Title: Developing Value from Produced Waters through Resource Recovery

Abstract:

Goal: The proposed research is designed to assess the water resource value and resource recovery value derived from treatment of oil and gas, produced waters. The treatment is a patented process that is in the development phase and requires additional evaluation from both technical and economic perspectives. The owner of the technology (JS Meyer Engineering, St. Louis, MO) is interested in having the University of Wyoming investigate the technology and is also interested in possibly using the capabilities of the Wyoming Technology Business Center to assist in commercializing the technology. The overall goal of this research is to assess the technical and economic aspects of the technology for treatment of produced waters, identifying the opportunity for increasing water resources and providing value through resource recovery of marketable minerals. If found to provide value commercialization activities will follow.
Research: The proposed research and development project will be conducted under the auspices of the Center of Excellence in Produced Water Management. The Center is within the College of Engineering and the School of Energy Resources. The overall research plan consists of 6 Task with a number of subtasks and investigation imperatives. The major tasks are as follows: Task 1. Project Management: refinement of a project management plan, scope of work, and overall work plan; Task 2. Sample Collection and analysis from various locations; Task 3. Bench Scale Assessment: equipment setup, process simulation and analysis minerals/water; Task 4. Economic Analysis: water and mineral recovery economics from bench scale followed by pilot scale testing; Task 5. Pilot Scale Evaluation *(to begin if bench scale results and economic analysis warrant)*: equipment assembly; site preparation; construction, operation, decommissioning, and report preparation; Task 6. Technology and Business Development *(to begin if bench scale results and economic analysis warrant)*: concept development; start-up; first growth; stability and strategic planning.
Technology Description: Treatment process claims' include the capable of removing contaminants from wastewaters including, but not limited to, industrial wastewater, brackish water, municipal wastewater, drinking waters, and particularly waters obtained from fracking operations. The basic technology includes some or all of the processes of high pH precipitation of minerals, filtration, carbon adsorption filtration, oxidation, and advanced oxidation with UV. There are a number of chemical combinations that can be used to achieve the treatment goals. The following is an example of the treatment sequence: (a) contacting the feed water with $Mn04^{-}$; (b) increasing the pH with NaOH and NaHCO3; (c) separating solution and precipitate; (d) filtering the supernatant; (e) lowering the pH; (f) filtering through activated carbon; and/or (g) expose to ultraviolet (UV) light and separating precipitate. The researchers will then assess both the water and the precipitated minerals and determine quality and value of water (with or without further treatment) as well as the potential commercial value of the recovered minerals.
Research Team: The work with be accomplished through the Center of Excellence in Produced Water Management by William Bellamy (Assistant Director) and Jonathan Brant (Director). This team has experience with precipitation chemistry, advance oxidation, adsorption, and economic evaluations as well as working with oil and gas exploration and production companies.
Expected Outcome: The research will address the possible value proposition and commercialization of technology with the potential of adding to source waters in Wyoming while providing economic incentive to further reduce disposal costs and impacts resulting from oil and gas produced waters. If determined effective and economically feasible, there is the opportunity to commercialize the technology in Wyoming with the assistance of the Wyoming Technology Business Center.

Body of Proposal

Title: Developing Value from Produced Waters through Resource Recover

The following presents the proposed research and development of a produced water treatment technology with the potential of lowering overall produced water management costs through resource recovery while augmenting Wyoming's water resources.

Statement of critical regional or State water problem:

Resource rich states, like Wyoming, are faced with both the challenges and opportunities that accompany the development of oil and natural gas reserves. Water is one resource that lies at the nexus of many converging activities including energy development, energy production, environmental protection, and the wellbeing of the citizenry. The recent explosion of development of domestic oil and natural gas reserves[1,2,3] presents an opportunity to make use of the large volumes of saline water that are co-generated with this development, known as produced water, for beneficial purposes such as for formation fracturing, "fracking" [4,5,6,7,8]

Wyoming is rich in energy resources, yet relatively poor in water resources; it is currently the third driest state in the union. As a result of this constraint, as well as others, it is vitally important that we maximize the usefulness of our produced water resources. The importance of this was highlighted in a 2003 study which determined that if produced water from oil production was treated for domestic consumption, it could supply 66% of the water used per day in Wyoming[9]. Simply providing for reuse of this water can offset a significant water resource demand. In addition, any profitable resource recovery (e.g., minerals such as lithium, iodine, rare earth elements) can assist in reducing the overall cost of produced water management.

Wyoming's oil and gas developers have a major interest and stake in state and federal waters. Energy development, fracking, and other needs are an essential component of energy development. For this research, flow back and produced waters are of interest as a possible additional water resource as well as having the potential to offset produced water management cost through mineral resource recovery. In addition, if the research results prove to be economically feasible, ultimate implementation will result in additional employment and improve the environmental standing of the industry.

The proposed research will be carried out in the Center of Excellence in Produced Water Management (Center) within the College of Engineering and School of Energy Resources. This research as well as other ongoing activities, will grow our collective abilities to utilize our produced water resources, thereby benefiting Wyoming and the University in a number of ways. A positive outcome from this research has the opportunity to diversify Wyoming's economy while maximizing the usefulness of our natural resources. Furthermore, the sustainability of energy development will be improved through development of environmentally friendly water management approaches and technologies.

Statement of results or benefits:

The proposed research is designed to assess the water resource value and resource recovery value (e.g., minerals such as iodine[10] and rare earth elements[11] derived from treatment of oil and gas, produced waters. The treatment technology is a patented process that is in the development phase and requires additional evaluation from both technical and economic perspectives. The owner of the technology (JS Meyer Engineering, St Louis, MO) is interested in partnering and having the University of Wyoming investigate the technology and is also interested in possibly using the capabilities of the Wyoming Technology Business Center to assist in commercializing

the technology. If determined effective and economically feasible, there is the opportunity to commercialize the technology. This outcome will provide economic incentive for the oil and gas industry to further reduce disposal costs and impacts resulting from produced waters.

Scientifically significance outcomes from this research (and the Center) will be important to an array of fields that are of direct relevance to the management and exploitation of produced water resources. Topics of scientific significance from the technology development include improved understandings of the fundamental mechanisms, and our ability to manipulate them, associated with precipitation, catalytic, and oxidative separation chemistry associate with metals and other minerals. The treated water resulting from this type of process can provide feed-water to further treatment technologies including high quality water recovery and ultimately to zero liquid discharge technologies. The resulting product water from this process is lower in di and tri valent minerals, which are associated with precipitation in many types of water recovery, water volume reduction, and desalting technologies. This type of treatment leads to enhanced abilities to apply membrane, thermal, and evaporative technologies to further enhance resource recovery and ultimately provide maximum value while minimizing wastes that required disposal.

As stated above, if the process demonstrates economic viability, plans will move forward to commercialize the technology. The current plan is to use the Wyoming Technology Business Center to assist with this commercialization.

Nature, scope, and objectives of the project and a timetable of activities:

The follow describes the objectives and the research timeline to achieve the intent of the research and development activities. Overall, it is the intent of this proposal to identify the opportunity to cost effectively treat and manage produced water with the goal of increasing water resources and offsetting overall produced water management costs by gaining value for mineral resource recovery. The proposed research and development project will be conducted under the auspices of the Center of Excellence in Produced Water Management. The Center is within the College of Engineering and the School of Energy Resources.

