SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: **$2,100,000**

TITLE OF PROPOSED PROJECT: **Sustaining the Competitiveness of the Food Industry in Southern Idaho: Integrated Water, Energy, and Waste Management**

SPECIFIC PROJECT FOCUS: Food production and processing are vital to the social and economic integrity of the Eastern Snake River Plain. However, in some areas there are limits on both existing operations and growth due to water supply and water quality limits. Additionally, food processing companies are on the front line of rapidly increasing consumer expectations for sustainability in both their operations and supply chain. Reducing the energy/water/waste footprint of Idaho producers/processors will enhance their market competitiveness. Recovery of valuable products from waste will generate economic value and improve the environment. Reduced resource use allows more stakeholders to sustainably maintain their operations, including producers, processors and communities.

The objective of this effort is to build capacity and partnerships among our 3 institutions to assist Idaho food producers and processors in reducing water, energy and waste footprints by: a) demonstrating/transferring technologies for reducing water/nutrient use; b) piloting at field-scale and transferring technology for recovering valuable nutrients/byproducts from waste streams and c) providing decision support tools for community and business stakeholders to better understand the interconnections and trade-offs between energy, water, nutrients and land use. It is important that consideration of all three footprints (water, waste, energy) be considered in an integrated fashion by an appropriately multidisciplinary team, because all are strongly coupled. We will develop capacity to test promising technologies at the field-based pilot scale in a manner that facilitates private/commercial development at operational scales. To fully build the pipeline from research to implementation, our plan also includes workforce development in the use of these new technologies.

The work proposed here will contribute to building capacity for the newly developing Food Processing Innovation and Education Center, which is arising from recent negotiations between the UI and Food Northwest (a consortium of 150 major food processing companies is the Northwest). It will also build capacity to meet the needs of other stakeholders represented among the letters of support (producer/processors such as Simplot, Idaho Dairyman's Association, wastewater engineering firms), as well as municipalities, communities and the Idaho work force, both current and future.

PROJECT START DATE: July 1, 2018	PROJECT END DATE: June 30, 2021
NAME OF INSTITUTION: University of Idaho (with partners Boise State University and Idaho State University)	DEPARTMENT: Dept of Geography, Dept of Civil Engineering, Dept of Soil/Water Systems, Dept of Forest, Range and Fire Sciences

ADDRESS: Office of Sponsored Programs, 875 Perimeter Dr., MS 3020; Moscow, ID 83844-3020

E-MAIL ADDRESS: osp@uidaho.edu	PHONE NUMBER: (208) 885-6651

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Dr. Karen Humes	Professor, College of Science	Karen S. Humes
Co-Investigator	Dr. Erik Coats	Associate Professor, College of Engineering	[signature]
Co-Investigator	Dr. Armando McDonald	Professor, College of Natural Resources	[signature]
Co-Investigator	Dr. Jae Ryu	Associate Professor, College of Agriculture and Life Sciences	[signature]

	NAME:	SIGNATURE:
Authorized Organizational Representative	Deborah N. Shaver, Director Office of Sponsored Programs The Regents of the University of Idaho	Deborah N. Shaver

Sustaining the Competitiveness of the Food Industry in Southern Idaho: Integrated Water, Energy, and Waste Management

1. Idaho institutions: University of Idaho (UI) with partners Boise State University (BSU), Idaho State University (ISU) and the Center for Advanced Energy Studies (CAES)

2. Principal investigator: Karen Humes, with multidisciplinary teams named below

3. Project objective and total amount requested: Food production and processing are vital to the social and economic integrity of the Eastern Snake River Plain. However, in some areas there are limits on both existing operations and growth due to water supply and water quality limits. Additionally, food processing companies are on the front line of rapidly increasing consumer expectations for sustainability in both their operations and supply chain. Reducing the energy/water/waste footprint of Idaho producers/processors will enhance their market competitiveness. Recovery of valuable products from waste will generate economic value and improve the environment. Reduced resource use allows more stakeholders to sustainably maintain their operations, including producers, processors and communities.

The objective of this effort is to build capacity and partnerships among our 3 institutions to assist Idaho food producers and processors in reducing water, energy and waste footprints by: a) demonstrating/transferring technologies for reducing water/nutrient use; b) piloting at field-scale and transferring technology for recovering valuable nutrients/byproducts from waste streams and c) providing decision support tools for community and business stakeholders to better understand the interconnections and trade-offs between energy, water, nutrients and land use. It is important that consideration of all three footprints (water, waste, energy) be considered in an integrated fashion by an appropriately multidisciplinary team, because all are strongly coupled. We will develop capacity to test promising technologies at the field-based pilot scale in a manner that facilitates private/commercial development at operational scales. To fully build the pipeline from research to implementation, our plan also includes workforce development in the use of these new technologies. The total amount requested is $700,000/yr for 3 years.

4. Resource commitments:

The effort proposed here is well-aligned with long-standing priorities of our institutions to assist Idaho businesses in making their operations as economically and environmentally sustainable as possible, as well as recent initiatives. The UI, on behalf of CAES, is in the process of negotiating with Food Northwest (a consortium of 150 major food processing companies is the Northwest) to form the Food Processing Innovation and Education Center (PFIEC). This proposal builds capacity for the center to serve its stakeholder needs, as well as developing statewide capacity in "upstream" concerns such as reducing the excess waste and nutrient loads in some types of production. Specifically, the work proposed here will: a) strengthen partnerships among faculty at all 3 institutions to solidify the statewide multi-disciplinary teams necessary for an integrated approach to water, energy and waste management, and b) develop capability to evaluate at pilot-scale activities that are critical to bridging the so-called "Valley of Death" between research and operational/commercial implementation of promising technologies. We leverage and build on significant past, present and future investments by all partner institutions (in the time and existing laboratory resources of the 6 faculty who have come together to comprise this state-wide team), as well as the benefits of several earlier investments by CAES, INL, the IGEM/Incubation Fund and state investments in the Idaho EPSCoR program.

The proposed initiative is also well aligned with the Strategic Research Plan for Idaho Higher Education. Our team is inter-institutional, comprised of faculty affiliated with CAES and our work will strengthen our relationships with stakeholders in the private sector, with the specific intent to contribute to the economic development of Idaho. Thus, this effort is very well-aligned with Goals 1, 2 and 3 in the HERC strategic plan.

