COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $50,000
TITLE OF PROPOSED PROJECT: Constructing a Pilot-scale Bioplastic Production Facility	
SPECIFIC PROJECT FOCUS: At a lab-scale we have advanced a novel process to upcycle dairy manure to a high-value product: PHA, which is a bioplastic. To advance this process to full-scale we need to 1st validate the process at a pilot-scale. The funding requested will facilitate this goal.	
PROJECT START DATE: 2/2011	PROJECT END DATE: 12/30/2011
NAME OF INSTITUTION: University of Idaho	DEPARTMENTS: Civil Engineering; Forest Products
ADDRESS: PO Box 441022, Moscow, ID 83844-1022	

	E-MAIL ADDRESS:	PI PHONE NUMBER:
	ecoats@uidaho.edu	208.885.7559

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR	Erik R. Coats	Assistant Professor	
CO-PRINCIPAL INVESTIGATOR	Armando G. McDonald	Professor	
CO-PRINCIPAL INVESTIGATOR	Nick Guho	PhD Student, civil engineering	

	NAME:	SIGNATURE:
Authorized Organizational Representative	~~Polly J Knutson, Director~~ **Office of Sponsored Programs** **University of Idaho** SK	

SUMMARY PROPOSAL BUDGET

Name of Institution: University of Idaho

Name of Project Director: Erik R. Coats

A. FACULTY AND STAFF

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
None					
% OF TOTAL BUDGET: 0.0				**SUBTOTAL:**	0.0

B. VISITING PROFESSORS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
None					
% OF TOTAL BUDGET: 0.0				**SUBTOTAL:**	0.0

C. POST DOCTORAL ASSOCIATES / OTHER PROFESSIONALS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
None					
% OF TOTAL BUDGET: 0.0				**SUBTOTAL:**	0.0

D. GRADUATE / UNDERGRADUATE STUDENTS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
% OF TOTAL BUDGET: 0.0				**SUBTOTAL:**	0.0

E. FRINGE BENEFITS

Rate of Pay (%)	Salary Base	Dollar Amount Requested
None		
	SUBTOTAL:	0.0

F. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
Enclosed trailer	$8,000
Moyno 500-series progressive cavity pumps (5 units @ $2,400 each)	$12,000
Hach dissolved oxygen probes (2)	$6,000
Allen Bradley PLC	$1,500
Variable frequency drives (5 each @ $400 – for the pump motors)	$2,000
Pump motors (5 @ $200 each))	$1,000
Mechanical mixer motors (6)	$4,000
Solenoid valves (6)	$5,400
Misc items: pressure transducers, tanks, pipe, valves, couplings, bulkhead fittings, steel plate and rods, gravity belt thickener fabric, wiring, etc.	$10,100
SUBTOTAL:	$50,000

G. TRAVEL: Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
none						
					SUBTOTAL:	0

H. Participant Support Costs:	Dollar Amount Requested
1. Stipends	0
2. Travel (other than listed in section G)	0
3. Subsistence	0
4. Other	0
SUBTOTAL:	0

I. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies	0
2. Publication Costs/Page Charges	0
3. Consultant Services (Include Travel Expenses)	0
4. Computer Services	0
5. Subcontracts	0
6. Other (specify nature & breakdown if over $1000	0
SUBTOTAL:	0

J. Total Costs: (Add subtotals, sections A through I)	TOTAL:	$50,000
K. Amount Requested:	TOTAL:	$50,000

Project Director's Signature: [signature]	Date: 12.2.10

FY 2011 SBOE IDAHO INCUBATION FUND PROGRAM
Constructing a Pilot-scale Bioplastic Production Facility

1. Executive Summary:

Over 12M dairy cows generate >50M tons/yr of dry manure in the U.S. [1], and produce 6.4M tons of CO_2 equivalents/yr [2]. In Idaho there are ~530,000 dairy cows that produce ~3M dry ton of manure/yr. Dairies are being challenged to handle this waste stream more effectively. Of particular concern are greenhouse gas (GHG; in particular CH_4), nitrogen (N), and phosphorus (P) emissions. Each ton of manure contains 9.9 lbs of N and 1.8 lbs of P [3]. Not only can manure disposal result in the release of excess contaminants to water, manure biodegradation is the 2nd largest source of GHG emissions from dairies [2]. We are conducting research to advance an integrated set of processes centered on converting manure to commercially-viable, high-value products. Our goal is to provide dairy owners with enhanced options for managing this waste stream in an environmentally and economically sustainable manner.

In this proposal we are requesting funding to construct a mobile pilot-scale unit for our commercial polyhydroxyalkanoate (PHA) process. PHAs are bioplastics that are biosynthesized by bacteria using a variety of organic carbon (C) sources. PHA is a direct replacement for many plastics currently used. Our process uses mixed microbial consortia to synthesize PHA on organic-acid rich fermented dairy manure. We estimate that a 2,000 head dairy implementing our PHA production process could generate a net profit ($200,000-$400,000/year). We intend to operate, test, and evaluate the pilot system at the UI dairy for 6 months.

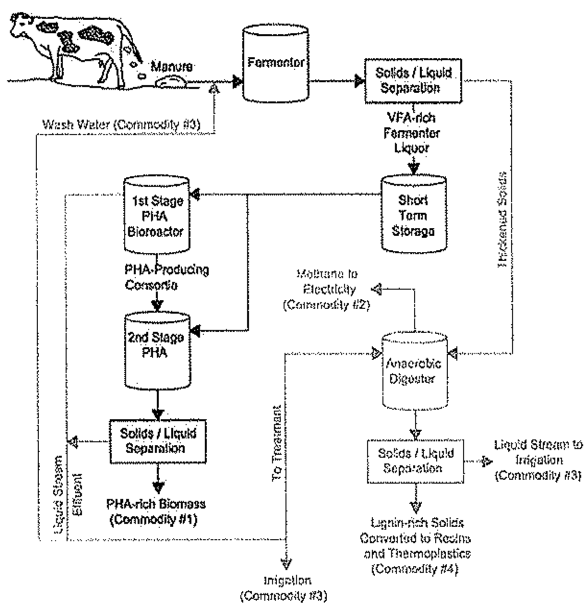

Figure 1: Proposed Manure-to-Commodities Process Diagram

2. <u>"Gap" Project Objective and Total Amount Requested</u>

Technology Description. Our proposed manure-to-commodities process is illustrated in Fig. 1. Manure is fermented to generate volatile fatty acids (VFAs). The VFA liquid stream is then bioconverted to PHA [4-7]. The 1st stage PHA reactor maintains an enrichment of microbes capable of rapidly synthesizing PHA, while production occurs in a 2nd stage reactor. Many value-added products can be derived from this process.