Nature and Objectives: The proposed research is designed to assess the water resource value and resource recovery value derived from treatment of oil and gas - produced waters. The treatment is a patented process[12] that is in the development phase and requires additional evaluation from both technical and economic perspectives. The owner of the technology is interested in having the University of Wyoming investigate the technology and is also interested in possibly using the capabilities of the Wyoming Technology Business Center to assist in commercializing the technology. The overall goal of this research is to assess the technical and economic aspects of the technology for treatment of produced waters, identifying the opportunity for increasing water resources and providing value through resource recovery of marketable minerals. If found to provide value, commercialization activities will follow.

Scope and Timeline: The overall research plan consists of 6 Task with a number of subtasks and investigation imperatives over a 3 year period (Figure 1). The major tasks are as follows:

- Task 1 Project Management: refinement of a project management plan, scope of work, and overall work plan
- Task 2 Sample Collection and Analysis: collect samples from various locations in Wyoming, transport to lab for analysis (participating industry partners have agreed to allow sampling)
- Task 3. Bench Scale Assessment: equipment setup, process simulation and analysis of minerals and water (Figure 2)
- Task 4. Economic Analysis: water and mineral recovery economics from bench scale followed by pilot scale water and mineral result assessment

- Task 5. Pilot Scale Evaluation *(to begin if bench scale results and economic analysis warrant)*: assembly; site preparation; construction, operation, decommissioning, and report preparation
- Task 6. Technology and Business Development *(to begin if bench scale results and economic analysis warrant)*: concept development; start-up; first growth; stability and strategic planning

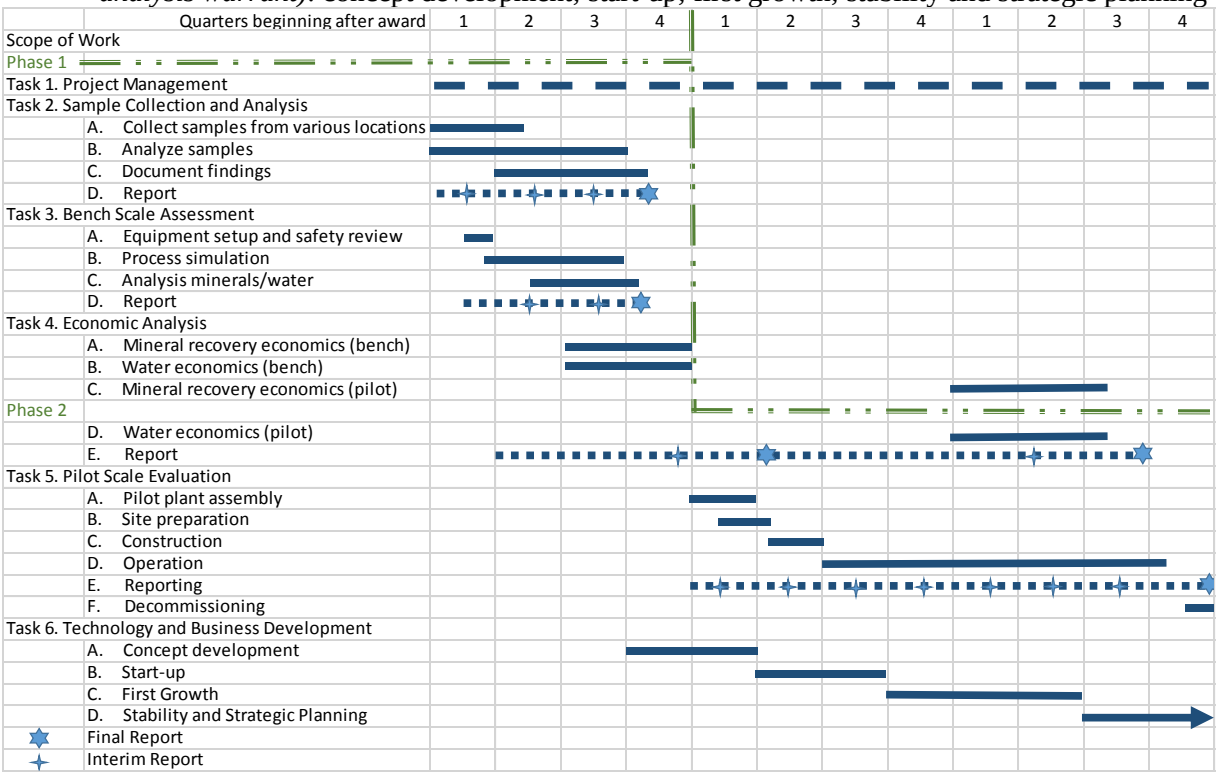

Figure 1 Gantt chart with tasks, milestones, and schedule identified

It is important to note that the schedule is broken up into Phases 1 and 2 for funding considerations. If the technology is economically and technically feasible, Phase 2 funding for the second and third years will be used. <u>If not, the project will terminate and no additional funding will be sought for years 2 and 3</u>.

Methods, procedures, and facilities: The following describes the method, procedures and facilities required for the research in the order of the tasks presented in Figure 1[13]. An important aspect of the scope of work is the ability to end the investigation (and expenditure of money) in the middle of Task 3, if the economics do not prove to achieve one of the goals of lowering disposal costs, producing high quality reuse water, resulting in mineral recovery value, resulting in water suitable for resource augmentation.

Figure 2. Example bench scale results for treatment of produced water

Task 2 requires the collection of samples from producing oil and gas fields in Wyoming followed by analysis of the samples for those minerals of value as well as the overall water quality. Over 6 producers have been contacted and agreed to have samples collected from their production facilities. Analytics will be conducted in the Center's laboratory where the basic instrumentation and equipment is available for routine as well as sophisticated metals identification and quantification, through the use of an inductively coupled plasma mass spectrometry (ICP-MS). Major expenses will be associated with supplies and maintenance of the equipment, not new purchases.

Task 3 includes the evaluation of the technology at bench scale. This evaluation will be conducted in the Center's laboratory. The major equipment for the bench scale work is comprised of glassware, chemicals, mixers, and analytical equipment. All of this is currently included in the laboratory. Addition chemicals, some glassware and consumables for the lab will be a required and included in the budget.

The bench scale evaluation will simulate the treatment process to the greatest extent possible. The following presents a brief description of the process to enable an evaluation of the technical adequacy of the approach. The following are representative of the steps that will be followed during the simulation[13] .

(a) pre-filtering samples as needed prior to first chemical addition;
(b) contacting the feed water with soluble permanganate ions ($Mn04^{-}$);
(c) increasing the pH sufficient to form a contaminant precipitate and an alkaline solution;
(d) separating the alkaline solution and the contaminant precipitate;
(e) filtering the supernatant to form a first eluate and a first filtrate;
(f) lowering the pH of the liquid portion;
(g) filtering the reduced pH first eluate through activated carbon; and/or
(h) exposing the second eluate to ultraviolet (UV) light and separating any precipitate formed from the treated water, wherein the treated water is purified relative to the feed water composition.[12]

Figure 3 Pilot plant equipment owned by JS Meyer CO

At the completion of the bench scale work, the researchers will assess both the water and the precipitated minerals to determine their composition. This information will be documented and entered into the Center's data base on produced waters. The researchers will also supply cost information associated with the capital and operating expenditures to conduct this same type of treatment at full scale. This information will also be used in Task 3 to assist in determining the economic potential or value of the water and concentrated minerals.