5. Specific project plan: We propose 3 major research tasks and a 4th educational component.

Task A) Recovery of energy, nutrients, water and bioproducts from waste streams: bench to place-based pilot projects

Team: Erik Coats (UI, environmental engineering/molecular biology; emphasis on resource recovery from waste streams); Armando McDonald (UI, biomass conversion and bioproducts); Kevin Feris (BSU, algae-based resource recovery and microbial ecology)) comprise the CAES Bioenergy and Bioproducts group. This team collaborated for 10+ years and has the required multidisciplinary experience to integrate biological, chemical, physical and thermal approaches to the recovery of energy, bioproducts and nutrients from multiple waste streams [1-8]. The team will leverage investments made by the INL, CAES, HERC, and the IGEM incubation fund.

Integrated wastewater-to-value added products research began as a collaboration between the UI and BSU. Our efforts resulted in multiple extramurally funded awards, student training, scientific publications and a pending patent. We have worked across bench and pilot scales. Recent support from SBOE HERC allowed us to build a pilot scale system to convert dairy waste to value added products (biogas, bio-plastic, algal biomass); previous HERC funding supported construction of two pilot systems at UI by Dr. Coats–one located at the Moscow WWTP, designed for municipal wastewater and one mobile system (24 ft. trailer) designed for dairy manure resource recovery. We propose to test, validate, and extend these systems to evaluate opportunities to recover high-value products (bioplastics, algae, biofuels) from industrial/municipal wastewater while achieving treatment. Research will focus on further understanding/optimizing our integrated system to maximize utility across input streams and demonstrate "real-world" applicability. Research objectives will further technology interrogations and advance wastewater as an economic resource. Ultimately, research will advance solutions that can be applied in Idaho agricultural and food processing sectors; producing economic value from waste will enhance Idaho-based industries by diversifying product portfolios. Research will build upon past and ongoing investigations [1, 9-17]. *Sub-tasks*:

- Bench scale: a) Characterization of waste streams from a variety of producers and processors in the Twin Falls area (e.g., dairies, yogurt, cheese, and potato processors); b) Assessment of optimal process sequences (biological, chemical, physical, thermal) to recover energy, bioproducts (biofuels; bioplastics) and nutrients from mixed waste
- Pilot scale assessments: Conduct pilot scale evaluations from mixed waste streams; implement/evaluate treatment resource recovery processes.
- Produce prototype products (bioplastic mulch film, biochar, biofuel) for evaluation.
- Partnerships with producers, processors and municipal treatment personnel are fundamental to all of these tasks. Team will build on existing relationships with Twin Falls wastewater treatment facility, Food Northwest, Chobani, Amalgamated Sugar, J.R. Simplot, Idaho Dairymen's Association, and Glanbia, and expand to new partners throughout this project.

Task B) Decision-support tools for industry and community leaders to quantify and visualize trade-offs among water, energy, land use and municipal growth.

Team: (Jae Ryu, UI, systems dynamics modeling, water resources; Karen Humes (UI, hydrology, geospatial analysis), Travis McLing (INL/CAES, INL Water/Energy Lead), J. Jacobson (INL, retired, systems modeling consultant). *Sub-tasks:*

- Build on two existing systems dynamics models: a) WEST (Water Energy Simulation Toolkit) model (developed at INL, quantifies some of the interdependencies among water, energy, land use, and economics in the Eastern Snake River Plain) and b) Systems dynamics model by Co-I J. Ryu [18] of water availability and use in the Eastern Snake River Plain, including water availability under variable climate.

- Integrate models to allow for analysis of the interactions/feedback between current water/energy use for specific land cover types/activities, including improvement in efficiency derived from Task A and Task C activities.
- Train community/business leaders to evaluate management alternatives for water supply/use, energy supply/use, land use, cropping/irrigation types, industrial/municipal growth

Task C) Technical innovations/sensing systems to reduce water/energy/nutrient use in targeted production systems:

Team: Donna Delparte, (ISU, drone-based sensing systems, Jae Ryu (UI, drought and drone applications, Karen Humes (UI, soil moisture, sensing systems) and grower partners. Team expertise in innovative sensing systems (field and satellite based) [19, 20, 21, 22]. Dr. Delparte will be leveraging her prior IGEM work on drone-based detection of potato virus. *Sub-tasks (described in more detail in Appendix F):*

- Pilot projects to use drone-based, other field-based and satellite sensors to reduce water/nutrient/energy use in production of targeted crops
- Development of decision-support tools for producers that incorporate sensor-based information in operations and train producers, stakeholders, extension agents in their use

Task D) Engaging the present and future workforce in the adoption of new technologies

Team: All Co-I's, Marc Skinner (UI Idaho Falls Center Director), partners at CSI, partner professional organizations such as Food Northwest, Idaho Technology Council, Jae Ryu (Idaho Drone League (I-Drone), Founder and Principal Investigator). *Sub-tasks:*

- Develop courses and/or workshops for delivery at CSI and/or other partner institutions
- Stakeholder engagement/training in new technologies from Tasks A and C through professional organizations such as Food Northwest
- Outreach to Treasure Valley and Magic Valley 7th–12th Grade and CSI students to engage them with new technologies, providing exposure to/encouragement toward STEM careers

6. Potential economic impact

In addition to the direct economic benefits to food producers and processors (both multi-billion dollar enterprises [23] and major employers in Idaho), there are many indirect economic benefits to all Idaho stakeholders (e.g., citizens, communities, municipal water supply and treatment) in the development of the capacities described here. Examples are provided in the table below.

