

Annual Report

(July 1, 2012 – June 30, 2013)



Richard G. Lugar Center for Renewable Energy (LCRE),
Purdue School of Engineering and Technology,
Indiana University-Purdue University Indianapolis

June 30, 2013

The mission of the Richard G. Lugar Center for Renewable Energy is to:

Address the societal needs for clean, affordable and renewable energy sources, improve the nation's energy security, and help mitigate the negative impacts of climate change.

Promote research excellence in the area of renewable energy through collaborative efforts among faculty in the disciplines of engineering, chemistry, physics, biology, environmental affairs, and public policy.

Promote renewable energy applications through teaching, learning, civic engagement, and synergistic partnerships with industry, government labs and local communities.

Introduction

The Richard G. Lugar Center for Renewable Energy (LCRE) is located on the campus of Indiana University Purdue University-Indianapolis (IUPUI), and is administratively housed in the Purdue School of Engineering and Technology, IUPUI. *The LCRE consists of 44 Research Members spanning multiple disciplines, 26 Advisory Board Members, and 14 Entrepreneurs-in-Residence, plus about 60 students, interns and post-doctoral researchers.*

The LCRE is an interdisciplinary research center, and strives to meet the societal and public needs and challenges in these key energy and environmental areas. The Center helps create a collaborative environment for solving these challenges. The following report summarizes these activities and represents the hard work and commitment of our Research Members, Advisory Board, staff, and entire LCRE family.

Focus Areas – Renewable Energy

- Batteries
 - Li-metal
 - Anode/cathode/electrolyte chemistry
 - Seawater flow battery
- Fuel Cells
 - Non-Pt catalyst for PEM
 - Hydrogen storage
 - Hydrogen generation
 - SOFC for APU and home energy
- Combustion Engines
 - Advanced gas turbines
 - Internal combustion engines
 - Power and propulsion systems
- MSW Energy from Waste
 - Heat, oils for refining, electricity
 - Advanced gasification for MSW and biomass
- Policy & Economics
 - Urban, State, Federal
 - Energy forecasting
 - Environment & Human health
- Commercial/Institutional & Buildings
 - Sustainable institutions
 - Energy and resource
- Traditional Renewables
 - Solar power (including installing)
 - Wind power (including hydraulic)
- Installation & Maintenance
 - Training
 - Automation
 - Diagnostics
- Manufacturing Science
 - Photovoltaic
 - Power Electronics
 - Fuel Cells
- Efficiency
 - Industrial assessment
 - Curriculum development
 - Combustion engines and HVAC
 - Sustainable Technologies Certificate
- Entrepreneurism
 - Economic pro forma & business plans
 - Incubators and mentoring
 - Entrepreneurs-in-Residence
- Sustainability & Lifecycle Analysis
 - Electric vehicles
 - Energy storage
 - Urban environment
- Switchgear, Diagnostics & Cybersecurity
 - Single transistor inverter
 - Synchronous distributed generation (patented)
 - Microgrids

Summary of Research and Educational Activities

The LCRE is continuing to make progress and achieve results in its core research fields and is continuing to establish itself as a leader, especially with regards to alkaline anion exchange membrane (AAEM) fuel cells, lithium ion batteries, and electric vehicle research and education. Additionally, the capabilities of the LCRE are being expanded in these and new areas as evidenced by the departmental hiring of several new faculty members in the fields of electrical and mechanical engineering, and the induction of several new Research Members, along with the establishment of new core areas of research such as waste-to-energy WTE and industrial energy efficiency management.

Below is a summary of the latest updates with regard to existing and new research and educational programs at the LCRE:

Fuel Cell Research

Dr. Jian Xie was awarded a grant for \$600,196 from Argonne National Labs for a project titled: “Integration of Polymer Electrolyte Fuel Cell Cathodes.” This is a landmark accomplishment for Dr. Xie, and will result in substantially upgraded facilities for conduct of this research. The LCRE labs in the new Science and Engineering Laboratory Building (SELB) are being adapted now to accommodate the equipment he and his students will require.

Industrial Assessment Center (IAC)

IUPUI was awarded a ***\$1.3 million grant*** from the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy (EERE) Program in the Fall of 2011 to establish an Industrial Assessment Center (IAC). ***The IAC at IUPUI is the only center of its kind in the state of Indiana.*** The missions are to train the next generation of energy efficiency experts and provide energy assessments to small- and medium-sized companies for improving energy efficiency, see the IAC website for more information: www.engr.iupui.edu/IAC.

As of the conclusion of the 2012-13 AY, the IAC has had 4 students receive DOE certificates for energy auditing. A \$5,000 service project grant was awarded, and one student completed a MS in ME, and is now working as a fuel cell application engineer. A publication from this work was presented at a SAE conference, and titled: “Compressed Air Efficiency: A Case Study Combining Variable Speed Control with Electronic Inlet Valve Modulation”, jointly authored by the two IAC directors (Razban and Goodman) and three IAC students.

Electricity from Bio-Ethanol Powered Fuel Cells

This \$600,000 2 year NSF project features Dr. Rongrong Chen as PI, with support from co-PIs Peter Schubert and Mark Goebel, all of whom serve on the Executive Committee of LCRE. This

builds upon the groundbreaking work in anion-exchange membrane fuel cells pioneered by Dr. R. Chen at IUPUI, and expands it to include ethanol derived from various biomass sources, such as farm residue and chow hall waste. Partner companies include Xylogenics (Indianapolis), which was co-founded by Dr. Goebel, Faraday Technology, Inc., (Clayton, OH), and Tremont Technology, LLC (co-owned by Dr. Chen). As of this report the grant was freshly-awarded. Further updates will be provided in the 2013-2014 Annual Report.

MSW Gasifier

The MSW gasifier donated last year by Conversion Energy Systems is now operational. The technology is called Gasification-Plus-Oxidation (GPOX) and so far two publications have arisen from this work, and one Master's thesis is in progress. The unit is sited at SAIC in Bedford, IN, and has been operated approximately 9 times. Grad student Drew Witte spent two weeks at the University of Milano, Italy, studying under waste-to-energy (WTE) expert Prof. Consonni and his Ph.D. student. This work will be instrumental in developing a plant model for quick-turn controls development for this batch-operated WTE system.



Biomass Gasifier

The “Stalk Stoker” (photo below) has been successfully installed and operated at the new Outdoor Biomass Research Lab (OBRL) of the LCRE, with a ribbon-cutting ceremony presided over by the Dean of the Purdue School of Engineering and Technology, Dr. David Russomanno. He then introduced Mr. John Kirkwood in his final act as Chair of the LCRE Advisory Board by reading remarks provided by Senator Lugar for this occasion. The Dean then introduced Marine Corps Colonel Timothy Tocwish who spoke on the importance of this technology to US warfighters, and that by reducing supply lines lives are saved. Dr. Russomanno then introduced Mr. David Rosenberg, the City of Indianapolis Director of Enterprise Development. Mr. Rosenberg delivered remarks about the value of this research, the significance of its location in Indy, and then proceeded to cut the ribbon for the man gate admitting researchers to the OBRL.



