VALLEY 25x'25 FALL RESEARCH REVIEW

EMPOWERING OUR COMMUNITY'S FUTURE

Monday, October 10, 2011
ISAT/CS Building, nTelos Room 259
James Madison University

VALLEY 25x'25

Led by James Madison University, Valley 25x'25 promotes using a diverse energy portfolio to achieve 25 percent renewable energy in the Shenandoah Valley before 2025, including wind, biomass, solar, and geothermal energy. A primary emphasis is energy efficiency, which offers the best opportunities to decrease the use and impact of non-renewable energy sources. Endorsed by national 25x'25, Valley 25x'25 serves as an East Coast Demonstration Project, and as such, will be partnering with regional businesses, local and state government, institutions of higher education, and K-12 schools to explore how Valley resources can contribute to the development of innovative energy solutions. A central goal of Valley 25x'25 is to educate and inform Valley residents about renewable energy opportunities. Other goals include advocacy for policies that incentivize and enable renewable energy projects and for streamlining local and state ordinances, building codes, and regulations to facilitate more rapid introduction of new technologies. Encouraging public acceptance and adoption of sensible and environmentally sustainable renewable energy technologies is the single most important contribution we can make toward the long-term prosperity of the region and country.

http://valley25x25.org

INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH

The Institute for Energy and Environmental Research (IEER) at James Madison University builds on JMU's recognized leadership in the Commonwealth of Virginia for developing and implementing innovative alternative energy solutions and applied environmental research programs. In addition to working with faculty, staff, and students at JMU, the Institute for Energy and Environmental Research, housed within the Office of the Vice Provost for Research and Public Service, facilitiates strategic alliances with external partners to advance the University's research and service projects. In addition to Valley 25x'25, IEER houses the Virginia Center for Wind Energy and serves as the point of contact for the Virginia Coastal Energy Research Consortium.

http://www.jmu.edu/ieer

INSTITUTE FOR STEWARDSHIP OF THE NATURAL WORLD

A commitment to being model environmental stewards is one of a handful of characteristics that defines JMU, "The University will be an environmentally literate community whose members think critically and act, individually and collectively, as model stewards of the natural world." The role of the Institute for Stewardship of the Natural World (ISNW) is to facilitate sustainability by coordinating environmental stewardship efforts across campus, advocating for priorities, and challenging all members of the James Madison community to think critically about their role in achieving the long-term stewardship of Earth. The ISNW serves as an internal and external point of contact for university-wide environmental stewardship activities.

http://www.jmu.edu/stewardship

RESEARCH REVIEW **AGENDA**

12:00 p.m.	Introductions	Ken Newbold Director of Research Development
12:05 p.m.	Welcome Remarks	John Noftsinger Vice Provost for Research and Public Service
12:15 p.m.	Valley 25x'25 Overview	Jeffrey Tang Associate Professor of Integrated Science and Technology
12:30 p.m.	Construction and Implementation of a Prolysis Unit for the Production of Biochar in a Sustainable Greenhouse Heating System	Wayne Teel Associate Professor of Integrated Science and Technology
12:55 p.m.	On-Campus GPS Bike Sharing Program	Anthony Teate Professor of Integrated Science and Technology
1:20 p.m.	Valley Geothermal Project	Tony Hartshorn Assistant Professor of Geology and Environmental Science
1:45 p.m.	Harley Davidson Partnership	Chris Bachmann Associate Professor of Integrated Science and Technology
2:00 p.m.	Cultivation of Algae Strains to Produce Oil	Chris Bachmann Associate Professor of Integrated Science and Technology
2:15 p.m.	Break/Refreshments	
2:30 p.m.	Range Estimation of Electric Vehicles Based on Energy Modeling	Robert Prins Assistant Professor of Engineering
2:55 p.m.	Residential Solar Energy in The Valley: A Feasibility Assessment and Carbon Mitigation Poultry, Dairy, and Greenhouses in the Valley: A Technology Assessment of On-Farm Renewable Energy Carbon Mitigation Strategies	Maria Papadakis Professor of Integrated Science and Technology
3:20 p.m.	Materials for Solar Hydrogen Production and Next-Generation Photovoltaic Cells	S. Keith Holland Assistant Professor of Engineering David Lawrence Professor Emeritus of Integrated Science and Technology
3:45 p.m.	Educating and Engaging Local Organizations, Community Members, and University Students through an Energy Efficiency and Sustainable Buildings Community Outreach Program	Carol Hamilton Lecturer of Management
4:15 p.m.	Biodiesel Research and Development Update	Chris Bachmann Associate Professor of Integrated Science and Technology
4:30 p.m.	Closing	Ken Newbold Director of Research Development

