



Pacific Northwest
NATIONAL LABORATORY

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Building Energy Systems & Technologies (BES&T)

STAFF DIRECTORY



May 2010

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BUILDING ENERGY SYSTEMS & TECHNOLOGIES (BES&T) Group

The Building Energy Systems and Technologies (BES&T) Group is part of the Pacific Northwest National Laboratory's Energy Environment Directorate. Our signature capabilities include sustainable design and development, building systems and energy technology analysis, and carbon management. We work with government and private sector clients to solve energy, environmental, and economic systems challenges, such as global climate change, sustainable development energy systems. Examples of our current work include FutureGen, sustainable design rating system comparisons, and ASHRAE guides for designing highly energy efficient buildings.

We are located in Richland, Washington where we have access to 4000 PNNL staff members working in world-class chemistry, biology, physical sciences, and process and applied engineering.

Awards

- » R&D Magazine, *R&D 100*
- » Presidential Awards, *Leadership in Federal Energy Management*
- » Presidential Awards, *Closing the Circle*
- » Department of Energy, *Pollution Prevention*
- » Department of Energy, FEMP Energy and Water Management
- » Sustainable Buildings Industrial Council, *Best Sustainable Practice*
- » Alliance to Save Energy, *Stars of Energy Efficiency*
- » U.S. Green Building Council, *2005 Leadership Award*
- » ASME, *Dedicated Service*, 2004
- » ASHRAE, *Distinguished Service*, 2005 & 2006
- » AEE, *Energy Managers' Hall of Fame*
- » AEE, *Distinguished Service Award*, 2001
- » AEE, *Energy Professional Development Award*, 2001
- » AEE, *International Energy Project Award*, 2000
- » Tri-Cities chapter of the Washington Society of Professional Engineers, *2004, 2005 & 2007 Tri-Cities Engineer of the Year Award*
- » *Woman of Achievement*, 2009
- » *LASER Program Award*, 2009
- » *Laboratory Director's Award for Administrative Excellence Nominee*, 2010
- » *2010 Outstanding Mentor Award*

For additional information, please contact Sriram Somasundaram at (509) 375-6842 or sriram.somasundaram@pnl.gov or visit our group website at <http://best.pnl.gov/>

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Rahul Athalye

Engineer

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Biography

Rahul Athalye graduated from North Carolina State University in 2008. Since joining PNNL, Mr. Athalye has been part of the team supporting the Commercial Building Energy Codes Program. He is also working for the Commercial Building Partnership Program and on the Advanced Energy Design Guidelines, performing energy and daylighting simulations. Mr. Athalye is involved with the development of the Commercial Lighting Solutions and COMcheck web tools.

Research Interests

- Daylighting: Daylight modeling and simulation, daylighting systems, human response and behavior to daylighting
- Building energy simulation and programs
- Building energy codes and energy efficiency
- Energy policy, RPS, renewable energy economics
- Passive solar design

Education

- M.S. Mechanical Engineering, North Carolina State University
- B.S. Mechanical Engineering, University of Mumbai, India



Gopal Bandyopadhyay

Scientist

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Biography

Gopal Bandyopadhyay is a recent hire to PNNL. His recent projects include: building energy simulation, renewable energy assessment in military facilities (for the geothermal and ground source heat pump segments), performance data analysis for new technology evaluation, appliance standard development, and heat exchanger modeling.

Prior to PNNL, Dr. Bandyopadhyay had extensive work experience in diverse assignments in the areas of techno-analytic consulting, project development, engineering, and management. He earned his doctorate degree in energy engineering specializing in energy conservation and renewable energy. Dissertation: 'Ground heat exchangers: Analytical and Numerical Modeling and Experimental Validation.'

Research Interests

- Techno-analytic consulting
- Project development
- Engineering and management

Education

- Ph.D. Energy Engineering from the University of North Dakota
- Master of Technology from Indian Institute of Technology, Kanpur, India
- Bachelor of Engineering from Calcutta University, India

Signature Capabilities

- » Building and Facility Energy and Water Assessments
- » Building Energy Simulations and Analysis
- » Sustainable Building Design and Best Practices
- » Carbon Management
- » Building Energy Systems and Technologies





Tracy Beeson

Engineer

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Biography

Tracy Beeson joined Pacific Northwest National Laboratory after earning an M.S. in Architectural Sciences with a Concentration in Lighting from Rensselaer Polytechnic Institute, and became Lighting Certified (LC) by the National Council on Qualifications for the Lighting Professions (NCQLP) in 2008. Ms. Beeson has a considerable knowledgebase of general lighting applications and technologies, and has experience in field demonstrations, developing lighting measurement protocols, and establishing best lighting practices to improve energy efficiency for the ARMY. She is currently involved in developing the National Energy Standard for ASHRAE 90.1-2010, and remains committed to reducing lighting energy consumption without compromising lighting quality of the visual environment.

Education

- M.S. Architectural Sciences with a Concentration in Lighting from Rensselaer Polytechnic Institute
- Lighting Certified (LC) by the National Council on Qualifications for the Lighting Professions (NCQLP)

Primary Products

- » ASHRAE Standard 90.1, International Energy Conservation Code (IECC)
- » ASHRAE Advanced Energy Design Guides (AEDG)
- » Facility Energy Decision System (FEDS)
- » Building Energy Metering and Operations & Maintenance Best Practices
- » Appliance and Equipment Standards – Technical Support Documents





Daryl Brown

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Biography

Daryl Brown has a broad range of experience directing and performing analyses of advanced technology systems. The majority of this experience has been oriented toward energy technologies where he has authored or co-authored over 150 publications. Mr. Brown specializes in cost estimating and life-cycle costing and has conducted many preliminary engineering feasibility studies incorporating design, performance, cost, and economic analyses.

Mr. Brown's recent experience includes conducting studies examining the cost and performance of coal-fired electric power and coal-to-liquid plants, both with and without CO₂ capture. He has collaborated with ANL and NREL on the development of hydrogen delivery component and systems analysis models. Mr. Brown is also actively involved with other TSA colleagues in using the Facility Energy Decision System to model current and prospective energy use and identify cost-effective energy retrofits at Army facilities.