Project Objective. We have advanced our bioplastic production process to a point where it is necessary to conduct pilot scale investigations. Thus, **this proposal is focused on constructing a mobile pilot-scale of the 3-stage PHA production system** (Fig. 1; fermenter, 1st stage PHA reactor, 2nd stage PHA reactor). The proposed process must be validated at a pilot-scale before we can design and construct a full-scale system and evaluate PHA properties. The funds requested will support the design, construction, operation, and monitoring equipment..

Funding Request. We are requesting $50,000 to construct the pilot-scale PHA production system. All of the funds will be used to construct the pilot unit; the team's time is covered.

3. <u>Name of Idaho public institution:</u> University of Idaho

4. <u>Name of faculty members directing project:</u> Erik Coats; Armando McDonald.

5. <u>Description of how resource commitments reflect the priorities of the home institution</u>

The UI has established five core signature research areas that prioritize desired research. Our proposal integrates with the area known as "Nexus of Energy Production and Use, Agriculture and the Environment." As evidence of UI support for the proposed research, over the past four yrs we have received over $70,000 in internal support toward our laboratory-scale research. Funding has been provided through multiple channels, including but not limited to EPSCoR, UI Environmental Science (funds for interdisciplinary team-based research), and the COGS.

6. <u>Evidence that the project will have a potential impact to the economy of Idaho</u>

Idaho is 3rd in dairy production nationally. The Idaho dairy industry continues to grow and has a significant impact on Idaho's economy. Based on data from the United Dairymen of Idaho: (i) In

2008, on-farm (Idaho) cash receipts from milk amounted to $2.1B, ranking it as the largest single sector in the state's agriculture industry; and (ii) Idaho dairies employ >29,000 people.

As Idaho dairies look to a sustainable future, they face two economic challenges: i) their product is perishable and profit margins are small, and ii) they are under increasing pressure to more effectively manage manure. **Our proposed process to generate high-value products from manure will ultimately construct a more stable economic foundation for dairies, thereby enhancing the sustainability of this critical Idaho industry**. Specifically, a preliminary economic assessment of our PHA production process estimates that **a 2,000 head dairy could generate a net profit of $0.25-0.50/cow/day**. This revenue would be significant (currently milk sales generate $0.50-0.60/cow/day). Further, the milk and forage (corn) markets can be quite volatile. Our process would yield an enhanced and more stable economic portfolio for dairies.

7. <u>Establishes partnerships with public/private sector or contributes to company creation</u>

Our research success has not only validated the 'proof-of-concept' for our proposed PHA production process but also established operational criteria to maximize PHA production. We have thus started networking with Idaho and regional dairies as listed below:

- The Idaho Dairymen Association and their partner Idaho dairies.
- Western States Caterpillar –currently constructing an anaerobic digestion complex to process manure from three dairies (estimate 11,000 head).
- Innovation Center for U.S. Dairy – collaborative discussions are ongoing.
- Center for Advanced Energy Studies (CAES) –currently supporting AD investigations (Fig. 1).

Conversations have occurred with the above entities, but no business relationships have been established. Support of this proposal will provide additional traction for future entrepreneurial opportunities that will benefit UI, the project team, and Idaho through new business.

8. <u>The Market Opportunity</u> – Address the following items:

a. Describe need the project would address

The proposed project will address two needs concurrently; it advances a technology that will:

i) enhance dairy operations by waste management to generate value-added products, and ii) contribute toward reducing the U.S. demand on imported fossil fuels. As mentioned earlier, dairy operations generate large quantities of pollutants (GHG, P, N)[2]. Current manure management strategies are, at best, treatment centric, focusing on lagoon storage, composting, and direct land application. Anaerobic digestion (AD) has also been employed, with the goal of producing electricity from methane [8]. However, AD technology is not yet sufficiently economical or reliable to support widespread use at dairies [9-11]. **The challenge is to advance technologies that convert manure to value-added products.**

Recognizing the economic importance of dairies in Idaho (and the U.S.) – but also the need to improve dairy environmental sustainability – **we are focused on advancing an integrated set of processes to convert manure to value-added products while concurrently reducing the environmental footprint.**

b. Describe applications markets for the technology. Include market demand projections.

As reported by Frost & Sullivan, the market size for PHA was 2.7 kt in 2007 and is expected to grow to 72.7 kt by 2013. Concurrently, the price of PHAs is expected to decrease from $7.3 to $1.75 per lb due to large-scale (pure-culture centered) conventional commercial plants coming on line in the US and China. Suppliers of PHA are seeking innovative niche markets (e.g., sanitary ware applications, electronic enclosures, cosmetic enclosures) that can exploit the "green" aspect of the PHA.

c. Describe the product, its market audience, the competition, and barriers to market entry

The Product. PHA is a direct replacement for many plastics currently used in the commodities market – for example, plastic containers, bags, automotive interior panels, and packaging [12]. We have conducted preliminary investigations on how to initially penetrate the bioplastic market and have identified two products: ink cartridges and horticultural containers.

Product Description. PHAs are biodegradable plastics that exhibit numerous commercial applications. PHA structure [13] can be manipulated to exhibit different polymeric properties.

Our process targets the ductile polyhydroxybutyrate-valerate (PHBV) [14]. PHA is currently produced commercially using pure microbial cultures grown on glucose from corn under sterile conditions [15]. Tianjin (China) has the capability to produce 10,000 tons/yr [16], and China appears to be a major player in this field. In the U.S., the primary producer is Telles (Metabolix / ADM joint venture). Their PHA is marketed as "Mirel™". While PHA produced by these companies is biodegradable , it has been shown that this current polymer production approach uses more fossil fuel and generates more GHG emissions than conventional plastics; thus **current PHA production methods are not sustainable** [17, 18]. There are no PHA manufacturers currently employing our production approach – that is, using mixed microbial consortia and waste manure.

Product Market. While current PHA production methods are unsustainable, the commodity has nonetheless penetrated the plastics market [12]. This is quite advantageous for us, since market barriers are being minimized. Broadly speaking, the demand for bioplastics continues to realize significant growth, in part due to consumer interest in reducing their net environmental footprint. It is estimated that bioplastics can displace ~90% of the traditional plastics, and global production capacity is estimated to reach 3.45 million metric tonnes by 2020 [19]; current growth rates in bioplastic usage are approaching 30% per year [20]. Our bioplastic – PHA – is recognized as a direct substitute for most petroleum-based plastics [19]. The fact that PHA is a direct replacement for plastics is quite significant – by the end of this century, it is estimated that plastic consumption will require 25% of current oil production to meet the demand [20].