Task 4 will assess the economics of the process and anticipated value of the resource recovered during treatment. This analysis will determine the value of the minerals present in the precipitate by including costs for precipitation, separation, and refining with value provided by sales of the minerals. In addition, the water value will be assessed based on the current costs per unit of volume for different purposes based on quality and quantity. The results of the economic assessment will provide the basic information necessary to

Task 5 The pilot scale evaluation will only begin if the bench scale results and economic analysis demonstrate the process is economically feasible at full scale. In addition, no additional funds will be spent if Task 5 is not needed. Task 5 includes the assembly; site preparation; construction, operation, and decommissioning of a pilot plant at a selected oil and gas production facility. Pilot scale equipment (Figure 3) will need to be located in the field due to the quantity of water necessary to accurately simulate a full scale, flow-through, process. The pilot plant equipment presented in Figure 3 is the technology owner's and critical equipment can be made available for the pilot study, thus, lowering overall cost (availability will be time dependent).

Task 6 Technology and Business Development (to begin if bench scale results and economic analysis warrant): concept development; start-up; first growth; stability and strategic planning

with the Wyoming Technology Business Center. This work will not require funds as part of this proposal request. It is included in this proposal to demonstrate a thorough approach and commitment of the team and technology owner.

Related research: Produced water treatment is relatively distinct from that employed for other wastewaters given the high concentrations or organics originating the flowback portion of hydraulic fracturing fluids and dissolved salts/metals/minerals from the formation water.[14,15,16,17] Recent efforts have focused on closing many of the knowledge gaps in our understanding of produced water chemistry in order to develop technologies that can facilitate the economical and environmentally sustainable reuse of this resource.

No two produced waters are alike and thus there is no singular approach to managing them from a treatment perspective. Overall however, the key challenges for produced water managers arise from the following water characteristics: total dissolved solids (TDS) concentrations ≥ of seawater, composition/chemistry, presence of synthetic organics and gels in frac flowback water, oils and greases, and volatile organic compounds (VOCs). Despite much progress in addressing many of these challenges much remains to be resolved before the full benefits of produced water reuse can be realized.

While membrane processes remain at the forefront of many produced water efforts, new advancements are also being made with electrodialysis[18,19], pervaporation[20], mechanical vapor compression[21], evaporation, precipitation, and crystallization[22]. The renewed interest in inorganics separation results from the need to reduce wastewater volumes and recover as much water for reuse as possible. A reasonable approach is precipitation chemistry which will remove the inorganic compounds that impact desalination technologies[23] as well as providing the opportunity to recover inorganic resources.[24]

Numerous valuable minerals have been identified in produced waters[25] and there are commercial operations that are making a profit from extracting and purifying minerals for sale. Synergies for resource recovery also exist where desalination is producing a brine and so concentrating minerals resulting in the possible reduction in cost and expansion of technologies available for mineral extraction [26]. Although mineral extraction from produced water has not been a significant area of development, there are positive examples such as iodine extraction and indications are that mineral recovery can be viable approach to beneficial use and used to offset produced water management costs.

Basic metals precipitation has been practiced for over 10 decades in water and wastewater treatment[27]. There are literally hundreds of articles and text books that discuss different approaches, most using high pH precipitations as the basis, as does the process to be researched. The difference in this process is the type of precipitate and the sequential method of precipitation together with oxidation that is used to separate the metals.[12] Based on the award of the patent, it is reasonable to conclude that the technology has unique capabilities and processes for metals separation from produced water.

Training potential: The research activities that will be conducted within the Center and will involve graduate students pursuing their masters and doctoral degrees in energy economics and environmental engineering. One PhD student in environmental engineering in years 1, 2, and 3. One PhD student in economics will work on the project in year 1. Two MS students in environmental engineering will work on the project in years 1, 2, and 3. One MS student in economics will work on the project in year 3. There will be one hourly undergraduate in year 2.

By organizing the research in the Center, research participants will interact with graduate students both in and outside of their programmatic areas subsequently expanding the types of training that the students will receive. The holistic approach to produced water management being emphasized within the Center requires an interdisciplinary approach, exposing each participant to principles of economics, operational practicality, environmental and social issues; all of which are important to the state of Wyoming and their citizens.

Investigators qualifications: Our team (lead by Drs., Bellamy, Brant, and Mason) has a proven track record of research in important areas of produced water management and related treatment, recovery, and disposal: to include technology development, economic analysis and specific technologies include in the process to be assessed, i.e., high pH precipitation, oxidation, solids processing advanced oxidation, GAC and filtration. Dr. Bellamy is a licensed professional engineer and a Professor of Practice at the University of Wyoming. He has been active in water and wastewater treatment for over 40 years. During this time, he has participated in over 100 studies and technology development efforts, leading to full scale implementation. This experience includes work with or for Texaco, Aramco, Southern Oil Company of Iraq, and Chevron. Technical expertise includes technologies such as metals precipitation, oxidation, filtration, granular activated carbon, advanced oxidation, biological processes, desalination, membranes, zero liquid discharge technologies, and the facilities used to house these technologies.

Dr. Jonathan Brant is a licensed professional engineer (environmental engineering) in Wyoming and an associate professor at the University of Wyoming. Jon's research focuses on the development and implementation of innovative physicochemical separation processes for water and industrial wastewater treatment. Oil and natural gas produced water research has been the center point of Jon's research since 2008 in addition to work on the optimization of membrane processes (MF, UF, NF, and RO) in terms of energy consumption, mitigation of membrane fouling, and concentrate management. Specific research thrusts in these areas include: (i) subsurface desalination irrigation system development, (ii) fate and transport of nanoparticles in natural and engineered environmental systems, (iii) reactive/smart membrane synthesis for improved membrane performance (low-fouling, high permeate flux), and (iv) development of nano-composite membranes for non-pressure driven applications.

Dr. Mason is the H. A. "Dave" True, Jr. Chair in Petroleum and Natural Gas Economics in the Department of Economics and Finance at the University of Wyoming. He is an internationally-known scholar who specializes in Environmental and Resource Economics. He served as the managing editor of the top international journal in this field, the Journal of Environmental Economics and Management, from 2006-2011. His current research interests include modeling prices for crude oil and natural gas, the role of delivery infrastructure in natural gas markets, and motivations to hold stockpiles of oil and gas.

Additional information on previous works and products done by our team members is summarized in our respective biosketches.

In addition, the owner of the technology (JS Meyer Engineering) will be assisting in establishing the experimentation protocol and the work products. This assistance will be invaluable in getting the project off the ground in a reasonable time frame and assuring the appropriate implementation for metals separation and isolation.