Recent Publications

1. Dumortier, J. , “Co-firing in Coal Power Plants and its Impact on Biomass Feedstock Availability,” in *Energy Policy*.
2. Dumortier, J., “Uncertainty, Competition, and Time-to-Build in Bioenergy Crop Production,” International Consortium on Applied Bioeconomy Research, Ravello, Italy.
3. R. Chen, J. Guo and A. Hsu, “Non-Pt Cathode Electrocatalysts for Anion-Exchange-Membrane Fuel Cells” for Book “*Electrocatalysis in Fuel Cells*”, Chapter 15, p. 437-481 (03/31/2013) ISBN 978-1-4471-4910-1.
4. L. Ma, H. He, A. Hsu and R. Chen, “PdRu/C catalysts for ethanol oxidation in anion-exchange membrane direct ethanol fuel cells”, *J. Power Sources*, 241 (2013) 696-702.
5. J. Guo, J. Zhou, D. Chu and R. Chen*, “Tuning the Electrochemical Interface of Ag/C Electrodes in Alkaline Media with Metallophthalocyanine Molecules”, *J. Phys. Chem. C*, 117 (2013) 4006-4017.
6. J. Zhou, J. Guo, D. Chu and R. Chen*, “Impacts of Anion-Exchange-Membranes with Various Ionic Exchange Capacities on the Performance of H₂/O₂ Fuel Cells”, *J. Power Sources*, 219 (2012) 272-279.
7. H. He, Y. Lei, C. Xiao, D. Chu, R.Chen* and G. Wang, “Molecular and Electronic Structures of Transition Metal Macrocyclic Complexes as Related to Catalyzing Oxygen Reduction Reactions: A Density Functional Theory Study”, *J. Phys. Chem. C*, 116 (2012) 16038-16046.
8. J. Guo, H. He, D. Chu and R. Chen*, “OH-Binding Effects on Metallophthalocyanine Catalysts for the O₂ Reduction Reaction in Anion-Exchange-Membrane Fuel Cells”, *Electrocatalysis*, 3 (2012) 252-264.
9. L. Ma, A. Hsu, D. Chu and R. Chen*, “Comparison of ethanol electro-oxidation on Pt/C and Pd/C catalysts in alkaline media”, *International Journal of Hydrogen Energy*, 37 (2012) 11185–11194.
10. R. Chen, J. Shao, Y. Zheng, H. Yu, Y. Xu, Lattice Boltzmann simulation for complex flow in a solar wall, *Comm. Theo. Phys.*, 59 (2013) 370 - 374.
11. N. Chen and H. Yu, Mechanism of axis switching in low aspect-ratio rectangular jets, *Comp. Math. Appl.*, in press.
12. H. Yu, K. Kanov, E. Perlman, J. Graham, E. Frederix, R Burns, A. Szalay, G. Eyink and C. Meneveau, “Studying Lagrangian dynamics of turbulence using on-demand fluid particle tracking in a public turbulence database”, *Journal of Turbulence*, 13 (2012), 1-29.
13. H. Yu, R Chen, and H. Wang, Inverse energy cascade in decaying isotropic turbulence, The 65th Annual Meeting of the American Physical Society's Division of Fluid Dynamics, San Diego, California, Nov. 2012. (Yu)
14. H. Yu, Mass-conserved lattice Boltzmann method for fluid-structure interaction with willfully moving boundaries, The 9th European Fluid Mechanics Conference, Rome, Italy, Sep. 2012
15. H. Yu, R. Chen, H. Wang, Lattice Boltzmann simulation for decaying isotropic turbulence in the presence of rotation, The 9th International Conference for Mesoscopic Methods in Engineering and Science, Taipei, Taiwan, July 2012.

16. Schubert, P.J., Paganessi, J., Wilks, A., Murray, M., “Distributed Hydrogen Generation and Storage from Biomass”, Materials Challenges in Alternative and Renewable Energy II, J. Wiley, Wicks, G., Simon, J., et. al, Eds. 2012.
17. Witte, D., Schubert, P.J., “Optimization of a Municipal Solid Waste (MSW) to Energy System,” ASEE Annual Conference and Expo, Atlanta, GA 24-26 June 2013.
18. Schubert, P.J., “Creating and Managing a Nationwide Student Movement,” ASEE Annual Conference and Expo, Atlanta, GA 24-26 June 2013.
19. Schubert, P.J., Zusack, S., “How Close to Space Before Nobody Can Hear You Scream,” ASEE Annual Conference and Expo, Atlanta, GA 24-26 June 2013.
20. Davik, J., From, B., Koehler, G., Torp, T., Rohloff, J., Eidem, P., Wilson, R.C., Sønsteby, A., Randall, S.K., Alsheikh, M.K. 2013 Dehydrin, alcohol dehydrogenase, and central metabolite levels are associated with cold tolerance in diploid strawberry (*Fragaria* spp.) *Planta* 237, 265-277
21. Alsheikh, M. Winge P and Rohloff, J, Davik, J, Wilson RC, Koehler, G and Randall, SK 2013, Insights into Cold Tolerance in *Fragaria* x *ananassa* Crowns: Transcriptomic Analyses *Acta Hort. International Society for Horticultural Sciences (ISHS)* (in press)
22. Yamasaki, Y., Koehler, G., Blacklock, B.J., and Randall, S.K. 2013 Dehydrin Expression in soybean. *Plant Physiology and Biochemistry* 70, 213-20 <http://dx.doi.org/10.1016/j.plaphy.2013.05.013>
23. Astroski², J., Fernandez², P., Lewis², M., McDaniel², J., and Stachel², A. (mentors; Blacklock², B.J., Minto², R.E., and Randall¹, S.K.) 2012 Engineering an oleaginous yeast for the production of biodiesel. 2012 Research Day, Undergraduate Poster Presentation, Indianapolis, IN
24. Kyazike², S. (mentor, Stephen K. Randall), 2012 Analyzing cold stress responses in soybean plants. 2012 Summer Research Program, Poster Symposium & Recognition Program. July 26, 2012. Indianapolis, IN
25. Yamasaki¹, Y., Randall, S.K. 2012 Responsiveness of Soybean CBF and COR genes to cold stress. Annual Meeting American Society for Plant Biology, Austin, TX July 20-24 Poster # P13022
26. Yamasaki¹, Y., Randall, S.K. 2012 Responsiveness of Soybean CBF and COR genes to cold stress. The 14th Biennial Conference: Cellular and Molecular Biology of the Soybean, August 12-15, 2012 Des Moines, IA
27. Koehler¹, G., Rohloff, J., Wilson, R., Winge, P., Sønsteby, A., Alsheikh, M., Randall, S. 2012 Elevated Gene Expression Prior to Cold Exposure Correlates with Increased Freezing Tolerance in Strawberry (*Fragaria* x *ananassa*) Cultivars. Annual Meeting American Society for Plant Biology, Austin, TX July 20-24 Poster # P13011
28. Jens Rohloff, Pankaj Barah, Per Winge, Jahn Davik, Robert C. Wilson, Stephen K. Randall, Muath Alsheikh, and Atle M. Bones 2012 Varietal genotype determines transcriptional and metabolic regulation in strawberry (*Fragaria* × *ananassa* Duch.) under cold acclimation. PlantBio Conference, Oct 17-18, 2012, Oslo, Norway
29. Muath Alsheikh, Gage Koehler¹, Robert C. Wilson, Jens Rohloff, Anita Sønsteby, Jahn Davik, and Stephen K. Randall 2012 Identification of molecular markers associated with

