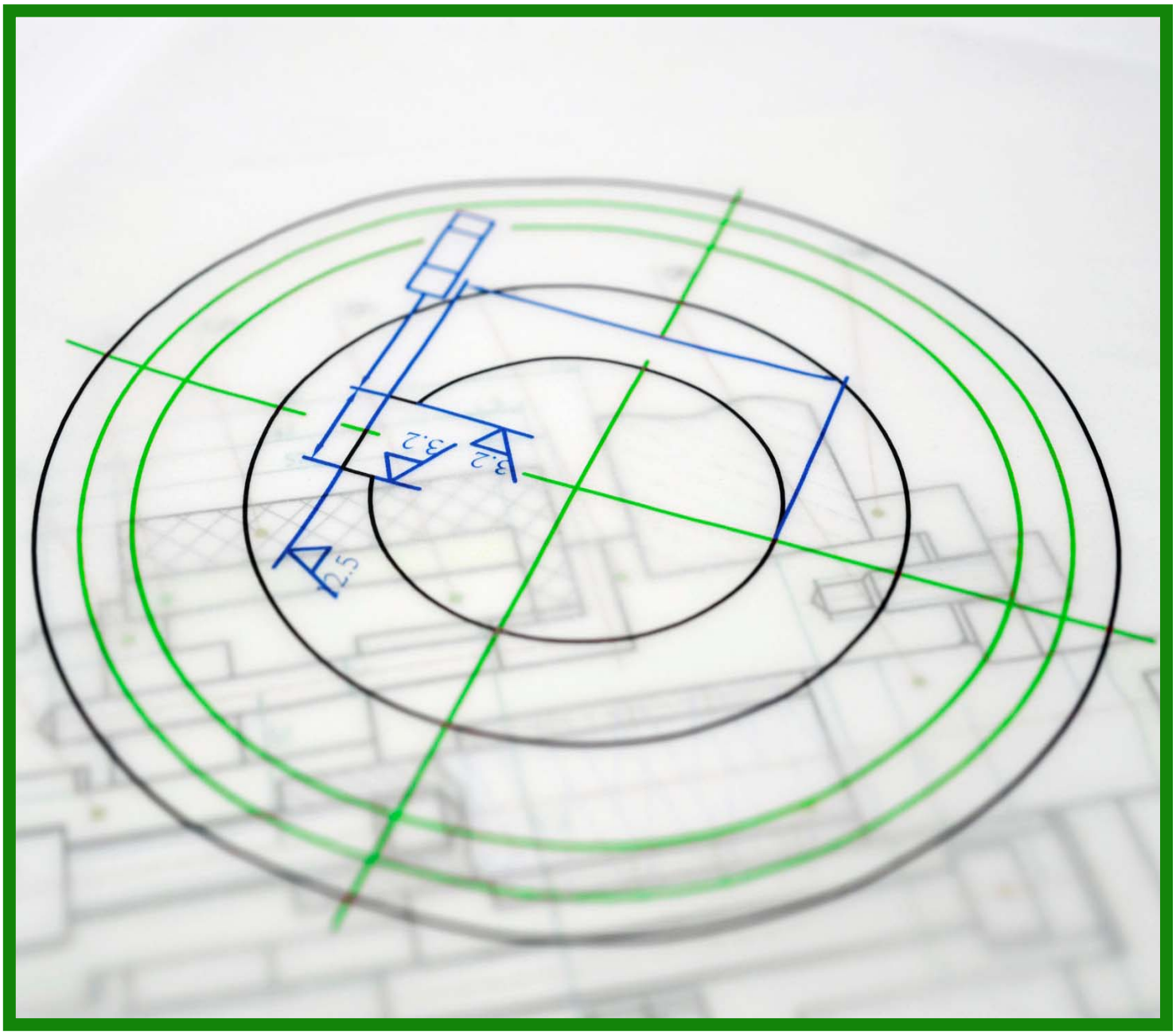


March 2013

National Energy Efficiency Technology Roadmap Portfolio

Appendix B: Existing R&D Projects

Enhanced PDF Functionality

Functionality of the PDF version of this document has been enhanced in the following ways:

- **Bookmarks:** Enabled PDF reader applications (i.e., Adobe Acrobat) can navigate this document using the Bookmark feature.
- **Embedded Links:** The Table of Contents has been linked to the appropriate sections of the document.
- **"Back to Table of Contents":** In the footer of each evenly-numbered page is an embedded hyperlink back to the Table of Contents.
- **Control + F:** As always, one can navigate through the document by searching for specific words or phrases by pressing the "Control" and "F" keys simultaneously.

Table of Contents

Introduction

This appendix to the *National Energy Efficiency Technology Roadmap Portfolio*—"Appendix B"—provides a centralized, concise source of information about current research and development being done in areas of interest to stakeholders.

Each individual roadmap in the portfolio contains an accompanying "R&D Project Summaries" page providing additional information and website links to ongoing or recently completed research and development projects. When applicable, these summary statements refer readers to "Appendix B," this appendix of existing R&D programs.

Bonneville Power Administration staff, with essential input and guidance from a wide range of regional stakeholders and subject matter experts, created the first version of the *Roadmap Portfolio* in 2010, and the resource continues to be revised as a live, working document. This R&D appendix first appeared in March 2012. Like the *Roadmap Portfolio*, this appendix is an evolving document and reflects our best knowledge as of the date of publication.

For electronic versions of these documents, see http://www.bpa.gov/energy/n/emerging_technology/.

The March 2013 version of Appendix B benefitted from extensive content analysis and refinement from Sarah Inwood and Bienvenido (Ben) Clarin of the Electric Power Research Institute.

Appendix B Project Team

Project Manager

James V. Hillegas-Elting, Bonneville Power Administration (Nov. 2012–Present)

Joshua Binus, Bonneville Power Administration (March 2011–Nov. 2012)

Project Coordinator

James V. Hillegas-Elting, Bonneville Power Administration (Dec. 2011–Nov. 2012)

Research Assistance & Content Analysis

Sarah Inwood & Bienvenido (Ben) Clarin, Electric Power Research Institute

Ibrahim Iskin, Portland State University, Department of Engineering and Technology Management

Peter Criscione, Katie Elliott, Mary Horsey, Bryan Jungers, Leland Keller, Ira Krepchin, Andrea Patterson, Essie Snell, Jay Stein, & Tim Stout, E Source

Content Input

See complete list of workshop participants in the National Energy Efficiency Technology Roadmap Portfolio.

Graphics & Design

David Moody, Bonneville Power Administration

For more information about the National Energy Efficiency Technology Roadmap Portfolio, contact:

James V. Hillegas-Elting
jvhillegas@bpa.gov
503.230.5327

How to Use and Navigate Appendix B

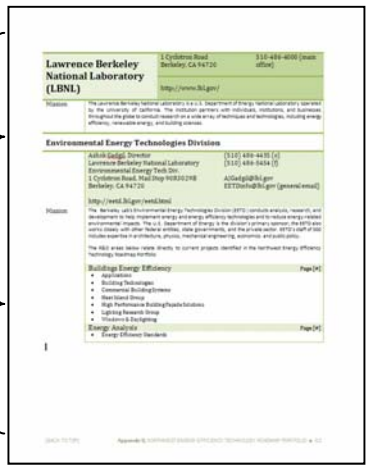
Appendix B is organized in a “nested” or “tiered” fashion that enable readers, at a glance, to :

- Gain a broad understanding of the institution managing the listed research projects;
- Learn how a given research project fits within the context of other institutional projects; and
- Navigate the document efficiently to find information about specific research projects.

To accomplish these goals, individual research and development programs are listed under their respective institutions, within three categories of interrelated pages, as outlined on the following page.

Institutional Pages

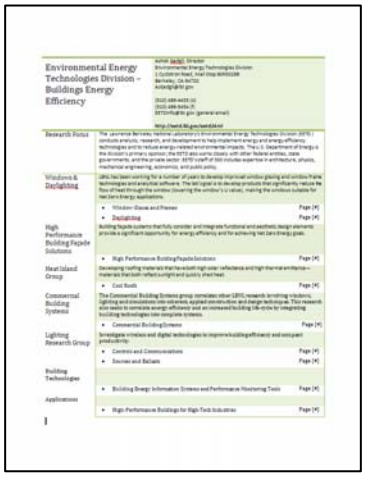
- These pages identify the institution or organization conducting the research.
- The pages also identified the applicable divisions, departments, or other second-tier sub-groups within the institution.
- Under the headings of each division or department are listed the research groups working on one or more current R&D programs identified in the *Roadmap Portfolio*.



Research Group Pages

- Each research group title listed on the Institutional Page is featured in its own Research Group Page. These pages provide a brief overview of the broader work of the group.
- Following this overview is a listing of the specific projects of this group.

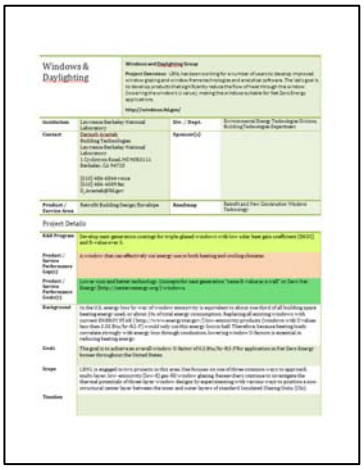
Note: Smaller organizations may not have a distinct Research Group Page; in these cases, the Institutional Page will flow directly into R&D Program Page(s)



Level of detail on a given research project **increases**

R&D Program Pages

- R&D Program Pages takes the level of detail of the Research Group Page to its final step by providing an overview of the relevant details of individual R&D projects identified in individual roadmaps within the full portfolio.



[Back to Table of Contents]

Energy Efficiency Technology Research & Development Institution List

On the pages that follow is a list of selected international institutions doing work in energy efficiency technology research & development within one or more product and service areas covered in the *National Energy Efficiency Technology Roadmap Portfolio*.

This information is compiled for informational and reference purposes only. While compilers of the *Roadmap Portfolio* have the goal of being as thorough as possible, this list is subject to revision and is not intended to be exhaustive. Further, inclusion or exclusion of any specific institution does not constitute endorsement—or lack of endorsement—of the institution, individual staff members, or the research being done.

Organization/ Program	Parent Institution	Location	Website
Advanced Research Projects Agency-Energy (ARPA-E)	U.S. Department of Energy (DOE)	Washington, DC	http://arpa-e.energy.gov/
Air Conditioning, Heating, and Refrigeration Institute (AHRI)		Arlington, VA	http://www.ahrinet.org/default.aspx
American Society of Heating, Refrigerating, & Air-Conditioning Engineers (ASHRAE)		Atlanta, GA	http://www.ashrae.org/
Ames Laboratory	U.S. Department of Energy (DOE), with Iowa State University	Ames, IA	http://www.ameslab.gov/
Argonne National Laboratory	U.S. Department of Energy (DOE), with UChicago Argonne, LLC	Argonne, IL	http://www.anl.gov/energy
Brookhaven National Laboratory (BNL)	U.S. Department of Energy (DOE), with Stony Brook University and Battelle Memorial Institute	Upton, NY	http://www.bnl.gov/world/
California Energy Technology Systems Integration (ETSI) Program	California Energy Commission (CEC) Energy Research and Development Division	Sacramento, CA	http://www.energy.ca.gov/research/integration/index.html
California Lighting Technology Center (CLTC)	University of California Davis	Davis, CA	http://cltc.ucdavis.edu/
California Public Interest Energy Research (PIER) Program	California Energy Commission (CEC) Energy Research and Development Division	Sacramento, CA	http://www.energy.ca.gov/research/index.html
CanmetENERGY	Natural Resources Canada (NRCAN)	Ottawa, ON	http://canmetenergy.nrcan.gc.ca/home
Center for the Built Environment (CBE)	University of California Berkeley	Berkeley, CA	http://www.cbe.berkeley.edu/research/briefs-ufadmodel.htm
Cornell University Program of Computer Graphics	Cornell University	Ithaca, NY	http://www.graphics.cornell.edu/
E Source		Boulder, CO	http://www.esource.com/
Electric Power Research Institute (EPRI)		Palo Alto, CA	http://my.epri.com/portal/server.pt?
EMerge Alliance		San Ramon, CA	http://www.emergealliance.org/
Energy Efficient Buildings Hub (EEB Hub)	The Pennsylvania State University	Philadelphia, PA	http://www.eebhub.org/
European Centre and Laboratories for Energy Efficiency Research (ELCEER)		France	http://www.ecleer.com/

Organization/ Program	Parent Institution	Location	Website
Government of Canada Office of Research and Development (OERD)	Government of Canada	Ottawa, ON	http://www.nrcan.gc.ca/energy/science/programs-funding/1509
Industrial Technology Research Institute (ITRI)		Chutung, Hsinchu, Taiwan	http://www.itri.org.tw/eng/
Institute for Energy Efficiency (IEE)	University of California Santa Barbara (UCSB)	Santa Barbara, CA	http://iee.ucsb.edu/
Intel Labs	Intel Corporation	Santa Clara, CA	http://www.intel.com/content/www/us/en/research/intel-research.html
Lawrence Berkeley National Laboratory (LBNL)	U.S. Department of Energy (DOE), with the University of California	Berkeley, CA	http://www.lbl.gov/
Lighting Research Center (LRC)	Rensselaer Polytechnic Institute	Troy, NY	http://www.lrc.rpi.edu/
Los Alamos National Laboratory (LANL)	U.S. Department of Energy (DOE), with Los Alamos National Security, LLC	Los Alamos, NM	http://www.lanl.gov/
Microsoft Research	Microsoft Corporation	Seattle, WA	http://research.microsoft.com/en-us/
MIT Building Technology Research Program	Massachusetts Institute of Technology (MIT)	Cambridge, MA	http://web.mit.edu/bt/www/bt/Research.html
MIT Electrochemical Energy Laboratory	Massachusetts Institute of Technology (MIT)	Cambridge, MA	http://web.mit.edu/eel/
MIT Concrete Sustainability Hub	Massachusetts Institute of Technology (MIT)	Cambridge, MA	http://web.mit.edu/cshub/
MIT Media Laboratory	Massachusetts Institute of Technology (MIT)	Cambridge, MA	http://www.media.mit.edu/
National Energy Technology Laboratory (NETL)	U.S. Department of Energy (DOE)	Morgantown, WV	http://www.netl.doe.gov/
National Institute of Standards and Technology (NIST)	U.S. Department of Commerce	Gaithersburg, MD	http://www.nist.gov/index.html
National Renewable Energy Laboratory (NREL)	U.S. Department of Energy (DOE)	Washington, DC, and Golden, CO	http://www.nrel.gov/
New York State Energy Research and Development Authority (NYSERDA)	State of New York	Albany, NY	http://www.nyserda.ny.gov/
Oak Ridge National Laboratory (ORNL)	U.S. Department of Energy (DOE), with UT-Battelle, LLC	Oak Ridge, TN	http://www.ornl.gov/
Office of Energy Efficiency & Renewable Energy (EERE)	U.S. Department of Energy (DOE), with the Alliance for Sustainable Energy, LLC	Washington, DC	http://www.eere.energy.gov/

Organization / Program	Parent Institution	Location	Website
Pacific Northwest National Laboratory (PNNL)	U.S. Department of Energy (DOE), with Battelle Memorial Institute	Richland, WA	http://www.pnl.gov/
Precourt Energy Efficiency Center (PEEC)	Stanford University	Stanford, CA	http://peec.stanford.edu/index.php
Rocky Mountain Institute (RMI)		Snowmass, CO	http://www.rmi.org/
Toyota Housing Corporation	Toyota Motor Corporation	Nagoya City, Japan	http://www.toyota-global.com/company/profile/non_automotive_business/
UCSD Computer Science and Engineering Department	University of California San Diego (UCSD)	San Diego, CA	http://www.cs.ucsd.edu/
Western Cooling Efficiency Center (WCEC)	University of California Davis	Davis, CA	http://wcec.ucdavis.edu/

Research & Development Institution & Project Listings

Brookhaven National Laboratory (BNL)

P.O. Box 5000
Upton, NY 11973-5000

(631) 344-8000 (o)

http://www.bnl.gov/world/

Mission	Staff and scientists at Brookhaven National Laboratory (BNL) conduct research in the physical, biomedical, and environmental sciences, national security, and energy technologies. BNL is one of ten national laboratories primarily funded by the DOE's Office of Science (http://science.energy.gov/), and is overseen by Brookhaven Science Associates, a partnership between Battelle (http://battelle.org/) and Stony Brook University of New York (http://www.stonybrook.edu/). Two BNL departments are doing work of relevance to the Northwest Energy Efficiency Technology Roadmap Portfolio, the Center for Functional Nanomaterials (http://www.bnl.gov/cfn/) and the Sustainable Energy Technologies Department (within the Global and Regional Solutions Directorate, http://www.bnl.gov/GARS/).

Center for Functional Nanomaterials

User Administration Office
Brookhaven National Laboratory
P.O. Box 5000, Bldg. 735
Upton, NY 11973-5000

(631) 344-NANO (6266) (o)
(631) 344-7072 (f)
cfnuser@bnl.gov

http://www.bnl.gov/cfn/

Mission	Research in this area focuses on developing and understanding nanoscale materials to facilitate atomic-level tailoring to achieve desired properties and functions that help achieve the DOE's energy security goals.

Soft and Biological Nanomaterials

Page 4

- Transparent thin-film photovoltaic materials

Soft and Biological Nanomaterials

Oleg Gang
P.O. Box 5000
Upton, NY 11973-5000

(631) 344-3645 (o)

ogang@bnl.gov

http://www.bnl.gov/cfn/research/Soft_and_Biological_Materials.asp

Research Focus	Develop methods to assemble hybrid nanoscale systems from organic and inorganic components and increase understanding of science behind nanoscale structure formation and energy-conversion properties to produce functional optical, electrical, magnetic and bio-sensing materials.
Transparent thin-film photovoltaic materials	By applying a thin, clear photovoltaic (PV) film on windows, power can be generated to help buildings achieve Net Zero Energy goals.

Transparent thin-film photovoltaic materials

Soft and Biological Nanomaterials

Project Overview: By applying a thin, clear photovoltaic (PV) film on windows, power can be generated to help buildings achieve Net Zero Energy goals.

http://www.bnl.gov/cfn/research/Soft_and_Biological_Materials.asp

Institution	Brookhaven National Laboratory	**Div. / Dept.**	Center for Functional Nanomaterials
Contact	Andy Shreve, Thrust Leader Soft, Biological and Composite Nanomaterials Los Alamos National Laboratory MPA-CINT, MS K771 Los Alamos, NM 87545 (505) 667-6933 (o) (505) 665-9030 (f) shreve@lanl.gov	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Fenestration & Daylighting

Project Details

R&D Program	Integration of glazing and PV coating.
Technology Characteristics	Self-powered electrochromic-photovoltaic windows. Net energy producing skylights. PV-integrated window shades.
Capability Gap(s)	Need to address seamless photovoltaic integration into fenestration. Need lower costs. Need to address electrochromic issues such as cost, life, performance.
Driver(s)	More and cheaper products due to globalization of manufacturing. Achieve energy savings. Reduced call backs / warranty, increased durability. Can not get high performance buildings without daylighting. Achieve energy savings. Increase window and skylight area. Increase occupant health, comfort and safety.
Background	Researchers have fabricated nanonmaterials into transparent thin films capable of absorbing light and generating electric charge over a relatively large area.
Goals	This material might be useful in developing transparent solar panels or windows that can absorb solar energy and generate electricity, thereby improving building energy efficiency.
Scope	Honeycomb-patterned transparent thin films have been constructed using semiconductors and fullerenes to absorb light, generate charge, and efficiently separate the charge. Developing larger, cost-effective sheets of this film would enable material to be used in a wide array of applications.
Timeline	

Continued . . .

Brookhaven National Laboratory

Milestones & Publications	Tsai, Hsinhan; Xu, Zhihua; Pai, Ranjith Krishna; Wang , Leeyih; Dattelbaum, Andrew M.; Shreve, Andrew P.; Wang, Hsing-Lin; and Cotlet, Mircea (2011, Nov.). "Structural Dynamics and Charge Transfer via Complexation with Fullerene in Large Area Conjugated Polymer Honeycomb Thin Films." *Chemistry of Materials* 23:3, pp. 759-761.
Budget	
Other parties involved	Los Alamos National Laboratory (http://www.lanl.gov/source/orgs/mpa/cint/science_thrusts.shtml).
Next steps	Continue testing to determine feasibility of creating larger sheets of thin nanonmaterial for practical applications such as flexible organic solar cells.
Associated R&D strategy	
References	Brookhaven National Laboratory (2010, Nov. 3). "Transparent Conductive Material Could Lead to Power-Generating Windows." Physorg.com. http://www.physorg.com/news/2010-11-transparent-material-power-generating-windows.html, accessed Jan. 17, 2012. Brookhaven National Laboratory (2010). "Soft and Biological Nanomaterials." http://www.bnl.gov/cfn/research/Soft_and_Biological_Materials.asp, accessed Dec. 14, 2011. Tsai, Hsinhan; Xu, Zhihua; Pai, Ranjith Krishna; Wang , Leeyih; Dattelbaum, Andrew M.; Shreve, Andrew P.; Wang, Hsing-Lin; and Cotlet, Mircea (2011, Nov.). "Structural Dynamics and Charge Transfer via Complexation with Fullerene in Large Area Conjugated Polymer Honeycomb Thin Films." *Chemistry of Materials* 23:3, pp. 759-761.

California Energy Commission (CEC)

California Energy Commission
Media and Public Communications Office
1516 Ninth Street, MS-29
Sacramento, CA 95814-5512

http://www.energy.ca.gov/

(916) 654-4287 (o)

mediaoffice@energy.state.ca.us

Mission	The California State Legislature created the California Energy Commission in 1974 to serve as the state's primary energy policy and planning agency. In addition to forecasting energy needs, licensing power plants, and providing contingency planning, the Commission also promotes energy efficiency, provides public interest energy research, and develops alternative and renewable fuel programs.

Energy Research and Development Division

Laurie ten Hope, Deputy Director
Energy Research & Development Division
California Energy Commission
1516 Ninth Street, MS-29
Sacramento, CA 95814-5512

http://www.energy.ca.gov/research/index.html

(916) 327-1521 (o)

Ltenhope @ energy.state.ca.us

Mission

The work of the California Energy Commission's Energy Research and Development Division helps provide a reliable and affordable electricity supply by assisting in demand side management and providing research, development, and testing of new technologies. The division also provides grants and contracts to spur research and development of energy technologies and systems. Programs directly related to the Northwest Energy Efficiency Roadmap Portfolio include:

Energy Technology Systems Integration (ETSI) Program

Mike Gravely
Energy Systems Research
California Energy Commission
1516 Ninth Street, MS 43
Sacramento, CA 95814-5512

(916) 327-1370 (o)
MGravely@energy.state.ca.us

http://www.energy.ca.gov/research/integration/index.html

Research Focus	Supports interdisciplinary, systems approach to development of efficient, affordable, and reliable energy services and products that integrate fully within the California grid. The ETSI program also funds Public Interest Energy Research (PIER) projects.
Energy Innovation Small Grants Program (EISG)	Program offers research grants to small businesses, non-profits, individuals, and academic institutions working to establish the product and system concept feasibility. Funded projects must target a PIER-identified need, address a pressing California energy issue, and provide a potential ratepayer benefit.
	• *[R&D projects not yet identified]*

Public Interest Energy Research (PIER) Program

Panama Bartholomy
Deputy Director
California Energy Commission
1516 Ninth Street, MS-29
Sacramento, CA 95814-5512

(916) 654-5013 (o)

pbarthol @ energy.state.ca.us

http://www.energy.ca.gov/research/index.html

Research Focus	Works with businesses, utilities, energy companies, public advocacy groups, and scientists at California's universities and national laboratories to advance science and technology in a variety of energy-related fields, including advanced electricity technologies and energy efficiency. Efforts are part of California's "Energy Efficiency Standards for Residential and Nonresidential Buildings" (Title 24, Part 6, California Code of Regulations, http://www.energy.ca.gov/title24/). Research is funded by the Energy Innovation Small Grants Program (EISG) under the Energy Research and Development Division's Energy Technology Systems Integration (ETSI) Program (http://www.energy.ca.gov/research/integration/index.html).
Buildings End-Use Energy Efficiency Research	Research and development to provide energy-efficient technologies and systems for appliances and for new and retrofitted buildings to help California achieve Net Zero Energy (http://netzeroenergy.org/) residential buildings by 2020 and commercial buildings by 2030. (http://www.energy.ca.gov/research/buildings/index.html). Broad study areas include Lighting; Heating, Ventilation, and Air Conditioning; Equipment, Appliances and Plug Loads; Whole Building and Envelope; and Codes and Standards. The following specific projects relate to the Northwest Energy Efficiency Roadmap Portfolio: • Development of Diagnostic, Measurement and Verification Tools for Commercial Buildings — Page 10 • Improved Insulation for Buildings and Refrigeration — Page 12 • Sweet SPOT™ for Daylighting — Page 13
Data Centers Research	Projects to improve efficiency at data centers, including cooling systems, construction planning, and daily operation. Research conducted under the aegis of PIER's Industrial, Agriculture and Water Research program (http://www.energy.ca.gov/research/iaw/datacenter.html). • *[R&D projects not yet identified]*

Development of Diagnostic, Measurement and Verification Tools for Commercial Buildings

Public Interest Energy Research (PIER) Program

Project Overview: Develop tools and methods to integrate HVAC fault detection and diagnostics software to drive energy efficiency and improve reliability.

http://www.energy.ca.gov/research/buildings/index.html

Institution	California Energy Commission	**Div. / Dept.**	Energy Research and Development Division
Contact	Chris Scruton 1516 9th St, MS 49 Sacramento, CA 95814-5512 (916) 327-2341 (o) cscruton@energy.state.ca.us	**Sponsor(s)**	
Product / Service Area	Sensors, Meters, Energy Management Systems	**Roadmap**	Low-Cost Savings Verification Techniques

Project Details

R&D Program	M&V project for universal software.
Technology Characteristics	Software tools to implement International Performance Measurement and Verification Protocols (IPMVP) and other more specific M&V protocols
Capability Gap(s)	Need to be able to attribute energy performance improvements and effects. Need to leverage building management systems and analytics to verify system performance for M&V. Need to improve standardization and specificity of M&V protocols and tools.
Driver(s)	Increasing development and availability of analytics / intelligent systems. about cost of measurement and verification. Demand by utilities and owner for measurement based verification. Justification of DSM investment. Business drivers to decrease cost and increase productivity. Push for performance based procurement.
Background	Building HVAC systems routinely fail to meet performance expectations, and these shortcomings are not always detected in a timely manner, which increases energy consumption. Fault detection & diagnostics (FDD) methods that have been developed are not integrated with common analytical tools, which means that it's difficult to get reliable measurements from complex systems. There is also a lack of consensus standards for energy analysis. The result is that economic benefits of many types of efficiency measures are difficult to prove, and energy efficiency investments difficult to justify. PG&E's Universal Translator (http://www.pge.com/mybusiness/edusafety/training/pec/toolbox/tll/software.shtml, http://utonline.org/cms/) offers the potential of integrating diagnostic technology and energy analysis but the tool's architecture makes it difficult to add functions. Improved HVAC FDD tools for California commercial buildings can potentially reduce electricity consumption by about 3,800 GWh/yr and gas consumption by about 97 Mtherms/yr, and reduce peak electricity demand by about 1.5 GW.
Goals	The goals of this project are: 1) develop tools and methods to: a) reduce M&V difficulty; b) improve fault detection and diagnostics for dual duct systems and fan coil equipment ; 3) characterize fan and duct system performance; 2) devise, implement, and evaluate a generic Application Programming Interface (API) for the Universal Translator tool.

Continued . . .

Scope	Develop tools and methods to enhance PG&E's Universal Translator software.
Timeline	Agreement between CEC and LBNL finalized Dec. 16, 2008. Chris Scruton reported via email on Jan. 31, 2012: "No major outcomes yet, but it's moving."
Milestones & Publications	
Budget	$1,959,879 for 36 months as of Dec. 16, 2008.
Other parties involved	Lawrence Berkeley National Laboratory.
Next steps	
Associated R&D strategy	This R&D project addresses Warren-Alquist Act section 25620.1 stipulating that the PIER program shall include a full range of RD&D activities not adequately provided for by markets. It also is in accord with the goals of the California Integrated Energy Policy Report 2005 to increase energy efficiency.
References	Scruton, Chris (2008, Dec. 16). "Agreement between California Energy Commission and DOE- Lawrence Berkeley National Laboratory." Lawrence Berkeley National Laboratory (2009, July 15). "Exhibit A – Scope of Work."

Improved Insulation for Buildings and Refrigeration

Public Interest Energy Research (PIER) Program

Project Overview: Research to pursue the feasibility of developing a hydrophobic, easy to manufacture a ceramic insulation made with perlite and other materials. 500-98-014 Project # 72 in Palm Springs, CA.

http://www.energy.ca.gov/pier/portfolio/Content/06/EISG/Improved%20Insulation%20for%20Buildings.htm

Institution	California Energy Commission	**Div. / Dept.**	Energy Research and Development Division
Contact	David Michel III Energy Systems Research Office Energy Innovations Small Grant Prog. (916) 651-9381 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	New Construction Insulation

Project Details

R&D Program	Application technology "easy and cheap."
Technology Characteristics	Adapt code language for attaching cladding insulating sheathing to framing. Cost effective insulation materials. Thermal performance measurement techniques, innovative new materials.
Capability Gap(s)	Cladding attachment systems (e.g. residential siding over foam). Need affordable, widely available construction materials with outstanding insulating characteristics. Need to be easier to install. Need better modeling / technology. Development of tests and protocols to assess thermal insulation.
Driver(s)	Increase occupant health, comfort and safety. Need cost effective energy efficiency programs. Need for cost effective assessment of structures. More and cheaper products due to globalization of manufacturing. Reduced call backs/warranty, increased durability. Poor performing curtain walls. Use of codes to lock in efficiency gains.
Background	Prior research concluded that a highly efficient ceramic insulation product could be made with perlite and other materials. This insulation would be useful for both building and refrigeration systems. To be widely useful, the product should be hydrophobic, easy to manufacture, and have mechanical properties to make it marketable.
Goals	Project goals include using low cost materials to make a high efficiency insulating material; demonstrating that perlite helps increase insulation efficiency beyond current materials; and showing that a cost-effective product can be produced easily.
Scope	
Timeline	
Milestones & Publications	As of April 2008, project was still active.
Budget	
Other parties involved	Jeffrey Zuker, contractor.
Next steps	
Associated R&D strategy	Efforts are part of California's Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24, Part 6, California Code of Regulations, http://www.energy.ca.gov/title24/).
References	California Energy Commission Public Interest Energy Research (PIER) Program (2008). "Improved Insulation for Buildings and Refrigeration." http://www.energy.ca.gov/pier/portfolio/Content/06/EISG/Improved%20Insulation%20for%20Buildings.htm, accessed Jan. 12, 2012.

Sweet SPOT™ for Daylighting

Public Interest Energy Research (PIER) Program

Project Overview: Developing and enhancing the Sensor Placement Orientation Tool (SPOT™) software tool to help designers in the proper placement of light sensors, and to analyze and predict system performance.

http://www.energy.ca.gov/2005publications/CEC-500-2005-178/CEC-500-2005-178-FS.PDF

Institution	California Energy Commission	**Div. / Dept.**	Energy Research and Development Division
Contact		**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Software for daylight design – sensor placement.
Technology Characteristics	Sensors & Control Systems.
Capability Gap(s)	Need responsive and reliable controls and photo sensors for daylighting. Need applications that can utilize natural light. Need methods to compensate for daylight color shift, glare, intensity, focus. Need to have applications easier to design, commission and operate.
Driver(s)	Energy security. Climate change. Increased consumer resistance to complex features and controls. Optimize human performance (health, productivity). Optimize work environment for using computers of the future keep up as computers evolve. End user comfort / satisfaction. Aesthetics. Increase in available funding for EE. Increased interest among legislators in efficiency and renewables. Consumer desire to be "green" and reduce embedded & used energy.
Background	Daylighting systems have significant energy efficiency potential, but only if sensors are placed in the correct locations for each situation. There are a lack of adequate daylighting system design software tools available to aid in deployment of the most effective daylighting layouts.
Goals	To help designers comply with California's Title 24 energy code by creating an easy-to-use, MS Excel worksheet with calculations done by the Radiance software program.
Scope	The tool provides customized design layouts based on user input including room geometry, surface reflections, solar orientation, electric lighting layout, and window design.
Timeline	SPOT™ was available in the marketplace as of late 2005, but with some limitations; future versions are to allow for input of complex-geometry interior spaces and interface with a database of manufacturer product specifications.
Milestones & Publications	First iteration of tool available in marketplace in late 2005.
Budget	
Other parties involved	Architectural Energy Corporation (http://www.archenergy.com/) developed the software.
Next steps	As of late 2005, work continued on enhancing features and functionality of the SPOT™ tool.
Associated R&D strategy	Efforts are part of California's Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24, Part 6, California Code of Regulations, http://www.energy.ca.gov/title24/).
References	California Energy Commission Public Interest Energy Research (PIER) Program (2005, Dec. 23). "Sweet SPOT™ for Daylighting." http://www.energy.ca.gov/2005publications/CEC-500-2005-178/CEC-500-2005-178-FS.PDF, accessed Jan. 12, 2012.

Cornell University

Day Hall Lobby
Cornell University
Ithaca, NY 14853

(607)254-4636 (o)
(607)255-5396 (f)

info@cornell.edu

http://www.cornell.edu/

Mission	Cornell is both a private university and the land-grant institution of New York State composed of 11 undergraduate, graduate, and professional schools.

Program of Computer Graphics

Dr. Donald P. Greenberg, Director
580 Rhodes Hall
Cornell University
Ithaca, NY 14853

(607) 255-7444 (o)
(607) 255-0806 (f)
dpg@graphics.cornell.edu

http://www.graphics.cornell.edu/

Mission	Program provides interdisciplinary education, research, and development in graphics, digital arts, and related areas. Departments represented include Computer Science, Computing & Information Science, Architecture, and Mechanical & Aerospace Engineering. Green building design software development team comprised of faculty from computer science, mechanical engineering and architecture departments.

Green Building Design Computer Simulation Software Page 16

Cornell University

Green Building Design Computer Simulation Software	**Program of Computer Graphics** **Project Overview:** Interdisciplinary software design project to build more accurate and dynamic modeling and simulation tool that couples buildings to their environments so as to reduce energy use and the buildings' carbon footprints. **http://www.graphics.cornell.edu/**

Institution	Cornell University	**Div. / Dept.**	Program of Computer Graphics
Contact	Dr. Donald P. Greenberg, Director 580 Rhodes Hall Cornell University Ithaca, NY 14853 (607) 255-7444 (o) (607) 255-0806 (f) dpg@graphics.cornell.edu	**Sponsor(s)**	
Product / Service Area	Building / Envelope	**Roadmap**	Zero Net Energy Buildings
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab and Field Testing

Project Details

R&D Program	Predictive modeling for control.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
R&D Program	Need more accurate modeling to compare systems more easily.
Technology Characteristics	Improved building energy simulation software with parametric analysis capabilities to model more accurately variations in real-world operating conditions. Building simulation software.
Capability Gap(s)	Need to reduce high energy use to distribute heating and cooling beyond the actual vent need. Need to optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, and heat recovery. Need to tie model to building needs / loads. Need benchmarking categories at end use level; to improve modeling and better represent real world conditions. Need to account for large number of variables in building modeling, standards, and training. Current energy modeling engines under development by DOE (energy +) do not have wide market adoption because perceived to be too detailed, too difficult to use - and hence to expensive to use. Tools for accelerating inputs, and accelerating computation time(2 minutes or less) are needed.
Driver(s)	Electric utility need for resources to meet growing loads, and/or to replace oil and coal fired power plants. Consumer demand for reduced / low cost of utilities / operation. IAQ separate ventilation from HVAC loads / equipment. Need to understand where energy savings can be achieved and demonstrate actual. Validation of performance of new HVAC technologies through utility field test. Reduced first cost of new systems / design. Need to understand where energy savings can be achieved and demonstrate actual.

Continued . . .

Background	The process of designing sustainable buildings is in need of streamlining so as to reduce the need for engineers to implement post-design fixes such as modifying building orientation and ventilation systems.
Goals	To improve accuracy and accelerate computation simulation methodology of a simulation tool that couples buildings to their environments so as to reduce energy use and the buildings' carbon footprints. Incorporate this simulation tool to current CAD software packages. Long term goal is to use codes to reflect simulation performance as contrasted to prospective metrics to evaluate LEED certifications.
Scope	To refine a 3-D simulation tool that enables designers to incorporate at the start of the design process complex, site-specific dynamics such as radiant energy, shading devices, shadows, and other environmental effects to make building modeling more accurate and help cut down on consultation and labor expenses.
Timeline	The Cornell Center for a Sustainable Future Academic Venture Fund provided initial funding in 2008.
Milestones & Publications	Program now functions on a cloud of computers at Cornell's Program of Computer Graphics running multiple parallel simulations. Nathaniel L. Jones and Donald P. Greenberg, "Fast Computation of Incident Solar Radiation From Preliminary to Final Building Design, " *Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, Sydney*, Nov. 14-16, 2011, http://www.ibpsa.org/proceedings/BS2011/P_1271.pdf, accessed Sep. 11, 2012.
Budget	$1.83 million grant from the Department of Energy (using American Recovery and Reinvestment Act (ARRA) funds) that will support seven years of student research and two postdoctoral associate positions.
Other parties involved	
Next steps	
Associated R&D strategy	
References	Ju, Anne (2010, Sep. 29). "Computer Graphics to help Streamline Green Building Design." *Cornell Chronicle*. http://www.news.cornell.edu/stories/Sept10/SustBuilding.html, accessed Feb. 14, 2012.

Cornell University

Electric Power Research Institute (EPRI)

3420 Hillview Avenue
Palo Alto, CA 94304

800-313-3774 (o)
650-855-2121 (o)
askepri@epri.com

http://my.epri.com/portal/server.pt?

Mission	The Electric Power Research Institute (EPRI) is an independent non-profit organization that collaborates with universities and private and public entities to conduct research, development, planning, and analysis in the areas of electricity generation, distribution, and use. EPRI has offices in California, North Carolina, Tennessee, and Massachusetts, and collaborates with researchers worldwide. EPRI program areas can be found at http://portfolio.epri.com/Programs2012.aspx.

Power Delivery & Utilization

Don Kintner
Electric Power Research Institute
1300 West W.T. Harris Boulevard
Charlotte, NC 28262

(704) 595-2506 (o)
dkintner@epri.com

Mission

EPRI's Power Delivery & Utilization research sector works to improve grid reliability and promote energy efficiency.

End Use Energy Efficiency and Demand Response (Program 170) Page 20

- Advanced Dehumidification for Improved Building Performance
- Advanced Lighting Technologies
- Assessment of Building Energy Management Systems
- Assessment of Daylighting Technologies
- Computers and Electronics
- DC Power for Data Centers
- Electronic Street Lighting Technologies and Control Systems
- Electronics Plugs & Loads
- Evaporative Cooling Systems
- Heat Pump Water Heaters
- Increasing Energy Savings with Dimmable Daylighting Systems
- Modern Lighting Control Systems
- Performance Comparison Between Induction and LED Outdoor Lighting
- Performance Mapping and Model Development of VRF Systems
- Thin-Film Electrochromic Window Coatings
- Variable Speed Air-Source Heat Pumps
- Zero Net Energy Buildings (Data Centers)
- Zero Net Energy Buildings (Grocery & Convenience Stores)

Electric Power Research Institute (EPRI)

End Use Energy Efficiency and Demand Response (Program 170)

Omar Siddiqui 650-855-2328
Program Manager osiddiqui@epri.com

http://portfolio.epri.com/ProgramTab.aspx?sId=PDU&rId=203&pId=6396

Research Focus	This EPRI program area contributes to the development and adoption of emerging energy-efficient technologies and best practices and demand response strategies.
Advanced Dehumidification for Improved Building Performance	Characterization of the potential benefits of using air conditioning strategies and equipment that can separate control of latent and sensible cooling.
	• Advanced Dehumidification for Improved Building Performance Page 22
Advanced Lighting Technologies	Identification and assessment of innovative lighting technologies.
	• Advanced Lighting Technologies Page 24
Assessment of Building Energy Management Systems	Assessment of state-of-the-art energy management systems.
	• Assessment of Building Energy Management Systems Page 26
Assessment of Daylighting Technologies	Explore photometric and energy performance of daylighting technologies.
	• Assessment of Daylighting Technologies Page 28
Computers and Electronics	Research involving electronics and computer components and systems such as gaming consoles and network devices.
	• Computers and Electronics Page 30
DC Power for Data Centers	Joint EPRI- Lawrence Berkeley National Laboratory project investigating the possibility of increasing energy efficiency at data centers by using direct current DC.
	• DC Power for Data Centers Page 32
Electronic Street Lighting Technologies and Control Systems	Study of available dimmable lighting technologies and control systems for street lighting.
	• Electronic Street Lighting Technologies and Control Systems Page 34
Electronics Plugs & Loads	Identify and promote the best-in-class efficiencies for residential and commercial power supply technologies.
	• Electronics Plugs & Loads Page 36
Evaporative Cooling Systems	Laboratory and field testing of next generation evaporative cooling systems.
	• Evaporative Cooling Systems Page 37
Heat Pump Water Heaters	Testing of new heat pump water heater products for commercial and residential applications.
	• Heat Pump Water Heaters Page 39
Increasing Energy Savings with Dimmable Daylighting Systems	Develop a guidebook summarizing the assessments of each dimmable lighting technology and lighting control system.
	• Increasing Energy Savings with Dimmable Daylighting Systems Page 41

Modern Lighting Control Systems	Evaluation of Modern Lighting Control Systems.	
	• Modern Lighting Control Systems	Page 44
Performance Comparison Between Induction and LED Outdoor Lighting	Comparison between induction and LED lighting for four outdoor lighting applications: street, wall, canopy, and post-stop lighting.	
	• Performance Comparison Between Induction and LED Outdoor Lighting	Page 45
Performance Mapping and Model Development of VRF Systems	Conduct laboratory testing and modeling of advanced Heating & Cooling Production and Delivery systems.	
	• Performance Mapping and Model Development of VRF Systems	Page 47
Thin-Film Electrochromic Window Coatings	Analysis of efficiency, durability, and market potential of electrochromic window coatings	
	• Thin-Film Electrochromic Window Coatings	Page 49
Variable Speed Air-Source Heat Pumps	Assessment of latest developments in variable speed air-source heat pump technology.	
	• Variable Speed Air-Source Heat Pumps	Page 51
Zero Net Energy Buildings (Data Centers)	Assessment of most effective measures for energy savings in both cooling systems and the power chain of data centers.	
	• Zero Net Energy Buildings (Data Centers)	Page 53
Zero Net Energy Buildings (Grocery & Convenience Stores)	Address the convergence of trends in efficient design, materials, and end-use technologies of grocery and convenience stores.	
	• Zero Net Energy Buildings (Grocery & Convenience Stores)	Page 55

Advanced Dehumidification for Improved Building Performance

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Characterization of the potential benefits of using air conditioning strategies and equipment that can separate control of latent and sensible cooling.

http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ron Domitrovic, Sr. Manager Rdomitrovic@epri.com (865) 218-8061	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	Advanced heat pumps.
Technology Characteristics	Variable refrigerant flow systems and controls.
Capability Gap(s)	Variable refrigerant flow energy savings potential and control optimization not well understood. Increase design capability to handle zonal and radiant heating & cooling delivery. Need the equivalent of ASHRAE Manual chapter on variable refrigerant flow design, control, and energy savings optimization. Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies for mini-split air conditioning and heat pumps.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation.
Background	By using heat pump air, an entire new family of product configurations can be introduced that use efficiently generated reactivation air, and couple the heat pump evaporator into the dehumidifying process. The result is the ability to use efficient desiccant dehumidification as a complement to high SEER DX equipment to provide the appropriate amount of sensible and latent cooling to a space.
Goals	1. Develop performance maps showing the cooling performance, energy and power draw characteristics and efficiency across the full range of operating conditions. 2. Model energy use for the tested systems in simulated buildings and climates 3. Create report containing collective knowledge and the implications for fostering the adoption of techniques for separating latent and sensible cooling when such a technique improves energy efficiency and comfort.
Scope	Characterization of the potential benefits of using air conditioning strategies and equipment that can separate control of latent and sensible cooling focusing on two primary areas: direct expansion (DX) systems with variable Sensible Heat Ratio capability and integration of desiccant drying technology with DX sensible cooling.
Timeline	
Milestones & Publications	
Budget	

Other parties involved	
Next steps	
Associated R&D strategy	The project will survey the currently available products in these categories and select at least two systems to test and characterize at the EPRI Thermal Environmental Lab. This project will focus on: 1. Gather information about available DX technologies specifically designed for humidity control and for desiccant systems designed for integration into other sensible cooling DX equipment. 2. Performance analysis of DX technologies 3. Performance analysis of desiccant technologies 4. Climate and building performance data will be overlaid onto the performance maps developed to provide simulated energy use profiles for the tested technologies.
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Advanced Lighting Technologies

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Identification and assessment of innovative lighting technologies.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Frank Sharp, Project Manager FSharp@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Luminaires

Project Details

R&D Program	Review and audit various luminaire designs for various lighting applications.
Technology Characteristics	Developing acceptance configurations for consumers. Fixture design for many different applications. Metrics should pertain to light (spectral content) delivered, task and aesthetic performance, not light emitted from source and energy use of entire package.
Capability Gap(s)	Need better lens designs to aim light without excessive glare. Need standardized affordable and reliable SSL components allowing fixture designers wide freedom to innovate and meet consumer needs. Need to design lighting and luminaires to optimize the effectiveness for the task from the user's point of view. Need to make mesopic lighting standards accessible to appropriate users. Need ability to retrofit an existing luminaire and achieve good optics. Need to change common metrics from source efficacy to luminaire efficacy.
Driver(s)	Availability of new technologies such as solid state lighting. Optimize work environment for using computers of the future-keep up as computers evolve. End user comfort / satisfaction. Corporate image, desire for new style. Enhance human performance (health, productivity). Majority of energy efficiency potential is in retrofit applications. A large number of existing luminaire are candidates are retrofit.
Background	Lighting manufacturers continue to work under pressure to develop new advanced lighting technologies to meet the efficacy requirements of the Energy Independence and Security Act of 2007, while meeting consumers' energy and aesthetic expectations. As the use of incandescent lamps diminishes, advancements in lamp materials, power electronics, and new methods of converting electricity into light are ushering in new and improved technologies for compact fluorescent lamps (CFLs), linear fluorescent lamps, high-intensity discharge (HID) lamps, light-emitting diodes (LEDs), and new hybrid technologies.
Goals	Evaluate the development of new or updated lighting technologies. Engage manufacturers in energy efficiency testing efforts, and perform application studies and alignment with industry regarding standards.
Scope	Assessment of six innovative lighting technologies. 1. 72W Eco Halogen bulbs for residential screw in applications 2. Architectural LED Lights for residential/commercial specialized applications 3. LED Panels for office applications 4. Linear LED for assembly/manufacturing applications 5. Induction/High Bay technology for warehouse applications 6. Unique LED Screw in Technology
Timeline	
Milestones & Publications	
Budget	

Continued . . .

Other parties involved	
Next steps	
Associated R&D strategy	
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Assessment of Building Energy Management Systems

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Assessment of state-of-the-art energy management systems.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ingrid Bran Senior Project Manager IBran@epri.com (650) 855-1064 (o)	**Sponsor(s)**	
Product / Service Area	Sensors, Meters, Energy Management Systems	**Roadmap**	Energy Management Services

Project Details

R&D Program	Integrated household energy management products and services including electric vehicle wiring, energy audits, smart phone applications, etc.
Technology Characteristics	Cheap, standardized, user aware, modular control sensor packages responding to occupancy temperature light level, air quality and user input. Self learning control systems that provide action oriented communication and maintenance alerts. Whole house energy monitoring and disaggregated device level monitoring from meter data. Affordable two way communicatable programmable thermostats. Web based home, small commercial energy management systems and services. Cost effective and secure delivery of energy management software (i.e. for residential and small businesses Alara and Siemens APOGEE). Open source code and standard communication protocols for EMS to enhance cost effectiveness and accessibility. Self learning control system that optimize energy use based on environmental conditions, occupant preferences, and utility signals.
Capability Gap(s)	Optimization and automation of control system responses. Consumers (residential/small, medium business) do not have expertise to manage energy. Self learning control systems. Very small marginal savings. Optimization and automation of control system responses. Rates are changing and hard to understand.
Driver(s)	Smart grid technology Development. Business drivers to decrease cost and increase productivity. People getting overwhelmed with device settings. Changing utility price structures: peak pricing. People getting overwhelmed with device settings. Escalating energy prices. Incremental efficiency gains at product / equipment level.
Background	The energy management system space is dynamic. Its assessment must cover current applications, suppliers, and products.
Goals	1. Identify applications of energy management systems (EMS) 2. Characterize suppliers of EMS 3. Provide information on functions, communication, grid integration, demand response, and stakeholders of EMS.
Scope	Provide an assessment on various facets of the energy management system space such as updates on controls manufacturers, and suppliers as well as protocols, standards, and applications of energy management systems.

Continued . . .

Electric Power Research Institute (EPRI)

Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Assessment of Daylighting Technologies

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Explore photometric and energy performance of daylighting technologies.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Frank Sharp Project Manager FSharp@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Assessment of daylighting technologies.
Technology Characteristics	Increased research on human and technology barriers.
Capability Gap(s)	Need methods to compensate for daylight color shift, glare, intensity, focus. Need for improved shading devices to reduce glare and improve light quality. Need better light quality as perceived by users. Need for tunable glazings and / or glazings that can optimize light transmission without heat / cool or excessive glare. Need to disperse daylighting better to achieve higher daylight factors.
Driver(s)	Optimize human performance (health, productivity). Optimize work environment for using computers of the futurekeep up as computers evolve. End user comfort / satisfaction. Aesthetics. Increasing and uncertain future cost of electricity and gas.
Background	Solar daylighting technologies capture the sun's energy, transfer it to interior spaces, and make use of various optical delivery elements. Results of which can have a significant impact on energy use in the building and lighting industries. New systems are constantly being introduced and their designs are constantly evolving.
Goals	1. Assess current state and market penetration of daylighting technology. 2. Identify most effective applications and climates. 3. Examine impact of building orientation.
Scope	Explore photometric and energy performance of solar daylighting technologies.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	

Continued . . .