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Professional Preparation

University of Wyoming	Electrical (Bio-medical) Engineering	B.S., 1972,
University of Wyoming	Civil (Environmental) Engineering	M.S., 1974,
Colorado State University	Civil (Environmental) Engineering	Ph.D., 1984,

Appointments

2013 to Present, Professor of Practice, Dept. of Civil and Architectural Engn., Univ. of Wyo.
1984 to 2014, CH2M HILL, Denver, Colorado; Fellow and Senior Vice President
1980 to 1984, Colorado State University, Fort Collins, Colorado; Research Assistant
1978 to 1980, ARAMCO Inc., Dhahran, Saudi Arabia; Senior Environmental Engineer.
1974 to 1978, Texaco, Inc., Port Arthur, Texas; Senior Process Engine
1982 to 1991, Cpt. US Army Reserve, Environmental Hygiene Agency
1966 to 1969, Lt. US Army, Infantry

Publications

William Bellamy, Paul D Swaim, Jason M Curl, Adam Carpenter, J Alan Roberson: *Sustainability Principles and Regulatory Development*, JAWWA, March 2015.

Bill Bellamy, Mike Matichich, *How to Finance the Energy Portion of the Water/Energy Nexus*, Public Works Magazine June 2012.

Beth Dart, J Whittier, W Bellamy, Y Choi, K Lyell, *Solar Water Desalination Business Case Analysis*, Final report to King Abdullah University of Science & Technology, Dec. 2014

William Bellamy, J Whittier, I Faghali, *Combined Concentrated Photovoltaic and Seawater Reverse Osmosis Facilities*, Final report to King Abdullah University of Science & Technology, April 2013

A State of the Art Concentrate Management Technology Selection Tool and Application of the Tool to a Full-Scale Study, Ufuk G. Erdal, Jim Lozier, Vivek Shyamasundar, Bill Bellamy 84th Annual WEF, Technical Exhibition and Conf., Los Angeles CA, October 15-19, 2011.

William Bellamy, G.T. Hickman, P.A. Mueller, N Ziemba, *Treatment of VOC-Contaminated Groundwater by Hydrogen Peroxide and Ozone Oxidation,* Research Journal WPCF, 63:2 March/April 1991.

Kerry J. Meyer, Paul D. Swaim, William D. Bellamy, Bruce E. Rittmann, Youneng Tang, and Rick Scott, *Biological and Ion Exchange Nitrate Removal Evaluation,* Water Research Foundation, 2010

Jim Lozier, William Bellamy, *Design and Performance of an Integrated Microfiltration/Nanofiltration Membrane Water Treatment Plant.* AWWA Annual Conference and Exposition, Toronto, Canada. June 18-22, 1996.

Douglas E. Huxley, William D. Bellamy, Priya Sathyanarayan, Matt Ridens, *Greenhouse Gas Emission Inventory and Management Strategy Guidelines for Water Utilities,* Water Research Foundation, November 2009.

Paul Wobma, William Bellamy, James Malley, *UV Disinfection and Disinfection By-Product Characteristics of Unfiltered Water,* Awwa Research Foundation, November 2004.

Dean Gregory, Ken Carlson, William Bellamy, *The Impact of Chemical Sequencing on Filtration Performance.* IWA Publishing June 2004.

Bevin Beaudet,William Bellamy, Mike Matichich, John Rogers, *Capital Planning Strategy Manual*. IWA Publishing October, 2003.

Ken Carlson, William Bellamy, *Use of a Mass Balance Model to Develop Guidelines for Treatment Plant Recycle Streams*, Water Science & Technology: Water Supply 1:4 2001.

Opportunities for Implementing Water Reuse, Presented at AWWA Northwest Section Meeting, May 1991.

Synergistic Activities

- Board Member, Center for Advanced Energy Systems (CAES), 2015 to present
- Board Member, Colorado Water and Energy Consortium 2010 to 2014
- Senior Vice President and Technology Fellow, CH2M Hill, Lead for energy water nexus activities for the firm 1984 to 2014

Collaborates and Other Affiliations

- Project manager for the investigation of solar desalination with CPV linked to RO, King Abdulla University of Science and Technology (KAUST) 2012 - 2013
- Project manager for the investigation of adsorption / desorption desalination and district cooling, engineering and cost estimating for King Abdulla University of Science and Technology (KAUST) 2011 - 2012
- Co-author for the Guidance for Reporting GHG Emissions for Water Utilities, AwwaRF Project 4156, 2008 – 2009

Other Selected Affiliations:

- CH2MHILL Foundation, Board Member 2012 to present
- Drinking Water Subcommittee, Board of Scientific Counselors (BOSC), to USEPA, 2010 to 2012
- Science Advisory Board, USEPA, Homeland Security Advisory Committee 2005 to 2010
- Advisory Board, College of Environmental Policy and Management, University of Denver 2004 - 2007
- National Advisory Board, University of Wyoming, College of Engineering 2002 - 2010
- National Drinking Water Advisory Council, USEPA, 1998 to 2000
- Co-chairman of AwwaRF and EPA's experts workshop on Microbial and Disinfection Byproduct Research Needs, 1999
- AWWA Working Committee on Filter Backwash Rule, 1999

Awards:

- Engineering Hall of Fame, University of Wyoming, 2005
- Outstanding Engineering Alumnus, University of Wyoming, 2001
- EPA award of recognition for Outstanding Contribution to the National Drinking Water Advisory Committee, 2000
- Best Paper of the Year 1994 by AWWA Water Quality Division, *Assessing Water Treatment Plant Performance*. AWWA Journal. 85:12. December 1993
- Selected as best paper AWWA Tennessee/Kentucky Section, September 1991, *Controlling Disinfection Byproducts, Flexibility by Design*

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PROFESSIONAL PREPARATION

Virginia Military Institute	Civil Engineering	B.S., 1998
University of Nevada, Reno	Civil Engineering	M.S., 2000
University of Nevada, Reno	Civil Engineering	Ph.D., 2003
Rice University	Environmental Engineering	2004 – 2006
Duke University	Environmental Engineering	2006 - 2007

APPOINTMENTS

2014 – Pres. Associate Professor, Department of Civil & Architectural Engineering, University of Wyoming

2008 - 14 Assistant Professor, Department of Civil & Architectural Engineering, University of Wyoming

2007 – 08 Project Engineer, HDR Engineering, Inc., Bellevue, Washington

2006 – 07 Research Associate, Department of Civil & Environmental Engineering, Duke University, Durham, North Carolina

2004 – 06 Post-Doctoral Research Associate, Department of Civil & Environmental Engineering, Rice University, Houston, Texas

PRODUCTS

Closely Related Products

Muthu, S.,and Brant, J.A., Interrelationships between Flux, Membrane Properties and Soil Water Transport for a Subsurface Pervaporation Irrigation System, Environmental Engineering Science, Vol. 32 (6), 2015.

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Brant, J.A., Daniel, U., Valencia, R., and Kwan, P., Pilot-Scale Evaluation of Chemical Cleaning Protocols for Organic and Biologically Fouled Microfiltration Membranes, Journal of Environmental Engineering, Vol. 136 (5), 2010 pages 535-553.

Hendren, Z., Brant, J.A. and Wiesner, M.R., Surface Modification of Nanostructured Ceramic Membranes for Direct Contact Membrane Distillation, Journal of Membrane Science, Vol. 331 (1-2) (2009) 1-10.

Significant Products

Labille, J., Mason, A., Ziarelli, F., Rose, J., Brant, J.A., Villieras, F., Pelletier, M., Borshneck, D., Wiesner, M.R., and Bottero, J.-Y., Hydration and Dispersion of C60 in Aqueous Systems: The Nature of Water-Fullerene Interactions, Langmuir (2009) - Accepted.