- winter survival in the cultivated strawberry by integration of “omics” technologies. PlantBio Conference, Oct 17-18, 2012, Oslo, Norway
30. Sharifah Kyazike 2012 Analyzing Cold Stress Responses in Soybean Plants. 18th Annual Indiana University Undergraduate Research Conference (**IUURC18**), November 16, 2012, Indianapolis, IN
 31. Yuji Yamasaki, Stephen K. Randall 2013 Cold Response in Soybean: Transcriptional Responses and Functionality of GmCBF Poster #22 Midwest American Society for Plant Physiology Annual Meeting, 23-24 March Chicago, Ill.
 32. E. C. dos Santos Jr. “Dual-Output Dc-Dc Buck Converters with Bidirectional and Unidirectional Characteristics”. (*in press*) IET Transactions on Power Electronics, vol.PP, 2013.
 33. E. C. dos Santos Jr. and E. R. C. da Silva. “Power Blocks Geometry Applied to the Building of Power Electronic Converters”. IEEE Transactions on Education, vol.56, no.2, pp.191-198, May 2013.
 34. D. A. Fernandes, F. F. Costa and E. C. dos Santos Jr. “Digital-Scalar PWM Approaches Applied to Four-Leg Voltage-Source Inverters”. IEEE Transactions on Industrial Electronics, vol.60, no.5, pp.2022-2030, 2013.
 35. E. C. dos Santos Jr., C. B. Jacobina, E. R. C. da Silva and N. Rocha. “Single-phase to Three-phase Power Converters: State of the Art”. IEEE Transactions on Power Electronics, v. 27, no. 5, pp. 2437-2452, May 2012.
 36. E. C. dos Santos Jr. “Series-Voltage-Action Converter”. IET Transactions on Power Electronics, vol.5, no.7, pp.1127-1136, Aug. 2012.
 37. E. C. dos Santos Jr. “Configuration 5S: A Bi-directional ac-dc Converter”. Brazilian Power Electronics Transactions, vol. 17, no. 2, pp. 529-537, 2012.
 38. J.M. Pacas, M.G. Molina and E. C. dos Santos Jr. “Design of a Robust and Efficient Interface for the Grid Connection of Photovoltaic Solar Power Generation”. International Journal of Hydrogen Energy, v. 37, no. 13, pp. 10076–10082, July 2012.
 39. E. C. dos Santos Jr., F. Bradaschia, M. C. Cavalcanti and E. R. C. da Silva. “Voltage Type Z-Source Converters: Overview of the Main Topologies”. Brazilian Power Electronics Transactions - SOBRAEP, v.17, no. 4, pp. 730-743, Set./Nov. 2012.
 40. E. C. dos Santos Jr., M. Darabi, “Novel Bidirectional DC-DC-AC Three-phase Power Converter.” PECE 2013 - IEEE Power and Energy Conference at Illinois, Feb. 22-23, 2013, Champaign, IL - US.
 41. E. C. dos Santos Jr., M. Alibeik and B. Creek, “New Power Electronics Converter Interfacing a DG System with Hybrid Dc/Ac Microgrid”. PECE 2013 - IEEE Power and Energy Conference at Illinois, Feb. 22-23, 2013, Champaign, IL - US.
 42. E. C. dos Santos Jr., M. Darabi. “Single-phase and Three-phase Non-Isolated Bidirectional Dc-Dc-Ac Converters.” APEC 2013 - Applied Power Electronics Conference and Exposition, 2013 IEEE, Long Beach, CA.
 43. E. C. dos Santos Jr., “A Bidirectional Dc-Ac Converter”. IECON 2012 - 38th Annual Conference of the IEEE Industrial Electronics Society, Oct. 25-28, 2012, Montréal, Canada.
 44. G. A. A. Carlos, E. C. dos Santos Jr., C. B. Jacobina, “Hybrid PWM Strategy for Voltage Source Inverters Feeding Three-Phase Open-End-Winding Equipment”. IECON 2012 - 38th Annual Conference of the IEEE Industrial Electronics Society, Oct. 25-28, 2012, Montréal, Canada.

45. N. Rocha, C. B. Jacobina, E. C. dos Santos Jr., R. M. de B. Cavalcanti, "Parallel Connection of Two Single-Phase Ac-Dc-Ac Three-Leg Converter with Interleaved Technique". IECON 2012 - 38th Annual Conference of the IEEE Industrial Electronics Society, Oct. 25-28, 2012, Montréal, Canada.
46. E. C. dos Santos Jr., Joao H. G. Muniz, E. R. C. da Silva, C. B. Jacobina. "Nested Multilevel Configurations." ECCE 2012 -IEEE Energy Conversion Congress & Expo, Raleigh, North Carolina, Sept. 15-20, 2012, pp. 324-329.
47. A. L. de Lacerda, E. R. C. da Silva, E. C. dos Santos Jr., C. B. Jacobina. "Reduced Switch Count Three-phase AC-to-AC Converters with Input Power Factor Control." ECCE 2012 -IEEE Energy Conversion Congress & Expo, Raleigh, North Carolina, Sept. 15-20, 2012, pp. 1017-1023.
48. C. B. Jacobina, N. Segundo, E. C. dos Santos Jr., N. Rocha. "Single-Phase to Three-Phase DC-Link Converters With Reduced Controlled Switch Count." ECCE 2012 -IEEE Energy Conversion Congress & Expo, Raleigh, North Carolina, Sept. 15-20, 2012, pp. 1128-1135.
49. Lane, B., Messer, N., Hartman, D., Carley, S., Krause, R., Graham, J. 2013. "Government promotion of the electric car: Risk management or industrial policy?" *European Journal of Risk Regulation* 2.
50. Carley, S., Krause, R., Lane, B. Graham, J. 2013. "Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites". *Transportation Research Part D: Transport and Environment* 18.
51. Carley, S. "Global expansion of renewable energy generation: An evaluation of policy instruments." Paper presented at the 32nd U.S. Association of Energy Economists/International Association for Energy Economists Conference, Anchorage, AK, July, 2013.
52. Carely, S., "Global expansion of renewable energy generation: An evaluation of policy instruments." Paper presented at the annual Transatlantic Policy Consortium, The Hague, Netherlands. May 2013.
53. Jing Zhang, Bin Tian, Chengbiao Wang, "Long-term Surface Restoration Effect Introduced by Advanced Silicate Based Lubricant Additive", *Tribology International*, Vol. 57, pp.31-37, 2013
54. Jing Zhang, "Thermal Cycling Effect on Mechanical Properties of Yttria-stabilized Tetragonal Zirconia", *Key Engineering Materials*, Vol.538, pp. 121-124, 2013
55. Jing Zhang, "Thermal Cycling Effect on Mechanical Properties, Grain Size and Residual Stress in Alumina and Yttria-stabilized Tetragonal Zirconia", *Advanced Materials Research*, in press.
56. Jing Zhang, Jiayang Liu, "Experimental and Simulation Study of Microhardness Indentation of Solid Oxide Fuel Cell Using Progressive Damage Material Model", *Key Engineering Materials*, Vol.538, pp. 89-92, 2013
57. Jing Zhang, "Novel Thermal-Electrical-Mechanical Model for Simulating Coupled Phenomena in High-Frequency Electronic Devices", *Key Engineering Materials*, Vol.538, pp. 173-176, 2013
58. S. M. Rovnyak, M. N. Nilchi, D. W. Longbottom and D. C. Vasquez, "Angle Stability Predictive Indices," *Proceedings of the IEEE PES General Meeting*, San Diego, July 22-26, 2012.