Barriers to Market Entry. The central challenges we face in entering the market are i) validating the ability to scale-up our PHA production process, and ii) advanced PHA testing. Support of this proposal will contribute significantly toward eliminating these barriers.

9. The Technology – The following sections discuss both our value-added PHA product and the proposed mobile pilot-scale unit we propose to construct with these funds. Collectively this is considered the technology that is the core of this proposal.

a. Describe the technology and the current state of the technology

Success of our PHA process is predicated on (i) maximizing enrichment of PHA producing microbes in the 1st stage reactor and (ii) maximizing PHA production (>50%) in the 2nd stage reactor (Fig. 1). Preliminary results are highly encouraging, with production of ~70% PHA. Moreover, we are producing very high quality copolymer PHA with good polymer properties.

b. Describe how the technology contributes to the product and market need and its intellectual property status.

To successfully produce commercial levels of PHA (product) using mixed microbial consortia and fermented dairy manure, we need to validate our three-stage PHA production process (technology) at a pilot-scale. Pilot-scale investigations are also necessary to convince candidate business partners of the process viability, such that we can enter the commercial PHA production market. We are currently working with the UI Office of Technology Transfer to define the intellectual property associated with this dairy manure-based process.

c. Identify who developed the technology and with what funding

Drs. Coats and McDonald originally developed the technology. To date, research has been supported by the NSF, the U.S. DOT Sun Grant program, and the Idaho Dairymen. Lab-scale research has centered on optimizing PHA production (Fig. 1). Nick Guho (Dr. Coats' PhD student and former BS, MS student) also contributed significantly toward advancing the technology. The team will construct, operate, test the pilot PHA system, and test PHA properties.

d. Describe the theoretical soundness of the project

Through exhaustive laboratory-scale research, the process and technology has moved from concept to lab validation. As described in 9(a) above, our lab research has led to a preliminary optimization of the technology. Ongoing research is focused on transferring our process to a commercial entity via the pilot-scale.

e. Describe the maturity of the science/technology

As described herein, our R&D has matured to the point where it is necessary to begin validating

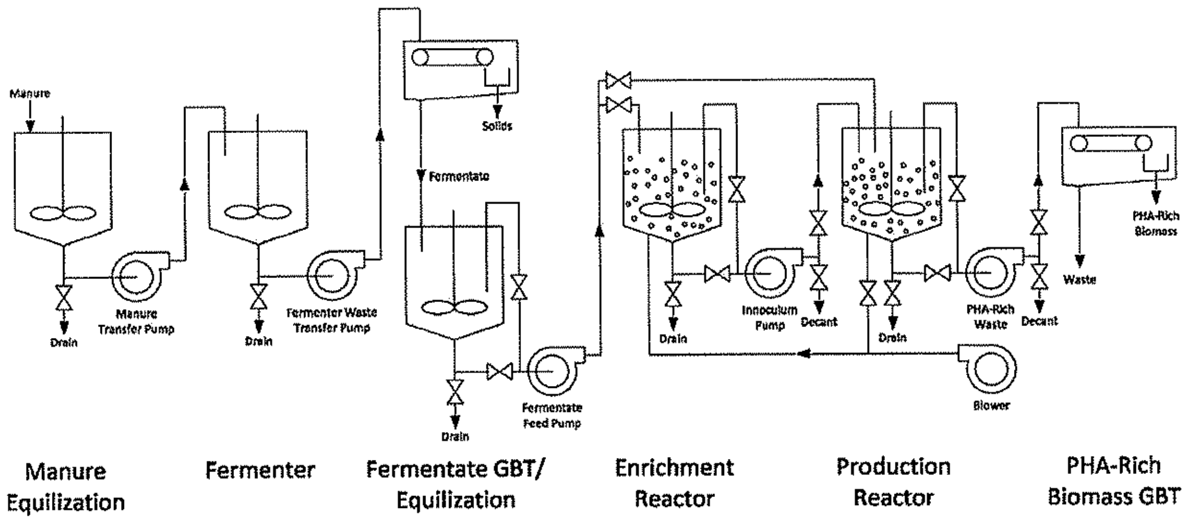

Figure 2 – Schematic Diagram of Proposed Mobile Pilot-scale 3-Stage PHA System

the process in the field and at a pilot-scale. We have documented success on this process in peer-reviewed publications [4-7, 21]. With a solid understanding of the technology, our research success has accelerated in the last two years as we have focused on upcycling [22] dairy manure to produce PHA. Research has matured rapidly and the next step is to begin validating operational criteria at a pilot-scale level. In a more succinct manner, using the Technology Readiness Level (TRL) metric applied by the U.S. government, **we would categorize the stage of our technology as TRL 5/6**; further, **funding of this proposal would allow us to reach TRL 7/8**, with the inherent potential in the next few years to reach TRL 9.

f. Explain the hardware development and integration risk

The project does not involve any hardware and integration risks.

g. Describe the maturity of the system - See response for 9(e) above.

h. Describe the viability of the technology

The core processes in our technology are fundamentally bioreactors. As such, the intrinsic bioprocesses are generally well understood. What makes our process unique is the integration of processes to not only treat dairy manure but produce PHA. In regards to the proposed pilot unit, all of the equipment we propose to procure and install is 'off-the-shelf' technology.

10. <u>Commercialization Partners</u> – see item (7) above.

11. <u>Specific Project Plan and Detailed Use of Funds</u>

Our research on this dairy manure-to-PHA process has been extraordinarily successful in the laboratory. As described herein, we have identified optimal operating conditions that can be leveraged to produce biomass containing 70% PHA. The next step toward ultimately deploying this technology at full-scale dairies is to validate operations at a pilot scale. Thus, **this proposal is a request for funds to construct a trailer-mounted pilot scale PHA production system.**

Task 1 – Pilot System Design. The goal of this task will be to complete the engineering design of the mobile 3-stage PHA production system. A schematic diagram of the proposed pilot unit is shown in Figure 2. Key features of this system include:

- The mobile system will be constructed inside a fully enclosed trailer (8' x 26') and will comply with OSHA and NFPA regulations.
- Daily reactor operation will be automated with a programmable logic controller (PLC) integrated with the mixer and pump motor drives.
- Flexible process piping and conservative component sizing will be incorporated to allow for the evaluation of a wide range of operating states.
- Sensors in each of the reactors will measure relevant parameters (e.g., dissolved oxygen, pH, redox, etc.) which will be interfaced to the PLC, allowing for real-time process monitoring and control operation.

