SECTION 08: EVALUATION OF RESEARCH, SCHOLARSHIP, OR CREATIVE ENDEAVOR

EVIDENCE OF QUALITY RESEARCH OR CREATIVE IDEAS VIA GRANTS

External Grants

I have been successful on a number of grants totaling more than $1.52 million dollars, well above the department expectation of $20k that were in effect until April of last year. Although I have already discussed the teaching and training aspect of the following grant, it also has a strong research component with a huge economic impact across the state and nation that must also be addressed from a research perspective:

- Chen, J (PI, 40% effort), Goodman, D. (Co-PI, 25% effort), Razban, A (Co-PI, 25% effort), Anwar, S (Co-PI, 5% effort), Xie, J (Co-PI, 5% effort) "DE-FOA-0000490 Establishing an Industrial Assessment Center". ($1,320,000). 2011-2016.

When Dr. Chen and I applied for the Industrial Assessment Center (IAC) grant, I added strength to the proposal due to several years of prior experience in conduction energy assessments. Thus when the grant was awarded I developed the educational material and led the training of other faculty and students in the methods and application of conducting energy audits and to date we have conducted forty-seven assessments. During the on-site assessments we inspect the manufacturers energy usage, deal with waste, and look at production methods. Off-site we research new methods, new technology, and generate ideas on how to improve efficiency and save money. The resulting twenty-seven confidential technical reports are peer reviewed by professors at Rutgers University then presented to the Indiana manufacturing companies and published on the national database. The national and international impact cannot be fully quantified, but the database and the technical reports I (and others) submit provide a unique opportunity to quantify the effectiveness of energy management recommendations and pollution prevention measures in small and medium sized industry and the potential of assessments to improve manufacturing productivity. The direct environmental impact from my work, with respect to energy and waste reductions and the improved economic stability results, can be ascertained from the following tables:
(Per IAC Field manager Database at http://iac.rutgers.edu/database/statistics/)

Table 1: Summary of Recommended Savings

Number of assessments		47
Number of assessments reported		44
Recommended Waste Savings ($)		$5,439,906
Recommended Productivity Savings ($)		$342,131
Energy Stream	**Recommended Energy Conservation (MMBTU)**	**Recommended Energy Cost Savings ($)**
Electricity		
Demand	22,034 kW/Month	$ 266,929
Fees		$ 122,603
Consumption - Site	18,688,299 kWh	

Consumption - Source	191,557	$ 1,026,917
Natural Gas	39,161	$ 256,029
Other Gas	17,594	$ 75,817
Other Energy	0	$ -
Energy Totals	186,803	$ 1,748,295

Table 1 reveals that my students have assessed, researched, and recommended new methods/procedures/equipment/etc. that could result in energy savings in excess of 186,000 MMBTU's and that could result in monetary savings of more than $1.7 million dollars across forty-seven companies in Indiana. Table 2 reveals that, with 71% of the companies responding within eleven months of the recommendation report, Indiana companies actually reduced energy usage by over 122, 000 MMBTU's, which reduces CO2 emissions by over 31 million pounds per year, and actually saved over $805,000 dollars in their operations budget. Our implementation rate is approximately 40%, which is well over the national average, which I believe implies that Indiana companies are quick to see the value of the service we provide and they have shown that understanding in other ways as well. After my student audited one company, they asked me to help setup an internship program (in process), two other companies have extended service contracts (which will be discussed in the service section), and a supplier company has extended a research contract to validate a novel control system that may reduce compressed air usage of diaphragm pumps (discussed below).