59. Wang H., Barthelmie R.J., Pryor S.C. Kim, H-G. (2013): "A new turbulence model for offshore wind turbine standards" *Wind Energy (in press)*.
60. Smith C.M., Barthelmie R.J and Pryor S.C. (2013): "In-situ observations of the influence of a large onshore wind farm on near-surface temperature, turbulence intensity and wind speed profiles". *Environmental Research Letters* **8(3)** 034006 doi:10.1088/1748-9326/8/3/034006
61. Barthelmie R.J., Hansen K., Pryor S.C. (2013): "Meteorological controls on wind turbine wakes". *Proceedings of the Institute of Electrical and Electronics Engineers* **101** 1010-1019 doi: 10.1109/JPROC.2012.2204029
62. Barthelmie R.J. and Pryor S.C. (2013): "Wake model evaluation using data from the Virtual Wakes Laboratory," *Applied Energy* **104** 834–844
63. Pryor S.C., Barthelmie R.J. (2013): Renewable Energy Resources- Ocean Energy: Wind/Wave/Tidal/Sea currents. Chapter 3.11 in *Climate Vulnerability* Ed. R. Pielke. Elsevier, ISBN 9780123847034.

Inventions Submitted

1. Tovar, A. and P. Bandi, United States Patent Application in preparation through IUPUI: Compliant Tubular Structures for Controlled Energy Absorption under Crash. Invention disclosure: IU 13069, November 2012.
2. Dos Santos, E.C., "A Bidirectional DC-AC Converter"
3. Schubert, P.J., "Precipitate Reduction in Anion-Exchange Membrane Fuel Cells, IU 13074, 5 October 2012.
4. Schubert, P.J., "Volume Reducing Gasifier Plus Oxidizer," IU 13097, 7 November 2012.
5. Schubert, P.J., "Corrosion Detection Sensor," IU 13101, 16 November, 2012.
6. Schubert, P.J., "System Architecture Optimization," IU 13124, 14 December, 2012.

Patents Granted

1. S. M. Rovnyak, Y. Chen, Y. Sheng, V. S. Rajput, T. Pahls, L. George, J. Malkoff, and X. Hu, "Integrated and Optimized Distributed Generation and Interconnect System Controller," US Patent No. 8,190,299; May 29, 2012.
2. Schubert, P.J., "Scalable Biomass Reactor and Method," US 8,465,562, 18 June 2013.

Conferences attended, Invited Talks, Collaborations featuring LCRE

1. The PRIME Electrochemical Society, October 2012 (R. Chen)
2. Research on Power Electronics and Microgrids at IUPUI (Dos Santos).
3. Federal University of Paraiba (Dos Santos).
4. Federal University of Campina Grande (Dos Santos).
5. "Power for Development." Invited talk, Global Mini-Conference, Indiana University, May, 2013 (Carley)
6. "The business and policy of sustainable energy." Invited talk, Kelley School of Business Renaissance Week, Indiana University, February, 2013 (Carley)
7. "U.S. State Experiences with Renewable Portfolio Standards: Adoption Trends, Effectiveness, and Unintended Consequences." Invited talk, Energy and Climate Seminar Series, Georgetown University, March, 2013 (Carley)

8. “Quadratic scaling in PT fluids”, Turbulence Symposium, Texas A&M University, March 26-30, 2013(Yu)
9. “Parity time-reversal symmetry in viscous fluid with balanced inflow and outflow,” American Mathematics Society/Spring Western Section/Special Session on Subjects in between Pure and Applied Mathematics, April, 2013, Boulder, Colorado (Yu)
10. WTIU “IN Focus” program panelist for 30 minute program on Renewable Energy in Indiana. (Schubert), 27 June 2013.
11. “The Future of Energy: Motivations and Solutions for a Better World”, American Chemical Society, Chicago Section, Oakbrook, IL (Schubert)
12. “Energy Security” at Richard G. Lugar Symposium for Tomorrow’s Leaders, University of Indianapolis, 8 December 2012 (Schubert)
13. “The Ultimate Solution for Renewable Energy,” Physics Colloquium, IUPUI School of Science 13 September 2012 (Schubert)
14. “Hydrogen Transportation Fuel,” Lugar Collegiate Energy Forum, Purdue University, W. Lafayette, IN, 14 September 2012 (Schubert)
15. “Gasification Plus Oxidation for Energy and Portland Cement” 23rd Annual Solid Waste Technical Conference by the Engineering Society of Detroit, E. Lansing, MI, 17 April 2013 (Schubert)
16. Summer Institute on Sustainability and Energy, Chicago (students of J. Zhang).

Research Grants and Milestones

- Innovatek, Inc. (Richland, WA) “Catalytic Membrane Reactor for the Production of Hydrogen from Butanol,” STTR Phase I and II, \$213,050, PI Rongrong Chen.
- NSF, “ Collaborative Research: Self-circulating, self-regulating microreactor for on-chip gas generation from liquid reactants”, \$196,848, 2013-2015 Co-PI Whitney Yu.
- Outstanding Junior Faculty Award, Office of the Vice Provost for Faculty and Academic Affairs and the Office of the Vice Provost for Research, Indiana University-Bloomington. "State Energy Policy and the American Recovery and Reinvestment Act." PI Sanya Carley \$14,500.
- PRF Summer Faculty Grant “Energy Conversion Unit with Higher Efficiency,” \$10,000, PI E.C. Dos Santos.
- Developing Diverse Researchers with InVestigative Expertise (DRIVE), “Two-phase Microgrid System,” \$9,811, PI E.C. Dos Santos.
- International Development Fund (IDF) “Multilevel Power Electronics Converters with Fault Tolerance Capability,” \$11,280, PI E.C. Dos Santos.
- Duke Energy and Simon Property Group “Derivation of Design Guidelines using Clay Terrace Data,” \$4,000, PIs Peter Schubert and E.C. Dos Santos.
- Faculty Research Support Program, IU, “Informing Energy Policy Choices in Indiana using an Econometric and Technology Model,” \$72,341, PIs Barry Rubin and Sanya Carley.
- Faculty Research Support Program, IU, “Power for Development: Sustaining Small-Scale Electricity Implementation in Africa.” \$74,484, PIs Jennifer Brass and Lauren MacLean.
- Dr. R. Chen sent a graduate student to the University of Warwick to explore collaboration opportunities. Warwick sent a delegation to IUPUI in April 2013 which helped identify

additional areas of overlapping interest. The LCRE provided the Warwick Manufacturing Center a letter of support for a grant application.

- Jing Zhang (PI), received a grant from NASA Summer of Innovation mini-award “Energy and Aerospace”
- Dr. Hazim El-Mounayri (PI) and Jing Zhang (co-PI) received a contract from VIP Tooling “Optimization of Tooling Design in Extrusion Process”
- Dr. T. Wasfy (PI) and Jing Zhang (co-PI) received a contract from Praxair Surface Technologies "Electron Beam Physical Vapor Deposition Process Modeling".
- Jing Zhang (PI) received a grant from the Indiana Space Grant Consortium (INSGC) “Research Program on Energy for Aerospace Applications”.
- Student Jie Zhou graduated, with R. Chen as Advisor.
- Maryam N. Nilchi, Electric Utility Planning Methods for the Design of One Shot Stability Controls, Masters Thesis, Purdue University Indianapolis, December 2012.
- Technical Track Leader – 4 sessions on Space Solar Power at the Int’l Space Development Conference 2013 (ISDC) by P. Schubert, who was introduced to Dr. A.P.J. Kalam, the 11th President of India and a passionate advocate for SSP.