PROJECT **DESCRIPTIONS**

Construction and Implementation of a Prolysis Unit for the Production of Biochar in a Sustainable Greenhouse Heating System

Wayne Teel, PI, Associate Professor of ISAT
Julianne Decker, ISAT
Amanda Martindale, ISAT
Dorottya Spolarics, ISAT
Marlee Najamy Winnick, ISAT

Biochar is a form of charcoal made using pyrolysis. This process involves the burning of biomass in the absence of oxygen resulting in a carbon rich, high surface area product. The main byproduct of the pyrolysis process is excess heat that is often unused and released into the atmosphere. Our project involves building an efficient pyrolysis unit and capturing the excess heat. This energy is incorporated into an existing system at Avalon Acres Farm in Broadway, Virginia as a backup method for heating a greenhouse. Their current heating system is powered by solar thermal collectors, which are ineffective during cloudy periods in winter. The overall effect of integrating the two units is a sustainable system. We are currently in Phase I of our project involving the construction of the system. The basic construction of the pyrolysis unit is complete; however the plumbing installation is still underway. Phase II will involve producing and characterizing different forms of biochar from agricultural waste. Types of waste include animal manure, crop residue, and forestry prunings. Our project is likely to lead to future projects within ISAT or Engineering. On a local level, Avalon Acres will reap the majority of the benefits from this project. These benefits include increased soil quality, crop yields and animal health, all of which can be repeated regionally and nationally. At the national scale biochar could prove beneficial to curbing global climate change by improving soil quality, sequestering carbon and providing an alternative energy source. Currently funding must come from the interested parties who wish to build new biochar systems. As the biochar field expands beyond the research phase, an industry will develop yielding more funding possibilities.

On-campus GPS Bike Sharing Program

Anthony Teate, PI, Professor of ISAT
Julianne Decker, ISAT
Dorottya Spolarics, ISAT
Joe Crosbie, ISAT
Renee Parilak, ISAT

The researchers have developed a Prototype GPS Bike-Sharing Program, which includes two bicycles (one for male riders and one for female riders), each outfitted with a GPS-enabled phone which transmits its location, one of the bicycles being additionally outfitted with a bicycle-powered generator to help maintain the cell phone battery charge; a database which logs the bicycles' movements and rider usage; and a website which displays the current location of each bicycle and allows students to register and "check out" a bike online.

The bike-location tracking system was effectively installed and is currently being tested by students on campus, and the data points are actively being stored in a database designed specifically for this project. A website was developed using ASP.NET technology which displays the bicycles' current locations can be viewed by students with access to determine whether the bikes are in use and where they are currently located.

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It is recommended that further research be conducted on additional methods of transmitting the bike locations, and that the project be expanded to be utilized by the general student population at James Madison University.

Valley Geothermal Project

Tony Hartshorn, PI, Assistant Professor of Geology & Environmental Science
Jeremiah Vallotton, Environmental Science
Fernando Perez, Writing, Rhetoric, and Technical Comm.

In Spring 2011, Tony Hartshorn, an Assistant Professor with the Department of Geology & Environmental Science at JMU, received ~$9,000 as Seed Research Funding from Valley 25x'25 to promote the use of geothermal heat pumps (GHP).

GHP is an energy efficiency approach that can dramatically reduce energy consumption associated with heating and cooling buildings, from residential to commercial applications. They should not be confused with geothermal sources of electricity, which are industrial-scale operations that tap the heat of the Earth to generate steam, which is used, in turn, to produce electricity.

As part of this project, the VGP team (Hartshorn and three research assistants: Jeremiah Vallotton, Fernando Perez, and Liz Weisbrot) decided to distinguish between these two geothermal facets of our lives by using a lowercase "geothermal" for the energy-efficient heat pump and uppercase "Geothermal" for the electrical generation complexes. This project focused exclusively on the former.

There were three deliverables from the VGP.

1. We generated a web-accessible soil temperature dataset with standalone dataloggers. Users can compare soil temperatures across 5 campuses (from south to north): Roanoke College, Washington & Lee University, Virginia Tech.'s McCormick Farm (Raphine, VA), JMU, and Shenandoah University.