Research Interests

- Energy technology systems
- Cost estimating/discounted cash flow analysis
- Integrated cost, performance, and economic studies

Education

- B.S. Chemical Engineering, Oregon State University
- M.B.A. Business Administration and Finance, University of Washington



Stephen Butterworth

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Biography

Steve Butterworth comes to the Pacific Northwest National Laboratory after a 42 year career with the National Park Service. Serving in a multitude of positions from park ranger to Regional Energy Manager, his travels have allowed him to visit over 100 national parks and expose him to a great variety of organizations, situations, and partnerships. Most recently, he served as a Regional Energy Manager for 60 national parks. In that role, he got first-hand experience in applying energy management principles in climates from arctic to tropic, utilities ranging in complexity of an IOU to a co-op, facilities large and small, grid connected and remote, seasonal to year round, and owned, leased, or shared. Along the way, he was a MOD for Hilton Hotels, taught law at the University of Washington, and a Public Information Officer for Incident Management Teams on forest fire or hurricane deployments.

He helped launch the first GovEnergy conference, the Federal Network for Sustainability and is a recipient of two Federal Energy Management and Water Conservation Awards and was a member of a Presidential Closing the Circle team award.

Research Interests

- Energy efficiency, renewable energy, sustainability

Education

- University of Washington (BSF/MSF), American University, Federal Law Enforcement Academy



Heejin Cho

Engineer

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Biography

Heejin Cho joined Pacific Northwest National Laboratory in 2009 as a building energy systems modeler after earning a Ph.D. degree in Mechanical Engineering from Mississippi State University. His specialties are modeling, dynamic simulation, optimization, and uncertainty analysis of energy systems including alternative energy technologies, HVAC systems, and buildings. He is proficient in energy/building simulation programs including EnergyPlus, TNRSYS, Matlab and Mathcad. Dr. Cho's research interests revolve around developing and improving advanced and sustainable energy technologies for buildings to increase overall system efficiency, designing and enhancing energy efficient buildings, and developing an optimal control algorithm for energy systems to minimize operational costs, primary energy consumption, and air pollutants.

Research Interests

- Development of advanced and sustainable energy technology
- Energy efficient building design, analysis, and modeling
- Building energy codes and standards

Education

- Ph.D. Mechanical Engineering, Mississippi State University, 2009
- B.S. Mechanical Engineering, Mississippi State University, 2005



William Chvala

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Biography

William Chvala (pronounced *Koala*, like the bear) came to Pacific Northwest National Laboratory in 1991 to work on energy performance evaluations of office equipment, building HVAC equipment, and lighting. Since then, he has been involved in numerous metering, data collection, demand-side management (DSM), and load-shedding projects. Mr. Chvala's specialties include field data collection, utility data and rate analysis, and energy performance evaluations for Federal facilities and large military installations. He is also active in PNNL's long-standing program with the U.S. Army, helping them understand energy consumption on an installation level and identifying potential energy projects, fuel switching opportunities, load-shedding, and other operations improvements.

Research Interests

- Energy efficiency technology analysis and economics
- Field data collection, technology demonstrations, and site audits
- Federal sector energy consumption with emphasis in military installations
- Technical assistance for Federal-sector energy-related activities

Education

- M.S. Environmental Science, Energy Emphasis, Miami University, Oxford, Ohio
- B.Sc. Physics and B.Sc. Applied Mathematics, Nebraska Wesleyan University, Lincoln, Nebraska

Whitney Colella

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Biography

Dr. Whitney G. Colella spearheads computer simulation, testing, and independent analysis of novel, low-carbon energy systems to improve their thermodynamics, economics, and environmental performance. Colella develops and applies analytic approaches to understand the design and performance space of networked stationary polygenerative fuel cell power plants and other distributed energy generation and storage devices against the energy demands of buildings and vehicles they may supply. An aim of Colella's research is to use relatively inexpensive computer simulation to better design fuel cell systems and other low-carbon energy devices so that they meet these demands; reduce greenhouse gas emissions, air pollution, and energy costs; and benefit national security through increased electricity grid integrity, energy efficiency, and security and diversity of fuel supply.

As a Senior Research Engineer at PNNL, Dr. Colella serves as the principal investigator (PI) on a multi-million dollar research project for the U.S. Department of Energy (DOE) to model, deploy, and test stationary micro-Combined Heat and Power (CHP) and Combined Cooling, Heating, and Electric Power (CCHP) and Fuel Cell Systems (FCSs). Colella also serves as the U.S. Technical Expert Representative on behalf of the DOE to the International Energy Agency (IEA)'s Advanced Fuel Cell Annex XIX on Stationary Fuel Cells. Colella previously spearheaded research on polgenerative fuel cells and distributed energy technologies as a Senior Member of Technical Staff at Sandia National Laboratories and was awarded the President Harry S. Truman Fellowship in National Security Science and Engineering.

Research Interests

- Optimizing the design, installation, and control of stationary, polygenerative fuel cell systems (FCSs), including Combined Heat and Power (CHP); Combined Cooling, Heating, and Electric Power (CCHP); and hydrogen co-production (CHHP) systems.
- Analyzing the thermodynamics and chemical engineering design of CHP, CCHP, and CHHP FCSs.
- Engineering design, economics, and environmental impacts of renewable, low carbon, and efficient energy technologies.
- Industrial economics, the design of national systems of innovation, and energy policy.

Education

Dr. Colella earned a Bachelor of Science (B.S.) in Mechanical Engineering with highest honors and a minor in public policy from Princeton University, a Master of Science (M.S.) in Science and Public Policy from Sussex University, a Master of Science (M.S.) in Engineering with a specialization in Mechanical from Stanford University, a Masters of Business Administration (MBA) from Oxford University with highest honors, and a doctorate in Engineering Science from Oxford University. Colella has been recognized with British Marshall, National Science Foundation, Thomas J. Watson, Lillian Moller Gilbreth, British Overseas Research, and Harry S. Truman scholarships and fellowships.



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Senior Research Engineer

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Biography

Bob Dahowski manages and contributes to a wide array of energy and environmental systems analyses for government agencies and industrial clients. Working closely with the Joint Global Change Research Institute as well as other experts across the globe, one focus of Mr. Dahowski's research is examining the deployment potential of climate change mitigation technologies. He performs techno-economic assessments to quantify the potential impacts of advanced energy technologies including CO₂ capture and storage (CCS), and has led key studies to assess the geologic CO₂ storage capacity and economic potential for CCS in North America and China.

Mr. Dahowski is experienced in model development and analysis in the areas of energy efficiency and carbon management and has led the creation and development of the Battelle *CO₂-GIS*, the first geospatial economic model for examining the potential deployment of CCS systems. He is also co-developer of the Facility Energy Decision System (FEDS) software, a unique and powerful energy efficiency assessment model for existing buildings.