Next steps	
Associated R&D strategy	1. In 2012, EPRI plans on evaluating products within three daylighting technology categories: • Skylights; • Solar Concentrators; and • Light Pipes. 2. Analysis of potential daylighting systems in commercial and industrial applications, with emphasis on building type, orientation, regional effects, etc. 3. Discuss potential market and applications for each technology. 4. Publish technical report. 5. Development a baseline for future work and reporting in this area.
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Computers and Electronics

End Use Energy Efficiency and Demand Response (Program 170)

Project Overview: Research involving electronics and computer components and systems such as gaming consoles and network devices.

http://my.epri.com/portal/server.pt?open=512&objID=432&&PageID=873&mode=2&in_hi_userid=2&cached=true

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Brian Fortenbery 942 Corridor Park Blvd. Knoxville, TN 37932 (865) 218-8012 bfortenbery@epri.com	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Sleep Mode

Project Details

R&D Program	Software compatible with stand-by modes.
Technology Characteristics	Software compatibility with standby modes. Video game systems with sleep modes that do not erase scores, progress, etc.
Capability Gap(s)	Need to integrate sleep mode applications with product standby software and hardware configurations. Need to optimize sleep mode energy impacts without degrading user experience. Need to require minimal user interaction.
Driver(s)	Consumer desire to be "green" and reduce embedded & used energy. Diffusion of common communication protocols into energy consuming devices. Consumer desire for comfort and aesthetics.
Background	EPRI's current work in electronics system and component energy efficiency is based on successful R&D on internal power supplies for desktop computers, which spawned the 80PLUS program was born, which is a utility funded incentive program administered by Ecova, Inc.
Goals	Ongoing efforts are focused on determining efficiency improvements that lead to opportunities for large-scale energy savings and possible inclusion in incentive programs.
Scope	EPRI's ongoing research on gaming systems is part of a California Energy Commission Public Intereste Energy Research (PIER) program effort on high-end (gaming) and low-end (kiosks) computing platforms.
Timeline	Electronics research timeline and product identification: ▪ 2011: Product ID#1021975, included commencing effort to measure UPS, network devices, and smart meter power supply efficiency. ▪ 2010: No research on most electronics, but gaming consoles studies briefly. ▪ 2009: Product ID# 1017892, included testing of televisions, DVD players, and digital picture frames.

Continued . . .

Milestones & Publications	EPRI researchers looked briefly at gaming consoles in 2010 and produced a press release as the only deliverable; see Electric Power Research Institute (2010, Dec. 16). "Power Play: EPRI Analysis Reveals That Video Game Consoles Differ in Energy Consumption." (http://my.epri.com/portal/server.pt/gateway/PTARGS_0_230564_317_205_776_43/http%3B/uspalecp604%3B7087/publishedcontent/publish/power_play__epri_analysis_reveals_that_video_game_consoles_differ_in_energy_consumption_da_753432.html). EPRI produces a yearly project deliverables summary, the most recent of which is: Electric Power Research Institute (2011). "End-Use Energy Efficiency and Demand Response, EPRI Program 170: 2010 Summary of Deliverables" http://my.epri.com/portal/server.pt?Abstract_id=000000000001022649. Reported in project #170.021.
Budget	
Other parties involved	California Energy Commission Public Interest Energy Research (PIER).
Next steps	2012: Uninterrupted power supply (UPS) and network devices is ongoing; smart meters turned out to be such a small load that there is little opportunity for significant savings, even on a nationwide scale. Ongoing gaming research is part of a California Energy Commission PIER effort on high-end (gaming) and low-end (kiosks) computing platforms.
Associated R&D strategy	All of EPRI's efforts are in accord with their Technology Strategy, which "encompasses the long-term visions and broad societal goals defined by the Electricity Technology Roadmap; the mid- to long-term targets for innovation identified via scenario planning and energy-economy modeling activities; and the near- to mid-term technical and business objectives of EPRI's members." [http://my.epri.com/portal/server.pt?open=512&objID=237&mode=2&in_hi_userid=2&cached=true]
References	Electric Power Research Institute (2011). "End-Use Energy Efficiency and Demand Response, EPRI Program 170: 2010 Summary of Deliverables" http://my.epri.com/portal/server.pt?Abstract_id=000000000001022649, accessed Feb. 2, 2012. Electric Power Research Institute (2011, Dec. 14)."Energy Efficiency Demonstration Webcast 14Dec2011 FINAL." Electric Power Research Institute (2010, Dec. 16). "Power Play: EPRI Analysis Reveals That Video Game Consoles Differ in Energy Consumption." http://my.epri.com/portal/server.pt/gateway/PTARGS_0_230564_317_205_776_43/http%3B/uspalecp604%3B7087/publishedcontent/publish/power_play__epri_analysis_reveals_that_video_game_consoles_differ_in_energy_consumption_da_753432.html, accessed Feb. 3, 2012. Electric Power Research Institute (n.d., circa Feb. 2012). "Kiosk and Gaming Project Scope of Work."

DC Power for Data Centers

Project Overview: Joint EPRI- Lawrence Berkeley National Laboratory project investigating the possibility of increasing energy efficiency at data centers by using direct current DC.

http://my.epri.com/portal/server.pt?Abstract_id=000000000001020818

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Satish Rajagopalan 942 Corridor Park Blvd. Knoxville, TN 37931	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source

Project Details

R&D Program	Basic R&D needed on DC loss reduction and reliability improvements
Technology Characteristics	Simple, reliable, efficient DC voltage conversion.
Capability Gap(s)	Need new thinking for optimization of DC systems
Driver(s)	Avoid DC to AC transformation energy losses.
Background	Consumer demand for Internet-related services has led to significant increase in the electricity consumption of data centers. The U.S. Environmental Protection Agency reported in 2007 that in 2006 data centers consumed about 1.5 percent of the nation's electricity, and by 2011 this figure would double. Finding ways to make data centers more energy efficient will help reduce data center load requirements.
Goals	This research project investigated the potential benefits of direct current (DC)-powered data centers.
Scope	The project investigated the component costs, energy use, reliability, design, interconnectivity, and data center configuration.
Timeline	EPRI published a white paper in November 2010 outlining the potential benefits and need for additional research; further research appears to be ongoing.

Continued . . .

Milestones & Publications	Researchers concluded in 2010 that there were appreciable potential cost savings, energy efficiency, and other benefits to DC-powered data centers, and that areas for additional research included connectors, safety, power quality, the need to develop standards. See Satish Rajagopalan, Brian Fortenbery, Dennis Symanski, and William Tschudi. "DC Power for Data Centers." Electrical Power Research Institute, Nov. 2010 (http://my.epri.com/portal/server.pt?Abstract_id=000000000001020818). Brian Fortenbery of EPRI reported in February 2012 that EPRI had successfully completed three field trials showing feasibility, reliability, and efficiency improvement. Details of the first project can be found in My Ton, Brian Fortenbery, and William Tschudi, "DC Power for Improved Data Center Efficiency," Jan. 2007 (http://hightech.lbl.gov/documents/DATA_CENTERS/DCDemoFinalReport.pdf). Stakeholders interest has increased as this work has progressed, to the point where EPRI recently joined the Emerge Alliance (http://www.emergealliance.org/), a group dedicated to standardizing DC products. Emerge has published a standard for 24 VDC lighting products and is very close to publication of a standard for 380 VDC power distribution, not just in data centers, but in commercial buildings in general. EPRI's Dennis Symanski chairs the 380 V committee. 2012 Power Delivery & Utilization Research projects listed at http://portfolio.epri.com/Sector.aspx?sId=PDU EPRI produces a yearly project deliverables summary, the most recent of which is: Electric Power Research Institute (2011). "End-Use Energy Efficiency and Demand Response, EPRI Program 170: 2010 Summary of Deliverables" http://my.epri.com/portal/server.pt?Abstract_id=000000000001022649, accessed Feb. 2, 2012.
Budget	
Other parties involved	Lawrence Berkeley National Laboratory.
Next steps	EPRI concluded that "Several challenges remain to be addressed before the DC data center can be a successful replacement to today's AC data center. Foremost are issues of safety, with several manufacturers already moving to address these issues. Examples include the development of new DC-specific interconnects that extinguish arcing during disconnects without endangering personal at the data center who handle powered equipment. Discussions are also happening to choose the best possible distribution architecture that can minimize any hazard. As a part of this effort, significant work is also underway to develop standards, warning labels, and notices that can increase awareness and reduce any possible risks associated with DC distribution systems."
Associated R&D strategy	All of EPRI's efforts are in accord with their Technology Strategy," which "encompasses the long-term visions and broad societal goals defined by the Electricity Technology Roadmap; the mid- to long-term targets for innovation identified via scenario planning and energy-economy modeling activities; and the near- to mid-term technical and business objectives of EPRI's members.." [http://my.epri.com/portal/server.pt?open=512&objID=237&mode=2&in_hi_userid=2&cached=true]
References	Rajagopalan, Satish, Fortenbery, Brian, Symanski, Dennis, and Tschudi, William (Nov. 2010). "DC Power for Data Centers." Palo Alto, CA: Electrical Power Research Institute. http://my.epri.com/portal/server.pt?Abstract_id=000000000001020818, accessed Jan. 10, 2012. Electric Power Research Institute (2012). "Tech nology Strategy: A Strategy for Innovation in the Electricty Enterprise." http://my.epri.com/portal/server.pt?open=512&objID=237&mode=2&in_hi_userid=2&cached=true, accessed Jan. 10, 2012. Electric Power Research Institute (2011). "End-Use Energy Efficiency and Demand Response, EPRI Program 170: 2010 Summary of Deliverables" http://my.epri.com/portal/server.pt?Abstract_id=000000000001022649, accessed Feb. 2, 2012. Electric Power Research Institute (2011, Dec. 14)."Energy Efficiency Demonstration Webcast 14Dec2011 FINAL." My Ton, Brian Fortenbery, and William Tschudi (2007, Jan.). "DC Power for Improved Data Center Efficiency," http://hightech.lbl.gov/documents/DATA_CENTERS/DCDemoFinalReport.pdf, accessed Feb. 2, 2012.

Electronic Street Lighting Technologies and Control Systems

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Study of available dimmable lighting technologies and control systems for street lighting.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Frank Sharp , Project Manager FSharp@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Development of advanced user Interfaces,
Technology Characteristics	Easy to change and reporting sensor settings. Need adjustable lighting levels based on the time of the day. Intuitive operation, ease of use and commissioning. Space sensing beyond occupancy, e.g., task, location in room, traffic, population.
Capability Gap(s)	Need integration with building automation / management systems. Need more reliable controls. Need adaptive lighting guidance, best practices (IES). Need better user Interfaces. Optimized/ideal luminaire control communication protocol. Need to improve capability of controls to work with a diversified product range.
Driver(s)	Controllable; integrated with other entertainment, communication mobility. Interoperability. Need for professionals to be credible and deliver systems that work and avoid callbacks. Individual control over lighting. End user comfort / satisfaction. Optimize work environment for using computers of the future keep up as computers evolve. Controllable; integrated with other entertainment, communication mobility. Majority of energy efficiency potential is in retrofit applications. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety),
Background	Industry experts predict that 30 to 40 percent of the energy used for street lighting systems can be saved if illumination and power were controlled. Some manufacturers now market add-on control systems for use with magnetic ballasts. Wireless communication and other control systems, paired with sophisticated software packages, can allow utilities to manage energy and maintenance needs and track existing and future installations.
Goals	1. Assess energy and operational impacts of street lighting control technologies 2. Standardize technology comparisons 3. Evaluate technologies for energy monitoring, record keeping, billing, and maintenance 4. Provide the following: • Technical Update describing the lighting devices and control systems available for street lighting systems. • Test Protocol for the lighting devices and one for the control systems. • Technical Report describing the results of laboratory testing lighting devices and control systems. • Technical Update describing the results of each demonstration.
Scope	Conduct a market study of available dimmable lighting technologies and control systems for street lighting. Study will include street lighting software and control systems designed for overlay on existing magnetic street lights and for complete electronic products, and control systems for these products.

Continued . . .

Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	Development of a test protocol to determine energy performance, reliability, environmental exposure, power system compatibility, and inter-compatibility.
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Electronics Plugs & Loads

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Identify and promote the best-in-class efficiencies for residential and commercial power supply technologies.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Brian Fortenbery Senior Project Manager BFortenbery@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Power Management Control and Communication

Project Details

R&D Program	Electronics energy savings opportunity analysis,
Technology Characteristics	Standard protocols to get device calculate its energy use and communicate that out. Monitoring devices: end-use, algorithms for load disaggregation. Quality open communication standards (simple and few). Software compatibility with standby modes.
Capability Gap(s)	Need peer to peer communication to control power levels to a minimum necessary. Need network standby "horizontal" standards for all devices. Need to develop low cost systems that permit quick adoption. Need interactive / communicating devices that are designed in, not added-on systems (less hardware). Need to integrate sleep mode applications with product standby software and hardware configurations. Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting.
Driver(s)	Use codes to lock in efficiency gains. Proliferation of consumer electronics (increased plug loads). More and cheaper products due to globalization of manufacturing. Diffusion of common communication protocols into energy consuming devices. Smart grid technology development. Consumer desire to be "green" and reduce embedded & used energy. Diffusion of common communication protocols into energy consuming devices. People are more "plugged in" electronically, digital information,social networking.
Background	Energy consumption of electronic devices continues to grow at a rapid pace. EPRI's partnership w/ governmental/non-governmental agencies and utilities creates awareness among vendors to improve the efficiency of their products.
Goals	• Establish baseline efficiency for large uninterruptible power supply (UPS) • Determine networking equipment efficiency with respect to throughput • Understand potential energy savings of gallium nitride transistors
Scope	Identify and promote the best-in-class efficiencies for residential and commercial power supply technologies.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Evaporative Cooling Systems

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Laboratory and field testing of next generation evaporative cooling systems.

http://my.epri.com/portal/server.pt?

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ammi Amarnath Sr. Manager AAmarnath@epri.com (650) 855-1007	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	Need more accurate modeling to compare systems more easily.
Technology Characteristics	Improved building energy simulation software with parametric analysis capabilities to model more accurately variations in real-world operating conditions, Building simulation software.
Capability Gap(s)	Need to reduce high energy use to distribute heating and cooling beyond the actual vent need. Need to optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, and heat recovery. Need to tie model to building needs / loads. Need benchmarking categories at end use level; to improve modeling and better represent real world conditions. Need to account for large number of variables in building modeling, standards, and training. Current energy modeling engines under development by DOE (energy +) do not have wide market adoption because perceived to be too detailed, too difficult to use - and hence to expensive to use. Tools for accelerating inputs, and accelerating computation time(2 minutes or less) are needed.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Electric utility need for resources to meet growing loads, and/or to replace oil and coal fired power plants. IAQ separate ventilation from HVAC loads / equipment. Need to understand where energy savings can be achieved and demonstrate actual. Validation of performance of new HVAC technologies through utility field test. Reduced first cost of new systems / design.
Background	New generation evaporative cooling systems, such as systems that incorporate both indirect and direct evaporative cooling claim very high efficiency. Such systems have never been tested, and reliability and efficiency information are not generally available.
Goals	Test and evaluate the performance of new evaporative cooling system technologies, especially the hybrid technologies (i.e. technologies that incorporate both direct & indirect evaporative cooling combined w/ standard air conditioners, etc.).
Scope	Laboratory and field testing of next generation evaporative cooling systems and incorporating efficiency data in appropriate energy efficiency databases.
Timeline	
Milestones & Publications	
Budget	

Continued . . .

Electric Power Research Institute (EPRI)

Other parties involved	
Next steps	
Associated R&D strategy	1. Assessment and selection of evaporative cooling air conditioning technologies to be tested. 2. Design and construction of a test stand for measuring performance of the selected evaporative cooler(s). Measuring the efficiency (or COP) of cooler(s) at various ambient temperatures and humidity. 3. Performance modeling. Incorporate results into existing building simulation tools (eQuest, EnergyPro, EnergyPlus, etc.) 4. Field evaluation of selected evaporative cooler. 5. Harmonization of field results obtained from the model.
References	Electric Power Research Institute, "Evaporative Cooling Systems," Product ID: 1023112, Project ID: 071877, April 2011.

Heat Pump Water Heaters

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Testing of new heat pump water heater products for commercial and residential applications.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utlilization
Contact	John Bush Project Engineer/Scientist Jbush@epri.com (865) 218-8153(o)	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Commercial and Residential Water Heating
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Commercial and Residential Water Heating

Project Details

R&D Program	A "family" of HPWHs for specific applications.
Technology Characteristics	Noise cancellation and / or dampening HPWH. Lighter and smaller HPWH.
Capability Gap(s)	The Energy Efficient versions are not better than their non Energy Efficient alternative in some cases.
Driver(s)	Need to understand where hot water savings can be achieved and demonstrated.
R&D Program	Demand response.
Technology Characteristics	Energy efficient micro technology for on demand applications.
Capability Gap(s)	Need for cost effective high efficiency water heating to reduce energy required to provide DHW.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Contractor interest to increase profits. Increasing and uncertain future cost of electricity and gas. Reduced first cost of new systems / design. Need to understand where energy savings can be achieved and demonstrate actual.
Background	Heat pumps have been used in niche markets for commercial water heating. New developments in technology for both conventional refrigerant systems, such as R-410a and more advanced systems using carbon dioxide are being made. Carbon dioxide is an effective refrigerant for water heating because it maintains high coefficient of performance with high temperature gradients, allowing water to be heated to temperatures in excess of 200°F.
Goals	(1) Expand Data Set for high-performance Heat Pump Water Heating (HPWH) technologies. (2) Examine Technologies overcoming HPWH challenges: cool climates, demand response capability, thermal storage.
Scope	Examine heat pump water heaters, through field demonstration of a commercial HPWH, and laboratory testing of advanced residential systems including CO_2 – based systems and other R134a systems.

Continued . . .

Electric Power Research Institute (EPRI)

Timeline	
Milestones & Publications	
Budget	
Other parties involved	Tennessee Valley Authority (TVA)
Next steps	Field evaluation of commercial HPWH system to confirm results of 2011 base laboratory testing. Monitoring of real world conditions will be completed at a Birmingham, AL hotel. Laboratory testing in steady state, simulated usage scenarios to map performance of advanced heat pump water heater technology (R-410a, CO_2 based systems, and modifiable R134a systems). Field monitoring of CO_2 based HPWH systems will be completed in collaboration w/ Tennessee Valley Authority. Technical update on Advanced Air Sourced Heat Pump Technologies planned for 12/31/12.
Associated R&D strategy	
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Increasing Energy Savings with Dimmable Daylighting Systems

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Develop a guidebook summarizing the assessments of each dimmable lighting technology and lighting control system.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Frank Sharp Project Manager FSharp@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Assessment of daylighting technologies.
Technology Characteristics	Increased research on human and technology barriers.
Capability Gap(s)	Need methods to compensate for daylight color shift, glare, intensity, focus. Need for improved shading devices to reduce glare and improve light quality. Need better light quality as perceived by users. Need for tunable glazings and / or glazings that can optimize light transmission without heat / cool or excessive glare. Need to disperse daylighting better to achieve higher daylight factors.
Driver(s)	Optimize human performance (health, productivity). Optimize work environment for using computers of the futurekeep up as computers evolve. End user comfort / satisfaction. Aesthetics. Increasing and uncertain future cost of electricity and gas.
Background	Lighting represents about 23 percent of the grid load. Market acceptance of dimmable lighting systems will be required to help utilities meet load reduction goals. Research projects can demonstrate how new dimmable light sources and control systems could enable lighting load reduction in commercial and industrial facilities. Research can also help to determine demand response (DR) parameters and options for communication and verification of energy savings.
Goals	1. Accelerate application of dimmable daylighting-capable lighting systems (DDS) with natural daylighting 2. Resolve barrier use of DDS 3. Generate verified case studies from demo sites
Scope	1. Identification of new dimmable light sources and lighting control systems using each communication media; analog 0 to 10 Vdc, wireless, power-line carrier, and digitally addressable lighting interface will proceed a system assessment for their use in various commercial and industrial facilities. 2. Develop a guidebook summarizing the assessments of each dimmable lighting technology and lighting control system, including a reference guide allowing utilities to pair dimmable lighting technologies with lighting control systems.
Timeline	

Continued . . .

Electric Power Research Institute (EPRI)

Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Modern Lighting Control Systems

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Evaluation of Modern Lighting Control Systems.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Frank Sharp , Project Manager FSharp@epri.com (865) 218-8055 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls (Dimming, Occupancy, Sensors)

Project Details

R&D Program	Assessment of modern lighting control systems.
Technology Characteristics	Increased research on human and technology barriers.
Capability Gap(s)	devices to reduce glare and improve light quality. Need better light quality as perceived by users. Need for tunable glazings and / or glazings that can optimize light transmission without heat / cool or excessive glare. Need to disperse daylighting better to achieve higher daylight factors.
Driver(s)	Optimize human performance (health, productivity). Optimize work environment for using computers of the futurekeep up as computers evolve. End user comfort / satisfaction. Aesthetics. Increasing and uncertain future cost of electricity and gas.
Background	Evaluating the performance lighting control systems in enabling more automated and ubiquitous demand response with respect to the requirements of building owners, occupants, and the utility can foster their more widespread use to help meet future energy and demand objectives. Control systems used in intelligent buildings should support configurable control strategies in which building owners and/or occupants can program or select subroutines to optimize performance levels based on a variety of parameters, such as external price signals—including real-time pricing (RTP), time-of-use (TOU), reliability-driven demand response events, external ambient conditions, and occupant preferences.
Goals	Assessment of new or updated lighting control technologies
Scope	Assessment five modern lighting control system applications: 1. Residential Application (Add-on Motion Socket) 2. Commercial New Install Application (Power Line Carrier) 3. Commercial Retrofit Application (Wireless Building Control) 4. Commercial Add On Application (Motion) 5. Unique Control Technology (Zero Power Controls)
Timeline	
Milestones & Publications	
Budget	

Continued . . .

Electric Power Research Institute (EPRI)

Other parties involved	Modern Lighting Control System manufacturers include: GE, Daintree Networks, EnOcean Alliance, GreenWorx, & various other manufacturers.
Next steps	Currently beginning testing at EPRI lighting lab (6/2012). Deliver Technical Update (12/2012).
Associated R&D strategy	1. Test Modern Lighting Control System Technologies for: • Emissions and Immunity • Compatibility w/ various Lighting technologies & communicating devices 2. Discuss potential market and applications for each technology 3. Publish accompanying report
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 24, 2012.

Performance Comparison Between Induction and LED Outdoor Lighting

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Comparison between induction and LED lighting for four outdoor lighting applications: street, wall, canopy, and post-stop lighting.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Tom Geist , Sr. Project Manager TGeist@epri.com 865-218-8014(o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	*[Not yet specified]*
Technology Characteristics	*[Not yet specified]*
Capability Gap(s)	*[Not yet specified]*
Driver(s)	*[Not yet specified]*
Background	Following the trend for indoor lighting, outdoor lighting technologies are now available with induction lamps and light-emitting diodes (LEDs). Demonstrations of induction and LED technologies across the U.S. show there is promise in using both technologies, many in similar applications. Shortcomings have occurred in various demonstrations regarding energy, illuminance, power quality, compatibility, and reliability performance. An outdoor lighting environment will benefit with products that offer predictable performance that reduce energy consumption while improving the quality of light and color.
Goals	Compare performance of LED and Induction lighting for outdoor applications and provide the following: • EPRI Technical Report describing the products selected and the results of laboratory and field testing. • EPRI Workshop presenting the results of this project along with specific laboratory demonstrations of selected areas of performance. • Use of an EPRI-provided monitor for recording energy and power quality performance at each site. • Use of the EPRI Scotty robot for illuminance measurements at each demonstration site.
Scope	Compare performance of LED and Induction lighting for four outdoor applications: street, wall, canopy, and post-stop lighting.
Timeline	

Continued . . .

Electric Power Research Institute (EPRI)

Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	Identify four (4) induction and four (4) LED lighting technologies for outdoor lighting applications: street, wall, canopy, and post-top lighting. Determine comparison of energy, illuminance, power quality, compatibility, and reliability performance through laboratory testing. Field testing will be carried out at selected demonstration sites using the EPRI Scotty robot to measure luminance and light distribution for each outdoor lighting application and a cellular-equipped monitor to record energy and power quality performance at each site.
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 24, 2012.

Performance Mapping and Model Development of VRF Systems

End Use Energy Efficiency and Demand Response (Program 170)

Project Overview: Conduct laboratory testing and modeling of advanced Heating & Cooling Production and Delivery systems.

http://my.epri.com/portal/server.pt?

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ron Domitrovic (865) 218-8061 (o) rdomitrovic@epri.com	**Sponsor(s)**	Bonneville Power Administration Southern California Edison
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	More information about energy use; improve controls.
Technology Characteristics	Variable refrigerant flow systems and controls. Need to downscale what is currently available on big chillers for smaller units and integrate with maintenance systems. Drop-in replacement condensing unit with variable speed compressor.
Capability Gap(s)	Increase design capability to handle zonal and radiant heating & cooling delivery. Need the equivalent of ASHRAE Manual chapter on variable refrigerant flow design, control, and energy savings optimization. Variable refrigerant flow energy savings potential and control optimization not well understood. Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation
Background	Thirty-five subject matter experts representing BPA, the Electrical Power Research Institute (EPRI), Southern California Edison, and seventeen other institutions collaborated from 2009-2011 to produce the Variable Capacity Heat Pump Measure Development Roadmap. One outcome of this collaboration is this BPA- and Southern California Edison-funded project to test two Heating & Cooling Production and Delivery heat recovery (VRF-HR) systems.
Goals	To analyze system performance under various parameters so as to develop coded modules available for incorporation into building simulation software. Expected value to BPA and the region includes 4.6 aMW to offset load growth and $21 million cost savings.
Scope	The VRF-HR test unit from LG Electronics has a three pipe heat recovery setup, and the Mitsubishi system will has a two pipe heat recovery setup. While controlling relevant air-side parameters, this experiment will collect output performance data at discreet points of steady-state operation. Experiments will include variable performance parameters to build a multi-dimensional performance map relating output to input.
Timeline	Began in late 2010, projected to continue into fiscal year 2013.

Continued . . .

Electric Power Research Institute (EPRI)

Milestones & Publications	In early February 2012, Ron Domitrovic provided project update at the BPA Technology Innovation 2012 R&D Summit Week Event. As of February 2012, Ron Domitrovic authored six deliverable documents: ▪ Deliverable for Task 1 – Design of Test Stand ▪ Deliverable for Task 2A – Summary of Materials Ordered and Equipment ▪ Task 2B Deliverable – Test Stand Construction ▪ Deliverable for Task 2C – Test Stand Operational Testing ▪ Task 3A, 3B: Test Report for 2 Pipe VRF-HR System – Heating, Cooling and Simultaneous Cooling and Heating Mode ▪ Task 4A, 4B: Test Report for 3 Pipe VRF-HR System – Heating, Cooling and Simultaneous Cooling and Heating Mode.
Budget	BPA and Southern California Edison have provided project funding; total project budget is $784,842, BPA's share is $392,421.
Other parties involved	
Next steps	FY 2012: ▪ Provide data to modelers ▪ Stage Gate: Is data appropriate for modelers? ▪ Adjust data as appropriate ▪ Test 3rd & 4th systems ▪ Stage Gate: Can test-stand accommodate non-ducted systems? (Testing to date has been on ducted systems) FY 2013: ▪ Vet models with field data
Associated R&D strategy	All of EPRI's efforts are in accord with their Technology Strategy, which "encompasses the long-term visions and broad societal goals defined by the Electricity Technology Roadmap; the mid- to long-term targets for innovation identified via scenario planning and energy-economy modeling activities; and the near- to mid-term technical and business objectives of EPRI's members." [http://my.epri.com/portal/server.pt?open=512&objID=237&mode=2&in_hi_userid=2&cached=true]
References	Bonneville Power Administration (2012). "Variable Capacity Heat Pump Technology Roadmap and Overview." http://www.bpa.gov/energy/n/emerging_technology/VCHPOverview.cfm, accessed Feb. 7, 2012. Domitrovic, Ron (2012). "Project 216: Lab Testing and Modeling of Advanced Heating & Cooling Production and Delivery Systems." PowerPoint Presentation delivered at BPA Technology Innovation 2012 R&D Summit Week Event, Feb. 2012. Undated deliverable documents listed in "Milestones & Publications" section above.

Thin-Film Electrochromic Window Coatings

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Analysis of efficiency, durability, and market potential of electrochromic window coatings.

http://mydocs.epri.com/docs/TI/frontPage_pdf/1023474.EnergyEfficiency.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery and Utilization
Contact	Ammi Amarnath, Sr. Program Manager Aamarnath@epri.com 650-855-1007 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Fenestration & Daylighting

Project Details

R&D Program	Fenestration systems – retrofit surface applied films.
Technology Characteristics	Retrofit surface applied films.
Capability Gap(s)	Need for retrofit technologies in products.
Driver(s)	Achieve energy savings. Increase occupant health, comfort and safety.
Background	Even with today's energy-efficient low-emissivity (low-E) coatings, more than 4 quads of energy are lost through windows each year, costing building owners over $40 billion. Electrochromic windows that allow active control of transmitted light and solar heating offer a pathway to improved window performance that maintains optimal occupant comfort while minimizing the energy footprint. This report reviews the benefits of electrochromic window technology to help meet these goals and the opportunity for new products to overcome the limitations of existing offerings. In particular, it documents the development of an all solid-state electrochromic coating on flexible plastic that promises dramatically reduced manufacturing cost to drive widespread application of the technology in pursuit of twenty-first century net zero-energy buildings.
Goals	(1) Modeling the performance of electrochromic window coatings (2) Testing their efficiency and durability in the laboratory (3) Analyzing market potential.
Scope	Develop a thin-film electrochromic (EC) coating on a flexible substrate that could be applied to retrofit conventional windows to “smart window” status.
Timeline	
Milestones & Publications	
Budget	Supported by a grant from the U.S. Department of Energy’s Advanced Research Projects Agency—Energy (ARPA-E),

Continued . . .

Electric Power Research Institute (EPRI)

Other parties involved	ITN Energy Systems
Next steps	Develop larger production units, optimizing the production controls for consistent quality. Improve the clear state transmittance of the EC coating.
Associated R&D strategy	
References	Electric Power Research Institute, "Strategic Program: Energy Efficiency," July 2011, http://mydocs.epri.com/docs/TI/frontPage_pdf/1023474.EnergyEfficiency.pdf, accessed July 16, 2012. Electric Power Research Institute, "Shaping the Future: Innovative Approaches to Upcoming Challenges," *EPRI Journal* (Spring 2012), http://mydocs.epri.com/docs/CorporateDocuments/EPRI_Journal/2012-Spring/1025049_ShapingFuture.pdf, accessed July 16, 2012.

Variable Speed Air-Source Heat Pumps

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Assessment of latest developments in variable speed air-source heat pump technology.

http://portfolio.epri.com/ProgramTab.aspx?sId=PDU&rId=236&pId=7175&pjId=7177

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery and Utilization
Contact	Ron Domitrovic, Sr. Project Manager Rdomitrovic@epri.com (865) 218-8061(o)	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	Field test variable speed heat pumps.
Technology Characteristics	Variable refrigerant flow systems and controls. Fast, accurate controls for enthalpy and air flow. Self-optimizing controls.
Capability Gap(s)	Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies. Variable refrigerant flow energy savings potential and control optimization not well understood. Increase design capability to handle zonal and radiant heating & cooling delivery. Need the equivalent of ASHRAE Manual chapter on variable refrigerant flow design, control, and energy savings optimization. Need to eliminate current high-energy distribution of heat and cooling. Need proven systems that provide safe and adequate ventilation. Need to have "on-board" diagnostics or data streams to collect. Need to correlate ventilation, temperature, and humidity delivery with actual uses at granular level so controls and monitoring devices can be designed appropriately. Need to optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, and heat recovery. Need two-way communication with building controls to monitor equipment and systems performance.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Contractor interest to increase profits. Consumer desire for comfort and aesthetics. Need to understand where energy savings can be achieved and demonstrate actual. Customer desire for low maintenance costs for HVAC equipment. Reduced HVAC loads in buildings / lack properly sized equipment options.
Background	Breakthrough adoption of advanced air-source heat pumps, combined cooling and dehumidifying technologies hinges on functional and cost improvements. Improved performance at very high and low outdoor temperatures is a priority for many applications, especially in hot/dry, hot/humid, and sub-zero conditions. Such advanced systems also have the ability for improving customers' comfort.
Goals	(1) Determine the cooling performance of air-source heat pumps (ASHP) at non-rating conditions. (2) Examine how Seasonal Energy Efficiency Ratio (SEER) translate over a broad range of air conditions. (3) Comparison of federal minimum ASHP to high efficiency ASHP.
Scope	Assess the latest advances in vapor compression heat pump technology, including systems developed specifically for the American market such as commercial packaged unitary and residential ducted multi-split systems.

Continued . . .

Electric Power Research Institute (EPRI)

Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Laboratory testing of variable speed 19.5 SEER (High Efficiency) heat pumps. Technical update on Advanced Air Sourced Heat Pump Technologies planned for 12/31/12.
Associated R&D strategy	Laboratory testing using dual zone psychometric test chambers used to simulate two residential ducted ASHP in a variety of indoor and outdoor air conditions: • Single Speed 13 SEER (Federal Minimum) • Variable Speed 19.5 SEER (High Efficiency)
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 12, 2012.

Zero Net Energy Buildings (Data Centers)

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Assessment of most effective measures for energy savings in both cooling systems and the power chain of data centers.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Brian Fortenberry Sr. Program Manager Bfortenberry@epri.com 865-218-8012 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Retrofit	**Roadmap**	Zero Net Energy (ZNE) Buildings

Project Details

R&D Program	*[Not yet specified]*
Technology Characteristics	*[Not yet specified]*
Capability Gap(s)	*[Not yet specified]*
Driver(s)	*[Not yet specified]*
Background	Energy use in data centers is projected to grow at the fastest pace of any building segment in the United States. It has doubled in just the past five years, from about 61 billion kWh in 2006—nearly 1.5% of the total electricity use—to more than 120 billion kWh by 2011. Ancillary data center loads, such as cooling and other infrastructure, use as much or more energy than the actual servers that perform computations. In addition, many data centers have reached the limit of their cooling system capacity, which means that they can no longer add servers to the space. With such limits to their productivity, data center operators have a desperate need to address the heat load and improve their building efficiency.
Goals	(1) Review existing analysis tools for airflow management (AFM). (2) Obtain field data from direct expansion (DX) units for incorporation into new analysis tools.
Scope	Provide recommendations the most effective measures for energy savings in both cooling systems and the power chain of data centers. Aid in the establishment of performance specifications for individual components, systems, or whole buildings in data centers.
Timeline	
Milestones & Publications	

Continued . . .

Electric Power Research Institute (EPRI)

Budget	
Other parties involved	
Next steps	Technical Update: Zero Net Energy Grocery and Convenience Stores planned for 12/31/12.
Associated R&D strategy	Currently implementation of airflow management of direct expansion units voids warranty of these units. Goal is to develop safe operating area for these airflow management units in order to obtain vendor buy-in to overcome warranty issues and open up the market for airflow management as a simple, cost effective retrofit for overcooled for data centers. Field test of automated airflow management technology to accomplish: • Assess effectiveness of chilled water systems • Assess use of DX systems • Process and checklist to assess possible energy savings • Review utility data of existing AFM analysis tools. • Analyze calculation tools such as DOE's DC Pro • Comprehensive savings calculator to facilitate use in incentive programs
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 24, 2012.

Zero Net Energy Buildings (Grocery & Convenience Stores)

Program 170 – End Use Energy Efficiency and Demand Response

Project Overview: Address the convergence of trends in efficient design, materials, and end-use technologies of grocery and convenience stores.

http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ram Narayanamanurthy, Sr. Program Manager Rnarayanamurthy@epri.com 650-855- 2419(o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy (ZNE) Buildings

Project Details

R&D Program	*[Not yet specified]*
Technology Characteristics	*[Not yet specified]*
Capability Gap(s)	*[Not yet specified]*
Driver(s)	*[Not yet specified]*
Background	Grocery and convenience stores use 60GWh or energy annually, driven by significant refrigeration and space conditioning loads as well as lighting. They are also a ubiquitous segment with a presence in every community in the country.
Goals	(1) Analyze energy use and market size of grocery and convenience stores. (2) Identify advanced energy efficiency technologies that will serve as a catalyst for low energy and zero energy grocery and convenience stores. (3) Understand grid impact of low energy and zero energy grocery and convenience stores.
Scope	Address the convergence of trends in efficient design, materials, and end-use technologies of grocery and convenience stores. Also addressed will be integration with smart grid and energy management systems and on-site renewable generation (for example, photovoltaic) and storage.
Timeline	
Milestones & Publications	Milestone: Completion of market analysis and energy use characteristics of grocery and convenience stores (as of 7/2012).
Budget	
Other parties involved	

Continued . . .

Electric Power Research Institute (EPRI)

Next steps	Currently pursuing completion of goals (2) and (3). Technical Update: Zero Net Energy Grocery and Convenience Stores planned for 12/31/12.
Associated R&D strategy	Review of energy use in grocery stores divided into three (3) subsections: • Refrigeration systems (secondary loop systems, efficient condensing units, and case design). • Lighting (daylighting & LED lighting) • HVAC (advanced RTUs, DOAS w/ dessicants) Review of energy use in convenience stores divided into three (3) subsections: • HVAC (efficient packaged RTUs, Fault Determination & Detection) • Refrigeration (CO_2 Vending Machines and Condensing Units) • Lighting (Display Case Lighting & Store Lighting)
References	Electric Power Research Institute, "End-Use Energy Efficiency and Demand Response - Program 170 Program Overview," 2012 Research Portfolio, http://mydocs.epri.com/docs/Portfolio/PDF/2012_P170.pdf, accessed July 24, 2012.

EMerge Alliance	2400 Camino Ramon, Suite 375 San Ramon, CA 94583	(925) 275-6617 (o) (925) 884-8668 (f) help@EMergeAlliance.org http://www.emergealliance.org/

Mission	An open industry association working with public and private entities to develop EMerge Alliance standards that will facilitate the adoption of safe and efficient direct current (DC) power distribution systems in commercial buildings. EMerge Alliance's ongoing "DC power distribution standards" project addresses two Northwest Energy Efficiency Technology Roadmaps, *Direct Current (DC) Power Source* and *Solid State Lighting*.
	DC power distribution standards Page 58

EMerge Alliance

DC power distribution standards	**Project Overview:** Eliminate inefficient alternating current (AC) to direct current (DC) conversions and improve reliability by facilitating the creation of DC microgrids throughout commercial buildings by way of a hybrid AC and DC platform. This ongoing project addresses two Northwest Energy Efficiency Technology Roadmaps, *Direct Current (DC) Power Source* and *Solid State Lighting*. **http://www.emergealliance.org/**

Institution	EMerge Alliance	**Div. / Dept.**	
Contact	2400 Camino Ramon, Suite 375 San Ramon, CA 94583 (925) 275-6617 (o) (925) 884-8668 (f) help@EMergeAlliance.org	**Sponsor(s)**	See full list at http://www.emergealliance.org/About/OurMembers.aspx
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program Needed	DC safety.
Technology Characteristics	Work with national and international entities to invoke codes and standards.
Capability Gap(s)	Need updated electrical codes to address DC distribution systems, including safety.
Driver(s)	Use of codes for efficiency and safety
R&D Program Needed	Electric system compatibility.
Technology Characteristics	Super SSL: The ca. 2010 winner of the DOE's next generation L-Prize (www.lightingprize.org/) meets all needs identified in Performance Gap boxes above.
Capability Gap(s)	Need better color rendering. Need to provide full dimming capabilities while maintaining light quality (i.e., reduce "flicker"). Need to improve lumen maintenance. Need to improve lighting reliability over time. Need to increase energy efficiency.
Driver(s)	Optimize work environment for using computers of the futurekeep up as computers evolve. Aesthetics. Optimize human performance (health, productivity). End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. The number of solid state lighting products available in the marketplace is rapidly growing with varying performance. Consumers need to be able to tell what they are getting.. Utilities are mandated to produce more energy with renewable sources and energy-efficiency measures. Energy-efficiency measures can reduce the impact of increasing energy costs.

Continued . . .

EMerge Alliance

Background	Commercial buildings use up to 50 percent of all electricity produced and distributed by public utilities in the U.S., and most electrical devices inside these buildings are inefficient because they must convert incoming AC to DC power.
Goals	EMerge Alliance standards that will facilitate the adoption of safe and efficient direct current (DC) power distribution systems in commercial buildings.
Scope	Group is creating standards for building interiors, data centers, building exteriors, and building services.
Timeline	
Milestones	In 2010, the first available EMerge Alliance Standard created a 24-volt DC commercial interior microgrid (http://www.emergealliance.org/Standard/Overview.aspx).
Budget	
Other parties involved	
Next steps	Currently developing a 380-volt DC power standard for data centers, and continuing work on building exteriors and building services (such as heating, ventilation, and air conditioning systems).
Specific R&D strategy	
References	EMerge Alliance. "EMerge Alliance." http://www.emergealliance.org/, accessed Jan. 5, 2012.

EMerge Alliance

[Back to Table of Contents]

Energy Trust of Oregon (ETO)	421 SW Oak Street Suite 300 Portland, OR 97204 http://energytrust.org/	(1-866) 368-7878 (o) (503) 546-6862 (f) info@energytrust.org
Mission	The Energy Trust of Oregon (ETO) is an independent nonprofit organization with the mission of helping regional utility customers benefit from saving energy and generating renewable energy by providing an array of services, incentives, and solutions. State legislation, tariffs, and other requirements have established exclusive funding to ETO by the customers of Portland General Electric, Pacific Power, NW Natural and Cascade Natural Gas.	

Planning and Evaluation Department

	Fred Gordon, Director 421 SW Oak Street Suite 300 Portland, OR 97204 http://energytrust.org/	(503) 445.7602 (o) Fred.Gordon@energytrust.org
Mission	ETO's Planning and Evaluation Department provides economic and engineering planning, project management, analysis, and evaluation services for energy efficiency and other initiatives.	

Heating, Ventilation, and Air Conditioning (HVAC) Systems Page 62

- Heating, Ventilation, and Air Conditioning (HVAC) Systems

Heating, Ventilation, and Air Conditioning (HVAC) Systems

Fred Gordon, Director of Planning & Evaluation
421 SW Oak Street
Suite 300
Portland, OR 97204

(503) 445.7602 (o)
Fred.Gordon@energytrust.org

http://energytrust.org/

Research Focus	ETO works with regional stakeholders, including the Northwest Power & Conservation Council's Regional Technology Forum (http://www.nwcouncil.org/energy/rtf/Default.htm), to increase energy efficiency by devising, implementing, and evaluating strategic energy management programs and pilot tests for industrial and commercial applications.
Heating, Ventilation, and Air Conditioning (HVAC) Systems	ETO has a number of projects and programs to improve HVAC system energy efficiency, including managing a rooftop tune-up program, piloting energy information systems for commercial buildings, and providing customer and contractor feedback on equipment energy use and operation, among others.

- Heating, Ventilation, and Air Conditioning (HVAC) Systems Page 63

Heating, Ventilation, and Air Conditioning (HVAC) Systems

Project Overview: ETO has a number of projects and programs to improve HVAC system energy efficiency, including managing a rooftop tune-up program, piloting energy information systems for commercial buildings, and providing customer and contractor feedback on equipment energy use and operation, among others.

http://energytrust.org/

Institution	Energy Trust of Oregon	**Div. / Dept.**	Planning and Evaluation Department
Contact	Fred Gordon, Director of Planning & Evaluation 421 SW Oak Street Suite 300 Portland, OR 97204 (503) 445.7602 (o) Fred.Gordon@energytrust.org	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Fault Detection and Predictive Maintenance

Project Details

R&D Program	Research to reduce maintenance.
Technology Characteristics	Predictive Maintenance. User notification of system status.
Capability Gap(s)	Need to have "onboard" diagnostics or data streams to collect. Need to eliminate failure modes by design simplification of systems.
Driver(s)	Integration of info, communication & entertainment devices. Reduced HVAC loads in buildings / lack properly sized equipment options. Consumer demand for reduced / low cost of utilities / operation. Diffusion of common communication protocols into energy-consuming devices.
Background	ETO has been engaged in a variety of HVAC system energy efficiency efforts the legislature established the organization in 1999; since 2004, ETO's work has also been in partnership with the Commercial Rooftop Unit Working Group (RTUG) of the Northwest Power & Conservation Council's Regional Technology Forum.
Goals	ETO's 2012-2013 action plan establishes the goals of: 1) Increasing operations-based savings and low-cost/no-cost approaches to save energy in a capital constrained market; 2) Continuing the Strategic Energy Management pilot, including a) Cohort approach with 10-15 commercial real estate participants and b) Long-term energy efficiency planning with 2-3 targeted customers; 3) Expand Building Information System Pilot to: a) provide benchmarking, b) work with operators to implement improved procedures, and c) incentivize and evaluate improved procedures by applying measured performance gains.
Scope	ETO facilitates regional HVAC energy efficiency research and pilot programs for commercial, industrial, and residential applications. This work includes energy management systems, equipment tune-up and repair, . Specifically within the area of HVAC maintenance, ETO staff do not work formally within a fault detection paradigm, but they do solicit customer and contractor feedback on energy use and equipment operation to help manage energy use.

Continued . . .

Energy Trust of Oregon

Timeline	Ongoing.
Milestones & Publications	As of February 2012, ETO's Strategic Energy Management (SEM) pilot projects are underway and, in some cases, not yet fully designed; these projects have not yet passed beyond the stage of internal management plans. ETO staff published the final report of their roof top unit (RTU) pilot project in 2009: Robison, David (2009, Nov.). "Small Commercial HVAC Pilot Program Final Impact Evaluation For Energy Trust of Oregon." Portland, Oreg.: Stellar Processes, Inc. http://energytrust.org/OMRTUPilotResultsFINAL.pdf, accessed Feb. 2, 2012. ETO also shares regular updates with the Commercial Rooftop Unit Working Group (RTUG) of the Northwest Power & Conservation Council's Regional Technology Forum; see http://www.nwcouncil.org/energy/rtf/subcommittees/rtug/.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	The Oregon legislature established a stable funding infrastructure for ETO in 1999, and the organization began operation in early 2002. As a public purpose organization all of ETO's work is focused on maintaining the lowest possible energy costs while implementing energy efficiency, renewable, and other sustainable systems, methods, and technologies. Within this context, ETO's 2012-2013 research agenda can be found in: Harris, Margie (2011, Dec. 16). "Memorandum: 2012-2013 Action Plan and Proposed Final 2012 Budget." http://energytrust.org/library/plans/2012-2013_Proposed_Final_BudgetActionPlan.pdf, accessed Feb. 2, 2012.
References	Robison, David (2009, Nov.). "Small Commercial HVAC Pilot Program Final Impact Evaluation For Energy Trust of Oregon." Portland, Oreg.: Stellar Processes, Inc. http://energytrust.org/OMRTUPilotResultsFINAL.pdf, accessed Feb. 2, 2012. Harris, Margie (2011, Dec. 16). "Memorandum: 2012-2013 Action Plan and Proposed Final 2012 Budget." http://energytrust.org/library/plans/2012-2013_Proposed_Final_BudgetActionPlan.pdf, accessed Feb. 2, 2012. Regional Technical Forum (2012). "Commercial Rooftop Unit Working Group (RTUG): Phase 4." http://www.nwcouncil.org/energy/rtf/subcommittees/rtug/, accessed Feb. 2, 2012. Energy Trust of Oregon (2012). "Energy Trust of Oregon." http://energytrust.org/, accessed Feb. 2, 2012.

GridPoint, Inc.

GridPoint, Inc.
2801 Clarendon Blvd, Suite 100
Arlington, VA 22201

(888) 998-GRID (4743) (o)
(703) 667-7000 (o)
(703) 667-7001 (f)

Email: http://www.gridpoint.com/Contact-Us.aspx

http://www.gridpoint.com/

Mission	GridPoint provides software, hardware, and services for both energy consumers and producers, including strategic energy management program designs and smart grid applications. Peter L. Corsell founded the company in 2003; it is headquartered in Arlington, Virgina, and has offices in Austin, Texas; Ottawa, Ontario; Roanoke, Virginia; and Seattle, Washington.

GridPoint, Inc.

GridPoint Energy Manager	**Project Overview:** Software platform to provide enterprise and utility energy management for smart energy endpoints including "building management systems, solar arrays, electric vehicle charging stations, and home energy management technologies." **http://www.gridpoint.com/energy-management-systems/enterprise-manager.aspx**

Institution	GridPoint, Inc.	**Div. / Dept.**	
Contact	2801 Clarendon Blvd, Suite 100 Arlington, VA 22201 (888) 998-GRID (4743) (o); (703) 667-7000 (o); (703) 667-7001 (f) http://www.gridpoint.com/Contact-Us.aspx	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source

Project Details

R&D Program	UPS-PV integration (large or small) (AC + DC).
Technology Characteristics	Better energy storage in the electrical system, Standard uninterruptible power supply (UPS) interface hardware and control protocols to accept power from photovoltaic (PV) and other DC distributed generation sources.
Capability Gap(s)	Need for better energy storage including batteries to be cost effective and reliable. Need new thinking for optimization of DC systems.
Driver(s)	More use of DC supply. Improve safety and reliability. Reduce cost and resource use.
Background	Provides a unified enterprise and utility energy management platform to integrate smart energy endpoints including "building management systems, solar arrays, electric vehicle charging stations, and home energy management technologies."
Goals	To provide enterprise and utility energy management teams with a unified and comprehensive tool integrating control algorithms and analytics to help reduce energy costs.
Scope	The cloud-based system provides visibility and monitoring, data analysis for ease of system evaluation, and problem identification and control.
Timeline	Software released June 2011, currently available in the market.
Milestones & Publications	Product released to market in June 2011.
Budget	
Other parties involved	
Next steps	GridPoint continues to work on other products and systems.
Associated R&D strategy	
References	GridPoint Inc.,. "New GridPoint Energy Manager Software Provides Comprehensive Visibility, Analysis, and Control of Energy Endpoints," June 28, 2011, http://www.gridpoint.com/News/PressReleaseShare/11-06-28/New_GridPoint_Energy_Manager_Software_Provides_Comprehensive_Visibility_Analysis_and_Control_of_Energy_Endpoints.aspx, accessed Jan. 6 2012. GridPoint Inc.,. "GridPoint to Provide Software Solutions for SMUD`s Smart Grid Solar Project," Nov. 3, 2009, http://www.reuters.com/article/2009/11/03/idUS182687+03-Nov-2009+BW20091103, accessed Sep. 12, 2012.