Task	Goals	Benefits
A: Integrated approaches to recovery of energy, bioproducts, nutrients and re-usable water from single source and mixed waste streams - *Integrated* refers to using all manner of processes (bio, chemical, physical, thermal) to extract all valuable entities from waste streams (bioproducts, energy, nutrients, reusable water)	- Reduction in carbon, energy, waste, and water footprints for operators (per unit product) - Identify new valuable bioproducts - Demonstrate costs and effectiveness at pilot scale, closing the gap on "Valley of Death" between research and operational implementation	- Reduced waste loads and associated treatment costs - Value in bioproducts extracted - Enhanced ability to demonstrate environmental sustainability, a key to competitiveness in future [24] - Increased social and economic sustainability of agricultural production and processing - Less use of finite resources per unit product frees them up for other uses and/or increases resilience for all stakeholders.
B: Decision-support tools for industry and community leaders to quantify and visualize trade-offs among water, energy, land use and municipal growth	-Allow researchers, stakeholders and communities better understand and quantify tradeoffs in water, energy, land use	- Stakeholders can make informed choices regarding water/energy use relative to economic benefits - Reduced risk of water shortages - Increased resilience in Idaho water/energy systems
C: Technical innovations and sensing systems to reduce water/energy/nutrient use in targeted production systems	-Increase in efficacy of water/agrichemical use -Less water use, energy use and decreased	- Decreased costs per unit of production - Finite resources freed up for other uses

	nutrient loads per unit produced	- Reduction in nutrient loads reduces treatment costs
D: Engaging stakeholders and the present/future workforce in the adoption of new technologies -Training at 2/4 yr colleges - Stakeholder education through professional groups - Outreach to next generation	-Decrease barriers to adoption of new technologies by stakeholders - Position more Idahoans for "high tech" jobs that sustain our economy	- Idaho citizens qualify for "high tech" jobs in production and processing - Helps ensure current businesses remain in Idaho and facilitates the recruitment of new businesses by having well-prepared workforce in "high tech" jobs

7. Criteria for measuring success

Quantitative Metrics	Target-Yr 1	Target-Yr 2	Target-Yr 3
# of Industry stakeholders engaged	8	14	20
# municipal and state stakeholders	4	6	10
# Stakeholder meetings (video/live)	3/1	3/1	3/1
# graduate students supported	7	7	7
# undergraduates supported	3-4	3-4	3-4
# grad students completing	0	2	3
# of other grants/contracts	2	4	6
# Drone League participants	60	80	100
# of Patent applications	0	1	1
# New business partnerships	0	1	2

Other task-specific metrics/outcomes for measuring success:

Task A: agro-industrial waste streams characterized at bench scale (Y1); customized prescriptions for treatment/resource recovery (e.g., energy, nutrients, bioproducts and water) from specific waste streams or combinations thereof (Y2); successful pilot-scale treatment and recovery from mixed waste streams (Y2/3); Design recommendations for operational-scale recovery/treatment for various waste stream combinations (Y3) ; *Task B:* integration of WEST and existing SD model of water supply (Y1); system analysis by incorporating management options and alternatives (Y2); community and stakeholder outreach and training (Y3); *Task C:* stakeholder participation in utilizing online agricultural decision support tool (Y1); Optimized sensor and algorithm development for plant assessment, decision-making and autonomous action (Y2/3) *Task D:* evaluate stakeholder and workforce needs for training relevant to technologies being developed in Tasks A and C and appropriate pathways (Y1); Deliver training courses or professional development workshops (3 in Y2, 5 in Y3); K-12/public outreach , including I-Drone in Treasure Valley (Y1), I-Drone in Magic Valley (Y2), I-Drone X for adults at CSI (Y3).

SUMMARY PROPOSAL BUDGET

Name of Institution: **University of Idaho, with Boise State University and Idaho State University as sub-contractors**

Name of Project Director: Karen Humes, University of Idaho

A. PERSONNEL COST (Faculty, Staff, Graduate/Undergraduate Students, Other) Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Graduate Research Assistant – 5 /yr for 3 yrs: (3 on Task A; 2 on Task B)	$ 23,000/yr	3.8%	$358,100
Undergraduate Research Assts (3333.3 hrs/yr for 3 yrs)	$ 12/hr average	3.8%	$124,600
Research Scientist (Task A): 50% time, $18/hr Y1, 3% increase in each of Yr2 and Yr3	$18, 18.54,$19.10	33.1%	$ 77,000
PI Humes/Professor, summer salary – 6 weeks/yr Yr 1,2; 8 weeks Yr 3	$71.70/hr	26.5%	$ 72,600
Co-I Coats/Professor, summer salary – 4 weeks/yr	$67.45/hr	26.5%	$ 41,000
Co-I McDonald/Professor, summer salary – 4 weeks/yr	$68.94/hr	26.5%	$ 41,900
Co-I Ryu/Associate Professor, summery salary – 4 weeks/yr	$57.30/hr	26.5%	$ 34,800
% OF TOTAL BUDGET: 58.5% (UI portion only)		**SUBTOTAL:**	$750,000

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.) Item/Description	Dollar Amount Requested
Improvements to existing bioproducts extruder to enable the fabrication of biofilms (Task A, McDonald)	$ 40,000
Upgrades to pilot-system for resource recovery to enable field-scale testing (Task A, Coats)	$ 20,000
Work stations and peripherals to support Task B (2@$3000/each); (Humes)	$ 6,000
Server ($6000, Yr 1); Upgrades to server ($1500/yr for Yr 2 and 3) to support Task B (Ryu)	$ 9,000
Other equipment in BSU and ISU subcontracts are shown, detailed and justified in Appendix E and F, respectively	
SUBTOTAL:	$ 75,000

C. TRAVEL: Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
Yr 1 – 3: Field work/collaboration	36 (12/yr) (faculty, students)	228(36*6 days avg/ yr/person)	(36@$203 avg) $7308	(228@$110/nt) $25,080	(228@$45/day) $10,260	$ 42,600
Yr 1-3: Professional societies	18 (6/yr)	72(18@ 4 days ea)	(18@ $700) $12,600	(72@$170) $12,240	(72@$51/day) $ 3672	$ 28,500
Yr 1-3:Stakeholder/Team Mtgs(*Some meals in participant costs)	30 (10/yr)	90 (30@ 3 days ea)	(30@$300) $ 9,000	(90@$120) $10,800	(90@$11.55/ day avg*) $ 1040	$ 20,900
					SUBTOTAL:	$ 92,000

D. Participant Support Costs:	Dollar Amount Requested
1. Stipends – Non Co-I instructors for workforce training courses/workshops in Task D; Y1: $8000 for 2 workshops @$2000 each and 1 course@$4000; Y2:$12000 for 4 workshops @$2000 ea and 1 course @ $4000	$20,000
2. Other – Annual meetings for stakeholders (facilities, meals for 35 participants/yr) $5333/yr for each of 3 yrs	$16,000
SUBTOTAL:	$36,000

E. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies: Task A: The materials and supplies budget has been estimated based on historical expenditures necessary to complete similar work, and to specifically meet the needs of (1) bioreactor (bench; pilot) setup, sample collection and preparation, and analyses, (2) molecular investigations including DNA extraction/cleanup, primer design, qPCR, metabolomics, and instrument time, (3) analytical chemistry analyses (e.g., PHBV, organic acids, nutrients, etc.), (4) expendable laboratory supplies include standard glassware, centrifuge and microcentrifuge tubes/bottles, glass fiber filters, syringes and syringe filters, chemicals, chemical standards, reagents, gases, gloves, etc. Task B: License for Powersim software ($3000/yr), computer-related supplies and back-up media ($2000/yr); Task D: Educational drones will be purchased for Idaho Drone League (I-Drone) activities. Drones for Idaho Youth is estimated $10,000 ($250 per drone, 20 teams/workshops, 2 workshops) and Drone for I-Drone X for adult is estimated $5,000 ($1,000 per drone, 5 drones). $2,500/yr is also budgeted for drone parts and research supplies (software/drone remote controllers, etc). Total requested budget for drone education for this project is $22,500.	$ 133,500
2. Publication Costs/Page Charges (10 papers @ $1000 each)	$ 10,000
3. Consultant Services ($7000 Services/ $1000 Travel for Mindspring Consultant, developer of the Water Energy Simulation Tool, now retired from INL, to provide services for integration of WEST with Ryu model (Yr 1 only; Task B)	$ 8,000
4. Computer Services	$ 0
5. Subcontracts (See detailed budgets and justifications for BSU and ISU in Appendix E and F, respectively)	$ 817,500
6. Other (specify nature & breakdown if over $1000) In-state fees and health insurance for 5 graduate students/yr ($11,023 ea Yr 1, 7% increase Yr 2 and 3	$ 178,000
SUBTOTAL:	$1,147,000
F. Total Costs: (Add subtotals, sections A through E) TOTAL:	$2,100,000
G. Amount Requested: TOTAL:	$2,100,000
Project Director's Signature: Karen S Humes	Date: 3/28/2018

INSTITUTIONAL AND OTHER SECTOR SUPPORT (add additional pages as necessary)	
A. INSTITUTIONAL / OTHER SECTOR DOLLARS Source / Description	Amount
Stakeholders, including food processing companies, Food Northwest, waste water engineering firms and municipal participants will contribute their own personnel and travel costs to the annual stakeholder meetings held in person, as well as time spent with the research team.	Difficult to estimate, highly variable among participants
B. FACULTY / STAFF POSITIONS: Each of the 6 tenure-track and tenured faculty member CO-Is (4 at UI; 1 at BSU, 1 at ISU) will spend considerable time on this project in the academic year (on the order of 10-25% of their time), with salaries supported by normal operating funds at their institutions.	
C. CAPITAL EQUIPMENT/ D. FACILITIES and INSTRUMENTATION: The value of the existing equipment, facilities and instrumentation at the various research labs over our three institutions (detailed in Appendix A) being brought to bear directly on this work is approximately $2,000,000	

9. Budget Justification – Details for the BSU/ISU subcontracts are provided in Appendices E/F. For the UI budget, details are provided in the budget table above. Overall three institutions, the project will support 7 graduate students and 3-4 undergraduate research assistants each year. Equipment costs are modest because we are leveraging previous investments.

10. Institutional commitment and project management structure

Institutional commitments: This proposal has the full support and endorsement of the VP for Research at all three universities and CAES leadership. Each Co-I will devote considerable time to this effort during the academic year, supported with normal university operating funds. The universities will provide offices and labs for the researchers. *Project management structure:* An important centerpiece of our project management structure will be the ***Stakeholder Steering Committee (SSC).*** A subset of the SSC will be representatives from the FPIEC Industrial Advising Board. Additional members will include a representative from the UI CAFE initiative (Center for Agriculture, Food and the Environment), representatives from current providers of wastewater treatment services (private and municipal), the Idaho Dairymen's Association, the Idaho Water Resources Research Institute, the Idaho Department of Water Resources and other stakeholders as appropriate. We will hold SSC meetings on a quarterly basis to a) review project plans/progress; b) coordinate research to address stakeholder needs; and c) keep at the forefront the opportunities/barriers to commercial implementation of promising technologies. For technical management, the entire team of Co-Is will participate in technical meetings on a monthly basis, by video and in person once/year, saving on travel costs by combining these meetings with on-site field work in Southern Idaho.

11. Additional institutional and other sector support - As noted in the Appendix and second page of the budget sheet, existing equipment purchased with both institutional funding and prior IGEM and EPSCoR support will be used to build the capacity described here. These resources, totaling over $2 million, bring considerable value to this effort.

Literature cited: Listed in Appendix D

APPENDIX A:

Facilities and Equipment

FACILITIES AND EQUIPMENT

1) University of Idaho

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 an extensive list of peer-reviewed 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.

Multi-User University equipment

- Mass-spectrometry facility
  - LC-MS-MS (Micromass Quattro-II mass spectrometer,0- 4000 Da; electrospray andAPCI 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 (Hewlett Packard 1090 instruments 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

Civil Engineering Environmental Engineering Laboratory (Dr. Coats) – in support of Task 1

The Civil Engineering environmental engineering laboratory (Dr. Coats' lab) is housed in the Buchanan 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, laminar flow cabinet, reagent-grade water, etc.). Available equipment, in both Dr. Coats' lab and otherwise accessible on campus by Dr. Coats' research group, is listed below.

Graduate students have office space in the Department of Civil Engineering equipped with personal computers, each of which has independent access to a 100 megabits-per-second internet connection.

