducing Greenhouse Gas Emissions from Transportation Sources in Minnesota, paper submitted to Transportation Research Board

Kittelson, D., W. Watts, J.P. Johnson, C. Thorne, C. McCann, M. Payne, S. Goodier; C. Warrens, H. Preston, U. Zink, D. Pickles, C. Goersmann, M. Twigg, A. Walker, R. Boddy, 2008. Effect of Fuel and Lube Oil Sulfur on the Performance of a Diesel Exhaust Gas Continuously Regenerating Trap, in press Environmental Science and Technology.

Swanson, Jacob and David Kittelson, 2008. A method to measure static charge on a filter used for gravimetric analysis, Aerosol Science and Technology, v 42, n 9, September, 2008, p 714-721

Ma, Hongbin, Heejung Jung, and David B. Kittelson, 2008. Investigation of Diesel Nanoparticle Nucleation Mechanisms, Aerosol Science and Technology, vol:42 iss:5 pg:335 -342.