Transatlantic Climate Bridge

# Undergraduate Research Symposium

focusing on

# Energy and Climate Change

**Tuesday, November 16**
**5:00 to 7:00**
**Fifth Floor, Alumni Hall**
**University of Pittsburgh**

The German Foreign Office and German Environment Ministry established the Transatlantic Climate Bridge initiative to foster transatlantic cooperation between Germany and the United States, helping these countries to find solutions on issues related to environmental change and energy use. Climate and Energy Campus Week, a project launched via the initiative, highlights undergraduate students' work in these areas. Tonight's symposium is sponsored by the Campus Week project. The event is co-sponsored by the University of Pittsburgh's Center for Energy and Office of the Provost.

The symposium is comprised of two sections. In the first, students will present videos on issues ranging from clean and secure sources of energy to climate and environmental change. In the second, students will present posters on research related to the same subjects. The videos and posters may not frame issues explicitly in terms of German-American relations, but the underlying science will address problems common to both countries. The video summaries and poster abstracts follow this introduction. They are listed in alphabetical order by first author.

# Video Summaries

## Inspiration for Today's College Students: Renewable Energy for Families and Citizens of the 21st Century

Authors: Megan Cichon, Ohiremen Dibua, Matt Dukewich, Matt Franklin, Elise Hinderliter, Chelsea Milito, Rachel Sandercock, Sam Schock, Rebecca Schroeder, Dustin Smith, Wen Xu, and Evan Crader
Faculty Mentor: Joseph J. Grabowski

Since copious amounts of natural resources are used each year to meet the energy needs of society, time is limited before these sources of energy are depleted. Therefore, there is a major push to investigate and to implement alternative and renewable forms of energy in the 21st century. There is hope for our generation! In this short informative video we will share the technological advances that are taking place that will create usable and renewable energy from several abundant sources. The video summarizes the world's growing ability to harness energy from ocean waves and tides, the capability to produce power from wind turbines, and the capacity to generate electricity from sunlight. Luckily our generation will not have to be "loyal to oil" forever.

## Smart Grid Control Methodology for Integrated Distribution Management

Authors: Chris Lippert, Ansel Barchowsky, and Adam Sparacino
Faculty Mentor: Gregory Reed

Research and development in the field of "smart grids" is advancing at an ever expanding rate, with an increasing number of industry participants and other key constituents internationally, including government entities and educational institutions. It is vital to understand the approaches being taken by these various entities in order to determine the optimal method by which to proceed with defining the smart grid and associated future developments. A survey was undertaken with the intent of determining representative approaches from various international participants, and combining them into an overarching view of the industry as a whole. This included smart

grid activities across North America, Europe, Australia, and Asia. As a result, the more practical and efficient methods of improving the electrical grid were revealed, as well as gaps within the existing technology and standards. The most apparent gaps were determined to be in the following main areas: common communications; improved transmission and distribution controls; real-time information and incentives for both the end-user and the utility; self-healing grids; energy storage and renewable integration; and improved standards for the industry. In particular, future work into the development of improved control software for renewable integration utilizing energy storage is discussed, which will contribute to further research within the field.

**From Unseen to Green**

Author: Michael Reber
Faculty Mentor: Alex Star

Hydrogen sulfide ($H_2S$) and carbon dioxide ($CO_2$) are two gasses that come from the production of energy through burning of fossil fuels. The concentrations of both $H_2S$ and $CO_2$ have been increasing in recent times, and they have been linked to adverse health and a rise in the global climate, respectively. In this video we will look at two different gas sensors using functionalized carbon nanotubes (CNTs) to detect these gasses at both low concentrations and with good selectivity. Along with the applications that are available with the use of CNTs, the material poses many health and toxicity issues that are known. Therefore, we are also using the enzyme of Horseradish Peroxidase (HRP) for the degradation of CNTs.

**Biofuels on Marginal Lands To Remediate Heavy Metal Soil Contamination**

Author: Chris Rovensky
Faculty Mentors: Amy Landis and Jason Monnell

Biofuel-based phytoremediation is being evaluated as a beneficial means to repurpose potentially contaminated, underutilized urban marginal lands. Heavy metal concentration data has been collected from several sites since 2008 (shared

through the generosity of a local Pittsburgh nonprofit community group) and analyzed by atomic absorption spectroscopy. New sites have been identified for the 2010 growing seasons. The biofuel crops could improve soil conditions at the sites, as well as alleviate the economic and social blight associated with vacant urban lands.

**Hydrokinetic Power Generation for a Clean Energy Future**

Authors: M. Brooke Sciarrotta and Michael Oyler
Faculty Mentor: Laura Schaefer

Hydrokinetic energy extraction (HEE) has received increasing attention recently as a sustainable means to alleviate the strain on current energy technologies. HEE extracts kinetic, rather than potential (as in traditional hydropower dams), energy, and can be applied to tidal, some ocean, and river energy applications. Our research focuses on quantifying both the power capacity of HEE and its environmental consequences.

