Rec 2/18/16

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MTSU Clean Energy Initiative Project Funding Request

There are five (5) sections of the request to complete before submitting. See http://www.mtsu.edu/sga/cleanenergy.shtml for funding guidelines. Save completed form and email to cee@mtsu.edu or mail to MTSU Box 57.

1. General Information	
Name of Person Submitting Request **Ngee Sing Chong with Keying Ding as faculty co-sponsors**	
Department/Office **Chemistry/SCI 3067**	Phone # (Office) **898-5487**
MTSU Box # **Box 68, MTSU**	Phone # (Cell) **615-556-5509**
E-mail **nchong@mtsu.edu; Keying.Ding@mtsu.edu**	Submittal Date **2/18/2016**

2. Project Categories (Select One)			
Select the category that best describes the project.			
X	Energy Conservation/Efficiency	**X**	Sustainable Design
	Alternative Fuels		Other
	Renewable Energy		

3. Project Information
a. Please provide a brief descriptive title for the project. **b.** The project cost estimate is the expected cost of the project to be considered by the committee for approval, which may differ from the total project cost in the case of matching funding opportunities. **Any funding request is a 'not-to-exceed' amount. Any proposed expenditure above the requested amount will require a resubmission.** c. List the source of project cost estimates. d. Provide a brief explanation in response to question regarding previous funding.
3a. Project Title **Equipping the New Science Building with a Microwave Reactor to Enhance Student Laboratory Experience in Chemistry Courses**
3b. Project Cost Estimate **Total Amount Requested=$24,090.50-$2,500 (departmental match) = $21,590.50** **MARS Synthesis Reactor for Chemistry Laboratory**
3c. Source of Estimate **Price quote from CEM (Microwave Reactor Vendor) is attached.**

3d. If previous funding from this source was awarded, explain how this request differs?

The previous funding (Fall 2014) was for the purchase of a hydrogenation reactor intended to eliminate the use of hydrogen cylinder as a reactant source so that lab environment is safer without the high pressure cylinders of hydrogen gas which is explosive if it is leaked and accumulated to a high level. In this proposal, a microwave reactor will be used for student research or class experiments in order to (i) reduce energy usage, (ii) shorten reaction time, (iii) increase the yields of reaction products by following the principle of sustainable synthesis, and (iv) improve safety by eliminating the traditional heating mantles or Bunsen flame burners.

4. Project Description

(Completed in as much detail as possible.)

a. The scope of the work to be accomplished is a detailed description of project activities.
b. The benefit statement describes the advantages of the project as relates to the selected project category.
c. The location of the project includes the name of the building, department, and/or specific location of where the project will be conducted on campus.
d. List any departments you anticipate to be involved. Were any departments consulted in preparation of this request? Who? A listing may be attached to this form when submitted.
e. Provide specific information on anticipated student involvement or benefit.
f. Provide information for anticipated future operating and/or maintenance requirements occurring as a result of the proposed project.
g. Provide any additional comments or information that may be pertinent to approval of the project funding request.

4a. Scope: Work to be accomplished

The MARS6-TA microwave reactor system include the reactor with the features of reagent stirring, fiber optic temperature control, and the option of doing open vessel synthesis. The GlassChem vessels for reactions have a working volume of 14 milliliters, heating range up to 180 C and can withstand about 200 psi and they can be used for sample extraction prior to chemical analysis. The MARS6-TA reactor will be set up for student use in SCI 3070 and its small size allows it to be moved to other laboratories if necessary. Faculty sponsors will do the installation of the reactor for student use.

4b. Scope: Benefit Statement

With the new microwave system, chemistry students will no longer heat flasks in the lab using older, less efficient methods such as heating mantles or Bunsen burners. Instead they will insert tubes with chemicals into the microwave system. The heat generated by the instrument will produce chemical reactions much quicker than before, with the added benefit of minimizing the production of byproducts and chemical waste. Students will also learn about modern microwave syntheses and will be better prepared in using the emerging microwave reactor technology that is being adopted by industry and the academia. The new microwave synthesis system is based on green chemical principles that include waste prevention, use of methods to minimize toxicity, using safer solvents, energy efficiency, and preventing accidents.

4. Project Description (continued)

4c. Location of Project (Building, etc.)