Literature Reviewing Service (selected)

- Intl J. Hydrogen Energy (R. Chen)
- J. Power Sources (R. Chen)
- J. Electrochem. Soc. (R. Chen)
- J. Physical Chem. (R. Chen)
- Assoc. Public Policy Anal. and Mgmt. Conf (Carley)
- National Energy Lab academic affiliate (Carley)
- IEEE Trans. Power Electronics (Dos Santos)
- IEEE Trans. Industry Applications (Dos Santos)
- IEEE Trans. Industrial Electronics (Dos Santos)
- IET Power Electronics (Dos Santos)
- Intl Trans. Electrical Energy Sys. (Dos Santos)
- European Trans. On Electrical Power (Dos Santos)
- J. Power Electronics Brazilian Soc. (Dos Santos)
- NSF Civil, Mechanical and Manufacturing Innovation (Zhang)
- EPA Science to Achieve Results (Zhang)

Outreach

In addition to research and training, the LCRE continues to achieve its mission through public outreach activities. The Center hosts the annual Lugar Center Renewable Energy Forum, which provides a platform for the discussion of critical and timely energy issues. The Lugar Center Renewable Energy Forum consistently attracts an audience of between 120-150 clean energy stakeholders from all across Indiana and beyond, representing numerous industries and organizations that are directly involved in a variety of related activities. The Forum also receives significant visibility and publicity through local and regional media outlets, such as the

Indianapolis Star, WFYI, Hoosier Ag Today, WISH-TV, Indiana Living Green magazine, and many others. Participants and stakeholders represent a diverse range of industries and interests, keeping in line with the LCRE's interdisciplinary approach to addressing societal needs for clean, affordable and renewable energy. Last year's Forum focused on the topic of Waste to Energy, Chemicals, Fuels, and Heat, and included participation from such organizations as IDEM, SAIC, BSA Life Structures, Keramida, Inc., Prosperity Ag and Energy Resources, TGER Technologies, Inc., Conversion Energy Systems, and many other key players that are helping to contribute to the waste-to-energy market segment.

The 2013 Spring Forum topic was "Challenges to Commercialization of Renewable Energy in Indiana", and drew 100 participants to the Crown Plaza Hotel in downtown Indianapolis. Sponsorship for this event was received from Mr. Robert McFarling (private citizen), Krieg Devault, Citizens Energy Group, and Cummins. Keynote speakers included Mr. Maurice Kaya, former renewable energy czar at the State of Hawaii, and now Project Director of the Pacific International Center for High Technology Research, and Mr. John May, Managing Director of Stern Brothers & Co., one of the top renewable energy bankers in the US. Of the 22 moderators and blue ribbon panelists, we were privileged to include Advisory Board members Ms. Terry Hall and Mr. Keni Washington, plus Executive Committee member Dr. Eric Dannenmaier. A special presentation by IUB student Josh Cisney featured work performed as an intern for LCRE (more details below).

Other recent outreach activities include the following:

- **IUPUI Energy Club-** Research Member Dr. Jerome Dumortier is now the Faculty Advisor. A planned trip to Duke Energy's Edwardsport gasification plant is planned for September 2013. The goal of this student organization is to inform and educate students on campus of research, careers, and opportunities in the fields of energy. The club also generates awareness and discussion about key global issues related to energy use, such as sustainability and energy security. The relationship between the LCRE and Energy Club also provides many opportunities for IUPUI students to get involved in the workings of the LCRE as volunteers or interns.
- **Battery Innovation Center (BIC)** – IUPUI has joined with the BIC to submit a pre-proposal to the US Navy on the seawater flow battery concept invented by Research Member Dr. Young Kim. Note that Dr. Kim has moved his family back to Korea, and will retain his position at IUPUI through at least December, 2013.
- **Indianapolis Public Schools (IPS)** – Dr. Mark Goebel has been working with Lawrence North and Lawrence Central students on uses of yeast as a bioengineering platform.
- **Students for the Exploration and Development of Space (SEDS @ IUPUI)** is a new student group formed in August 2012 as part of SEDS-USA. The faculty advisor is Dr. Peter J. Schubert. In October, a team of 10 SEDS students launched an experimental payload in a hydrogen-filled weather balloon. Results were published at the American Society of Engineering Education (ASEE) Annual Conference in June 2013.

New Personnel at LCRE

The LCRE continues to rely upon its highly qualified staff and Research Members to advance its mission and benefit the university, city, state, and world. Below is a list of new personnel at the LCRE and some additional background about each:

Staff

Aneena E. Urbanek, Visiting Research Associate

Mrs. Urbanek served a 3 month part-time paid assignment with the LCRE to bring greater focus to philanthropic donation and corporate sponsored research. She is a graduate of Purdue University with a BS in Mechanical Engineering, and had worked for 10 years as a Senior Associate and Project Engineer at Eli Lilly and Company. In 2009 she worked with the University College of Cork (Ireland) on energy policy related to the emissions from various fuel sources, including electrical vehicles, in the private transportation sector. At the conclusion of this assignment, she cycles back into the Entrepreneur-in-Residence program, working to bring funds into LCRE research in hydrogen storage materials.

Research Members

Huidan “Whitney” Yu, Ph.D., Assistant Professor, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI

Dr. Yu has degrees in Physics and Aerospace Engineering, joining IUPUI in August of 2011 after completion of a Keck Foundation Postdoctoral Fellowship at Johns Hopkins University, and two other postdoc positions, with Los Alamos National Lab and the Aerospace Department at Texas A&M University. Her work in fluid dynamics has been applied to renewable energy topics, such as turbulent flow in a solar wall. Dr. Yu received a NSF CAREER Jump Start Award, which runs through August of this year, and is the PI for a Multi-disciplinary Undergraduate Research Institute grant at IUPUI. She teaches thermodynamics and fluid dynamics in the ME department at IUPUI.

Euzeli C. Dos Santos, Jr., Ph.D., Assistant Professor, Electrical and Computer Engineering, Purdue School of Engineering and Technology, IUPUI

Dr. Dos Santos joined IUPUI in August of 2012, having most recently been a tenured professor of Electrical Engineering at the Federal University of Campina Grande in Brazil. His interests are in renewable energy and energy efficiency, specifically through design and development of power converters, fault tolerant systems, and active power filters. He is a Senior Member of IEEE and has served as a reviewer on no fewer than seven technical journals and transactions. He has published 34 journal papers and 62 conference papers, several of which earned “best paper” awards. He is currently mentoring 9 graduate students, two of whom participated in a

study of solar car charging ports for a project funded jointly by Duke Energy and Simon Property Group. Her many grants include

Sanya Carley, Ph.D., Assistant Professor, School of Public and Environmental Affairs (SPEA), Indiana University

Dr. Carley has been in the SPEA department at IU-Bloomington since 2010, teaching and conducting research on energy policy, electric vehicles, distributed generation, and electricity technology innovation policy. She is a member of the International Association for Energy Economics and the US version of the same, where she currently serves as a Presidential Advisor. Dr. Carley holds an additional appointment as Fellow of the E3 Foundation through the University of Cambridge. Her many grants include sponsors such as Navistar and the Mitsui Environment Fund. Her impressive list of publications, invited lectures, and media reports can be browsed on her faculty research page, accessible through the Research Member section of the www.lugarenergycenter.org website. Dr. Carley is a highly-sought consultant in the areas of energy policy and electric vehicles, with clients including the EPA, the Research Triangle Institute International, The World Bank Group, and ARCEconomics in South Carolina. She is a reviewer with 10 journals, has served on the Ph.D. committee of 5 students, and has 20 students graduate with energy concentrations in the past year!