Our results suggest that JMU has the warmest summer soil temperatures of all five locations, an unexpected result given its relatively high elevation (~1300 feet): air temperatures, and by extension soil temperatures, are generally cooler with increasing elevation. One factor that may compound comparisons between campuses, and helps explain JMU's relatively warm soils, is that the installation site for JMU needed to be adjacent to a paved surface, and the 25-foot-wide service road next to the soil temperature probes most likely creates an artefactually warmer set of conditions during the summer months.

2. The VGP team also assembled energy usage statistics on a voluntary basis from 25 Valley residents. These houses represented a spectrum from multi-resident apartments to single person homes, with square footage ranging from 675 to 5000 ft^2, and with a variety of energy systems (including GHP, HVAC, space heating, fossil-fuel based heater, and others). These data were collected with the intention of examining how electrical usage changed following installation of a GHP, as this would provide a real-world example of energy savings specific to a Shenandoah Valley installation.

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Unfortunately, several individuals with access to GHP clients (who might have been willing to share their electrical usage) were extremely difficult to track down. Nevertheless, we obtained electricity data from two individuals who had monitored electrical consumption before and after their installation of a GHP. In aggregate, these data showed that there is a small decrease in total kilowatt-hours used after the GHP is installed, and then only in the more extreme months in the summer and winter. This suggests that GHP may not be quite as cost-effective as advertisements may claim, although there are still savings, however small, that will continue to accrue for however long utilities are used. As one counterpoint, however, we did meet and interview a JMU staffer who installed his own GHP in his Bridgewater backyard for a total out-of-pocket cost of ~$3000, and with a payback period of <2 years.

3. Finally, the VGP assembled an educational 6-minute video available via YouTube.

Harley Davidson Project

Chris Bachmann, PI, Associate Professor of ISAT
Will Meisne, ISAT
Billy Copely, ISAT
Josh Magura, ISAT
Brent Kiomall, ISAT

The Harley-Davison 2.0 team has worked with a variety of engine platforms and methods for controlling the functionality of these platforms in order to promote a lean-burning, low-polluting and fuel-economic engine. The process began with a prototype Briggs and Stratton engine that was attached to a piece of plywood and monitored for all engine "vital signs" such as intake temperature, crank position, engine temperature, air-to-fuel ration, and rotations per minute. As all of these parameters are vital to the performance of an engine, not only was it necessary to monitor them, but also necessary to control certain parameters responsible for the degree at which the engine performs in a way that is lean-burning and low-polluting – specifically the amount of fuel used during each cycle.

The second step in the team's process was to apply their knowledge of the working systems of an engine on a platform that has a load on the engine. This was accomplished by refitting a carbureted Briggs and Stratton engine that is attached to a "dune-buggy" set-up (to be referred to as the "Baja" from here on) with a fuel-injecting system and all of the necessary sensors. Various options for computational control of fuel dump, such as the use of a MicroSquirt electronic fuel injection (EFI) control system, have been explored. The hardware for this system has repeatedly failed and the team awaits additional hardware.

In that light, progress was started on the Harley-Davidson 48 after the EFI control hardware failed. A system called Power Vision which allows for control of the motorcycle's electronic control module (ECM) was installed to enable modification of the engine performance. During testing of this system and the modification of engine variables responsible for the degree at which the engine performs as lean-burning or low-polluting, the ECM was apparently unresponsive to the modifications made. This was determined by utilizing a dynamometer that showed identical results no matter the adjusts made to the ECM by team members through the Power Vision unit.

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A branch of the team explored options for tuning the engine on a cycle-to-cycle basis by using what is known as an ion current sensor. This system allows for currents produced by the spark plug during ignition to be analyzed and then communicated to the ECM for modification of engine performance. For research purposes and hands on experience, this branch of the team constructed an ion sensor from scratch based upon information publically available from the beginning era of ion sensor development.

As it stands, the team is in progress with their developments due to various obstacles. The future of the project will be centered around effectively controlling the EFI in the Harley and implementing strategies for increased fuel economy, such as turbo-charging, and furthering the underlying goals of a lean-burning and low-polluting end product.