Heart Transverter, S.A.	6A-A Zona Franca Metropolitana Barreal de Heredia Heredia, Costa Rica http://transverter.com/	011-506-2293-3468 (o) 011-506-2293-9879 (f) heart@transverter.com
Mission	Company creates products to facilitate increased use of alternate energy sources such as photovoltaics and fuel cells. Their primary focus is to create a "real smart grid" by developing and patenting scalable, household-level systems to integrate renewable energy, demand response, data acquisition, advanced metering, power quality control, community energy storage, communications, and energy security.	
	Advanced Power Electronics for Sustainable Energy Page 68	

Heart Transverter, S.A.

Advanced Power Electronics for Sustainable Energy	**Manufacturing & Engineering Group** **Project Overview:** Company is developing "highly programmable building blocks" that can "reshape the entire electrical infrastructure" by integrating renewable energy and energy storage with the smart grid . . . one house and office at a time." **http://transverter.com/**

Institution	Heart Transverter S.A.	**Div. / Dept.**	
Contact	6A-A Zona Franca Metropolitana Barreal de Heredia Heredia, Costa Rica 011-506-2293-3468 (o) 011-506-2293-9879 (f) rodolfo@transverter.com	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source

Project Details

R&D Program	UPS-PV integration (large or small) (AC + DC).
Technology Characteristics	Better energy storage in the electrical system, Standard uninterruptible power supply (UPS) interface hardware and control protocols to accept power from photovoltaic (PV) and other DC distributed generation sources.
Capability Gap(s)	Need for better energy storage including batteries to be cost effective and reliable. Need new thinking for optimization of DC systems.
Driver(s)	More use of DC supply. Improve safety and reliability. Reduce cost and resource use.
Background	Start-up company filling a need for integrated power inverter systems to facilitate move away from fossil fuel-based energy sources and move toward renewable energy and fuel cells.
Goals	The company's goals are to provide a "deep cradle to grave Life Cycle Analysis of the Transverter to maximize beneficial environmental impact and promote Green Engineering. Financial benefits are created to motivate the move to greener energy management. The net effect will be less pollution from fossil fuels used for energy & materials, less aluminum and copper mined and less total energy used directly & for manufacturing & transportation."
Scope	Company develops products to create a "real smart grid," which they define as scalable, household-level systems to integrate renewable energy, demand response, data acquisition, advanced metering, power quality control, community energy storage, communications, and energy security.

Continued . . .

Heart Transverter, S.A.

Timeline	Company appears still to be engaged in research, development, and product patenting as of January 2012.
Milestones & Publications	Fully-functional, full-scale examples of household transverter systems showcased at Solar Panel International 2011 (http://www.solarpowerinternational.com/2011/public/enter.aspx) and Connectivity Week, May 2011 (http://www.connectivityweek.com/2011/#home). Heart Transverter partnered with OSIsoft (http://www.osisoft.com/) to showcase a fully-functional microgrid system at Distributech 2011 (http://www.distributech.com/index.html). Heart Transverter has developed and patented at least three products to date (http://transverter.com/products.html).
Budget	
Other parties involved	OSIsoft (http://www.osisoft.com/).
Next steps	
Associated R&D strategy	
References	"Heart Transverter" (2012). http://transverter.com/, accessed Jan. 6, 2012.

Heart Transverter, S.A.

iPower

(Integrated Power Corporation)

Headquarters
504 Redwood Blvd Suite 230
Novato, CA 94947

(877) 88-iPower (884-7693) (o)
(415) 884-5555 (o)
(415) 884-5557 (f)
info@ipowercorp.com

http://www.ipowercorp.com/

Mission	iPower (Integrated Power Corp.) works to increase the use of renewable energy by providing architecturally-designed building-integrated photovoltaic systems and providing solar system expertise and guidance. The company was founded in 2005 and is headquartered in San Francisco.

New Construction Solutions

Headquarters
504 Redwood Blvd Suite 230
Novato, CA 94947

(877) 88-iPower (884-7693) (o)
(415) 884-5555 (o)
(415) 884-5557 (f)
info@ipowercorp.com

http://www.ipowercorp.com/index.php?option=com_content&view=article&id=5&Itemid=4

Mission	iPower's New Construction Solutions team offers technical knowledge, design services, and financial analysis support to develop efficient, building-integrated photovoltaic systems.

Grid Tie Inverters

Page 72

- iPower® SHO Series Grid Tie Inverters

iPower Corp.

iPower® SHO Series Grid Tie Inverters	**Project Overview:** Firm's SHO Series inverters make use of maximum power point tracking (MPPT) algorithms to provide reliable, high efficiency energy yield. **http://www.ipowercorp.com/index.php?option=com_content&view=article&id=105%3Anew-construction-solutions-1&catid=4&Itemid=4**

Institution	iPower (Integrated Power Corp.)	**Div. / Dept.**	New Construction Solutions
Contact	Headquarters 504 Redwood Blvd Suite 230 Novato, CA 94947 (877) 88-iPower (884-7693) (o) (415) 884-5555 (o) (415) 884-5557 (f) info@ipowercorp.com	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source

Project Details

R&D Program	UPS-PV integration (large or small) (AC + DC).
Technology Characteristics	Better energy storage in the electrical system, Standard uninterruptible power supply (UPS) interface hardware and control protocols to accept power from photovoltaic (PV) and other DC distributed generation sources.
Capability Gap(s)	Need for better energy storage including batteries to be cost effective and reliable. Need new thinking for optimization of DC systems
Driver(s)	More use of DC supply. Improve safety and reliability. Reduce cost and resource use.
Background	Inverters are necessary to integrate solar photovoltaic arrays within existing grid.
Goals	Company sought to provide reliable, high-efficiency, integration of photovoltaic-generated electricity.
Scope	To develop a series of inverters to use with some of the company's building integrated photovoltaic systems.
Timeline	iPower® SHO Series Grid Tie Inverters are currently available in the marketplace.
Milestones & Publications	Project information and specifications available at http://www.ipowercorp.com/index.php?option=com_content&view=article&id=105%3Anew-construction-solutions-1&catid=4&Itemid=4
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	iPower's products and services are coordinated to help integrate clean energy into commercial and residential buildings.
References	Integrated Power Corporation (2012). "iPower® SHO Series Grid Tie Inverters." http://www.ipowercorp.com/index.php?option=com_content&view=article&id=105%3Anew-construction-solutions-1&catid=4&Itemid=4, accessed Jan. 6, 2012.

Industrial Technology Research Institute (ITRI)	195, Sec. 4, Chung Hsing Rd. Chutung, Hsinchu, Taiwan 31040, R.O.C. http://www.itri.org.tw/eng/	+886-3-582-0100 (o) +886-3-582-0045 (f) Email: http://www.itri.org.tw/eng/econtent/contact/contact01.aspx

Mission	The non-profit Industrial Technology Research Institute (ITRI) collaborates with global partners to help propel technology innovation and commercialization in a variety of sectors including information technologies, electronics, and the material, chemical, and nanotechnology research area.

Material, Chemical, and Nanotechnology

	195, Sec. 4, Chung Hsing Rd. Chutung, Hsinchu, Taiwan 31040, R.O.C. http://www.itri.org.tw/eng/	+886-3-582-0100 (o) +886-3-582-0045 (f) Email: http://www.itri.org.tw/eng/econtent/contact/contact01.aspx
Mission	Researchers work with industry to develop and commercialize advances in electronics, optoelectronics, and panel displays, as well as high-tech fibers and specialty chemicals for the textile and chemical industries.	
	High Value-added Materials Page 74 • High Performance Thermoelectric Materials	

Industrial Technology Research Institute

High Value-added Materials	195, Sec. 4, Chung Hsing Rd. Chutung, Hsinchu, Taiwan 31040, R.O.C.	+886-3-582-0100 (o) +886-3-582-0045 (f) Email: http://www.itri.org.tw/eng/econtent/contact/contact01.aspx
	http://www.itri.org.tw/eng/econtent/research/research04_01.aspx?SItem=3	

Research Focus	Conducting research in a variety of areas to develop value-added materials and nanomaterials, including high performance thermoelectric materials.
High Performance Thermoelectric Materials	Developing materials to generate heat from solid state lighting systems by taking advantage of the Seebeck effect, which describes the phenomenon of generating voltage based on temperature differences between junctions of dissimilar metals in the same circuit.

- High Performance Thermoelectric Materials Page 75

High Performance Thermoelectric Materials

High Value-added Materials

Project Overview: Developing materials to generate heat from solid state lighting systems by taking advantage of the Seebeck effect, which describes the phenomenon of generating voltage based on temperature differences between junctions of dissimilar metals in the same circuit.

http://www.itri.org.tw/eng/econtent/research/research04_02.aspx?sid=11#

Institution	Industrial Technology Research Institute	**Div. / Dept.**	Material, Chemical, and Nanotechnology
Contact	Amanda Cheng +886-3-5919193 (o) hjc@itri.org.tw	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Thermoelectric heat recovery from LEDs.
Technology Characteristics	Thermoelectric generation mounted on LED driver chip to reduce power requirements and waste heat output.
Capability Gap(s)	Need to increase energy efficiency.
Driver(s)	Utilities are mandated to produce more energy with renewable sources and energy-efficiency measures. Energy-efficiency measures can reduce the impact of increasing energy costs.
Background	Thermoelectric solid state devices have been used to recover exhaust heat from vehicles, factories, incinerators, and precision temperature controllers, but not yet to light emitting diodes (LEDs). This project is the first to apply a silicon-based thermoelectric (TE) device on high-power LEDs.
Goals	Evaluate the feasibility of generating electricity from the waste heat of high-power LEDs.
Scope	Microfabrication and flip-chip assembly processes were used to fabricate the silicon-based TE device. Since the LED chip is fully enclosed and the LED chip junction temperature cannot be measured directly, an infrared camera was used to demonstrate the cooling abilities of the TE devices.
Timeline	
Milestones & Publications	Research as of 2005 indicated that the silicon-based TE device can reduce the thermal resistance of the high power LED; see Jen-Hau Cheng, Chun-Kai Liu, Yu-Lin Chao, and Ra-Min Tain (2005, June). "Cooling Performance of Silicon-Based Thermoelectric Device on High Power LED ." Proceedings, Institute of Electrical and Electronics Engineers (IEEE) 24th International Conference on Thermoelectrics (ICT 2005), pp. 53-56.

Continued . . .

Industrial Technology Research Institute

Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Jen-Hau Cheng, Chun-Kai Liu, Yu-Lin Chao, and Ra-Min Tain (2005, June). "Cooling Performance of Silicon-Based Thermoelectric Device on High Power LED ." Proceedings, Institute of Electrical and Electronics Engineers (IEEE) 24th International Conference on Thermoelectrics (ICT 2005), pp. 53-56. [Abstract at http://ieeexplore.ieee.org/Xplore/login.jsp?reload=true&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F10188%2F32527%2F01519885.pdf%3Farnumber%3D1519885&authDecision=-203, accessed Jan. 27, 2011.] Industrial Technology Research Institute (2012). "High Performance Thermoelectric Materials." http://www.itri.org.tw/eng/econtent/research/research04_02.aspx?sid=11#, accessed Jan. 27, 2012.

Lawrence Berkeley National Laboratory (LBNL)

1 Cyclotron Road
Berkeley, CA 94720

510-486-4000 (main office)

http://www.lbl.gov/

Mission	The Lawrence Berkeley National Laboratory is a U.S. Department of Energy National Laboratory operated by the University of California. The institution partners with individuals, institutions, and businesses throughout the globe to conduct research on a wide array of techniques and technologies, including energy efficiency, renewable energy, and building sciences.

Environmental Energy Technologies Division

Ashok Gadgil, Director
Lawrence Berkeley National Laboratory
Environmental Energy Tech Div.
1 Cyclotron Road, Mail Stop 90R3029B
Berkeley, CA 94720

(510) 486-4435 (o)
(510) 486-5454 (f)

AJGadgil@lbl.gov
EETDinfo@lbl.gov (general email)

http://eetd.lbl.gov/eetd.html

Mission

The Berkeley Lab's Environmental Energy Technologies Division (EETD) conducts analysis, research, and development to help implement energy and energy efficiency technologies and to reduce energy-related environmental impacts. The U.S. Department of Energy is the division's primary sponsor; the EETD also works closely with other federal entities, state governments, and the private sector. EETD's staff of 300 includes expertise in architecture, physics, mechanical engineering, economics. and public policy.

The R&D areas below relate directly to current projects identified in the Northwest Energy Efficiency Technology Roadmap Portfolio.

Buildings Energy Efficiency Page 78

- Applications
- Building Technologies
- Commercial Building Systems
- Heat Island Group
- High Performance Building Façade Solutions
- Lighting Research Group
- Windows & Daylighting

Energy Analysis Page 96

- Energy Efficiency Standards

Buildings Energy Efficiency

Ashok Gadgil, Director
Lawrence Berkeley National Laboratory
Environmental Energy Tech. Div.
1 Cyclotron Road, Mail Stop 90R3029B
Berkeley, CA 94720

(510) 486-4435 (o)
(510) 486-5454 (f)

AJGadgil@lbl.gov

http://eetd.lbl.gov/eetd.html

Research Focus	Researchers on the Buildings Energy Efficiency team of the Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division (EETD) works with private industry to research, develop, and implement building systems and technologies to increase efficiency and improve occupant comfort, health, and safety.
Windows & Daylighting	LBNL has been working for a number of years to develop improved window glazing and window frame technologies and analytical software. The lab's goal is to develop products that significantly reduce the flow of heat through the window (lowering the window's U value), making the windows suitable for Net Zero Energy applications.
	• Daylighting Page 84 • Windows Page 94
High Performance Building Façade Solutions	Building façade systems that fully consider and integrate functional and aesthetic design elements provide a significant opportunity for energy efficiency and for achieving Net Zero Energy goals.
	• High Performance Building Façade Solutions Page 86
Heat Island Group	Developing roofing materials that have both high solar reflectance and high thermal emittance—materials that both reflect sunlight and quickly shed heat.
	• Cool Roofs Page 81
Commercial Building Systems	Correlates other LBNL research involving windows, lighting and simulations into coherent, applied construction and design techniques; also seeks to correlate energy efficiency and an increased building life-cycle by integrating building technologies into complete systems.
	• Commercial Building Systems Page 82
Lighting Research Group	Investigates wireless and digital technologies to improve building efficiency and occupant productivity.
	• Lighting Controls and Communications Page 90 • Lighting Sources and Ballasts Page 92
Energy Information Systems	Works to develop energy information systems and performance monitoring and analysis technologies.
	• Building Energy Information Systems and Performance Monitoring Tools Page 79
Applications	Helps transfer new building technologies to the marketplace.
	• High-Performance Buildings for High-Tech Industries Page 88

Building Energy Information Systems and Performance Monitoring Tools

Energy Information Systems Team

Project Overview: The Lawrence Berkeley National Laboratory is working with the California Energy Commission and the Department of Energy to evaluate and improve tools for tracking and monitoring energy use in commercial buildings.

http://eis.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	
Contact	Mary Ann Piette Building Technologies 1 Cyclotron Road, MS 90R3111 Berkeley, CA 94720 (510) 486-6286 (o) (510) 486-4089 (f) MAPiette@lbl.gov	**Sponsor(s)**	California Energy Commission U.S. Department of Energy
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit and New Construction Labeling

Project Details

R&D Program	Energy information systems.
Technology Characteristics	Develop automated math-based utility bill-based calibration methods.
Capability Gap(s)	Evidence that labeling matters and that they are accurate. Access to utility metered data without negative impact on payer privacy. No inexpensive, accurate, regularly reproducible, system exists.
Driver(s)	The need for measured and persistent results to provide meaningful feedback to investment and R&D programs. Need apples to apples comparison between buildings. Policy mandates for rating and labeling.
Background	The LBNL has been working with the California Energy Commission and the Department of Energy for fifteen years to test and track emerging and in-use energy information systems. This work supports the 2007 Energy Independence and Security Act (http://energy.senate.gov/public/_files/getdoc1.pdf), the U.S. Department of Energy's Zero-Energy Commercial Building Initiative (http://www1.eere.energy.gov/buildings/commercial_initiative/), and similar efforts.
Goals	To help make energy information systems technologies more robust and widely available.
Scope	The LBNL's Energy Information Systems team tracks ongoing and completed research involving software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. Systems often also include analysis methods such as baselining, benchmarking, utility and carbon tracking, load profiling, and energy anomaly detection.

Continued . . .

Lawrence Berkeley National Laboratory

Timeline	Project began about 1996 and is ongoing.
Milestones & Publications	J. Grandersone, M.A. Piette, B. Rosenblum, L. Hu, et al. Energy Information Handbook: Applications for Energy-Efficient Building Operatoins. Berkeley, Calif: Lawrence Berkeley National Laboratory, 2011. Other project reports and case studies available at http://eis.lbl.gov/ and http://gaia.lbl.gov/btech/pubs/pubs.php?code=Energy%20Information%20Systems.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2012). "Building Energy Information Systems and Performance Monitoring Tools." http://eis.lbl.gov/, accessed Jan. 3, 2012.

Cool Roofs

Heat Island Group

Project Overview: Developing roofing materials that have both high solar reflectance and high thermal emittance—materials that both reflect sunlight and quickly shed heat.

http://heatisland.lbl.gov/coolscience/cool-science-cool-roofs

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Dept.
Contact	Ronnen Levinson 1 Cyclotron Road, MS 90R2000 Berkeley, CA 94720 (510) 486-7494 (o) RMLevinson@lbl.gov	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Solar / Smart Roofing

Project Details

R&D Program	Photovoltaic / solar water heating roofing (hybrid solar).
Technology Characteristics	Cool / photovoltaic / solar water heating roofing.
Capability Gap(s)	Need intelligent buildings with integrated photovoltaic systems. Need modularization of building PV components. Need products readily available in marketplace at a low cost. Need building codes that require solar systems.
Driver(s)	Availability of new technologies. Availability of crosscutting, low-cost technology building blocks. Declining price of PV Systems.
Background	Horizontal surfaces can receive up to 1000 watts of sunlight per square meter. Traditional, dark roofing materials absorb this energy, which increased the temperature of both the building and surrounding air. This heating can increase building energy as air conditioning systems work to counteract the increased temperature. Lighter-colored roofing materials can significantly decrease this heating effect.
Goals	In addition to a variety of benefits that these improved roofing materials have in terms of reducing heat island effects and slowing climate change, the project also has some specific energy efficiency goals. These include reducing peak demand loads and reducing overall energy use at the household level.
Scope	This project is focused on developing alternative roofing materials; research does not include other aspects such as integrated photovoltaics or solar water heating.
Timeline	
Milestones & Publications	R. Levinson and H. Akbari (2010) "Potential Benefits of Cool Roofs on Commercial Buildings: Conserving Energy, Saving Money, and Reducing Emission of Greenhouse Gases and air Pollutants." *Energy Efficiency* 3, pp. 53-109.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "Cool Science: Cool Roofs." http://heatisland.lbl.gov/coolscience/cool-science-cool-roofs, accessed Dec. 23, 2011. Lawrence Berkeley National Laboratory (2011). "The Cool Colors Project." http://coolcolors.lbl.gov/, accessed Dec. 23, 2011.

Commercial Building Systems

Commercial Buildings Systems Group

Project Overview: The Commercial Building Systems group correlates other LBNL research involving windows, lighting and simulations into coherent, applied construction and design techniques. This research also seeks to correlate energy efficiency and an increased building life-cycle by integrating building technologies into complete systems.

http://cbs.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Department
Contact	Philip Haves 1 Cyclotron Road MS 90R111 Berkeley, CA 94720 (510) 486-6512 (office) PHaves@lbl.gov	**Sponsor(s)**	The group works within a number of research areas has a variety of public and private sector sponsors, as necessary.
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Building

Project Details

R&D Program	Predictive modeling for control.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	This group at LNL has been conducting research for more than thirty years in support of the U.S. Department of Energy's Zero Energy Commercial Building initiative (http://www1.eere.energy.gov/buildings/commercial_initiative/).
Goals	In accordance with the U.S. Department of Energy's Zero Energy Commercial Building initiative, the group's goal is to achieve significant energy efficiency improvements in both existing and new commercial buildings.
Scope	Within the area of energy efficiency, this group conducts research in Advanced Building Technologies and Systems (windows, lighting, heating/ventilation, office equipment, etc.); Building Operations (commissioning/decommissioning, benchmarking, energy information systems, etc.); and Tools, Guides, and Standards (energy design and simulation, technical analysis, etc.).
Timeline	Ongoing; website periodically updated with new research and publications.

Continued . . .

Milestones & Publications	Group website provides links and information on more than fifty ongoing and recent commercial buildings projects, categorized into "Technologies & Systems" and "Tools & Process" subject areas: http://buildings.lbl.gov/
Budget	
Other parties involved	U.S. Department of Energy, University of California Berkeley, Numerous private and public sector partners
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "Commercial Building Systems." http://cbs.lbl.gov/, accessed Dec. 23, 2011. Lawrence Berkeley National Laboratory (2011). "R&D for the Net-Zero Energy Commercial Building." http://buildings.lbl.gov/, accessed Dec. 23, 2011. Lawrence Berkeley National Laboratory. "Continuous Performance Monitoring Systems." http://cbs.lbl.gov/performance-monitoring/specifications/, accessed Dec. 23, 2011.

Daylighting

Windows and Daylighting Group

Project Overview: LBNL has been working for a number of years to develop improved window glazing and window frame technologies and analytical software. The lab's goal is to develop products that significantly reduce the flow of heat through the window (lowering the window's U value), making the windows suitable for Net Zero Energy applications.

http://windows.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Department
Contact	Building Technologies Lawrence Berkeley National Laboratory 1 Cyclotron Road, MS 90R3111 Berkeley, CA 94720	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Daylighting system field testing, measurement, and verification. Integrated lighting simulation tools..
Technology Characteristics	Sensors & Control Systems. Assessment / field testing / etc. of daylighting options.
Capability Gap(s)	Need responsive and reliable controls and photo sensors for daylighting. Need applications that can utilize natural light. Need methods to compensate for daylight color shift, glare, intensity, focus. Need to have applications easier to design, commission and operate. Need better light quality as perceived by users. Need to disperse daylighting better to achieve higher daylight factors.
Driver(s)	Energy security. Climate change. Increased consumer resistance to complex features and controls. Optimize human performance (health, productivity). Optimize work environment for using computers of the future keep up as computers evolve. End user comfort / satisfaction. Aesthetics. Increase in available funding for EE. Increased interest among legislators in efficiency and renewables. Consumer desire to be "green" and reduce embedded & used energy.
Background	Daylighting tools, techniques, design strategies, and systems are designed to decrease energy consumed by artificial lighting.
Goals	This Group appears to be working on additional daylighting projects, but specific ongoing projects are not readily discernable as of Dec. 2011.
Scope	A significant portion of LBNL's work in this area appears to have been as a member of the International Energy Agency Task 21 work group, 1995-1999, and the New York Times Headquarters Building daylighting project, 2003-2009.

Continued . . .

Timeline	
Milestones & Publications	Lawrence Berkeley National Laboratory (2009). "Daylighting the New York Times Headquarters Building." http://windows.lbl.gov/comm_perf/newyorktimes.htm, accessed Dec. 13, 2011. Kjeld Johnsen (Operating Agent) (1999). "International Energy Agency Task 21, Daylight in Buildings: Design Tools and Performance Analysis." http://www.iea-shc.org/task21/index.html, accessed Dec. 23, 2011. International Energy Agency (2000). "Daylight in Buildings: A Source Book on Daylighting Systems and Components.: http://gaia.lbl.gov/iea21/, accessed Dec. 23, 2011. Other products and publications available at: http://windows.lbl.gov/daylighting/Default.htm, http://www.iea-shc.org/task21/publications/.
Budget	
Other parties involved	Solar Heating and Cooling Program, International Energy Agency (http://www.iea-shc.org/).
Next steps	
Associated R&D strategy	LBNL's Windows and Daylighting Group serves as the U.S. representative regarding International Energy Agency Task 21: Daylight in Buildings (http://www.iea-shc.org/task21/index.html).
References	Lawrence Berkeley National Laboratory (2011). "Daylighting." http://windows.lbl.gov/daylighting/Default.htm, accessed Dec. 23, 2011. Johnsen, Kjeld (1999). "International Energy Agency Task 21, Daylight in Buildings: Design Tools and Performance Analysis." http://www.iea-shc.org/task21/index.html, accessed Dec. 23, 2011.

High Performance Building Façade Solutions

High Performance Building Façade Solutions

Project Overview: Building façade systems that fully consider and integrate functional and aesthetic design elements provide a significant opportunity for energy efficiency and for achieving Net Zero Energy goals.

http://lowenergyfacades.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Dept.
Contact	Eleanor S. Lee Lawrence Berkeley National Laboratory (510) 486-4997 (o) ESLee@lbl.gov Project team members identified at http://lowenergyfacades.lbl.gov/team.html	**Sponsor(s)**	California Energy Commission (Public Interest Energy Research (PIER)) U.S. Department of Energy (Assistant Secretary for Energy Efficiency and Renewable Energy)
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	2030 Challenge.
Technology Characteristics	Design & analysis tools to integrate components and predict whole system energy performance.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices.
Driver(s)	Policy / codes including Environmental. Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Opportunity for large framework change.
Background	Building façade systems significantly impact energy use, functionality, and aesthetics. These systems require integration of insulation, lighting, and mechanical systems while also considering long-term performance and human tastes. For these reasons, developing façade systems with these considerations in mind often requires complex, interrelated technical and design solutions.
Goals	Develop integrated façade technologies, modeling tools, financial information, and other data to help achieve Net Zero Energy and 2030 Challenge targets (http://netzeroenergy.org/, http://www.architecture2030.org/), and make this information available by way of periodic website updates.
Scope	Facilitate the development and application of high-performance building façade systems by developing best practices, disseminating knowledge, and devising technologies and software tools.
Timeline	

Continued . . .

Milestones & Publications	Reports at http://windows.lbl.gov/highRtechnologies/Publications.html
Budget	
Other parties involved	Field Test Materials Provided By: Advanced Glazings Ltd.; Hunter Douglas; Köster Lichplanung; Lutron Electronics, Inc.; MechoShade Systems, Inc.; NYSAN Solar Control; Somfy Systems; Viracon; Warema; Wausau Window and Wall Systems
Next steps	This initiative is part of an ongoing, collaborative R&D effort, and website content is updated as new work is completed.
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "High Performance Building Façade Solutions." http://lowenergyfacades.lbl.gov/, accessed Dec. 23, 2011.

High-Performance Buildings for High-Tech Industries

Applications Team

Project Overview: The Lawrence Berkeley National Laboratory works with Silicon Valley high tech firms on projects to benchmark energy use at laboratories, clean rooms, data centers, and other high base-load industries and then develop technologies, tools, and strategies to improve energy efficiency.

http://hightech.lbl.gov/htindex.html

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Dept.
Contact	William Tschudi 1 Cyclotron Road, MS 90R3111 Berkeley, CA 94720 (510) 495-2417 (o) WFTschudi@lbl.gov	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Use and Virtualization

Project Details

R&D Program	Network/web energy usage research leading to better awareness of energy use of Internet, email, and other computer uses.
Technology Characteristics	Networking communication data compression / speed / bandwidth. Match data center power to use "elastic power". Software, hardware and protocols that enable virtualization for computing at all scales.
Capability Gap(s)	Need information on current baseline performance and metrics, current trends, and ongoing R&D related to usability, energy use, and virtualization potential. Need to develop cloud approach for delivering multiple services to minimize electronics energy use. Need data on the energy savings potential for software and systems that automatically summarize information for users vs. transmission, receipt and possibly printing of more extensive information. Need optimize energy use by servers, routers, PCs and other devices involved in Internet interactions without degrading user experience. Need optimal visual experience for TV and computer users with minimum display energy consumption.
Driver(s)	Four "any's" content, place, time, device. People more "plugged in" electronically, digital information, social networking. Emergence of component level standards addressing energy use optimization. IP v.6 – Internet protocol version 6. Consumer desire to be “green” and reduce embedded & used energy. Higher data rates and processing intensity and energy use. Proliferation of consumer electronics (increased plug loads).
Background	High-technology buildings such as laboratories, cleanrooms, and data centers operate twenty-four hours per day and consume larger base loads than typical commercial buildings. There are often untapped opportunities for energy savings at these buildings.
Goals	Provide tools, technologies, and approaches to improve efficiency at these facilities, to achieve a potential 30-50% energy efficiency improvement.
Scope	Project team works actively with professional and technical committees to demonstrate and disseminate results. They also provide a range of technology transfer activities such as delivering presentations and trainings, providing free design tools, and issuing technical and other publications.
Timeline	LBNL began this work in the mid-1990s, and it is ongoing.

Continued . . .

Milestones & Publications	This team prepares research and development roadmaps for the Public Interest Energy Research (PIER) program of the California Energy Commission (http://www.energy.ca.gov/research/index.html) to help set the strategic agenda for improved technologies and best practices.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2012). "High-Performance Buildings for High-Tech Industries." http://hightech.lbl.gov/htindex.html, accessed Jan. 3, 2012.

Lighting Controls and Communications

Lighting Research Group

Project Overview: Investigate wireless and digital technologies to improve building efficiency and occupant productivity.

http://lighting.lbl.gov/l_controls.html

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Dept.
Contact	Francis Rubinstein, Lighting Group Leader 1 Cyclotron Road MS 90R3111 Berkeley, CA 94720 (510) 486-4096 (o) FMRubinstein@lbl.gov	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Predictive modeling for dynamic lighting needs.
Technology Characteristics	Need adjustable lighting levels based on the time of the day. Space sensing beyond occupancy, e.g., task, location in room, traffic, population. Minimal impact and maximal compatibility on existing infrastructure. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need better user interfaces. Need integration with building automation / management systems. Optimized / ideal luminaire control communication protocol. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need more reliable controls. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing.
Driver(s)	Individual control over lighting. Controllable; integrated with other entertainment, communication mobility. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety). Optimize work environment for using computers of the future-keep up as computers evolve. End user comfort / satisfaction. Cost of new technology. Majority of energy efficiency potential is in retrofit applications. Need for professionals to be credible and deliver systems that work and avoid callbacks. Impacts on wildlife. Need for dark sky.
Background	This work falls under the guidelines of both the U.S. Department of Energy's Energy Efficiency and Renewable Energy program (http://www.eere.energy.gov/) and the California Energy Commission's Public Interest Energy Research (PIER) Buildings Program (http://www.energy.ca.gov/research/index.html).
Goals	Reduce lighting energy consumption by 50% over twenty years.

Continued . . .

Scope	The Lighting Group's research falls under three broad categories: Light Distribution Systems (http://cltc.ucdavis.edu/index.php); Sources and Ballasts (http://lighting.lbl.gov/l_sources.html); and Controls and Communications (http://lighting.lbl.gov/l_controls.html). Specifically within Controls and Communications, this Group is working on integrating wireless and embedded technologies to improve energy efficiency and enhance environmental sensing and monitoring.
Timeline	
Milestones & Publications	Publications listed and linked at http://gaia.lbl.gov/btech/pubs/pubs.php?code=Lighting%20Systems and http://lighting.lbl.gov/l_controls.html.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "Lighting Research Group." http://lighting.lbl.gov/, accessed Dec. 23, 2011. U.S. Department of Energy (2011). "Energy Efficiency & Renewable Energy." http://www.eere.energy.gov/, accessed Dec. 23, 2011. California Energy Commission (2011)."Research, Development, and Demonstration: Looking Toward the Future." http://www.energy.ca.gov/research/index.html, accessed Dec. 23, 2011.

Lighting Sources and Ballasts

Lighting Research Group

Project Overview: Conduct research into next generation light sources (such as light emitting diodes, LEDs) and power supplies to facilitate incorporation of technologies into the marketplace and improve functionality.

http://lighting.lbl.gov/l_sources.html

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Dept.
Contact	Francis Rubinstein Lighting Group Leader 1 Cyclotron Road MS 90R3111 Berkeley, CA 94720 (510) 486-4096 (office) FMRubinstein@lbl.gov	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	SSL life extension. Improved light extraction.
Technology Characteristics	Thermoelectric generation mounted on LED driver chip to reduce power requirements and waste heat output. Super SSL: The ca. 2010 winner of the DOE's next generation L-Prize (www.lightingprize.org/) meets all needs identified in Performance Gap boxes above.
Capability Gap(s)	Need better color rendering. Need to provide full dimming capabilities while maintaining light quality (i.e., reduce "flicker"). Need to improve lumen maintenance. Need to improve lighting reliability over time. Need to increase energy efficiency.
Driver(s)	Optimize work environment for using computers of the futurekeep up as computers evolve. Aesthetics. Optimize human performance (health, productivity). End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. The number of solid state lighting products available in the marketplace is rapidly growing with varying performance. Consumers need to be able to tell what they are getting.. Utilities are mandated to produce more energy with renewable sources and energy-efficiency measures. Energy-efficiency measures can reduce the impact of increasing energy costs.
Background	This work falls under the guidelines of both the U.S. Department of Energy's Energy Efficiency and Renewable Energy program (http://www.eere.energy.gov/) and the California Energy Commission's Public Interest Energy Research (PIER) Buildings Program (http://www.energy.ca.gov/research/index.html).
Goals	Reduce lighting energy consumption by 50% over twenty years.

Continued . . .

Scope	The Lighting Group's research falls under three broad categories: Light Distribution Systems (http://cltc.ucdavis.edu/index.php); Sources and Ballasts (http://lighting.lbl.gov/l_sources.html); and Controls and Communications (http://lighting.lbl.gov/l_controls.html). Specifically within Sources and Ballasts, this Group is working on providing next generation lighting and power sources, including light emitting diodes (LEDs) and organic light emitting diodes (OLEDs).
Timeline	
Milestones & Publications	Specific current projects listed at http://lighting.lbl.gov/l_sources.html Publications listed and linked at http://gaia.lbl.gov/btech/pubs/pubs.php?code=Lighting%20Systems and http://lighting.lbl.gov/l_controls.html.
Budget	
Other parties involved	California Lighting Technology Center, University of California Davis (http://cltc.ucdavis.edu/index.php)
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "Lighting Research Group." http://lighting.lbl.gov/, accessed Dec. 23, 2011. U.S. Department of Energy (2011). "Energy Efficiency & Renewable Energy." http://www.eere.energy.gov/, accessed Dec. 23, 2011. California Energy Commission (2011)."Research, Development, and Demonstration: Looking Toward the Future." http://www.energy.ca.gov/research/index.html, accessed Dec. 23, 2011.

Windows

Windows and Daylighting Group

Project Overview: LBNL has been working for a number of years to develop improved window glazing and window frame technologies and analytical software. The lab's goal is to develop products that significantly reduce the flow of heat through the window (lowering the window's U value), making the windows suitable for Net Zero Energy applications.

http://windows.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Building Technologies Department
Contact		**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Fenestration & Daylighting

Project Details

R&D Program	Fenestration system -Glazing.
Technology Characteristics	Heavily insulated electrochromic windows. Glazing, vacuum filled 2- pane, low-energy windows. Next-generation triple-glazed insulated glass with superior solar heat gain coefficient (SHGC) and Ufactor ratings (R5+).
Capability Gap(s)	Need better technologies, such as windows that can effectively cut energy use in both heating and cooling climates. Need lower costs. Need concepts for next generation "same R-value as a wall" or Net Zero Energy windows.
Driver(s)	Increase occupant health, comfort and safety. Increase window and skylight area. Achieve energy savings. More and cheaper products due to globalization of manufacturing. Reduced call backs / warranty, increased durability. Increase window and skylight area. Poor performing curtain walls. Reduce glare while providing natural daylighting.
Background	In the U.S., energy loss by way of window emissivity is equivalent to about one third of all building space heating energy used, or about 2% of total energy consumption. Replacing all existing windows with current ENERGY STAR (http://www.energystar.gov/) low-emissivity products (windows with U values less than 0.35 Btu/hr-ft2-F) would only cut this energy loss in half. Therefore, because heating loads correlate strongly with energy loss through conduction, lowering window U-factors is essential in reducing heating energy.
Goals	The goal is to achieve an overall window U-factor of 0.2 Btu/hr-ft2-F for application in Net Zero Energy homes throughout the United States.
Scope	LBNL is engaged in two projects in this area. One focuses on one of three common ways to approach multi-layer, low-emissivity (low-E) gas-fill window glazing. Researchers continue to investigate the thermal potentials of three-layer window designs by experimenting with various ways to position a non-structural center layer between the inner and outer layers of standard Insulated Glazing Units (IGs).
Timeline	

Continued . . .

Milestones	Gustavsen, Arild, Jelle, Bjørn Petter, Arasteh, Dariush, and Kohler, Christian (2007). "State-of-the-Art Highly Insulating Window Frames: Research and Market Review." Blindern, Norway: SINTEF Building and Infrastructure. Additional reports written between 2002 and 2006 at http://windows.lbl.gov/highRtechnologies/Publications.html
Budget	
Other parties involved	Norwegian University of Science.
Next steps	
Associated R&D strategy	
References	Lawrence Berkeley National Laboratory (2011). "Windows & Daylighting." http://windows.lbl.gov/, accessed Dec. 23, 2011. Lawrence Berkeley National Laboratory (2011). "Environmental Energy Technologies Division, Buildings Energy Efficiency." http://eetd.lbl.gov/r-bldgsee.html, accessed Dec. 23, 2011.

Energy Analysis

Lawrence Berkeley National Laboratory
Environmental Energy Technologies Div.
1 Cyclotron Road, MS 90R4000
Berkeley, CA 94720

http://eetd.lbl.gov/eetd.html

(510) 486-6049 (o)
(510) 486-6996 (f)

JEMcMahon@lbl.gov

Research Focus	Provides research and analysis to help governments and international institutions formulate energy and environmental policies.
Energy Efficiency Standards	The Energy Efficiency Standards (EES) Group researches and analyzes energy-consuming domestic, commercial, and industrial equipment, and promulgates standards to maximize energy efficiency

Energy Efficiency Standards

Energy Efficiency Standards (EES) Group

Project Overview: The Energy Efficiency Standards (EES) Group researches and analyzes energy-consuming domestic, commercial, and industrial equipment, and promulgates standards to maximize energy efficiency.

http://ees.ead.lbl.gov/

Institution	Lawrence Berkeley National Laboratory	**Div. / Dept.**	Environmental Energy Technologies Division, Energy Analysis Department, Appliance Energy Standards Group
Contact	Lawrence Berkeley National Laboratory Environmental Energy Technologies Div. 1 Cyclotron Road, MS 90R4000 Berkeley, CA 94720	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Interlock Devices to Manage Energy Use

Project Details

R&D Program	Requirement standards for sleep /stand-by modes.
Technology Characteristics	Quality open communication standards (simple and few). User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC. Standardized power hardware, software, and protocols to enable device sleep/standby modes. Software compatibility with standby modes. Video game systems with sleep modes that do not erase scores, progress, etc..
Capability Gap(s)	Need to optimize sleep mode energy impacts without degrading user experience. Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting.. Need interactive / communicating devices that are designed in, not added-on systems (less hardware). Need to develop low cost systems that permit quick adoption. Need to have cost effective for hospitality industry to install and operate. Need network standby "horizontal" standards for all devices. Need to integrate sleep mode applications with product standby software and hardware configurations. Need to optimize sleep mode energy impacts without degrading user experience. Need to require minimal user interaction.
Driver(s)	Smart grid technology development. More and cheaper products due to globalization of manufacturing. Diffusion of common communication protocols into energy consuming devices. Proliferation of consumer electronics (increased plug loads). More and cheaper products due to globalization of manufacturing. Consumer desire for comfort and aesthetics. Use codes to lock in efficiency gains. Consumer desire to be "green" and reduce embedded & used energy.
Background	The Energy Efficiency Standards (EES) Group supports the U.S. Department of Energy's Appliances & Commercial Equipment Standards program (http://www1.eere.energy.gov/buildings/appliance_standards/) by analyzing technical, economic, and environmental facets of energy use internationally and across all sectors and promulgating standards to maximize energy efficiency. The EES Group's mandate is provided by the Energy Policy and Conservation Act (EPCA) of 1975, the National Energy Conservation and Policy Act (NECPA) of 1978, and 1987 National Appliance Energy Conservation Act (NAECA) amendments to the NECPA.

Continued . . .

Lawrence Berkeley National Laboratory

Goals	The EES Group seeks to determine if any proposed energy efficiency standard meets feasibility requirements primarily in terms of technology, economics, and projected energy savings.
Scope	Analyzes and reports on impacts and energy-saving potential of standards related to home appliances, heating/air conditioning/ventilation systems, electric motors, distribution transformers, lighting systems, and a range of other residential, commercial, and industrial equipment.
Timeline	Lawrence Berkeley National Laboratory's Energy Efficiency Standards Group has been a prime contractor for engineering and economic analyses of appliance and lighting standards since 1979, and the Group's work is ongoing.
Milestones & Publications	Current projects listed at http://ees.ead.lbl.gov/taxonomy/term/1 Publications listed at http://ees.ead.lbl.gov/bibliography.
Budget	
Other parties involved	U.S. Department of Energy.
Next steps	
Associated R&D strategy	The EES Group's standard setting process is specified at http://ees.ead.lbl.gov/node/2 and http://ees.ead.lbl.gov/about. The U.S. Department of Energy's Appliance and Commercial Equipment Standards information can be found at http://www1.eere.energy.gov/buildings/appliance_standards/.
References	Lawrence Berkeley National Laboratory (2011). "Energy Efficiency Standards." http://ees.ead.lbl.gov/, accessed Dec. 23, 2011. U.S. Department of Energy (2011). "Appliance and Commercial Equipment Standards." http://www1.eere.energy.gov/buildings/appliance_standards/, accessed Dec. 23, 2011.

Microsoft Corporation	One Microsoft Way Redmond, WA 98052-6399	Press Contact: Waggener Edstrom Worldwide: (503) 443-7000 (o) msrpr@wagged.com http://www.corporateofficeheadquarters.com/2011/03/microsoft.html

Mission	A world-wide leader in information technology systems.

Microsoft Research

	Peter Lee, Director Microsoft Research Redmond One Microsoft Way Redmond, WA 98052-6399	Press Contact: Waggener Edstrom Worldwide: (503) 443-7000 (o) msrpr@wagged.com http://research.microsoft.com/en-us/default.aspx

Mission	Microsoft's team conducts basic and applied research in sixty-plus areas of computer science and software engineering in partnership with government, academic, and private institutions. Microsoft Research has eight locations worldwide. Microsoft Research Redmond's office was established in 1991.

Microsoft Corporation

Networking Research Group

One Microsoft Way
Redmond, WA 98052
(800) 642-7676 (o)

http://research.microsoft.com/en-us/groups/nrg/

Research Focus	Microsoft's Networking Research Group researches, designs, develops, and studies technologies and methodologies to achieve reliable, scalable products.
Desktop PC Energy Savings for Enterprises	Develop enterprise software solutions to enable a networked desktop to be put in sleep mode whenever the computer is not being used by maintaining a proxy desktop on the server; desktop could be quickly and seamlessly awakened when needed by the user or by way of an automated script.

- Desktop PC Energy Savings for Enterprises Page 101

Desktop PC Energy Savings for Enterprises

Networking Research Group

Project Overview: Develop enterprise software solutions to enable a networked desktop to be put in sleep mode whenever the computer is not being used by maintaining a proxy desktop on the server; desktop could be quickly and seamlessly awakened when needed by the user or by way of an automated script.

http://research.microsoft.com/en-us/projects/desktopenergy/default.aspx

Institution	Microsoft	**Div. / Dept.**	Microsoft Research
Contact	Jitu Padhye One Microsoft Way Redmond, WA 9805 (800) 642-7676 (o) padhye@microsoft.com	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Power Management Control and Communication

Project Details

R&D Program	Network management for computer network administrators.
Technology Characteristics	Software compatibility with standby modes. Sleep mode more responsive to late-night network updates.
Capability Gap(s)	Need to optimize sleep mode energy impacts without degrading user experience. Need to require minimal user interaction.
Driver(s)	Consumer desire for comfort and aesthetics.
Background	Enterprise desktop computers consume a great deal of energy—an estimated 65TWh/year. A typical desktop with a 17-inch LCD consumes up to 100W while sleeping computers, on the other hand, consume only about 2-3W. For a variety of reasons, most people do not power-down their computer when they are not using it.
Goals	The project seeks to create software that will put networked desktops into sleep mode when they are not being used, while maintaining a virtual computer in the proxy cloud that can be easily and seamlessly powered-up when needed.
Scope	Two methods are proposed: 1) SleepServer that would maintain the presence of the sleeping desktop on the network and wake the desktop when needed; 2) LiteGreen program that provides continual hosting of the desktop as a virtual machine in the network cloud, and seamless functionality when the desktop is awake.
Timeline	As of 2012, approximately 1100 machines are on Microsoft campuses for pilot studies.

Continued . . .

Microsoft Corporation

Milestones & Publications	Reich , Joshua, Goraczko, Michel, Kansal, Aman, and Padhye, Jitu (2010). "Sleepless In Seattle No Longer." *Proceedings of USENIX Annual Technical Conference, June 22, 2010*. http://research.microsoft.com/apps/pubs/default.aspx?id=131390, accessed Jan. 4, 2012. Siddhartha Sen, Jacob R. Lorch, Richard Hughes, Carlos Garcia Jurado Suarez, Brian Zill, Weverton Cordeiro, and Jitendra Padhye, "Don't Lose Sleep Over Availability: The GreenUp Decentralized Wakeup Service," *9th USENIX Symposium on Networked Systems Design and Implementation*, April 25-27, 2012, http://research.microsoft.com/en-us/um/people/padhye/publications/greenup-nsdi12.pdf, accessed Sep. 12, 2012.
Budget	
Other parties involved	Pradeep Padala (intern, University of Michigan), Joshua Reich (intern, Columbia University), Sid Sen (intern, Princeton University).
Next steps	
Associated R&D strategy	
References	Reich , Joshua, Goraczko, Michel, Kansal, Aman, and Padhye, Jitu (2010). "Sleepless In Seattle No Longer." *Proceedings of USENIX Annual Technical Conference, June 22, 2010*. http://research.microsoft.com/apps/pubs/default.aspx?id=131390, accessed Jan. 4, 2012. Microsoft Research (2012). "Desktop PC Energy Savings for Enterprises." http://research.microsoft.com/en-us/projects/desktopenergy/default.aspx, accessed Jan. 4, 2012.

Microsoft Corporation

Sensing and Energy Research Group	One Microsoft Way Redmond, WA 98052	(800) 642-7676 (o) http://research.microsoft.com/en-us/groups/serg/default.aspx

Research Focus	Microsoft's Networking Research Group researches, designs, develops, and studies technologies and methodologies to achieve reliable, scalable products.
Energy-Efficient Enterprise and Cloud Computing	Improve energy use of software, online systems, and applications. • Energy-Efficient Enterprise and Cloud Computing Page 104

Microsoft Corporation

Energy-Efficient Enterprise and Cloud Computing	**Sensing and Energy Research Group** **Project Overview:** Improve energy use of software, online systems, and applications. **http://research.microsoft.com/en-us/projects/eec/**

Institution	Microsoft Corp.	**Div. / Dept.**	Microsoft Research
Contact	Michael Goracko Senior Research & Development Engineer http://research.microsoft.com/en-us/people/michelg/	**Sponsor(s)**	
Product / Service Area	Sensors, Meters, Energy Management Systems	**Roadmap**	Enterprise Energy and Maintenance Management Systems

Project Details

R&D Program	Development of algorithms/intelligence interface of sensor information with central system.
Technology Characteristics	Enterprise energy management software (many providers, easily 30+ companies). Existing information technology utilized energy management players. Standard communication protocol for enterprise EMS data. Develop a standard data model for EMS data. Automation of data collection analytics , and commissioning process.
Capability Gap(s)	Data ownership and security issue. Need to integrate formal energy management practices into consumers services and business processes. Business model and cost-effectiveness. Standard protocols for performance metrics and data. Need to transform raw data and implement feedback loops into actionable insights through improve data analytics. Establish truly universal, simple, seamless plug and play interoperability. Need better and more accurate data from systems submeters, and more properly cx.
Driver(s)	Policies requiring Energy disclosure. Performance based procurement. Lack of engagement and interest in energy efficiency from customers. People getting overwhelmed with device settings. Business drivers to decrease cost and increase productivity. Increasing development and availability of analytics / intelligent systems. Market driven communication interface standard. diffusion of common communication protocols into energy-consuming devices. Availability of crosscutting, low-cost technology building blocks. Smart grid technology development.
Background	The growth rate of energy use for computing infrastructures is faster than the growth rates of other energy uses and in some cases is out-stripping the capacities of local utilities. Microsoft Research Redmond continues to investigate ways to make computer systems more energy efficient.
Goals	Project teams first develop tools to provide benchmarking and better understand needs and gaps, including examining the output of individual hardward components, virtual machines, and software processes. They then develop systems and techniques to decrease energy needs.

Continued . . .

Scope	Includes three primary initiatives: "Joulemeter" modeling tool to estimate computer system power consumption (http://research.microsoft.com/en-us/projects/joulemeter/); "Cuanta" project to save energy by developing techniques to optimize hardware workload consolidation (http://research.microsoft.com/en-us/projects/cuanta/); and "Virtualized Power Shifting" to provide platform power budgeting in virtual ("cloud") environments.
Timeline	Project is ongoing, with regular reports and conference presentations.
Milestones & Publications	Project publications available at http://research.microsoft.com/en-us/projects/eec/.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Microsoft Research (2012). "Energy-Efficient Enterprise and Cloud Computing. "http://research.microsoft.com/en-us/projects/eec/, accessed Jan. 5, 2012.

Microsoft Corporation

Massachusetts Institute of Technology (MIT)	77 Massachusetts Avenue Cambridge, MA 02139-4307 http://web.mit.edu/
Mission	Leading educational institution for science, technology, engineering, and related fields.

Architecture Department

Nader Tehrani — (617) 253-7791 (o)
Department Head — ntehrani@MIT.EDU
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 7-337
Cambridge, MA 02139-4307

http://architecture.mit.edu/

Mission

Department contains five semi-autonomous discipline groups: Architectural Design; Building Technology; Computation; History, Theory and Criticism of Architecture and Art; and Art, Culture, and Technology.

Daylighting Modeling Page 108

- Assessment of environment in daylit spaces via simulation.

The Lorax Project: Giving Architects A Voice in Daylighting Standards Page 109

- A method of testing current and emerging daylight availability metrics such as daylighting factor, daylight autonomy, useful daylightil luminance and LEED 3.0 requirements against building occupant assessments of a daylit space.