We are in the process of completing the engineering design of this mobile unit, and **we will have the design completed by the time these SBOE funds are awarded (Fig. 3)**. From our perspective, this pilot system is a critical and necessary next-step in the evolution of this technology, and **the design will be 'shovel-ready' when funding is available.**

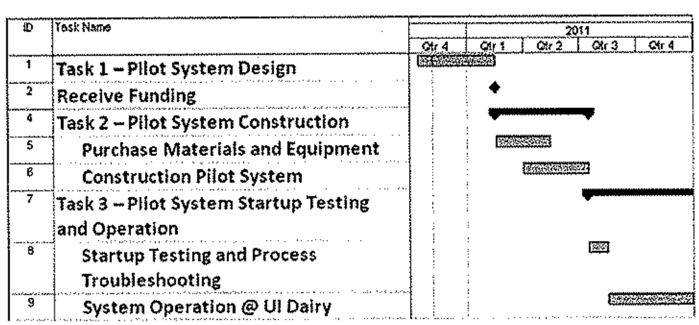

Figure 3 – Proposed Project Schedule

Task 2 – Pilot System Construction. With the design completed and the funds secured, we will proceed (Fig. 3) to procure the necessary materials and construct the PHA production system.

Task 3 – Pilot System Startup Testing and Operation. Extended testing of the mobile pilot unit will be required to troubleshoot operations and stabilize the processes. Startup testing will commence in mid-summer 2011. Our plan is to operate the system continuously at the UI dairy through the end of 2011 during which time we will assess system performance and data quality, test PHA, and manufacture prototypes.

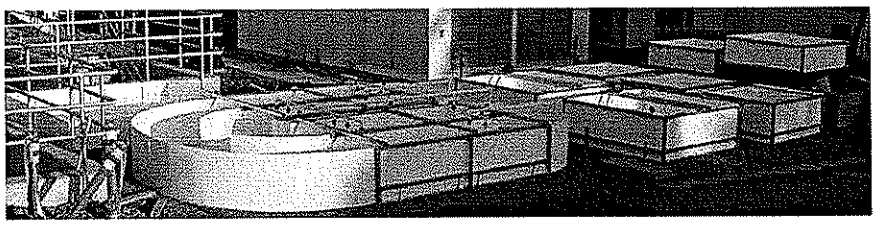

Figure 4 – Coats' Moscow, ID scale model wastewater treatment plant; demonstration of our research group's capability to transfer research from the laboratory to the field

We recognize that undertaking the construction and operation of a pilot-scale system of this magnitude is certainly ambitious. Dr. Coats and Nick Guho have experience in constructing and operating large scale models, including a 1:1,000 scale model for enhanced biological phosphorus removal at the Moscow, ID treatment plant (Fig. 4) , and a pilot-scale nitrifying trickling filter at the Colfax, WA wastewater treatment plant (Fig. 5). Dr. McDonald has pilot-plant materials processing equipment to generate prototype samples for market evaluation.

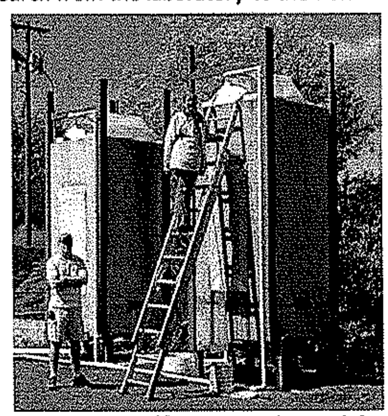

Figure 5 – Colfax, WA Scale Model Nitrifying Trickling Filter

Project Team. The project will be undertaken by Dr. Coats, Dr. McDonald, and Nick Guho.

Erik Coats, P.E., Ph. D.: Dr. Coats is an assistant professor in Civil Engineering at UI. Dr. Coats spent 10 years consulting as a Professional Engineer in the planning and design of wastewater treatment facilities. Dr. Coats' lab group is largely focused on producing PHA from fermented manure. For the proposed project, Dr. Coats will serve as overall project manager, and will provide QA/QC on the pilot system design, startup testing, and operational analyses.

Armando McDonald, Ph.D.: Dr. McDonald is a professor in Forest Products at UI. Drs. McDonald and Coats are actively collaborating on this PHA research. Relevant work currently ongoing in Dr. McDonalds' group is the characterization of bioplastics from waste streams. Dr. McDonald will provide technical support in the design of the pilot unit, and will be actively involved in operational testing of PHA produced and optimize system operations.

Nick Guho, EIT: Nick recently completed his M.S. in Civil Engineering at UI, working with Drs. Coats and McDonald to advance the dairy manure-to-PHA process, and started a PhD program in August 2010. Nick's Master's thesis focused on optimizing the PHA production at a lab scale. Nick will lead design and construction of the pilot unit and its operation, testing, and analysis.

12. Education and Outreach

With this mobile PHA production system we will be able to demonstrate the technology to dairy owners and operators at an appropriate scale. The pilot unit will also provide opportunities for Drs. Coats and McDonald's students to gain invaluable experience and process knowledge at a scale necessarily larger than the laboratory. In the future and as opportunities are presented, we plan to appropriately locate the mobile PHA system at full-scale dairies in Idaho. Not only will this further validate the process, this critical exposure will facilitate its commercialization.

13. Institutional and Other Sector Support

Ongoing laboratory-scale research for this broad manure-to-commodities integrated set of processes (Fig. 1) is currently being financially supported by the National Science Foundation, the Idaho Dairymen, and the Idaho National Laboratory. To date, the research has been largely supported through extramural funds; the UI has provided nominal support through a few internal grants. Activities to be supported with this proposed funding will be augmented through current extramural support, principally in the form of PI salaries, student salaries and fees/tuition, and materials required for process monitoring and testing. In brief, once we have constructed our pilot-scale unit, we have sufficient resources to conduct extensive operational testing for the time period proposed.

Appendices

References:

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22. McDonough, W. and M. Braungart, *Cradle to cradle: remaking the way we make things.* 2002, New York: North Point Press. 193.

Facilities and Equipment:

The University of Idaho (UI) was founded in 1889 as the state's comprehensive land-grant institution with primary responsibility statewide for doctoral degrees, research programs, and professional public service. UI maintains significant infrastructure to support research. The UI library has subscriptions to many pertinent journals (hardcopy and electronic) as well as books and databases necessary to support the proposed project. The library also maintains a subscription to SciFinder Scholar, ISI Web of Knowledge, and many other database search engines to support research. The UI has multi-user facilities for mass spectrometry, electron microscopy, NMR spectroscopy, chemical analysis, confocal microscopy and image analysis, molecular biology and proteomics which are available to researchers.