Cultivation of Algae Strains to Produce Oil

Chris Bachmann, PI, Associate Professor of ISAT
Jackson Adolph, ISAT
Mike Depaola, ISAT

Algal biofuels offer a far more comprehensive solution to the problem at hand than any other fuel source. A massive demand will need to be met when petroleum based fuels are finally depleted to the point where they are no longer economically viable. Algal fuels are the only clean renewable option that is truly scalable to the production level of oil. Unlike the production of ethanol or biodiesel from designated crops, competition for land and resources is not a factor when it comes to algal biofuels. Designated energy crops have been known to cause fluctuations in the price of food, destabilizing the market and negatively affecting the farmer and consumer alike. All parties benefit when this type of competition is removed. Algae has the capacity to produce far more fuel per unit area than any designated biodiesel crop. A lack of soil quality depletion is another aspect in which algal fuels reign supreme over designated energy crops simply because they do not require land to grow. The energy input and time commitment required to grow algae are far less than that of a designated energy crop. Most microalgae species have a doubling time of around one week, as opposed to a full season of growth to produce a limited number of harvests per year. The ability to synthesize energy from the Sun is a very large contributor to the success of algal biofuels. The Sun is an infinite, and free, source of energy. Utilization of light energy minimizes costly inputs into the process and thus creates a far more efficient system with a higher net energy gain. Carbon dioxide sequestration is an integral part of this process as well. Due to their simplicity as single celled organisms they are afforded a fast growth rate; because of this microalgae have the unique ability to take in far more CO2 than any land based plant ever could. The lack of complex structures like root and shoot systems afford as much energy as possible to be put toward cellular division and the production of fat which will be isolated in order to create fuel. Furthermore, algae possess the unique ability to grow in waste streams unfit for most other life and take up nutrients from their environment that may cause harm to the given ecosystem. A carbon neutral process as well as nutrient sequestration is of central importance to recovering from the negative environmental impact created by reliance on fossil fuels. Low energy input, fast growth rate, a lack of competition for resources, carbon neutrality, and positive environmental impacts, paired with nearly limitless potential for growth make algal biofuels a very appealing solution to the question of fuel.

Range Esimation of Electric Vehicles based on Energy Usage Modeling

Robert Prins, PI, Professor of Engineering
Lee Winslow, Geographic Sciences
Robbie Hurlbrink, Engineering

Electric vehicles show significant promise as a viable means of transportation. They use their stored energy more than twice as efficiently as their typical internal combustion engine powered counterparts, and are classified as having zero point of use emissions. While concerns about their ultimate energy source are well founded, they are positioned to take advantage of a wide range of renewable energy sources since many such sources produce electrical energy. One of the largest consumer concerns related to electric vehicles is their perceived lack of range. Although range estimates for particular vehicles are available these estimates are used as a marketing tool and may be unreliable, especially if the vehicles will experience duty cycles that are dissimilar to standard test duty cycles. Speed, load, and topography all play a significant role in the real range of an electric vehicle. Fleet managers and other potential owners do not have a reliable way to estimate vehicle range prior to purchase and operation. The current approach to range modeling is typically based on fixed duty cycles such as SAE J1711 or Federal Urban Driving Schedules. While such duty cycles provide valuable comparative data they do not typically correlate to the real duty cycle that a particular vehicle is subject to. This can lead to unrealistic expectations of electric vehicle range and the associated "buyer's remorse" at having invested in an emerging technology when the anticipated performance is not achieved. This proposal seeks to further develop a novel energy usage modeling approach that could be applied by fleet managers and other owners to help them make appropriate decisions regarding electric vehicle deployment.

Residential Solar Energy in The Valley: A Feasibility Assessment and Carbon Mitigation

Maria Papadakis, PI, Professor of ISAT
Deanna Zimmerman, SERM/MSISAT

This project explores whether the Shenandoah Valley can achieve its 25x'25 goals in the residential sector using the two most feasible solar energy technologies, solar photovoltaic electric power production and solar thermal hot water generation. After a review of the barriers to the adoption of solar energy by households, we estimate the potential rates of adoption and energy output using US Census data and Department of Energy data. Multiple scenarios are explored, including the "maximum theoretical" contribution of solar energy to the residential sector as well as scenarios of household behavior under different constraints. With respect to solar photovoltaic, we argue that the "most likely" theoretical scenario is one in which about 21% of Valley households adopt a 1-kilowatt system. If that was so, then solar photovoltaic electricity would contribute less than 3% of the residential sector's total energy needs in the Shenandoah Valley. The associated carbon mitigation is equivalent to about 8200 passenger vehicles.