Daylighting Modeling

Architecture Department

Project Overview: Assessment of environment in daylit spaces via simulation.

http://architecture.mit.edu/faculty/christoph-reinhart

Institution	MIT	**Div. / Dept.**	MIT Architecture
Contact	Joe Paradiso Associate Professor of Architecture (617) 253-7714 (o) tito_@mit.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Architect involvement.
Technology Characteristics	Inclusive environment during standards/codes development,
Capability Gap(s)	Need to have improved modeling tools, codes, standards.
Driver(s)	Increased consumer resistance to complex features and controls.
Background	Daylight simulations can help design teams to address these multiple aspects by allowing them to (a) predict the amount of light available inside or outside of buildings under selected sky conditions or over the course of a whole year and (b) to interpret the results by converting them into meaningful performance metrics.
Goals	1. Assessment of the luminous environment in daylit spaces via simulation. 2. Develop emerging metrics to evaluate the performance of daylit spaces.
Scope	Overview of the different steps required to use daylight simulations for building design. Address Issues such as what daylighting performance metrics to use, how to address building occupant behavior and expectations and how to interpret simulation results in order to help design teams to make more informed design decisions.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	C.F. Reinhart, "Simulation-based Daylight Performance Predictions" in *Building Performance Simulation for Design and Operation*, J. Hensen and R. Lamberts, eds. (Philadelphia: Taylor & Francis, 2011).

The Lorax Project: Giving Architects A Voice in Daylighting Standards

Architecture Department

Project Overview: A method of testing current and emerging daylight availability metrics such as daylighting factor, daylight autonomy, useful daylight illuminance and LEED 3.0 requirements against building occupant assessments of a daylit space.

http://mit.edu/tito_/www/Projects/DaylitAreaStudy/DaylitAreaStudyContinued.html

Institution	MIT	**Div. / Dept.**	MIT Architecture
Contact	Joe Paradiso Associate Professor of Architecture tito_@mit.edu (617) 253-7714 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Architect involvement.
Technology Characteristics	Inclusive environment during standards/codes development,
Capability Gap(s)	Need to have improved modeling tools, codes, standards.
Driver(s)	Increased consumer resistance to complex features and controls.
Background	Standard organizations and committees working on building codes and green building standards are typically not frequented by architects. Yet, these committees do more and more influence what performance criteria architects have to design for. This situation is obviously undesirable since there is not feedback mechanism that reports how standard requirements influence design decisions in practice.
Goals	Collaboration with Building Science Educators worldwide and to repeat the Daylit Area Exercise in a variety of climates and cultures. Results will be used to help the IESNA and others to gage the validity of the daylight autonomy metric.
Scope	A method of testing current and emerging daylight availability metrics such as daylighting factor, daylight autonomy, useful daylight illuminance and LEED 3.0 requirements against building occupant assessments of a daylit space.
Timeline	

Continued . . .

Massachusetts Institute of Technology

Milestones & Publications	Christoph F. Reinhart and Daniel A. Weissman, "The daylit area – Correlating Architectural Student Assessments with Current and Emerging Daylight Availability Metrics," *Building and Environment* 50 (April 2012), 155-164. (Abstract at http://www.sciencedirect.com/science/article/pii/S0360132311003817).
Budget	
Other parties involved	19 Universities across the globe are interested in participating. 4 Universities have sent student assessments.
Next steps	
Associated R&D strategy	
References	"The Lorax Project - Giving Architects A Voice In Daylighting Standard," http://mit.edu/tito_/www/Projects/DaylitAreaStudy/DaylitAreaStudyContinued.html, accessed Sep. 11, 2012. Christoph F. Reinhart and Daniel A. Weissman, "The daylit area – Correlating Architectural Student Assessments with Current and Emerging Daylight Availability Metrics," *Building and Environment* 50 (April 2012), 155-164. (Abstract at http://www.sciencedirect.com/science/article/pii/S0360132311003817).

Massachusetts Institute of Technology (MIT)	77 Massachusetts Avenue Cambridge, MA 02139-4307 http://web.mit.edu/
Mission	Leading educational institution for science, technology, engineering, and related fields.

Building Technology Research Program

John Fernandez, Associate Professor
Director of Building Technology
Massachusetts Institute of Technology
77 Massachusetts Avenue, 5-418B
Cambridge, MA 02139-4307

http://bt.mit.edu/

(617) 253-5266 (o)
fernande@mit.edu

Mission

Interdisciplinary program jointly sponsored by the departments of Architecture, Civil and Environmental Engineering, and Mechanical Engineering.

Building Materials & Construction

Page 112

- Building Design to Optimize Natural Ventilation
- Fault Detection Software for HVAC Units in Commercial Buildings
- New Insulation for Retrofitting Existing Buildings

Building Materials & Construction Group

Massachusetts Institute of Technology
77 Massachusetts Avenue, 5-418B
Cambridge, MA 02139-4307

http://bt.mit.edu/?page_id=40

Research Focus	Within the Building Technology Research Program, research in this area focuses specifically on construction and insulation materials and systems.
Building Design to Optimize Natural Ventilation	Minimizing the need for air conditioning through building designs which optimize benefits of natural ventilation.
	• Building Design to Optimize Natural Ventilation Page 113
Fault Detection Software for HVAC Units in Commercial Buildings	Develop a practical means of fault detection of HVAC units in commercial buildings.
	• Fault Detection Software for HVAC Units in Commercial Buildings Page 114
New Insulation for Retrofitting Existing Buildings	Research into the creation and installation of thin, inexpensive, and easily applied silica aerogel-based insulation.
	• New Insulation for Retrofitting Existing Buildings Page 116

Building Design to Optimize Natural Ventilation

Building Materials & Construction Group

Project Overview: Minimizing the need for air conditioning through building designs which optimize benefits of natural ventilation.

http://bt.mit.edu/?page_id=40

Institution	MIT	**Div. / Dept.**	Building Technology Research Program
Contact	Professor Leon Glicksman Professor of Building Technology and Mechanical Engineering (617) 253-2233 glicks@mit.edu	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization

Project Details

R&D Program	Optimized natural ventilation commercial building design to reduce cooling loads.
Technology Characteristics	Building design to reduce natural ventilation.
Capability Gap(s)	Need to optimize use of ambient or indoor conditions. Need to correlate ventilation, temperature, and humidity delivery with actual uses at granular level so controls and monitoring devices can be designed appropriately. Need predictive controls to optimize operation. Need reliable and effective economizer systems & controls (i.e., seals, actuators, dampers).
Driver(s)	Reduced HVAC loads in buildings / lack properly sized equipment options. Diffusion of common communication protocols into energy-consuming devices. IAQ separate ventilation from HVAC loads / Equipment. Increasing and uncertain future cost of electricity and gas. Heat recovery should have bypass ducting, but added cost and added control complexity need defunding as do adequate exhaust air filtration QC therefore difficult. Simultaneous interest in energy efficiency and IAQ. Air size economizers augment both, but have high cost and difficult QC.
Background	During summertime, the use of air conditioning units drive up energy peak demands.
Goals	Mitigate cooling needs through the use of buildings designed with natural ventilation systems. Develop building design using operable openings, such as windows, coupled with interior building design for optimal airflow, resulting in comfortable indoor conditions, mitigating, if not eliminating the use of air conditioning.
Scope	Assess prospects of natural ventilation in terms of energy efficiency.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Current ongoing construction for an office building design using a natural ventilation system in downtown Tokyo to be completed Summer/Fall 2012. After building completion, performance of system will be monitored.
Associated R&D strategy	
References	Massachusetts Institute of Technology Building Technology Research Program, "Building Materials & Construction,"2012, http://bt.mit.edu/?page_id=40, accessed June 20, 2012.

Fault Detection Software for HVAC Units in Commercial Buildings

Building Materials & Construction Group

Project Overview: Develop a practical means of fault detection of HVAC units in commercial buildings.

http://bt.mit.edu/?page_id=40

Institution	MIT	**Div. / Dept.**	Building Technology Research Program
Contact	Professor Leon Glicksman Professor of Building Technology and Mechanical Engineering (617) 253-2233 glicks@mit.edu	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Fault Detection and Predictive Maintenance

Project Details

R&D Program	Hardware is available;, need more reliable fault detection and diagnostics controls at smaller scale to drive market acceptance.
Technology Characteristics	Support for ASHRAE standard sequence of operations technology committee. Market intelligence on cost and saving for FDD. User-aware & self-diagnosing controls for packaged HVAC units. Need to have "on-board" diagnostics or data streams to collect. Predictive maintenance. Expand specification for regular use of closed-loop controls. Self-optimizing controls.
Capability Gap(s)	Lack of strong consensus about what correct (nonfaults) sequence of operation are.. Lack of information on saving from FDD. Need to eliminate failure modes by design simplification of systems. Need to have corrective hardware such as predictive controls to optimize operation and intelligent systems with predictive, diagnostic controls & self-healing processes. Need to have "on-board" diagnostics or data streams to collect.
Driver(s)	Increasing interest in operator behavior based energy saving as capital investment. Diffusion of common communication protocols into energy-consuming devices. Increasing interest in public funding for retro-cx. Usefulness of DDC systems in bringing down cost of RCxg vir auto fault detection and verification of correction. Potential of DDC in large commercial to calculate energy loss/cost of faults to prioritize faults in human response and justify public funding. Consumer demand for reduced / low cost of utilities / operation. Advanced HVAC technologies FOD tools. Contractor interest to increase profits. Integration of info, communication & entertainment devices.
Background	Energy needed by HVAC systems can consist of as much as 50% of the total building energy use. Simultaneous heating and cooling, or other extraneous efforts is a major cause of HVAC losses. Detecting, evaluating, and diagnosing faulty HVAC use is central to scalable energy efficiency.
Goals	To develop a simple program which gives building operators identifying top HVAC faults and using probability estimation to determine cost associated.

Continued . . .

Massachusetts Institute of Technology

Scope	Simple program development that operates alongside HVAC control system that can be used by building maintenance personnel for HVAC fault identification.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Currently applying HVAC fault identification software to hospitals in Europe.
Associated R&D strategy	
References	Massachusetts Institute of Technology Building Technology Research Program, "Building Materials & Construction,"2012, http://bt.mit.edu/?page_id=40, accessed June 20, 2012.

New Insulation for Retrofitting Existing Buildings

Building Materials & Construction Group

Project Overview: Research into the creation and installation of thin, inexpensive, and easily applied silica aerogel-based insulation.

http://bt.mit.edu/?page_id=40

Institution	MIT	**Div. / Dept.**	Building Technology Research Program
Contact	Professor Leon Glicksman Professor of Building technology and Mechanical Engineering (617) 253-2233 glicks@mit.edu	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit Insulation

Project Details

R&D Program	"Smart" material that fills all cavities and is mistake-free and inexpensive.
Technology Characteristics	Materials or method to better insulate walls.
Capability Gap(s)	Need easier to use, affordable insulation materials.
Driver(s)	More and cheaper products due to globalization of manufacturing. Ever changing installation processes to match technologies**.**
Background	Building heating and cooling consumes a large percentage of energy used in the U.S. addressing this issue for existing buildings will involve the development of inexpensive and easier-to-install insulation materials.
Goals	Create a material for use in the less-expensive retrofits to existing buildings.
Scope	Make use of silica aerogel to develop insulation panels that can be installed without the need of deep retrofits.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Develop full panel assembly that can be used for retrofit insulation purposes. Will attempt to finish and demonstrate these panels at the end of the calendar year. in order to improve insulating properties of aerogel.
Associated R&D strategy	
References	Massachusetts Institute of Technology Building Technology Research Program (2012). "Building Materials & Construction." http://bt.mit.edu/?page_id=40, accessed Jan. 6, 2012.

Massachusetts Institute of Technology (MIT)	77 Massachusetts Avenue http://web.mit.edu/	Cambridge, MA 02139-4307
Mission	Leading educational institution for science, technology, engineering, and related fields.	

Concrete Sustainability Hub

John Ochsendorf, Co-Director
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 1-372
Cambridge, MA 02139

(617) 253-4087 (o)
(617) 253-6152 (f)
jao@mit.edu

http://web.mit.edu/cshub/index.html

Mission

Interdisciplinary program involving MIT faculty from the School of Engineering, School of Architecture and Planning, and the Sloan School of Management.

Concrete Building Technology Platform Page 118

- The Edge of Concrete: A Life-Cycle Investigation of Concrete and Concrete Structures

Massachusetts Institute of Technology

Concrete Building Technology Platform

Massachusetts Institute of Technology
77 Massachusetts Avenue, 5-418B
Cambridge, MA 02139-4307

http://web.mit.edu/cshub/research/projects.html

Research Focus	Team's research focuses on research and development of new materials-structural combinations for a range of concrete applications including insulated wall systems.
Concrete Building Technology Platform	Research on closed-cell foam insulation for appliances and buildings exhibited improved insulative ability and reduced environmental hazards.

The Edge of Concrete: A Life-Cycle Investigation of Concrete and Concrete Structures

Concrete Sustainability Hub

Project Overview: Applying life cycle assessment (LCA) to quantify environmental and energy-efficiency performance of residential and commercial building concrete applications.

http://web.mit.edu/cshub/research/projects.html

Institution	MIT	**Div. / Dept.**	Concrete Building Technology Platform
Contact	John Ochsendorf, Co-Director 77 Massachusetts Avenue, Room 1-372 Cambridge, MA 02139 (617) 253-4087 (o) (617) 253-6152 (f) jao@mit.edu	**Sponsor(s)**	Portland Cement Association (http://www.cement.org/), RMC Research & Education Foundation (http://www.rmc-foundation.org/)
Product / Service Area	Building Design/Envelope	**Roadmap**	New Construction Insulation

Project Details

R&D Program	Application technology "easy and cheap."
Technology Characteristics	Adapt code language for attaching cladding insulating sheathing to framing. Cost effective insulation materials. Thermal performance measurement techniques, innovative new materials.
Capability Gap(s)	Cladding attachment systems (e.g. residential siding over foam). Need affordable, widely available construction materials with outstanding insulating characteristics. Need to be easier to install. Need better modeling / technology. Development of tests and protocols to assess thermal insulation.
Driver(s)	Increase occupant health, comfort and safety. Need cost effective energy efficiency programs. Need for cost effective assessment of structures. More and cheaper products due to globalization of manufacturing. Reduced call backs/warranty, increased durability. Poor performing curtain walls. Use of codes to lock in efficiency gains.
Background	Buildings emit the largest amount of greenhouse gases of any sector in the U.S. (39%). Better understanding concrete performance and life cycle will enable a significant reduction in emissions as well as an increase in buildings energy efficiency.
Goals	Devise concrete aggregate formulae and structural models that incorporate up-to-date knowledge and best practices to create solutions with enhanced performance, lengthened lifespan, reduced environmental impacts, and improved insulative properties. Contributed to the creation of a standardized buildings life cycle assessment approach.

Continued . . .

Massachusetts Institute of Technology

Scope	Provide life cycle assessment for concrete materials and structures applied in commercial and residential buildings in two climate zones (Phoenix, AZ, and Chicago, IL) so as to benchmark current performance and compare to other structural materials (such as wood-framed walls). Insulative ability of concrete walls are analyzed within a broader life cycle assessment that includes the embodied energy and emissions of the concrete material itself.
Timeline	
Milestones & Publications	Produced interim report in Dec. 2010 (http://web.mit.edu/cshub/news/pdf/BuildingsLCAsummaryDec2010.pdf), follow-up report published Aug. 2011 (http://web.mit.edu/cshub/news/pdf/MIT%20Buildings%20LCA%20Report.pdf).
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Massachusetts Institute of Technology Building Technology Research Program (2012). "Concrete Sustainability Hub." http://web.mit.edu/cshub, accessed Jan. 18, 2012. Ochsendorf, John (2010, Dec.). "Life Cycle Assessment (LCA) of Buildings: Interim Report." Massachusetts Institute of Technology Concrete Sustainability Hub. http://web.mit.edu/cshub/news/pdf/BuildingsLCAsummaryDec2010.pdf, accessed Jan. 18, 2012. Ochsendorf, John, *et al.* (2011, Aug.). "Methods, Impacts, and Opportunities in the Concrete Building Life Cycle." http://web.mit.edu/cshub/news/pdf/MIT%20Buildings%20LCA%20Report.pdf, accessed Jan. 18, 2012.

Massachusetts Institute of Technology (MIT)	77 Massachusetts Avenue Cambridge, MA 02139-4307 http://web.mit.edu/
Mission	Leading educational institution for science, technology, engineering, and related fields.

MIT Media Laboratory

	77 Massachusetts Avenue, E14/E15 Cambridge, MA 02139-4307 http://media.mit.edu/	(617) 253-5960 (o) email: http://media.mit.edu/contact
Mission	Founded in 1985, the MIT Media Lab provides a multidisciplinary environment for engineers, artists, and scientists to work on varied projects that include neuroengineering, urban design, education, and an array of other initiatives.	
	Object-Based Media Group Page 122 • SurroundVision	
	Responsive Environments Research Group Page 125 • Beyond the Light Switch: New Frontiers in Dynamic Lighting • Wristique	

Massachusetts Institute of Technology

Object-Based Media Group

V. Michael Bove Jr.
Principal Research Scientist
MIT Media Lab
E15-432, 20 Ames Street
Cambridge, MA 02139

(617) 253-0334 (o)
vmb@media

http://obm.media.mit.edu/

Research Focus	Investigates human sensing and understanding to develop new interface technologies and systems.
SurroundVision	Investigating the technical and creative applications of enhanced screen viewing using a mobile phone or tablet computer as a controllable "second screen."

SurroundVision

Object-Based Media Group

Project Overview: Investigate technical and creative applications of enhanced screen viewing using a mobile phone or tablet computer as a controllable "second screen."

http://obm.media.mit.edu/

Institution	MIT	**Div. / Dept.**	MIT Media Laboratory
Contact	Professor V. Michael Bove, Jr. Director of Consumer Electronics Lab E15-448, 20 Ames Street Cambridge, MA 02139 (617) 253-0334 vmb@media.mit.edu	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Use and Virtualization

Project Details

R&D Program	Develop more immersive video content using handheld devices.
Technology Characteristics	Display devices (such as TVs and computer screens) that provide optimal image quality for human perception of text and images.
Capability Gap(s)	Need optimal visual experience for TV and computer users with minimum display energy consumption.
Driver(s)	Higher data rates and processing intensity and energy use. Consumer desire to be "green" and reduce embedded & used energy. Proliferation of consumer electronics (increased plug loads).
Background	Researchers are seeking ways to enhance user experience and the functionality of electronic devices, including advanced interfaces.
Goals	Enable users to see beyond the edges of, zoom within, and otherwise enhance viewing of television or other screens.
Scope	Investigating the technical and creative applications of enhanced screen viewing using a mobile phone or tablet computer as a controllable "second screen."
Timeline	Project is ongoing with no identifiable completion date.
Milestones & Publications	Recent developments have included creating a mobile application for Apple products and conducting user studies involving different kinds of broadcast television programming.
Budget	
Other parties involved	

Continued . . .

Massachusetts Institute of Technology

Next steps	Currently working with MIT Media Lab funders in consumer electronics and television content space to develop experiments to build upon SurroundVision application.
Associated R&D strategy	
References	Santiago Alfaro, "Surround Vision: A Handheld Screen for Accessing Peripheral Content Around the TV," MS thesis, Massachusetts Institute of Technology, Sep. 2010. http://web.media.mit.edu/~vmb/papers/alfaroms.pdf, accessed Sep. 12, 2012. Hardesty, Larry (2010, April 9). "TV Outside the Box." *MIT News*. http://web.mit.edu/newsoffice/2010/augmented-tv-0409, accessed Jan. 6, 2012. MIT Media Laboratory (2012). "Object-Based Media." http://obm.media.mit.edu/, accessed Jan. 6, 2012. MIT Media Laboratory (2012). "Research: Object-Based Media." http://media.mit.edu/research/groups/object-based-media, accessed Jan. 6, 2012.

Massachusetts Institute of Technology

Responsive Environments Research Group

Joseph A. Paradiso, Director
Associate Professor of Media Arts and Sciences
MIT Media Lab
E14-548p, 20 Ames Street
Cambridge, MA 02139

(617) 253-8988 (o)
(617) 253-6285 (f)
joep@media

http://www.media.mit.edu/research/groups/responsive-environments

Research Focus	Group explores the ways in which human experience, interaction, and perception can be augmented and mediated using sensor networks and ubiquitous computing.
Beyond the Light Switch: New Frontiers in Dynamic Lighting	Dynamic lighting control systems offer opportunities to lower energy use and find new ways to augment lighting.
	• Beyond the Light Switch: New Frontiers in Dynamic Lighting Page 126
Wristique	A personal wristband for sensing and smart infrastructure.
	• Wristique Page 128

Massachusetts Institute of Technology

Beyond the Light Switch: New Frontiers in Dynamic Lighting	**Responsive Environments Research Group** **Project Overview:** Dynamic lighting control systems offer opportunities to lower energy use and find new ways to augment lighting. **http://resenv.media.mit.edu/lighting/**

Institution	MIT	**Div. / Dept.**	MIT Media Lab
Contact	Joe Paradiso Associate Professor Responsive Environments Group (617) 253-8988 (o) joep@media.mit.edu	**Sponsor(s)**	Philips-Color Kinetics (http://colorkinetics.com/)
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Predictive modeling for dynamic lighting needs.
Technology Characteristics	Need adjustable lighting levels based on the time of the day. Space sensing beyond occupancy, e.g., task, location in room, traffic, population. Minimal impact and maximal compatibility on existing infrastructure. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need better user interfaces. Need integration with building automation / management systems. Optimized / ideal luminaire control communication protocol. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need more reliable controls. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing.
Driver(s)	Individual control over lighting. Controllable; integrated with other entertainment, communication mobility. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety). Optimize work environment for using computers of the future-keep up as computers evolve. End user comfort / satisfaction. Cost of new technology. Majority of energy efficiency potential is in retrofit applications. Need for professionals to be credible and deliver systems that work and avoid callbacks. Impacts on wildlife. Need for dark sky.
Background	Lighting currently accounts for about 22 percent of energy use in the U.S. Given the growing complexity of building lighting systems, there is an increasing need for dynamic lighting systems controlled by infrared detection or simplified collective controls, in order to improve energy efficiency.
Goals	To develop enhanced, integrated, and adaptive lighting system controls for large areas (such as an entire office floor) that can be operated by a single person.
Scope	To develop sensor node configuration and MATLAB tools for calculating light sources.

Continued . . .

Timeline	
Milestones & Publications	Suite of MATLAB tools created to calculate lux and color rendering index of virtual and measured light sources. Lee, B., Aldrich, M., and Paradiso, J., "Methods for measuring work surface illuminance in adaptive solid state lighting networks ," *SPIE Proceedings* 8123 (Aug. 21, 2011). (Abstract at http://dx.doi.org/10.1117/12.893562.) Paradiso, J.A., Aldrich, M., Zhao, N., "Energy-efficient control of solid-state lighting ," *SPIE Proceedings* 7784 (Aug. 1, 2010). (Abstract at http://dx.doi.org/10.1117/12.860755.) Aldrich, M., "Dynamic Solid State Lighting," MA thesis, Massachusetts Institute of Technology, 2010. Zhao, N., "Smart Solid-State Lighting Control," Diploma, Rheinisch-Westfaelische Technische Hochschule, Aachen University, 2010.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Massachusetts Institute of Technology Media Laboratory (2012). "Adaptive Lighting Homepage." http://resenv.media.mit.edu/lighting/, accessed Jan. 10, 2012. Massachusetts Institute of Technology Media Laboratory (2012). "Responsive Environments." http://www.media.mit.edu/research/groups/responsive-environments, accessed Jan. 10, 2012.

Massachusetts Institute of Technology

Wristque	**Responsive Environments Research Group** **Project Overview:** A personal wristband for sensing and smart infrastructure. https://media.mit.edu/research/groups/1454/wristque-personal-wristband-sensing-and-smart-infrastructure

Institution	MIT	**Div. / Dept.**	MIT Media Lab
Contact	Joe Paradiso Associate Professor Responsive Environments Group MIT Media Lab (617) 253-8988 (o) joep@media.mit.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Development of advanced user Interfaces.
Technology Characteristics	Easy to change and reporting sensor settings. Need adjustable lighting levels based on the time of the day. Intuitive operation, ease of use and commissioning. Space sensing beyond occupancy, e.g., task, location in room, traffic, population.
Capability Gap(s)	Need integration with building automation / management systems. Need more reliable controls. Need adaptive lighting guidance, best practices (IES). Need better user Interfaces. Optimized/ideal luminaire control communication protocol. Need to improve capability of controls to work with a diversified product range.
Driver(s)	Controllable; integrated with other entertainment, communication mobility. Interoperability. Need for professionals to be credible and deliver systems that work and avoid callbacks. Individual control over lighting. End user comfort / satisfaction. Optimize work environment for using computers of the future keep up as computers evolve. Controllable; integrated with other entertainment, communication mobility. Majority of energy efficiency potential is in retrofit applications. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety),
Background	While many wearable sensors have been developed, few are actually worn by people on a regular basis. A sensor that is comfortable and customizable is needed to encourage widespread adoption.
Goals	Create a low-power wristband device that works with sensors embedded in buildings to adjust to lighting and temperature to maintain at desired conditions.
Scope	Develop a personal wristband for sensing and smart infrastructure
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Niall Firth, "Wristband Plugs You Into Smart Buildings ," *NewScientist* Jan. 16, 2012, http://www.newscientist.com/article/mg21328476.100-wristband-plugs-you-into-smart-buildings.html, accessed Sep. 11, 2012.

National Institute of Standards and Technology (NIST)

100 Bureau Dr.
Gaithersburg, MD 20899

(301) 975-NIST (6478) (o)
(301) 975-2000 (o)
inquiries@nist.gov

http://www.nist.gov/index.html

Mission

The National Institute of Standards and Technology (NIST) is an agency of the U.S. Department of Commerce and has, for more than a century, been a leading federal entity conducting physical science laboratory research.

Energy and Environment Division

A. Hunter Fanney, Chief

(301) 975-5864 (o)
hunter.fanney@nist.gov

http://www.nist.gov/el/building_environment/

Mission

The Energy and Environment Division works to improve building energy efficiency by conducting research and development, developing models, and collecting performance data on components and systems. This Division also strives to improve building design and construction by integrating information and communications systems, sensors, and automation systems.

Works closely with a variety of groups including the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, the American Society of Mechanical Engineers, the American Society for Testing and Materials, and the Fully Integrated and Automated Technology Consortium.

Embedded Intelligence in Buildings Program

Research Focus	
Commissioning Building Systems for Improved Energy Performance	Advance commercial building system commissioning as a standard quality assurance practice. • Commissioning Building Systems for Improved Energy Performance Page 131
Intelligent Building Agents	Development and testing distributed intelligent agents that can control and optimize the performance of building systems. • Page 133
Smart Building Automation and Control Testbed and Standards	Creating a testbed for investigating building system integration challenges and providing the technical basis for improved industry standards. • Smart Building Automation and Control Testbed and Standards Page 135

Commissioning Building Systems for Improved Energy Performance

Embedded Intelligence in Buildings Program

Project Overview: Advance commercial building system commissioning as a standard quality assurance practice.

http://www.nist.gov/el/building_environment/mechsys/eib.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Natascha S. Milesi-Ferretti Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 natascha.milesi-ferretti@nist.gov (301) 975-6420 (o)	**Sponsor(s)**	
Product / Service Area	Building Design / Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Automate commissioning and system performance monitoring
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New performance based utility paradigm.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices. Need small capacity HVAC systems for low load homes. Need to minimize power conversion losses among loads and zones.
Driver(s)	Non-energy benefit such as health and comfort. Grid integration, including stability and disaster / mitigation. Increasing and uncertain future cost of electricity and gas. Personal energy independence / interest. Policy / codes including environmental. Opportunity for large framework change.
Background	To be effective, commissioning results must become an integral part of the day-to-day practice of building managers and operators. The new idea is to build software tools with embedded intelligence that will automate labor-intensive commissioning processes, to develop measurement systems that can monitor component and system performance in buildings, and document key building metrics that practitioners can use to address the lack of performance data for the U.S. building stock.
Goals	To improve the operating efficiency of building systems by 10 % to 30 % by providing the measurement science that enables improved building commissioning practices and accelerating the adoption of cost-effective commissioning as standard practice through (1) documentation and demonstration of the economic benefits, (2) development and field implementation of a comprehensive set of automated commissioning tools for commercial HVAC systems, and (3) transferring the proven technologies to the private sector by 2013.
Scope	NIST will advance commercial building system commissioning as a standard quality assurance practice by developing techniques to automate labor-intensive commissioning processes, establishing industry-accepted metrics for improved documentation of the quality and persistence of benefits, and incorporating improvements into high-impact industry best practice guidelines.

Continued . . .

National Institute of Standards and Technology

Timeline	
Milestones & Publications	"Commissioning Overview", Edited by Chloé Legris, Natascha Milesi Ferretti and Daniel Choinière, 2*010, National Institute of Standards and Technology, and Natural Resources Canada.* "Flow Charts and Data Models for Initial Commissioning of Advanced and Low Energy Building Systems", Edited by Ömer Akin, Natascha Milesi Ferretti, Daniel Choiniere and David Claridge, *2010, National Institute of Standards and Technology, and Natural Resources Canada.* "Commissioning Tools for Existing and Low energy Buildings", Edited by Christian Neumann, Harunori Yoshida, Daniel Choinière and Natascha Milesi Ferretti, *2010, National Institute of Standards and Technology, and Natural Resources Canada.* "Commissioning Cost-Benefit and Persistence of Savings", Edited by Hannah Friedman, David Claridge, Daniel Choinière and Natascha Milesi Ferretti, *2010, National Institute of Standards and Technology, and Natural Resources Canada*
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	NIST will enable the development and commercialization of automated commissioning tools and embedded intelligence building control systems. The research plan has a two-pronged approach, one advancing the development of automated commissioning and the second establishing protocols for key metrics to document building performance and commissioning benefits.
References	National Institute for Standards and Technology, "Embedded Intelligence in Buildings Program," n.d., http://www.nist.gov/el/building_environment/mechsys/eib.cfm, accessed Sep. 11, 2012.

Intelligent Building Agents

Embedded Intelligence in Buildings Program

Project Overview: Development and testing distributed intelligent agents that can control and optimize the performance of building systems.

http://www.nist.gov/el/building_environment/mechsys/iba.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Steve Bushby, Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 steven.bushby@nist.gov (301) 975-5873 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Commercial Buildings

Project Details

R&D Program	Predictive modeling for control.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Achieving national goals of net zero energy buildings requires substantial reduction in the energy consumption of commercial building systems. Although significant progress has been made in the integration of building control systems through the development of standard communication protocols, such as BACnet and BACnet/IP, little progress has been made in making them “intelligent” or in optimizing the performance of building systems.
Goals	To substantially reduce energy consumption in commercial building systems by developing and demonstrating the feasibility of distributed intelligent agent techniques for optimizing the control and performance of interacting building systems by 2013.
Scope	Development and testing distributed intelligent agents that can control and optimize the performance of building systems.
Timeline	FY2012: Collaboration will continue in parallel with further exploration of the potential of intelligent agents using the current generation IBAS. A new laboratory will be constructed that will enable implementation of intelligent agent control of a mixed system of chillers, boilers, and air distribution components to conduct research on real equipment under controlled conditions. FY2013: The new laboratory facility will be used for experimental testing of intelligent agent designs. Different approaches to "distributed optimization" in building HVAC applications will be explored including how agents can use negotiation techniques to optimize the performance of entire building HVAC systems.

Continued . . .

National Institute of Standards and Technology

Milestones & Publications	G.E. Kelly and S.T. Bushby, "Optimization of Building HVAC Systems Using Intelligent Agents – A Proof of Concept Study," NIST TN 1707, 2011.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	National Institute for Standards and Technology, "Intelligent Building Agents," http://www.nist.gov/el/building_environment/mechsys/iba.cfm, accessed Sep. 11, 2012.

Smart Building Automation and Control Testbed and Standards

Embedded Intelligence in Buildings Program

Project Overview: Creating a testbed for investigating building system integration challenges and providing the technical basis for improved industry standards.

http://www.nist.gov/el/building_environment/mechsys/sbact.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Michael Galler Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 michael.galler@nist.gov (301) 975-6521 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Net Zero Energy Buildings
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Commercial Integrated Buildings

Project Details

R&D Program	Automate commissioning and system performance monitoring
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New performance based utility paradigm.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices. Need small capacity HVAC systems for low load homes. Need to minimize power conversion losses among loads and zones.
Driver(s)	Non-energy benefit such as health and comfort. Grid integration, including stability and disaster / mitigation. Increasing and uncertain future cost of electricity and gas. Personal energy independence / interest. Policy / codes including environmental. Opportunity for large framework change.
R&D Program	Tools and procedures for integrated design and operation.
Technology Characteristics	Optimization tools for design to support well educated designers.
Capability Gap(s)	Integration of buildings and utilities - today there is regional utilities that are trying to integrate but there is no common approach and standard. Need to understand and valuation of thermal storage and related. Lack of adequate benchmarking and mechanisms for market internalization of value of low energy buildings. Tools for integrated design with feedback on results (software, dashboards, hands on feedback).
Driver(s)	For commercial building and groups at buildings where appropriate need to transition to energy production at the system and not at component levels as done today. Renewable on grid – Demand responsive HVAC / Integrated System. Market demand for energy efficiency / "Green" market Differentiation. Consumer demand for reduced / low cost of utilities / operation. Workforce issues – Retirement wave, poorly prepared newcomers, inadequate apprenticeship programs.

Continued . . .

National Institute of Standards and Technology

Background	Better information about the practical implications of integrating historically separate building automation systems and improved industry standards are needed to meet the growing demand from building owners and operators to use system integration as a key method for reducing operating costs, improving energy efficiency, and better managing their facilities.
Goals	To enable the development of a new generation of commercial products for integrated cybernetic building systems and transform industry practices for building operations, including commissioning, fault detection and diagnostics, optimization strategies, and integration with smart grid and other utility systems.
Scope	Creating a testbed for investigating building system integration challenges and providing the technical basis for improved industry standards.
Timeline	
Milestones & Publications	"Enhancement of the Virtual Cybernetic Building Testbed to Include a Zone Fire Model with HVAC Components", Park, Reneke, Galler, Bushby, Davis, NISTIR 7414, April 2007. "A Performance Analysis of BACnet Local Area Networks", Song, Hong, Bushby, HVAC&R Journal, Vol. 14 No. 2, March 2008. "BACnet for Utilities and Metering", Holmberg, Bushby, Butler, ASHRAE Journal, Vol 50, No. 4, April 2008. "Using the BACnet Communications DLL", Galler, NIST TN1607, August 2008. "The Virtual Cybernetic Building Testbed- A Building Emulator", Bushby, S. T., Castro, N.S., Galler, M.A., Park, C, ASHRAE Transactions Vol. 116, Part 1, 2010. Milestones: • A fault simulation library with a user interface for selecting and tracking faults during emulation runs to serve for testing HVAC FDD and commissioning tools. • HVACSIM+ type models developed to enable emulation of cooling towers, boilers and chillers.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	A combination of research enabled by state-of-the-art testbeds and direct involvement in key standards development and policy activities.
References	National Institute for Standards and Technology, "Smart Building Automation and Control Testbed and Standards," n.d., http://www.nist.gov/el/building_environment/mechsys/sbact.cfm, accessed Sep. 11, 2012.

HVAC&R Equipment Performance Group

Piotr A. Domanski, Leader
HVAC&R Equipment Performance Group
Building and Fire Research Laboratory
(301) 975-5877 (o)
piotr.domanski@nist.gov

http://www.nist.gov/el/building_environment/hvac/index.cfm

Research Focus	This group works to increase scientific understanding of air-conditioning, heat pumping, and refrigeration technologies, and improve energy efficiency of these technologies by conducting research and development on components and systems, developing software modeling tools, and formulating testing and rating methods.
Design and In-Situ Performance of Vapor Compression System Project	Seeks to address one facet of the development of Net Zero Energy buildings by improving installation and energy use of air conditioning and heat pump systems and to devise simulation-based software tools to evaluate and predict performance of vapor compression systems.

Design and In-Situ Performance of Vapor Compression System Project

HVAC&R Equipment Performance Group

Project Overview: Seeks to address one facet of the development of Net Zero Energy buildings by improving installation and energy use of air conditioning and heat pump systems and to devise simulation-based software tools to evaluate and predict performance of vapor compression systems.

http://www.nist.gov/el/building_environment/hvac/dipvc.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	David Yashar Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 (301) 975-5868 (o) david.yashar@nist.gov	**Sponsor(s)**	
Product / Service Area	New Construction Building Design / Envelope	**Roadmap**	Zero Net Energy Buildings
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	Predictive modeling for controls..
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
R&D Program	Do field tests to compare building models to actual energy use to provide feedback in order to help develop more accurate building simulations.
Technology Characteristics	Building simulation software. Validated building energy models.
Capability Gap(s)	Need to optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, and heat recovery. Current energy modeling engines under development by DOE (energy +) do not have wide market adoption because perceived to be too detailed, too difficult to use - and hence to expensive to use. Tools for accelerating inputs, and accelerating computation time (2 minutes or less) are needed. Need to account for large number of variables in building modeling, standards, and training. Need benchmarking categories at end use level; to improve modeling and better represent real world conditions. Need to quantify and deliver predictable energy savings from HVAC distribution zone control systems. Need functional performance test definition for factory testing. Need to tie model to building needs / loads. Energy efficiency metering to pay for performance.
Driver(s)	IAQ separate ventilation from HVAC loads / equipment. Consumer demand for reduced / low cost of utilities / operation. Need to understand where energy savings can be achieved and demonstrate actual. Reduced first cost of new systems / design. Validation of performance of new HVAC technologies through utility field test. Stake holders requesting post occupancy building performance data and analysis and reporting. Electric utility need for resources to meet growing loads, and/or to replace oil and coal fired power plants.

Continued . . .

Background	Since space-conditioning equipment is a leading consumer of a building's energy, achieving a Net Zero Energy building rating (http://netzeroenergy.org/) requires practices, models, and technologies to ensure the proper design and functioning of air conditioner and heat pump systems.
Goals	Evaluate the energy efficiency effects of improperly-installed space-conditioning and heat pump equipment and generate design tools to overcome these negative effects. Develop the applicable measurement science and deploy the resultant findings to achieve two primary goals by fiscal year 2013: 1) Enhance commissioning methods for residential space-conditioning systems; 2) Facilitate the design of highly-efficient, cost-effective, vapor-compression cooling and heating equipment by creating a novel simulation and optimization tools.
Scope	Complete a sensitivity study of quality installation parameters for space-conditioning systems that incorporates and integrates previous research on common installation errors, including relative and compounding effects of buildings, equipment, and climate. The goal of this study is to validate the Standard 5[2] of the Air Conditioning Contractors of America (ACCA) and generate potential modification recommendations. Devise a methodology and simulation tool for designing high-efficiency air-conditioning and heat pump systems with optimized finned-tube, air-to-refrigerant heat exchangers. This will incorporate particle image velocimetry (PIV) and thermal measurements, computational algorithms development, and component- and system-level simulation modeling. Collaborate w/ Manufacturers to develop products using simulation and optimization tools.
Timeline	Project commenced Oct. 1, 2011. Fiscal year 2011 work included characterizing heat pump performance degradation in cooling and heating modes caused by single installation faults. Work in fiscal year 2012 will include extensive simulations of annual energy use by an improperly installed heat pump in a residential house. Plans during fiscal year 2012 include modifying the EVAP-COND software tool to improve the robustness and the manufacturability of automatically-generated refrigerant circuitry designs. A fiscal year 2013 goal with this tool is to incorporate automated simplification of complex refrigerant circuitries. In fiscal year 2012, , collaborative efforts to use modeling software developed in order to optimize design of a large rooftop air conditioning unit.
Milestones & Publications	Team developed the EVAP-COND simulation model for finned-tube heat exchangers and made it available for free download on the NIST website during fiscal year 2011. Team provided manufacturers, academics, and consultants with the means to improve equipment efficiency by 2 to 5 percent with no additional manufacturing cost using detailed air flow knowledge with artificial intelligence design software. Domanski, P.A., Yashar, D.A., Lee, S., and Wojtusiak, J. (2011). "Practical Aspects of Applying Evolutionary Algorithms for Optimizing Refrigerant Circuitry in Heat Exchangers." Prague, Czech Republic: 23rd IIR Congress of Refrigeration. Yashar, D.A., Domanski, P.A., Wojtusiak, J., and Kaufman, K. (2011). "A Dual Mode Evolutionary Algorithm Approach for Designing Optimized Finned-Tube Heat Exchangers." Special FDD Issue of J. HVAC&R Research, accepted for publication.

Continued . . .

National Institute of Standards and Technology

Budget	
Other parties involved	Department of Energy
Next steps	Modeling software and technique to be tested using residential and window air conditioner unit.
Associated R&D strategy	To develop optimization techniques to current units that are cost neutral (connection optimizations etc.).
References	National Institute of Standards and Technology (2012). "Design and In-Situ Performance of Vapor Compression System Project." http://www.nist.gov/el/building_environment/hvac/dipvc.cfm, accessed Jan. 23, 2012.

Mechanical Systems and Controls Group

Steven T. Bushby, Leader
Mechanical Systems and Controls Group
(301) 975-5870 (o)
steven.bushby@nist.gov
http://www.nist.gov/el/building_environment/mechsys/

Research Focus	Conducts research and development to devise intelligent, integrated, and optimized building systems, controls, tools, and modeling software. Specializes in heating, ventilation, and air conditioning (HVAC) and building management and control systems.
Fault Detection and Diagnosis for Air-Conditioners and Heat Pumps	Investigating opportunities to improve commercial building performance by integrating automation and control technologies, such as fault detection and diagnostic (FDD) methods, with heating, ventilation, and air conditioning systems. • Fault Detection and Diagnosis for Air-Conditioners and Heat Pumps Page 142
Fault Detection and Diagnostics for Commercial HVAC Systems	Work to accelerate market introduction of air conditioner and heat pump technologies by devising effective fault detection and diagnostic (FDD) algorithms and standard technology rating procedures. • Fault Detection and Diagnostics for Commercial HVAC Systems Page 144

Fault Detection and Diagnosis for Air-Conditioners and Heat Pumps

Mechanical Systems and Controls Group

Project Overview: Investigating opportunities to improve commercial building performance by integrating automation and control technologies, such as fault detection and diagnostic (FDD) methods, with heating, ventilation, and air conditioning systems.

http://www.nist.gov/el/building_environment/mechsys/fdachp.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Vance Payne, Principal Investigator (Piotr Domanski, Co-Investigator) 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 (301) 975-6663 (o) vance@email.nist.gov	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Fault Detection and Predictive Maintenance

Project Details

R&D Program	Research to reduce maintenance.
Technology Characteristics	Predictive Maintenance. User notification of system status.
Capability Gap(s)	Need to have "onboard" diagnostics or data streams to collect. Need to eliminate failure modes by design simplification of systems.
Driver(s)	Integration of info, communication & entertainment devices. Reduced HVAC loads in buildings / lack properly sized equipment options. Consumer demand for reduced / low cost of utilities / operation. Diffusion of common communication protocols into energy-consuming devices.
Background	Increasingly, fault detection and diagnostic (FDD) methods are being analyzed for their potential to provide energy efficiency savings for space-conditioning systems such as air conditioners and heat pumps. This project seeks to spur introduction of FDD systems into the marketplace by developing effective algorithms and formulating standards with which to rate FDD system potential to sustain optimal performance and reduce energy consumption.
Goals	Develop methods by the end of fiscal year 2013 that will ensure that air conditioners and heat pumps perform as they were designed throughout their lifetime, and devise a methodology by which to rate commercially-available FDD products.
Scope	Three tasks in fiscal year 2012: 1) Develop an adaptive learning scheme for FDD algorithms based on manufacture's equipment lifetime performance data; 2) Continue to develop a test method for rating AC and HP commercial FDD products, and devise a standardized information exchange format between FDD tester / evaluator and the tested commercial FDD product; 3) Ensure proper operation of high-efficiency, air-source heat pump selected for the NIST Engineering Laboratory Net-Zero Energy Residential Test Facility (NZERTF), and develop a new FDD method.

Continued . . .

Timeline	Project commenced Oct. 1, 2011.
Milestones & Publications	As of January 2012, Researchers had provided contacts in the HVAC&R industry and academia cooling and heating mode, fault-applied performance data given. Also, at least one commercial developer of HVAC FDD equipment has used cooling and heating mode performance data to develop commercially-available residential and small commercial products. As of Jan. 2012, California state regulators have included energy conservation credits in the state's Title 24 Energy Efficiency Standards (http://www.energy.ca.gov/title24/) for rooftop air conditioners and heat pumps based upon advancements in FDD technology and resultant potential energy savings. At the Federal level, the U.S. Department of Energy and U.S. Environmental Protection Agency are both considering including FDD technology in energy conservation codes. Yoon S.H., Payne W.V., Domanski .PA. (2011). "Residential heat pump heating performance with single faults imposed." *Applied Thermal Engineering* 31 ,pp. 765-771. Kim M., Yoon S.H., Payne W.V., Domanski P.A (2010). "Development of the reference model for a residential heat pump system for cooling mode fault detection and diagnosis." *Journal of Mechanical Science and Technology* 24:7, pp. 1481-1489. Kim M., Payne W.V., Domanski P.A., Hermes C.J.L., Yoon S.H. (2008). "Performance of a residential heat pump operating in the cooling mode with single faults imposed." *Applied Thermal Engineering* 29:4, pp. 770-778.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	National Institute of Standards and Technology (2012). "Fault Detection and Diagnosis for Air-Conditioners and Heat Pumps." http://www.nist.gov/el/building_environment/mechsys/fdachp.cfm, accessed Jan. 23, 2012.

Fault Detection and Diagnostics for Commercial HVAC Systems

Mechanical Systems and Controls Group

Project Overview: Work to accelerate market introduction of air conditioner and heat pump technologies by devising effective fault detection and diagnostic (FDD) algorithms and standard technology rating procedures.

http://www.nist.gov/el/building_environment/mechsys/fddchac.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Michael Galler, Project Manager 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 (301) 975-5874 (o) michael.galler@nist.gov	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Fault Detection and Predictive Maintenance

Project Details

R&D Program	Research to reduce maintenance.
Technology Characteristics	Predictive Maintenance. User notification of system status.
Capability Gap(s)	Need to have "onboard" diagnostics or data streams to collect. Need to eliminate failure modes by design simplification of systems.
Driver(s)	Integration of info, communication & entertainment devices. Reduced HVAC loads in buildings / lack properly sized equipment options. Consumer demand for reduced / low cost of utilities / operation. Diffusion of common communication protocols into energy-consuming devices.
Background	There is a need to use modern HVAC system automation and control systems to measure operational performance of commercial buildings and then apply these measurements to enhance performance. To do this, a measurement science must first be developed and integrated within fault detection and diagnosis (FDD) software to enable automatic detection and diagnosis of equipment faults, sensor failures, and control errors of HVAC systems.
Goals	Develop and demonstrate feasibility of fault detection and control error measurement science that will improving operating efficiency of commercial HVAC equipment and systems, and have these systems be available in the marketplace by 2014.
Scope	Develop embedded FDD tools and microcontrollers that take advantage of the untapped capabilities of modern building automation and control systems to monitor performance and identify errors, thereby increasing system-wide reliability and energy efficiency. Do this by: 1) Devising a rapid prototyping platform for FDD algorithms; 2) Incorporating FDD and learning algorithms into new FDD tools to develop an expert system framework; 3) Testing prototypes & conducting field tests.

Continued . . .

Timeline	Project commenced October 1, 2011, and has a goal of introducing solutions to the marketplace in 2014.
Milestones & Publications	As of Jan. 2012, researchers had prepared an initial version of Rapid Interactive Virtual Prototyping for Intelligent Buildings (RIVPIB) platform running HVACSIM+ within an interactive Matlab environment. They had also developed embedded tools Air–handler Performance Assessment Rules (APAR) and Variable-air -volume (VAV) box Performance Assessment Control Charts (VPACC). Available in the marketplace as of Jan. 2012 were some APAR- and VPACC-based commercial products and services that monitor buildings energy performance and allow staff to locate malfunctioning valves, dampers, coils, sensors, and controllers. As of Jan. 2012, California state regulators have included energy conservation credits in the state's Title 24 Energy Efficiency Standards (http://www.energy.ca.gov/title24/) for rooftop air conditioners and heat pumps based upon advancements in FDD technology and resultant potential energy savings. Veronica, D. A. (2010). "Detecting Cooling Coil Fouling Automatically – Part 1: A novel Concept." *HVAC&R Research* 16:4. Veronica, D. A. (2010). "Detecting Cooling Coil Fouling Automatically – Part 2: Results Using a Multilayer Perceptron." *HVAC&R Research* 16:5. "Results from Field Testing of Embedded Air Handling Unit and Variable Air Volume Box Fault Detection Tools." *Journal of Research (NIST JRES)* 7365.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	National Institute of Standards and Technology (2012). "Fault Detection and Diagnostics for Commercial Heating, Ventilating, and Air-Conditioning Systems." http://www.nist.gov/el/building_environment/mechsys/fddchac.cfm, accessed June 27, 2012. Turner, C. and M. Frankel (2008, March 4). "Energy Performance of LEED for New Construction Buildings." Washington, D.C.: U.S. Green Building Council. http://www.usgbc.org/ShowFile.aspx?DocumentID=3930, accessed Jan .23, 2012.