EQUIPMENT

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 ($5000)
- Lachat FIA for P and N analysis (including autosampler)
- Unisense meter with nitrate and nitrite probes
- Hach digestion blocks ($2000)
- Muffle furnace & autoclave ($5000)
- Reagent grade water system
- HP model 6890 GC-FID ($25000)
- Agilent model 6890 GC-NPD
- Gow Mac GC/TCD
- Waters HPLC with RI, UV, and DA detectors
- Laboratory-scale bioreactors with 16 Watson-Marlow peristaltic pumps and 30+ microprocessor-controlled magnetic stir plates
- Programmable Logic Controller (PLC) to automate laboratory operations, with 32 input/output relays ($10000)
- Applied Biosystems Step One Plus real time PCR system ($25000)
- Bio-Rad 96 well PCR with Dcode DGGE system and UV imager with camera
- Thermo-electron RC6+ and RC5B floor mounted centrifuges ($30000)
- Micro centrifuges ($2000)
- Laminar flow hood
- High volume muffle furnace
- Incubator and incubator/shaker table
- Balances (10^{-3} and 10^{-4} gram accuracy/precision)

EQUIPMENT

Renewable Materials Laboratory (Dr. McDonald, also in support of Task 1)

- Laboratory auger pyrolysis unit (1 kg/h)
- ABRI Pilot scale auger pyrolysis unit (1/2-ton/day) with biomass dryer and grinder
- Waters Alliance HPLC-SEC system which has triple detection (Multi-angle light scattering – PostNova, UV-VIS, and refractive index)
- Dionex 1000 ion exchange (anion and cation) analysis system
- Two HPLC's with AS200 autosampler and refractive index/UV-VIS detection dedicated for organic acid analysis and carbohydrate analysis.
- GC-TCD (Gow-Mac 350) for gas analysis
- GC-MS^n (PolarisQ iontrap with EI and CI ionization modes)
- GC-MS (Focus-ISQ quadrapole with EI) with pyrolysis and head-space analysis capabilities
- LC-MS^n (Thermofinnigan LCQ deca iontrap with ESI and APCI ionization source)

- FTIR spectrometers (Thermo Avatar 370 and Thermo iS5) with ATR and DRIFT probes
- Portable Raman spectrometer (Enwave Optronics portable) (785 nm excitation)
- UV-VIS spectrometers (Beckman 640, Biomate 5 and StellarNet with fiber optic probes)
- NIR spectrometer (900-1700 nm; Control Development) with various fiber optic probes
- Olympus BX51 microscope (fluorescence, polarized light, DIC) with digital image capture plus hot-stage/DSC (Mettler FP9000/FP82H)
- Protein 1D and 2D-electrophoresis system (mini-Biorad) and protein extraction/purification
- SPSS, Unscramber and Design-expert statistical analysis software
- Instron 5500R-1137 and 5500R-1122 universal testing machines (bending, tensile and compression testing modes) with variable temperature testing oven/chamber
- Differential scanning calorimeter (DSC) TA instruments model Q200 with cooling
- Dynamic mechanical analyzer (DMA) TA instruments model Q800 with cryogenic cooling
- Dynamic mechanical analyzer (DMA) Perkin Elmer model DMA-7 with cooling
- Thermomechancial analyzer (TMA) Perkin Elmer model TMA-7 with cooling
- Thermogravimetric analyzers (TGA) two Perkin Elmer model TGA-7
- Differential Thermal analyzer (DTA) Perkin Elmer DTA-7
- Dynamic Rheometer Bohlin CVO100 with extended temperature oven
- Laboratory hot presses: 50 ton (Wabash 18"x18"), 30 ton (Carver 8"x8") and 30 ton (PHI 12"x12") all 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
- Injection molding machine (15 Ton, Yuh-Dak model YH30) for test specimen preparation
- Laboratory California Pellet mill with feeder
- 3D printer by PrinterBot
- Q-Sun model Xe1S xenon-arc accelerated weathering chamber
- Contact angle goniometer (Pocket goniometer model 2)
- Benchtop lab molding machine (Dynisco LMM) for preparation of test specimens
- CEAST model 7203 Melt Flow indexer
- Two flow through bed bench top reactors (for biofuels catalysis work) with tube furnace, metering pumps and gas mass flow controllers.
- Parr Instruments high pressure/temp reactors (model 4740, 75mL; model 4652, 500mL and 1000mL) plus controllers and (model 4561, 300mL) with heating/cooling control and stirrer
- Karl-Fischer titrator (Mettler V20)
- Surface area analyzer with H_2 temperature programed reduction (Micromeritics 2720)
- QMS x-ray profile densitometer
- Stress wave non-destructive test equipment (FibreGen ST300 and HT200; Metriguard)
- General wet chemistry lab, ovens, centrifuges, extractors, reactors, balances, fume hoods, furnaces, freeze drier, mills, vacuum system, vacuum ovens, environmental chambers, autoclave, Wiley mills

2. Boise State University

Boise State University – Boise State University is the fastest growing university in Idaho with the most rapidly increasing research portfolio among the three research institutions in the state. Undergraduate enrollment has been > 18,000 over the last three years and approximately 2000 graduate students. Dedicated laboratory space with essential equipment and instrumentation is available along with office and greenhouse space. In addition, the Department of Biological Sciences also has multi-user facilities that this project will have access to that include laminar flow cabinets, centrifuges, autoclaves, microscopes, plate readers, etc. A valuable asset to the proposed work scope is the state-of-the art greenhouse. The greenhouse is divided into a head house and four bays. Temperature, watering, and light can be controlled separately in each of the bays by a fully automated system. One of the bays is 400 sq. ft. and the other three 200 sq. ft. each. This facility also has suitable bench space for set up, maintenance and operation of pilot-scale algal cultivation systems. BSU has guaranteed us sufficient space in the greenhouse facility to construct and run our experiments. All costs associated with maintaining climate controls, water supplies, and water removal will be covered by the Boise State Universities Biological Sciences Greenhouse Facility.