Poultry, Dairy, and Greenhouses in the Valley: A Technology Assessment of On-Farm Renewable Energy Carbon Mitigation Strategies

Maria Papadakis, PI, Professor of ISAT
Laura Kossey, SERM/MSISAT

This project explores whether the Shenandoah Valley can achieve its 25x'25 goals in energy-intensive farms in the agricultural sector, which are primarily poultry, dairy, and greenhouse operations. We assess the two most feasible renewable energy technologies for such farms, solar photovoltaic electric power production and wind power. After a review of the barriers to the adoption of renewable energy by agricultural operations, we estimate the potential rates of adoption and energy output using US data from the US Census of Agriculture, pilot farm energy audits, the Department of Energy, and the Virginia Renewables Siting Scoring System. Multiple scenarios are explored, including the "maximum theoretical" contribution of renewable energy to the agricultural sector as well as scenarios of farm behavior under different constraints. We find that the payback period for these technologies typically exceed 30 years, well beyond the agricultural sector's preferred payback period for comparable investments of 3-5 years or less.

Materials for Solar Hydrogen Production and Next-Generation Photovoltaic Cells

S. Keith Holland, Assistant Professor of Engineering
David Lawrence, Professor Emeritus of ISAT

Widespread, large-scale use of solar energy requires methods to efficiently convert light energy into electrical energy. Further, methods for converting captured solar energy into a fuel, such as hydrogen, for use when sunlight is not available and/or for transportation applications are needed. Hydrogen gas can be obtained through photoelectrolysis by illuminating photosensitive semiconductor materials immersed in an electrolyte solution. To date, suitable, low-cost, chemically stable materials for photoelectrolysis have not been developed. However, there is significant interest in doped $BiVO_4$ and CZTS thin films for photoelectrolysis and next-generation PV cells.

Based on substantial theoretical work, National Renewable Energy Laboratory (NREL) researchers recently concluded that the addition of dopants such as Ca, Na, and K to $BiVO_4$ thin films should produce excellent p-type semiconductor properties and conductivity. This work also concluded that Mo and W doping of $BiVO_4$ should result in excellent n-type conductivity. Such enhanced electrical conductivity is expected to lead to enhanced hydrogen production efficiencies in photoelectrochemical (PEC) cells. Additionally, if $BiVO_4$ with sufficiently high p-type and n-type conductivities can be prepared, this material may also be used as tunnel junction material for next-generation multi-junction photovoltaic (PV) cells.

This investigation examined the effects of specific dopants on the electrical and PEC water splitting performance of $BiVO_4$. Doped thin-film $BiVO_4$ samples were prepared from a variety of different chemical precursors using a spray pyrolysis technique, a relatively low-cost technique that could be scaled for high volume production, followed by annealing. The morphology, chemical consumption, and crystallinity of the prepared $BiVO_4$ films were analyzed using scanning electron

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microscopy, UV/VIS spectroscopy, and x-ray diffractometry. Electrical conductivity and PEC performance tests were also performed on the samples.

Results of this investigation demonstrated that doped BiVO4 thin-films can be created using the spray pyrolysis deposition technique. Chemical precursors and additives greatly influenced by the morphology of the produced thin-films; however, the morphology of the thin films were not significantly impacted by the inclusion of dopants. Films deposited from precursors containing ethylene glycol and EDTA resulted in thinner, smoother films which provided higher optical transmittance for wavelengths greater than 500 nm, a characteristic desirable for next-generation PV cell tunnel junction materials. Consistent with the NREL theoretical predictions, the addition of Mo and W dopants resulted in n-type behavior which the addition of Ca dopants indicated p-type behavior when tested in the PEC cell. W doped samples annealed in 3% H2 generated the highest photocurrent densities during PEC testing. However, high material conductivity was not achieved in any of the samples produced.

Future work will focus on increasing the conductivity of the BiVO4 samples through the selection of precursor chemicals and dopants. Additionally, work on CTZS thin film materials is proposed.

Educating and Engaging Local Organizations, Communitity Members, and University Students through an Energy Efficieny and Sustainable Buildings Community Outreach Campaign

Carol Hamilton, PI, Lecturer of Management
Daniel Hill, MBA
David Hussey, MBA

The Valley 25x'25 funded project, "Educating and Engaging Local Organizations, Community Members, and University Students thru an Energy Efficiency and Sustainable Buildings Community Outreach Program" has developed a fully operational community outreach project that is currently being implemented in the Shenandoah Valley and other communities. The project, Green Impact Campaign, connects students with local businesses as a way to recognize tangible energy efficiency opportunities within organizations through public recognition and free energy services.