Table 2: Summary of Implemented Savings

Number of assessments		44
Number of assessments reported		31
Percent of year represented by data below		71.07%
Implemented Waste Savings ($)		$ 2,655
Implemented Productivity Savings ($)		$ 14,815
Energy Stream	**Implemented Energy Conservation (MMBTU)**	**Implemented Energy Cost Savings ($)**
Electricity		
Demand	12,169 kW/Month	$159,330
Fees		$30,801
Consumption - Site	11,309,451 kWh	
Consumption - Source	115,923	$562,716
Natural Gas	5,835	$41,012
Other Gas	496	$ 11,638
Other Energy	0	$ -
Energy Totals	122,254	$ 805,497

Although this is typically a confidential process, the following companies wanted to speak out about the quality of the students, research recommendations, etc.:

- “Thanks again for your very professional presentation and evaluation. Please feel free … to let them know I will be a reference for the quality of the presentation.” (IP-0028) Craig S. Carson, CEO, Jeco Plastic Products
- "We were thrilled with not only the speed, efficiency and professionalism that was exhibited by this department, but the in depth report we received at the end. We have made recommendations to other businesses and will continue to do so. We are working on all the suggestions now" (IP-0017) Mary Gordon, Plant Manager, Electro-Spec
- "Your team did an outstanding / professional assessment at PHD in which we have implemented a number of the recommendations and achieved significant savings" (IP-0011) David French, VP Operations, PHD, Inc.

In order to make the IAC grant work, I have radically increased the number of visited, calls, and mailings to industry. One of the outcomes includes research spinoffs and visibility for other opportunities with IUPUI. While discussing auditing with the VP of Operations at the Proportion Air facility in McCordsville, the idea of conducting pump efficiency testing to validate energy efficiency changes due to a novel, patented controller developed by Proportion Air. I submitted a proposal to fund the project and it was funded in 2012 but work was delayed until May 2014, although I am still working on the final report, the results reveal a 20-45% reduction in compressed air usage on diaphragm pumps. Compressed air is a major efficiency issue in facilities because it takes approximately seven electrical horsepower to generate one air horsepower, so any savings are magnified. This will likely have huge energy efficiency and cost reduction impact in businesses that make or use diaphragm pumps, such as painting operations, cleaning operations with caustic fluids, and waste water treatment facilities.

- Goodman, D. (PI, 100% effort). “Pump Efficiency Validation”. Proportion Air Inc. ($9,353). 2013-2014.
    - The project funded four students.
    - It has resulted in at one refereed conference publication at the 2015 World Energy Engineering Congress, and has been submitted to the International Journal of Modern Engineering (Impact Factor of 3.0).
    - It will also provide a positive metric for the IAC grant when we reapply in 2016 because new assessment recommendations are rare.

The other research spinoff from the IAC grant occurred when I took students on a training audit at a commercial facility. The owners requested assistance designing a new Heating Ventilation Air Conditioning (HVAC) system for the building. We originally planned to use it as a course design project but decided to use it as a living lab and develop wireless equipment and procedures to help streamline industrial assessments. Then after collaborating with Johnson Controls, we hope to expand the scope again with this internal grant and use it to win an external grant.

- Goodman, D. (PI), Chen, J., Razban, A., Chen, S., Wasfy, T., Carley, S. “PAR (Predictive, Adaptive, Real-Time) Building Energy Monitoring and Control System”, IUPUI Collaborative Research Grant, ($75,000) 2014-Pending, (equal 17% effort).
    - This grant will fund approximately six students and building automation equipment necessary to model a commercial building and develop metrics and tools to create a novel building information system that displays information about energy usage, it also predicts and reports on methods to improve energy efficiency. Three of my students (Jing, Arash, and Akram) have already started or completed smaller scale tangential research thesis projects in this area.
    - This internal grant will provide the equipment and initial data necessary to apply for an $800,000 external US National Science Foundation (NSF) NSF-PFI-BIC 15-587 grant to “Development of a Smart Service Platform for Improving

Building Energy Efficiency". Aside from my department (ENT), this collaboration includes two local companies (Johnson Controls and Mundell Associates) as well as colleagues from Mechanical Engineering and Electrical Engineering at IUPUI, and the School of Public and Environmental Affairs from Bloomington.