Brant, J.A. and Childress, A.E., "Membrane-Colloid Interactions: Comparison of Extended DLVO Predictions with AFM Force Measurements", Environmental Engineering Science, Vol. 19 (6), December 2002, pages 413-427.

Brant, J.A. and Childress, A.E., "Assessing Short Range Membrane-Colloid Interactions Using Surface Energetics", Journal of Membrane Science, Vol. 203 (1-2) June 2002, pages 257-273.

Brant, J.A. and Childress, A.E., "Colloidal Adhesion to Hydrophilic Membrane Surfaces", Journal of Membrane Science, Vol. 241 (2), 2004, pages 235-248.

Rose, J., Thill A., Brant, J.A., Labille, J., Jean-Yves Bottero, J.-Y., and Wiesner, M.R., "Methods for Structural and Chemical Characterization of Nanomaterials", Environmental Nanotechnology Applications and Impacts of Nanomaterials, McGraw Hill (2007).

SYNERGISTIC ACTIVITIES

- Curricular material development: Book chapters authored - Fullerol Clusters in *Handbook of Nanophysics,* Nanoparticle Fate and Transport in the Environment and Methods for Structural and Chemical Characterization of Nanomaterials in *Environmental Nanotechnology Applications and Impacts of Nanomaterials,* and *Water Resources and Environmental Depth Reference Manual for the Civil PE Exam 1st Edition.*

- Student Services: Conducts review courses twice a year in environmental engineering for rising seniors at the University of Wyoming who are preparing to take their Fundamentals of Engineering (FE) Exam. Develops a variety of lectures and practice exams whose goal is to refresh the student's understanding of critically important environmental engineering concepts prior to their taking the FE Exam.

- Student Recruitment and Retention: Advises/conducts undergraduate research projects to develop students' interests in pursuing advanced degrees in civil and environmental engineering. Four previous students, Sean Gossner, Kigen Limo, Sierra Johnson and Emily Huth, have participated in EPScOR sponsored undergraduate research projects. Three students were from underrepresented groups in engineering, one African American and two females. Through this effort, one student, Emily Huth, pursued her Master's Degree in Environmental Engineering with the PI.

- Outreach program: *Exploring Engineering – A Hands on Experience*, whose objective is to stimulate the interest of K-12 students in engineering careers.

- Professional and College Service: Reviewer for the following journals - Environmental Science & Technology, Journal of Membrane Science, Desalination, J. Colloid and Interface Science, Industrial and Engineering Chemistry Research, J. Environmental Engineering, and Langmuir. Faculty advisor – Student Chapter of the American Water Works Association (AWWA) and Water Environment Federation, and the University of Wyoming Engineering Fund for Enrichment (UWEFE). Professional Committees - Membrane Technology Research Committee, and the AWWA University Student Activities Committee.

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators and Co-Editors:

P. Kwan, HDR Engineering, Inc. J. Rose, CEREGE, France, J.-Y. Bottero, CEREGE, France, J. Labille, CEREGE, France

Graduate Advisors and Postdoctoral Sponsors:

M. Wiesner, Duke University, A. Childress, University of Nevada, Reno

Thesis Advisor and Postgraduate-Scholar Sponsor:

C. Henry, TriHydro, Q. Jia, University of Toledo, B. Dorr, TriHydro, E. Huth, Stewart Environmental, L. Birgen, Stewart Environmental, C. Harns, Terracon, L. Ruff, Rockpile Energy Services.

CHARLES F. MASON

EDUCATION: Ph.D., University of California, Berkeley; Dissertation: "Regulation and Information in the U.S. Uranium Industry" (June 1983); A.B. in Economics and Mathematics with honor, University of California, Berkeley (June 1977)

APPOINTMENTS

1/14- Visiting Professor, London School of Economics, Grantham Institute

1/14- Visiting Academic, University of Southern Denmark

12/13- Non-resident Fellow, Resources for the Future

12/13 Visiting Researcher, Center for Economic Studies, Faculty of Economics of Ludwig-Maximilians-Universität Munich

6/13 Visiting Scholar, Toulouse School of Economics

3/13-5/13 Visiting Scholar, Fondazione Eni Enrico Mattei – Venice

1/13-2/13 Visiting Academic, Energy and Environmental Economics, Bren School of the Environment, University of California-Santa Barbara

6/11- External Research Associate, Oxford Centre for the Analysis of Resource Rich Economies, University of Oxford

8/07- H. A. "Dave" True Chair in Petroleum & Natural Gas Economics, University of Wyoming

PRODUCTS

Closely Related Products

Mason, Charles F., Lucija A. Muehlenbachs, and Sheila M. Olmstead, "The Economics of Shale Gas Development," *Annual Review of Resource Economics* forthcoming.

Mason, Charles F. and Neil Wilmot, "Jumps in Natural Gas Prices: Implications for Infrastucture," *Energy Economics* 2014, v. 46, S69-S79..

Mason, Charles F., Victoria Umanskaya and Edward Barbier, "On the Strategic Use of Border Tax Adjustments as a Second-Best Climate Policy Measure," *Environment and Development Economics* forthcoming.

Oliver, Matthew E., Charles F. Mason and David Finnoff, "Pipeline Congestion and Natural Gas Basis Differentials: Theory and Evidence," *Journal of Regulatory Economics* 2014, v. 46 261-291.

Mason, Charles F., "The Organization of the Oil Industry, Past and Present," *Foundations and Trends in Microeconomics* 2014, v. 10, pp. 1 – 83.

Significant Products

Mason, Charles F., "Uranium and Nuclear Power: The Role of Exploration in Framing Public Policy," *Resource and Energy Economics* 2014, v. 36, 49-63.

Oliver, Matthew E., Charles F. Mason and David Finnoff, "Natural Gas Expansion and the Cost Of Congestion," *Energy Forum* 2014, pp. 31-32.

Van ‘t Veld, Klaas, Charles F. Mason and Andrew Leach, “The Economics of CO2 Sequestration Through Enhanced Oil Recovery,” *Energy Procedia* 2013, v. 37, 6909-6919.

Mason, Charles F., “The Economics of Eco-Labeling,” *International Review of Environmental and Resource Economics* 2013, v. 6, 341-372.

Mason, Charles F. and Andrew Plantinga, “Contracting for Impure Public Goods: Carbon Offsets and Additionality,” *Journal of Environmental Economics and Management* 2013, v. 66 1-14.

SYNERGISTIC ACTIVITIES

(2014-) Co-Editor, *Journal of the Association of Environmental and Resource Economists;* (2013) Joint Interim Managing Editor, *Journal of the Association of Environmental and Resource Economists;* (2012- Pres.) Associate Editor, *European Economic Review* (2012-); Joint Editor-in-Chief (2012-) *Strategic Behavior and the Environment* (2012- Pres.); (2006-2011) Managing Editor, *Journal of Environmental Economics and Management*; (2012- Pres.) Editorial Board: *Challenges in Sustainability* (2012- Pres.)