Green Impact Campaign (www.greenimpactcampaign.com) is an innovative training program that allows students to perform energy audits for local businesses in their community. The program is centered around a web-based platform that requires no previous energy auditing knowledge and allows students to complete a full energy audit in less than one hour, all while receiving energy audit experience. The web-based, mobile accessible program, GEMS (gems.greenimpactcentral.com), is a self-training energy audit tool that guides student volunteers through a facility identifying lighting, plug load, HVAC, building envelope and water energy conservation measures (ECMs). Based on user input, GEMS then references a catalog of ECMs, calculates energy saving estimates and compiles a report that is then sent to the participating business. Through this process, local businesses receive free energy efficiency advice, students gain real world hands on green job experience, and both are working to make a positive impact on the planet.

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For any organization or business that is interested in having a free energy audit performed, they are required to take a sustainability oath called the Green Impact Pledge. The Pledge is an online, public oath that confirms that the organization is interested in reducing its environmental impact and they plan to take action in implementing changes. Any organization who takes the Pledge is then promoted to the community as an active organization who is concerned with environmental sustainability.

Net Impact has entered into a partnership with Green Impact Campaign to offer the project as a sponsored project to its network of student chapters. As of this report's creation, twenty student Net Impact chapters have agreed to implement Green Impact Campaign in their community. Twelve businesses have taken the Green Impact Pledge and four have received energy audits. In total, 22,258 kWh of energy reductions have been discovered during the energy audits. Green Impact Campaign won the 2011 Force for Change Award for its positive environmental and social impact through its use of grassroots efforts.

In the future, the project will be improved and further developed in several ways. First, the follow up process for businesses that have received energy audits will be more comprehensive. Second, further refinements to the GEMS program will be made to improve the accuracy of estimates and additional unit conversions. Third, GEMS' project management features will be further expanded by adding a service provider directory and an ECM/utility tracker. Fourth, additional audit topics will be replicated using the GEMS energy audit methodology.

Biodiesel Research and Development

Chris Bachmann, PI, Associate Professor of ISAT
Scott Teigeler, ISAT
Jeff Wiggins, ISAT
Bernard Newman, Chemistry

Our project focuses on the incorporation of biodiesel as a key fuel source for the U.S and the ability for farmers to complete it on a small to medium scale. Currently biodiesel processors on the small scale are not cost effective and do not ensure the product produced will meet with ASTM standards for commercially viable biodiesel. Our goal is to discover a solid-state catalyst that will enable a more cost effective and reliable process for small to mid sized biodiesel processors. Currently much of the canola that is grown in the Shenandoah Valley is shipped across the state to be pressed and have the oil extracted, then the dry grains returned as feed. If there was a viable mid-scale biodiesel processor that could produce quality fuel reliably, there could be a market in the area for farmers to start to press and use the oil themselves. This would give another opportunity for farmers to make money on another aspect of their harvest as well as providing the valley with an opportunity to use more renewable fuels.

MEET THE **VALLEY 25x'25 TEAM**

John Noftsinger	Principal Investigator, Vice Provost for Research and Public Service
Kenneth Newbold	co-PI, Director of Research Development
Chris Bachmann	co-PI, Associate Professor of Integrated Science and Technology
Jeffrey Tang	co-PI, Associate Professor of Integrated Science and Technology
Benjamin Delp	Associate Director of Research Development
Becky Rohlf	Fiscal Technician for Research and Public Service
Craig Honeycutt	Valley 25x'25 Outreach Coordinator
Nathan Miller	Valley 25x'25 Research Assistant
Elise Lintelman	Valley 25x'25 Research Assistant
Garrett Stern	Valley 25x'25 Research Assistant
Sallie Drumheller	Print Production Assistant for Research and Public Service

The Valley 25x'25 Fall Research Review is a half-day event featuring presentations from student, faculty, and staff researchers whose projects received funding during the summer of 2011. The Research Review provides a venue for interested community members to hear about the challenges, successes, and recommendations from a variety of different research endeavors. Valley 25x'25 funding comes from a generous grant from Senators Warner and Webb, DE-EE0003100 "Shenandoah Valley as a National Demonstration Project Achieving 25 Percent Renewable Energy by the Year 2025 (VA)," which is administered through the U.S. Department of Energy.

For more information, please visit our website at **Valley25x25.org**

JAMES MADISON UNIVERSITY.

JMU RESEARCH AND PUBLIC SERVICE