**The Consumer and Composting**

Author: Nick Stamatakis
Faculty Mentors: Amy Landis and Melissa Bilec

Increased Mixed Solid Waste Composting can make waste management and agriculture processes more sustainable; however, there are several issues that need addressing for such a system to be practical. In this video, we focus on the industrial processing of commercial organic waste and the home composting of biodegradable service waste as two areas of magnified concern.

**Algae: Nature's Power "Plant"**

Authors: Grace Witter and Monica Rothermel
Faculty Mentors: Amy Landis and Willie Harper

The coupling of wastewater treatment and microalgal photobioreactors produces a sustainable system able to create a great amount of important and essential products such as clean

water, biological fuels, polyhydroxyalkanoates (PHAs) and fertilizers. Using wastewater streams as a source of food for microaglae facilitates the process of reducing the concentration of nutrients in wastewater and has the potential of replacing chemical treatment with an organic method. To test the feasibility of the linked water treatment system an experimental prototype was designed. A sequencing batch reactor (SBR) was used to complete a biological means of treating wastewater via the activated sludge method. The effluent from the SBR was fed to the chosen algae strain, *Chlorella vulgaris*, which was placed and grown in aerated photobioreactors (PBRs). The scope of the project includes measurements related to water quality through the testing of chemical oxygen demand (COD), total suspended solids (TSS), and nitrogen and phosphorus concentration. Bio-fuel applications of the system were determined by testing lipid and carbohydrate concentrations. The system was found to remove some phosphate and convert ammonium to nitrate while producing lipids for biodiesel, though much more study is needed to improve the efficiency of the water treatment cycle.

# Poster Abstracts

## A Comprehensive Approach to Light Water Reactor Fuel Recycling and Lowering Radiotoxicity of High Level Waste: Assessment of Technical Requirements for Partition Technologies

Author: Yasir Arafat
Faculty Mentor: Edward Lahoda

A proper solution to the growing inventory of spent nuclear fuel has major implications on the future of nuclear power. The "open cycle" strategy currently adopted in the USA is a threat to the sustainability of the nuclear option and to its potential growth vs. other energy sources. The current trend can be reversed by adopting a proper strategy for closing the fuel cycle, with a judicious choice of isotopes to be separated from used nuclear fuel (UNF) and transmuted by further irradiation cycles. Many specific solutions have been proposed on this regard. This report is proposing a new approach, which involves redefining the specifics of the main systems involved (fuel type, reactor design and reprocessing techniques) to minimize the radiotoxic content of the final high-level waste (HLW) to be disposed.

In a closed fuel cycle, although the transmutation rate of actinides depends on the specific properties of the system adopted for transmutation (e.g. fast reactors, accelerator-driven systems etc), the final waste will be predominantly characterized by the reprocessing plants. The efficiency that can be achieved in the separation and recovery of some critical isotopes is a key to reduce the HLW radiotoxic content. This paper focuses on identifying these critical isotopes, which are responsible for the long- and intermediate-term radiotoxicity in the conventional uranium-based fuel cycle, and on a proposed alternative, the thorium-based fuel cycle.

**Modeling Designs for Electromagnetic Energy Harvesting Devices**

Author: Jonathan Bumstead
Faculty Mentor: William Clark

In order to be more sustainable, creative means to produce power is of great importance. One particular area in which this can be achieved is electromagnetic energy harvesting techniques. By simply opening a door or sliding a card, electromagnetic harvesting devices are capable of producing energy. To better engineer electromagnetic energy harvesting devices that could harness this energy, an accurate model for describing the phenomenon is desirable. The dynamics of three different designs were modeled using a system of coupled differential equations for each case. Due to the many parameters involved in each model, GUI's (Guided User Interfaces) were created that enable a user to input parameters of each design and receive the resulting, expected voltage and energy output of the design. One of the designs was then experimentally tested to check the accuracy of the model. Ongoing work includes the continuation of experimental tests to verify the models for the three designs.

**The Impact of Seasonal Change over 30 Years on Phenology Events in a High Altitude Site: An Example of Student Research Projects Using Rich Place-Based Data Resources**

Authors: Katie Casella and Elia Crisucci
Faculty Mentor: Sam Donovan

Increasing access to scientific data and online analysis tools has important consequence for both scientific research and science education. Our project involves working with a rich data set of phenology events collected over a 30 year span from the Rocky Mountain Biological Laboratory in Colorado. Specifically, in collaboration with the C3 Cyberlearning project, we are developing models for student investigations and exploring ways to visualize complex scientific data. During this process, we are also conducting our own research by analyzing the impact of seasonal change over 30 years on two important phenological events – the timing of hibernation emergence of the Marmot and

altitudinal migration of the Robin. Our analysis shows that documented trends in earlier emergence from hibernation and earlier migration caused in response to climate change are supported by current data. Additionally, an analysis of the timing of the availability of food resources for the Marmot was completed to explore the coupling of resource availability and emergence. By developing strategies for working with rich research data and providing models for original student research projects, we hope to inform curriculum design so that it supports more realistic scientific inquiry.