Research Interests

- Carbon management, energy and environmental systems analysis
- Sustainable development and utilization of resources

Education

- M.S. Environmental Engineering, Washington State University
- B.S. Mechanical Engineering, Clarkson University



Casie Davidson

Scientist

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Biography

Casie Davidson's research focuses on developing and utilizing models to refine our understanding of how geological, technical, economic, regulatory, and societal drivers combine to impact the deployment of carbon dioxide capture and geologic storage (CCS) technologies domestically and abroad. Casie was a principal author of the first-of-its-kind CO₂ storage capacity assessment and coupled cost curve for North America, recently completing a similar study for China. Her broader contribution includes cross-disciplinary work with regulators and researchers to understand how complex, real-world constraints may impact geologic storage, groundwater, and other resources. Applications of this work include preliminary CCS project siting; consulting work for governmental and non-governmental organizations working to support and craft regulation based on robust science; and clients seeking a broader understanding of the potential for CCS technologies to serve a global role in addressing climate change.

Research Interests

- Technoeconomic modeling of carbon dioxide capture and geologic storage (CCS) as a climate change mitigation technology
- Potential impacts of societal and technical CCS constraints on the geologic CO₂ storage resource and groundwater
- Supporting strong, science-based efforts to regulate a safe, effective CCS industry including project siting, characterization and permitting

Education

- B.S. Geology
- M.S. Resource and Applied Economics



Marcus De La Rosa

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Biography

Marcus De La Rosa started working at PNNL through internship programs while in high school and college. He joined PNNL full time in 2008 after graduating from Gonzaga University with a Bachelor degree in Mechanical Engineering. Since that time he has worked mostly with the Army through the EEAP program, contributing to multiple renewable energy, water conservation, and energy conservation reports. Mr. De La Rosa is also a member of the WICF Equipment Standards team and has also contributed to other equipment standards projects.

Research Interests

- Water conservation
- Energy conservation
- Renewable energy research
- Equipment standards

Education

- B.S. Mechanical Engineering, Gonzaga University, 2008



Jim Dirks

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Biography

Jim Dirks has been with Pacific Northwest National Laboratory since 1982. He has a wide range of interests including system analysis, technology assessment, economic evaluation, and computer simulation. Jim has primarily focused on improving the energy and water efficiency of buildings and building systems; this work has principally been funded by DOE, DOD, and the Russian government. For the past 14 years, he has been project manager and principal investigator for the development of FEDS, a building energy simulation and retrofit optimization model.

Other work includes research on superconducting equipment for the electric utility industry, hazardous waste minimization, innovative financing/shared energy savings, evaluation and design of alternative solar thermal power concepts, photovoltaics, electrochemical and thermal energy storage.

Research Interests

- Building energy efficiency modeling and analysis
- Energy efficiency technology analysis and economics
- System analysis of complex and emerging technologies
- Finance and economics

Education

- M.B.A. Business Economics and Finance, University of Washington, 1982
- B.S. Electrical Engineering, University of Washington, 1980



Doug Dixon

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Biography

Doug Dixon has served as a program manager for work related to energy efficiency with the U.S. Army for over 14 years. The work has included strategic planning, energy audits and analysis, technology demonstrations, energy project development, tactical plans, third party financing, utility supply alternatives and rate assessments, and privatization support. The primary client was the U.S. Army Forces Command at Fort McPherson, GA, until 2002 when the energy program became the responsibility of the Installation Management Agency (IMA). PNNL is currently supporting the IMA, Southeast region office.

Mr. Dixon supports the Energy Products and Operations product line in marketing to the Department of Defense sector. In this capacity, he represents the laboratory energy capabilities to all DOD services and the major installations. Mr. Dixon works with the DOD sector managers to understand the needs of customers that use the products and services of this product line.

Research Interests

- Program management
- Energy efficiency technology analysis and economics
- Technical training development and execution
- Department of Defense, Army sectors

Education

- M.S. Management and Administrative Sciences, University of Texas at Dallas, 1985



Nick Fernandez

Engineer

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Biography

Nick Fernandez joined the Building Energy Systems & Technologies (BES&T) group at PNNL in 2009. Mr. Fernandez has been involved in a variety of projects and has been the principal building modeler for the “Regency Center” National Accounts Project. He has been working on a concept comparing the economics of net zero energy on the community level to the building level. He has designed algorithms and analyzed laboratory data for a self-correcting controls project for commercial building economizers and has reviewed emerging building technologies for an alliance of retail customers.

Research Interests

- Building energy efficiency modeling and analysis
- Passive solar building energy systems
- Renewable energy deployment and integration
- Intersections between peak oil and economics

Education

- M.S. Mechanical Engineering, University of Maryland, 2008
- B.S. Mechanical Engineering, University of Maryland, 2006



Kim Fowler

Engineer

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Biography

Kim Fowler is the lead researcher at the Pacific Northwest National Laboratory for sustainable design and development related research. She works for private industry and government clients evaluating processes for efficiency opportunities, and assessing the environmental, social, and economic consequences of process, product, and facility designs. Her current work includes developing and applying performance metrics for sustainably designed building operations and applying strategies for developing sustainable, net zero emission, communities.

Ms. Fowler is a U.S. Green Building Council Leadership in Energy & Environmental Design (LEED) accredited professional. She has co-authored two handbooks: Pollution Prevention Opportunity Assessments for Research & Development Laboratories (Battelle Press) and How Interested Parties Become Partners: A Communications Guide for Sustainable Development (Battelle Press). She has also co-authored chapters in the Handbook of Complex Environmental Remediation Problems (McGraw-Hill) and Unfolding Stakeholder Thinking (Greenleaf Publishing).

Education

- M.S. Environmental Engineering, Washington State University
- B.A. Political Science and Business Administration (minor), Pacific Lutheran University

Elisabeth Giever



Engineer

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Biography

Elisabeth Giever joined the laboratory in early 2009. Ms. Giever's major project is to support the U.S. DOE Federal Energy Management Program's water efficiency activities. Before joining the Laboratory, Ms. Giever worked with a small civil engineering consulting firm in Portland, Oregon, working in the design of residential subdivisions.

Research Interests

- Potable water efficiency
- Storm water management and sustainability

Education

- BS Civil Engineering, University of Portland, Portland, OR
- Oregon Engineer-in-Training license



Will Gorrissen

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Biography

Will Gorrissen's background is primarily in building design and analysis. Trained as a Building Engineer at Concordia University in Montreal, Quebec, he has experience with various whole building modeling techniques, current HVAC technologies and design methodologies as well as a strong background in building science. Before joining Pacific Northwest National Laboratory, he has had diverse work experiences that have included helping to develop quality improvement techniques for a jet engine manufacturing company and plan development for an architecture firm. Mr. Gorrissen also has experience working in the construction industry, including the design development and construction of zero energy homes.