Andres Tovar, Ph.D., Assistant Professor, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI

Dr. Tovar joined IUPUI at the start of the 2012 academic year after having served as a research assistant professor at Notre Dame University, which followed his post as an Associate Professor at the National University of Columbia. His interest lie in optimization and the realization of robust engineering systems, products and materials, all of which can help improve energy efficiency and reliable engineering solutions. Dr. Tovar has 24 journal papers published, a book chapter, and over 100 conference papers, in addition to providing reviews for a wide range of technical publications. His many grants include projects funded by the US Army TARDEC group, and several NSF GOALI grants. Dr. Tovar's graduate student cohort includes 2 Ph.D. candidates, 7 MS students, and 8 undergraduates. He also serves as the faculty advisor for both the IUPUI Robotics Club and the IUPUI Society of Hispanic Professional Engineers.

Paul E. Sokol, Ph.D., Professor, Department of Physics, Indiana University

Dr. Sokol is an expert in condensed matter physics, with particular emphasis on experimental work, who holds a dual posting with the Physics Department of Pennsylvania State University, and is a Fellow of the American Physical Society. He directs the IU Cyclotron Facility in Bloomington where his studies of the microstructure of matter using x-ray and neutron scattering techniques provide insight into topics such as hydrogen storage in carbon nanotubes and structural changes in battery electrodes after aging. Dr. Sokol has over 90 publications and has delivered over 100 technical talks, and has provided service to his profession by organizing conferences, and serving on national committees.

Student Projects

Energy Bootstrapping for Rural Villages, IUPUI Innovation to Enterprise Center (ITEC) project by students Jason Cambridge, Chizuki Lothamer, and Heath Blankenship, under the supervision of Dr. Schubert and IUPUI Solution Center director Teresa Bennett. This study was commissioned to address energy needs in remote rural areas with the intention to more efficiently convert local biomass to heat and electric power. The study focused on villages in Kenya, although many other areas were also considered. The 150 page final report identified existing and potential technology solutions and evaluated them in light of the considerable challenges in financing, training and operation, feedstock availability, and sustainability. This sobering study illustrated the considerable difficulties in serving such challenging markets.

Green Garage Microgrid by students Yici Jing, Stephen Sargent, Saeed A Lyenaki, Vy Tran, and John Hertig, all Electrical and Computer Engineering Seniors, with Dr. Schubert as mentor. The team developed a detailed layout and equipment list for an integrated microgrid designed to be implemented as part of the Green Garage project being developed by LCRE. This microgrid includes a syngas-fed genset, vertical axis wind turbines, three types of photovoltaic cells, power conversion electronics, and a visual dashboard for displaying real-time performance. As part of their research, team members took a field trip to Johnson-Melloh Solution in Indianapolis.

Biomass Gasification by students Abhishek Mathur, Manju Kaushal, and Raghav Jaithaliya, all Juniors in Chemical Engineering at the India Institute of Technology-Bombay, widely regarded as the premier engineering university in India. Under the direction of IUPUI graduate student Mr. Drew Witte, the team helped install and assemble the “Stalk Stoker” biomass gasification reactor at the new Outdoor Biomass Research Lab at 1000 Waterway. A ribbon-cutting event on June 11 opened the facility for research. An additional project was to develop detailed design and performance metrics for a large-scale hydrogen plant using locally-sourced biomass feedstock in an energy self-sufficient configuration. This work will be published in September at the World Hydrogen Technology Convention in Shanghai. All four students are co-authors with mentor Dr. Schubert.

Energy Policy Issues in Indiana by student Josh Cisney, SPEA student at IU Bloomington, supervised by Dr. Schubert. The goal was to identify any barriers to the commercialization of renewable energy that might exist in the Indiana Code. The short summary of findings is that there are few if any regulatory hurdles. On the other hand, non-renewable sources such as the ill-named “clean coal” are bundled together with truly renewable sources of energy. The key dynamic identified is that coal-based electricity costs will be increasing due to power plant closures and pollution control upgrades at the same time that the cost of renewable sources such as wind and solar continue to drop. Mr. Cisney found a dearth of policy initiatives to take proactive advantage of this trend.

Breathable Indy “An Investigation of Indianapolis Area Odor: Origins and Observations”, by students Elizabeth L. Andrew, Sara Miller Chonaiew, Diana M. Leonard, Joseph Meluch,

William P. Peebles, with mentor Dr. Schubert, and advisors Teresa Bennett, Director, IUPUI Solution Center, and Dr. Seth Payton, Assistant Professor, SPEA. The American Lung Association lists Indianapolis as #19 or #20 worst in the US, depending on the pollutant. With a focus on weather, asthma, and public impact, the team evaluated prevailing winds and dispersion plumes for known sources, as assessed Marion County Health and Hospital Corporation data, plus Indianapolis city complain records and ad hoc interviews. A total of 85 potential odor sources were identified and analyzed, with the finding that there does not exist a widespread odor problem; however, three areas have a high concentration of odor complaints: the near northside, the near westside, and downtown. No causal effects were discernible with readily-observable smoke stacks.

Wound-Rotor Motor (WORM) Project, by Shiva Priya Patibanda, sponsored by Mechanical Engineering Systems (Indianapolis), and supervised by Dr. Schubert. This joint industry-academic project involved a graduate student working on-site at a local switchgear design firm on the control system for a WORM. WORMs are electric motors having the advantage of a controllable torque, allowing for lower-energy start-up, and further allowing the motor to run at its optimal speed while still maintaining the drive shaft at 1800 rpm for generating 3-phase power.

Internally-Displace Persons by Jeanna Vycas, a graduate student in Library Sciences, hired from a donation to the LCRE, performing research for a study team consisting of: Ms. Colleen McCormick, Director of the Office of Sustainability, IUPUI; Dr. Pamela Martin, Director of the Center for Earth and Environmental Sciences, IUPUI; Dr. Gabriel Filippelli, Director of the Center for Urban Health, IUPUI; Mr. Jim Poyser, Managing Editor of NUVO, and Editor of *Indiana Living Green*, Mr. Matt Klein, Adjunct Professor, IU Robert H. McKinney School of Law; and Mr. Charles Sutfin, Director and Executive Committee Member with the Central Indiana Community Foundation. The purpose of this study is to assess Indianapolis as a destination for Americans proactively seeking domestic relocation based on their perceptions of increased man-made or natural threats to their home regions. The goal is a suite of recommendations, hopefully at low or zero added cost, for the City of Indianapolis to position itself for an influx of new residents and their businesses.

Rocket Cane by students Jeff Mersinger, Autumn Mills, Ketan Mistry, Lian Julian, and Eduardo Muller, all Mechanical Engineering Seniors working under the direction of Dr. Schubert. While not strictly renewable energy, the goal for this work was to build a prototype using advanced battery technology which helps the holder stay upright on un-even surfaces. The patent for the Rocket Cane was donated to the university by Mr. Ed Meader, of Springfield, VA as a way to explore the pathway for LCRE technologies to reach the commercial marketplace. The team designed and built a working sub-scale prototype under the direction of Dr. Schubert.

Smart Farms Indiana “Renewable Energy v. Environment on Indiana Farms: Water, Biomass, Manure,” by students Carol Baker, Sarah Hamang, Elsa Kramer, Kathleen Molinder, and Julia Yoder, all SPEA graduate students, under direction by Dr. Schubert. The purpose of this work was to identify problems and opportunities for LCRE research to serve

Indiana farms in increasing their own on-site production of renewable resources. Findings included a number of individual farmers using advanced sustainability practices, such as “no-till” farming and wildlife buffer zones, but no widespread adoption or outreach. Rather the team heard from such farmers that our land-grant university programs produce graduates that continue with traditional science-based farming, including ample use of GPS-directed tractors, hybrid seeds, and petroleum-based pesticides, fertilizers, and herbicides. Students felt intimidated by then-pending “ag gag” legislation which may have made illegal their study of existing farming practices. Fortunately, in Indiana, this bill was not passed. A sobering result is the conservatism and independence of farmers precludes ready adoption of alternative technologies.