The Civil Engineering (Dr. Coats) environmental laboratory is housed in the Buchannan Engineering Laboratory on the University of Idaho campus in Moscow, ID. The laboratory, which is temperature controlled, has facilities to undertake in-depth environmental research, including physical, chemical, biological, microbiological, and molecular biological investigations, in a 4,000 ft^2 laboratory space (which includes benches, utilities, fume hoods, muffle furnace, laminar flow cabinets, reagent-grade water, etc). Available equipment is listed in the equipment section below.

The Forest Products (Dr. McDonald) laboratory is housed in the College of Natural Resources on the University of Idaho campus in Moscow, ID. The Forest Products Department has facilities to undertake wood and biomaterials research in a 5,000 ft^2 laboratory space (which includes chemistry labs, thermal analysis labs, chemical instrumental lab, work and lab benches, utilities, fume hoods, ovens, lumber drying kiln, environmental chambers, treatment vessels, extruder, presses, test machines, etc). Available equipment is listed in the equipment section below.

Civil Engineering Environmental Laboratory:

- Over 4,000 ft^2 of laboratory space for water and environmental studies
- Shimadzu RF 5301 PC Spectrofluorophotometer with 3D visualizing software
- Shimadzu uv/visible spectrophotometer
- Thermo visible spectrophotomers
- Hach digestion blocks
- Muffle furnace & autoclave
- Reagent grade water system
- HP model 6890 GC-FID/ECD
- Gow Mac GC/TCD
- Waters HPLC with RI detector dedicated for methanol and glycerol analysis, and a UV detector
- Laboratory-scale bioreactors with 14 Watson-Marlow peristaltic pumps and >40 microprocessor-controlled magnetic stir plates
- Programmable Logic Controller (PLC) to automate laboratory operations, with 32 input/output relays
- Bio-Rad 96 well PCR with Dcode DGGE system and UV imager with camera
- Thermo-electron RC6+ floor mounted centrifuge

- Micro centrifuge
- Laminar flow hood
- High volume muffle furnace
- Incubator and incubator/shaker table
- Balances (10^{-3} and 10^{-4} gram accuracy/precision)

Forest Products laboratory (Dr. Coats has ready access):

- Waters Breeze HPLC/ Viscotek GPC system which has quad detection (UV-VIS, laser light scattering (LALLS, RALLS), differential viscometer and refractive index)
- Dionex 1000/pulsed ampiometric detection ion exchange carbohydrate analysis system
- GC-MS^n (Thermofinnigan PolarisQ iontrap with EI and CI ionization modes) with pyrolysis capabilities
- LC-MS^n (Thermofinnigan LCQ iontrap with ES ionization source) with TSP HPLC system
- FTIR spectrometer (Thermonicolet Avatar 370) with ATR and DRIFT probes
- FT-Raman spectrometer (Thermonicolet 960,1064 nm excitation)
- Portable Raman spectrometer (Enwave Optronics portable) (785 nm excitation)
- UV-VIS spectrometers (Beckman 640 and StellarNet with various fiber optic probes)
- NIR spectrometer (900-1700nm; Control Development) with various fiber optic probes
- Instron 5500R-1137 and 5500R-1122 universal testing machines (bending, tensile and compression testing modes) with variable temperature testing oven/chamber
- DSC TA instruments model Q200 with cooling
- DMA TA instruments model Q800 with cryogenic cooling
- Dynamic Rheometer Bohlin CVO100 with extended temperature oven
- Laboratory hot presses 50 ton (Wabash 18"x18") and 30 ton (12"x12") both with cooling
- Leistritz co-rotating twin screw extruder (18 mm dia, LD40) with gravimetric feeding, sheet forming die/3-roll calendaring unit, pelletizing unit, ribbon die, and strand die
- Vertical injection molding machine (15 Ton, Yuh-Dak model YH30) for preparation of test specimens
- Benchtop lab molding machine (Dynisco LMM) for preparation of test specimens
- CEAST model 7203 Melt Flow indexer
- Olympus BX51 microscope (fluorescence, polarized light, DIC) with digital image capture
- QMS x-ray profile densitometer
- Stress wave non-destructive test equipment (FibreGen ST300 and HT200; Metriguard)
- Protein 1D-electrophoresis system (Biorad)

Multi-User University equipment (Dr. Coats is an affiliate faculty with ready access):

- Mass-spectrometry facility
    - LC-MS-MS (Micromass Quattro-II mass spectrometer,0- 4000 Da; electrospray and APCI ionization modes)
    - Hewlett Packard 5973 GC/MS system (EI and CI ionization modes)

- Waters QTof-Premier MS-MS system with APCI/MALDI MS/MS platform for proteomics analysis.

- Multiple HPLCs (with UV-visible scanning diode array and radioactivity detectors);
- Several UV-visible spectrometers;
- FluorMax 3 fluorimeter (Jobin-Yvon SPEX);
- Bruker 300, 400 and 500 MHz NMR spectrometers
- OI Analytical Flow Solution 3000 Flow Injection Analyzer
- Machines for microtiter plate reading (fluorescence of transmitted light);
- Pulsed-field gel electrophoresis (BioRad)
- High-throughput PCR (4 x 384 well blocks; MBS Thermocyclers, ThermoHybaid)
- Real-time PCR
- Highly controlled microtiter plate temperature incubation and shaking (HiGrow)
- Olympus and Zeiss Confocal Laser Scanning microscopes
- Zeiss variable pressure field emission scanning electron microscope and a conventional SEM with EDS capabilities
- Two transmission electron microscopes with EDS capabilities
- Siemens' powder x-ray diffraction spectrometer

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Professional Preparation

University of Idaho - B.S., Civil Engineering 1990
University of Idaho - M.S., Civil Engineering 1994
Washington State University - Ph.D., Civil Engineering 2005

Employment Record

Teaching, Extension and Research Appointments:

Adjunct Professor (Microbiology, Molecular Biology, & Biochemistry dept), University of Idaho, January 2010-present

Assistant Professor (Civil Engineering dept), University of Idaho, August 2006-present

Lecturer, University of Idaho (Civil Engineering dept), August 2005-May 2006

Postdoctoral Scholar (Civil Engineering dept), University of California at Davis, September 2005-August 2006

Adjunct Professor (Civil Engineering dept), University of Idaho, August 2002-May 2005

Graduate Research Assistant (Civil/Environmental Engineering dept), Washington State University, August 2002-May 2005

Non-Academic Employment:

Murray, Smith & Associates, Inc., Portland, OR, Project Manager, August 1998-July 2002.