Net-Zero Energy, High-Performance Buildings Program

William Healy
100 Bureau Drive, M/S 8632
Gaithersburg, MD 20899-8632
(301) 975-4922 (o)
william.healy@nist.gov

http://www.nist.gov/el/building_environment/heattrans/netzero.cfm

Research Focus	Helping propel national building industry toward designs and technologies that achieve high-performing Net Zero Energy status in a cost-effective manner, including reducing heating and cooling loads, developing measurement science to quantify systems accurately, aiding in the integration and evaluation of photovoltaic and micro-generation systems, facilitating whole-building evaluations, and promoting and implementing solutions in building energy codes, practices, and standards.
Measurement Techniques for Thermal Insulation Project	Development of high temperature measurement capabilities and investigation of measurement techniques of insulating materials by 2013.
	• Measurement Techniques for Thermal Insulation Project Page 147
Measuring Performance of Net-Zero Energy Homes Project	Build and calibrate test facility that will enable comprehensive, accurate measurements used to assess in-situ performance of net-zero energy homes, and thereby help remove barriers to increased adoption of green building technologies and integrated energy efficiency systems.
	• Measuring Performance of Net-Zero Energy Homes Project Page 149
Novel Working Fluids for High-Efficiency HVAC&R Equipment Project	Improved chiller energy efficiency through nanolubricants & benchmarking heat transfer properties of leading replacement refrigerant candidates.
	• Novel Working Fluids for High-Efficiency HVAC&R Equipment Project Page 151
Ventilation and Indoor Air Quality In Low-Energy Buildings Project	Achieving heating and cooling load reductions through application of technologies and designs based on ventilation, infiltration and indoor air quality control by 2014.
	• Ventilation and Indoor Air Quality In Low-Energy Buildings Project Page 152
Whole Building Energy Modeling and Measurements Project	Quantify and model energy efficiency performance of residential buildings including providing snapshot measurements (for retrofit evaluation), continuous measurements (for energy-use feedback to occupants), and building performance quantification (for standards bodies).
	• Whole Building Energy Modeling and Measurements Project Page 154

Measurement Techniques for Thermal Insulation Project

Net-Zero Energy, High Performance Buildings Program

Project Overview: Development of high temperature measurement capabilities and investigation of measurement techniques of insulating materials by 2013.

http://www.nist.gov/el/building_environment/heattrans/mtti.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Robert Zarr Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 Robert.zarr@nist.gov (301) 975-6436 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	New Construction Insulation
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit Insulation

Project Details

R&D Program	Thermal insulation measurement techniques.
Technology Characteristics	Thermal performance measurement techniques, innovative new materials.
Capability Gap(s)	Need to be easier to install. Need better modeling / technology. Development of tests and protocols to assess thermal insulation.
Driver(s)	More and cheaper products due to globalization of manufacturing. Reduced call backs / warranty, increased durability. Need cost effective energy efficiency programs. Need for cost effective assessment of structures. Increase occupant health, comfort and safety.
R&D Program	Measurement techniques for thermal insulation.
Technology Characteristics	Development of measurement capabilities and performance assessment of novel insulating materials.
Capability Gap(s)	Need easier to use, affordable insulation materials.
Driver(s)	Ever changing installation processes to match technologies. More and cheaper products due to globalization of manufacturing.
Background	The most cost effective means of reducing greenhouse gas emissions associated with building energy consumption is through the use of thermal insulation. Insulation in the building envelope and thermal devices, such as furnaces, boilers, refrigerators, and air-conditioning units, greatly reduce the need for heating and cooling the space, hot water, and other thermal processes. Accurate determination of the insulating capability of these materials is critical to achieve the energy savings that are expected.
Goals	Develop high temperature measurement capabilities (ie SRM and/or Calibration Service) and investigation of measurement techniques for insulating materials by 2013.

Continued . . .

National Institute of Standards and Technology

Scope	Yield the measurement science needed to accurately predict the insulating ability of these materials by developing reference materials and measurement techniques to allow for accurate assessment of the properties of thermal insulating materials.
Timeline	Pre-Production (FY2012): The first step in this effort is to commission the NIST 500 mm guarded-hot-plate apparatus by extending the current temperature of 355 K to nearly 500 K. In FY12, NIST will begin an investigation of new and emerging insulation materials and their incorporation in the thermal management of buildings by implementing a grant or contract. These new insulation materials are designed with different performance characteristics and, therefore will require entirely different measurement evaluation techniques.
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Initial study to identify the most promising materials for building applications as well as the key measurement science challenges that must be overcome before such materials can assist in reducing thermal loads in buildings. In future years, NIST will conduct experimental assessments of the most viable techniques to solve those challenges.
Associated R&D strategy	1) pilot study on thermal conductivity under the Bureau International des Poids et Mesures (BIPM); 2) development of thermal insulation reference materials for extended temperatures; and, 3) development of measurement science techniques for advanced thermal insulation materials.
References	R.R. Zarr and W.C. Thomas, W. C., "Title: Thermal Response Simulation for Tuning PID Controllers in a 1016 mm Guarded Hot Plate Apparatus," *Isa Transactions* 50 (July 1, 2011), 504-512. Abstract at http://www.nist.gov/manuscript-publication-search.cfm?pub_id=90498. R.R. Zarr, A.C. Harris, J.F. Roller, and S.D. Leigh, S. D., "SRM 1450d, Fibrous-Glass Board, for Thermal Conductivity from 280 K to 340 K," NIST SP - 260-173 (Aug. 01, 2011). Abstract at http://www.nist.gov/manuscript-publication-search.cfm?pub_id=908780. "Measurement Techniques for Thermal Insulation Project," n.d., http://www.nist.gov/el/building_environment/heattrans/mtti.cfm, accessed Sep. 11, 2012.

Measuring Performance of Net-Zero Energy Homes Project

Net-Zero Energy, High Performance Buildings Program

Project Overview: Build and calibrate test facility that will enable comprehensive, accurate measurements used to assess in-situ performance of net-zero energy homes, and thereby help remove barriers to increased adoption of green building technologies and integrated energy efficiency systems.

http://www.nist.gov/el/building_environment/heattrans/mpnz.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Mark Davis 100 Bureau Drive, M/S 8632 Gaithersburg, MD 20899-8632 (301) 975-6433 (o) mark.davis@nist.gov	**Sponsor(s)**	
Product / Service Area	Building Design / Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Advanced modeling programs to predict energy performance.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	There is a distinct need for the development of knowledge and best practices about how to measure net Zero Energy building performance to enable designer, builders, and regulators to resolve differences between design intentions and realistic building performance; to enable direct comparisons of Net Zero Energy systems with conventional buildings; and to provide governing bodies the data they need to set measurable high-performance goals.
Goals	Develop measurement science to analyze Net Zero Energy home performance monitoring systems, evaluate integrated performance metrics, and validate building energy and ventilation models by 2014.
Scope	Design and build NIST's Net-Zero Energy Residential Test Facility (NZERTF); gather detailed performance measurements; apply quantified information to evaluate potential performance metrics; publish Net Zero Energy guidelines. Comprehensively monitor and record conditions in and around the home, including energy consumption, thermal energy provided by space conditioning and water heating systems, and contributions of the photovoltaic modules. Record outdoor weather and temperature conditions.

Continued . . .

National Institute of Standards and Technology

Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	In future, NZERTF research will be used to identify data requirements and evaluate this performance data to determine the accuracy of whole-home performance metrics that integrate energy, economic, and environmental factors.
Associated R&D strategy	NIST's "Measurement Science Roadmap for Net-Zero Energy Buildings" of March 2010 and the National Science and Technology Council (in 2008) have both identified an ongoing need to improve Net Zero Energy building monitoring techniques, metrics, and modeling tools.
References	National Institute of Standards and Technology (2012). "Measuring Performance of Net-Zero Energy Homes Project." http://www.nist.gov/el/building_environment/heattrans/mpnz.cfm, accessed June 28, 2012.

Novel Working Fluids for High-Efficiency HVAC&R Equipment Project

Net-Zero Energy, High Performance Buildings Program

Project Overview: Improved chiller energy efficiency through nanolubricants & benchmarking heat transfer properties of leading replacement refrigerant candidates.

http://www.nist.gov/el/building_environment/hvac/nwfhvac.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Dr. Mark Kedzierski Principal Investigator 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 Mark.Kedzierski@nist.gov (301) 975-5282(o)	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	New refrigerant testing.
Technology Characteristics	New refrigerant testing for efficiency and global warming contribution.
Capability Gap(s)	Need information on energy performance, optimization, and mini-split system control bestpractices.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Need to understand where energy savings can be achieved and demonstrate actual.
Background	Concerns over global warming and ozone depletion will limit or phase out several refrigerants currently used in commercial and residential cooling and heating equipment. Consequently, the environmental criteria for the future refrigerants include zero ozone depletion potential (ODP), low global warming potential (GWP), and high efficiency.
Goals	(1) Develop heat transfer and system performance information on low-GWP refrigerants, which will assist in the selection and implementation of the best replacements for high-GWP hydrofluorocarbon (HFC) refrigerants. (2) Demonstrate improved energy efficiency of chillers through application of nanolubricants, by 2013
Scope	(1) Benchmark the heat transfer properties of the leading replacement refrigerant candidates and measure and model their overall thermal performance in a vapor compression system. (2) Seek cost-neutral efficiency improvements of chillers through application of nanolubricants - lubricants with dispersed nano-size particles.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	National Institute of Standards and Technology (2012). " Novel Working Fluids for High-Efficiency HVAC&R Equipment Project ." http://www.nist.gov/el/building_environment/hvac/nwfhvac.cfm", accessed July 1, 2012.

Ventilation and Indoor Air Quality In Low-Energy Buildings Project

Net-Zero Energy, High Performance Buildings Program

Project Overview: Achieving heating and cooling load reductions through application of technologies and designs based on ventilation, infiltration and indoor air quality control by 2014.

http://www.nist.gov/el/building_environment/airquality/viaq.cfm

Institution	National Institute for Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Steven J. Emmerich 100 Bureau Drive, M/S 8631 Gaithersburg, MD 20899-8631 Steven.Emmerich@nist.gov (301) 975-6459(o)	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery & Economizer Optimization

Project Details

R&D Program	Reduce energy demands without degrading indoor air quality.
Technology Characteristics	Technologies to reduce heating and cooling loads without negatively affecting indoor air quality. Need to optimize use of ambient or indoor conditions.
Capability Gap(s)	Need to optimize use of ambient or indoor conditions.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. . IAQ separate ventilation from HVAC loads / Equipment.
Background	Capabilities are needed to assess the indoor air quality (IAQ) impacts of low energy building designs and technologies as well as to support the implementation of strategies that can both save energy and improve IAQ. Current energy design and analysis software tools need to have the capability to consider airflow, ventilation, and indoor contaminants with more technical completeness.
Goals	(3) Develop the tools and data required to determine the ventilation and indoor air quality (IAQ) impacts of strategies to achieve low energy buildings (4) Achieve heating and cooling load reductions through the application of technologies and designs based on ventilation, infiltration, and IAQ control by 2014.
Scope	Development of tools and metrics to reduce the building heating and cooling loads associated with ventilation and infiltration and to evaluate the indoor air quality (IAQ) impacts of designs and technologies used in low-energy buildings to reduce the likelihood that efforts to reduce building energy use will negatively impact IAQ.

Continued . . .

Timeline	Project Start Date: October, 2011 FY12: NIST will support improvement of the airflow and IAQ modeling capabilities of EnergyPlus by developing a capability within CONTAM to create an EnergyPlus AirflowNetwork input file. FY13: Adding a simulation mode within CONTAM to generate wind pressure profiles for use in EnergyPlus and by developing an Application Guide for using the current airflow modeling capabilities in EnergyPlus
Milestones & Publications	ASHRAE Standard 62.2 adopted as code by California, Maine and other U.S. jurisdictions and as requirement for new EPA Indoor Air Plus label program. Andrew K. Persily and Steven J. Emmerich, "Indoor Air Quality in Sustainable,Energy Efficient Buildings," National Institute of Standards and Technology Feb. 29, 2012, http://www.nist.gov/customcf/get_pdf.cfm?pub_id=908145, accessed Sep. 11, 2012.
Budget	
Other parties involved	Department of Energy as well as TRNSYS and Energy Plus Development Teams
Next steps	
Associated R&D strategy	Coordination with the developers and users of energy design and analysis tools to incorporate enhanced capabilities into their tools
References	National Institute of Standards and Technology (2012). " Ventilation and Indoor Air Quality In Low-Energy Buildings Project." http://www.nist.gov/el/building_environment/airquality/viaq.cfm", accessed July 1, 2012.

Whole Building Energy Modeling and Measurements Project

Net-Zero Energy, High Performance Buildings Program

Project Overview: Quantify and model energy efficiency performance of residential buildings including providing snapshot measurements (for retrofit evaluation), continuous measurements (for energy-use feedback to occupants), and building performance quantification (for standards bodies).

http://www.nist.gov/el/building_environment/heattrans/wbem.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	Tania Ullah 100 Bureau Drive, M/S 8632 Gaithersburg, MD 20899-8632 (301) 975-8410 (o) tania.ullah@nist.gov	**Sponsor(s)**	
Product / Service Area	Building Design / Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Advanced modeling programs to predict energy performance.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Buildings use approximately 40% of the total energy consumed in the US and one-half of that amount is attributed to homes, making the residential building sector an important area on which to focus energy efficiency efforts. There is an ongoing need for more thorough and accurate energy efficiency performance measurement tools and techniques for both retrofits and new construction, and for the generation of energy efficiency standards. Estimates are that as much as 20% reduction in building energy use can occur by raising awareness of real-time energy consumption among building occupants.
Goals	Develop improved tools and techniques for use in energy audits, residential energy monitoring systems, and whole-building modeling to help achieve 2014 national energy conservation goals.
Scope	Develop measurement tools and methods to decrease uncertainty in energy audits; contributing to the development and testing of continuous energy monitoring tools. Measure and model whole building energy efficiency performance of residential buildings with a number of tools that provide snapshot measurements (for retrofit evaluation), continuous measurements (for energy-use feedback to occupants), and quantification of building performance (for standards bodies).

Continued . . .

Timeline	
Milestones & Publications	NIST supported Washington State University's creation of the 2009 educational video "Air Leakage in Homes" (http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx) outlining methods to quantify and mitigate air leakage. NIST team led the writing of a section of the ASHRAE Handbook on Wireless Applications. Report on "Round robin" study in which multiple energy auditors implement audit plans on identical homes and compare results. Team was awarded two Phase II Small Business Innovation Research (SBIR) grants to develop novel residential energy monitoring systems. Team published three peer-reviewed journal articles and 6 conference papers. Findings will be integrated into International Energy Conservation Code revisions. Team will work with the Building Performance Institute (http://bpi.org/) and Residential Energy Services Network (RESNET, http://www.resnet.us/professional) to integrate applicable residential energy efficiency retrofit guidelines into standards and codes.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	NIST staff in fiscal year 2012 will focus on refining the short-term measurements needed to establish a clearer understanding of residential building performance, evaluate optimized sensor networks, and contribute to building code refinement by performing building energy simulations. Research will also include raising awareness of energy consumption among building occupants, and working with ASHRAE Standard Project Committee (SPC) 90.2 (Energy Efficient Design of New Low-Rise Residential Buildings) to modify residential building codes.
References	National Institute of Standards and Technology (2012). "Whole Building Energy Modeling and Measurements Project." http://www.nist.gov/el/building_environment/heattrans/wbem.cfm , accessed July 2, 2012.

National Renewable Energy Laboratory (NREL)

1617 Cole Blvd.
Golden, CO 80401-3305

(303) 275-3000 (o)

http://www.nrel.gov/

Mission

The National Renewable Energy Laboratory (NREL) is a federal laboratory dedicated to research, development, commercialization, and deployment of renewable and energy-efficient technologies. The laboratory's projects are part of broader U.S. Department of Energy's mandate to achieve net-zero energy use for all new commercial buildings by 2030 and for all commercial buildings by 2050.

The NREL is also the principal research laboratory for the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE), conducts research for the DOE's Office of Science and the Office of Electricity Delivery and Energy Reliability. It is managed by the Alliance for Sustainable Energy, LLC, a partnership between Battelle and MRI Global.

Science & Technology Division

Dana Christensen, Deputy Lab Directory
1617 Cole Blvd
Golden, CO 80401-3305

(303) 275-3008 (o)
(303) 275-3097 (f)
(303) 275-3094 (Admin. Assistant)
Dana.Christensen@nrel.gov

http://www.nrel.gov/science_technology/

Mission

Division works to bring renewable energy and energy-efficient technologies to the marketplace, including: renewable electricity conversion and delivery systems; renewable fuels formulation and delivery; efficient and integrated energy systems; and strategic energy analysis.

Research groups within the Science & Technology Division working in areas apropos to the Northwest Energy Efficiency Technology Roadmap Portfolio include:

Buildings Research Page 158

- Automated Home Energy Management System Evaluation
- Building Agent
- Building America: Residential Systems Integration R&D
- DEnCity/179D
- Desiccant Enhanced Evaporative (DEVAP) air conditioner
- Electrochromic Research Activities- Advanced Prototypes for Electrochromic Windows
- Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing
- Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)
- Mobile Audit and PV Assessment Tool (simuwatt)
- OpenStudio
- Performance Testing of Residential HVAC Systems

National Center for Photovoltaics Page 181

- Building Integrated Solar Technologies

Buildings Research

1617 Cole Blvd.
Golden, CO 80401-3305
(303) 275-3000 (o)

http://www.nrel.gov/buildings/

Research Focus	Commercial and residential buildings have a significant impact on energy use and the environment, and the Buildings Research group of the National Renewable Energy Laboratory works to increase energy efficiency and the introduction of renewable energy by developing advanced building technologies and systems. This work also supports the U.S. Department of Energy's Building Technologies Program (http://www1.eere.energy.gov/buildings/).
Automated Home Energy Management System Evaluation	Assess capabilities, interoperability, performance and usability of available and prototype home energy management products and systems. Develop grid-award system architectures to enable demand response savings, increased homeowner comfort, and energy cost savings. • Automated Home Energy Management System Evaluation Page 159
Building Agent	Create a replicable data platform, visualizations, and occupant/facility manager interfaces that exploit the temporal and spatial nature of building performance data. The user experiences is tailored to engage occupants as active participants in achieving building efficiency goals, and provide new tools for facility managers to attain and maintain building performance using occupant feedback. • Building Agent Page 162
Building America: Residential Systems Integration R&D	A residential test bed where different building system options are evaluated, designed, built, retrofitted, and vetted to ensure that requirements for energy efficiency, quality, sustainability, risk mitigation, and comfort are met. Research is conducted on individual measures and systems, test houses, and community-scale housing in order to validate the reliability, cost-effectiveness, and marketability of technologies when integrated into existing and new homes. • Building America: Residential Systems Integration R&D Page 164
DEnCity/179D	Pre-computed, mass simulation results exposed via easy-to-use web interfaces can put the power of building energy analysis in the hands of decision-makers without requiring them to master new tools. • DEnCity/179D Page 165
Desiccant Enhanced Evaporative (DEVAP) air conditioner	Development of a non-vapor compression air conditioning system based on liquid desiccants and evaporative cooling that works in all climate zones and provides 40% to 80% energy savings over high efficiency refrigeration based cooling technologies. • Desiccant Enhanced Evaporative (DEVAP) air conditioner Page 167
Electrochromic Research Activities- Advanced Prototypes for Electrochromic Windows	NREL researches materials and systems to improve energy efficiency of windows during both cooling and heating periods, including research into electrochromic and integrated photovoltaic systems. Integrate thin-film photovoltaic material into electrochromic windows to generate the voltage necessary to darken or lighten the electrochromic material, thereby increasing window energy efficiency during both heating and cooling periods. • Electrochromic Research Activities- Advanced Prototypes for Electrochromic Windows Page 169

Continued . . .

Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing	Project funded in part by the BPA Technology Innovation office to develop an enhanced Image Processing Occupancy Sensor (IPOS) prototype. • Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing Page 171
Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)	Project funded in part by the BPA Technology Innovation office to study the feasibility of integrating building energy models for new and existing buildings that evaluates daylighting as a viable energy efficiency strategy and that can be analyzed using emerging building energy efficiency metrics such as the Energy Utilization Index (EUI). • Integrated Daylighting and Energy Analysis Toolkit (IDEAKit) Page 173
Mobile Audit and PV Assessment Tool (simuwatt)	Project funded by the DoD ESTCP and DOE Sunshot projects to produce and demonstrate a tablet computer-based audit and PV assessment tool that reduces the cost of audits by 75% and solar installation soft cost by $0.30 per watt. The tool persists data in a common electronic format for aggregation and reuse, and includes methods to automatically and reliably generate models for rigorous assessment of energy conservation measures and PV system designs. • Page 175
OpenStudio	OpenStudio is an open source project funded by the DOE and CEC to produce a software development kit (SDK) and related applications tools for building energy analysis. The SDK enables extremely rapid application of desktop and web applications for design and analysis. Example application software is designed to enable A&E practitioners, students, researchers, and policy analysts to easily and reliably produce energy models. OpenStudio-based tools are being used by CEC's Title 24 compliance engine and the energy design assistance program of a major utility. • OpenStudio Page 177
Performance Testing of Residential HVAC Systems	Perform laboratory testing and develop detailed performance models of residential HVAC systems. These "performance maps" are used for accurate predictive simulation of the systems in any US climate and any building type. The tests are also used to explore performance deficiencies in products, and to inform codes & standards activities. • Performance Testing of Residential HVAC Systems Page 181

Automated Home Energy Management System Evaluation

Buildings Research

Project Overview: Assess capabilities, interoperability, performance and usability of available and prototype home energy management products and systems. Develop grid-award system architectures to enable demand response savings, increased homeowner comfort, and energy cost savings.

http://www.nrel.gov/buildings/residential.html

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Dane Christensen 303-384-7437 dane.christensen@nrel.gov	**Sponsor(s)**	U.S. DOE
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Technologies used to integrate and diagnose building control tools in order to improve energy performance.
Technology Characteristics	Design & analysis tools to integrate components and predict wholesystem energy performance. Test beds to assess new energy efficiency products.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices. Need control of plug loads especially for work stations and entertainment centers electric cars. Need new appliance standards, installation techniques and supporting technologies.
Driver(s)	Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental. Opportunity for large framework change. Grid integration, including stability and disaster / mitigation.
Background	To improve consumer buy-in to demand response and peak mitigation in the residential sector, simple and cost-effective measures that automate savings behavior must be developed and aligned with proper incentives. One class of potential measures is home appliances. Several manufacturers have been developing communicating suites of appliances, but their capabilities and thus savings potential are unknown.
Goals	In FY12-13 test and evaluate the whole-house peak demand and average energy saving benefits of an integrated appliance suite, using the GE Profile Smart appliances and NREL's Automated Home Energy Management Laboratory.
Scope	Residential building integrated systems research.
Timeline	April 2012–March 2013.
Milestones & Publications	Reporting in early calendar 2013 on this project.

Continued . . .

Budget	
Other parties involved	
Next steps	Having identified opportunities, explore collaborations with industry to improve products and systems to enhance the benefits to homeowners and utilities.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing and demonstrating energy efficiency technologies, by optimizing system integration practices, and by advancing related science and engineering.
References	National Renewable Energy Laboratory, "Buildings Research," http://www.nrel.gov/buildings/residential.html, accessed Sep. 12, 2012. National Renewable Energy Laboratory, "Maximizing Thermal Efficiency and Optimizing Energy Management," FS-5500-53657, March 2012, http://www.nrel.gov/docs/fy12osti/53657.pdf, accessed Sep. 12, 2012.

Building Agent

Buildings Research

Project Overview: Create a replicable data platform, visualizations, and occupant/facility manager interfaces that exploit the temporal and spatial nature of building performance data. The user experiences is tailored to engage occupants as active participants in achieving building efficiency goals, and provide new tools for facility managers to attain and maintain building performance using occupant feedback.

http://www.nrel.gov/buildings/residential.html

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Larry Brackney Principal Investigator (303) 384-7443 larry.brackney@nrel.gov	**Sponsor(s)**	DOE BTP and CEC
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings
Product / Service Area	Sensors, Meters, Energy Management Systems	**Roadmap**	Easy / Simple User Interface Controls
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Commercial Integrated Buildings

Project Details

R&D Program	Technologies used to integrate and diagnose building control tools in order to improve energy performance.
Technology Characteristics	Design & analysis tools to integrate components and predict wholesystem energy performance. Test beds to assess new energy efficiency products.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices. Need control of plug loads especially for work stations and entertainment centers electric cars. Need new appliance standards, installation techniques and supporting technologies.
Driver(s)	Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental. Opportunity for large framework change. Grid integration, including stability and disaster / mitigation.
R&D Program	User interface and human comfort factors.
Technology Characteristics	Tailored to user device (phone, tablets, computers). Energy information display systems that are aligned with decision maker needs. User-friendly energy management systems. User initiated DR capability (peak load shifting). Portable controls. Built-in Intelligence learning algorithm.
Capability Gap(s)	Energy management systems (EMS) do not consider demographic operability. Make user experience as important to EMS manufacturers as it is to Intuit and Sony. Need to implement control management systems where appropriate that reflect user / occupant preferences. Need to develop user-friendly Interfaces that recognize different levels of user sophistication. Need to establish truly universal, simple, seamless plug and play interoperability. Lack of design for user enabled DR (load controlled, pricey). Need to conduct market research to understand customer drivers.
Driver(s)	People like cool, new technologies. People more "plugged in" electronically, digital information, social networking. Lack of engagement and interest in energy efficiency from customers. Diffusion of common communication protocols into energy-consuming devices. Smart grid technology development. Availability of crosscutting, low-cost technology building blocks. Integration of energy management, security information systems in building management. Market awareness (e.g., BPA E3T, utility demos and outreach).

Continued . . .

R&D Program	Building energy dashboard development.
Technology Characteristics	Simple system to report energy use to occupants / operators in manner to affect use / maintenance.
Capability Gap(s)	Ongoing operations support for continuous commissioning. Lack of adequate benchmarking and mechanisms for market internalization of value of low energy buildings.
Driver(s)	Workforce issues - Retirement wave, poorly prepared newcomers, inadequate apprenticeship programs. For commercial building and groups at buildings where appropriate need to transition to energy production at the system and not at component levels as done today. Market demand for energy efficiency / "Green" market differentiation.. Consumer demand for reduced / low cost of utilities / operation. Market demand for energy efficiency / "Green" market differentiation.
Background	Occupants do not perceive themselves to be required and active participants in achieving building energy performance outcomes. Facility managers respond to occupant feedback on an ad-hoc, reactive basis. A holistic approach that provides coherency between existing EMS data, occupant feedback, and local measurements coupled with occupant and operator-centric user interfaces creates new opportunities to engage both parties in meaningful and actionable ways that benefit energy performance.
Goals	Create replicable, scalable software architectures, databases, client software, web software, and performance visualizations that exploit the temporal and spatial nature of data along with occupant feedback. This architecture and software will be deployed in NREL's flagship Research Support Facility (RSF) to understand the human-dimension of building performance and integrate it into whole-building control and optimization processes. The client software creates a bi-directional communications pathway between occupancy and the building. Facility operators are better able to assess the performance of the building by evaluating traditional performance data alongside correlated occupant feedback and local measurements.
Scope	Scope includes the underlying software architecture and databases along with multiple client applications and web services that are being deployed within NREL's RSF and eventually other buildings.
Timeline	November 2011 to present.
Milestones & Publications	M. Schott, N. Long, J. Scheib, K. Fleming, K. Benne, and L. Brackney, "Progress on Enabling an Interactive Conversation Between Commercial Building Occupants and Their Building To Improve Comfort and Energy Efficiency," *ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, Calif.,* Aug. 12-17, 2012 (preprint), , http://www.nrel.gov/buildings/pdfs/55197.pdf, accessed Sep. 12, 2012.
Budget	
Other parties involved	
Next steps	Create additional client software functionality and web services and perform longer term performance study
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Information from NREL staff c.a July 2012.

Building America: Residential Systems Integration R&D

Buildings Research

Project Overview: A residential test bed where different building system options are evaluated, designed, built, retrofitted, and vetted to ensure that requirements for energy efficiency, quality, sustainability, risk mitigation, and comfort are met. Research is conducted on individual measures and systems, test houses, and community-scale housing in order to validate the reliability, cost-effectiveness, and marketability of technologies when integrated into existing and new homes.

http://www1.eere.energy.gov/buildings/building_america/

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Ren Anderson 303-384-7433 ren.anderson@nrel.gov	**Sponsor(s)**	USDOE
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Testing of residential and commercial building systems.
Technology Characteristics	Test beds to assess new energy efficiency products.
Capability Gap(s)	Need control of plug loads especially for work stations and entertainment centers electric cars. Need new appliance standards, installation techniques and supporting technologies.
Driver(s)	Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Opportunity for large framework change. Policy / codes including environmental. Grid integration, including stability and disaster / mitigation.
Background	
Goals	Current overall goals aim to reduce home energy use by 30%-50% compared to 2009 energy codes for new homes and pre-retrofit energy use for existing homes.
Scope	Residential building integrated systems research.
Timeline	Ongoing since 1990s
Milestones & Publications	Over 400 publications. See http://www1.eere.energy.gov/library/default.aspx?page=2&spid=2
Budget	
Other parties involved	LBNL, ORNL, PNNL, industry research teams as listed here: http://www1.eere.energy.gov/buildings/building_america/research_teams.html
Next steps	
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	National Renewable Energy Laboratory, "Buildings Research," http://www.nrel.gov/buildings/residential.html, accessed Sep. 12, 2012.

DEnCity/179D

Buildings Research

Project Overview: Pre-computed, mass simulation results exposed via easy-to-use web interfaces can put the power of building energy analysis in the hands of decision-makers without requiring them to master new tools.

http://apps1.eere.energy.gov/buildings/commercial_initiative/179d/building_parameters.cfm

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Larry Brackney Principal Investigator (303) 384-7443 larry.brackney@nrel.gov	**Sponsor(s)**	DOE BTP and CEC
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Technologies used to integrate and diagnose building controls in order to improve energy performance.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. Test beds to assess new energy efficiency products.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices. Need control of plug loads especially for work stations and entertainment centers electric cars. Need new appliance standards, installation techniques and supporting technologies.
Driver(s)	Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Opportunity for large framework change. Policy / codes including environmental. Grid integration including stability and disaster / mitigation.
Background	While progress is being made to reduce the complexity of building energy analysis tools (OpenStudio), there is a class of decision-making users, that require still simpler interfaces. Pre-computed, mass simulation databases with simple web or application program interfaces (API) provide one means of addressing this group of users.
Goals	Create processes and methods that utilize high performance computing resources to create populations (billions) of building energy simulations reflecting building type, climate zone, envelope and equipment variations, etc. These simulation results are stored in a high performance, scalable database with an API that enables a variety of web interfaces to be tailored for diverse use cases.
Scope	Applications to date include the 179D tax credit calculator tool – http://179d.energy.gov. This same approach is being leveraged to produce a prototype asset rating tool for CEC and a site-scale simulation at NREL.

Continued . . .

National Renewable Energy Laboratory

Timeline	January 2011 to present.
Milestones & Publications	http://www.aceee.org/files/proceedings/2012/data/papers/0193-000374.pdf
Budget	
Other parties involved	California Energy Commission
Next steps	Demonstrate approach in the context of multi-building, grid and district-connected real-time simulation for site design, optimization, and control.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Information from NREL staff c.a July 2012.

Desiccant Enhanced Evaporative (DEVAP) air conditioner

Buildings Research

Project Overview: Development of a non-vapor compression air conditioning system based on liquid desiccants and evaporative cooling that works in all climate zones and provides 40% to 80% energy savings over high efficiency refrigeration based cooling technologies.

http://energy.gov/articles/lab-breakthrough-desiccant-enhanced-evaporative-air-conditioning

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Eric Kozubal Principal Investigator (303) 384-6155 eric.kozubal@nrel.gov	**Sponsor(s)**	Department of Energy
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization

Project Details

R&D Program	High-performance evaporative systems.
Technology Characteristics	Need to downscale what is currently available on big chillers for smaller units and integrate with maintenance systems. Drop-in replacement condensing unit with variable speed compressor.
Capability Gap(s)	Increase design capability to handle zonal and radiant heating & cooling delivery. Need the equivalent of ASHRAE Manual chapter on variable refrigerant flow design, control, and energy savings optimization. Variable refrigerant flow energy savings potential and control optimization not well understood. Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation.
Background	Space cooling represents approximately 13% of the primary energy consumption in commercial buildings and it represents a very large percentage of the peak electricity demand. Current technologies on the market today can reduce the cooling energy by 30% to 40% and make much smaller reductions to the peak demand.
Goals	Develop the DEVAP air conditioning from a laboratory prototype into a marketable product.
Scope	Further refine the DEVAP technology to improve the performance, prove performance to minimize the risk to manufacturers through development and testing of a full scale prototype unit, and provide an updated market assessment.

Continued . . .

National Renewable Energy Laboratory

Timeline	A lab prototype was developed and tested in FY11. FY 2013 tasks will be: 1) Updated market assessment; 2) Develop new core technologies; 3) Construct a field ready prototype. Performance period: Oct. 1, 2012 to Sep. 30, 2013.
Milestones & Publications	Kozubal, E.; Woods, J.; Judkoff, R. (2012). Development and Analysis of Desiccant Enhanced Evaporative Air Conditioner Prototype. 78 pp.; NREL Report No. TP-5500-54755.
Budget	
Other parties involved	AIL Research, Munters Corporation, 7AC
Next steps	FY13 tasks.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Kozubal, E.; Woods, J.; Judkoff, R. (2012). "Development and Analysis of Desiccant Enhanced Evaporative Air Conditioner Prototype," NREL Report No. TP-5500-54755.

Electrochromic Research Activities- Advanced Prototypes for Electrochromic Windows

Buildings Research - Windows

Project Overview: Integrate thin-film photovoltaic material into electrochromic windows to generate the voltage necessary to darken or lighten the electrochromic material, thereby increasing window energy efficiency during both heating and cooling periods.

http://www.nrel.gov/buildings/electrochromic_activities.html

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Rob Tenent 15013 Denver West Parkway Golden, CO 80401-3305 (303) 384-6775 (o) Robert.Tenent@nrel.gov	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Fenestration & Daylighting

Project Details

R&D Program	Add a small PV panel to electrochromic windows.
Technology Characteristics	Self-powered electrochromic-photovoltaic windows. PV-integrated window shades.
Capability Gap(s)	Need to address seamless photovoltaic integration into fenestration. Need lower costs. Need to address electrochromic issues such as cost, life, performance.
Driver(s)	More and cheaper products due to globalization of manufacturing. Achieve energy savings. Reduced call backs / warranty, increased durability. Can not get high performance buildings without daylighting. Achieve energy savings. Increase window and skylight area. Increase occupant health, comfort and safety.
Background	Electrochromic windows need to be able to stand-up to harsh heating-and-cooling cycles for many years while also performing consistently to achieve energy efficiency savings. NREL is working to address fundamental and supporting R&D for next-generation devices and electrochromic windows.
Goals	Improve overall energy efficiency in commercial and residential buildings by designing marketable window-tinting systems integrating photovoltaic and electrochromic technologies.
Scope	Conduct research into photovoltaic-powered electrochromic devices, photoelectrochromic devices, and other systems to determine performance characteristics and system durability, and to standardize equipment and testing regimes.

Continued . . .

National Renewable Energy Laboratory

Timeline	This is an ongoing project with many elements, and NREL researchers have published findings since the late 1990s.
Milestones & Publications	Research areas include durability testing, materials and degradation mechanisms, advanced prototypes, education and new markets, standards and ratings, and insulating glass. Report citations can be found at http://www.nrel.gov/buildings/electrochromic_activities.html#prototypes.
Budget	
Other parties involved	Battelle (http://battelle.org/) and MRI Global (http://www.mriglobal.org/Pages/Default.aspx).
Next steps	
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Torcellini, Paul, Pless, Shanti, Lobato, Chad and Hootman, Tom (2012, July). "Main Street Net-Zero Energy Buildings: The Zero Energy Method in Concept and Practice." *ASME 2010 4th International Conference on Energy Sustainability, Phoenix, AZ, May 17–22, 2010*, http://www.nrel.gov/sustainable_nrel/pdfs/47870.pdf, accessed Jan. 17, 2012. National Renewable Energy Laboratory (2012). "Electrochromic Research Activities." http://www.nrel.gov/buildings/electrochromic_activities.html, accessed Jan. 17, 2012.

Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing

Buildings Research

Project Overview: Project funded in part by the BPA Technology Innovation office to develop an enhanced Image Processing Occupancy Sensor (IPOS) prototype.

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Luigi Gentile Polese Principal Investigator (303) 275-4362 Luigi.Gentile.Polese@nrel.gov	**Sponsor(s)**	Bonneville Power Administration
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Define and develop virtual sensors.
Technology Characteristics	Cheaper, simpler self-calibration. Easy to change and reporting sensor settings.
Capability Gap(s)	Need a unified set of "software" and visualization/controls tool for utility workers of the future that are manufacturer-agnostic to explore, tweak, set up and optimize control to sensor and device lighting mappings. Some of this would be also user-accessible. Need integration with building automation / management systems. Need better user interfaces. Need adaptive lighting guidance, best practices (IES).Need integration of task ambient, precision daylighting. Need for plug and forget controls that work without commissioning, tuning or user action. Need cheaper controls.
Driver(s)	End user comfort / satisfaction. Utility incentives for influencing designers, contractors, manufacturers. Need for professionals to be credible and deliver systems that work and avoid callbacks. Optimize work environment for using computers of the future-keep up as computers evolve. Individual control over lighting. Controllable; integrated with other entertainment, communication mobility. Interoperability. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety). Cost of new technology.
Background	Occupancy sensing is a common element of building automation systems (BAS), but current passive infrared (PIR) sensors are only effective when occupants are moving. This is BPA Technology Innovation office Project #247.
Goals	Demonstrate the feasibility of improving occupancy control lighting systems by using Image Processing Occupancy Sensor (IPOS) technology, and investigate other IPOS building automation applications including temperature, ventilation, and lighting controls, and security systems.

Continued . . .

National Renewable Energy Laboratory

Scope	Develop reliable occupancy sensor that detects occupancy, location of occupant, and occupied-area luminance levels in less than ten seconds and an occupancy detection confidence value over 90; establish parameters within which this enhanced sensor system can be used to replace commercially-available PIR sensors; devise field testing plan to evaluate new sensors directly with PIR sensors; document results and draft recommendations document.
Timeline	FY 2012 tasks will be: 1) draft an Enhanced IPOS Prototype Proof-of-Concept experiment design, conduct the experiment, report on project results, and provide a project presentation at the BPA TI R&D Summit; 2) Enhanced IPOS Prototype field testing and final report. Performance period: Nov. 1, 2011 to Sep. 30, 2012.
Milestones & Publications	FY 2012 task area 1 completed with presentation delivered at BPA TI R&D Summit, Jan. 31-Feb. 2, 2012. "Intergovernmental Contract #54178 Release 002, Technology Innovation Project #247, Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing," Nov. 1, 2011.
Budget	$299,970 (BPA share = $149,970; NREL's cost-share contribution = $100,000; third-party cost-share contribution-in-kind = $50,000).
Other parties involved	Fabriq, Inc. Boulder CO
Next steps	FY 2012 task area 2.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	"Intergovernmental Contract #54178 Release 002, Technology Innovation Project #247, Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing," Nov. 1, 2011.

Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)

Buildings Research

Project Overview: Project funded in part by the BPA Technology Innovation office to study the feasibility of integrating building energy models for new and existing buildings that evaluates daylighting as a viable energy efficiency strategy and that can be analyzed using emerging building energy efficiency metrics such as the Energy Utilization Index (EUI).

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Robert P. Guglielmetti Principal Investigator (303) 275-4319 robert.guglielmetti@nrel.gov	**Sponsor(s)**	Bonneville Power Administration
Product / Service Area	Building Design/Envelope	**Roadmap**	Fenestration & Daylighting

Project Details

R&D Program	Performance assessment – simulation / modeling.
Technology Characteristics	Testing and modeling of performance of electrochromic window coatings. Easier, cheaper daylight modeling tools that give energy benefits.
Capability Gap(s)	Need lower costs. Need better technologies, such as windows that can effectively cut energy use in both heating and cooling climates. Savings need to be measurable and predictable. Need better design support tools to reduce design cost and complexity.
Driver(s)	More and cheaper products due to globalization of manufacturing. Achieve energy savings. Reduced call backs / warranty, increased durability. Reduce glare while providing natural daylighting. Poor performing curtain walls. Increase window and skylight area. Can not get high performance buildings without daylighting. Increase occupant health, comfort and safety.
Background	Evolving building codes and enhanced sustainability rating systems means that high-performance building design must improve to meet more stringent standards. Since lighting accounts for 21% of commercial building energy use in the U.S., there is ample opportunity to contribute significantly to overall energy efficiency by improving lighting systems. Some of the shortcomings of current lighting models and designs are a lack of tools to prove the energy efficiency savings of daylighting measures; poorly implemented daylighting designs; improperly-commissioned daylighting systems; and widespread barriers to adoption of daylighting systems. This is BPA Technology Innovation office Project #252.
Goals	The goal of this project is to develop tools for easier energy modeling for both new and retrofit buildings that integrates daylighting, electric lighting, and lighting controls and facilitate easier evaluation of emerging building energy efficiency metrics, such as the Energy Utilization Index (EUI). This improved tool will be useful for generating energy-saving analyses of daylighting options; ensuring code, standard, and building rating compliance; and for conducting additional research involving multivariate optimization analyses and sector-wide daylighting/energy evaluations.

Continued . . .

National Renewable Energy Laboratory

Scope	NREL has commenced the development of the OpenStudio Platform analysis tool that integrates EnergyPlus to provide for user-friendly building energy management; however, EnergyPlus' daylighting algorithms do not characterize daylight accurately for most applications, particularly in interaction with sunlight and lighting controls. This project enhances the OpenStudio Platform by integrating it with EnergyPlus and Radiance software tools, linked to a single model and outcome dataset, to generate more accurate and dynamic modeling.
Timeline	Performance period: Nov. 7, 2011 to Oct. 31, 2012.
Milestones & Publications	There are three milestones for this project: 1) Integrate Radiance tool with OpenStudio Platform; 2) validate integrated building energy model with Radiance functionality, and compare EnergyPlus' native daylight calculations with Radiance calculations; and 3) release back-end version of IDEAKit. Project team presented at BPA TI R&D Summit, Jan. 31-Feb. 2, 2012.
Budget	$289,343 total (BPA cost-share contribution = $144,671.50, NREL cost-share contribution = $144,671.50).
Other parties involved	
Next steps	Continue to move forward with project milestones and document progress in quarterly reports.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	"Intergovernmental Agreement 54178 – Release 001, Technology Innovation Project #252, Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)." Nov. 7, 2011.

Mobile Audit and PV Assessment Tool (simuwatt)

Buildings Research

Project Overview: Project funded by the DoD ESTCP and DOE Sunshot projects to produce and demonstrate a tablet computer-based audit and PV assessment tool that reduces the cost of audits by 75% and solar installation soft cost by $0.30 per watt. The tool persists data in a common electronic format for aggregation and reuse, and includes methods to automatically and reliably generate models for rigorous assessment of energy conservation measures and PV system designs.

http://www.nrel.gov/buildings/residential.html

Institution	National Renewable Energy Laboratory with concept3D	**Div. / Dept.**	Science & Technology Division
Contact	Larry Brackney Principal Investigator (303) 384-7443 larry.brackney@nrel.gov	**Sponsor(s)**	DoD ESTCP and DOE Sunshot
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit and New Construction Labeling

Project Details

R&D Program	Test tools for modeling including those that are attempting new approaches to computer applications.
Technology Characteristics	Develop automated math-based utility bill-based calibration methods. Clearly define potential errors due to uncertainties in building characteristics and variations in occupant use.
Capability Gap(s)	Evidence that labeling matters and that they are accurate. Access to utility metered data without negative impact on payer privacy. No inexpensive, accurate, regularly reproducible, system exists.
Driver(s)	The need for measured and persistent results to provide meaningful feedback to investment and R&D programs. Need apples to apples comparison between buildings. Policy mandates for rating and labeling.
Background	Much of the cost for an energy audit is due to a tedious, non-standardized, and error-prone process in which outdated pen and paper methods are used to collect data and ad-hoc calculation tools are used to conduct analyses. Highly trained personnel spend a significant amount of time transcribing data, gathering equipment information, sorting through utility bills, and developing customized calculations for each audit. In addition, non-standardized reporting prohibits large-scale audit data management, quality control, and analysis; diminishing the benefits of the audit as a long-term investment.
Goals	The objective of this project is to demonstrate a tablet-based software tool that significantly lowers the cost of energy audits, PV assessment, design, permitting, and incentive application, while improving the quality of audit and PV application outcomes, and preserving the data to facilitate portfolio-wide tracking, reporting, decision making, and data reuse.
Scope	NREL and concept3D have been developing prototype software and processes for over a year, and are on track for initial field tests of the tablet-based software and supporting servers in early CY2013. Wider field tests at DoD facilities across a broader range of climate zones and building types are planned for late CY2013.

Continued . . .

National Renewable Energy Laboratory

Timeline	Performance period: March, 2012 to March, 2014.
Milestones & Publications	Milestones include prototype versions of tablet and server software, field test results, and performance comparisons relative to traditional processes, and releases of branded "simuwatt" software in the private sector.
Budget	
Other parties involved	concept3D – private sector commercialization partner
Next steps	Complete initial prototypes and demonstrate workflows in initial field trials.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Information from NREL staff c.a July 2012.

OpenStudio

Buildings Research

Project Overview: OpenStudio is an open source project funded by the DOE and CEC to produce a software development kit (SDK) and related applications tools for building energy analysis. The SDK enables extremely rapid application of desktop and web applications for design and analysis. Example application software is designed to enable A&E practitioners, students, researchers, and policy analysts to easily and reliably produce energy models. OpenStudio-based tools are being used by CEC's Title 24 compliance engine and the energy design assistance program of a major utility.

http://openstudio.nrel.gov/openstudio-getting-started/policy-analysis-tool/

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Larry Brackney Principal Investigator (303) 384-7443 larry.brackney@nrel.gov	**Sponsor(s)**	NREL LDRD
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit and New Construction Labeling

Project Details

R&D Program	Test tools for modeling including those that are attempting new approaches to computer applications.
Technology Characteristics	Develop automated math-based utility bill-based calibration methods. Clearly define potential errors due to uncertainties in building characteristics and variations in occupant use.
Capability Gap(s)	Evidence that labeling matters and that they are accurate. Access to utility metered data without negative impact on payer privacy. No inexpensive, accurate, regularly reproducible, system exists.
Driver(s)	The need for measured and persistent results to provide meaningful feedback to investment and R&D programs. Need apples to apples comparison between buildings. Policy mandates for rating and labeling.
Background	Much of the cost for an energy audit is due to a tedious, non-standardized, and error-prone process in EnergyPlus, Radiance, CONTAM, etc. are capable engines for assessing the energy, lighting, and airflow performance of buildings, however they each require a substantial degree of knowledge and skill to correctly apply to design and analysis problems. OpenStudio is an open source (free), cross-platform SDK that allows rapid development of easy-to-use graphical user interfaces that can produce models for use by each of these engines that enable practitioners to understand the impacts of design choices at each stage of a building design.

Continued . . .

National Renewable Energy Laboratory

Goals	The objective of OpenStudio is to produce a SDK that enables extremely rapid and cost-effective development of new desktop and web applications that eliminates barriers to adoption of whole-building analysis and emerging technologies. This will be accomplished by demonstrating easy, user-focused desktop applications that enable a broad range of A&E professionals, students, and researchers to engage in whole-building analysis; web tool, parametric analysis, and optimization capabilities that leverage OpenStudio's ability to quickly and easy articulate sophisticated building models; and engagement with third-party developers to create new modeling and analysis capability.
Scope	NREL released version 0.2 of OpenStudio in December 2010. Each quarterly public release includes new backend functionality that exposes EnergyPlus, Radiance, CONTAM, or other engine capability through a high-level, object-oriented SDK; continuously improved usability and workflow supported by graphical user interfaces and web-based training materials; software developer engagement and market adoption (e.g. concept3D is building their simuwatt products using OpenStudio); user engagement and adoption through training programs; and utility engagement and adoption through CEC's Title 24, NRCan, and a major utility energy design assistance program.
Timeline	Ongoing with first public release in December 2010.
Milestones & Publications	Quarterly public releases available at http://openstudio.nrel.gov
Budget	
Other parties involved	CEC, AEC, EEB Hub in Philadelphia, NRCan, ANL, LBNL, ORNL, PNNL, concept3D, and others
Next steps	Continue quarterly releases and support the rapidly growing user base and third-party developers
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing renewable energy and energy efficiency technologies and practices and advancing science and engineering in these areas.
References	Information from NREL staff c.a July 2012.

Performance Testing of Residential HVAC Systems

Buildings Research

Project Overview: Perform laboratory testing and develop detailed performance models of residential HVAC systems. These "performance maps" are used for accurate predictive simulation of the systems in any US climate and any building type. The tests are also used to explore performance deficiencies in products, and to inform codes & standards activities.

http://www.nrel.gov/buildings/residential.html

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	Dane Christensen 303-384-7437 dane.christensen@nrel.gov	**Sponsor(s)**	USDOE
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	Development of RTU testing protocols for systems performance maps.
Technology Characteristics	Rooftop unit performance test protocols.
Capability Gap(s)	Need reliable and effective economizer systems & controls (i.e., seals, actuators, dampers). Need functional performance test definition for factory testing. Need predictable, enforceable rooftop unit efficiency standards to enable maximum savings.
Driver(s)	Validation of performance of new HVAC technologies through utility field test. Need to understand where energy savings can be achieved and demonstrate actual.
Background	The ability to compare HVAC technologies and predict annual energy, cost and peak savings through building simulation relies on accurate representation of those technologies. Manufacturers seldom provide sufficient data to model these systems. Under certain operating conditions, some HVAC systems have been shown to consume over 40% more energy than the manufacturer data would suggest.
Goals	In FY12-13 test and develop detailed performance maps & models for the following systems: • Mini-Split Heat Pumps (collaborative project with BPA, Ecotope & Purdue/Herrick Labs) • Residential ventilation systems: ERVs/HRVs • Initial studies on how to model/characterize Window and Portable Air Conditioners in residential building simulations
Scope	Residential building integrated systems research.
Timeline	3/2012 – 10/2013

Continued . . .

National Renewable Energy Laboratory

Milestones & Publications	Several milestones/reports throughout FY12 & 13 Initial report on first phase of MSHP testing: Jon Winkler, "Laboratory Test Report for Fujitsu 12RLS and Mitsubishi FE12NA Mini-Split Heat Pumps," National Renewable Energy Laboratory, Sep. 2011,http://www.nrel.gov/docs/fy11osti/52175.pdf.
Budget	
Other parties involved	BPA, Ecotope, Purdue, NIST
Next steps	Having identified opportunities, explore collaborations with industry to improve products and systems to enhance the benefits to homeowners and utilities.
Associated R&D strategy	This project fits within NREL's broader mission to address the nation's energy and environmental goals by developing and demonstrating energy efficiency technologies, by optimizing system integration practices, and by advancing related science and engineering.
References	National Renewable Energy Laboratory, "Buildings Research," http://www.nrel.gov/buildings/residential.html, accessed Sep. 12, 2012. "Maximizing Thermal Efficiency and Optimizing Energy Management," FS-5500-53657, March 2012, http://www.nrel.gov/docs/fy12osti/53657.pdf, accessed Sep. 12, 2012. Jon Winkler, "Laboratory Test Report for Fujitsu 12RLS and Mitsubishi FE12NA Mini-Split Heat Pumps," National Renewable Energy Laboratory, Sep. 2011,http://www.nrel.gov/docs/fy11osti/52175.pdf , accessed Sep. 12, 2012. Jon Winkler, Dane Christensen, and Jeff Tomerlin, "Laboratory Test Report for Six ENERGY STAR® Dehumidifiers," National Renewable Energy Laboratory Technical Report TP-5500-52791, Dec. 2011, http://www.nrel.gov/docs/fy12osti/52791.pdf , accessed Sep. 12, 2012.