EQUIPMENT – BSU

Additional facilities and equipment in the Feris Lab and BSU Biology Department

- Dr. Feris has been supplied with approximately 750 sq. ft. of dedicated research lab space for these and other experiments, in addition to the departmentally available sterilization, storage, and other facilities.
- Agilent 6890N GC (network communication) Dual split/splitless inlet with Electronic Pressure Control FID Detector and Thermal Conductivity Detector (TCD) with Electronic Pressure Control. Dual 7683 injection towers and autosampler 100-sample tray. GC system includes an Agilent 7694 headspace sampler for measurement of volatile organics associated with intact solid and liquid environmental samples.
- Applied Biosystems 310 Capillary Electrophoresis DNA Analyzer
- Applied BIosystems 7300 Real-time PCR machine
- Techne Genius Thermocycler with 96-well block
- ESCO Airstream PCR Cabinet model PCR-3AX
- Molecular biology supplies (e.g. electrophoresis rigs, pipettors, freezers, refrigerators, microcentrifuges, etc.)
- -20oC and -80oC freezers for storage of clones and environmental isolates
- Microbiological culturing supplies
- Incubators, water baths, etc.
- Autoclave
- Shaking and static incubators (both dark and those with controlled light sources)
- UV-Vis Hach 2800 spectrophotometer
- Zeiss Confocal microscope
- BioTex Synergy MX fluorescent plate reader
- Nanodrop ND-1000 spectrophotometer for quantifying DNA for plasmid sequencing, transformation studies, etc..
- Bio-Rad Gel doc XR for agarose gel imaging

Multi-User University equipment (BSU)

- Lachat's QuikChem® 8500 Series 2 Flow Injection Analysis System
- ThermoElectron X-Series II quadrupole ICPMS
- FlashEA 1112 NC Analyzer

3. Idaho State University

The **Department of Geosciences**, College of Science and Engineering, is located in the Physical Sciences Building on Idaho State University's main campus in Pocatello, ID. Within the department in a climate controlled equipment room advanced remote imaging sensors (Rikola's Hyperspectral Camera, Tetracam's ADC Micro multispectral camera, Velodyne LiDAR, etc.) specific for deployment on Unmanned Aircraft System (UAS) are securely stored. Several UAS platforms, all registered with the Federal Aviation Administration, are also housed in the department (DJI Matrice 600 Pro, Parrot Discos, Steadidrone QU4D, QU4D X, and several custom built long flight duration quad and hexacopters). A ground-based spectrometer (ASD FieldSpec Pro 4) complements the aerial sensors for confirmation to ground spectral response conditions. Within ISU's Geosciences department, the **Digital Mapping Lab** (DML) houses a comprehensive suite of powerful geo-computing resources and software. This facility includes four high-end 8-32 core workstations with RAM ranging from 128 GB to 256 GB, Nvidia K6000 graphic cards, combined disk space of 20 TB, and each equipped with large screen monitors for visualization. The DML facilities are also equipped with teaching labs which will enable our outreach, education and training efforts related to the processing and analysis of data collected with the remote imaging sensors and ground-based spectrometry. Complementary processing power also exists at ISU through the campus-wide resource at the **Research Data Center (RDC)**. Through the RDC, this project has access to two secure Virtual Machines (VM) for extended data processing and storage. VM 1 is a geoprocessing powerhouse with a Microsoft operating system, 64 cores, 64 GB RAM and 10 TB storage and high speed networking connectivity. VM 2 is a Linux based open source geoserver platform for data processing of UAS and satellite imagery. Both platforms are secured behind a firewall and backed up regularly and maintained by a systems administrator. To directly support UAS and the goals of this proposal (Task 3, primarly), high end and large format 3D printing (Stratasys Connex 350), carbon fiber laser cutting (Universal Laser System ILS 12.75), electronics card design and production, embedded electronic systems design and maintenance are available on demand.

APPENDIX B:

Biographical Sketches for Team Members, including Current/Pending Support

KAREN S. HUMES
Department of Geography; University of Idaho, Moscow, ID 83844-3021
khumes@uidaho.edu; (208) 885-6506

Education

Ph.D. Hydrology, 1992, Department of Hydrology and Water Resources, University of Arizona
M. S. Soil Science, 1986, Department of Soil and Water Science, University of Arizona
B. S. Geophysics, *summa cum laude*, 1979, New Mexico Institute of Mining and Technology

Professional Experience

2011-2016	**Chair**, Department of Geography, University of Idaho
2007-present	**Professor**, Department of Geography, University of Idaho
1999- 2006	**Associate Professor**, Department of Geography, University of Idaho
1995-1999	**Assistant Professor**, Department of Geography, University of Oklahoma
1992-1995	**Postdoctoral Research Associate and Research Hydrologist**, USDA Agricultural Research Service, Hydrology Laboratory, Beltsville, Maryland.
1988-1991	**NASA Graduate Student Research Fellow**, Dept. of Hydrology and Water Resources, University of Arizona and NASA Goddard Space Flight Center.
1979-1984	**Engineer and Technical Group Leader**, NASA Jet Propulsion Laboratory, California Institute of Technology.

Capacity-Building Experience and Research Interests

Dr. Humes has significant experience in developing, leading and following through on the long-term goals of capacity-building interdisciplinary grants. She served as leader of a 7 member team focusing on Carbon/Water Cycling in Forests in the Idaho EPSCoR(Experimental Program to Stimulate Competitive Research) NSF Research Infrastructure Improvement (RII) grant from 2005-2008, which included oversight of the interdisciplinary research team, reporting and strategic hiring. She also played a lead role in the scoping for the state-wide NSF/EPSCoR RII grant from 2008-2013 "Water Resources in a Changing Climate" and had the opportunity to follow through on its capacity-building goals via her leadership and mentoring role as Department Chair from May 2011-May 2016.

Dr. Humes' own research interests have consistently involved partnerships with operational agencies and other stakeholders to solve real world problems. Her research focuses primarily on the use of remote sensing and GIS for applications in natural resources, hydrology, hazards, and agriculture. In addition to her service on the capacity-building grants noted above, she has served as PI or Co-I on approximately $4 million of external competitive research funding from NOAA, NASA and NSF. These grants have included some of the first use of Lidar data in Idaho to assist operational land managers (in this case, forest managers on the Nez Perce reservation) and technology transfer for new streamflow forecast capability for the USDA/NRCS Snow Survey and calibration of soil mosture sensors used for real-time soil moisture monitoring by the USDA/NRCS Snotel and SCAN networks. Dr. Humes has emerging research interests in the use of GIS and remote sensing to develop sustainable energy systems, including biofuels, distributed energy production and energy/water use efficiency in the food system.