Balfour Consulting, Inc., West Linn, OR, Principal Engineer, July 1995-August 1998

Cascade Pacific Engineering, Inc., Milwaukie, OR, Project Engineer, February 1994-July 1995

KPFF Consulting Engineers, Portland, OR, Engineer, July 1992-February 1994

Publications (Peer Reviewed)

Coats, Erik R.; Loge, Frank J.; Smith, William A.; Thompson, David N.; Wolcott, Michael P. 2007. Functional stability in a mixed microbial consortia producing PHA from waste carbon sources. *Applied Biochemistry and Biotechnology*. 2007.

Coats, Erik R.; Loge, Frank J.; Englund, Karl; Wolcott, Michael P.; McDonald, Armando G. 2007. Commercial production of polyhydroxyalkanoates in municipal and industrial wastewater treatment. *Water Environment Research*. 2007.

Coats, Erik R.; Loge, Frank J.; Englund, Karl; Wolcott, Michael P.; McDonald, Armando G. 2007. Production of natural fiber reinforced thermoplastic composites through the use of PHB-rich biomass. *Bioresource Technology*. 2008.

Liu, Hsin-Ying; Hall, Patrizia V.; Darby, Jeannie L.; Coats, Erik R.; Green, Peter G.; Thompson, Donald E.; Loge, Frank J. Production of poly(hydroxyalkanoate) during treatment of tomato cannery wastewater. *Water Environment Research*. 2008.

Horgan, Christopher J., Coats, Erik R. (corresp. author), Loge, Frank J. Assessing the effects of solids residence time and volatile fatty acid augmentation on biological phosphorus removal using real wastewater. *Water Environment Research.* 2010.

Coats, Erik R. (corresp. author); VanderVoort, Kristen E.; Darby, Jeannie L.; Loge, Frank J. Toward Polyhydroxyalkanoate Production concurrent with Municipal Wastewater Treatment in a Sequencing Batch Reactor System. *ASCE Journal of Environmental Engineering.* 2011.

Coats, Erik R. (corresp. author), Mockos, Alexander, Loge, Frank J. Post-anoxic Denitrification driven by PHA and Glycogen within Enhanced Biological Phosphorus Removal. *Bioresource Technology.* 2011.

Dobroth, Zachary T., Hu, Shengjun, Coats, Erik R. (corresp. author), McDonald, Armando G. Polyhydroxybutyrate Synthesis on Crude Glycerol using Mixed Microbial Consortia. *Bioresource Technology.* 2010-accepted.

Coats, Erik R. (corresp. author), Watkins, David L., Brinkman, C.K., Loge, F. J. Effect of Anaerobic HRT on Biological Phosphorus Removal and the Enrichment of Phosphorus Accumulating Organisms. *Water Environment Research.* 2010-accepted.

Coats, Erik R. (corresp. author), Gregg, Matthew, Crawford, Ronald L. Effect of Organic Loading and Retention Time on Dairy Manure Fermentation. *Bioresource Technology.* 2010-accepted.

Coats, Erik R. (corresp. author), Watkins, David L., Kranenburg, Daniel. A Comparative Environmental Life Cycle Analysis for removing Phosphorus from Wastewater: Biological versus Physical/Chemical Processes. *Water Environment Research.* 2010-in 2nd review.

Synergistic Activities

Synergistic activities that have arisen from current research projects include: (1) development of research collaborations with Dr. Andrzej Paszczynski (Univ of Idaho, Environmental Biotechnology Institute) and Ken Cain (UI College of Natural Resources) that include application of proteomic and transcriptomic techniques to better understand microbial functions in wastewater environments, (2) development of research collaborations with Dr. Armando McDonald (U Idaho) focused on alternative methods to synthesize and characterize bio-commodities using waste organic matter, (3) development of research collaborations with Dr. Ron Crawford (U Idaho) focused on application of microarrays and PCR to detect human pathogens in agriculturally-impacted waters, (4) collaboration with Dr. Larry Makus (UI) to advance economic metrics for the commercial production of PHA on waste organics, and (5) collaboration with Dr. Aurelio Briones (UI) to advance a novel two-stage process for methane production via anaerobic digestion of manure.

List of Collaborators

Ron Crawford, Andrzej Paszczynski, Ken Cain, Armando McDonald, Larry Makus, Aurelio Briones-University of Idaho; Mike Wolcott, Karl Englund-Washington State University; Frank Loge, University of California-Davis; David Thompson-Idaho National Laboratory; Kevin Feris, Boise State University.

Names and Institutions of Graduate and Post-graduate Advisors

Frank Loge, Dept of Civil and Environmental Engineering, UC Davis

Michael Wolcott, Dept of Civil and Environmental Engineering, Washington State University

Armando McDonald, Dept of Forest Products, University of Idaho
Janice Strap, Faculty of Science, Univ of Ontario Institute of Technology, Oshawa, ON, Canada
Shulin Chen, Dept of Biological Systems Engineering , Washington State University
Doug Call, Dept of Veterinary Microbiology and Pathology , Washington State University

Graduate Students Advised or Postdoctoral Scholars Sponsored

Completed

Sammie Muttai-Univ of Idaho (MSCE 9/2007); Rob Kimble-Univ of Idaho (M Engr 8/2006); Kristen Vandervoort-Univ of California-Davis (MSCE, 8/2008); Alexander Mockos, Christopher Horgan, David Watkins-Univ of Idaho (all MSCE, 5/2009); Dan Kranenburg-Univ of Idaho (M Engr 8/2009); Hsin-Ying Liu, University of California-Davis (PhD, 2008); Nick Guho, Matt Gregg, Zack Dobroth, Univ of Idaho (MSCE 5/2010).

In Progress

Ph.D.

Nick Guho, Univ of Idaho (major professor)
Andrea Hanson, Univ of Idaho (major professor)
Fatimah Alhamlan, University of Idaho

MSCE or M. Engr.

Ibrahim Ibrahim, Univ of Idaho (major professor; MSCE expected 5/12)
Matt Winkler, Univ of Idaho (major professor; MSCE expected 5/11)
Kiersten Lee, Univ of Idaho (major professor; MEngr expected 5/11)

Currently Funded Research

USDA CSREES (PI). Use of Microarrays and qPCR/RT-qPCR for Characterization of Viral Populations within Water Supplies Affected by Agricultural Activities, $394,852. 2008-2011.