YEAR 1 BUDGET (FY16)

Start Date of FY16: 3/1/16 **End Date of FY16: 2/28/17**

Project Title:
Developing Value from Produced Waters through Resource Recovery

Principal Investigators (names only -- i.e., no addresses etc.):
William Bellamy, Jonathan Brant

Cost Category	Request	UW	Total
1. Salaries and Wages - Totals	**93,953**	**15,700**	**109,653**
Principal Investigator(s)	9472	6600	16072
Graduate Student(s) on assistantships (i.e., stipends)	60864		60864
Undergraduate or Grad Student(s) employed hourly			0
Others, full-time benefited	18517	6600	25117
Others, part-time non-benefited	5100	2500	7600
2. Fringe Benefits - Totals	**14,658**	**6,645**	**21,302**
Principal Investigator(s), 46.55%	4409	3072	7482
Graduate Student(s) on assistantships, 1%	609	0	609
Undergraduate or Grad Student(s) employed hourly, 9%	0	0	0
Others, full-time benefited, 46.55%	8620	3072	11692
Others, part-time non-benefited, 20%	1020	500	1520
3. Graduate Student Tuition, Fees, Health Insurance- - - - - Totals	**26,910**	**0**	**26,910**
Tuition and Fees	21642		21642
Health Insurance	5268		5268
4. Supplies -	**2,200**	**500**	**2,700**
5. Equipment - Totals	**0**	**0**	**0**
Individual items costing $5,000 or less	0	0	0
Individual items in excess of $5,000	0	0	0
6. Services or Consultants -	**-**	**6,400**	**6,400**
7. Travel -	**2,760**		**2,760**
8. Other Direct Costs -	**2,100**		**2,100**
9. Total Direct Costs* -	**142,581**	**29,245**	**171,825**
10. Total Indirect Costs -	XXXXXXX	**63,763**	**63,763**
Indirect costs on federal share	xxxxxxxx	50895	50895
Indirect costs on non-federal share	xxxxxxxx	12868	12868
(0.44 direct, except grad tuition/fees/health ins & equip>$5000)			
11. **Total Cost** -	**142,581**	**93,007**	**235,588**

YEAR 2 BUDGET (FY17)

Start Date of FY16: 3/1/17 **End Date of FY16: 2/28/18**

Project Title:
Developing Value from Produced Waters through Resource Recovery

Principal Investigators (names only -- i.e., no addresses etc.):
William Bellamy, Jonathan Brant

Cost Category	Request	UW	Total
1. Salaries and Wages - Totals	**55,216**	**6,500**	**61,716**
Principal Investigator(s)	9472	4500	13972
Graduate Student(s) on assistantships (i.e., stipends)	38484		38484
Undergraduate or Grad Student(s) employed hourly	2160		2160
Others, full-time benefited			0
Others, part-time non-benefited	5100	2000	7100
2. Fringe Benefits - Totals	**6,008**	**2,495**	**8,503**
Principal Investigator(s), 46.55%	4409	2095	6504
Graduate Student(s) on assistantships, 1%	385	0	385
Undergraduate or Grad Student(s) employed hourly, 9%	194	0	194
Others, full-time benefited, 46.55%	0	0	0
Others, part-time non-benefited, 20%	1020	400	1420
3. Graduate Student Tuition, Fees, Health Insurance- - - - - Totals	**17,940**	**0**	**17,940**
Tuition and Fees	14428		14428
Health Insurance	3512		3512
4. Supplies -	**3,000**	**-**	**3,000**
5. Equipment - Totals	**4,200**	**0**	**4,200**
Individual items costing $5,000 or less	4200		4200
Individual items in excess of $5,000	0		0
6. Services or Consultants -	**-**	**12,400**	**12,400**
7. Travel -	**1,380**		**1,380**
8. Other Direct Costs -	**17,000**		**17,000**
9. Total Direct Costs* -	**104,744**	**21,395**	**126,139**
10. Total Indirect Costs -	XXXXXXX	**47,608**	**47,608**
Indirect costs on federal share	xxxxxxxx	38194	38194
Indirect costs on non-federal share	xxxxxxxx	9414	9414
(0.44 direct, except grad tuition/fees/health ins & equip>$5000)			
11. **Total Cost -**	**104,744**	**69,002**	**173,747**

YEAR 3 BUDGET (FY18)

Start Date of FY16: 3/1/18 **End Date of FY16: 2/28/19**

Project Title:
Developing Value from Produced Waters through Resource Recovery

Principal Investigators (names only -- i.e., no addresses etc.):
William Bellamy, Jonathan Brant

Cost Category	Request	UW	Total
1. Salaries and Wages - Totals	**87,677**	**13,720**	**101,397**
Principal Investigator(s)	9472	5620	15092
Graduate Student(s) on assistantships (i.e., stipends)	54588		54588
Undergraduate or Grad Student(s) employed hourly			0
Others, full-time benefited	18517	5600	24117
Others, part-time non-benefited	5100	2500	7600
2. Fringe Benefits - Totals	**14,595**	**5,723**	**20,318**
Principal Investigator(s), 46.55%	4409	2616	7025
Graduate Student(s) on assistantships, 1%	546	0	546
Undergraduate or Grad Student(s) employed hourly, 9%	0	0	0
Others, full-time benefited, 46.55%	8620	2607	11226
Others, part-time non-benefited, 20%	1020	500	1520
3. Graduate Student Tuition, Fees, Health Insurance- - - - - Totals	**26,910**	**0**	**26,910**
Tuition and Fees	21642		21642
Health Insurance	5268		5268
4. Supplies -	**4,800**	**1,000**	**5,800**
5. Equipment - Totals	**0**	**0**	**0**
Individual items costing $5,000 or less			0
Individual items in excess of $5,000			0
6. Services or Consultants -	**-**	**9,400**	**9,400**
7. Travel -	**2,760**		**2,760**
8. Other Direct Costs -	**12,080**		**12,080**
9. Total Direct Costs* -	**148,822**	**29,843**	**178,665**
10. Total Indirect Costs -	XXXXXXX	**66,772**	**66,772**
Indirect costs on federal share	xxxxxxxx	53641	53641
Indirect costs on non-federal share	xxxxxxxx	13131	13131
(0.44 direct, except grad tuition/fees/health ins & equip>$5000)			
11. **Total Cost** -	**148,822**	**96,615**	**245,437**

TOTAL PROJECT BUDGET (Covering All Years)

Project Start Date: 3/1/16 **Project End Date: 2/28/19**

Project Title:
Developing Value from Produced Waters through Resource Recovery

Principal Investigators (names only -- i.e., no addresses etc.):
William Bellamy, Jonathan Brant