Committee and Panel Memberships

- National Academy of Science/National Research Council Panel on GEWEX (Global Water and Energy Experiment), January 1994-December 1996
- U.S. National Representative to the IUGG for the International Association of Hydrologic Science, 1997-1999
- Proposal review panels for NASA (1999, 2002, 2007); NOAA Office of Global Programs (2002)

- USDA/Agricultural Research Service Science Quality Review Panel, 2006, 2011, 2016

Honors and Awards

- Donald Crawford Graduate Student Mentoring Award, University of Idaho, 2011 (University-wide award – 1 faculty member selected each year)
- National Oceanic and Atmospheric Association, Distinguished Service award for efforts in soil moisture monitoring, 2002.

Recently Funded Research - as P.I. or Team Leader, unless otherwise noted

Water/Energy Conservation Analysis for a Food Processing Plant, Avista Corp, $70K, 2016-2017. Rich Christensen (UI Idaho Falls Engineering) and Karen Humes, Co-PIs, also includes INL and other CAES/UI Idaho Falls faculty

Pre-disaster hazard mitigation planning – 6 Idaho Counties, Idaho Office of Emergency Management, $283,000, August 2016 – Sept 2018.

Pre-disaster hazard mitigation planning – 10 Idaho Counties, Idaho Bureau of Homeland Security, $330,000. August 2015-September 2017.

Landslides and Climate Change in the PNW, USGS Northwest Climate Science Center, $18,000. Graduate student fellowship, D Matsche (student) and K. Humes (faculty advisor). May 2015-May 2016.

Idaho Geographic Alliance, National Geographic Society, $110,000 ($27,500/yr for each of four years), most recent grant was Sept 2017-Oct 2018.

Recent Publications – fully refereed

(* *indicates that first author was an M.S. or Ph.D. student for whom K. Humes served as major advisor during the research implementation and/or manuscript preparation)*

Compton, M., S. Willis, B. Rezaie, K. Humes, Food processing industry energy and water consumption in the Pacific Northwest, under review, *Innovative Food Science and Emerging Technologies.*

Boyden, E., T. Frazier, A. Peterson and K. Humes, Implications of National Flood Insurance Policy reform and Flood Insurance Rate Map revisions on community vulnerability, 2017, under review, *Applied Geography.*

Harshburger, B. J.*, Walden, V. P., Humes, K. S., Moore, B. C., Blandford, T. R., & Rango, A. (2012). Generation of Ensemble Streamflow Forecasts Using an Enhanced Version of the Snowmelt Runoff Model1. *JAWRA Journal of the American Water Resources Association*, 48(4), 643–655. doi:10.1111/j.1752

Jensen, J.R.*, Humes, K.S., Hudak, A.T. and L.A. Vierling (2011). Evaluation of the MODIS LAI product using independent lidar-derived LAI: a case study in mixed conifer forest, *Remote Sensing of Environment*, 115 (12), 3625-3639. DOI: 10.1016/j.rse.2011.08.023

Harshburger, B. J.*, Humes, K. S., Walden, V. P., Blandford, T. R., Moore, B. C. and Dezzani, R. J. (2010). Spatial interpolation of snow water equivalency using surface observations and remotely sensed images of snow-covered area. *Hydrological Processes*, Volume 24, Pages 1285–1295.

Harshburger, B. J.*, Humes, K. S., Walden, V. P., Moore, B. C., Blandford, T. R. and Rango, A. (2010), Evaluation of Short-to-Medium Range Streamflow Forecasts Obtained Using an Enhanced Version of SRM. *JAWRA Journal of the American Water Resources Association*, 46: 603–617.

Graduate Student Mentoring

Dr. Humes has served as major advisor for 30 graduate students (4 Ph.D., 17 M.S. with thesis, 9 M.S. non-thesis) and served as a committee member on more than 40 other graduate committees.

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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

Appointments

Teaching, Extension and Research Appointments:

Professor (Civil & Environmental Engineering), University of Idaho, 7/2018-present
Director of Engineering Management, University of Idaho, 4/2016-present
Associate Professor (Civil & Environmental Engineering), University of Idaho, 7/2012-6/2018
Affiliate Faculty (Chemical Engineering), Univ of Idaho, 6/14-present
Assistant Professor (Civil & Environmental Engineering), University of Idaho, 8/2006-6/2012
Lecturer, University of Idaho (Civil & Environmental Engineering), 8/2005-5/2006
Postdoctoral Scholar (Civil Engineering), Univ of California-Davis, 9/2005-8/2006
Adjunct Professor (Civil Engineering), University of Idaho, 8/2002-5/2005
Graduate Research Asst (Civil/Environmental Engr), Washington St. Univ, 8/2002-5/2005

Non-Academic Appointments:

Murray, Smith & Associates, Inc., Portland, OR, Sr. Project Manager, August 1998-July 2002.
Balfour Consulting, Inc., West Linn, OR, Principal, July 1995-August 1998
Cascade Pacific Engineering, Inc., Milwaukie, OR, Project Engineer, February 1994-July 1995
KPFF Consulting Engineers, Portland, OR, Project Engineer, July 1992-February 1994

Five Products (most closely relevant to the research)

1. Coats, E.R., B. Watson, and C.K. Brinkman, Polyhydroxyalkanoate Synthesis by Mixed Microbial Consortia cultured on Fermented Dairy Manure: Effect of Oxygen Mass Transfer on Process Rates/Yields and Microbial Ecology. Water Res., 2016. 106: p. 26-40.
2. Hanson, A.J., Guho, N.M., Paszczynski, A.J. and Coats, E.R. (2016) Community proteomics provides functional insight into polyhydroxyalkanoate production by a mixed microbial culture cultivated on fermented dairy manure. Appl. Biochem. Biotechnol., 1-20.
3. Hanson, A.J., Paszczynski, A.J. and Coats, E.R. (2016) Proteomic profiling of an undefined microbial consortium cultured in fermented dairy manure: Methods development. Electrophoresis 37(5-6), 790-794.
4. Winkler, Matt J., Coats, Erik R., Brinkman, C.K. 2011. Advancing Post-Anoxic Denitrification for Biological Nutrient Removal. Water Res. 45(18), 6119-6130.
5. Coats, Erik R., Mockos, Alexander, Loge, Frank J. 2011. Post-anoxic Denitrification driven by PHA and Glycogen within Enhanced Biological Phosphorus Removal. Bioresource Technology. 102 (2), 1019-1027.