Research Interests

- Building Energy Efficiency
- Sustainable Building Design
- Building Energy Modeling

Education

- B. Eng, Building Engineering, Concordia University Montreal, Quebec



Krishnan Gowri

Engineer

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Biography

Krishnan Gowri leads the Building Energy Codes Software development team at PNNL. Since beginning his career with PNNL in 1995, he has been part of the COMcheck and REScheck code compliance software development for the International Energy Conservation Codes and the ASHRAE Standard 90.1 based codes. Dr. Gowri has also been involved in developing whole building diagnostic tools as web services.

Before joining PNNL, he was an Assistant Professor at the Centre for Building Studies of Concordia University, teaching building envelope design and integrated building design courses. Dr. Gowri was the Technical Program Coordinator for an award-winning Advanced House built in St. Dorethee, Quebec, during 1992-93 integrating energy efficient design features and home automation technologies.

Research Interests

- Building Energy Codes and Standards
- Advanced Computer Technologies and Software Development
- Sustainable Design, Building Automation and Integrated Building Design

Education

- Ph.D. Philosophy, Concordia University, Montreal, Canada, 1991



John Hail

Engineer

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Biography

John Hail supports the development and deployment of new concepts, methods, and technologies related to the planning, design, construction, and operation of facilities and systems. At PNNL, Mr. Hail began as a facility planner and operations program developer for the Facilities & Operations Directorate. He was a key developer of capital and operations and maintenance proposals. John developed and managed an energy management program for the Laboratory's 2 million square feet with a \$10M utility and staffing budget.

He joined the Laboratory's Energy Division to help develop and deploy facility and energy management programs and projects for the Laboratory's federal clients. The major deployments include Energy Savings Performance Contracts and nation-wide building retuning initiatives. A major current project is deploying multi-million dollar national security technology projects for the Department of Homeland Security.

Research Interests

- Construction documents and contracting
- Facility operations and management
- HVAC retuning/commissioning
- National security technology deployments

Education

- B.A., a five-year Professional Degree, University of Oregon
- Registered Architect in Alaska and California
- Certified Energy Manager (CEM), Association of Energy Engineers



Lucy Huang

Scientist

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Biography

Yunzhi Huang's research interests concentrated in building energy efficiency, green building technology, integrated building simulation, building automation and sustainable design. Since joining PNNL in March 2009, she has supported several projects including energy-efficient measure analysis and system analysis for National Account projects, national wide simulation for developing ASHRAE 90.1-2010 code, detailed modeling, and cost analysis for Advanced Energy Design Guide development.

Research Interests

- Building energy efficiency strategy analysis and economics
- Building Integrity Strategy
- Building Automation Control Strategy

Education

- B.S. Electrical Engineering, Fudan University, China, 2006
- M.S. Building Science, University of Southern California, 2008



Ron Jarnagin

Scientist

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Biography

Ron Jarnagin has been with PNNL since 1988. He has a diverse background in the field of energy including work in fluid flow, power plants, automotive and transportation systems, HVAC systems, energy use in buildings, and energy standards development. Mr. Jarnagin has been involved in numerous projects for DOE, DOD, DHS, and the U.S. Army Corps of Engineers. His focus has been on the energy aspects of buildings and building systems. In addition, Mr. Jarnagin has been active in AHSRAE, serving on the Board of Directors as both a director and officer. He chaired the Technology Council, ASHRAE Standard 90.1 committee, ISO TC205 Committee, three Advanced Energy Design Guide Committees, and six Presidential Ad Hoc Committees. He also served on a U.S. delegation to China supporting design of a renewable energy-based hydrogen refueling station for the buses used at the 2008 Beijing Olympics.

Research Interests

- Building energy codes and standards
- Building energy modeling and analysis
- Energy systems design and analysis

Education

- M.S. Mechanical Engineering, University of Florida, 1980
- M.S. Accounting, Louisiana State University, 1971



John Kaufmann

Manager

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Biography

John Kaufmann worked as energy specialist, policy analyst, and program manager for 29 years with the Oregon Department of Energy. He headed Oregon's nation-leading building energy code efforts for many years, and received the American Planning Association Professional Achievement Award in 1989 for his work in getting 26 local governments in the Portland metro area to jointly adopt solar rights and solar orientation ordinances.

In 2009, John received the Energy Manager of the Year Award from Association of Professional Energy Managers-Oregon for Lifetime Achievement. He was lead staff to the City of Portland's Peak Oil Task Force in 2006-07 and was primary author of its report, "Descending the Oil Peak: Navigating the Transition from Oil and Natural Gas." John serves as Senior Fellow for the Post Carbon Institute, and has made numerous presentations in the Northwest and nationally on the status and implications of declining world oil supplies.

Research Interests

- World oil supply
- Energy return on energy invested
- Policies and strategies to deploy energy efficiency technologies

Education

- B.A. University of Wisconsin-Milwaukee
- M.C.P. Urban Planning, Hunter College-City University of New York



Angela Kora

Scientist

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Biography

Angela Kora's research interests focus on sustainable design, energy efficiency, and carbon management. Since joining PNNL in 2008, Ms. Kora has supported projects such as assessing whole building performance of green buildings, identifying energy and water conservation opportunities in federal and private facilities, calculating carbon inventories, and analyzing domestic and international carbon management projects and policies. She also works on identifying and analyzing potential biomass projects on U.S. Army installations.

Research Interests

- Sustainable design and development
- Energy efficiency technology analysis
- Pollution prevention
- Carbon policy and management

Education

- B.S. Mechanical Engineering, University of Arkansas
- Engineer-In-Training (EIT)
- U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design Accredited Professional (LEED AP)

Jeanene Lee

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Biography

Jeanene Lee came to PNNL in 2000 and joined Building Energy Systems & Technologies in October 2007, in addition to supporting Energy Technology Development (65+staff) through 2009. She has over 28 years of experience related to group/program support such as accounting, computer programming, instructor, plus planning/facility coordination for large meetings, training seminars, and tours. In addition participating in strategic planning activities, research preparation and QR review auditing/reporting. Excellent organizational and planning skills, Purchasing and Expense system (PACQ), FNVA, P-Card auditing, badging, ERICA, CARS, EJTA, financials (WBS, MAT, etc.), Access Control support, junior staff training, Zone Warden, L-Clearance.