**Examining the Role of Climate Change and Bird Behavior: A Student's Perspective To Understanding Migratory Patterns through Databases**

Authors: Robert Charland and Katlyn Grossman
Faculty Mentor: Sam Donovan

Citizen science databases provide potentially useful data for scientific investigations and science education. This project is a collaboration between the Cornell Laboratory of Ornithology and the C3 Cyberlearning Project, which explores the use of online data and analysis tools in educational settings. As a model of the student research, we are examining the impact of climate change on the timing of bird migration. We used the Science Pipes data query environment to characterize the migrations of five common Pennsylvanian species using citizen science data collected in the eBird database. These results are compared to published migration statistics to assess the quality of ebird data and our measure of migration timing. As part of this research, we are developing guidelines for student use of the Science Pipes environment as an inquiry tool. By exploring the use of citizen science data and providing models for analysis and visualization of that data, we hope to promote the use of realistic science in undergraduate classrooms.

**Sustainability Metrics: Life Cycle Assessment and Green Design in Polymers**

Author: James Cregg
Faculty Mentors: Amy Landis and Eric Beckman

This study evaluates the efficacy of green design principles such as the "12 Principles of Green Chemistry," and the "12 Principles of Green Engineering" with respect to environmental impacts found using life cycle assessment (LCA) methodology. A case study of 12 polymers is presented, seven derived from petroleum, four derived from biological sources, and one derived from both. The environmental impacts of each polymer's production are assessed using LCA methodology standardized by the International Organization for Standardization (ISO). Each polymer is also assessed for its adherence to green design principles using metrics generated specifically for this paper. Metrics include atom economy, mass from renewable sources, biodegradability, percent recycled, distance of furthest feedstock, price, life cycle health hazards and life cycle energy use. A decision matrix is used to generate single value metrics for each polymer evaluating either adherence to green design principles or life-cycle environmental impacts. Results from this study show a qualified positive correlation between adherence to green design principles and a reduction of the environmental impacts of production. The qualification results from a disparity between biopolymers and petroleum polymers. While biopolymers rank highly in terms of green design, they exhibit relatively large environmental impacts from production.

**Synthesizing Chemical Data for Acidic Mine Drainage**

Author: Hannah Fried-Petersen
Faculty Mentor: Dan Bain

There are many abandoned bituminous coal mines in southwestern Pennsylvania. Some of these mines generate and discharge acidic water contaminated with a variety of metals into local surface waters. This project synthesizes existing data on AMD to characterize typical metal mixtures and use these mixtures to understand changes in local surface water chemistry. While trace metals can pose risks from toxicity, etc., information on trace metals in AMD is limited, likely because of

the disproportionate occurrence of iron species, sulfate, and manganese in these waters. However, interesting patterns emerge when looking at trace metal ratios. For example, preliminary findings show lithium to be correlated with calcium, copper, and europium. Finding characteristic trace metal relationships in AMD will help water managers to predict the trace metal concentrations in local surface water, gauge the extent of contamination and environmental impact, and better locate contamination sources.

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**Synthesis and Characterization of a Series of Pore Functionalized Pillared-Layered Metal Organic Framework Type Materials for $CO_2$ Capture**

Author: Catherine Madden
Faculty Mentor: Christopher Matranga, National Energy Technology Laboratory

Pillared-layered compounds are an exciting material that shows promise as $CO_2$ capture agents. They belong to a general class of compounds called Porous Coordination Polymers (PCPs), which are formed by reacting transition metal ions with various organic linker molecules. The chemistry used to synthesize these compounds creates a material whose pore size, network type, and chemical makeup is controlled in a directed and rational manner by the choice of metal ions and organic linkers. In this regard, pillared-layered compounds are closely related to metal organic frameworks (MOFs), but typically have distinct performance and stability advantages over traditional MOFs.