In 2011 I partnered with Endress and Hauser, an international instrumentation company, to do end of life testing on pH sensors. This grant was a little out of my research area, but I have prior experience with similar sensors and data acquisition. The research involved running a series of experiments, in an environmental chamber I repaired, with different caustic fluids on pH sensors to help predict life expectancy. The work on the project is confidential and we were not allowed to report the data, etc. in any publications. However, Endress and Hauser provided positive feedback and have since donated equipment to the department.

- Goodman, D. (PI, 100% effort). "Accelerated pH Electrode Failure Data Capture Initiative". Endress & Hauser Inc. ($9,969). 2011-2012.
    - This grant funded three students.

Publications

I already discussed the teaching related publications in the teaching section and will discuss discipline-specific research papers below.

Refereed Journals

- **Campos, U., **Zamenian, H., Koo, D., and **Goodman, D**. (2015). Waste-to-Energy (WTE) Technology Applications for Municipal Solid Waste (MSW) Treatment in the Urban Environment. *International Journal of Emerging Technology and Advanced Engineering*. Vol. 5 (2), pp. 504-508.
    - This paper introduces the three new WTE technologies and provides guidance to make a more sustainable alternative choice for MSW treatment.
    - The project funded two graduate students.
    - Journal Impact Factor = 2.324.
- †* **Goodman, D**., and **Edalatnor, A. (2015). Waste, Just another Resource: A Case for Waste Wood. *International Journal of Mechanical Engineering and Technology*. Vol. 6 (3). pp 25-33.
    - This paper is first of a series that describes various industrial waste streams and describes how they can be resources. It also provides calculations, analysis, etc. for a feasibility study and explains how this can be used on energy audits.
    - The project funded one graduate student.
    - Journal Impact Factor = NA.
- †* **Goodman, D**., **Edalatnoor, A., and Cooprider, M. (2015). Waste, Just another Resource: A Case for Process Water. *Energy Engineering*. Vol. 113. pp. (accepted, in process)
    - This paper is the second of a series that describes various industrial waste streams and describes how they can be resources. It also provides calculations, analysis, etc. for a feasibility study and explains how this can be used on energy audits.
    - The project funded two graduate students.
    - Journal Impact Factor = NA, however this is the primary journal for the Association of Energy Engineers and has been in publication for 107 years.

Refereed Conference Proceedings

- *** Goodman, D**. and Durkin, R. (2015). Diaphragm Pump Controller Performance Testing: 20-50% Efficiency Improvement. 2015 World Energy Engineering Congress, Orlando. (Accepted: in process, proceedings published October 2015)
    - In this paper performance testing methods were used to validate a new electronic compressed air controller that can save 20-50% of an air operated pumps consumption. This has huge potential for energy and cost savings.
    - This is the premier conference of the Association of Energy Engineers, the leading professional society in the energy efficiency field.
- †Cambridge, J., **Goodman, D**., Frazier, S., Nofal, M., and Razban, A. (2013). Compressed Air Efficiency: A Case Study Combining Variable Speed Control with Electronic Inlet Valve Modulation. Society of Automotive Engineers World Congress, Detroit.
    - In this paper a method of merging two compressed air control schemes is modeled. The system was constructed in an industrial facility and data was collected and analyzed to support the hypothesis.
    - The project funded two undergraduate students and one graduate student.
    - Other than mentoring, I also contributed approximately thirty percent of the written text and harmonized each authors section.
    - The conference is probably the largest gathering of automotive and supplier manufacturers in the country (over 11,000 attended) and compressed air is one of the top three utilities in manufacturing plants.
    - The audience for this presentation was approximately fifteen people.

- **†Goodman, D**., Fitzwater, D., and Zarzecki, F. (2011). Effect on System Efficiency from Combining Solar Thermal and Photovoltaic Energy Systems in non-Grid Applications: Phase 1. American Solar Energy Society: Solar 2011 Conference Proceedings, Raleigh.
    - In this paper a math model was utilized to predict potential changes in overall efficiency of a residential system that combined solar thermal and photovoltaic systems together. The model showed that complimenting these two technologies gave an overall improvement of 15% efficiency for this hybrid type system.
    - The project funded two undergraduate researchers, one of whom went on to be a Top 100 student at IUPUI and a second that was from France on an international research internship.
    - ASES is the largest society in the US dedicated to solar energy, so it provided access to large audience of similar researchers. Approximately twenty people attended the presentation and approximately fifty attended the poster and approximately ten asked questions.