National Center for Photovoltaics

1617 Cole Blvd.
Golden, CO 80401-3305
(303) 275-3000 (o)

http://www.nrel.gov/buildings/

Research Focus	The National Center for Photovoltaics (NCPV) serves as the nation's central resource for research, development, deployment, outreach, and coordination involving solar and photovoltaic technology innovations. The NCPV is part of the U.S. Department of Energy's SunShot Initiative solar technologies program (http://www1.eere.energy.gov/solar/sunshot/index.html). The NCPV works closely with a number of other national laboratories, research universities, and industry partners, including Sandia National Laboratories (http://sandia.gov/), Brookhaven National Laboratory (http://www.bnl.gov/world/), Georgia Institute of Technology (http://www.energy.gatech.edu/), and the Institute of Energy Conversion at the University of Delaware (http://www.udel.edu/iec/).
Building Integrated Solar Technologies	As part of the 2006 Advanced Energy Initiative (http://georgewbush-whitehouse.archives.gov/ceq/advanced-energy.html), NREL is conducting research and development on an array of building-integrated solar electric and solar thermal technologies to improve energy efficiency. • Building Integrated Photovoltaics / Daylighting / Heating and Cooling Buildings with Solar Energy / Solar Water Heating Page 182

Building Integrated Photovoltaics

National Center for Photovoltaics - Building Integrated Solar Technologies

Project Overview: Research into advanced materials and systems to integrate photovoltaic technologies seamlessly into buildings so as to reduce construction costs and increase energy efficiency.

http://www.nrel.gov/pv/

Institution	National Renewable Energy Laboratory	**Div. / Dept.**	Science & Technology Division
Contact	David Christensen Renewable Energy Conservation Manager National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3305 (303) 275-3015 (o) david_christensen@nrel.gov National Center for Photovoltaics: (303) 384-6491 (o)	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Solar / Smart Roofing

Project Details

R&D Program	Effective, cost competitive solar shingles.
Technology Characteristics	Solar shingles.
Capability Gap(s)	Need products readily available in marketplace at a low cost. Need intelligent buildings with integrated photovoltaic systems. Need building codes that require solar systems.
Driver(s)	Declining price of PV systems. Availability of cross-cutting, low-cost technology building blocks. Availability of new technologies.
Background	To improve energy efficiency of commercial and residential buildings, there is much need to boost solar cell conversion efficiencies, lower solar system costs, and component and system reliability while also providing materials that can be fully integrated into new and existing buildings.
Goals	To develop photovoltaic materials that can be used functionally like conventional commercial and residential building materials (i.e., roofing shingles) so as to reduce costs and improve energy efficiency.
Scope	Research incorporates material design and testing, systems evaluation, the development of best practices and standards, and aiding in introduction of new technologies into the marketplace.
Timeline	Various projects and products to help DOE achieve its goal of bringing affordable zero-energy buildings to the marketplace by 2025.

Continued . . .

Milestones & Publications	Since 20002, the NREL has organized the DOE's biennial Solar Decathlon (http://www.solardecathlon.gov/). This competition challenges college students to design and build integrated solar-powered houses that are affordable, well-built, and aesthetically pleasing. Members of the public are then invited to the free event to see how current technologies can be integrated into daily life. The NREL Publications Database contains bibliographic information about technical publications, journal articles, and other materials developed or written by NREL staff and subcontractors from 1977 to the present. Many of these are available for download as Portable Document Format (PDF) files. See http://www.nrel.gov/publications/.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	NREL scientists are working on photovoltaic technologies as part of the DOE's SunShot Initiative (http://www1.eere.energy.gov/solar/sunshot/) to develop widely-available cost-effective solar technologies by 2020. NREL work on building-integrated photovoltaics is also part of DOE's goal to develop affordable zero energy buildings (buildings that produce as much energy as they consume) by 2025 for both large-scale home builders and commercial builders. Building America Program (http://www1.eere.energy.gov/buildings/building_america/).
References	National Renewal Energy Laboratory (2011). "Building Integrated Solar Technologies." http://www.nrel.gov/buildings/building_solar.html, accessed Dec. 20, 2011. National Renewal Energy Laboratory (2011). "Photovoltaics Research." http://www.nrel.gov/pv/, accessed Dec. 20, 2011. National Renewal Energy Laboratory (2011). "National Center for Photovoltaics." Retrieved 4/28/11, from http://www.nrel.gov/ncpv/, accessed Dec. 20, 2011.

Oak Ridge National Laboratory (ORNL)

P.O. Box 2008
Oak Ridge, TN 37831

http://ornl.gov/

Mission	Science and technology laboratory managed by UT-Battelle LLC for the U.S. Department of Energy. Conducts basic and applied research and development to contribute knowledge and technologies in the areas of energy, environmental protection, and national security.

Energy and Transportation Science Division

Johney Green, ETSD Director (865) 576-3711 (o)
Oak Ridge National Laboratory greenjbjr@ornl.gov
P.O. Box 2008, MS-6168
Oak Ridge, Tennessee 37831-6168

http://www.ornl.gov/sci/ees/etsd/index.shtml

Mission

Leads research and development efforts to achieve energy use reduction and renewable energy production. Efforts are organized within four Technology Centers: Building Technologies Research and Integration Center; Power Electronics and Electrical Power Systems Research Center; Fuels, Engines, and Emissions Research Center; and the Center for Transportation Analysis.

Building Technologies Research and Integration Center (BTRIC) Page 186

- Air Barriers
- Appliances
- Autotunig Building Energy Models
- Cool Roofs
- Envelope Moisture Durability
- Geothermal (Ground-Source) Heat Pump Systems
- HVAC
- Insulations
- Integrated HVAC and Water Heating
- Light Commercial System/Building Integration
- Residential System/Building Integration
- Roof/Attic Systems
- Sensors, Controls, Fault Detection, Diagnosis, and Commissioning
- Supermarket Refrigeration
- Water Heating
- Working Fluids

Cooling Heating & Power Technologies Program Page 220

- Cooling Heating & Power Technologies

Building Technologies Research and Integration Center (BTRIC)

Patrick Hughes, BTRIC Director
Energy & Transportation Science Div.
Oak Ridge National Laboratory
P.O. Box 2008, MS-6070
Oak Ridge, Tennessee 37831-6070

http://ornl.gov/sci/ees/etsd/btric/index.shtml

Research Focus	The Oak Ridge National Laboratory's Building Technologies Research and Integration Center Supports the U.S. Department of Energy's goals to devise and deploy energy efficient technologies by conducting research and development on cost effective energy efficiency technologies and systems for residential and commercial buildings.
Air Barriers	Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable air barriers for residential and light commercial buildings.
	• Air Barriers Page 188
Appliances	Develop and support deployment of more energy-efficient appliances for residential and commercial buildings.
	• Appliances Page 190
Autotunig Building Energy Models	Develop a generalized, automated building energy model tuning methodology.
	• Autotunig Building Energy Models Page 192
Cool Roofs	Develop and support deployment of cost-effective, energy-efficient, and moisture-durable cool roof systems for residential and commercial buildings.
	• Cool Roofs Page 194
Envelope Moisture Durability	Enable making envelopes for residential and commercial buildings more airtight and highly insulated without fear of unintended consequences (mold, rot, freeze/thaw damage, corrosion).
	• Envelope Moisture Durability Page 196
Geothermal (Ground-Source) Heat Pump Systems	Develop and support deployment of more cost-effective and energy-efficient geothermal (ground-source) heat pump systems for residential and commercial buildings.
	• Geothermal (Ground-Source) Heat Pump Systems Page 198
HVAC	Develop and support deployment of more energy-efficient HVAC equipment for residential and commercial buildings.
	• HVAC Page 200
Insulations	Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable insulation systems for residential and commercial buildings.
	• Insulations Page 202
Integrated HVAC and Water Heating	Develop and support deployment of a new category of products (integrated heat pumps) that provide more energy-efficient space conditioning and water heating for residential and commercial buildings.
	• Integrated HVAC and Water Heating Page 204

Continued . . .

Light Commercial System/Building Integration	Reduce industry and builder risk associated with emerging component technologies and design/construction techniques using entire light commercial "test buildings."
	• Light Commercial System/Building Integration Page 206
Residential System/Building Integration	Reduce industry and builder risk associated with emerging component technologies and design/construction techniques using entire residential "test buildings."
	• Residential System/Building Integration Page 208
Roof/Attic Systems	Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable roof/attic systems for residential and light commercial buildings.
	• Roof/Attic Systems Page 210
Sensors, Controls, Fault Detection, Diagnosis, and Commissioning	Develop and deploy sensors, control, and fault detection & diagnosis algorithms for improving building energy efficiency.
	• Sensors, Controls, Fault Detection, Diagnosis, and Commissioning Page 212
Supermarket Refrigeration	Develop and support deployment of more energy-efficient supermarket refrigeration equipment for residential and commercial buildings.
	• Supermarket Refrigeration Page 214
Water Heating	Develop and support deployment of more energy-efficient water heating equipment for residential and commercial buildings.
	• Water Heating Page 216
Working Fluids	Experimentation and models to help guide industry investments so vapor compression equipment energy-efficiency improves while transitioning to refrigerants with very low global warming contribution.
	• Working Fluids Page 218

Air Barriers

ORNL Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable air barriers for residential and light commercial buildings.

BTRIC Website: www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Air Barrier Association of America (ABAA), individual industry members of ABAA
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit Insulation?

Project Details

R&D Program	Air barriers.
Technology Characteristics	Materials or method to better insulate walls.
Capability Gap(s)	Need easier to use, affordable insulation materials.
Driver(s)	More and cheaper products due to globalization of manufacturing.Ever changing installation processes to match technologies.
Background	Infiltration and exfiltration account for 20 to 30% of the space conditioning loads in residential and light commercial buildings.
Goals	Characterize the efficacy of air barriers in reducing space conditioning energy use. Uncertainty over energy savings has hindered stronger air leakage language in model energy codes, wider use of air barriers (especially in retrofit applications), and has delayed research to improve air barrier technologies. Also provide clear identification of improvement avenues for air barrier technology.
Scope	The research addresses: quantification of the effectiveness of the 8 generic types of air barriers via side-by-side measurements at a natural exposure test facility; sub-assembly tests in lab to characterize major air leakage paths and assess methods of sealing; full envelope assembly tests in lab to simultaneously characterize air and moisture penetration; add air barrier modeling capabilities to WUFI hygrothermal model; and model validation; and achieve stronger air leakage language in model energy codes.

Continued . . .

Timeline	Ongoing
Milestones & Publications	ABAA built and donated a 36-bay natural exposure test (NET) facility in Syracuse NY for the project in FY09; ORNL facilities used to measure fresh and exposure-aged properties of the entire industry's products; phase 1 baseline testing of the entire industry's products at the NET completed in FY11; consensus achieved with industry in FY11 that all their products fall into 8 generic categories; phase 2 testing at NET to establish empirical relationships between air leakage and wall heat flux for each generic air barrier type began in FY12; and sub-assembly tests in lab to characterize major air leakage paths and assess methods of sealing began in FY12.
Budget	Varies year-to-year but $300-$550K annually of DOE funds matched with equal or higher industry in-kind cost share in recent years.
Other parties involved	Air Barrier Association of America and 13 members (essentially every major company that sells air barrier products into North American buildings-industry markets).
Next steps	Complete phase 2 NET testing and sub-assembly lab testing; add air barrier modeling capabilities to WUFI hygrothermal model; validate model; use model to generalize results; and use generalized results to achieve stronger air leakage language in future model energy codes.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Appliances

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of more energy-efficient appliances for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Energy-efficient Appliances.
Technology Characteristics	Test beds to assess new energy efficiency products. Smarter electrical plugs, programmable, addressable (in development). Foster acceptance and development of more energy efficient appliances.
Capability Gap(s)	Need new appliance standards, installation techniques and supporting technologies. Need of ZNE design practices. Need control of plug loads especially for work stations and entertainment centers electric cars. Lack of direct current micro-grids for homes and commercials and integration of renewable and digital world standards and availability of equipment. Need branding certification to increase manifest acceptance.
Driver(s)	Policy codes / including environmental. Increasing and uncertain future cost of electricity and gas. Grid integration, including stability and disaster/mitigation. Opportunity for large framework change. More and cheaper products due to globalization of manufacturing. Non-energy benefit such as health and comfort. Personal energy independence / interest.
Background	Appliances (defined as refrigerators/freezers, washers, dryers and dish washers) are responsible for about 9% of residential and commercial building primary energy consumption.
Goals	Provide science-to-solution ORNL participation in industry collaborations to accelerate development of new appliance technologies resulting in industry partners launching new and significantly more energy-efficient appliance products.
Scope	The research addresses: contributions to DOE's appliance R&D roadmap; new categories of appliances such as heat pump coupled washer-dryer pair or heat pump coupled dryer; appliance components such as novel heat exchangers, alternative refrigerants, and different compressor technologies; heat exchangers with integrated phase change materials (PCM) for fast waste heat recovery, energy storage, and retrieval; use of hardware-based models for vapor compression cycle and other components; optimization of heat pump cycle for the novel applications being investigated; additive manufacturing 3D printing of novel heat exchanger designs; use of bench top wind tunnel for the experimental evaluation of novel heat exchanger designs enabling energy storage; prototype development; prototype performance characterization in lab; calibration of models to lab data; use of models to optimize novel appliance design; and novel appliance validation via field test.

Continued . . .

Timeline	Project began in FY11 and is expected to run about 5 years
Milestones & Publications	Additive manufacturing 3D printer commissioned (Nov 2011); initial hardware-based design model completed for heat pump coupled washer/dryer (Dec 2011); received multiple PCM samples each with a different phase change temperatures (May 2012)
Budget	$500 to 800K annually of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	One or more CRADA partners for novel appliances, PCM suppliers
Next steps	Focus CRADA(s) based on learning to date and industry partner cost analysis; complete breadboard prototype design(s); build prototype(s); etc.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5e develop and commercialize appliance technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Autotunig Building Energy Models

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop a generalized, automated building energy model tuning methodology

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, ORNL director's discretionary (DD means free) hours on Jaguar/Titan, Nautilis and Frost supercomputers
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Autotuning building energy models.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Building energy models (EnergyPlus or other simulations, energy audit tools, etc.) of existing buildings are unreliable unless calibrated so they correlate well with actual energy usage. Calibrating models is costly because it is currently an "art", requiring significant manual effort by an experienced skilled professional. Manual tuning is also imperfect, non-repeatable, and non-transferrable.
Goals	Develop a generalized, automated building energy model tuning methodology that enables models to reproduce measured data as best they can, by selecting best-match input parameters in a systematic, automated, and repeatable fashion. If a generalized, building energy model autotuning methodology is successfully developed, the costs to develop building energy retrofit projects would be significantly reduced, enhancing the cost-effectiveness of retrofit projects and expanding their reach into smaller buildings. An autotuning methodology would also significantly improve the state of the art in energy savings measurement and verification (M&V) for performance contracting and other purposes.

Continued . . .

Scope	The research addresses: multi-objective optimization via sensitivity analysis; data mining to provide automated mapping between available data and model input variables; application of a suite of machine learning algorithms to generate calibration functions; quantification of trade-off between tuning accuracy and amount of data available; creation of the equivalent of an Autotune "Easy Button" on the user's PC with database and software tools in background; demonstrations of end-to-end Autotune prototype on ORNL's fleet of research houses, test buildings on ORNL's light commercial building flexible research platforms, and perturbed "golden models" of fictional buildings using faux sensor data; demonstrations of end-to-end Autotune prototype on buildings "in the wild"; and Autotune commercialization.
Timeline	The project began in FY12 and is expected to be completed in FY13 or FY14 depending on funding level.
Milestones & Publications	A paper describing Autotune will be presented at SimBuild 2012 in August.
Budget	About $450K annually for three years from DOE Building Technologies Program
Other parties involved	University of Tennessee-Knoxville and Jacksonville State University
Next steps	Complete development of end-to-end Autotune prototype; demonstrations of end-to-end Autotune prototype on ORNL's fleet of research houses, test buildings on ORNL's light commercial building flexible research platforms, and perturbed "golden models" of fictional buildings; demonstrations of end-to-end Autotune prototype on buildings "in the wild"; and Autotune commercialization.
Associated R&D strategy	Supports DOE Building Technologies Program existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3b facilitate integration of advanced technologies and solutions into existing (and new) buildings; existing commercial buildings strategy 3d increase awareness among commercial building owners and operators of opportunities to cost-effectively save energy while maintaining or improving occupant comfort and safety; existing commercial buildings strategy 3e reduce investment risk to increase financing for commercial retrofits; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4b facilitate integration of advanced technologies and solutions into existing (and new) buildings; and technology development strategy 5f significantly increase the number of users of building energy models.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Cool Roofs

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of cost-effective, energy-efficient, and moisture-durable cool roof systems for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, CEC PIER Program, DoD ESTCP Program, US-China Clean Energy Research Center for Building Energy Efficiency, Several industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Solar/Smart Roofing Technology

Project Details

R&D Program	Energy-efficient roofing systems.
Technology Characteristics	Cool / photovoltaic / solar water heating roofing,
Capability Gap(s)	Need intelligent buildings with integrated photovoltaic systems. Need modularization of building PV components. Need products readily available in marketplace at a low cost. Need building codes that require solar systems.
Driver(s)	Availability of new technologies such as solid state lighting. Availability of crosscutting, low-cost technology building blocks. Declining price of PV Systems.
Background	Commercially-available cool roof products are cost-effective in cooling-dominated residential and commercial applications as a relatively non-intrusive means of improving building energy efficiency. However, cool roof market acceptance has been hampered due to their relatively short service life and doubts about the longevity of the initial high solar-reflectivity. The commercial low-sloped roof market is well served by white cool roof products but the aesthetic demands of the steep-sloped roof market require darker "cool colored" products for broad acceptance. This makes broad market appeal challenging because asphalt shingles have 80-90 percent steep-slope market share and they are more difficult than other roofing surfaces to make "cool".
Goals	For low-slope roofs, develop a long-lasting spray-on white cool roof coating that enables cost-effective immediate retrofit of existing roofs to "cool" without waiting until re-roofing at the end of service life. [Metric: Products in the market enabling the performance standard for qualifying as a low-slope "cool roof" to be raised from the current 55% minimum Total Solar Reflectance (TSR) after three years of weathering to 75% TSR after five years of weathering. This increase in minimum standard would effectively double the energy savings over life of a cool roof versus conventional roof.] For steep-slope cool-colored shingled roofs, improve the TSR by 10 points (from 25 to 35%) without compromising the aesthetics or service life of the shingles.

Continued . . .

Scope	The research is in collaboration with several Cooperative Research and Development Agreement (CRADA) industry partners and LBNL. The research addresses: materials; polymer technology; long-term retention of high Total Solar Reflectance (TSR); UV, soiling, microbial growth, and water resistance; hygrothermal analysis; and development of accelerated aging test methods to predict TSR performance in 1/6th the calendar time required by today's industry test methods to establish certified performance. [Today's test methods require 3 years of natural exposure weathering so there is a long delay between when new products are ready for market and when they can be certified as "cool".]
Timeline	It is expected that the CRADA partners will begin launching new products in 2014. The process of gaining industry adoption of the new accelerated aging test methods, and raising "cool roof" minimum standards to double the energy savings may take several additional years.
Milestones & Publications	New products beginning in 2014 with invention protection through development of intellectual property.
Budget	Varies year-to-year but $300-$400K annually of DOE funds matched with equal or higher industry in-kind cost share in recent years.
Other parties involved	Three CRADA partners and LBNL.
Next steps	Integrate the improved cool roof options into deployment programs and codes and standards working primarily through ASHRAE, ASTM, and IECC.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Envelope Moisture Durability

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Enable making envelopes for residential and commercial buildings more airtight and highly insulated without fear of unintended consequences (mold, rot, freeze/thaw damage, corrosion)

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Fraunhofer Institute of Building Physics, Numerous industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit and New Construction Air/Water Management

Project Details

R&D Program	Envelope moisture durability.
Technology Characteristics	Increase service life of envelope systems.
Capability Gap(s)	Need to collect data about cost effectiveness of air sealing and water management applications. Need to improve methods of training people in effective air sealing because existing methods are too complex and poorly understood by many practitioners.
Driver(s)	Increase occupant health, comfort and safety. Noise transmission associated with leakage. Increased contribution of airflow to energy use. Use of codes to lock in efficiency gains. Lack of code enforcement for retrofits.
Background	Although some in the building energy efficiency community continue to deny there is a problem, the fact is there have been billions of dollars worth of moisture-related building envelope failures, and these failures are continuing due to insufficient understanding of building science [e.g., Bloomberg Businessweek (14 Feb 2011) "Pulte Group, the largest U.S. homebuilder, records a one-time expense of $272.2 million in third quarter (25% of revenue) to increase reserves to cover homeowner damage repair claims, most related to water intrusion"; Dr. Carl-Eric Hagentoft, Operating Agent for IEA Annex 55 (12 participating countries, 3 observing countries, ongoing through 2014) "Sweden estimates that 60-80% of attics have moisture damage due to strategy of insulating the attic assembly").
Goals	Enable making envelopes for residential and commercial buildings more airtight and highly insulated without fear of unintended consequences (mold, rot, freeze/thaw damage, corrosion)

Continued . . .

Scope	The research addresses: advancing building science and practitioner understanding of the flow of heat, air, and moisture through envelope assemblies, storage of heat and moisture in the assemblies, and thresholds for onset of failure modes; development of hygrothermal models; establishment of lab test facilities to measure essential construction material property values needed by hygrothermal models; model validation through establishment of side-by-side roof/attic and wall natural exposure test facilities in challenging domestic humid climates (hot/humid, mixed/humid, cool/humid, and cold/humid) and collection of experimental data; establishment of ASTM standard test procedures to measure hygrothermal properties and to evaluate hygrothermal models; establishment of an ASHRAE standard on moisture control envelope design; and encouragement of federal leadership in the adoption of the new standards.
Timeline	Ongoing
Milestones & Publications	A range of hygrothermal models have been successfully developed from research- to practitioner-grade (e.g., Wärme Und Feuchte Instationär or WUFI); over 8000 licensed users of WUFI-ORNL; over 2000 trained users of WUFI-ORNL; lab test facilities established at ORNL for measuring hygrothermal properties of construction materials commonly used in USA; natural exposure test facilities established in Charleston SC (hot/humid), at ORNL in Oak Ridge TN (Mixed/humid), Tacoma WA (cool/humid), and Syracuse NY (cold/humid); hygrothermal models validated with lab and field experimental data; major contributor to ASHRAE Standard 160 "Criteria for Moisture-Control Design Analysis in Buildings", which has been adopted by the General Services Administration in P100 "Facilities Standards for the Public Buildings Service"
Budget	Varies year-to-year but $300-$550K annually of DOE funds matched with equal or higher Fraunhofer IBP and industry in-kind cost share in recent years.
Other parties involved	Fraunhofer IBP, national representatives to IEA Annex 55 (12 countries participating, 3 observing), essentially all suppliers of building envelope construction materials to North American markets
Next steps	A major new lab apparatus for measuring air and moisture penetration of large-scale wall specimens will be commissioned at ORNL in FY13; continue expanding the base of WUFI-ORNL licensees and trained users; advance the research-to-practitioner suite of hygrothermal models (i.e., improve capabilities to represent generic types of air barriers, basement walls and other sub-grade envelope assemblies, etc.)
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Geothermal (Ground-Source) Heat Pump Systems

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of more cost-effective and energy-efficient geothermal (ground-source) heat pump systems for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, DOE Geothermal Technologies Program, DoD (Navy and Army primarily), General Services Administration, Oklahoma Gas and Electric, US-China Clean Energy Research Center for Building Energy Efficiency, Several industry partners
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	
Technology Characteristics	
Capability Gap(s)	
Driver(s)	
Background	Space conditioning and water heating equipment is responsible for about 49% of residential and commercial building primary energy consumption. Geothermal (ground-source) heat pump (GHP) systems for space conditioning and water heating are among the technologies with the highest potential for reducing energy consumption and peak demand in buildings. Through in-action the US has ceded its leadership in GHP technology (e.g., China's current 5-year plan calls for GHPs to be applied in 3.5 billion sf of new buildings over 5 years). The primary barrier to widespread adoption of GHP technology is high first cost, of which 30 to 50% is the ground heat exchanger (GHX). GHXs outlive the building and many generations of heat pumps, and are akin to utility infrastructure. Even with consumers shouldering the full first cost, GHPs have been successful in the market.
Goals	Develop and support deployment of more cost-effective and energy-efficient geothermal (ground-source) heat pump systems for residential and commercial buildings.

Continued . . .

Scope	The research addresses: advanced grouts and borehole heat exchangers; advanced drilled and excavating techniques; using construction excavations (overcut around/under basement, utility trenches, in-ground pools, rainwater harvesting cisterns) for GHX installation; best configurations for various commercial applications (decentralized or central, pure GHP or hybrid, etc.); national certification standard for all primary personnel involved in the installation of geothermal heat pump (GHP) systems, including drillers, plumbers, electricians, HVAC specialists, engineers and architects; technical assistance to DoD and GSA on specific GHP projects; helping US industry access the Chinese market; and determining whether system approaches from China merit domestic use.
Timeline	Ongoing
Milestones & Publications	Recent GHP milestones: demonstrated that 50-60% of the ground heat exchanger required for a highly energy-efficient home in a mixed/humid climate can be installed in the overcut around the basement wall and utility trenches (other construction excavations such as below basement floor, around cisterns and pools have not yet been tried); developed models for GHX in overcut around basement and utility trenches and integrated them into EnergyPlus; developed a spreadsheet line-source-based tool for sizing GHX all in overcut, all in trench, or some in both; completed preliminary reports on the status of GSHP applications in U.S. and China; and identified 24 GSHP projects for performance evaluation (6 from US and 18 from China) and data collection is ongoing.
Budget	$200K to $400K annually from DOE and a variety of work-for-others sponsors with equal or more cost share from industry partners.
Other parties involved	The International Ground-Source Heat Pump Association; the Geothermal Exchange Organization; ASHRAE; Oklahoma Gas and Electric; several industry partners
Next steps	Finalize reports on the status of GSHP applications in U.S. and China; and complete performance evaluations of 24 GSHP projects (6 from US and 18 from China).
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; technology development strategy 5c develop and commercialize HVAC technologies to provide 20% energy savings; and technology development strategy 5b develop and commercialize water heating technologies to provide 60% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

HVAC

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of more energy-efficient HVAC equipment for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization

Project Details

R&D Program	Need more accurate modeling to compare systems more easily.
Technology Characteristics	Improved building energy simulation software with parametric analysis capabilities to model more accurately variations in real-world operating conditions. Building simulation software.
Capability Gap(s)	Need to reduce high energy use to distribute heating and cooling beyond the actual vent need. Need to optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, and heat recovery. Need to tie model to building needs / loads. Need benchmarking categories at end use level; to improve modeling and better represent real world conditions. Need to account for large number of variables in building modeling, standards, and training. Current energy modeling engines under development by DOE (energy +) do not have wide market adoption because perceived to be too detailed, too difficult to use - and hence to expensive to use. Tools for accelerating inputs, and accelerating computation time(2 minutes or less) are needed.
Driver(s)	Electric utility need for resources to meet growing loads, and/or to replace oil and coal fired power plants. Consumer demand for reduced / low cost of utilities / operation. IAQ separate ventilation from HVAC loads / equipment. Need to understand where energy savings can be achieved and demonstrate actual. Validation of performance of new HVAC technologies through utility field test. Reduced first cost of new systems / design. Need to understand where energy savings can be achieved and demonstrate actual.
R&D Program	Efficient water Heating technologies.
Technology Characteristics	Improved water heating technologies.
Capability Gap(s)	Need to reduce or eliminate space heating and/or water heating requirements in grocery stores and supermarkets by recovering waste heat from refrigeration and air conditioning equipment.
Driver(s)	Reduced first cost of new systems / design.
Background	Heating, ventilating, and air-conditioning (HVAC) equipment for providing comfortable indoor temperature and humidity levels and healthy air quality is responsible for about 40% of residential and commercial building primary energy consumption.

Continued . . .

Goals	Provide science-to-solution ORNL participation in industry collaborations to accelerate development of new HVAC technologies resulting in industry partners launching new and significantly more energy-efficient HVAC products.
Scope	The research addresses: contributions to DOE's HVAC R&D roadmap; (http://www.ornl.gov/sci/ees/etsd/btric/pdfs/WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf) traditional vapor compression and alternative (e.g., absorption, magnetocaloric) technologies; use of computational fluid dynamics (CFD) models, infrared thermography, environmental chamber tests, and hardware-based vapor compression cycle models to minimize airflow mal-distribution in heat exchangers; use of the previously mentioned tools plus neutron imaging to minimize refrigerant mal-distribution in heat exchangers in all phases (liquid, vapor, and two-phase flow); use of hardware-based vapor compression cycle models to identify optimal cycle features for the application (e.g., single-speed, multi-speed, variable-speed or multi-stage compression; dynamic charge adjustment to optimize performance over an extensive range of operating conditions; partial recovery of expansion losses; heat exchanger circuiting; refrigerant flow controls), fluid flows, and control strategies; calibration of models to feature-, cycle-, and unit-level lab data; use of cycle models integrated into whole-building models to aide overall optimization of HVAC unit design; and HVAC unit validation via field-test.
Timeline	Ongoing
Milestones & Publications	Recent industry partner product introductions include: SEMCO (now Fläkt Woods Group) Revolution™ hybrid vapor compression/desiccant rooftop unit (R&D 100 Award in 2005); Trane CDQ (Cool, Dry, Quiet)™ hybrid vapor compression/desiccant rooftop unit (R&D 100 Award in 2006); NORDYNE iQ Drive® inverter-driven rotary compressor residential central air conditioner (2006); and Southwest Gas NextAire™ gas-engine heat pump rooftop unit with heat recovery for space conditioning (R&D 100 Award in 2011)
Budget	Program had been stable historically, then funding dove to almost zero, but in the last few years funding gradually recovered and last year was about $1.5 million of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	Four CRADA partners addressing cold climate air-source heat pump, next generation rooftop unit, window air conditioners, and a product based on magnetocaloric technology (pending stage-gate review the first application of magnetocaloric may target a non-HVAC application and move to a different project).
Next steps	Product launches by the CRADA partners
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5c develop and commercialize HVAC/R technologies to provide 20% energy savings. See also: Navigant Consulting, Inc., "Research and Development Roadmap for Water Heating Technologies," Oak Ridge National Laboratory Subcontract Number 4000093134, Sep. 30, 2011. (http://www.ornl.gov/sci/ees/etsd/btric/pdfs/WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf)
.References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Insulations

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable insulation systems for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, DoD ESTCP Program, US-China Clean Energy Research Center for Building Energy Efficiency, Numerous industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Retrofit and New Construction Air / Water Management

Project Details

R&D Program	Air barrier location / performance diagnosis.
Technology Characteristics	An affordable, streamlined, simpler methodology for air sealing. Tools/methods that can evaluate location and integrity of air / moisture barrier.
Capability Gap(s)	Need to collect data about cost effectiveness of air sealing and water management applications. Need to address contractor shortcomings: Building air sealing is too often poorly done by contractors. Need to improve methods of training people in effective air sealing because existing methods are too complex and poorly understood by many practitioners. Diagnostic for air / moisture barrier location. Current tightness levels still resulted in significant sound transmission.
Driver(s)	Lack of code enforcement for retrofits. Use of codes to lock in efficiency gains. Increased contribution of airflow to energy use. Increase occupant health, comfort and safety. Noise transmission associated with leakage. Ever changing installation processes to match technologies. Increased reliability over time.
Background	Opaque areas of building envelopes requiring insulation (roof/attics, walls, foundations) account for about 50% of space conditioning loads.
Goals	Enable reduced below-grade energy losses through appropriate use of insulation by validating the ability of hygrothermal models to verify failure mode avoidance in below-grade applications. Prevent roofing contractor over or under-discounting of foam insulation R-value by testing roof field samples and verifying accelerated degradation aging test protocols. Enable market uptake of phase change material (PCM) enhanced insulations, which have been shown to shave peaks and reduce energy consumption in a variety of climates and integration configurations, by developing a rating method for PCM-enhanced insulation. Characterize the performance of the performance of envelope assemblies with vacuum insulated panels (VIPs) and other advanced insulations on a proprietary basis for industry through full cost recovery user agreements.

Continued . . .

Scope	The research addresses: materials; blowing agents; verification of foam insulation performance degradation aging test protocols; phase change materials (PCMs); vacuum insulated panels (VIPs); integration of PCMs and VIPs into insulation; rating methods for PCM-enhanced insulations; tools for estimated energy savings as a function of VIP configuration; integration of insulation (conventional, PCM-enhanced, VIP-enhanced) into envelope assemblies; below-grade insulation applications; heat, air, and moisture transfer models; experimental validation with data from large-scale guarded hot boxes in the lab and side-by-side natural exposure test facilities; and overall energy efficiency as well as moisture-durability on insulated envelope assemblies.
Timeline	Ongoing.
Milestones & Publications	A revised version of WUFI capable of below-grade hygrothermal modeling of basement assemblies is expected in Q4 FY13. Twenty samples of pentane-blow foam roof insulation (10 harvested from field, 10 new) will have as-received and accelerated aging characterization completed in Q4 FY14. An ORNL-led ASTM task group will have developed a method of test (MOT) for PCM-enhanced insulation and characterized 4 PCM-enhanced insulation products using the MOT by Q4 FY13.
Budget	Varies year-to-year but $600-$800K annually of DOE funds matched with equal or higher industry cash or in-kind cost share in recent years.
Other parties involved	Fraunhofer IBP is CRADA partner of WUFI, University of Minnesota on basements, National Roofing Contractors' Association, multiple roof foam insulation CRADA partners, ASTM C16, and on average ORNL implements 10 to 20 user agreements with individual industry partners annually
Next steps	Integrate advanced insulations into deployment programs and codes and standards working primarily through ASHRAE, ASTM, and IECC.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Integrated HVAC and Water Heating

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of a new category of products (integrated heat pumps) that provide more energy-efficient space conditioning and water heating for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery & Economizer Optimization

Project Details

R&D Program	Integrated HVAC & water Heating.
Technology Characteristics	Technology to integrate HVAC and water heating.
Capability Gap(s)	Need to reduce or eliminate space heating and/or water heating requirements in grocery stores and supermarkets by recovering waste heat from refrigeration and air conditioning equipment.
Driver(s)	Reduced first cost of new systems / design.
Background	HVAC and water heating equipment accounts for about 49% of residential and commercial building primary energy consumption. Most buildings in most climates during many times of the year have HVAC equipment rejecting heat energy to outdoor air while consuming new energy (electricity or natural gas) to heat water.
Goals	Provide science-to-solution ORNL participation in industry collaborations to accelerate development of integrated heat pumps (IHPs), resulting in industry partners launching IHP products that satisfy space conditioning and water heating requirements while consuming significantly less energy than the suite of conventional HVAC and WH products they displace.
Scope	The research addresses: contributions to DOE's HVAC and water heating R&D roadmaps; traditional vapor compression cycles applied to HVAC and WH end-uses simultaneously; ground-source and air-source versions of the IHP; use of computational fluid dynamics (CFD) models, infrared thermography, environmental chamber tests, and hardware-based vapor compression cycle models to minimize airflow mal-distribution in heat exchangers; use of the previously mentioned tools plus neutron imaging to minimize refrigerant mal-distribution in heat exchangers in all phases (liquid, vapor, and two-phase flow); use of hardware-based vapor compression cycle models to identify optimal cycle features for the application (e.g., single-speed, multi-speed, variable-speed or multi-stage compression; dynamic charge adjustment to optimize performance over an extensive range of operating conditions; partial recovery of expansion losses; heat exchanger circuiting; refrigerant flow controls), fluid flows, and control strategies; calibration of models to feature-, cycle-, and unit-level lab data; use of cycle models integrated into whole-building models to aide overall optimization of IHP unit design; and IHP unit validation via field-test.

Continued . . .

Timeline	Ongoing
Milestones & Publications	In March 2012 ClimateMaster announced limited production of the Trilogy™ 40 Q-Mode™, a variable speed geothermal (ground-source) integrated heat pump. The unit reduces annual energy use by up to 65% compared to conventional systems for space conditioning and water heating in residential applications. The savings are about 33% compared with previous state of the art geothermal (ground source) heat pumps with desuperheaters (such units partially satisfy hot water loads).
Budget	Planning for this program began about 5 years ago. Funding has gradually ramped up and last year was about $2.9 million of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	ClimateMaster, two separate CRADA partners addressing air-source integrated heat pumps, and one CRADA partner addressing a gas-fired engine-driven air-source integrated heat pump. In addition, ASHRAE Standard Project Committee 206 (SPC 206) has been formed to develop an integrated heat pump (IHP) method of test (MOT) through the consensus process, and AHRI has expressed interest in developing a certification rating program for this new class of equipment.
Next steps	Product launches by the CRADA partners, ASHRAE establishment of Standard 206 Method of Test for Integrated Heat Pumps, and AHRI establishment of a certification rating program for integrated heat pumps.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; technology development strategy 5c develop and commercialize HVAC technologies to provide 20% energy savings; and technology development strategy 5b develop and commercialize water heating technologies to provide 60% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Light Commercial System/Building Integration

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Reduce industry and builder risk associated with emerging component technologies and design/construction techniques using entire light commercial "test buildings."

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Dozens of construction materials and components industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Testing of residential and commercial building systems.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Evaluating preproduction prototypes of new energy-efficiency products for light commercial buildings in realistic test beds is an essential step before market introduction. Environmental chambers and other lab apparatus cannot reliably impose every operating condition encountered in a real building, while use of occupied buildings (the living lab approach) confounds experimental results, and is intrusive, high-risk for industry, and expensive if done right. Builders are also reluctant to embrace new design and construction techniques until they are proven with real buildings.
Goals	Provide industry partners access to low-risk realistic light commercial building test beds, referred to as flexible research platforms (FRPs).

Continued . . .

Scope	In general, the FRP research process involves the following chronological steps: 1. A group of industry partners is found in which (1) at least one industry partner exists for each major building system (walls; roof; and heating, ventilation, and air-conditioning, at a minimum); (2) the industry partners desire to improve the energy efficiency of their offerings and are willing to invest in cost-shared collaborative research to accelerate the availability of improved offerings; and (3) industry partner agendas are compatible enough with one another that an integrated test building adequately satisfying all partner needs can be conceptualized. 2. ORNL develops an integrated whole-building design for the test building to be erected on the FRP. 3. Each industry partner erects its building system on the FRP in accordance with the integrated design. Any test building gaps (i.e., required features having no donors) must be provided by ORNL. 4. ORNL characterizes baseline test building performance under natural weather exposure over a period of time. 5. ORNL and industry partners collaborate on the development of tune-up and/or retrofit solutions (multiple alternatives may be evaluated on other research apparatus for down-selection). 6. Industry partners implement their tune-up and/or retrofit solutions onto the test building. 7. ORNL characterizes modified test building performance under natural weather exposure over a period of time. 8. Items 5 through 7 may be repeated several times during a test building research cycle. 9. ORNL removes the test building and repeats the process for the next test building research cycle.
Timeline	For residential "test buildings", ORNL uses an innovative public/private partnership approach, in which the utility or private partners provide the land, building materials, and labor cost-share to build research houses, which then are leased for research purposes. This approach is not feasible for light commercial buildings because the land, building materials, and labor investment is too great. Competitively-awarded American Recovery and Reinvestment Act (ARRA) funds were used to establish realistic light commercial building test beds at ORNL. The permanent portions of the two FRPs were completed in May 2012; baseline test buildings will be installed on both FRPs by February 2013.
Milestones & Publications	ORNL's light commercial building flexible research platforms are described in detail in an ORNL report.
Budget	Industry partners have already invested, or committed to invest about $1.5 million in the first baseline test buildings. It is estimated that DOE funding in the 1st year (FY13) will be $1 to $2 million and continue at that level annually, matched with equal or higher industry in-kind cost share.
Other parties involved	Dozens of construction materials and components industry partners
Next steps	A host of experiments similar to those described in ORNL's project entitled "residential system/building integration", except they will be conducted in light commercial buildings
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; new construction strategy 2b develop systems and applications that reduce energy consumption by 50% from code at less than the cost of the energy saved; new construction strategy 2c accelerate the adoption of advanced new building construction techniques; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3b facilitate integration of advanced technologies and solutions into existing (and new) buildings; technology development strategy 5b develop and commercialize water heating technologies to provide 60% energy savings; technology development strategy 5c develop and commercialize HVAC/R technologies to provide 20% energy savings; technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings; and technology development strategy 5e develop and commercialize appliance technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Residential System/Building Integration

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Reduce industry and builder risk associated with emerging component technologies and design/construction techniques using entire residential "test buildings."

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Tennessee Valley Authority (TVA), Schaad Companies, Habitat for Humanity [Lenoir City TN], Many construction materials and components industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Testing of residential and commercial building systems.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Evaluating preproduction prototypes of new residential energy-efficiency products in realistic test beds is an essential step before market introduction. Environmental chambers and other lab apparatus cannot reliably impose every operating condition encountered in a real building, while use of occupied buildings (the living lab approach) confounds experimental results, and is intrusive, high-risk for industry, and expensive if done right. Builders are also reluctant to embrace new design and construction techniques until they are proven with real buildings.
Goals	Provide industry partners access to low-risk realistic residential test beds through innovative partnerships.
Scope	ORNL's utility and private partners provide the land, building materials, and labor cost-share to build research houses that are leased to ORNL for research purposes over extended periods. Each supports research on one envelope strategy and several generations of equipment, appliances, and controls before the house is sold. In addition to natural exposure weather, an average occupant effect on energy use is imposed using process control, so realistic loads, operating conditions, and interactive effects are provided for technology evaluation and physical validation of models.

Continued . . .

Timeline	Over the past decade 12 research houses have been built and used for research purposes. ORNL currently has access to seven research houses: three from TVA and four from Schaad Companies. The other five houses (Habitat for Humanity, Lenoir City TN) have been released and sold.
Milestones & Publications	Recent research house milestones: demonstrate the energy efficiency and moisture durability of the new self-drying exterior insulation and finish systems (EIFS); first whole-house demonstration and performance characterization of PCM-enhanced cellulose; verification that optimal value framing can achieve energy efficiency in the neighborhood of SIPs at less cost; demonstrated that GeoSpring™ heat pump water heater energy savings was 13 times greater than the additional heating load take-back effect for an energy-efficient home in a mixed/humid climate; provided a low-risk environment to work out the controls and fault detection and diagnostics wrinkles on the ClimateMaster Trilogy™ 40 Q-Mode™ prior to launch; means of using process control to impose an average occupant effect on energy use is documented in an ASHRAE paper; and demonstrated that 50-60% of the ground heat exchanger required for a highly energy-efficient home in a mixed/humid climate can be installed in construction excavations needed to build the home, significantly reducing geothermal (ground-source) heat pump system installed cost.
Budget	In recent years $100K to $1 million annually of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	Tennessee Valley Authority (TVA), Schaad Companies, Electric Power Research Institute, Habitat for Humanity [Lenoir City TN], dozens of construction materials and components manufacturers
Next steps	A host of experiments similar to those mentioned above are in progress.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; new construction strategy 2b develop systems and applications that reduce energy consumption by 50% from code at less than the cost of the energy saved; new construction strategy 2c accelerate the adoption of advanced new building construction techniques; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4b facilitate integration of advanced technologies and solutions into existing (and new) buildings; technology development strategy 5b develop and commercialize water heating technologies to provide 60% energy savings; technology development strategy 5c develop and commercialize HVAC/R technologies to provide 20% energy savings; technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings; and technology development strategy 5e develop and commercialize appliance technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Roof/Attic Systems

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of climate-optimized, cost-effective, energy-efficient, and moisture-durable roof/attic systems for residential and light commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, DoD ESTCP Program, Many industry partners
Product / Service Area	Building Design/Envelope	**Roadmap**	Solar/Smart Roofing

Project Details

R&D Program	Energy-efficient roofing systems.
Technology Characteristics	Cool / photovoltaic / solar water heating roofing,
Capability Gap(s)	Need intelligent buildings with integrated photovoltaic systems. Need modularization of building PV components. Need products readily available in marketplace at a low cost. Need building codes that require solar systems.
Driver(s)	Availability of new technologies such as solid state lighting. Availability of crosscutting, low-cost technology building blocks. Declining price of PV Systems.
Background	About 20% of whole-building space-conditioning loads are attributable to the roof/attic in residential and light commercial buildings.
Goals	Develop cost-effective advanced roof/attic new-construction and retrofit designs for residential and light commercial applications and convince industry to adopt and implement the designs to reduce roof/attic-related space conditioning requirements by 50% compared to code.
Scope	The research addresses: roof/attic systems; components in those systems; materials in those components; heat, air, and moisture transfer models; experimental validation with data from large-scale guarded hot boxes in the lab, side-by-side roof/attic natural exposure test facilities, and whole building experiments; and overall energy efficiency as well as moisture-durability.
Timeline	Roof/attic design guidelines for all regions will be completed in 2014. Maintaining the guidelines thereafter is expected to be a significantly lower level of effort.
Milestones & Publications	The project is generating roof/attic design guidelines by region. Guidelines for hot and humid climates are completed and under review at DOE. Cold climate recommendations will be completed in FY14.

Continued . . .

Budget	Varies year-to-year but $500-$600K annually of DOE funds matched with equal or higher industry in-kind cost share in recent years.
Other parties involved	Essentially every major manufacturer of materials commonly used in North America for the construction and maintenance of roof/attic systems on residential and light commercial buildings
Next steps	Integrate improved roof/attic designs and retrofits into deployment programs and codes and standards working primarily through ASHRAE, ASTM, and IECC.
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5d develop and commercialize envelope technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Sensors, Controls, Fault Detection, Diagnosis, and Commissioning

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and deploy sensors, control, and fault detection & diagnosis algorithms for improving building energy efficiency.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, DOE Advanced Manufacturing Office (formerly Industrial Technologies Program), DoD ESTCP, ORNL Lab Directed R&D (LDRD), ORNL Sustainable Campus Initiative
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Fault Detection, Predictive Maintenance and Controls
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Integrated lighting & HVAC sensors, controls, FDD, & commissioning.
Technology Characteristics	Develop low-cost controls for small medium enterprises buildings. Self-optimizing controls. FDD for evaporatively-cooled and pre-cooled HVAC.
Capability Gap(s)	Connectivity with smart meter. Need to have corrective hardware such as predictive controls to optimize operation and intelligent systems with predictive, diagnostic controls & self-healing processes. Need evaporatively-cooled and precooled HVAC FDD.
Driver(s)	Leverage smart meter system. Contractor interest to increase profits. Consumer demand for reduced / low cost of utilities / operation. Aging workforce, lack of trained workforce. Diffusion of common communication protocols into energy-consuming devices. Potential of DDC in large commercial to calculate energy loss/cost of faults to prioritize faults in human response and justify public funding.
R&D Program	Advanced lighting control systems for new and retrofit applications.
Technology Characteristics	Cheaper, simpler self-calibration. Minimal impact and maximal compatibility on existing infrastructure. Intuitive operation, ease of use and commissioning. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need integration with building automation / management systems. Need for plug and forget controls that work without commissioning, tuning or user action. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need more reliable controls. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing.
Driver(s)	Individual control over lighting. Leveraging lighting controls to integrate other environmental control, e.g., HVAC, count of number of occupants in building (fire safety). Interoperability. Optimize work environment for using computers of the future-keep up as computers evolve. End user comfort / satisfaction. Cost of new Technology. Majority of energy efficiency potential is in retrofit applications. Need for professionals to be credible and deliver systems that work and avoid callbacks. Need for dark sky. Impacts on wildlife.

Continued . . .

Background	Buildings and building components including lighting and heating ventilating and air-conditioning (HVAC) equipment degrade over time due to lack of attention and deferred maintenance. Most existing commercial buildings are rife with low-cost opportunities related to fault detection and diagnostics, control optimization, and commissioning that would save energy (10-30%) and pay for themselves quickly, if implemented. The primary opportunities involve HVAC, lighting controls, HVAC control, and plug load management.
Goals	Through development of new low-cost wireless sensors applied to fault detection and diagnostics, optimal whole-building controls, and/or whole-building commissioning (retro- or continuous), enable whole-building energy bills to be reduced by 10-30% compared with pre-improvement baselines while retrofits pay for themselves in 5 years or less.
Scope	The research addresses: fully-integrated wireless sensors specifically for building applications based on commercial off the shelf (COTS) technology; fully-integrated wireless sensors specifically for building applications based on novel low-temperature roll-to-roll manufacturing techniques and reduced in cost by 15-30x; fault detection and diagnosis (FDD) algorithms using as input the sensor data; translation of FDD findings into actionable information; advanced control systems; reduced order models of actual building behavior; controller platforms; optimal control formulations; and integration of an evaluation platform into the test buildings on ORNL's light commercial building flexible research platforms specifically for sensors, controls, FDD, and commissioning (e.g., force faults and observe whether intended responses actually occur).
Timeline	Ongoing
Milestones & Publications	Wireless sensor retrofit and overlay of optimal HVAC controller in a 7,000 sq ft building achieved 40-50% weather-normalized energy savings; demonstrated that fully-integrated wireless sensors specifically for building applications based on COTS has significant cost reduction potential from today's market pricing but not nearly the 15-30x reduction needed for market capture by 10-30% energy-saving retrofits with speed and scale.
Budget	$200 to 400K annually of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	Several HVAC/R equipment, building automation, and building energy management and control system manufacturers are involved. Initiation of one or more CRADAs anticipated in FY13.
Next steps	Integration of an evaluation platform into the test buildings on ORNL's light commercial building flexible research platforms specifically for sensors, controls, FDD, and commissioning (e.g., force faults and observe whether intended responses actually occur); scope and execute CRADAs; accelerate the advanced manufacturing pathway to 15-30x cost reduction of fully-integrated wireless sensors specifically for building applications.
Associated R&D strategy	Supports DOE Building Technologies Program existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3b facilitate integration of advanced technologies and solutions into existing (and new) buildings; existing commercial buildings strategy 3d increase awareness among commercial building owners and operators of opportunities to cost-effectively save energy while maintaining or improving occupant comfort and safety; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4b facilitate integration of advanced technologies and solutions into existing (and new) buildings; technology development strategy 5a capture a 70% savings due to improvements in lighting by 2020; and technology development strategy 5c develop and commercialize HVAC/R technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Supermarket Refrigeration

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of more energy-efficient supermarket refrigeration equipment for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	New refrigerant testing.
Technology Characteristics	New refrigerant testing for efficiency and global warming contribution.
Capability Gap(s)	Need information on energy performance, optimization, and mini-split system control bestpractices.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Need to understand where energy savings can be achieved and demonstrate actual.
Background	Refrigeration equipment is responsible for about 6.5% of residential and commercial building primary energy consumption. After refrigerators/freezers, supermarket refrigeration is the next largest end-use in this category. There are over 35,000 supermarkets in the US, averaging about 45,000 ft2 in size. Unlike HVAC applications, the annual refrigerant leakage rate in refrigeration systems can be significant, and therefore the environmental case is stronger for a near-term transition to refrigerants whose direct chemical emissions have very low global warming potential.
Goals	Provide science-to-solution ORNL participation in industry collaborations to accelerate development of new refrigeration technologies resulting in industry partners launching new and significantly more energy-efficient refrigeration products, including products for retrofit applications.
Scope	The research addresses: evaluation of alternative refrigerant options for supermarket refrigeration; evaluation of conventional and alternative refrigerants based on the life cycle climate performance (LCCP) methodology; use of hardware-based vapor compression cycle models to evaluate same-system/different-refrigerant and different-system/different-refrigerant options for supermarket refrigeration; calibration of cycle models to data from environmental chamber testing of supermarket refrigeration system; integration of cycle models into whole-building model of typical supermarket; selection of a different-system/different-refrigerant option for development into a next generation supermarket refrigeration system with CRADA partner; next generation system prototype development; modeling to aide overall optimization of next generation system; identification of low-hanging fruit retrofits for common existing supermarket refrigeration systems; field demonstrations of retrofits to common existing systems and the next generation system, when available.