MTSU Department of Chemistry (Science Building Room 3070 and 3007)

4d. Participants and Roles

Ngee Sing Chong – Purchase and installation of the MAR6-TA microwave reactor; using microwave reactor in teaching and research; evaluating energy savings by switching from heating mantles and Bunsen burners to the microwave reactor.

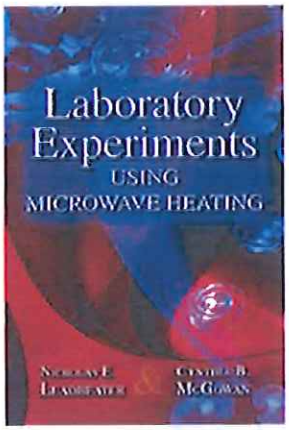
Keying Ding – Introduce students to the development of earth-abundant metal catalysts for organic transformations such as decarbonylation and deoxygenation which are particularly useful for biomass conversions to produce fuels and chemicals.

Jessie Weatherly – Maintenance of the microwave reactor by periodic replacement of consumable parts.

Other Chemistry Faculty and Students – Use the reactors and record usage duration to help track the cost or energy savings compared to traditional heating methods.

4e. Student participation and/or student benefit

Students will be the main beneficiaries of the microwave reactor because they will learn a modern laboratory technique for synthetic reactions that will enable some of them to adapt to the modern industrial laboratory practice of using microwave reactors rather than traditional heating methods. Students will be able to follow existing microwave based chemistry experiments such as those described in the following lab manual.



Laboratory Experiments Using Microwave Heating
Nicholas E. Leadbeater & Cynthia B. McGowan
CRC Press 2013

Presents 22 modern experiments for the chemistry lab

- Cycloaddition reactions
- Esterification reactions
- Condensation reactions
- Rearrangements
- Metal-catalyzed couplings, metathesis, click chemistry, cyanation
- Coordination chemistry
- Determination of empirical formula
- Extraction of essential oils
- Digestion and analysis by atomic absorption

4f. Future Operating and/or Maintenance Requirements

The microwave reactor has few consumable parts other than the glassware, which can be purchased using funds from Chemistry Department. Jessie Weatherly, the Instrument Support Engineer in the Department of Chemistry, is in charge of maintenance for all laboratory equipment and will be able to take care of the maintenance and repair of the microwave reactor if the need arises.

4g. Additional Comments: This proposal was submitted for campus fee funding last semester and it was declined. Subsequently, I contacted the reactor vendor to ask for a discount and received a revised quote for the amount of $24,090 instead of $30,000 for the earlier quote last semester. I have also talked to Dr. Van Patten, Chemistry departmental chair for equipment subsidy and he has committed $2,500 for the purchase if the campus fee funding is approved. So, the actual amount requested will be $21,590.50. We will submit another request for match from MTSU Graduate Studies if additional matching funds is necessary.

4g/ Information Pertinent to the Proposed Project

1. **Efficiency and Selectivity of Microwave Reactors in Organic Chemistry:**
   http://www.chem.tamu.edu/rgroup/djd/chem483/Projects/Microwave%20Chemistry.pdf

2. **Controlled Microwave Heating in Modern Organic Synthesis**
   http://onlinelibrary.wiley.com/doi/10.1002/anie.200400655/pdf

3. **Chemists Crank Up Heat On Microwaves**
   http://cen.acs.org/articles/90/i39/Chemists-Crank-Heat-Microwaves.html

4. **Greening the organic chemistry laboratory: a comparison of microwave-assisted and classical nucleophilic aromatic substitution reactions**
   http://www.tandfonline.com/doi/pdf/10.1080/17518253.2015.1065010

5. **Microwave chemistry**
   https://en.wikipedia.org/wiki/Microwave_chemistry

6. **A critical assessment of the greenness and energy efficiency of microwave-assisted organic synthesis**
   http://140.123.79.90/~mash1225/images/microwave%20reference/c0gc00823k.pdf

7. **Microwave Chemistry—Out of The Lab and into Production**
   http://ctechinnovation.com/papers/Microwave-chemistry-out-of-lab-into-production.pdf

5. Project Performance Information

Provide information if applicable.

a. Provide information on estimated annual energy savings stated in units such as kW, kWh, Btu, gallons, etc.
b. Provide information on estimated annual energy cost savings in monetary terms.
c. Provide information on any annual operating or other cost savings in monetary terms. Be specific.
d. Provide information about any matching or supplementary funding opportunities that are available. Identify all sources and explain.