Computer skills: Proficient in Microsoft Office Products (e.g., Word, Publisher, PowerPoint, Access, Excel, Outlook, Project, FrontPage, Visio), Adobe Acrobat Professional (pdf), PageMaker, Photoshop, Illustrator, AutoCAD, Internet research, scanning, Adobe Photoshop, Web page design, Brochure development (marketing), Training.

Research Interests

- Project related: Buildings, Lighting, Construction, Energy
- Mentoring/class instruction

Education

- Columbia Basin College
- WSU Extension
- Eastern Washington University



Bing Liu

Engineer

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Biography

Bing Liu has conducted facility onsite energy audits and performed building energy efficiency measures analysis including energy-related technical analysis, advanced building energy-efficient systems development and deployment, building simulation modeling, energy savings assessment analyses and sustainable building design/deployment.

Before joining PNNL in 2002, Ms. Liu worked with several M&E consulting firms for seven years. She has extensive experience on building HVAC systems design in commercial buildings, institutions, hospitals and schools.

Research Interests

- Building energy consumption and efficiency simulation
- Building energy metering and data acquisition
- Energy efficiency technology analysis and economics
- Building HVAC system design and review

Education

- M.S. Thermal Energy, Tianjin University, Tianjin, China, 1995
- B.S. Civil Engineering major in HVAC, Tianjin University, Tianjin, China, 1992
- Ms. Liu is a registered professional mechanical engineer (PE), certified energy manager (CEM), and LEED accredited professional



Guopeng Liu

Engineer

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Biography

Guopeng Liu has over ten years of research, design, and industry experience in HVAC engineering. He has published 16 journal and peer-reviewed conference papers. Many of his publications are focused on new building technology development, HVAC system optimization, and continuous commissioning case study. He has conducted the energy audit and preliminary assessment for more than 70 facilities including office, education facilities, clean room, lab, and manufacturing plants. He has led many projects with new technologies implementation and achieved significant energy savings already. Before joining PNNL in 2010, Dr. Liu worked as director of engineering in BES-Tech Inc. He has extensive experience on energy audit and management of retro-commissioning project for large commercial buildings.

Research Interests

- Building commissioning/retuning/retro-commissioning on existing buildings
- Develop new building energy efficiency technology
- Develop tools and methods of HVAC control optimization
- Building system optimization and fault detection

Education

- Ph.D. Mechanical Engineering, University of Nebraska-Lincoln
- B.Eng. in HVAC Engineering, Hunan University
- Registered professional mechanical engineer (PE) in Texas and LEED accredited professional

Susan Loper

Technician

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Biography

Susan Loper joined PNNL in June 2009. Previously, she worked for the Franklin Conservation District as a GIS Specialist. Ms. Loper has experience as the GIS lead for a Geologic Framework Project developing surface and isopach grids and maps of the subsurface geology in a four-county area in Southwest Washington. Other experience includes database development and maintenance and coordinating irrigation and well water management programs. Currently, she is working on updating federal agency's facilities data for the FEMP web-based GIS tool and the QuickSort Tool.

Research Interests

- GIS mapping and analysis
- Database development

Education

- B.S. Biology, Boise State University, 1992



Robert Lucas

Engineer

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Biography

Robert Lucas has 25 years of experience working on residential building energy efficiency codes and standards. Mr. Lucas developed the code used for federal residential buildings and also worked on setting the energy code for manufactured housing. He has been heavily involved with the development process for the International Energy Conservation Code, including writing key provisions now in the IECC. He has written reports assessing the energy and economic impacts in support of the energy code adoption process for over a dozen states and has conducted numerous analyses and assessments related to energy efficiency in residential buildings.

Research Interests

- Building energy efficiency
- Construction codes and standards

Education

- M.S. Mechanical Engineering, Oregon State University, 1991
- B.S. Mechanical Engineering, University of Washington, 1984

Eric Makela

Engineer

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Biography

Eric has over 20 years of experience in working with both residential and commercial building energy efficiency, particularly in the area of building energy codes. As a partner in Britt/Makela Group, he worked with states and stakeholders in the adoption, implementation and evaluation of building energy codes, working successfully with building design and enforcement industry as part of the process. He has also served on the International Code Council's International Energy Conservation Code Development Committee for 4 cycles, which was responsible for developing the 2006 and 2009 IECC.

Since 1986, he has trained or presented in over 22 states with sessions focused on residential and commercial building energy codes. Eric also served as the Senior Educational Programs Administrator for the International Conference of Building Officials, providing energy code support services. In July 2009, he received the "Jeffrey A. Johnson Award for Excellence in the Advancement of Building Energy Codes and Performance" by the U.S. Department of Energy.

Research Interests

- Energy regulation development
- Building energy efficiency
- Training and education

Education

- B.A. Environmental Studies and Planning ,Sonoma State University
- M.A. Education, California State University, Sacramento



Kate McMordie Stoughton

Engineer

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Phone: 720/379-3511

Biography

Kate McMordie Stoughton is a water resources engineer with Pacific Northwest National Laboratory, specializing in Federal water management. Ms. McMordie currently leads the water efficiency team for PNNL, working with the Federal Energy Management Program Water Efficiency program. Some of Ms. McMordie's work includes the development and instruction of Water Resource Management Workshops, development of strategic plans for water management at Federal sites, and Federal policy guidance in water management.

Ms. McMordie provides water management expertise to other PNNL programs such as the Army Office of Assistant Chief of Staff for Installation Management (OACSIM), Appliance and Commercial Equipment Standards Program and the Building Energy Codes and Standards Program. She also supports energy-water nexus initiatives at PNNL and sits on an ASME committee that aims at promulgating advanced technology and educational outreach in the energy-water nexus arena.

Research Interests

- Water use benchmarking
- Analysis of water end-use trends
- Water and energy interrelationship

Education

- B.S. in Civil Engineering from the University of Colorado
- Certified Energy Manager
- Leadership in Energy and Environmental Design

Vrushali Mendon

Engineer

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Fax: 509/375-2379

Biography

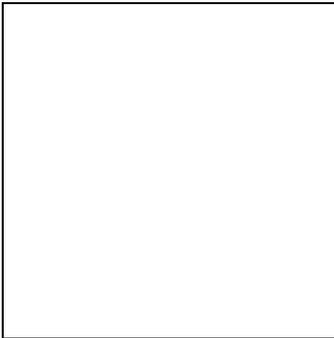
Vrushali Mendon's research interests center on Sustainable Design and Energy Efficiency in Buildings. Since joining PNNL in early 2010, Ms. Mendon has been providing Energy Simulation support for Residential and Commercial Building Energy Codes Development.