Continued . . .

Timeline	Field demonstrations of retrofits to common existing supermarket refrigeration systems in DOE BTP Commercial Building Energy Alliance (CBEA) facilities expected to begin in FY13. Field demonstration of next generation supermarket refrigeration system prototype in ORNL's one-story light commercial building flexible research platform expected to begin in FY14.
Milestones & Publications	Required models and algorithms for supermarket refrigeration systems identified (Dec 2010); algorithm and model development completed (Mar 2011); different-system/different-refrigerant option selected for development into a next generation supermarket refrigeration system (Mar 2012); and next generation supermarket refrigeration system prototype design (expected in Aug 2012).
Budget	$300 to 500K annually of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	One CRADA partner for the next generation supermarket refrigeration system; several industry-leading component suppliers for supermarket refrigeration systems; and active members of the CBEA Refrigeration and Food Service Project Team (Wal-Mart, Walgreen's, Target, Whole Foods).
Next steps	Field demonstrations of retrofits to common existing supermarket refrigeration systems; field demonstration of prototype next generation system; and product launches by the CRADA partners
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5c develop and commercialize HVAC/R technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov"

Water Heating

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Develop and support deployment of more energy-efficient water heating equipment for residential and commercial buildings.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Commercial and Residential Water Heating

Project Details

R&D Program	Efficient water Heating technologies.
Technology Characteristics	Improved water heating technologies.
Capability Gap(s)	Need to reduce or eliminate space heating and/or water heating requirements in grocery stores and supermarkets by recovering waste heat from refrigeration and air conditioning equipment.
Driver(s)	Reduced first cost of new systems / design.
R&D Program	Efficient water heating technologies and best building stock applications.
Technology Characteristics	Technologies to reduce heating and cooling loads without negatively affecting indoor air quality.
Capability Gap(s)	Use of waste heat to heat water. Need to optimize use of ambient or indoor conditions.
Driver(s)	Need to understand where energy savings can be achieved and demonstrate actuals
Background	Water heating equipment is responsible for about 9% of residential and commercial building primary energy consumption.
Goals	Provide science-to-solution ORNL participation in industry collaborations to accelerate development of new water heating technologies resulting in industry partners launching new and significantly more energy-efficient water heating products.

Continued . . .

Scope	The research addresses: contributions to DOE's water heating R&D roadmap; application of heat pump technologies (electric vapor compression, gas-fired absorption) technologies to double water heating efficiencies; development of additives to absorption fluid pair to prevent crystallization under possible water heating operating conditions; use of computational fluid dynamics (CFD) models, infrared thermography, environmental chamber tests, and hardware-based vapor compression cycle models to minimize airflow mal-distribution in heat exchangers; use of the previously mentioned tools plus neutron imaging to minimize refrigerant mal-distribution in heat exchangers in all phases (liquid, vapor, and two-phase flow); use of hardware-based vapor compression cycle models to identify optimal cycle features for the application (e.g., tank-wrap condenser heat exchangers; heat exchanger circuiting; refrigerant flow controls), fluid flows, and control strategies; calibration of models to feature-, cycle-, and unit-level lab data; Energy Factor (EF) environmental chamber testing; accelerated durability lab testing (equivalent of 10 years service in 10 months); use of cycle models integrated into whole-building models to aide development of installation guidance (best unit locations in building, climate impact on net-benefit, etc.); and water heater unit validation via field-test.
Timeline	Ongoing
Milestones & Publications	GE Appliances launched its GeoSpring™ heat pump water heater in November 2009. This technology saves 62% on energy use and pays for itself in about 2.5 years when compared to standard electric storage water heaters. Since then A.O. Smith and Rheem have introduced products to meet the competitive challenge. With multiple providers the regulatory side of DOE was able to promulgate a rule whereby all electric storage water heaters 55 gallons and up must have heat pumping efficiencies beginning January 1, 2016. GE Appliances moved production from China to Louisville KY in 2012, creating 100 GE manufacturing jobs and over 1,000 estimated US jobs. Also in 2012, ORNL published an ASHRAE paper documenting a field-test showing HPWH energy savings was 13 times greater than the additional space conditioning load take-back effect for an energy-efficient home in a mixed/humid climate.
Budget	Program has been periodically funded historically, but until recently was zeroed. In recent years the funding gradually recovered and last year was about $1.0 million of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	CRADA partners addressing an electric vapor compression heat pump water heater using CO_2 as the refrigerant (GeoSpring uses R-134a) and a gas-fired absorption heat pump water heater.
Next steps	Product launches by the CRADA partners
Associated R&D strategy	Supports DOE Building Technologies Program new construction strategy 2a deploy highly energy efficient end-use and building envelope technologies and processes; existing commercial buildings strategy 3a deploy highly energy efficient end-use and building envelope technologies and processes; existing residential buildings strategy 4a deploy highly energy efficient end-use and building envelope technologies and processes; and technology development strategy 5b develop and commercialize water heating technologies to provide 60% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov" Navigant Consulting, Inc., "Research and Development Roadmap for Water Heating Technologies," Oak Ridge National Laboratory Subcontract Number 4000093134, Sep. 30, 2011, http://www.ornl.gov/sci/ees/etsd/btric/pdfs/WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf.

Working Fluids

Building Technologies Research and Integration Center (BTRIC)

Project Overview: Experimentation and models to help guide industry investments so vapor compression equipment energy-efficiency improves while transitioning to refrigerants with very low global warming contribution.

www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy & Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Div. Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	DOE Building Technologies Program, Several industry Cooperative Research and Development Agreement (CRADA) partners, Every major refrigerant manufacturer
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	

Project Details

R&D Program	New refrigerant testing.
Technology Characteristics	New refrigerant testing for efficiency and global warming contribution.
Capability Gap(s)	Need information on energy performance, optimization, and mini-split system control bestpractices.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. Need to understand where energy savings can be achieved and demonstrate actual.
Background	Vapor compression cycles are the heart of air conditioners, heat pumps, chillers, supermarket refrigeration systems, and more. Refrigerants are the life blood. When the Montreal Protocol and US Clean Air Act drove the transition away from ozone-depleting chlorofluorocarbon and hydrochlorofluorocarbon (CFC and HCFC) refrigerants, experimentation and modeling by ORNL helped guide industry investments so the selected replacement refrigerants enabled vapor compression equipment energy-efficiency to improve. A similar transition away from refrigerants whose direct chemical emissions have significant global warming potential is underway, led by applications like supermarket refrigeration with high leakage rates. With this project ORNL is reprising its role to help guide industry investments, so U.S. manufacturers will be positioned as the global market suppliers of the next generation alternative technologies (rather than buyers).
Goals	Vapor compression equipment energy-efficiency improves while transitioning to refrigerants with very low global warming contribution

Continued . . .

Scope	The research addresses: contributions to DOE's working fluids R&D roadmap; executing NDAs or CRADAs with all major refrigerant manufacturers and obtaining samples of their candidate alternative refrigerants for supermarket refrigeration, unitary heat pumps and air conditioners, refrigerator/freezers, and heat pump water heaters; establishing the specific life cycle climate performance (LCCP) methodology for comparing conventional and alternative refrigerants for each end-use system type; testing the alternative refrigerants in various lab apparatus (compressor calorimeters, pumped liquid refrigerant test loop, etc.); dropping alternative refrigerants into systems designed for today's refrigerants, and determining impact on performance with environmental chamber tests; updating hardware-based cycle models of each system so they can access the properties of the alternative refrigerants; calibrating the cycle models for each system and refrigerant to lab data; using the cycle models for each system to re-optimize the systems for alternative refrigerants; and provide guidance to industry through participation in the AHRI Alternative Refrigerant Evaluation Program (AREP) and directly with refrigerant and equipment manufacturers.
Timeline	Project began in FY11 and is expected to run about 5 years
Milestones & Publications	Refrigerator/freezer, heat pump water heater, and air-source heat pump drop-in refrigerant testing begun or ongoing (Oct 2011); although still under development the life cycle climate performance (LCCP) model web tool on-line (Nov 2011); ASHRAE approves formation of a multi disciplinary task group (MTG) on Low GWP Refrigerants chaired by Dr. Abdelaziz of ORNL (Jan 2012); pumped liquid refrigerant test loop repaired and placed into service (Feb 2012); refrigerant specification report completed (quantifies the existing refrigerant charge associated with different HVAC&R equipment types and the associated direct and indirect emissions) (Mar 2012); existing hardware-based models updated so alternative refrigerant properties are accessible (models can now be used with compressor calorimeter data to predict system performance) (Mar 2012); hardware-based supermarket refrigeration model developed (June 2012); shakedown testing of the supermarket refrigeration system in the large environmental chamber began (June 2012); new compressor calorimeter test stands commissioned and placed into service (June 2012)
Budget	$2 to $3 million annually of DOE funds matched with equal or higher industry in-kind cost share.
Other parties involved	The major refrigerant, compressor and equipment manufacturers and AHRI
Next steps	Continue refrigerator/freezer, heat pump water heater, air-source heat pump, and supermarket refrigeration drop-in tests for additional alternative refrigerants; continue pumped liquid refrigerant loop tests for additional alternative refrigerants; continue compressor calorimeter tests for additional alternative refrigerants; calibrate the cycle models for each system and alternative refrigerant; re-optimize the systems for alternative refrigerants; and provide guidance to industry on the high-stakes decisions they must make.
Associated R&D strategy	Supports DOE Building Technologies Program technology development strategies 5b, 5c, and 5e to develop and commercialize water heating, HVAC/R, and appliance technologies to provide 20% energy savings.
References	Information provided by ORNL BTRIC staff July 2012, with the additional note: "Start with www.ornl.gov/sci/ees/etsd/btric and if you do not find what you seek contact BTRIC Director Assistant, Lori Frye, at fryela@ornl.gov" Navigant Consulting, Inc., "Research and Development Roadmap for Water Heating Technologies," Oak Ridge National Laboratory Subcontract Number 4000093134, Sep. 30, 2011, http://www.ornl.gov/sci/ees/etsd/btric/pdfs/WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf.

Cooling Heating & Power Technologies Program

Denise Overton
Project Management Specialist

Contact:
http://www.coolingheatingpower.org/contact/form.php

http://www.coolingheatingpower.org

Research Focus	One of eighteen research groups within the Engineering Science and Technology Division (ESTD) of the Oak Ridge National Laboratory (ORNL), the Cooling, Heating and Power (CHP) Technologies Program team collaborates with industry, academia, other national labs, and various federal agencies to devise cost-effective, energy-efficient technologies that also reduce peak power demand, reduce emissions, and increase system reliability.
Cooling Heating & Power Technologies	Team conducts research, development, and testing in heat transfer systems, thermally-activated technologies, distributed energy resources, and related systems.

Cooling Heating & Power Technologies

Cooling Heating & Power Technologies Program

Project Overview: Team conducts research, development, and testing in heat transfer systems, thermally-activated technologies, distributed energy resources, and related systems.

http://www.coolingheatingpower.org

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	Denise Overton Project Management Specialist Contact: http://www.coolingheatingpower.org/contact/form.php	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	2030 Challenge.
Technology Characteristics	Design & analysis tools to integrate components and predict whole system energy performance.
Capability Gap(s)	Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales. Need of ZNE design practices.
Driver(s)	Policy / codes including Environmental. Personal energy independence / interest. Increasing and uncertain future cost of electricity and gas. Opportunity for large framework change.
Background	Team works to develop cost-effective and energy efficiency technologies for commercial and industrial applications, in partnership with industry, academia, other national laboratories, and federal agencies
Goals	Staff is engaged in benchmarking, developing, testing, and integrating combined heat and power technologies.
Scope	integration testing for commercial applications at the university's Chesapeake Office Building. (http://www.coolingheatingpower.org/capabilities/chp-testing/). They are also working with partners in manufacturing and telecommunications on end-use systems integration.
Timeline	Projects appear to be ongoing.
Milestones & Publications	
Budget	
Other parties involved	University of Maryland is involved with commercial applications (http://www.coolingheatingpower.org/capabilities/chp-testing/).
Next steps	
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "Whole Building and Community Integration." http://www.coolingheatingpower.org/, accessed Jan. 4, 2012.

Rensselaer Polytechnic Institute

110 Eighth Street (518) 276-6000 (o)
Troy, NY USA 12180

http://www.rpi.edu/

Mission	The Rensselaer Polytechnic Institute (RPI) was founded in 1824 and is the nation's oldest technological university. RPI provides research and development to facilitate the transfer of technology from the laboratory to the marketplace, including energy-efficient products and systems.

Lighting Research Center

Mark Rea, Director. (518) 687-7100 (o)

http://www.lrc.rpi.edu/

Mission

Established in 1988 as part of Rensselaer Polytechnic Institute, the Lighting Research Center (LRC) is the leading university-based research institution studying lighting technologies, applications, and products. The LRC investigates energy efficiency, new products and technologies, design, and human factors related to lighting.

The LRC is engaged in a wide array of research areas applicable to the Northwest Energy Efficiency Technology Roadmap Portfolio:

Capturing the Daylight Dividend

- *[Current R&D projects not yet specified]*

DesignWorks

- *[Current R&D projects not yet specified]*

Energy Efficiency

- *[Current R&D projects not yet specified]*

Light and Health Program Page 224

- Investigating Impact of Daylight Exposure & Intermittent Blue Light Exposure on Circadian Rhythms
- Quantifying the Impact of Light on K-12 Students' Performance and Well-being

Lighting Metrics

- *[Current R&D projects not yet specified]*

Solid-State Lighting Page 229

- Estimating Complete LED System Life
- Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting

Transportation Lighting and Safety Page 234

- Outdoor Lighting

Light and Health Program

110 Eighth Street
Troy, NY USA 12180
(518) 276-6000 (o)

http://www.lrc.rpi.edu/researchAreas/healthVision.asp

Research Focus	The LRC's Health & Vision program brings together technology and human lighting requirements by conducting research to help understand human visual and circadian systems. This knowledge is then applied to develop systems that are energy-efficient and that improve human health. Sponsors of the Light & Health Program can be found at http://www.lrc.rpi.edu/programs/lightHealth/sponsors.asp.
Investigating Impact of Daylight Exposure & Intermittent Blue Light Exposure on Circadian Rhythms	Laboratory and field studies investigating impact of light and daylight on biomarkers and on performance.
	• Investigating Impact of Daylight Exposure & Intermittent Blue Light Exposure on Circadian Rhythms Page 225
Quantifying the Impact of Light on K-12 Students' Performance and Well-being	Investigation into the biological mechanisms associated with the link between building daylighting design and student performance in K-12 schools.
	• Quantifying the Impact of Light on K-12 Students' Performance and Well-being Page 227

Investigating Impact of Daylight Exposure & Intermittent Blue Light Exposure on Circadian Rhythms

Light and Health Programs

Project Overview: Laboratory and field studies investigating impact of light and daylight on biomarkers and on performance.

http://www.lrc.rpi.edu/programs/lightHealth/

Institution	Rensselaer Polytechnic Institute	**Div. / Dept.**	Lighting Research Center
Contact	Mariana Figueiro, Ph.D. Program Director Associate Professor (518) 687-7142 (o) figuem@rpi.edu	**Sponsor(s)**	United States Green Building Council (USGBC) (http://www.usgbc.org/); Trans-National Institutes of Health Genes, Environment and Health Initiative (http://www.genome.gov/19518663) National Science Foundation
Product / Service Area	Lighting	**Roadmap**	General Lighting

Project Details

R&D Program	Study health impacts of lighting.
Technology Characteristics	Dynamic lighting that can change SAD/CCTI, flux, intensity distribution.
Capability Gap(s)	Need better definition of relationship of lighting quality / safety. Dynamically adjustable light sources. Need to better understand human performance, health and comfort factors related to lighting alternatives.
Driver(s)	Lighting retrofits happen for many reasons which may or may not include using optics designed for the new light source. The challenge is to make it easier to improve the lighting quality and efficiency during a retrofit. Lighting should contribute to the health and productivity of occupants. General lighting should provide occupant comfort and satisfaction. The use of constantly evolving computer systems, along with changing work staff and their preferences, make a highly flexible and controllable lighting system in the workspace desirable. Users desire to have personal control over the lighting they work under and be comfortable when they can adjust it to suit varying conditions.
Background	Sustainable buildings should be able to minimize wasted energy while maximizing human benefits. With regard to maximizing human benefit in sustainable buildings, it is often argued that daylight improves worker productivity. Although there is a wealth of studies showing that people like daylight, there is no compelling evidence that daylighting actually improves human performance.
Goals	Investigate the impact of daylight exposure as well as intermittent blue light exposure on performance and feelings of sleepiness.

Continued . . .

Scope	Laboratory and field studies investigating impact of light and daylight on biomarkers and on performance.
Timeline	
Milestones & Publications	Milestones: • Through lab and field test results, daylighting is important for maintaining circadian rhythms, sleep and well being, but has little effect on tracking performance and feeling of fatigue in the daytime. • Restricting evening light may be just as important for maintaining a circadian clock. • Blue light at night, improved performance and feelings of sleepiness, suggesting that during normal sleep times light can have an alerting effect.
Budget	
Other parties involved	
Next steps	Further research is aimed at understanding how other colors of light impact performance and sleepiness as well as circadian disruption and health.
Associated R&D strategy	
References	"Sustainable buildings: More than just lumens per watt" by Dr. Mariana Figuerio and Dr, Mark Rea. Clean Tech for Sustainable Buildings: From Nano to Urban Scale (CISBAT '11) International Conference Proceedings. Lausanne, Switzerland. September 14-16, 2011.

Quantifying the Impact of Light on K-12 Students' Performance and Well-being

Light and Health Program

Project Overview: Investigation into the biological mechanisms associated with the link between building daylighting design and student performance in K-12 schools.

http://www.lrc.rpi.edu/programs/lightHealth/projects/K12light.asp

Institution	Rensselaer Polytechnic Institute	**Div. / Dept.**	Lighting Research Center
Contact	Mariana Figueiro, Ph.D. Program Director Associate Professor (518) 687-7142 (o) figuem@rpi.edu	**Sponsor(s)**	United States Green Building Council (USGBC) (http://www.usgbc.org/); Trans-National Institutes of Health Genes, Environment and Health Initiative (http://www.genome.gov/19518663)
Product / Service Area	Lighting	**Roadmap**	Luminaires
Product / Service Area	Lighting	**Roadmap**	General Lighting

Project Details

R&D Program	Optimize human factors (i.e., lighting quality, health effects, etc.).
Technology Characteristics	Developing acceptance configurations for consumers. Fixture design for many different applications. Metrics should pertain to light (spectral content) delivered, task and aesthetic performance, not light emitted from source and energy use of entire package.
Capability Gap(s)	Need better lens designs to aim light without excessive glare. Need standardized affordable and reliable SSL components allowing fixture designers wide freedom to innovate and meet consumer needs. Need to design lighting and luminaires to optimize the effectiveness for the task from the user's point of view. Need to make mesopic lighting standards accessible to appropriate users. Need ability to retrofit an existing luminaire and achieve good optics. Need to change common metrics from source efficacy to luminaire efficacy.
Driver(s)	Availability of new technologies such as solid state lighting. Optimize work environment for using computers of the future-keep up as computers evolve. End user comfort / satisfaction. Corporate image, desire for new style. Enhance human performance (health, productivity). Majority of energy efficiency potential is in retrofit applications. A large number of existing luminaire are candidates are retrofit.
R&D Program	Study health impacts of lighting.
Technology Characteristics	Dynamic lighting that can change SAD/CCTI, flux, intensity distribution.
Capability Gap(s)	Need better definition of relationship of lighting quality / safety. Dynamically adjustable light sources. Need to better understand human performance, health and comfort factors related to lighting alternatives.
Driver(s)	Lighting retrofits happen for many reasons which may or may not include using optics designed for the new light source. The challenge is to make it easier to improve the lighting quality and efficiency during a retrofit. Lighting should contribute to the health and productivity of occupants. General lighting should provide occupant comfort and satisfaction. The use of constantly evolving computer systems, along with changing work staff and their preferences, make a highly flexible and controllable lighting system in the workspace desirable. Users desire to have personal control over the lighting they work under and be comfortable when they can adjust it to suit varying conditions.

Continued . . .

Rensselaer Polytechnic Institute
Lighting Research Center

Background	When natural night/day and light/dark cycles do not correlate with human sleep/wake cycles, sleep deprivation may occur, which, in turn, can lead to increased stress and possible immune system deficiencies.
Goals	Researchers are testing the hypothesis that a lack of correlation to the 24-hour solar day (particularly during the darker winter months) is the primary contributor to decreased well-being and performance. Research will incorporate findings into guidelines for architects, designers, and school administrators to help improve the design of school buildings.
Scope	Develop deeper understanding of student circadian rhythms, and correlate this understanding with building daylighting design.
Timeline	
Milestones & Publications	Figueiro MG & Rea MS. 2010. Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students. NeuroEndocrinology Letters. Vol 31, No. 1 **IN PRESS** Additional publications, including original grant application, available at http://www.lrc.rpi.edu/programs/lightHealth/projects/K12light.asp
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Rensselaer Polytechnic Institute Lighting Research Center (2012). "Researchers Investigate Daylight and Electric Light on K-12 Students' Well-being and Performance." http://www.lrc.rpi.edu/programs/lightHealth/projects/K12light.asp, accessed Jan. 18, 2012. Rensselaer Polytechnic Institute Lighting Research Center (2012). "The Light and Health Program at the LRC." http://www.lrc.rpi.edu/programs/lightHealth/index.asp, accessed Jan. 18, 2012.

Solid State Lighting

Nadarajah Narendran
Director of Research
21 Union St.
Troy, NY 12180

(518) 687-7176 (o)
narenn2@rpi.edu

http://www.lrc.rpi.edu/programs/solidstate/index.asp

Research Focus

Conducts research, development, training, and outreach to speed the integration of energy-efficient light-emitting diode (LED) systems into commercial products and residential, commercial, and industrial buildings.

Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting

Seeks solutions to integrate interior architectural details with customizable energy-efficient lighting systems.

Estimating Complete LED System Life

Continued research into issues relating to longevity of LED lighting systems, such as component integration, optics, housings, and installation methods.

Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting

Solid State Lighting

Project Overview: Seeks solutions to integrate interior architectural details with customizable energy-efficient lighting systems.

http://www.lrc.rpi.edu/programs/solidstate/or_adaptableSSL.asp

Institution	Rensselaer Polytechnic Institute	**Div. / Dept.**	Lighting Research Center
Contact	Professor Nadarajah Narendran, Ph.D. Director of Research 21 Union St. Troy, NY 12180 (518) 687-7176 (o) narenn2@rpi.edu	**Sponsor(s)**	ASSIST ; California Energy Commission Building Energy Research Grant program; OSRAM Sylvania; Paramount Pictures; USG Corporation
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Better fixture design.
Technology Characteristics	Fixture design for many different applications.
Capability Gap(s)	Need to design lighting and luminaires to optimize the effectiveness for the task from the user's point of view. Need standardized affordable and reliable SSL components allowing fixture designers wide freedom to innovate and meet consumer needs. Need better lens designs to aim light without excessive glare.
Driver(s)	Corporate image, desire for new style. Availability of new technologies such as solid state lighting. Optimize work environment for using computers of the future - keep up as computers evolve. Enhance human performance (health, productivity). Availability of new technologies such as solid state lighting. End user comfort / satisfaction.
Background	Solid state lighting technologies presents new ways of integrating lighting seamlessly into living and working spaces, including embedding LEDs into architectural details and design. The long life of LEDs, their color options, their small size, and the ability to integrate them with dynamic control systems offers many opportunities for reliable, inexpensive lighting solutions.
Goals	Develop technologies, approaches, and best practices that will allow for easy reconfiguration of integrated solid state lighting systems without having to tear apart and patch walls, re-wire areas of buildings, etc.
Scope	Research and design into electrical grid and circuits, light source integration, and panel attachment and hinges.
Timeline	

Continued . . .

Milestones & Publications	The Alliance for Solid-State Illumination Systems and Technologies (ASSIST) (http://www.lrc.rpi.edu/programs/solidstate/assist/index.asp) provided initial funding to LRC researchers in 2004 to design and demonstrate interior design elements with integrated LED lighting. In 2005 an LRC team built a full-scale mock-up of an office building applying this approach. Field evaluation of this system commenced in 2009 at a demonstration site at Paramount Pictures in Hollywood, Calif. This field testing is funded by the California Energy Commission, and partners include OSRAM Sylvania and USG. Project was recently completed& installed in 2012.
Budget	
Other parties involved	Project sponsors and partners include ASSIST (http://www.lrc.rpi.edu/programs/solidstate/assist/index.asp); California Energy Commission Building Energy Research Grant program (http://www.energy.ca.gov/commission/index.html); OSRAM Sylvania (http://www.sylvania.com/en-us/Pages/default.aspx); Paramount Pictures (http://www.paramount.com/); USG Corporation (http://www.usg.com/index.html)
Next steps	More details on conference installation & field demonstration of the system will be covered in LED magazine.
Associated R&D strategy	All of LRC's solid-state lighting research is conducted as part of the LRC-initiated Alliance for Solid-State Illumination Systems and Technologies (ASSIST) industry partnership seeking to expand the adoption and functionality of LED lighting technology (http://www.lrc.rpi.edu/programs/solidstate/assist/index.asp).
References	Lighting Research Center (2012). "Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting." http://www.lrc.rpi.edu/programs/solidstate/or_adaptableSSL.asp, accessed Jan. 19, 2012.

Estimating Complete LED System Life

Solid State Lighting

Project Overview: Continued research into issues relating to longevity of LED lighting systems, such as component integration, optics, housings, and installation methods.

http://www.lrc.rpi.edu/programs/solidstate/LEDLife.asp

Institution	Rensselaer Polytechnic Institute	**Div. / Dept.**	Lighting Research Center
Contact	Professor Nadarajah Narendran, Ph.D. Director of Research 21 Union St. Troy, NY 12180 (518) 687-7176 (o) narenn2@rpi.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	SSL life extension.
Technology Characteristics	Super SSL: The ca. 2010 winner of the DOE's next generation L-Prize (www.lightingprize.org/) meets all needs identified in Performance Gap boxes above.
Capability Gap(s)	Need better color rendering. Need to provide full dimming capabilities while maintaining light quality (i.e., reduce "flicker"). Need to improve lumen maintenance. Need to improve lighting reliability over time. Need to increase energy efficiency.
Driver(s)	Optimize work environment for using computers of the futurekeep up as computers evolve. Aesthetics. Optimize human performance (health, productivity). End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. The number of solid state lighting products available in the marketplace is rapidly growing with varying performance. Consumers need to be able to tell what they are getting.. Utilities are mandated to produce more energy with renewable sources and energy-efficiency measures. Energy-efficiency measures can reduce the impact of increasing energy costs.
Background	Claims that LEDs had life expectancies of up to 100,000 hours proved not to be accurate considering real-life applications involving integration with other systems and components, various kinds of housings and fixtures, and the lack of accurate measurement tools.
Goals	To understand better the factors that contribute to LED longevity, including developing reliable means of measuring LED performance.
Scope	Evaluation of LED systems in a variety of real-life applications, including coupling with other components and integrating within various kinds of fixtures, to evaluate the impact of these factors on LED life.
Timeline	

Continued . . .

Milestones & Publications	Initial research projects led LRC to partner with industry and create the Alliance for Solid-State Illumination Systems and Technologies (ASSIST). In 2005, this group produced an LED component and system guide, the "ASSIST recommends: LED Life for General Lighting" (http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/ledlife.asp). This guide was revised in April 2006 and August 2007. Since developing the ASSIST life-test method in 2005 (with updates in 2007 and 2008), the LRC continues to research system life issues including: LED driver life (http://www.lrc.rpi.edu/programs/solidstate/cr_driverLife.asp); Alternating Current (AC) LED junction temperature (http://www.lrc.rpi.edu/programs/solidstate/cr_acLED.asp); LED thermal resistance (http://www.lrc.rpi.edu/programs/solidstate/cr_thermalresistance.asp); LED directional lighting (http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/directional.asp). More publications available at http://www.lrc.rpi.edu/programs/solidstate/LEDLife.asp.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	All of LRC's solid-state lighting research is conducted as part of the LRC-initiated Alliance for Solid-State Illumination Systems and Technologies (ASSIST) industry partnership seeking to expand the adoption and functionality of LED lighting technology (http://www.lrc.rpi.edu/programs/solidstate/assist/index.asp).
References	Lighting Research Center (LRC). "Estimating LED Life." http://www.lrc.rpi.edu/programs/solidstate/LEDLife.asp, accessed Jan. 19, 2012. Lighting Research Center (2008). "ASSIST recommends: LED Life for General Lighting." http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/ledlife.asp, accessed Jan. 19, 2012.

Transportation Lighting and Safety

John Bullough, Ph.D.
Senior Research Scientist
Adjunct Assistant Professor
Lighting Research Center, Rensselaer Polytechnic Institute
21 Union Street
Troy, NY 12180 USA

(518) 687-7100 (o)
(518) 687-7120 (f)
bulloj@rpi.edu

http://www.lrc.rpi.edu/programs/transportation/index.asp

Research Focus

Research in this area focuses on improving efficacy, efficiency, and safety of lighting systems for streets, airports, vehicles, and airplanes.

Mesopic Lighting

Mesopic lighting conditions are those under which the human eye is using both cones and rods under photopic (daylight) and scotopic (dim) lighting conditions. Mesopic lighting research seeks to find the most effective and efficient lighting systems for out-of-door and other conditions in which the human eye is operating in this environment.

- Mesopic Lighting Page 235

Mesopic Lighting

Transportation Lighting and Safety

Project Overview: Mesopic lighting conditions are those under which the human eye is using both cones and rods under photopic (daylight) and scotopic (dim) lighting conditions. Mesopic lighting research seeks to find the most effective and efficient lighting systems for out-of-door and other conditions in which the human eye is operating in this environment.

http://www.lrc.rpi.edu/programs/solidstate/LEDLife.asp

Institution	Rensselaer Polytechnic Institute	**Div. / Dept.**	Lighting Research Center
Contact	John Bullough, Ph.D. Senior Research Scientist 21 Union Street Troy, NY 12180 USA (518) 687-7100 (o) (518) 687-7120 (f) bulloj@rpi.edu	**Sponsor(s)**	Groton Utilities; Lumec; Philips
Product / Service Area	Lighting	**Roadmap**	Luminaires

Project Details

R&D Program	Legitimize mesopic lighting.
Technology Characteristics	Metrics should pertain to light (spectral content) delivered, task and aesthetic performance, not light emitted from source and energy use of entire package.
Capability Gap(s)	Need to make mesopic lighting standards accessible to appropriate users. Need to design lighting and luminaires to optimize the effectiveness for the task from the user's point of view. Need ability to retrofit an existing luminaire and achieve good optics. Need to change common metrics from source efficacy to luminaire efficacy.
Driver(s)	Enhance human performance (health, productivity. Corporate image, desire for new style. A large number of existing luminaire are candidates are retrofit. Majority of energy efficiency potential is in retrofit applications. Availability of new technologies such as solid state lighting.
Background	The human eye reacts differently at low light levels than it does during peak daylight. The precise dynamics of the human eye in low-light (mesopic) conditions are not yet fully understood, nor has this knowledge been applied as fully as possible to develop effective, energy-efficient lighting systems.
Goals	LRC researchers are currently engaged in a variety of research projects to understand how the human eye operates in mesopic conditions, and what kinds of lighting technologies can be developed with this knowledge.
Scope	Projects include investigating different kinds of outdoor and instrumentation lighting, and comparing results with existing lighting technologies.
Timeline	

Continued . . .

Milestones & Publications	Streetlight mesopic lighting field test conducted in 2008 concluded that such a system met all utility and safety requirements while using up to 50% less energy than standard high-pressure sodium lights and was, therefore, a valid mesopic solution for rural and urban applications. LRC staff published findings in 2010 concluding that light-emitting diodes (LEDs) were appropriate technologies for street lighting that delivered energy efficiency and improved mesopic lighting situations. Findings of other recent mesopic lighting research can be found at http://www.lrc.rpi.edu//programs/transportation/mesopic.asp and http://www.lrc.rpi.edu/programs/transportation/publications.asp.
Budget	
Other parties involved	Groton Utilities (http://www.grotonutilities.com/); Lumec (http://lumecllc.com/); Philips (http://www.usa.lighting.philips.com/)
Next steps	
Associated R&D strategy	All of LRC's solid-state lighting research is conducted as part of the LRC-initiated Alliance for Solid-State Illumination Systems and Technologies (ASSIST) industry partnership seeking to expand the adoption and functionality of LED lighting technology (http://www.lrc.rpi.edu/programs/solidstate/assist/index.asp).
References	Lighting Research Center (2012). "Transportation Lighting and Safety." http://www.lrc.rpi.edu/programs/transportation/index.asp, accessed Jan. 20, 2012. Lighting Research Center (2012). "Mesopic Street Lighting Systems Conserves Energy." http://www.lightingresearch.org/resources/newsroom/pdf/2008/MesopicGroton8511.pdf, accessed Jan. 20, 2012. Morante, Peter (2008, Jan. 31). "Mesopic Street Lighting Demonstration and Evaluation Final Report." http://www.lrc.rpi.edu/researchAreas/pdf/GrotonFinalReport.pdf, accessed Jan. 20, 2012. Brons, Jennifer (2010). "LED Street Lighting: Demonstration and Evaluation of Lighting Technologies and Applications." http://www.lrc.rpi.edu/programs/DELTA/pdf/FTDelta_LEDStreetLighting.pdf, accessed Jan. 20, 2012.

Toyota Motor Corporation	1 Toyota-Cho (0565) 28-2121 (o) Toyota City, Aichi Prefecture 471-8571 Japan http://www.toyota-global.com/
Mission	Leading global manufacturer of motor vehicles founded in 1937. Firm also produces marine pleasure craft, has a financial services branch, and has recently expanded into energy- and material-efficient manufactured housing.

Toyota Housing Corporation

	Nagoya Building (052) 552-2111 (o) 4-7-1 Meieki Nakamura-ku, Nagoya City, Aichi Prefecture 450-8711 Japan http://www.toyota-global.com/company/profile/non_automotive_business/housing.html
Mission	Toyota Motor Company has been building manufactured housing since the 1970s. In 2010, the company consolidated all housing-related efforts within its subsidiary, Toyota Housing Corporation (also known as Toyota Home Co.), to build and sell manufactured housing units and design housing developments. Production techniques blend housing-related equipment development with advanced automobile technologies.
	Manufactured Housing Construction Page 238

Toyota Motor Corporation

Manufactured Housing Construction	**Project Overview:** Toyota is producing environmentally considerate manufactured housing units that apply automobile production technologies and systems. **http://www.toyota-global.com/company/profile/non_automotive_business/housing.html**

Institution	Toyota Motor Corporation	**Div. / Dept.**	Toyota Housing Corporation
Contact		**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Manufactured Housing / Modular / Pre-Manufactured Systems / Offices

Project Details

R&D Program	Innovative factory type assembly of models.
Technology Characteristics	Plug & play assembly. Modular, pre-insulated wall, floor, and ceiling units. Automated / robotic assembly.
Capability Gap(s)	Lack of cheap, streamlined construction and installation of energy efficient manufactured housing reflecting best practices in other manufacturing industries. Need new or improved codes and programs.
Driver(s)	Availability of energy efficiency products through existing suppliers (manufactured home). Use of codes to lock in efficiency gains. Inherent efficiency; reduced labor and materials.
Background	Toyota Motor Company has been building manufactured housing since the 1970s. In 2010, the company consolidated all housing-related efforts within its subsidiary, Toyota Housing Corporation (also known as Toyota Home Co.), to build and sell manufactured housing units and design housing developments. Production techniques blend housing-related equipment development with advanced automobile technologies.
Goals	To design, build, and sell manufactured housing units that meet "Next-generation energy-saving standards," reduce CO2 emissions during production and while occupied, and have prolonged lifespans.
Scope	Company is working on projects involving earthquake resistance, free design post-and-beam steel frame construction, and "Skeleton & Infill" integrated insulation-frame-wall construction. "Next-generation energy-saving standards" for Toyota means hermetically-sealed, well-insulated housing to reduce energy needed for heating and air-conditioning by 20%, thereby reducing CO2 emissions that contribute to global climate change. Toyota also applies the Skeleton and Infill Home Making Concept involving reinforced supporting structural elements that allow for changing lifestyles without changing the fundamental structure. Company has also adopted measures to use clean natural energy sources (such as photovoltaic power generation) and reduce energy consumption.
Timeline	
Milestones & Publications	Toyota Housing sold 3,500 houses in FY2002.

Continued . . .

Budget	
Other parties involved	
Next steps	
Associated R&D strategy	Toyota Housing Business devised its Environmental Action Plan in accordance with Toyota Motor Company's environmental goals and the Eco Action 21 housing industry environmental action plan (Eco Action 21 housing industry environmental action plan).
References	Associated Press (2008, March 29). "Toyota Homes - Live In Your Next Toyota ." *IBS Modular*. http://ibsmodular.blogspot.com/2008/03/toyota-homes-live-in-your-next-toyota.html, accessed Jan. 18, 2012. Toyota Motor Corporation (2012). "Housing." http://www.toyota-global.com/company/profile/non_automotive_business/housing.html, accessed Jan. 18, 2012. Toyota Motor Corporation (2003). "Housing Business." http://www.toyota.co.jp/en/environmental_rep/03/jigyou.html, accessed Jan. 18, 2012. Kageyama, Yuri (2006, June 15). "Toyota Banking on Famed Production Ways in Housing Business." Seattle Times. http://seattletimes.nwsource.com/html/businesstechnology/2003062192_toyotahousing15.html, accessed Jan. 18, 2012. Toyota Motor Corporation (2009, Oct. 23). "Toyota's Housing Operations to Integrate Under Toyota Housing Corporation." http://japancorp.net/Article.Asp?Art_ID=22164, accessed Jan. 18, 2012. McClatchy-Tribune News Service (2010, Nov. 18). "Toyota, Panasonic sally into nascent green-housing sector." http://www.joplinglobe.com/dailybusiness/x1383437018/Toyota-Panasonic-sally-into-nascent-green-housing-sector, accessed Jan. 18, 2012.

Toyota Motor Corporation

University of California Davis

One Shields Ave. (530) 752-1011 (o)
Davis, CA 95616

http://www.ucdavis.edu/index.html

Mission	One of ten campuses in the University of California system.

California Lighting Technology Center (CLTC)

Michael Siminovitch, Ph.D (530) 747-3835 (o)
Director (530) 747-3812 (f)
633 Pena Drive
Davis, CA 95618 mjsiminovitch@ucdavis.edu

http://cltc.ucdavis.edu/content/view/716/420/

Mission	The California Lighting Technology Center (CLTC) exists to facilitate research, development, and commercialization of energy-efficient lighting and daylighting technologies. CLTC works to achieve these goals in close collaboration with utilities, manufacturers, end users, designers, builders, government agencies, and others. The California Energy Commission, U.S. Department of Energy, and National Electrical Manufacturers Association collaborated to establish the CLTC on the campus of the University of California Davis in 2003.
Algorithms for Advanced Control Lighting and Energy Management	Develop and demonstrate advanced electric lighting control algorithms. • Algorithms for Advanced Control Lighting and Energy Management Page 243
Core Sunlighting System	Collaboration with the University of British Columbia (UBC) and manufacturing partners to evaluate UBC's Core Sunlighting System usefulness in the mid-Central Valley latitude and climate. • Core Sunlighting System Page 245
Cost Effective Demand Response (CEDR) Lighting	Introduce a novel demand response (DR) lighting control technology that can be easily retrofit to existing buildings • Page 247
Dual-Loop Photosensor Controls for Daylight Harvesting	Develop a dual loop photosensor control system for skylight applications. • Dual-Loop Photosensor Controls for Daylight Harvesting Page 249

Continued . . .

LED Replacement Lamp Testing	Laboratory testing of color brilliance, light color appearance and light color uniformity of LED replacement lamps.	
	• LED Replacement Lamp Testing	Page 251
Organic Light Emitting Diodes (OLEDs)	Investigate the effectiveness of OLEDs as a potential source of ambient lighting in the office.	
	• Organic Light Emitting Diodes (OLEDs)	Page 253
Reliable Photo Sensing for Daylight Harvesting	Developing reliable, accurate photosensor control systems to optimize daylight harvesting and energy efficiency by optimizing open-loop and closed-loop sensor positions.	
	• Reliable Photo Sensing for Daylight Harvesting in Side-Lit Spaces	Page 254
Smart Corridors and Stairwells	Field Demonstrations of adaptive lighting control systems.	
	•	Page 256
Smart Windows and Skylights	Developing next-generation fenestration systems that incorporate automated operable systems, interior and exterior sensors, and integrated electronics to increase energy efficiency and enhance comfort using intelligent window and skylight shading and ventilation control.	
	• Smart Windows and Skylights	Page 258

Algorithms for Advanced Control Lighting and Energy Management

Project Overview: Develop and demonstrate advanced electric lighting control algorithms.

http://cltc.ucdavis.edu/content/view/1203/476/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Konstantinos Papamichael, Ph.D Co-Director 633 Pena Drive Davis, CA 95618 (530) 747-3834 (o) kpapamichael@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Lighting controls and verification of small load demand. Advanced lighting control systems for retrofit applications
Technology Characteristics	Standardized luminaire, control protocols and communication. Smart controls for lighting technologies. Verification of luminaire demand response. Cheaper, simpler self-calibration. Minimal impact and maximal compatibility on existing infrastructure. Intuitive operation, ease of use and commissioning. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need integration of task ambient, precision daylighting. Need better user interfaces. Need for plug and forget controls that work without commissioning, tuning or user action. Need more reliable controls. Need for better, cheaper CFL, LED dimmable Products. Optimized / ideal luminaire control communication protocol. Need interface with smart phones, tablets, etc. Need performance requirement for standards. Need to support color shifting and control of other new lighting capabilities. Integration need demand response support. Need to support demand response (metering, others?). Need optimized/ideal luminaire control communication protocol. Need integration with building automation / management systems. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing..
Driver(s)	Optimize work environment for using computers of the future-keep up as computers evolve. Utility incentives for influencing designers, contractors, manufacturers. End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. Majority of energy efficiency potential is in retrofit applications. Cost of new technology. Aesthetics. Controllable; integrated with other entertainment, communication mobility. Interoperability. Controls that will allow demand response for lighting.
R&D Program	Improved control systems and sensors for daylighting technologies.
Technology Characteristics	Sensors & Control Systems.

Continued . . .

University of California Davis
California Lighting Technology Center

Capability Gap(s)	Need to have applications easier to design, commission and operate. Need methods to compensate for daylight color shift, glare, intensity, focus. Need applications that can utilize natural light. Need responsive and reliable controls and photo sensors for daylighting.
Driver(s)	Increased consumer resistance to complex features and controls. Climate change. Energy security. End user comfort / satisfaction. Optimize work environment for using computers of the future-keep up as computers evolve. Optimize human performance (health, productivity). Aesthetics. Consumer desire to be "green" and reduce embedded & used energy. Increased interest among legislators in efficiency and renewable. Increase in available funding for EE.
Background	Control algorithms enable integration of multiple sMAP data streams from local and remote sources, improving the energy efficiency and comfort level of buildings. Incorporation on multiple local data streams from luminaire-integrated occupancy sensors and photosensors, as well as utility electricity rates. Advanced algorithms consider historical data for continuous automated calibration and optimal performance
Goals	Develop and demonstrate advanced electric lighting control algorithms that adjust electric lighting output in individual luminaires based on multiple sMAP data streams from multiple occupancy and light sensors as well as real-time electricity rates.
Scope	Investigation of how local building data streams (such as lighting system power, occupancy, available daylight, and temperature) as well as remote streams (such as utility and weather data) can be used in advanced control algorithms of building systems (such as lighting, operable fenestration and HVAC). This project is focused on advanced lighting controls for occupancy, daylight harvesting and demand response.
Timeline	
Milestones & Publications	
Budget	supported by a CITRIS seed grant
Other parties involved	UC Berkeley Professor of Mechanical Engineering David M. Auslander
Next steps	
Associated R&D strategy	
References	California Lighting Technology Center, "Algorithms for Advanced Lighting Control and Energy Management," http://cltc.ucdavis.edu/content/view/1203/476/, accessed Sep. 14, 2012.

Core Sunlighting System

Project Overview: Collaboration with the University of British Columbia (UBC) and manufacturing partners to evaluate UBC's Core Sunlighting System usefulness in the mid-Central Valley latitude and climate.

http://cltc.ucdavis.edu/content/view/796/409/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Konstantinos Papamichael, Ph.D Co-Director 633 Pena Drive Davis, CA 95618 (530) 747-3834 (o) kpapamichael@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Improved control systems and sensors for daylighting technologies.
Technology Characteristics	Sensors & Control Systems.
Capability Gap(s)	Need to have applications easier to design, commission and operate. Need methods to compensate for daylight color shift, glare, intensity, focus. Need applications that can utilize natural light. Need responsive and reliable controls and photo sensors for daylighting.
Driver(s)	Increased consumer resistance to complex features and controls. Climate change. Energy security. End user comfort / satisfaction. Optimize work environment for using computers of the future-keep up as computers evolve. Optimize human performance (health, productivity). Aesthetics. Consumer desire to be "green" and reduce embedded & used energy. Increased interest among legislators in efficiency and renewable. Increase in available funding for EE.
Background	University of British Columbia researchers devised a "Core Sunlighting System" composed of moveable and fixed mirrors and a horizontal light pipe to re-direct sunlight into building cores. This system is integrated with lighting controls that automatically dim electric lights when sufficient sunlight is available.
Goals	To conduct extensive testing on the Core Sunlighting System, in partnership with 3M and other manufacturers, to determine feasibility of this system for the mid-Central Valley of California so as to determine cost-effectiveness and technical feasibility.
Scope	The system will be installed on two UC Davis campus buildings and monitored to track comfort, energy, peak electricity demand, and occupant response.

Continued . . .

University of California Davis
California Lighting Technology Center

Timeline	
Milestones & Publications	Dr. Lorne Whitehead, University of British Columbia presented an overview of this project in January 2011, a video of which can be viewed at http://cltc.ucdavis.edu/content/view/942/439/. As of January 2012, the first system had been installed at building N-2, Center of Laboratory Animal Sciences (CLAS), School of Veterinary Medicine, UC Davis.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	California Lighting Technology Center (2012). "Core Sunlighting System." http://cltc.ucdavis.edu/content/view/796/409/ , accessed Jan. 20, 2012. Whitehead, Lorne (2011). "Bringing Daylight Indoors." Video presentation. http://cltc.ucdavis.edu/content/view/942/439/, accessed Jan. 20, 2012.

Cost Effective Demand Response (CEDR) Lighting

Project Overview: Introduce a novel demand response (DR) lighting control technology that can be easily retrofit to existing buildings.

http://cltc.ucdavis.edu/content/view/87/89/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Michael Siminovitch, Ph.D Directorf CLTC; Rosenfeld Chair in Energy Efficiency; Professor, Design Program mjsiminovitch@ucdavis.edu (530) 747-3834 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Lighting controls and verification of small load demand.
Technology Characteristics	Standardized luminaire, control protocols and communication. Smart controls for lighting technologies. Verification of luminaire demand response.
Capability Gap(s)	Need integration of task ambient, precision daylighting. Need better user interfaces. Need for plug and forget controls that work without commissioning, tuning or user action. Need more reliable controls. Need for better, cheaper CFL, LED dimmable Products. Optimized / ideal luminaire control communication protocol. Need interface with smart phones, tablets, etc. Need performance requirement for standards. Need to support color shifting and control of other new lighting capabilities. Integration need demand response support. Need to support demand response (metering, others?).
Driver(s)	Optimize work environment for using computers of the future-keep up as computers evolve. Utility incentives for influencing designers, contractors, manufacturers. End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. Majority of energy efficiency potential is in retrofit applications. Cost of new technology. Aesthetics. Controllable; integrated with other entertainment, communication mobility. Interoperability. Controls that will allow demand response for lighting.
Background	Utilities need additional demand response (DR) capacity to avoid rolling blackouts during peak usage periods and meet regulatory requirements. Most existing, commercial lighting does not currently contribute to peak demand reductions. Existing retrofit lighting control solutions are too expensive for DR use, which leaves existing, interior, commercial lighting as a largely untapped DR resource.
Goals	To use demand response (DR) to make retrofit installation economical by using existing power wiring to transmit a load shed signal to designated lighting loads. This signal, introduced at the lighting panel and transmitted to receivers installed in existing bi-level light switches, tells receivers to turn off half the lights.
Scope	Introduce a novel demand response (DR) lighting control technology that can be easily retrofit to existing buildings.

Continued . . .