5a. Estimated Annual Energy Savings (Estimated in kW, kWh, Btu, etc.)

The energy savings vary greatly among different reaction conditions and should be evaluated on a case-by-case basis as pointed out in Reference 6 above. The comparison of the energy efficiencies of selected chemical reactions carried out using the microwave reactor and traditional thermal heating is provided by Yvonne Barton in Reference 7. The comparison and analysis of data are shown in the two tables below where (MW) refers to microwave-assisted reactions.

Table 1. Summary of results comparing microwave heating to conventional heating

Reaction	Time	Temperature	Yield
Suzuki coupling	2 h	120°C	92%
	2 min (MW)	160°C	99%
	1 min (MW)	155°C	98%
Dihydropyrimidine	8 h	120°C	35%
	4 min (MW)	145°C	71%
Ionic liquid	4 h	130°C	95%
	1 min (MW)	200°C	95%

Table 2. Comparison of energy use in microwave reactor and batch reactor

Reaction	Energy/kg in MW	Energy efficiency	Energy/kg in batch (Croda)	% energy saving in MW
Suzuki	0.381 kWh/kg	57%	3.60 kWh/kg	89%
Cyclisation	3.84 kWh/kg	42%	3.60 kWh/kg	–
Ionic liquid	0.382 kWh/kg	39%	3.60 kWh/kg	89%

5b. Annual Energy COST Savings ($)

The savings in energy expenditure is 89% but the actual energy cost savings will depend on actual reaction conditions.

5c. Annual Operating or Other Cost Savings. Specify. ($) **Since the microwave reactor allows 14 chemical reactions to be performed simultaneously, this would amount to annual savings of about $5000 based on the capital cost of $2500 per heating mantle and control unit.**
5d.Matching or Supplementary Funding (Identify and Explain) **Department of Chemistry will provide a match of $2,500 toward the purchase of the reactor and the normal operating expenses for the additional glassware needed for the microwave reactor (~$1,200 per year). Additional matching funds from MTSU Graduate Studies will be sought if necessary.**

CEM Corporation
Innovators in Microwave Technology
3100 Smith Farm Road, P.O. Box 200, Matthews, NC 28106-0200 USA
Phone (704) 821-7015 * Fax (704) 821-5185 * Email: sales@cem.com * Web: http://www.cem.com

QUOTATION

Name	Ngee Chong	Created Date	2/10/2016
Phone	(615) 898-5487	Quote Number	00008420
Email	nchong@mtsu.edu	Expiration Date	3/31/2016

Bill To Name	Middle Tennessee State University	Account Name	Middle Tennessee State University
Bill To	1318 Nottaway Court Murfreesboro, TN 37132 United States		

Please Provide "Billing and/or Ship To" Information If Different Than Quote:

Contact _____
Address _____
City _____ State/Province _____
Zip _____ Country _____
Phone _____ Fax _____

CEM Corporation
Innovators in Microwave Technology
3100 Smith Farm Road, P.O. Box 200, Matthews, NC 28106-0200 USA
Phone (704) 821-7015 * Fax (704) 821-5185 * Email: sales@cem.com * Web: http://www.cem.com

Product Code	Product	Product Description	Sales Price	Discount	Quantity	Total Price
MARS6-TA	MARS 6 Academic Synthesis Configuration	Configured to perform a broad range of syntheses. Uses CEM vessels for pressurized rxns and standard lab glassware (250mL-5L RBF) for atmospheric (reflux) rxns. Features Fiber Optic temp control (0-330°C) and reagent stirring. System can also be utilized for acid digestion and/or extraction with certain vessel sets and options. Features: -Dual magnetrons provide 1800W of power for heating high throughput vessel sets & difficult samples -Magnetron protected from reflected energy, ensuring constant power output -UL approved by OSHA's Nationally Recognized Testing Laboratory (NRTL) Program -ReactiGaurd™ safety sensor for continuous cavity monitoring of vessel events -Robust & corrosion-resistant system -Easy-to-use touch screen control -Built-in video library provides vessel set and system option training -Communication ports for optional external control -Electrical requirements: 208/230 VAC, 60 Hz, 15A @ 230 VAC Included: Teflon™ vessel holder, fiber optic probe, operations manual, & quick startup guide Available Options: On-board Thermal Printer (hardcopy graph & data retrieval); IR Temp Control (Xpress vessels); Pressure Control (framed vessels) MARS6-TA includes the following part numbers: 927500, 512190, 512185, 907540	$26,965.00	30.00%	1.00	$18,875.50
907394	GlassChem Vessel Starter Set, 24 place, 20 mL	Includes (1) 24 place turntable, (23) standard vessel assemblies, & (1) control vessel assembly w/ sapphire thermowell for in situ temp control w/ fiber optic probe. Simple-to-use vessel assembly includes a 20mL glass liner, Teflon™ plug & Teflon™ cap. A safety composite sleeve surrounds each liner for added protection and a Teflon™ shield locks on top of the turntable to secure all vessels. The vent-reseal cap design minimizes vial failures and eliminates the need of costly pressure sensors. Max temperature control: 180°C. Max pressure rating: >500psi (vents 200psi). Working volume: 3-14mL.	$5,215.00		1.00	$5,215.00
SI-Synthesis	Self-Installation (Synthesis)	Customer installs system with provided self-installation instructions. Technical support available toll free at (800) 726-3331.	$0.00		1.00	$0.00