Five Additional Products

6. Coats, E.R., Brinkman, C.K. and Lee, S. (2016-accepted) Characterizing and Contrasting the Microbial Ecology of Laboratory and Full-scale EBPR Systems Cultured on Synthetic and Real Wastewaters. Water Res.

7. Dai, J., E.R. Coats, A.G. McDonald. (2015) Multivariate near infrared spectroscopy for predicting polyhydroxybutyrate biosynthesis by mixed microbial consortia cultured on crude glycerol. Biomass Bioenerg., 2015. 81: p. 490-495.

8. Coats, E. R.; Dobroth, Z. T.; Brinkman, C. K. (2015) EBPR using crude glycerol: Assessing process resiliency and exploring metabolic anomalies[1]. Water Environ. Res., 87, 68-79.

9. Wei, L.; Guho, N. M.; Coats, E. R.; McDonald, A. G. (2014) Characterization of poly(3-hydroxybutyrate-co-3-hydroxyvalerate) biosynthesized by mixed microbial consortia fed fermented dairy manure. J. Appl. Polym. Sci., 131.

10. Al-Najjar, M.M., Coats, Erik R., Loge, Frank J. (2011) The Role of the Microbial Stringent Response in Excess Intracellular Accumulation of Phosphorous in Mixed Consortia Fed Synthetic Wastewater. Water Research. 45 (16), 5038-5046.

Synergistic Activities

Synergistic activities that have arisen from research projects include: (1) development of research collaborations with Drs. Andrzej Paszczynski (UI), Ken Cain (UI), and Stephen Lee (UI) that include application and multivariate statistical analysis 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. Aurelio Briones (UI) to integrating environmental engineering with molecular biology to advance a novel two-stage process for methane production via anaerobic digestion of manure, and (5) collaboration with the Idaho National Lab and the Center for Advanced Energy Studies to advance sustainable technologies for converting dairy manure into energy and other co-products.

Current Funding

USDA-NIFA (PI). Engineering an economically-driven integrated suite of processes to maximize bio-recovery of carbon and nutrients from dairy manure. $332,905. 2018-2021

NSF-CBET Environmental Engineering (PI). GOALI:WE&RF:WRF: Mainstream Nitritation and Polyhydroxybutyrate-co-valerate Synthesis in a Next-generation Water Resource Recovery Facility (WRRF). $350,000. 2017-2020.

INBRE-Montana (PI). RAIN Metabolomics Pilot Grant. $3000. 2018.

Biographical Sketch for Armando G. McDonald, Ph.D.

Education and Training

- 1993 Ph.D., Chemistry, York University (Canada)
- 1986 M.Sc., Chemistry, University of Otago (New Zealand)
- 1983 B.Sc., Chemistry/Applied Chemistry, University of Otago (New Zealand)

Research and Professional Experience

***Professor**, Forest, Rangeland & Fire Science, University of Idaho* (2011–present). Supervise graduate/undergraduate student research (5+ member group) and teach biomass chemistry and biocomposites in the Renewable Materials program.

***Professor**, Forest Products, University of Idaho* (2006–2011). Supervise graduate/undergraduate student research (5+ member group) and teach wood chemistry and wood composites in the Forest Products program.

***Assistant Professor**, Forest Products, University of Idaho* (2001–2006). Supervise graduate/undergraduate student research (5+ member group) and teach wood chemistry and wood composites in the Forest Products program.

***Project Lead**, New Zealand Forest Research Institute* (1998–2001). Direct technology and scientific research projects in the Biomaterials group (8+ members).

***Senior Scientist**, New Zealand Forest Research Institute* (1993–1998). Performed scientific research projects in the Wood Materials Chemistry group.

***Scientist**, New Zealand Forest Research Institute* (1985–1989). Performed scientific research projects in the Wood Chemistry group.

Publications/Patents/Copyrights/Software Systems Developed (selected from 170)

1. Balogun, A., Lasode, O., McDonald, A.G. (2018) Thermo-chemical and pyrolytic analyses of Musa spp. residues from the rainforest belt of Nigeria. *Environmental Progress and Sustainable Energy*. DOI: 10.1002/ep.12869. http://onlinelibrary.wiley.com/doi/10.1002/ep.12869/epdf
2. Liang, S., Wei, L., Passero, M.L., Feris, K., McDonald, A.G. (2017) Hydrothermal liquefaction of laboratory cultivated and commercial algal biomass into crude bio-oil. *Environmental Progress and Sustainability*. 36(3): 781-787. DOI 10.1002/ep.12629. http://onlinelibrary.wiley.com/doi/10.1002/ep.12629/epdf
3. Balogun, A., Sotoudehniakarani, F., McDonald, A.G. (2017). Thermo-kinetic, spectroscopic study of brewer's spent grains and characterisation of their pyrolysis products. *Journal of Analytical and Applied Pyrolysis*. 127: 8-16. https://doi.org/10.1016/j.jaap.2017.09.009
4. Stankovikj, F., McDonald, A.G., Helms, G., Garcia-Perez, M. (2016) Quantification of bio-oil functional groups and evidences of the presence of pyrolytic humins. *Energy & Fuels*. DOI: 10.1021/acs.energyfuels.6b00994. http://pubs.acs.org/doi/ipdf/10.1021/acs.energyfuels.6b01242
5. Liang, S., Gliniewicz, K., Gerritsen, A.T., McDonald, A.G. (2016) Analysis of microbial community variation during the mixed culture fermentation of agricultural peel wastes to produce lactic acid. *Bioresource Technology*. 208: 7-12. DOI:10.1016/j.biortech.2016.02.054. http://www.sciencedirect.com/science/article/pii/S0960852416301870
6. Wei, L., Liang, S., Guho, N.M., Hanson, A.J., Smith, M., Garcia-Perez, M., McDonald, A.G. (2015) Production and characterization of bio-oil and biochar from the pyrolysis of residual bacterial biomass from a polyhydroxyalkanoate production process. *Journal of Analytical and Applied Pyrolysis*. 115: 268–278. http://dx.doi.org/10.1016/j.jaap.2015.08.005