Timeline	
Milestones & Publications	
Budget	
Other parties involved	NEV Electronics, Benya Lighting, Southern California Edison, Architectural Energy Corporation.
Next steps	
Associated R&D strategy	
References	California Energy Commission Public Interest Energy Research (PIER) Program Lighting California's Future Program, "CEDR," http://www.archenergy.com/lcf/integrated-projects/cedr.html, accessed Sep. 14, 2012. California Energy Commission Public Interest Energy Research Program, "Cost Effective Demand Response (CEEDR)," n.d., http://cltc.ucdavis.edu/images/case_studies/cedr.pdf, accessed Sep. 14, 2012.

Dual-Loop Photosensor Controls for Daylight Harvesting

Project Overview: Develop a dual loop photosensor control system for skylight applications.

http://cltc.ucdavis.edu/content/view/142/164/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Konstantinos Papamichael, Ph.D Co-Director 633 Pena Drive Davis, CA 95618 (530) 747-3834 (o) kpapamichael@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Improved control systems and sensors for daylighting technologies.
Technology Characteristics	Sensors & Control Systems.
Capability Gap(s)	Need to have applications easier to design, commission and operate. Need methods to compensate for daylight color shift, glare, intensity, focus. Need applications that can utilize natural light. Need responsive and reliable controls and photo sensors for daylighting.
Driver(s)	Increased consumer resistance to complex features and controls. Climate change. Energy security. End user comfort / satisfaction. Optimize work environment for using computers of the future-keep up as computers evolve. Optimize human performance (health, productivity). Aesthetics. Consumer desire to be "green" and reduce embedded & used energy. Increased interest among legislators in efficiency and renewable. Increase in available funding for EE.
Background	Photosensor control systems are electronic devices that sense light in a space and adjust electric light accordingly. Despite being commercially available for more than two decades, these systems have struggled to find widespread use and acceptance in interior environments. Ideally, the proper specification, installation, and commissioning of a photosensor control system result in energy savings and an appropriate light level for the task. However, problems with over- and underdimming often diminish reliability and energy savings.
Goals	Increase the reliability and effectiveness of daylighting control systems by improving their daylight-sensing capabilities in a cost-effective way
Scope	Develop a dual-loop photosensor control system for skylight applications
Timeline	
Milestones & Publications	

Continued . . .

University of California Davis
California Lighting Technology Center

Budget	
Other parties involved	WattStopper, Walmart, Sacramento Municipal Utility District, Southern California Edison, and San Diego Gas & Electric Company
Next steps	
Associated R&D strategy	CLTC worked with Walmart to develop a novel, reliable dual-loop system laboratory prototype and place it in the skylight well of a 150,000 ft Walmart store. The result is a system that can detect a true daylight change, automatically commission, provide a consistent light level, and save significant energy. A primary component of the system is a control algorithm that monitors the open-loop and closed loop photosensors and controls the electric light to provide the designed light level.
References	California Energy Commission's Public Interest Energy Research Program, "Tech Brief: Dual-Loop Photosensor Control System for Daylight Harvesting," n.d. (ca. 2010), http://cltc.ucdavis.edu/images/documents/case_studies/dual_loop_photosensor_case_study.pdf, accessed Sep. 14, 2012.

LED Replacement Lamp Testing

Project Overview: Laboratory testing of color brilliance, light color appearance and light color uniformity of LED replacement lamps.

http://cltc.ucdavis.edu/content/view/793/435/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Michael Siminovitch, Ph.D Directorf CLTC; Rosenfeld Chair in Energy Efficiency; Professor, Design Program mjsiminovitch@ucdavis.edu (530) 747-3834 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Measurement methods of lighting performance related to human factors and preferences.
Technology Characteristics	Measurement methods of lighting performance related to human factors.
Capability Gap(s)	Need better color rendering. Need more appealing color temperatures available.
Driver(s)	Optimize human performance (health, productivity. End user comfort / satisfaction. Aesthetics. Optimize work environment for using computers of the future-keep up as computers evolve.
Background	California utilities will roll out efficiency incentives for screw-based LED lamps in 2013. Promoting those LEDs that meet consumers' quality expectations in this way will help LEDs compete in the market, allow consumers to choose light sources that better meet their performance needs, and support the large-scale adoption of LEDs necessary to realize significant energy savings in California.
Goals	• Define screw-based LED lamp classifications • Identify commercially available LEDs for each classification • Select LED lamps for testing • Determine performance characteristics that contribute to consumer acceptance of LED lamps, including, but not limited to color brilliance, light color appearance, light uniformity, and dimmability • Design a test methodology for measuring LED performance in each performance area
Scope	Engage other organizations developing quality specifications and test methodologies for LEDs, including the U.S. ENERGY STAR program and the International Energy Agency (IEA).
Timeline	

Continued . . .

Milestones & Publications	
Budget	
Other parties involved	Collaborative Labeling and Appliance Standards Program (CLASP)
Next steps	CLTC will develop a final report describing the test methodology, data collected, and analysis of results, including key findings and recommendations with input from CLASP. The report will be completed by December 1, 2012.
Associated R&D strategy	CLTC will acquire and test each of the selected screw-based LED lamps. Results will be organized by lamp classification and will include laboratory test results and all available manufacturer product data. CLTC will analyze the test data and compare the results to draft performance requirements set forth by the California Energy Commission in a draft quality specification. This work will establish the actual performance of currently available LED screw-based lamps and determine whether the stringency of the draft specification will support or hinder the market adoption of LEDs in California. Test results for actual performance will also be compared to manufacturer statements of performance characteristics.
References	"Organic Light Emitting Diodes (OLEDs)," http://cltc.ucdavis.edu/content/view/793/435/, accessed Sep. 14, 2012.

Organic Light Emitting Diodes (OLEDs)

Project Overview: Investigate the effectiveness of OLEDs as a potential source of ambient lighting in the office.

http://cltc.ucdavis.edu/content/view/793/435/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Michael Siminovitch, Ph.D Directorf CLTC; Rosenfeld Chair in Energy Efficiency; Professor, Design Program mjsiminovitch@ucdavis.edu (530) 747-3834 (o)	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Measurement methods of lighting performance related to human factors and preferences.
Technology Characteristics	Measurement methods of lighting performance related to human factors.
Capability Gap(s)	Need better color rendering. Need more appealing color temperatures available.
Driver(s)	Optimize human performance (health, productivity. End user comfort / satisfaction. Aesthetics. Optimize work environment for using computers of the future-keep up as computers evolve.
Background	Organic Light Emitting Diodes (OLEDs) consist of layers of organic materials that are electroluminescent when a voltage is applied. OLEDs are increasingly popular choices for television and consumer electronic displays, but they eventually could become versatile tools for lighting designers. As OLEDs increase in efficiency and become more affordable, they could develop into an effective ambient light source. As a naturally diffuse emitter of light, they would provide a glare-free, quality light source.
Goals	Investigate the effectiveness of OLEDs as a potential source of ambient lighting in the office.
Scope	Assess the potential of this technology as a light source in an office environment.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	"Organic Light Emitting Diodes (OLEDs)," http://cltc.ucdavis.edu/content/view/793/435/, accessed Sep. 14, 2012.

Reliable Photo Sensing for Daylight Harvesting in Side-Lit Spaces

Project Overview: Developing reliable, accurate photosensor control systems to optimize daylight harvesting and energy efficiency by optimizing open-loop and closed-loop sensor positions.

http://cltc.ucdavis.edu/content/view/1060/451/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Konstantinos Papamichael, Ph.D Co-Director 633 Pena Drive, Davis, CA 95618 (530) 747-3834 (o) kpapamichael@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Improved control systems and sensors for daylighting technologies.
Technology Characteristics	Sensors & Control Systems.
Capability Gap(s)	Need to have applications easier to design, commission and operate. Need methods to compensate for daylight color shift, glare, intensity, focus. Need applications that can utilize natural light. Need responsive and reliable controls and photo sensors for daylighting.
Driver(s)	Increased consumer resistance to complex features and controls. Climate change. Energy security. End user comfort / satisfaction. Optimize work environment for using computers of the future-keep up as computers evolve. Optimize human performance (health, productivity). Aesthetics. Consumer desire to be "green" and reduce embedded & used energy. Increased interest among legislators in efficiency and renewable. Increase in available funding for EE.
Background	Photosensor control systems must consistently provide accurate daylight measurements in order to be most effective.
Goals	To develop a reliable photosensor-based lighting control system for residential and commercial buildings that can be used in side-lit applications.
Scope	This project expanded upon previous research in daylight harvesting and photosensor technology at UC Davis and CLTC. Researchers have conducted a series of tests of open-loop and closed-loop sensors to determine the most effective combinations of and positioning for photosensors.
Timeline	In progress.
Milestones & Publications	Research found that dual-sensor controls do provide daylight sensing for window applications more reliably than using open-loop or closed-loop sensors independently. Closed-loop photosensors performed best when configured on the ceiling, while open-loop sensors were most effective with only the window in its field of view and placed away from shading systems with low-resolution openness factors (such as Venetian blinds and louvers). Team is currently reviewing commercial prototypes to evaluate in field tests and demonstrations.

Continued . . .

Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	California Lighting Technology Center (2012). "Reliable Photo Sensing for Daylight Harvesting in Side-Lit Spaces." http://cltc.ucdavis.edu/content/view/1060/451/, accessed Jan. 20, 2012. Xu, Jingjing and Papamichael , Konstantinos (2011). "Reliable Photo Sensing for Daylight Harvesting in Side-Lit Spaces." Poster presentation. http://cltc.ucdavis.edu/images/documents/publications_reports/2011_cisbat_xu.pdf, accessed Jan. 20, 2012.

Smart Corridors and Stairwells

Project Overview: Field Demonstrations of adaptive lighting control systems.

http://cltc.ucdavis.edu/content/view/891/436/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Cori Jackson Program Director (530) 747-3843 (o) cmjackson@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Lighting Controls

Project Details

R&D Program	Advanced lighting control systems for retrofit applications
Technology Characteristics	Cheaper, simpler self-calibration. Minimal impact and maximal compatibility on existing infrastructure. Intuitive operation, ease of use and commissioning. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need interface with smart phones, tablets, etc. Need optimized/ideal luminaire control communication protocol. Need integration with building automation / management systems. Need for plug and forget controls that work without commissioning, tuning or user action. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need more reliable controls. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing.
Driver(s)	Optimize work environment for using computers of the future-keep up as computers evolve. Utility incentives for influencing designers, contractors, manufacturers. End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. Majority of energy efficiency potential is in retrofit applications. Cost of new technology. Aesthetics. Controllable; integrated with other entertainment, communication mobility. Interoperability. Controls that will allow demand response for lighting.
Background	Typical corridor lighting, installed in public spaces that require a minimum level of illumination for safety, usually operates 24 hours a day, 7 days a week. Due to the constant illumination requirements, these spaces, and other secondary spaces (like storage areas), constitute a large portion of California's commercial lighting energy use. The busiest corridors in commercial applications are vacant approximately 50% of the time. This means that most corridors are constantly lit at a high level that is necessary only when the space is occupied, creating an opportunity for significant energy savings when adaptive lighting solutions are implemented.
Goals	Develop occupancy-based adaptive control lighting by combining commercially based components . Demonstrate how a variety of commercially available, adaptive lighting solutions effectively reduce energy use in retrofit applications.
Scope	Field Demonstrations of adaptive lighting control systems

Continued . . .

Timeline	
Milestones & Publications	Milestones • A CLTC study at UC Davis found areas with no occupant ownership (e.g., corridors, bathrooms, storage areas) represent a significant DR and energy-saving opportunity. Many stairwells and corridors are illuminated continuously regardless of occupancy or activity requirements. • California utilities recognize this innovative approach to demand response. Southern California Edison, the Sacramento Municipal Utility District, and San Diego Gas & Electric Co. have awarded CLTC funds to explore the potential energy savings and peak demand reduction in commercial corridor spaces. • CLTC has engaged multiple industry partners on development and demonstration tasks of a next-generation corridor lighting system with advanced controls. • Proof-of-concept systems have been designed and demonstrated at CLTC, in partnership with Adura Technologies, LED Era, and Lithonia Lighting. • The demonstration phase will be used as a platform to build momentum toward a bi-level corridor statewide initiative, in the same model as the successful bi-level exterior statewide initiative. • The initiative will feed utility rebate and incentive programs for Smart Interior Lighting in secondary commercial spaces.
Budget	
Other parties involved	California Energy Commission's Public Energy Research Program (PIER), Adura Technologies, Lamar Lighting, Sensor Switch, Sylvania, and WattStopper
Next steps	
Associated R&D strategy	
References	California Energy Commission's Public Interest Energy Research Program "Case Study: Adaptive Corridors, University of California, Davis," n.d., http://cltc.ucdavis.edu/images/documents/case_studies/pier_adaptive_corridors_ucd.pdf, accessed Sep. 14, 2012.

Smart Windows and Skylights

Project Overview: Developing next-generation fenestration systems that incorporate automated operable systems, interior and exterior sensors, and integrated electronics to increase energy efficiency and enhance comfort using intelligent window and skylight shading and ventilation control.

http://cltc.ucdavis.edu/content/view/803/434/

Institution	University of California Davis	**Div. / Dept.**	California Lighting Technology Center
Contact	Konstantinos Papamichael, Ph.D Co-Director 633 Pena Drive Davis, CA 95618 (530) 747-3834 (o) kpapamichael@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Building core daylighting.
Technology Characteristics	Daylighting Systems.
Capability Gap(s)	Need to have applications easier to design, commission and operate. Need affordable, widely available daylighting options.
Driver(s)	People like cool, new technologies. Consumer desire to be "green" and reduce embedded & used energy. Increasing and uncertain future cost of electricity and gas. End user comfort / satisfaction. Energy security. Climate change. Optimize human performance (health, productivity). Optimize work environment for using computers of the futurekeep up as computers evolve. Increased consumer resistance to complex features and controls.
Background	Technologies that improve both automated and user-controlled operation of windows and skylights offer significant opportunities to improve both user comfort and energy efficiency.
Goals	To develop cost-effective smart fenestration technologies for residential and commercial applications that can feasibly be brought to market.
Scope	Pursue integrated window and skylight shading and ventilation technologies that will allow for automated control to regulate heat gain, daylighting, and ventilation; to maximized user control and comfort; and to improve efficiency using automated dynamic control systems.
Timeline	In progress.
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	California Lighting Technology Center (2012). "Smart Windows and Skylights." http://cltc.ucdavis.edu/content/view/803/434/, accessed Jan. 20, 2012.

University of California Davis	One Shields Ave. Davis, CA 95616	(530) 752-1011 (o)
	http://www.ucdavis.edu/index.html	
Mission	One of ten campuses in the University of California system.	

Western Cooling Efficiency Center

	Mark Modera, Director 1450 Drew Avenue, Suite 100 Davis, California 95618 http://wcec.ucdavis.edu/	(530) 754-7671 (o) (530) 754-7672 (f) mpmodera-at-ucdavis.edu
Mission	Conducting research and development into technologies that will lead to the application of innovative systems and programs that will reduce electrical demand and water consumption for cooling systems throughout the western United States. Established in 2007 in conjunction with the UC Davis Energy Efficiency Center (http://eec.ucdavis.edu/). The twelve-member Steering Committee includes representatives from the major California electric utilities, the California Energy Commission (http://www.energy.ca.gov/), the UC Davis Energy Efficiency Center, the U.S. National Renewable Energy Laboratory (http://www.nrel.gov/), major retailers, and the New Buildings Institute (http://newbuildings.org/).	
Fault Detection and Diagnostics: The Path to Commercial-ization	Contribute to efforts to speed introduction of advanced Automated Fault Detection and Diagnostics (AFDD) systems for rooftop HVAC units by developing technologies, integrating findings into building codes and equipment standards, and working with industry to develop strategic plans.	
	• Fault Detection and Diagnostics: The Path to Commercialization	Page 261
Multi-Tenant Light Commercial (MTLC) Retrofit	Energy efficiency improvements while maintaining indoor air quality of ventilation systems in multifamily buildings	
	• Multi-Tenant Light Commercial (MTLC) Retrofit	Page 263
Multifamily Ventilation	Energy efficiency improvements while maintaining indoor air quality of ventilation systems in multifamily buildings.	
	• Multifamily Ventilation	Page 265

Continued . . .

RTU Retrofit Initiative	Improved energy efficiency and peak energy demand of RTUs through retrofit.
	• RTU Retrofit Initiative Page 267
Swimming Pools as Heat Sinks for Air Conditioners	Use of swimming pools as heat sinks for air conditioners.
	• Swimming Pools as Heat Sinks for Air Conditioners Page 268
Western Cooling Challenge	Platform to encourage manufacturers to develop climate appropriate rooftop packaged air conditioning equipment that will reduce electrical demand and energy use in Western climates by at least 40% compared to DOE 2010 standards.
	• Western Cooling Challenge Page 269

[Return to Table of Contents

Fault Detection and Diagnostics: The Path to Commercialization

Project Overview: Contribute to efforts to speed introduction of advanced Automated Fault Detection and Diagnostics (AFDD) systems for rooftop HVAC units by developing technologies, integrating findings into building codes and equipment standards, and working with industry to develop strategic plans.

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact	Dr. Kristin Heinemeier (530) 754-7667 (o) kheinemeier@ucdavis.edu	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Fault Detection, Predictive Maintenance and Controls

Project Details

R&D Program	Research to reduce maintenance.
Technology Characteristics	Predictive Maintenance. User notification of system status.
Capability Gap(s)	Need to have "onboard" diagnostics or data streams to collect. Need to eliminate failure modes by design simplification of systems.
Driver(s)	Integration of info, communication & entertainment devices. Reduced HVAC loads in buildings / lack properly sized equipment options. Consumer demand for reduced / low cost of utilities / operation. Diffusion of common communication protocols into energy-consuming devices.
Background	Automated Fault Detection and Diagnostics (AFDD) systems use hardware, sensors, and software to detect and diagnose problems with rooftop HVAC units (RTUs). AFDD technology research has developed incrementally over the decades and currently shows more promise than ever in the goal to achieve Net Zero Energy buildings by 2030.
Goals	Continue to refine AFDD RTU systems; apply data from research and testing to revise codes and industry standards; work with subject matter experts to develop strategic research plans to spur AFDD development.
Scope	WCEC research includes developing proposal to change California's Title 24 Building Code to incorporate a prescriptive requirement for AFDD systems; once adopted, original equipment manufacturers would begin to include advanced AFDD systems into their RTUs. The WCEC also seeks to develop an ASHRAE Standard Method of Test for AFDD that will standardize AFDD technology in the marketplace. The WCEC has partnered with Southern California Edison to form a committee of industry representatives that will develop an AFDD technology development roadmap to help direct strategic planning.
Timeline	

Continued . . .

Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	Research is part of California's Long-Term Energy Efficiency Strategic Plan to develop climate-optimized HVAC equipment as part of the state's efforts to achieve Net Zero Energy commercial buildings by 2030.
References	Western Cooling Efficiency Center (2012). "Research Brief: Fault Detection and Diagnostics: The Path to Commercialization." http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_FaultDetectionAndDiagnostics.pdf, accessed Jan. 24, 2012.

[Return to Table of Contents

Multi-Tenant Light Commercial (MTLC) Retrofit

Project Overview: Energy efficiency improvements while maintaining indoor air quality of ventilation systems in multifamily buildings

http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_Multi-tenantVentilation.pdf

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact	John Markley Associate Development Engineer jamarkley@ucdavis.edu (530) 752-2525	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization
Product / Service Area	Lighting	**Roadmap**	General Lighting

Project Details

R&D Program	Reduce energy demands without degrading indoor air quality.
Technology Characteristics	Technologies to reduce heating and cooling loads without negatively affecting indoor air quality. Need to optimize use of ambient or indoor conditions.
Capability Gap(s)	Need to optimize use of ambient or indoor conditions.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. . IAQ separate ventilation from HVAC loads / Equipment.
R&D Program	**Advanced lighting control systems for new and retrofit applications.**
Technology Characteristics	Cheaper, simpler self-calibration. Minimal impact and maximal compatibility on existing infrastructure. Intuitive operation, ease of use and commissioning. Reliable, ongoing occupancy sensing.
Capability Gap(s)	Need interface with smart phones, tablets, etc. Need optimized/ideal luminaire control communication protocol. Need integration with building automation / management systems. Need for plug and forget controls that work without commissioning, tuning or user action. Need to improve capability of controls to work with a diversified product range. Need controls and sensors that are flexible for retrofit and with existing wiring and switches. Need more reliable controls. Need to balance energy efficiency features with reliability, low cost, ease of use. Need exterior sensors that function with existing pole spacing.
Driver(s)	Optimize work environment for using computers of the future-keep up as computers evolve. Utility incentives for influencing designers, contractors, manufacturers. End user comfort / satisfaction. Need for professionals to be credible and deliver systems that work and avoid callbacks. Majority of energy efficiency potential is in retrofit applications. Cost of new technology. Aesthetics. Controllable; integrated with other entertainment, communication mobility. Interoperability. Controls that will allow demand response for lighting.

Continued . . .

Background	In order to meet California's aggressive goals for increasing energy efficiency, reducing peak demand, and decreasing green house gas emissions a wide-scale deployment of whole-building energy efficiency retrofits will be required.
Goals	(1) Decrease cooling energy consumption and peak electricity demand in existing MLTC facilities by 30-50%. (2) Reduce connected load of HVAC equipment in existing MLTC buildings to match reductions in cooling loads from the envelope, lighting, and controls retrofits and capacity improvements provided by RTU retrofits. (3) Develop integrated technology packages that address lighting, envelope, HVAC, and controls suitable for cost-effective retrofits in the MLTC market. (4) Demonstrate energy consumption in MTLC can be cost-effectively reduced by at least 30% through deployment of energy-efficiency retrofit packages.
Scope	Develop technological and market-based approaches that will increase deployment of energy-efficient technologies and reduce peak demand for existing MTLC buildings through (1) developing cost-effective, commercially viable, whole-building, integrated technology and (2) financing solutions that address building envelop, lighting (interior and exterior), and heating ventilation air conditioning (HVAC) including integrated controls.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Western Cooling Efficiency Center, "Reserch Brief: Multifamily Ventilation," n.d., http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_Multi-tenantVentilation.pdf, accessed Sep. 14, 2012., http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_Multi-tenantVentilation.pdf

[Return to Table of Contents

Multifamily Ventilation

Project Overview: Energy efficiency improvements while maintaining indoor air quality of ventilation systems in multifamily buildings.

http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_Multi-tenantVentilation.pdf

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact	John Markley Associate Development Engineer jamarkley@ucdavis.edu (530) 752-2525	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heat Recovery and Economizer Optimization

Project Details

R&D Program	Reduce energy demands without degrading indoor air quality.
Technology Characteristics	Technologies to reduce heating and cooling loads without negatively affecting indoor air quality. Need to optimize use of ambient or indoor conditions.
Capability Gap(s)	Need to optimize use of ambient or indoor conditions.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation. . IAQ separate ventilation from HVAC loads / Equipment.
Background	Excess ventilation leads to increased energy consumption in the form of higher than necessary fan energy as well as an increased heating and cooling load. Under ventilation results in unacceptable indoor air quality. There are also discrepancies between current ventilation strategies employed in low-rise and high-rise multifamily residential buildings within the applicable codes and standards, including the Title-24 Residential Energy Standards.
Goals	(1) Evaluate ventilation system performance in multifamily buildings. (2) Provide cost effective solutions that provide cost-effective solutions that improve efficiency in multifamily ventilation while maintaining appropriate indoor air quality. (3) To address ventilation building codes in multifamily buildings. (4) Improve ventilation assessment and analysis methods in multifamily buildings.
Scope	Investigate current heating, ventilation, and cooling systems (along with their current construction methods) in multifamily buildings. Model, simulate, and measure ventilation performance of several multifamily buildings. Implement improved design strategies and solutions to demonstrate increased performance.
Timeline	

Continued . . .

Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Western Cooling Efficiency Center, "Reserach Brief: Multifamily Ventilation," n.d., http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_Multi-tenantVentilation.pdf, accessed Sep. 14, 2012.

[Return to Table of Contents

RTU Retrofit Initiative

Project Overview: Improved energy efficiency and peak energy demand of RTUs through retrofit

http://uccs.ucdavis.edu/assets/event-assets/event-presentations/modra-presentation

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact		**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	Development of RTU testing protocols for systems performance maps.
Technology Characteristics	Rooftop unit performance test protocols.
Capability Gap(s)	Need reliable and effective economizer systems & controls (i.e., seals, actuators, dampers). Need functional performance test definition for factory testing. Need predictable, enforceable rooftop unit efficiency standards to enable maximum savings.
Driver(s)	Validation of performance of new HVAC technologies through utility field test. Need to understand where energy savings can be achieved and demonstrate actual.
Background	Lack of standards of performance of RTU systems. RTU lifespan (15-20 years) causing limited opportunities to implement more energy efficient systems. Significant savings can be achieved through an RTU retrofit program.
Goals	(1) Develop test protocol and analysis method for impacts of evaporative pre-coolers for RTUs. (2) Analyze fan operation patterns and quantify potential impacts of efficient fans/motors as RTU retrofit technologies.
Scope	Improve energy efficiency and reduce peak energy demand of RTUs through retrofits.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	Currently presenting test protocols to test evaporative pre-coolers for RTUs to ASHRAE.
Associated R&D strategy	
References	Mark Modera, "Reducing Peak Electricty Demand and Energy Use Due to Cooling," April 19, 2012, http://uccs.ucdavis.edu/assets/event-assets/event-presentations/modra-presentation, accessed Sep. 14, 2012.

Swimming Pools as Heat Sinks for Air Conditioners

Western Cooling Efficiency Center (WCEC) at UC Davis

Project Overview: Use of swimming pools as heat sinks for air conditioners

http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_SwimmingPoolsAsHeatSinks.pdf

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact	Curtis Harrington Assistant Development Engineer csharrington@ucdavis.edu (530) 754-7670	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Modeling, Lab, and Field Testing

Project Details

R&D Program	Alternative heat sinks to improve air conditioning energy efficiency.
Technology Characteristics	Advance testing and modeling for new HVAC technologies.
Capability Gap(s)	Need to define performance parameters of new HVAC technologies. EVAP cool, VRF, zonal controls, desiccant cooling. Current energy modeling engines under development by DOE (energy +) do not have wide market adoption because perceived to be too detailed, too difficult to use - and hence to expensive to use. Tools for accelerating inputs, and accelerating computation time (2 minutes or less) are needed.
Driver(s)	Validation of performance of new HVAC technologies through utility field test. Need to understand where energy savings can be achieved and demonstrate actual.
Background	In California, where electric utilities experience their peak power demand in the summer, space cooling accounts for 29% of total peak power demand and approximately 40% of residential peak demand. This occurs in part because the COP for traditional air-cooled vapor-compression cooling equipment diminishes significantly at high outdoor temperatures, such that equipment efficiency can be at its worst when cooling demand is greatest.
Goals	(1) Develop modeling tools to accurately predict pool temperature response given mechanical thermal loading. (2) Develop guidelines for the most appropriate applications of pool-coupled heat pumps. (3) Provide industry & utilities with energy savings predictions & recommendations for cost effective systems.
Scope	To reject condenser heat to a swimming pool as opposed to ambient air in order to significantly improve efficiency of vapor compression air conditioning.
Timeline	
Milestones & Publications	"Swimming Pools as heat sinks for air conditioners: Model design and experimental validation for natural thermal behavior of the pool" Building and Environment Magazine, January 2011 Issues, pgs 187-195
Budget	
Other parties involved	Germania Pools (www.geremiapools.com)
Next steps	
Associated R&D strategy	
References	Western Cooling Efficiency Center, "Research Brief: Swimming Pools as Heat Sinks for Air Conditioners," n.d., http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/RB_SwimmingPoolsAsHeatSinks.pdf, accessed Sep. 14, 2012.

[Return to Table of Contents

Western Cooling Challenge

Project Overview: Platform to encourage manufacturers to develop climate appropriate rooftop packaged air conditioning equipment that will reduce electrical demand and energy use in Western climates by at least 40% compared to DOE 2010 standards.

http://wcec.ucdavis.edu/programs/western-cooling-challenge/motivation/

Institution	University of California Davis	**Div. / Dept.**	Western Cooling Efficiency Center
Contact	Jonathan Woolley Associate Engineer jmwooley@ucdavis.edu (530) 752-1101	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning (HVAC)	**Roadmap**	Heating & Cooling Production and Delivery

Project Details

R&D Program	More information about energy use; improve controls.
Technology Characteristics	Variable refrigerant flow systems and controls. Need to downscale what is currently available on big chillers for smaller units and integrate with maintenance systems. Drop-in replacement condensing unit with variable speed compressor.
Capability Gap(s)	Increase design capability to handle zonal and radiant heating & cooling delivery. Need the equivalent of ASHRAE Manual chapter on variable refrigerant flow design, control, and energy savings optimization. Variable refrigerant flow energy savings potential and control optimization not well understood. Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies.
Driver(s)	Consumer demand for reduced / low cost of utilities / operation
Background	According to the California Energy Commission California Commercial End-Use Survey (CEUS), roughly 65% of commercial floor area is cooled by packaged rooftop units, while more than 80% of the individually connected air conditioning systems fall in this category. There are broad opportunities for efficiency improvements with this type of system, especially in hot and arid climates of the Western United States where appropriate application of evaporative cooling in conjunction with other efficient design strategies can improve system efficiency by more than 50%.
Goals	(1) Address need for cooling in commercial buildings. (2) Foster innovation and application of climate controlled technologies (3) Advance market introduction of reliable efficiency solutions.
Scope	A multiple winner competition that encourages HVAC manufacturers to develop climate-appropriate rooftop packaged air conditioning equipment that will reduce electrical demand and energy use in Western climates by at least 40% compared to DOE 2010 standards.
Timeline	
Milestones & Publications	Search “western cooling challenge” at http://wcec.ucdavis.edu/resources/literature/.
Budget	
Other parties involved	Manufacturers providing Western Cooling Challenge Certified Equipment: Coolerado Corporation. Manufacturers developing Western Cooling Challenge Certified Equipment: Speakman Cooling Solutions, Trane Corporation
Next steps	WCEC/NREL/LBNL producing Performance Maps and Energy-Plus model for hybrid systems. Field demonstrations all around California (Along w/ SCE and PG&E.)
Associated R&D strategy	
References	Western Cooling Efficiency Center, "UC Davis Western Cooling Challenge Program Requirements," n.d., http://wcec.ucdavis.edu/sandbox/search/ResearchBriefsPDF/WCC%20Program%20Requirements.pdf, accessed Sep. 14, 2012.

[Return to Table of Contents

University of California San Diego

9500 Gilman Dr., (858) 534-2230 (o)
La Jolla, CA 92093

http://www.ucsd.edu/

Mission	Provides advanced education and research at the undergraduate, graduate, professional and postdoctoral levels, and offers venue for community engagement, public service and industry partnerships to facilitate advances in science, technology, and other areas.

Computer Science and Engineering Department

Dr. Rajesh K. Gupta (858) 822-4391 (o)
Professor and Qualcomm Endowed Chair rgupta@ucsd.edu
EBU3B Room 2120, 9500 Gilman Drive
La Jolla, CA 92093-0404

http://www-cse.ucsd.edu/

Mission	Provides undergraduate and graduate computer science and engineering education and research in such areas as Internet technologies, wireless communications, biotechnology, and computer industries.

Microelectronic Embedded Systems Laboratory Page 272

- SleepServer

University of California San Diego

Microelectronic Embedded Systems Laboratory

Dr. Rajesh K. Gupta
Professor and Qualcomm Endowed Chair
EBU3B Room 2120, 9500 Gilman Drive
La Jolla, CA 92093-0404

http://mesl.ucsd.edu/

(858) 822-4391 (o)
rgupta@ucsd.edu

Research Focus	Within the Computer Science and Engineering Department, the MESL research includes improving energy efficiency in a variety of electronic systems and components including radios, processors, computer networks, and building-scale technologies.
SleepServer	Research to commercialize software that allows PCs to maintain network presence and availability in low-power sleep modes to help reduce PC energy use 60 percent on average.

- SleepServer Page 273

SleepServer

Microelectronic Embedded Systems Laboratory

Project Overview: Research to commercialize software that allows PCs to maintain network presence and availability in low-power sleep modes to help reduce PC energy use 60 percent on average.

http://mesl.ucsd.edu/yuvraj/research/sleepserver.html#people

Institution	University of California San Diego	**Div. / Dept.**	Computer Science and Engineering Department
Contact	Dr. Yuvraj Agarwal Director of Systems Networking and Energy Efficiency – Synergy Labs @ UCSD CSE, Room 2116 University of California, San Diego 9500 Gilman Drive, La Jolla, CA 92093-0404 (858) 633-8485 (o) (858) 534-7029 (f) yuvraj@cs.ucsd.edu	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Power Management Control and Communication

Project Details

R&D Program	Network management for computer network administrators.
Technology Characteristics	Software compatibility with standby modes. Sleep mode more responsive to late-night network updates.
Capability Gap(s)	Need to optimize sleep mode energy impacts without degrading user experience. Need to require minimal user interaction.
Driver(s)	Consumer desire for comfort and aesthetics.
Background	Buildings, generally, are the leading consumers of energy in the U.S., and the energy loads of information technologies are a significant part of overall building energy use. Personal computers have long had sleep modes, but this feature is not convenient to many users, particularly because network connectivity requires that computers not enter in to their sleep modes.
Goals	To create a scalable, reliable, and secure software-based solution to deliver significant energy efficiency savings, and enhance the solution with a user-friendly interface and functionality in a variety of operating systems.
Scope	When operator attempts to connect remotely to their computer system, SleepServer wakes the physical PC seamlessly, thereby enabling the connection without the need for the PC to be on for the entire night or weekend. Agarwal and the project team are applying a $50,000 grant awarded in June 2010 to refine the SleepServer code to enable it to function in various operating systems, to scale it for thousands of host computers, improve security and fault tolerance, and enhance the user interface.
Timeline	

Continued . . .

University of California San Diego

Milestones & Publications	More than fifty PCs in the UCSD computer science building were running *SleepServer* as of Feb. 2012. In June 2010, the San Diego Clean Tech Innovation and Commercialization Program awarded the SleepServer research team a $50,000 grant for proof-of-concept studies, prototype development, and commercialization. (http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=956). Evaluations in September 2009 showed that energy consumption for PCs running *SleepServer* decreased from 27 to 86 percent—and averaged 60 percent—compared to 24/7 operation.
Budget	$50,000 grant from the San Diego Clean Tech Innovation and Commercialization Program, awarded June 2010.
Other parties involved	Rajesh Gupta (http://mesl.ucsd.edu/gupta/); Stefan Savage (http://cseweb.ucsd.edu/~savage/); Thomas Weng.
Next steps	Work continues on proof-of-concept studies, prototype development, and commercialization. Currently looking to deploy SleepServer in a limited setting across several buildings at UCSD.Over the next few months, will look for a few other test sites, outside of UCSD, to test and deploy SleepServer.''
Associated R&D strategy	The SleepServer project is within a larger Smart Building project at UCSD.
References	U.C. San Diego School of Engineering (2010, June 14). "San Diego CleanTech Innovators Get Boost Through Public-Private Grant Program." http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=956, accessed Feb. 10, 2012. Agarwal, Yuvraj, Savage, Stefan, and Gupta , Rajesh (2010, June). "SleepServer: A Software-Only Approach for Reducing the Energy Consumption of PCs within Enterprise Environments." *Proceedings of the USENIX Annual Technical Conference* (*USENIX ATC '10*). http://mesl.ucsd.edu/yuvraj/research/documents/Agarwal-Usenix10-SleepServers.pdf, accessed Feb. 10, 2012. Agarwal, Yuvraj, (2012). "SleepServer: A Software-Only Approach A Software-Only Approach for Reducing the Energy Consumption of PCs within Enterprise Environments." http://mesl.ucsd.edu/yuvraj/research/sleepserver.html#people, accessed Feb. 10, 2012.

University of California Santa Barbara (UCSB)

Santa Barbara, CA 93106

(805) 893-8000 (o)

http://www.ia.ucsb.edu/util/contact.aspx

http://www.ucsb.edu/

Mission	Institution within the University of California system that hosts the Institute for Energy Efficiency.

Institute for Energy Efficiency

UC Santa Barbara
Santa Barbara CA 93106-5160

(805) 893-4191 (o)
(805) 893-7119 (f)
information@iee.ucsb.edu

http://iee.ucsb.edu/

Mission

Research and development to spur advancements in energy production, use, and management. Efforts focused on critical energy issues are organized within six Solutions Groups and a variety of programs and initiatives outside of these core groups.

Solutions Groups currently conducting research in areas directly relevant to the Northwest Energy Efficiency Technology Roadmap Portfolio include the following:

Buildings & Design Solutions Group Page 276

- Economically viable Zero Net Energy building systems

Lighting Solutions Group Page 278

- Solid State Lighting

University of California Santa Barbara

Buildings & Design Solutions Group

Igor Mezic
Solutions Group Head
(805) 893-7603 (o)
mezic@engineering.ucsb.edu

http://iee.ucsb.edu/research/building-systems

Research Focus	This Solutions Group pursues research and development make buildings and building systems more energy efficient, including energy harvesting, data center efficiency, and smart buildings / integrated building systems, among others.
Economically viable Zero Net Energy building systems	Applying Dynamics of Energy Efficiency principles to optimize existing hardware systems and software tools for both new construction and building retrofits.

Economically viable Zero Net Energy building systems

Buildings & Design Solutions Group

Project Overview: Applying Dynamics of Energy Efficiency principles to optimize existing hardware systems and software tools for both new construction and building retrofits.

http://iee.ucsb.edu/research/building-systems

Institution	University of California Santa Barbara	**Div. / Dept.**	Institute for Energy Efficiency
Contact	Igor Mezic Solutions Group Head (805) 893-7603 (o) mezic@engineering.ucsb.edu	**Sponsor(s)**	
Product / Service Area	Building Design/Envelope	**Roadmap**	Zero Net Energy Buildings

Project Details

R&D Program	Predictive modeling for control.
Technology Characteristics	Design & analysis tools to integrate components and predict whole-system energy performance. New analytical tools, e.g., finite element analysis.
Capability Gap(s)	Need of ZNE design practices. Need easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on multitude scales.
Driver(s)	Personal energy independence / interest. Opportunity for large framework change. Increasing and uncertain future cost of electricity and gas. Policy / codes including environmental.
Background	Of the 40% of all the energy that buildings consume in the U.S., most of it is wasted. Energy efficiency measures for both residential and commercial buildings have great potential for delivering significant returns.
Goals	To enhance existing hardware and modeling tools and increase energy efficiency savings.
Scope	Integrated Building Systems to include active control of indoor airflows to improve ventilation and increase the efficiency of heating and cooling systems; integrated "smart" technologies including sensors and control systems to adjust lighting and HVAC units; enhance controls by developing dynamic models.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	This research project involves various entities, including colleagues in Hong Kong, the Lawrence Berkeley Laboratory (http://www.lbl.gov/), and United Technologies Corporation (http://www.utc.com/Home).
Next steps	
Associated R&D strategy	
References	Institute for Energy Efficiency (2012). "Buildings & Design Solutions Group: Projects." http://iee.ucsb.edu/research/buildings-design/projects, accessed Jan. 24, 2012. Institute for Energy Efficiency (2012). "Buildings & Design Solutions Group: Grand Challenge." http://iee.ucsb.edu/research/building-systems, accessed Jan. 24, 2012.

Lighting Solutions Group

Steven DenBaars
Solutions Group Head
(805) 893-8511 (o)
denbaars@engineering.ucsb.edu

http://iee.ucsb.edu/research/lighting-displays

Research Focus	Providing applied research and development in lighting and display solutions to improve energy efficiency.
Solid State Lighting	Improve the efficiency of the Group's recently-developed 150 lumen/watt light-emitting diode (LED) white light and ensure scalability of the resulting technology in order to spur commercialization of this product.

- Solid State Lighting Page 279

Solid State Lighting

Lighting Solutions Group

Project Overview: Improve the efficiency of the Group's recently-developed 150 lumen/watt light-emitting diode (LED) white light and ensure scalability of the resulting technology in order to spur commercialization of this product.

http://iee.ucsb.edu/research/lighting-displays

Institution	University of California Santa Barbara	**Div. / Dept.**	Institute for Energy Efficiency
Contact	Steven DenBaars Solutions Group Head (805) 893-8511 (o) denbaars@engineering.ucsb.edu	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Improved light extraction.
Technology Characteristics	Thermoelectric generation mounted on LED driver chip to reduce power requirements and waste heat output.
Capability Gap(s)	Need to increase energy efficiency.
Driver(s)	Utilities are mandated to produce more energy with renewable sources and energy-efficiency measures. Energy-efficiency measures can reduce the impact of increasing energy costs.
Background	Light-emitting diodes (LEDs) are already significantly more efficient than incandescent and fluorescent lights—LEDs top 50% efficiency and have the potential to reach 80%.
Goals	Team has developed a 150 lumen/watt LED white light source, and is working to make the LED even more efficient and ensure that this technology can be scaled-up for mass production. The goal is to enable a $1 LED Bulb that is 20 times more efficienct than an incandescent bulb. Increase the luminous efficiacy of LEDs to 200 lm/watt by icreasing light extraction, and improve current and thermal droop.
Scope	
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Institute for Energy Efficiency (2012). "Lighting Solutions Group: Grand Challenge." http://iee.ucsb.edu/research/lighting-displays, accessed Jan. 24, 2012. Institute for Energy Efficiency (2012). "Lighting Solutions Group: Projects." http://iee.ucsb.edu/research/lighting/projects, accessed Jan. 24, 2012.

U.S. Department of Energy (DOE)

U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

http://energy.gov/

202-586-5000 (main switchboard)
202-586-4403 (f)

Mission	The U.S. Department of Energy (DOE) helps ensure the security and prosperity of the United States by administering the nation's energy policies and standards and by fostering research, development, and deployment of energy systems and technologies.

Office of Energy Efficiency & Renewable Energy

Office of the Assistant Secretary
Energy Efficiency and Renewable Energy
Mail Stop EE-1
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

http://www.eere.energy.gov/

202-586-5000 (main switchboard)
202-586-4403 (f)

Email:
https://www1.eere.energy.gov/informationcenter/email.html

Mission	The DOE's Office of Energy Efficiency & Renewable Energy (EERE) works with private sector organizations, state and local government agencies, national laboratories, and universities to foster the research and development of technologies and best practices that foster energy efficiency measures and increased use of alternative energy sources.

Building Technologies Program (BTP) Page 282

- Appliances R&D
- Building Envelope R&D
- Indoor Air Quality R&D
- Lighting R&D
- Water Heating R&D
- Whole Building Design R&D

SunShot Initiative Page 285

Building Technologies Program (BTP)

U.S. Department of Energy
Building Technologies Program (BTP)
Mail Stop EE-2J
1000 Independence Ave, SW
Washington, DC 20585

(202) 586-9127
Email: http://www1.eere.energy.gov/buildings/contacts.html

http://www1.eere.energy.gov/buildings/

Research Focus	The Building Technologies Program works to make new and existing commercial and residential buildings more energy efficient, productive, and affordable by developing components, modeling tools, energy codes, and appliance standards. There are six constituent programs within the BTP: Appliances; Building Envelope; Indoor Air Quality; Lighting; Water Heating; and Whole Building Design.
Appliances R&D	http://www1.eere.energy.gov/buildings/appliances_rd.html Supports research and development of energy-efficient appliances including refrigerators, and clothes washers and dryers. Works with industry to foster the deployment of energy-efficient appliances, appliance integration, and appliance controls.
Building Envelope R&D	http://www1.eere.energy.gov/buildings/envelope_rd.html Help propel research in the full range of building envelope systems and materials (roof / wall / foundation, materials / envelop systems, and windows / doors); collaborate with private industry (through Cooperative Research and Development Agreements (CRADAs) and User Agreements) to develop more energy-efficient systems; serve as an online repository of proven technologies and ongoing research & development. Research and develop improved envelope materials and new software tools to measure and monitor materials performance; transfer technical information to industry, governmental agencies, and standards-setting organizations.

Continued . . .

Indoor Air Quality R&D	http://www1.eere.energy.gov/buildings/indoor_air.html Developing new ventilation strategies that improve indoor air quality while at the same time reducing the negative energy effects of increased ventilation. This program has three primary goals: ▪ Reducing the energy demands of ventilation systems while maintaining or improving indoor air quality; ▪ Revising and improving standards and building codes related to ventilation; and ▪ Developing and promulgating building practices to spur energy efficiency without degrading indoor air quality. Specifically within the realm of technology R&D, these goals are achieved through the following areas of research: • **Novel Ventilation Strategies:** Conduct research into hybrid ventilation, task ventilation, and demand control ventilation; • **Improving Ventilation in Residential and Commercial Buildings:** Research to improve airflow and ventilation measurement in commercial and residential buildings; enhancing filter efficiency; and investigating ultra-violet radiation and photocatalytic oxidation techniques to clean air; and • **Impacts on Energy Efficiency, Health, and Productivity:** Research seeking to develop an economic model incorporating the values of ventilation, health, and productivity to help in the design of optimized ventilation systems.
Lighting R&D	http://www1.eere.energy.gov/buildings/lighting.html Collaborate with manufacturers and other research and development institutions to devise technologies and best practices for advanced, energy efficient lighting systems. DOE's Lighting R&D program involves several lighting programs and studies to meet the nation's near-term and long-term needs: • **Solid State Lighting:** DOE's solid-state lighting portfolio activities target improvements in the efficiency, performance, lifetime, and quality of light from both organic and inorganic light emitting diodes (http://www1.eere.energy.gov/buildings/ssl/). • **Spectrally Enhanced Lighting:** Conduct studies on spectrally enhanced lighting which is a simple strategy that uses existing products and technology to significantly reduce energy use in commercial buildings (http://www1.eere.energy.gov/buildings/spectrally_enhanced.html). • **Commercial Building Energy Alliance:** Commercial Building Energy Alliances bring together building owners, managers, and operators from a variety of business sectors to minimize the energy use and environmental impact of commercial buildings (http://www1.eere.energy.gov/buildings/alliances/). • **Commercial Building Partnerships:** Companies and organizations are selected to work with DOE and its national laboratories on specific retrofit and new-construction building projects (http://www1.eere.energy.gov/buildings/commercial_initiative/building_partnerships.html). • **Commercial Lighting Solutions:** An interactive Web tool to help commercial building owners improve their lighting efficiency with a combination of commercially available but underused technologies, lighting controls, expert lighting design, and integrated systems (https://www.lightingsolutions.energy.gov/comlighting/login.htm).

Continued . . .

Water Heating R&D

http://www1.eere.energy.gov/buildings/water_heating.html

Research to improve the efficiency of water heating technologies. Current projects involve R&D in two primary areas:

- **"Drop-in" residential heat pump water heater:** Cooperate with private industry and the Oak Ridge National Laboratory to devlop and test a heat pump water heater to overcome long payback times, low perceived reliability, and the need for specialized installation and service of this technology.
- **Utility Solar Water Heating Initiative:** The Utility Solar Water Heating Initiative (USH_2O) coalition brings together utilities and private firms to increase the use of solar thermal technologies on a large scale.

Whole Building Design R&D

http://www1.eere.energy.gov/buildings/whole_building.html

The DOE's Building and Technologies Program's efforts in the area of whole building design focuses on a systems approach to energy efficiency. R&D projects include:

- **Advanced Controls:** Optimizing building operation and improving building energy performance by developing research and development plans for advanced control technologies for building applications (http://www1.eere.energy.gov/buildings/advanced_rd.html).
    - **Wireless Controls:** Collaborating with Pacific Northwest National Laboratory, Southern California Edison, Hines GS Properties, Inc., Inovonics Wireless Corporation, NorthWrite Inc., Sensor IQ, Trane, and Texas A&M University Energy Systems Laboratory to reduce the cost of advanced building sensing and control systems (http://www1.eere.energy.gov/buildings/wireless_rd.html).
- **Commissioning:** Optimizing the design, installation, testing, operation, and maintenance of building systems and equipment in accordance with operational needs (http://www1.eere.energy.gov/buildings/commissioning_rd.html).
    - **Integrated Commissioning & Diagnostics:** Collaborating with Lawrence Berkeley National Laboratory, California Energy Commission Public Interest Energy Research (PIER) Program, Texas A&M University, University of California at Berkeley, and Massachusetts Institute of Technology to develop manual tools, test procedures, and guides to support building systems commissioning (http://www1.eere.energy.gov/buildings/commissioning_integrated.html).
    - **Information and Monitoring Diagnostics System:** Collaborating with California Institute for Energy Efficiency, California Energy Commission, Lawrence Berkeley National Laboratory, University of California at San Diego, Stanford University, and Supersymmetry to develop and field test an improved building diagnostic system (http://www1.eere.energy.gov/buildings/commissioning_ monitoring.html).
    - **Whole-Building Diagnostician Software:** Collaborating with Pacific Northwest National Laboratory, Honeywell Technology Center, and University of Colorado to speed the transfer of building diagnostic technology into practice so as to streamline the detection and diagnosis of common problems in building systems (http://www1.eere.energy.gov/buildings/commissioning_software.html).
    - **International Commissioning:** Contribute to international efforts to assess and optimize building energy systems performance, including the Energy Conservation in Buildings & Community Systems (ECBCS) Annex 40 and the International Performance Measurement and Verification Protocol (MVP) (http://www1.eere.energy.gov/buildings/commissioning_international.html).

SunShot Initiative

Ramamoorthy Ramesh, Director
U.S. Department of Energy–
SunShot Initiative
1000 Independence Avenue, SW
Washington, DC, 20585

(202) 287-1862 (o)
solar@ee.doe.gov

http://www1.eere.energy.gov/solar/sunshot/

Research Focus

DOE efforts to decrease solar energy systems costs by 75% before 2020 so as to make solar technologies cost-competitive with other forms of energy. Efforts include selectively funding and providing loan guarantees for high risk, high payoff concepts promising transformative energy generating, storage, and use. Projects include:

- Solar Energy Grid Integration Systems (http://www1.eere.energy.gov/solar/sunshot/pvmi.html)
- Solar Extreme Balance of System Projects (http://www1.eere.energy.gov/solar/sunshot/extreme_bos.html)
- Solar Foundational Program to Advance Cell Efficiency Projects (http://www1.eere.energy.gov/solar/sunshot/advance_cell_efficiency.html)
- Solar Energy Grid Integration Systems—Advanced Concepts Projects (http://www1.eere.energy.gov/solar/sunshot/segis_advanced_concepts.html)
- Solar Projects to Reduce Non-Hardware Balance of System Costs (http://www1.eere.energy.gov/solar/sunshot/nonhardware_bos.html)
- Transformational Photovoltaic Science and Technology: Next Generation Photovoltaics II Projects (http://www1.eere.energy.gov/solar/sunshot/nonhardware_bos.html)