SOFc Lab by students Will Hammel and Zach Urbanek. A Junior in Electrical Engineering Technology paired with a Purdue-bound freshman from Park Tudor HS worked part-time during summer 2013 to identify equipment and utilities needed to create a lab space for the fabrication of solid oxide fuel cells (SOFCs). The outcome is a proposal-ready budget and justification that can be used in the overall objective of creating a high-temperature materials labs to synthesize and assemble apparatuses from refractory ceramics. This work was supervised by Dr. Schubert, with support from Dr. Jing Zhang.

Outlook for AY 2013-2014

For the first time the LCRE will have a specific location on campus, not just somebody’s office. The new SEL Building, slated for first occupant entry in November 2013 will include an executive conference room and two permanent offices on the same floor as the two LCRE laboratories, each having about 950 square feet of top-notch research capabilities. The conference room will be home to the growing number of models and samples created based on the technology subjects of LCRE Research Members. These tangible indicators of our work are important when conveying the relevance and importance of what we do, especially when addressing a lay audience interested in the real-world applications of renewable energy research. The labs themselves will be an impressive showcase of cutting-edge advances in batteries and fuel cells, helping to enhance the capability and the reputation of our Center.

The seawater flow battery invented by Dr. Young Kim has generated considerable interest in the US Navy and in Southern California. As mentioned above, a joint proposal with the BIC is under consideration. Meanwhile two EIRs are developing a marketing and business case study in order to seek sponsored research through private sources. The leading application is for “cold ironing”, by providing shipboard power for vessels in port. Rather than run dirty diesel engines and generators for refrigerator and container ships, a combination of solar power and a seawater flow battery can provide around-the-clock power to moored vessels without air pollution. Additional applications were proposed by members of The Maritime Alliance, a well-networked group in San Diego introduced to LCRE by Advisory Board member Jim Wheeler. Dr. Kim’s return to Korea has complicated plans for this development, but he retains his university posting at least through December. Other LCRE research members are being brought into this project to help maintain forward momentum. As circumstances permit, Dr. Kim will also be involved.

Microgrids are gaining increased interest from the US military, communities interested in self-sufficiency, and technology parks focused on sustainability. Intellectual property (IP) owned by the university is being complemented by IP from two other local companies to build a microgrid consortium in Indianapolis. Although still at an early stage, there are several exciting prospects on various drawing boards for this work to expand considerably.

Membership in LCRE now includes five Research Members on the IU-Bloomington campus. Additional outreach to other regional campuses is expected to broaden our scope to begin covering all 4 corners of our state.

The political and economic factors affecting renewable energy in general are a mix of good news and bad news. Low prices for natural gas due to the advent of hydraulic fracturing represent an economic bonanza to many sectors of the US economy, and help promote national security. However, cheap gas reduces incentives for renewable sources of electricity and heat, softening interest in research among American corporations. The continuing debate over anthropogenic climate change and the polarization of interests in the Congress hinders US leadership in developing alternative and renewable sources of energy. High-profile failures of solar panel and battery manufacturers has weakened investor risk tolerance for renewable energy projects. Proposed regulations addressing environmental pollution are under siege from fiscal conservatives, creating uncertainty in energy investment, and diminishing funding for innovation. All of these factors challenge the ability of the LCRE to fulfill its mission. In such a difficult fiscal environment it is heartening to see the tremendous amount of progress made this year by our Research Members. During the coming academic year this continued dedication to our mission and goals will help position LCRE to make positive contributions to Indiana, America, and the world, as burgeoning opportunities and nascent circumstances begin to ripen.

Appendix A

Executive Committee

1. Alan Jones, Ph.D., Assistant Professor of Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
2. Rongrong Chen, Ph.D., Research Associate Professor of Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
3. Steve Rovnyak, Ph.D. Associate Professor of Electrical and Computer Engineering, Purdue School of Engineering and Technology, IUPUI
4. Mark Goebel, Ph.D., Professor of Biochemistry and Molecular Biology, Indiana University School of Medicine
5. Eric Dannenmaier, Professor of Law and Dean's Fellow, Director, Environmental and Natural Resources Law Program, Indiana University Robert H. McKinney School of Law
6. M. Razi Nalim, P.E., Ph.D., Professor of Mechanical Engineering, Associate Dean for Research & Graduate Programs, Department of Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI

Note that Dr. Yaobin Chen and Dr. Kenneth Richards resigned their posts on the Executive Committee due to their overseas assignments for this academic year.

Appendix B

Advisory Board

The LCRE AB meets quarterly on campus to review progress and provide strategic advice. Members serve on one of several committees each having a tighter focus on specific issues of importance to the Center. We are especially grateful for the service of Mr. John Kirkwood, who served as Chair of the AB from the inception of the LCRE through the completion of this academic year, for a total of 3 consecutive terms. Mr. Kirkwood was presented with a commemorative plaque recognizing his leadership and support.

1. Dr. Seth W. Snyder, Section Leader, Energy Systems, Argonne National Laboratory, and President of the Council for Chemical Research.
2. Robert Galyen, Chief Technology Officer, Amperex Technology Limited
3. John Kirkwood, JD, Partner, Krieg DeVault, Chair of Advisory Board 2007-2013
4. Keni Washington, Managing Director, Earth Solar Technologies Corporation
5. Doug Wasitis, Director of Federal Relations, Indiana University
6. Bill Wylam, President, International Energy, LLC
7. Bill (William) Marsan, Vice President, General Counsel & Secretary, Indianapolis Power and Light
8. Lane Ralph, Private citizen, formerly State Director for Sen. Lugar.
9. John Waters, President, Waters and Associates Consulting
10. Kären Haley, Executive Director, Indianapolis Cultural Trail, Inc.
11. Carey Lykins, President and CEO, Citizens Energy Group
12. Dr. Wayne Eckerle, Vice President, Corporate Research and Technology, Cummins, Inc.
13. Cathy Tripodi, Senior Vice President, Council on Competitiveness
14. Cary Aubrey, Manager, Bio-energy Development, Indiana State Department of Agriculture
15. Steve Kozey, General Counsel, Midwest ISO
16. Todd Colpron, VP of Business Development, Skyron Systems, Inc.
17. Dr. Maureen McCann, Director, Purdue Energy Center, Purdue University
18. Katherine Winter, General Director, Advanced Engineering and Software & Services, Delphi Electronics and Safety
19. Doug Esamann, President, Duke Energy Indiana
20. Craig Herndon, Director of Critical Technology Innovation, NSWC Crane
21. Laurie Tuttle, VP Hybrid Program, Allison Transmission
22. William D. "Bill" Crawford, Senior Business Development Executive, American Solar Integrators, LLC (new in 2013)
23. Dan M. Martin, Senior Scholar, Woodrow Wilson International Center (new in 2013)
24. George Caraghiaur, Vice President of Sustainability, Simon Property Group (new in 2013)
25. Terry Hall, Partner, Faegre Baker Daniels (new in 2013)
26. Jim Wheeler, Thomas P. Miller and Assoc. (new in 2013)