Research Interests

- Energy Efficiency in Buildings
- Heating, Ventilation and Air Conditioning (HVAC) systems
- Energy Efficiency Technology Systems Analysis and Economics
- Renewable Energy

Education

- M.S. Mechanical Engineering, North Carolina State University
- B.S. Mechanical Engineering, University of Mumbai, India



Hung Ngo

Engineer

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Biography

Mr. Hung Ngo joins PNNL in late 2010. Since joining PNNL, he has been supporting for the Commercial Building Energy Codes Program. He is also working on HVAC control and monitoring, retuning, and building energy tool development projects.

Research Interests

- Building energy simulation
- Energy efficiency analysis
- Building control and automation

Education & Credential

- M.S. Computer Science, Texas A&M University – Corpus Christi
- B.S. Computer Science, University of Natural Sciences, Vietnam



Steven Parker

Engineer

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Biography

Steven Parker supports research activities in the assessment and deployment of new and emerging energy-efficient technologies. Since beginning his career with PNNL in 1992, Mr. Parker has supported and led numerous research programs for the U.S. DOE, primarily the Federal Energy Management Program; the Department of Defense; and other related service clients.

Deeply involved in energy management since 1981, Steven has conducted several hundred energy audits and has instructed over 50 energy-efficiency seminars, in addition to speaking at numerous conference events.

Research Interests

- New and emerging technologies
- Energy efficiency technology analysis and economics
- Technical training development and execution
- Federal sector

Education

- M.S. Industrial Engineering and Management, Oklahoma State University
- B.S. Industrial Engineering and Management, Oklahoma State University
- Registered Professional Engineer
- Certified Energy Manager



Emily Rauch

Engineer

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Biography

Emily Rauch specializes in sustainable design, energy efficiency, and carbon management research. Her projects include analyzing whole building performance, examining new building trends for impacts of and compliance with energy codes, and creating integrated assessment models for the building sector that address the potential impacts of technologies on future carbon emissions. Additional work includes identifying energy and water efficiency design and operation solutions for various building types in the federal and private sectors.

Before joining the laboratory, Ms. Rauch worked at a large engineering and construction management firm working in the design, project controls and field engineering offices. Ms. Rauch is a member of the U.S. Green Building Council's Research Committee.

Research Interests

- Sustainable design and development
- Energy efficiency field assessments and analysis
- Whole building performance measurement
- Carbon management solution development

Education

- M.S. Environmental Engineering, Washington State University
- B.S. Mechanical Engineering, Michigan Technological University

Ray Reilly

Scientist

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Biography

Ray Reilly has been at Pacific Northwest National Laboratory for 25 years, in which time he has filled almost every role in the Energy Division, from project contributor, through manager of the Division's internally funded research program, to acting Division Deputy Director. He established and managed a working group of 50+ people engaged in building energy research. He established and managed numerous new programs for the USDOE at the Laboratory, including the building systems research program, the building energy standards program, the Decision Support System for Operations and Maintenance (DSOM), and others.

Recently, Mr. Reilly has focused on nonproliferation activities in support of the USDOE Nuclear Cities Initiative, where he is responsible for establishing or expanding over 20 companies and creating up to 1,000 new jobs for Russian nuclear workers.

Research Interests

- Design and management of complex projects
- Energy technology and economic analysis for federal installations
- Analysis and evaluation of Russian-type energy systems
- Business development in the FSU (nonproliferation job creation)

Education

- M.B.A. University of Washington
- P. E. Geophysical Engineering, Colorado School of Mines



Eric Richman

Engineer

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Biography

Eric Richman supports research activities in the assessment of building energy and the application of energy-efficiency technologies. He is specifically involved in the evaluation of lighting technology and its application related to buildings as well as the development of lighting energy codes. Mr. Richman is deeply involved in the support of development of energy codes and their implementation. He has conducted many commercial and residential energy audits and provided multiple presentations on lighting energy efficiency. Mr. Richman has authored over 50 technical reports, conference papers, and journal articles on energy efficiency and related issues and studies.

Research Interests

- Lighting technology analysis and application
- Building energy evaluation, analysis, and auditing
- Energy code development, application, and training
- New technology energy efficiency analysis

Education

- B.S. Mechanical Engineering, Washington State University
- B.S. Hotel/Restaurant Institution Management, Oregon State University
- Lighting (NCQLP) and LEED (USGBC) Certified and a Certified Energy Manager



Michael Rosenberg

Scientist

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Biography

Michael Rosenberg has worked for over 15 years improving energy-efficient practices in non-residential facilities. He has been involved in designing high performance buildings, analyzing complex building systems, upgrading building energy codes, and developing and administering beyond-code energy programs.

Mr. Rosenberg is a member of the ASHRAE Standard 90.1 Energy Cost Budget Subcommittee and the LEED Energy and Atmosphere Technical Advisory Group. He was recognized by the Association of Professional Energy Managers as 2007 Oregon Energy Manager of the Year. He is a Certified Energy Manager and LEED Accredited professional. Prior to joining PNNL, Mr. Rosenberg spent eight years at the Oregon Department of Energy as a Senior Energy Analyst and seven years at Hatten/Johnson Associates, Mechanical Engineering Consultants.

Research Interests

- Energy codes and standards
- Building energy simulation
- Energy efficient building systems

Education

- B.S. Biology, Oregon State University
- M.S. Physiology, University of Oregon
- Certified Energy Manager (CEM)
- LEED Accredited Professional (LEED AP)
- Certified Sustainable Development Professional (CSDP)

Lorena Ruiz

Administrator

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Biography

Lorena Ruiz joined Pacific Northwest National Laboratory in December 1999. She started at the Laboratory as a Cooperative Office Education student. Following high school graduation she accepted a position as a Circulation Lead in the Access Services & Special Collections Group at the Hanford Technical Library. Seven years later she joined the Business Systems Department as a Contracts Administrator. Lorena then joined the Energy Policy & Program Analysis Group as a Project Administrator. She is currently working in the Technology Systems Analysis Group as a Project Administrator.