Cost Category	Request	UW	Total
1. Salaries and Wages - Totals	**236,846**	**35,920**	**272,766**
Principal Investigator(s)	28416	16720	45136
Graduate Student(s) on assistantships (i.e., stipends)	153936	0	153936
Undergraduate or Grad Student(s) employed hourly	2160	0	2160
Others, full-time benefited	37034	12200	49234
Others, part-time non-benefited	15300	7000	22300
2. Fringe Benefits - Totals	**35,261**	**14,862**	**50,123**
Principal Investigator(s), 46.55%	13228	7783	21011
Graduate Student(s) on assistantships, 1%	1539	0	1539
Undergraduate or Grad Student(s) employed hourly, 9%	194	0	194
Others, full-time benefited, 46.55%	17239	5679	22918
Others, part-time non-benefited, 20%	3060	1400	4460
3. Graduate Student Tuition, Fees, Health Insurance- - - - - Totals	**71,760**	**0**	**71,760**
Graduate Student(s), Tuition and Fees	57712	0	57712
Graduate Student(s), Health Insurance	14048	0	14048
4. Supplies -	**10,000**	**1,500**	**11,500**
5. Equipment - Totals	**4,200**	**0**	**4,200**
Individual items costing $5,000 or less	4200	0	4200
Individual items in excess of $5,000	0	0	0
6. Services or Consultants -	**-**	**28,200**	**28,200**
7. Travel -	**6,900**	**-**	**6,900**
8. Other Direct Costs -	**31,180**	**-**	**31,180**
9. Total Direct Costs* -	**396,147**	**80,482**	**476,629**
10. Total Indirect Costs -	XXXXXXX	**178,142**	**178,142**
Indirect costs on federal share	xxxxxxxx	142730	142730
Indirect costs on non-federal share	xxxxxxxx	35412	35412
(0.44 direct, except grad tuition/fees/health ins & equip>$5000)			
11. **Total Cost -**	**396,147**	**258,625**	**654,771**

SUMMARY OF AMOUNTS REQUESTED

Project Start Date: 3/1/16 **Project End Date: 2/28/19**

Project Title:
Developing Value from Produced Waters through Resource Recovery

Principal Investigators (names only -- i.e., no addresses etc.):
William Bellamy, Jonathan Brant

Cost Category	Yr 1 ($)	Yr 2 ($)	Yr 3 ($)	Project ($)
1. Salaries and Wages - Totals	**93,953**	**55,216**	**87,677**	**236,846**
Principal Investigator(s)	9472	9472	9472	28416
Graduate Student(s) on assistantships (stipends)	60864	38484	54588	153936
Undergrad or Grad Student(s) employed hourly	0	2160	0	2160
Others, full-time benefited	18517	0	18517	37034
Others, part-time non-benefited	5100	5100	5100	15300
2. Fringe Benefits - Totals	**14,658**	**6,008**	**14,595**	**35,261**
Principal Investigator(s)	4409	4409	4409	13228
Graduate Student(s) on assistantships	609	385	546	1539
Undergrad or Grad Student(s) employed hourly	0	194	0	194
Others, full-time benefited	8620	0	8620	17239
Others, part-time non-benefited	1020	1020	1020	3060
3. Tuition, Fees, Health Insurance - - - - - - - - - - - Totals	**26,910**	**17,940**	**26,910**	**71,760**
Graduate Student(s), Tuition and Fees	21642	14428	21642	57712
Graduate Student(s), Health Insurance	5268	3512	5268	14048
4. Supplies -	**2,200**	**3,000**	**4,800**	**10,000**
5. Equipment - Totals	**0**	**4,200**	**0**	**4,200**
Individual items costing $5,000 or less	0	4200	0	4200
Individual items in excess of $5,000	0	0	0	0
6. Services or Consultants -	**0**	**0**	**0**	**0**
7. Travel -	**2,760**	**1,380**	**2,760**	**6,900**
8. Other Direct Costs -	**2,100**	**17,000**	**12,080**	**31,180**
9. Total Direct Costs* -	**142,581**	**104,744**	**148,822**	**396,147**
10. Total Indirect Costs -	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
Indirect costs on federal share	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx
Indirect costs on non-federal share	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx
11. **Total Cost**- -	**142,581**	**104,744**	**148,822**	**396,147**

BUDGET JUSTIFICATION - Year 1

Project Title: Developing Value from Produced Waters through Resource Recover

Salaries and Wages for PIs. Provide personnel, title/position, and compensation proposed for each individual.
Dr. Bellamy CO PI, , part time no benefits, manage overall budget and schedule, supervise site work. Estimated to be $5,100 Dr. Brandt CO PI/ full time benefits): Funds totaling $9,472 are requested for summer salary PI/Co-PI salaries for full time benefited personnel were calculated using procedures that are established by the University of Wyoming. Summer salary for the PI/Co-PI'S was calculated as follows: annual salary*0.0037 = daily rate * # days in month = max salary available in any one month / 30-day period).
Salaries and Wages for Graduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, note that tuition and health insurance, if provided, have their own category below.
Doctoral Student (environmental): 12 person months, for which $22,380 in annual salary is requested Doctoral Student (economics): 12 person months, for which $22,380 in annual salary is requested Masters Student (engineering) 12 person months, for which $16,104 in annual salary is requested
Salaries and Wages for Undergraduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, health insurance, if provided, is to be included under fringe benefits.)
$0.00
Salaries and Wages for Others. Provide personnel, title/position, and compensation proposed for each individual.
Dr. Mason, manage economic evaluation with MS Student: Funds totaling $18,517 are requested for summer salary.
Fringe Benefits for PIs. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
PI 46.55%,
Fringe Benefits for Graduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project.
Graduate student 1%
Fringe Benefits for Undergraduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. Note: include health insurance here, if applicable
Undergraduate hourly 9%
Fringe Benefits for Others. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
Part time non benefit 20%
Tuition, Fees, and Health Insurance for Graduate Students. Specify tuition, fees, and health insurance (each, if provided) separately.
Doctoral Student (engineering): Tuition & Fees $7,214; health insurance $1,756 (for 12 months) Doctoral Student (economics): Tuition & Fees $7,214; health insurance $1,756 (for 12 months) Masters Student (engineering) Tuition & Fees $7,214; health insurance $1,756 (for 12 months)
Supplies. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies. Provide a breakdown of the supplies in each category
Field Supplies = $700 sample containers, chemical prep, shipping containers, ice Lab Supplies = $1,500 costs for chemicals for IPC MS and chemicals for conducting bench scale testing, and glassware Computing = $0 Office = $0 Existing glassware and
Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items. A detailed breakdown is required**.**
None
Services or Consultants. Identify the specific tasks for which these services, consultants, or subcontracts would be used. Provide a detailed breakdown of the services or consultants to include personnel, time, salary, supplies, travel, etc.

The consultants are the owners of the technology. They will be participating in the overall setup and review of bench scale study with approximately 2 weeks = $6,400 in-kind donation
Travel. Provide purpose and estimated costs for all travel. A breakdown should be provided to include location, number of personnel, number of days, per diem rate, lodging rate, mileage and mileage rate, airfare (whatever is applicable).
Location: Portland OR, ASCE National Conference No personnel: 2 No days: 3 Per diem: 60 Lodging per day: 150 Airfare: 500 Registration: 250
Other Direct Costs. Itemize costs not included elsewhere, including publication costs. Costs for services and consultants should be included and justified under "Services or Consultants (above). Please provide a breakdown for costs listed under this category.
Travel and lodging for sample collection at field locations Per diem: 60 Lodging per day: 80 Travel miles 250 per trip $0.56 per mile 10 day 5 trips
Indirect Costs. Provide negotiated indirect ("Facilities and Administration") cost rate.