National Science Foundation REU EAGER (PI). Toward Commercial PHA Production on Dairy Manure: Analysis of Mixed Microbial Consortia to Identify Critical Proteins and Metabolisms associated with Feast-Famine PHA Synthesis, $9,203, 2009-2011.

National Science Foundation EAGER (PI). Toward Commercial PHA Production on Dairy Manure: Analysis of Mixed Microbial Consortia to Identify Critical Proteins and Metabolisms associated with Feast-Famine PHA Synthesis, $123,922, 2009-2011.

United Dairymen of Idaho (PI). Toward Commodity Biopolymer Production from Dairy Manure, $102,342, 2010-2012.

Idaho National Laboratory-Idaho Center for Advanced Energy Studies (coPI). Design and Operational Improvements, and LCA in Anaerobic Digestion of Fermented Dairy Manure Using a 2-Stage process, $94,704, 2010-2012.

ARMANDO G. McDONALD

Professor, Forest Products Program — phone: (208) 885-9454
College of Natural Resources, CNR102 — fax: (208) 885-6226
University of Idaho, Moscow, ID 83844-1132 — e-mail: armandm@uidaho.edu

PROFESSIONAL PREPARATION

1983	B.Sc., Chemistry and Applied Chemistry, University of Otago, New Zealand
1984	P.G.DipSc., University of Otago, New Zealand
1986	M.Sc., Chemistry, University of Otago, New Zealand
1993	Ph.D., Chemistry, York University, Canada

APPOINTMENTS

2006-	Professor, Forest Products, University of Idaho, Moscow
2001-2006	Associate Professor, Forest Products, University of Idaho, Moscow
1998-2001	Project Leader, New Zealand Forest Research Institute, New Zealand
1993-1998	Senior Scientist, New Zealand Forest Research Institute, New Zealand
1985-1989	Junior Scientist, New Zealand Forest Research Institute, New Zealand

PUBLICATIONS (5 most relevant out of 59)

1. Sivasankarapillai G. and McDonald, A.G. (2011) Synthesis and Properties of Lignin-Highly Branched Poly (ester-amine) Polymeric Systems, *Biomass and Bioenergy*, In press.
2. Dobroth, Z.T., Hu, S., Coats, E.R., McDonald, A.G. (2011) Polyhydroxybutyrate Synthesis on Crude Glycerol using Mixed Microbial Consortia. *Bioresource Technology*, Under 2nd revision.
3. Fox, S.C., McDonald, A.G. (2010) Chemical and Thermal Characterizaion of three Industrial Lignins and their Corresponding Lignin Esters. *BioResources J.* 5(2):990-1009.
4. Coats, E.R., Loge, F.J., Wolcott, M.P., Englund, K., McDonald, A.G. (2008) Production of natural fiber reinforced thermoplastic composites through the use of PHB-rich biomass. *Bioresource Technology.*, 99:2680–2686.
5. Coats, E.R., Loge, F.J., Wolcott, M.P., Englund, K., McDonald, A.G. (2007). Synthesis of polyhydroxyalkanoates in municipal wastewater treatment. *Water Environment Research,* 79(12):2396-2403.

SYNERGISTIC ACTIVITIES

Advisor, for senior undergraduate capstone projects in "Biomaterials Product Development" involving wood enhancement, natural fiber based composites, biopolymers, and biofuels.

Instructor, Lignocellulosic Biomass Chemistry, Biocomposites, Biomaterials Bioproduct and Process Development, University of Idaho

Engineering Poster Judge, Graduate Student Research Exhibition, University of Idaho; *Panel Judge,* Chemical Engineering Graduate Student Research Presentation, Washington State University, Pullman

COLLABORATORS (not listed above): Fred Kamke, Wood Science and Engineering Dept, Oregon State University; Jeff Morrell, Wood Science and Engineering Dept, Oregon State University;

Marie Pierre Laborie, Institut für Forstbenutzung und Forstliche Arbeitswissenschaft, Germany

GRADUATE AND POSTDOCTORAL ADVISORS

PhD Advisor: Gerald Aspinall, Chemistry, York University, Toronto, Canada

MS Advisor: Donald Brasch, Chemistry, University of Otago, Dunedin, New Zealand

THESIS ADVISOR AND POSTGRADUATE-SCHOLAR SPONSOR

Graduate students advised/advisor as major professor: 21

Sang Yeob Lee, M.S., FORP, 2002; Anand Mangalam, M.S., FORP, 2005; Smith Sundar, M.S., FORP, 2005; Andres Soria, Ph.D., FORP, 2005; Carter Fox, M.S., FORP, 2006; Lance Gallagher, M.S., FORP, 2006; Karthik Pillai, M.S., FORP, 2007; Lina Ma, M.S., FORP, 2007; James Fabiyi, Ph.D., FORP, 2007; Ayiguli Keyoumu, M.S., FORP, 2008; Clay Dodson, M.S., EnvSci, 2008; Shengjun Hu, M.S., FORP, 2010; Janet Dai, M.S., FORP, 2010; Liqing Wei, M.S., FORP, current; Guanqun Luo, M.S., FORP, current; Noridah Osman Ph.D. candidate, FORP, current; Janet Dai, Ph.D., FORP, current; Sai Yadanaparthi, Ph.D., EnvSci, current; Jowita Laniak, Ph.D., EnvSci, current; Shaobo Liang, Ph.D., EnvSci, current; Hui Li, Ph.D., FORP, current

CURRENT GRANTS

Searcy, E., Briones, A., Coats, E., Feris, K., Keiser, D., Magnuson, T., McDonald, A., Shresth, D. Design and Operational Improvements, and LCA in Anaerobic Digestion of Fermented Dairy Manure Using a 2-Stage process. INL-LDRD, April 2010-Dec 2012, $592,000.

Gorman T.M., McDonald A.G., Bender, T., and Morgan, T. Inland Northwest Forest Products Consortium USDA-CSREES, July 2010-June 2010, $504,000.

Garcia-Perez M., McDonald A.G and Elliott D. Understanding Cellulose Primary Thermo-chemical Reactions to Enhance the Yields of Anhydro-saccharides Resulting from Fast Pyrolisis. NSF, Jan 2010-Dec 2012, $298,863.

Coats E and McDonald A.G., Toward Commodity Biopolymer Production from Dairy Manure. Idaho Dairyman's Assoc. Jan 2010 – Dec 2011, $102,300.