Education

- Courses from Columbia Basin College, Pasco, WA
- Pasco High School Graduate, Pasco, WA

Bryan Russo

Scientist

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Biography

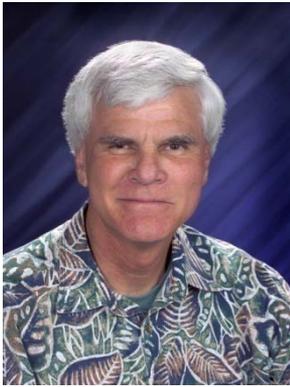
Bryan Russo's research interests center on sustainable development, renewable energy development, energy efficiency technologies, and energy performance evaluations for Federal facilities. Since joining the lab in late 2008, he has become involved with a variety of research projects including: impact analysis for proposed changes in the electric utility code that promote energy efficiency, data collection and energy performance evaluations of Federal facilities, indentifying and analyzing the potential for solar infrastructure on Federal facilities, and various projects for the Hydrogen Analysis Resource Center (HyARC).

Research Interests

- Sustainable development and design
- Energy efficiency technology analysis and economics
- Identifying and analyzing the potential for solar (photovoltaic and solar thermal) infrastructure

Education

- M.S. Materials Science and Engineering, University of Washington
- Masters Certificate in Environmental Management, University of Washington
- B.S. Materials Science and Engineering, University of Washington



Bill Sandusky

Manager

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Biography

Bill Sandusky has served in positions of a technical contributor, a member of intra- and interdisciplinary research teams, project/program manager, line manager, and manager of research operations since joining the Laboratory. He currently leads the laboratory's research activities in support of the USDOE Federal Energy Management Program.

He has either authored or co-authored over 150 technical reports and articles on a variety of technical subjects ranging from atmospheric transport and diffusion, renewable energy resource assessment, building energy efficiency, and siting of nuclear reactors.

Mr. Sandusky was part of the Pacific Northwest National Laboratory team that was presented the 2004 Presidential Award for Excellence in Federal Energy Management. He also has received six Certifications of Appreciation from the Assistant Secretary for US Department of Energy Office of Energy Efficiency, and received the 2009 Energy Champion award for the Department of Energy.

Research Interests

- Atmospheric transport processes, air quality, wind energy, building energy efficiency opportunities, and water conservation

Education

- M.S. Meteorology, Florida State University
- B.S. Space Technology, Florida Institute of Technology

Robert Schultz

Engineer

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Biography

Robert Schultz has been with Pacific Northwest National Laboratory since 1986. Since joining the Laboratory, he has participated in a variety of projects focused mainly in the areas of building science, energy policy and conservation analysis, radiological waste forecasting, cost-benefit analysis, and software development. Currently, Mr. Schultz supports the Building Energy Codes Program as a software engineer responsible for the desktop code compliance software. He also supports the Facility Energy Decision System (FEDS) assessment tool as a software engineer and is principal software developer for products related to the Solid Waste Forecasting program.

Mr. Schultz is proficient in the C++, Visual Basic, and Java programming languages with particular interest in development of desktop graphical user interface tools that focus on the energy efficiency and code compliance, and forecasting and analysis.

Research Interests

- Building sciences
- Energy systems modeling
- Energy efficiency software development

Education

- B.S. Agricultural Business and Economics, Montana State University
- M.S. Applied Economics, Montana State University



Sriram Somasundaram

Technical Group Manager

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Biography

Sriram Somasundaram has served as the Technical Group Manager of the TSA group since June 2008. In that period, the group size has grown from about 25 staff members to more than 50 staff members with various different backgrounds contributing to the growth of the buildings and sustainability business. He currently works on the DOE project that develops efficiency standards for commercial HVAC equipment. He has led several project teams over the past 20 years, involving complex, multi-year, multi-task projects characterized by numerous public and private stakeholders. Recently, he was selected as the Tri-Cities' Engineer of the Year (2005), received the ASHRAE Distinguished Service Award (2006) as well as became a Fellow of ASHRAE (2007). He is an Adjunct Professor of Mechanical Engineering at Washington State University.

Research Interests

- Building and Equipment Efficiency Standards
- Assessment of Cogeneration Systems
- Thermal Energy Storage Technologies
- Hydrogen Infrastructure and Fuel Cells

Education

- Ph.D. Case Western Reserve University, Cleveland, Ohio, 1981
- B.Tech. Aeronautical Eng., Indian Institute of Technology, Madras, India, 1976

Alice Soulek

Manager

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Biography

Alice Soulek's clients include government, private companies, and industry associations. Work includes development and coordination of green building performance databases, evaluation tools, and benchmarks and metrics for national-level accounts. Ms. Soulek started with the Pacific Northwest National Laboratory in 2009 following work for U.S. Green Building Council as the Vice President for Certification, SAIC as a Sustainability Engineer and Manager for the Army at Fort Bragg in North Carolina, and as the Capital Facilities Planning Coordinator for the City of Olympia, Washington. Ms. Soulek is a U.S. Green Building Council LEED accredited professional. She has developed capital facilities planning software used throughout Washington State and holds a U.S. patent for a mechanical system that control fouling on large ships.

Research Interests

- Green building design and construction
- Existing buildings – Sustainable renovations, materials, and equipment
- Sustainable community development
- Organizational development
- Sustainable processes and tools

Education

- J.D. Baylor University
- M.A. in Human Services, Saint Edwards University
- B.S. Mechanical Engineering, Saint Martins University
- B.A. with honors, Political Science, Baylor University



Don Stevens

Manager

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Biography

Don Stevens is a Senior Program Manager at PNNL with more than 30 years of experience in the conversion of biomass to renewable fuels, products and electricity. At present, he is the Laboratory Relationship Manager with DOE's Office of the Biomass Program and has oversight of the \$20 million in annual biomass-related funding. PNNL's work in this area focuses on the use of thermal catalysis and biotechnology to create fuels and higher value products from biomass residues. Dr. Stevens also participates in international biomass conversion projects for the International Energy Agency's Bioenergy Agreement. He is currently the Deputy Executive Committee member for the USA.

Over a 30-year period, he has conducted research and performed analysis on a variety of bioenergy systems. Dr. Stevens is the author or co-author of numerous publications and has been an editor of three books on biomass energy.

Education

- Ph.D. Physical Chemistry, University of Utah, 1978



Zachary Taylor

Engineer

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Biography

Building Energy Performance Standards: Todd Taylor is assisting in the development of proposed revisions to the ASHRAE Standard 90. His work has centered on the analysis of the impact of thermal mass on the energy performance of buildings, and the development of compliance procedures for the Standards. Mr. Taylor is also performing comparative analysis to determine the energy and economic impacts of various residential standards.