BUDGET JUSTIFICATION – Year 2

Project Title:

Salaries and Wages for PIs. Provide personnel, title/position, and compensation proposed for each individual.
Dr. Bellamy CO PI, , part time no benefits, manage overall budget and schedule, supervise site work. Estimated $5,100 Dr. Brandt CO PI/ full time benefits): Funds totaling $9,472 are requested for summer salary PI/Co-PI salaries for full time benefited personnel were calculated using procedures that are established by the University of Wyoming. Summer salary for the PI/Co-PI'S was calculated as follows: annual salary*0.0037 = daily rate * # days in month = max salary available in any one month / 30-day period).
Salaries and Wages for Graduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, note that tuition and health insurance, if provided, have their own category below.
Doctoral Student (environmental): 12 person months, for which $22,380 in annual salary is requested Masters Student (engineering) 12 person months, for which $16,104 in annual salary is requested
Salaries and Wages for Undergraduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, health insurance, if provided, is to be included under fringe benefits.)
Undergraduate hourly worker 10 hours per week 18 weeks $12/hr $2,160
Salaries and Wages for Others. Provide personnel, title/position, and compensation proposed for each individual.
$0.00
Fringe Benefits for PIs. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
PI 46.55%,
Fringe Benefits for Graduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project.
Graduate student 1%
Fringe Benefits for Undergraduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. Note: include health insurance here, if applicable
Undergraduate hourly 9%
Fringe Benefits for Others. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
Part time non benefit 20%
Tuition, Fees, and Health Insurance for Graduate Students. Specify tuition, fees, and health insurance (each, if provided) separately.
Doctoral Student (engineering): Tuition & Fees $7,214; health insurance $1,756 (for 12 months) Masters Student (engineering) Tuition & Fees $7,214; health insurance $1,756 (for 12 months)
Supplies. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies. Provide a breakdown of the supplies in each category
Field Supplies = $0 sample containers, chemical prep, shipping containers, ice Lab Supplies = $3,000 costs for chemicals for IPC MS and chemicals for conducting bench scale testing, and glassware Computing = $0 Office = $0 Existing glassware and
Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items. A detailed breakdown is required**.**
Plastic tanks used for chemical addition (2) $2300 Pumps for transfer between unit processes (2) $1700 Hosing $200

Services or Consultants. Identify the specific tasks for which these services, consultants, or subcontracts would be used. Provide a detailed breakdown of the services or consultants to include personnel, time, salary, supplies, travel, etc.
The consultants are the owners of the technology. They will be participating in the overall setup and review of bench scale study with approximately 2 weeks = $6,400 in-kind donation. Donation of 1st phase pilot equipment = $6,000.
Travel. Provide purpose and estimated costs for all travel. A breakdown should be provided to include location, number of personnel, number of days, per diem rate, lodging rate, mileage and mileage rate, airfare (whatever is applicable).
Location: SPE Hydraulic Fracturing Technology Conference, Woodlands, Texas, 24 - 26 Jan 2017 No personnel: 1 No days: 3 Per diem: 60 Lodging per day: 150 Airfare: $500 Registration: $250
Other Direct Costs. Itemize costs not included elsewhere, including publication costs. Costs for services and consultants should be included and justified under "Services or Consultants (above). Please provide a breakdown for costs listed under this category.
Pilot plant setup and operations Per diem: 60 Lodging per day: 80 $0.56 per mile Miles per trip 250 Trips 10, total days on site 40 Site preparation for pilot plant $10,000
Indirect Costs. Provide negotiated indirect ("Facilities and Administration") cost rate.
$0.00

BUDGET JUSTIFICATION – Year 3

Project Title:

Salaries and Wages for PIs. Provide personnel, title/position, and compensation proposed for each individual.
Dr. Bellamy CO PI, , part time no benefits, manage overall budget and schedule, supervise site work. Estimated to be $5,100 Dr. Brandt CO PI/ full time benefits): Funds totaling $9,472 are requested for summer salary PI/Co-PI salaries for full time benefited personnel were calculated using procedures that are established by the University of Wyoming. Summer salary for the PI/Co-PI'S was calculated as follows: annual salary*0.0037 = daily rate * # days in month = max salary available in any one month / 30-day period).
Salaries and Wages for Graduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, note that tuition and health insurance, if provided, have their own category below.
Doctoral Student (environmental): 12 person months, for which $22,380 in annual salary is requested Masters Student (engineering) 12 person months, for which $16,104 in annual salary is requested Masters Student (economics) 12 person months, for which $16,104 in annual salary is requested
Salaries and Wages for Undergraduate Students. Provide personnel, title/position, estimated hours and the rate of compensation proposed for each individual. (Other forms of compensation paid as or in lieu of wages to students performing necessary work are allowable provided that the other payments are reasonable compensation for the work performed and are conditioned explicitly upon the performance of necessary work. Also, health insurance, if provided, is to be included under fringe benefits.)
$0.00
Salaries and Wages for Others. Provide personnel, title/position, and compensation proposed for each individual.
Dr. Mason, manage economic evaluation with MS Student: Funds totaling $18,517 are requested for summer salary.
Fringe Benefits for PIs. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
PI 46.55%,
Fringe Benefits for Graduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project.
Graduate student 1%
Fringe Benefits for Undergraduate Students. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. Note: include health insurance here, if applicable
Undergraduate hourly 9%
Fringe Benefits for Others. Provide the overall fringe benefit rate applicable to each category of employee proposed in the project. . Note: include health insurance here, if applicable.
Part time non benefit 20%
Tuition, Fees, and Health Insurance for Graduate Students. Specify tuition, fees, and health insurance (each, if provided) separately.
Doctoral Student (engineering): Tuition & Fees $7,214; health insurance $1,756 (for 12 months) Masters Student (economics): Tuition & Fees $7,214; health insurance $1,756 (for 12 months) Masters Student (engineering) Tuition & Fees $7,214; health insurance $1,756 (for 12 months)
Supplies. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies. Provide a breakdown of the supplies in each category
Field Supplies = $700 sample containers, chemical prep, shipping containers, ice Field chemical = $2600 Lab Supplies = $1,500 costs for chemicals for IPC MS and chemicals for conducting bench scale testing, and glassware Computing = $0 Office = $0
Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items. A detailed breakdown is required**.**
None
Services or Consultants. Identify the specific tasks for which these services, consultants, or subcontracts would be used. Provide a detailed breakdown of the services or consultants to include personnel, time, salary, supplies, travel, etc.

The consultants are the owners of the technology. They will be participating in the overall setup and review of bench scale study with approximately 2 weeks = $6,400 in-kind donation. Donation of 2nd phase pilot equipment = $3,000.
Travel. Provide purpose and estimated costs for all travel. A breakdown should be provided to include location, number of personnel, number of days, per diem rate, lodging rate, mileage and mileage rate, airfare (whatever is applicable).
Location: SPE Annual Technical Conference Dallas, Texas, 23 - 25 Sep 2018 No personnel: 2 No days: 3 Per diem: 60 Lodging per day: 150 Airfare: 500 Registration $250
Other Direct Costs. Itemize costs not included elsewhere, including publication costs. Costs for services and consultants should be included and justified under "Services or Consultants (above). Please provide a breakdown for costs listed under this category.
Pilot plant setup and operations Per diem: 60 Lodging per day: 80 $0.56 per mile Miles per trip 250 Trips 12, total days on site 60 Decommissioning the site $2,000
Indirect Costs. Provide negotiated indirect ("Facilities and Administration") cost rate.