McDonald A.G. and Soria A.J. Bio-oils from high lignin feedstocks Inland Northwest Forest Products Consortium USDA-CSREES, July 2009-June 2011, $36,310.

McDonald A.G. and Morrell, J. Durable Wood plastic composites. Inland Northwest Forest Products Consortium USDA-CSREES, July 2009-June 2011, $54,200.

Wagner F. and McDonald A.G. Energy Consumption at Commercial Dry Kilns. Inland Northwest Forest Products Consortium USDA-CSREES, July 2009-June 2011, $47,409.

Gorman T.M. and A.G. McDonald. Sustainable building materials from at-risk intermountain species. USDA-Forest Products Laboratory, June 2009-May 2014, $100,000.

Gorman T.M. and A.G. McDonald. Assessing wood quality characteristics of the Intermountain Forest Resource. USDA-Forest Products Laboratory, Aug 2007-Aug 2012, $130,000.

NICHOLAS M. GUHO, EIT, MS

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Eagle, ID 83616
(208) 850-7814
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Education

Ph.D., Civil Engineering, University of Idaho	In Progress (May 2012)
M.S., Civil Engineering, University of Idaho	August 2010
B.S., Civil Engineering, University of Idaho	May 2008

Experience

Teaching and Research Appointments

Graduate Research Assistant, Civil Engineering Department, University of Idaho — 2007-Present

- Designed and constructed a 1:1000 scale model of the Moscow, ID WWTP including the individual basins, clarifiers, fermentation system, aeration system, control system, and piping
- Designed, constructed, and developed the software for an in-house programmable logic controller
- Performed research related to treatment of municipal and dairy manure waste streams focusing on the optimization and modeling of:
  - Polyhydroxyalkanoate production coupled with BNR for potential commercial implementation
  - Fermentation of municipal primary solids and dairy manure for use as the substrate in polyhydroxyalkanoate production

Non-Academic Employment

Structural Engineering Intern, Robert Peters Engineering, Nampa, ID — Summer 2006

- Performed structural calculations for the design of wood and steel structures including sizing members and designing connections
- Determined design wind and seismic loads under the provisions of IBC 2006
- Created a detailed finite element model of a large mat foundation
- Reviewed shop drawings and drafted minor structural components

Project Supervision, Estimation, General Labor, Guho Corp., Eagle, ID — 2001-Present

- Experienced in project bidding, scheduling, and implementation including:
  - Idaho Veteran's Cemetery Phases I, II, and III
  - Corpus Christi Catholic Church
- Supervised the installation of several projects, including:
  - Citizens Communications Diesel Fuel Spill Remediation
  - Holy Apostles Catholic Church Facility Maintenance Upgrade

Service Positions

Team Captain, University of Idaho Concrete Canoe Team	2007-2008
ASUI Representative, University of Idaho ASCE Student Chapter	2006-2007

Publications

Several in progress — Pending

Posters and Presentations

Biopolymers Symposium (Poster) — October 2010

Honors and Awards

Eagle Scout Award Recipient	2004
Biopolymers Symposium Best Poster	October 2010

Professional Registrations

Engineer In Training, Idaho — 2008-Present

Provide documentation of other sector resource commitments:

See attached Letters of Support.

Idaho Dairymen's Association, Inc.

1182 Eastland Drive North, Suite A
Twin Falls, ID 83301

Phone: (208) 733-6372
Fax: (208) 735-5955

November 22, 2010

Idaho SBOE
Higher Education Research Council

Re: SBOE Idaho Incubation Fund Proposal
Proposal Title: Constructing a Pilot-scale PHA Production Facility
Project PIs: Drs. Erik R. Coats and Armando G. McDonald
Institution: University of Idaho

With this letter, the Idaho Dairymen's Association expresses its support of Drs. Coats and McDonald related to their SBOE proposal for funding to construct a pilot-scale PHA production facility. The Idaho Dairymen's Association is currently financially supporting Drs. Coats and McDonald to help optimize their 3-stage PHA production process at a laboratory scale. Their project is just completing its first year, and the investigators have made impressive advances in this manure-to-commodities process. To ultimately construct this process at full-scale dairy operations, it will be necessary for the investigators to first validate operations at a pilot-scale. Their proposal to construct a mobile 3-stage PHA production unit would provide important flexibility to test operations at different full-scale dairies in Idaho.

Idaho dairies contribute significantly to the state's economy, providing critical revenue, taxes, and employment. However, dairies are coming under increasing pressure to employ alternative manure management practices. The research and processes being developed by Drs. Coats and McDonald at the University of Idaho exhibit significant potential to provide dairy owners with enhanced manure management strategies that importantly generate profit. In the long term their creative thinking and innovation will help to strengthen the dairy industry in Idaho. As such, we strongly support Drs. Coats and McDonald's proposal.

Thanks,

Bob Naerebout

Executive Director
Idaho Dairymens Association
bob@wdbs.us
(208) 308-3382

Western States Equipment Company
500 East Overland Road
Meridian, ID 83642
208-888-2287 (office)
208-884-2308 (fax)

State of Idaho
Board of Education
650 W State Street
Boise, ID

Re: FY 2011 SBOE Idaho Incubation Fund Program
Constructing a Pilot-scale PHA Production Facility
Drs. Erik R. Coats and Armando G. McDonald (Univ of Idaho)

Dear Sirs,

As the Caterpillar dealer for Idaho and parts of neighboring states, Western States Equipment Company is dedicated to the sustainability of the dairy industry in Idaho. We believe that sustainability means competing in a global market while constantly reducing the industry's impact on the environment.

Through our subsidiary, New Energy One, LLC, Western States is in the process of constructing an anaerobic digester facility at a large dairy in Twin Falls County. This facility will produce enough renewable electricity to power over 1000 homes. At the same time, it will significantly reduce greenhouse gas emissions and provide an economical solution for the dairy's nutrient management protocol.

Because of our interest in sustainability we have incorporated, in our design, a number of elements that will make it useful as a commercial scale test facility for future innovative technologies.

We have reviewed Drs. Coats and McDonald's proposal for "Constructing a Pilot-scale PHA Production Facility" and our conclusion is that this is one such technology. The research, to date, indicates that this technology has the potential to increase revenues for the farms, diminish the impact of economic cycles and create environmental benefits, of a very significant nature, to the community. These are all the elements of sustainability we believe should be promoted.

Therefore, we support this proposal and look forward to collaborating to help in its' successful conclusion.

Sincerely,

Jay Kesting
Engine Business Manager, Western States Equipment Co.
Manager, New Energy One, LLC