Appendix C

Research Members

1. Dr. Jie Chen, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
2. Dr. Hazim El Mounayri, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
3. Dr. M. Razi Nalim, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
4. Dr. Yaobin Chen, Electrical and Computer Engineering, Purdue School of Engineering and Technology at IUPUI
5. Dr. Sohel Anwar, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
6. Dr. David Goodman, Electrical and Computer Engineering Technology, Purdue School of Engineering and Technology at IUPUI
7. Dr. Stephen Hundley, Computer, Information, and Leadership Technology, Purdue School of Engineering and Technology at IUPUI
8. Dr. Youngsik Kim, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
9. Dr. Afshin Izadian, Electrical and Computer Engineering, Purdue School of Engineering and Technology at IUPUI
10. Dr. Lingxi Li, Electrical and Computer Engineering, Purdue School of Engineering and Technology at IUPUI
11. Dr. Rongrong Chen, Mechanical Engineering, Purdue School of Engineering and Tech at IUPUI
12. Dr. Maher Rizkalla, Electrical and Computer Engineering, Purdue School of Engineering and Tech at IUPUI
13. Dr. Steven Rovnyak, Electrical and Computer Engineering, Purdue School of Engineering and Technology at IUPUI
14. Dr. Alan Jones, Mechanical Engineering, Purdue School of Engineering and Tech at IUPUI
15. Dr. Tamer Wasfy, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
16. Dr. Dong Xie, Biomedical Engineering, Purdue School of Engineering and Technology, IUPUI
17. Dr. Jian Xie, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
18. Dr. Likun Zhu, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
19. Dr. Mark Goebel, Biochemistry and Molecular Biology, IU School of Medicine at IUPUI
20. Dr. Gabriel Filippelli, Professor of Earth Sciences, Director Center For Urban Health, Earth Sciences Department, Purdue School of Science at IUPUI
21. Dr. Asok Sen, Mathematical Sciences, Purdue School of Science at IUPUI
22. Dr. Xianzhong Wang, Biology, Purdue School of Science at IUPUI

23. Dr. Ken Richards, Public and Environmental Affairs/Law, IU School of Public & Environmental Affairs/IU Maurer School of Law
24. Dr. Eric Dannenmaier, Director, Environmental and Natural Resources Law Program, IU School of Law
25. Dr. Tom Iseley, Construction Engineering Management, Purdue School of Engineering and Technology, IUPUI
26. Dr. Pierre Atlas, Political Science, Marian University
27. Dr. David Craig, Religious Studies, IU School of Liberal Arts
28. Dr. Carol Rogers, Indiana Business Research Center, Kelley School of Business, IUPUI
29. Patricia Fox, Organizational Leadership and Supervision, Purdue School of Engineering and Technology at IUPUI
30. Dr. Jan Cowan Architectural Technology Program, Purdue School of Engineering and Technology at IUPUI
31. Dr. Jerome Dumortier, Public and Environmental Affairs, IU School of Public and Environmental Affairs
32. Dr. Peter J. Schubert, Electrical and Computer Engineering, Purdue School of Engineering and Technology at IUPUI
33. Dr. Jing Zhang, Mechanical Engineering, Purdue School of Engineering and Technology at IUPUI
34. Dr. Stephen K. Randall, Department of Biology, School of Science, IUPUI
35. Dr. Rebecca Barthelmie, Professor of Atmospheric Science and Sustainability, Department of Geological Sciences, Indiana University-Bloomington
36. Dr. Sara Pryor, Provost Professor of Atmospheric Science, Department of Geological Sciences, Indiana University-Bloomington
37. Andres Tovar, Ph.D., Assistant Professor, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
38. Sanya Carley, Ph.D., Assistant Professor, School of Public and Environmental Affairs (SPEA), Indiana University
39. Euzeli C. Dos Santos, Jr., Ph.D., Assistant Professor, Electrical and Computer Engineering, Purdue School of Engineering and Technology, IUPUI
40. Huidan “Whitney” Yu, Ph.D., Assistant Professor, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI
41. Dr. Elaine Cooney, Professor of Electrical and Computer Technology, Department Head, Technology, IUPUI.
42. Dr. E. Jane Luzar, Professor of Economics, Professor of Public and Environmental Affairs, Dean, IUPUI Honors College.
43. Dr. Paul E. Sokol, Professor of Experimental Physics, Department of Physics, IU-Bloomington.
44. Dr. Ali Razban, Senior Lecturer, Mechanical Engineering, Purdue School of Engineering and Technology, IUPUI

Appendix D

Entrepreneurs-in-Residence

The EIR program was initiated in December 2011 in cooperation with Dr. Joe Trebley of the Indiana University Research and Technology Corporation (IURTC) – the technology transfer organization for the IU system. Dr. Trebley heads the Startup Support and Promotion initiative to help faculty create businesses based on their intellectual property. Five new EIRs were added this year. The most crucial role for the EIRs is to serve as PI for federal Small Business Innovation Research (SBIR) grants made by spIn-Up companies which can then subcontract to university faculty. This allows faculty members to retain 100% appointments while benefiting from the entrepreneurial experience of the EIR and side-stepping the federal requirement that the PI be 51% or more associated with the small company. Four SBIR proposals have been submitted to the NSF, DOE, and USDA in AY 2012-2013. In addition to SBIRs, EIRs help develop business plans, often in concert with students from the Kelley School of Business, and they bring networking opportunities to LCRE. The following individuals provide pro bono work on behalf of the university with the hope and expectation that, upon receiving funding, they can begin to draw a salary commensurate with their level of interest and availability, while creating commercially-viable going concerns based on research from LCRE Research Members:

1. Mr. Bob Brockman
2. Mr. John Craun
3. Dr. Randall Gatz
4. Mr. Gary Guanac
5. Dr. Shashikala K
6. Dr. James Logson
7. Mr. Joe Paganessi
8. Mr. Edward F. Plocharczyk
9. Dr. Seth Potter
10. Mr. Peter Price
11. Dr. Bob Rosenstein
12. Mr. Lee Saberson
13. Mr. Morris Stillabower
14. Mrs. Aneena Urbanek

Appendix E

Director's Afterward

At 3 months shy of 2 years in this post, I believe we are now showing tangible signs of re-energization of the Lugar Center for Renewable Energy. The major competitive grants to Drs. R. Chen and J. Xie are an external validation of our capabilities. Our Research Member roster has grown by 13% this year, and we've added five strong contributors to our Advisory Board. An unusually large number of students worked on behalf of the LCRE, either for pay or credit. This was a deliberate investment in building research foundations, and identifying research opportunities for the whole organization. In order to afford so many interns, the long-standing position of General Manager was put on hiatus as of 31 December 2012. Appreciation is extended to Mr. Patrick Flynn for archiving this role for later re-activation. His departure, together with the student mentoring, resulted in a significant workload increase on the director. This was ameliorated by part-time development support by Mrs. Aneena Urbanek, and part-time administrative support by Mrs. Delana Gifford. Efforts are underway to seek philanthropic giving supporting an endowed chair in Senator Lugar's name which will provide basic funding in perpetuity for this important Center, and permit the hiring of a GM to manage daily affairs and organize outreach events.

The graph at right shows the degree to which your Director "walks the talk". In contrast to some hard core bike commuters who consider a "skunk stripe" of muddy road grime as a badge of honor, when the weather is bad and the dress is business, an internal combustion engine is a wonderful convenience. An ICE vehicle is also more conducive to trips around the state to meet with collaborators, and to take students on field trips. Look for "EV" to be added in 2014! Your Director is also a strict vegetarian (vegan). Look into it!



A great many people contribute to this organization. We are privileged to be administratively housed within the Purdue School of Engineering and Technology and to have the support of Dean David Russomanno and his staff. Administrators and facility services people from all across the Indianapolis campus have worked hard in creating an environment conducive to research and learning. Thanks to all of you who help make this important work possible.