Research Interests

- Commercial Building Energy Metering
- Commercial Building Energy Analysis
- Electric Distribution Loss Evaluation

Education

- M. Eng. Mechanical Engineering, Texas A&M University, College Station, 1986
- B.S. Mechanical Engineering, Texas A&M University, College Station, 1982



Brian Thornton

Engineer

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Biography

Brian Thornton, a Professional Engineer (mechanical), has been with Pacific Northwest National Laboratory since May 2009. Before joining PNNL, he was the Energy Trust Commercial Solar Program Manager for 18 months during a 400% increase in commercial photovoltaic installations participating in the Energy Trust program. He also managed the commercial solar thermal incentive program. Previously for ten years, he provided efficiency analysis for building design and regulatory programs with DOE-2 modeling including four years as the owner of his own business, Thornton Energy Consulting. In 2006, he received a Better Bricks Award (Northwest Energy Efficiency Alliance) for energy efficiency design support. He contributed to LEED certification of over a dozen projects, most LEED Gold and one LEED Platinum.

Research Interests

- Building sciences
- Building energy simulation
- Energy codes development
- Renewable energy

Education

- Professional Engineer, mechanical engineering, California 2001, Oregon 2006
- BS Mechanical Engineering, Portland State University, High Honors, 1997
- BA, International Studies, University of Washington, Cum Laude, 1988
- LEED AP

Nora Wang

Engineer

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Biography

Nora Wang specializes in daylighting design, behavioral study, and building performance analysis. She has been devoted to sustainable architecture since 1997, winning several design competitions and participating in a dozen design projects in Asia. She is currently involved in developing lighting design guidelines, climate action plan, and building performance evaluation.

Before joining the Laboratory, Dr. Wang was a Building Energy Analyst at the Smart Energy Design Assistance Center in Champaign, IL, providing advice and analyses to increase private and public facilities' economic viability through the efficient use of energy resources. Dr. Wang was the chief architect and student leader of the Illinois team entry for the 2007 Solar Decathlon competition and led the team to win two contests in Washington, D.C. She was also a visiting lecturer, teaching design studio in the School of Architecture, University of Illinois at Urbana-Champaign.

Research Interests

- Daylighting technology analysis and design application
- Human behavioral impacts on building performance
- Economic analysis of energy efficiency

Education

- Ph.D. (Architecture), University of Illinois at Urbana-Champaign
- M.A. (Architecture), National University of Singapore
- B.Arch., Tianjin University, China



Weimin Wang

Scientist

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Biography

Weimin Wang has been working as a Staff Scientist at Pacific Northwest National Laboratory since August 2008. Before joining PNNL, he worked as an NSERC visiting research fellow at Natural Resources Canada for two years. He has served as a technical contributor in several DOE-funded projects including building energy code development, advanced energy design guide for buildings, and commercial building National Accounts. With about eight years of research on building performance simulation program development and applications, Dr. Wang has extensive experiences of energy system modeling and simulation-based optimization for sustainable building design.

Research Interests

- Building performance simulation
- Building integrated renewable energy modeling and technology
- Advanced use of building simulation programs such as design optimization, decision support, and web-based simulation support
- Smart materials and products for building envelope
- Building life-cycle assessment education

Education

- Ph.D. Building Engineering, Concordia University, Canada
- M.E. Construction Economics and Management, Tongji University, China
- B.E. Agricultural Building and Environmental Engineering, Shenyang Agricultural University, China



David Winiarski

Engineer

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Biography

David Winiarski is a senior research engineer at Pacific Northwest National Laboratory with experience in experimental design, set-up, and operation of end-use energy metering and monitoring projects and subsequent performance analysis of large and small commercial HVAC systems and residential hot water systems.

Research Interests

- Experienced user of large scale building simulation programs (BLAST and DOE2.1), as well as statistical energy modeling methods including PRISM analysis
- Experienced with developing models of residential shell loads based on first principles and calibrating models with measured data. In addition, experienced in performing energy audits of commercial buildings and industrial processes.

Education

- M.S. Mechanical Engineering, Texas A&M University, 1992
- B.A./B.S. Physics, Oregon State University, 1983



YuLong Xie

Scientist

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Fax: 509/375-2379

Biography

YuLong Xie is a data analyst and an applied statistician. He has more than 15 years of experience in data analysis and data mining, multivariate statistics, stochastic simulation, spatial statistics, and optimization. Since joining PNNL in 2000, he has contributed to a variety of projects including simulation support to building energy codes and standards, evaluation of energy efficiency technology, source/receptor relationships of ambient air pollutants, geostatistical subsurface characterization of waste sites like Hanford, and Monte Carlo simulation of energy cascades of Gamma-Ray interaction with materials. Dr. Xie has authored/co-authored over 70 peer-reviewed journal articles and book chapters, and contributed many technical reports and conference papers.

Research Interests

- Building Energy Simulation and Energy Codes Development
- Analysis and Evaluation of Energy Efficiency Technology
- Statistical Analysis and Data Mining, Monte Carlo Simulation and Optimization
- Source/Receptor Relationships of Ambient Air Pollutants
- Geostatistics and Spatial Modeling
- Neural Networks, Simulated Annealing, and Genetic Algorithm

Education

- Ph.D. Analytical Chemistry (Chemometrics), Hunan University, China, 1993
- M.S. Analytical Chemistry, Hunan University, China, 1988
- B.S. Chemistry, Xiangtan University, China, 1979



Jian Zhang

Engineer

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Fax: 509/375-2379

Biography

Jian Zhang has been with PNNL as a research engineer since July 2009. He is involved in the Building Energy Codes Program for improving building energy standard ASHREA 90.1 and other energy-efficient commercial building design and analysis projects. Before joining PNNL, he had contributed to several national and international research projects during his graduate studies including IEA-ECBCS Annex 44, integrating environmentally responsive elements in buildings, and moisture control for exterior wall systems. Dr. Zhang has also worked as a thermal analyst in a Canadian railway engineering consulting firm.

Research Interests

- Design and analysis of energy-efficient buildings
- Building energy performance simulation
- Building-integrated renewable energy systems
- Fundamental research in air flow and heat transfer and its applications in buildings

Education

- Ph.D. Building Engineering, Concordia University, Canada, 2009
- M.A.Sc. Building Engineering, Concordia University, Canada, 2003
- Building Engineering Heating Ventilation and Air Conditioning Engineering, Shenyang University, China, 2000

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NATIONAL LABORATORY

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