Sales Rep	Sean Suggett	Subtotal	$32,180.00
		Savings	($8,089.50)
		Total Price	$24,090.50

Currency & Shipping Terms

CEM Corporation
Innovators in Microwave Technology
3100 Smith Farm Road, P.O. Box 200, Matthews, NC 28106-0200 USA
Phone (704) 821-7015 * Fax (704) 821-5185 * Email: sales@cem.com * Web: http://www.cem.com

Currency is US Dollars

USA Shipping Terms: FOB to Matthews, NC - prepay and add

Standard Delivery is 28 days ARO

Purchase Order

Note: This quote can be used as a purchase order by entering purchase order number and signing

Please sign here: _____ **Date:** _____ **PO Number:** _____

Tax Status: If Account is Tax-Exempt, please provide a Tax-Exemption or Resale Certificate along with the Purchase Order. Otherwise, the order will be processed as taxable.

Standard Terms & Conditions

For information on leasing CEM products, contact Marissa Reinhardt at CEM Financial Services
Phone 973-292-0025 x412, mreinhardt@captivelease.com

Standard Terms & Conditions

1. Payment - Make all checks payable to CEM Corporation and mail to Accounts Receivable at the below address:

12750 COLLECTIONS CENTER DRIVE, CHICAGO IL 60693 United States

2a. (USA) General - Net 30 Days FOB to Matthews, NC. Freight is prepaid and added to invoice. Clerical errors are subject to corrections.
2b. (Canada) General - Net 30 Days; Canada Shipping Terms: ExWorks PrePaid & Charge - EXP Matthews, NC USA. If DDP Shipping Terms are required, then contact CEM Corporation for revised quotation. CEM Corporation does not withold nor remit GST or QST taxes for Canada. Customer is responsible for remitting these directly. Clerical errors are subject to corrections.
3. All orders subject to shipping and handling charges.
4. Taxes - All prices are quoted excluded of any sales, excise, use, or similar tax. The amount of tax applicable is the buyers responsibility.
5. Renters Casualty - Renter shall bear the risk of loss or damage to the equipment from delivery to customer site until it is returned to CEM.
6. Warranty - All instruments are warrantied against defects in workmanship or material for one (1) year from date of shipment.

7. Returns - All returns must be authorized with an RMA# by the CEM Customer Service Department. Call (800) 726-3331 for authorization.
8. Quantity - Any changes to quantities other than complete instruments will not effect the validity of this quote.

Linda Hardymon

From: Ngee Chong
Sent: Thursday, February 18, 2016 4:52 PM
To: Center for Energy Efficiency
Cc: Keying Ding
Subject: Clean Energy Project Funding
Attachments: Clean Energy Project Funding-Microwave Reactor_Chong_2016.pdf

Dear Clean Energy Committee Chair,

Attached is my proposal for Clean Energy Project Funding Program. This is a re-submission of the declined proposal from last semester after I have made some changes in the forms of a smaller requested amount based on a substantial vendor discount (amount reduced from ~$30,000 to ~$24,000), approved matching funds from Chemistry Department, and emphasis on the sustainability principle embodied in the microwave reactor in addition to supporting references on the energy efficiency of microwave heating compared to resistive heating using hot plates in laboratories.

Sincerely,
Ngee Sing Chong
Professor of Chemistry, MTSU
615-898-5487