One of the largest obstacles in making new PCPs for $CO_2$ applications is creating the organic linkers needed for the pore walls of the structure. The addition of different functional side groups on these linkers allows one to modulate the chemical affinity of the PCP pore wall towards $CO_2$ or other impurity gases in the flue of a coal fired power plant. To this effort, several novel functionalized bi-pyridyl derivatives containing -$NH_2$, -$NO_2$, -$CH_3$, -F, -C(O)H, -C(O)OH, and -$OCH_3$ groups were synthesized by either an amidification reaction or the Suzuki coupling reaction. These linkers were then incorporated into a pillared-layered material to create new pore-functionalized PCPs. Each of these structural analogs was evaluated for $CO_2$ capture and separation applications using isotherm and porosimetry techniques. From this work, the systematic effect of adding these functional groups to the bi-pyridyl linkers was assessed and will be used to optimize these $CO_2$ capture materials.

**The Cold War: Plant Resistance to Bacteria at Sub-Optimal Temperatures**

Authors: Justin Seaman, Michael Hoglund, and Hao Ji
Faculty Mentor: Brian Traw

Because plants are stationary, they are particularly exposed to pathogens and extreme temperatures. When infected by bacteria, plants respond with rapid increases in salicylic acid (SA), which in turn induces plant-wide defenses. Interestingly, SA is also suppressed at high temperatures. Here, we ask whether high temperatures will therefore increase vulnerability to bacterial infection. To test this hypothesis, we grew plants at 23°C or 14°C for four weeks and then moved them all to a common environment at 20°C, where we challenged them with our focal bacterial strain, *Pseudomonas syringae* DC3000 and collected tissues for SA analysis. We compared responses of two genotypes of *Arabidopsis thaliana*, Col-0 from Germany (warmer environment) and Est-1 from Estonia (colder), as well as five SA pathway mutants. SA concentrations were lower at the high growth temperature but, surprisingly, six of our seven genotypes responded with greater bacterial resistance at the high temperature, contradicting our initial hypothesis. Our data suggest therefore that the decline in SA at high temperatures is not involved in the plant response to infection or that high temperatures have an alternative effect on resistance. These results have significance to global climate change and its effect on agriculture.

**A Nanoscale Approach to Carbon Capture**

Author: Craig Stevenson
Faculty Mentor: Goetz Veser

Anthropogenic $CO_2$ emissions are widely recognized as a leading cause for climate change. Capturing $CO_2$ from concentrated point emissions, such as fossil fuel power plants, is hence crucial for curbing atmospheric $CO_2$ concentrations. However, current $CO_2$ capture technologies, typically based on the use of liquid amines, result in large energy penalties and strongly increased cost of energy (up to 85%). In order to overcome some of the shortcomings of liquid amines, much work has recently focused on the use of silica-based solid sorbent materials, either via

impregnation with amines or via grafting of amine groups onto silica. In particular nanostructured silica materials are of great interest due to very high $CO_2$ capture capacities of amine-impregnated "nanosilicas", in some cases even exceeding that of liquid amines. In our work, we are evaluating novel hollow silica "nanobubbles" recently synthesized in our laboratory for the confinement of $CO_2$ sorbent materials. First results indicate that these materials hold great promise for $CO_2$ capture via nanoconfined liquid sorbents, with current sorption capacities of up to 125 mg $CO_2$/g sorbent and the potential for further increases based on tailoring of the silica nanostructure. Materials synthesis, characterization, and $CO_2$ sorbtion results will be presented in the poster.

**Marcellus Shale Flowback Water Treatment Feasibility Study with Acid Mine Drainage**

Author: Emily Wolff
Faculty Mentor: Radisav Vidic

In recent years natural gas extraction from the Marcellus Shale formation, which underlies much of Pennsylvania and some neighboring states, has become feasible due to developments of the hydraulic fracturing process. Hydraulic fracturing, known as “fracing” in industry, is an extremely water intensive process requiring 3 to 5 million gallons of freshwater to frac one well on average. The reuse of water recovered after the hydrofracturing, i.e. flowback, is limited by the low recovery, the high salinity and expensive treatment costs. The reuse of flowback water requires the removal of toxic heavy metals (barium, strontium) and other ions that can cause scaling and corrosion in the gas well. The objective of this study is to develop a sustainable management approach for Marcellus flowback water that will allow its reuse for hydrofracturing subsequent wells. In particular, the study is focusing on the feasibility of mixing flowback water with acid mine drainage (AMD) which will serve as make-up water and remove barium and strontium through sulfate precipitation. The work presented in this poster shows the initial steps in understanding the chemistry of different flowback waters and AMD mixes by studying precipitation kinetics and crystal size, morphology and composition.

# Acknowledgements

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We are grateful to Joe Grabowski, Department of Chemistry; Juan Manfredi, Office of the Provost; Mark Redfern, School of Engineering; Alberta Sbragia, Office of the Provost; and Dan Skrovanek, Strategic Corporate Research. These individuals donated their time to evaluate the videos and posters.

Finally, and certainly not least, we thank the undergraduate students who participated in this event. These students, and their faculty mentors, conducted the research that made this event possible. The summaries and abstracts included in this program represent months, if not years, of their effort.