Currently I am 85% complete on two journal level publication for the Association of Energy Engineering entitled “Waste Process Water: a resource for Hydroelectric Power” and “Waste Wood: a resource for district heating”, but have been delayed until Spring. I researched the ability to re-use these waste streams and improve the system efficiency of the facility as well as provide a new resource, i.e. hydroelectric and district heat. This concept could be applied to several industries that use water for their processes.

Interdisciplinary Activities

In the summer of 2011, I started collaboration with Professor Eric Nordgulen in the IUPUI art department on a project entitled, “Public Art as Renewable Energy.” This project was proposed to research and build an outdoor sculpture, which will integrate art with a functional, renewable energy system. This sculpture will also serve as a prototype for a larger work of art that will

provide all power requirements for a cultural community center to be developed in Indianapolis. This project will utilize solar panels and a hydrogen fuel cell as components of sculpture. I was initially asked to consult on the fuel cells after Dr. Hsu left IUPUI; I determined that the system was non-operable without significant investment. Mr. Nordgulen's past work has made reference to existing relationships between technology and the environment, which coincides well with my particular research interests of public education and finding different mediums through which to start a dialogue on energy issues. So, I joined Eric's team and designed a solar power system that could handle the full load. The completed sculpture will be made available for public exhibition at numerous locations, including urban sites, campus grounds, and art parks, depending on what opportunities become available. During this period, the sculpture will also serve to provide data for further research in order to determine the needs of a larger energy system to be installed at the planned community/cultural center. The piece is complete, but Eric is still searching for the right venue to host the exhibit.

The teaching and research aspects of the numerous grant proposals and publications listed in the various sections of this dossier have been discussed, but I should also mention that these collaborations have included faculty from Purdue University (William Hutzel, Mechanical Engineering Technology), Indiana University (Sanya Carley, School of Public and Environmental Affairs), as well as faculty within IUPUI from the following departments or programs: Electrical and Computer Engineering Technology, Mechanical Engineering Technology, Biomedical Engineering Technology, Organizational Leadership and Supervision, Architectural Technology, Mechanical Engineering, and Electrical and Computer Engineering. My role has varied depending on the research or publication topic, but my continued collaboration most shows that my talents were appreciated and fruitful and the feeling is mutual.

SUMMARY AND FUTURE DIRECTIONS

My area of excellence is teaching and I discussed my MURI research grants in that section because of the educational aspect, but as I join thesis committees and co-chair mechanical engineering graduate student I am increasingly pulled towards discipline-specific research. I plan to continue the trend as long as they relate to my work on energy efficiency, alternative energy sources, and industrial assessment. The IAC grant has been a boon in many ways and going forward, I expect 1-2 spinoff grants from the IAC each year. I will continue to pursue working with talented students in my research areas, collaborating with peers to find unique solutions, and creating innovative ideas for and solutions to many of today's most pressing issues. One such talented student, I trained in the IAC, works for the Indiana Municipal Power Association (IMPA). I contacted him early this summer about pursuing a $4 million dollar DOE Sunshot grant, since IMPA was in the process of installing three 1MW solar arrays. He was initially leery of putting in the capitol to push the project within IMPA, but later called and stated that others in the company had contacted him about the whitepaper I submitted. It was too late for the Sunshot grant, due to the submission deadline, but we are collaborating on a proposal for the next matching grant. If this comes to fruition, my focus will shift back to solar (my first love) and also lead into smart grid and power quality topics. I am collaborating with Dr. Izadian and Dr. Koo, with feedback from my contact at IMPA, on a new whitepaper and proposal. IMPA paid cash (approximately $3 million dollars) for the first three arrays and would like to build around twenty more; this collaboration could be huge for funding undergraduate and graduate researchers and placing IUPUI on the solar map.