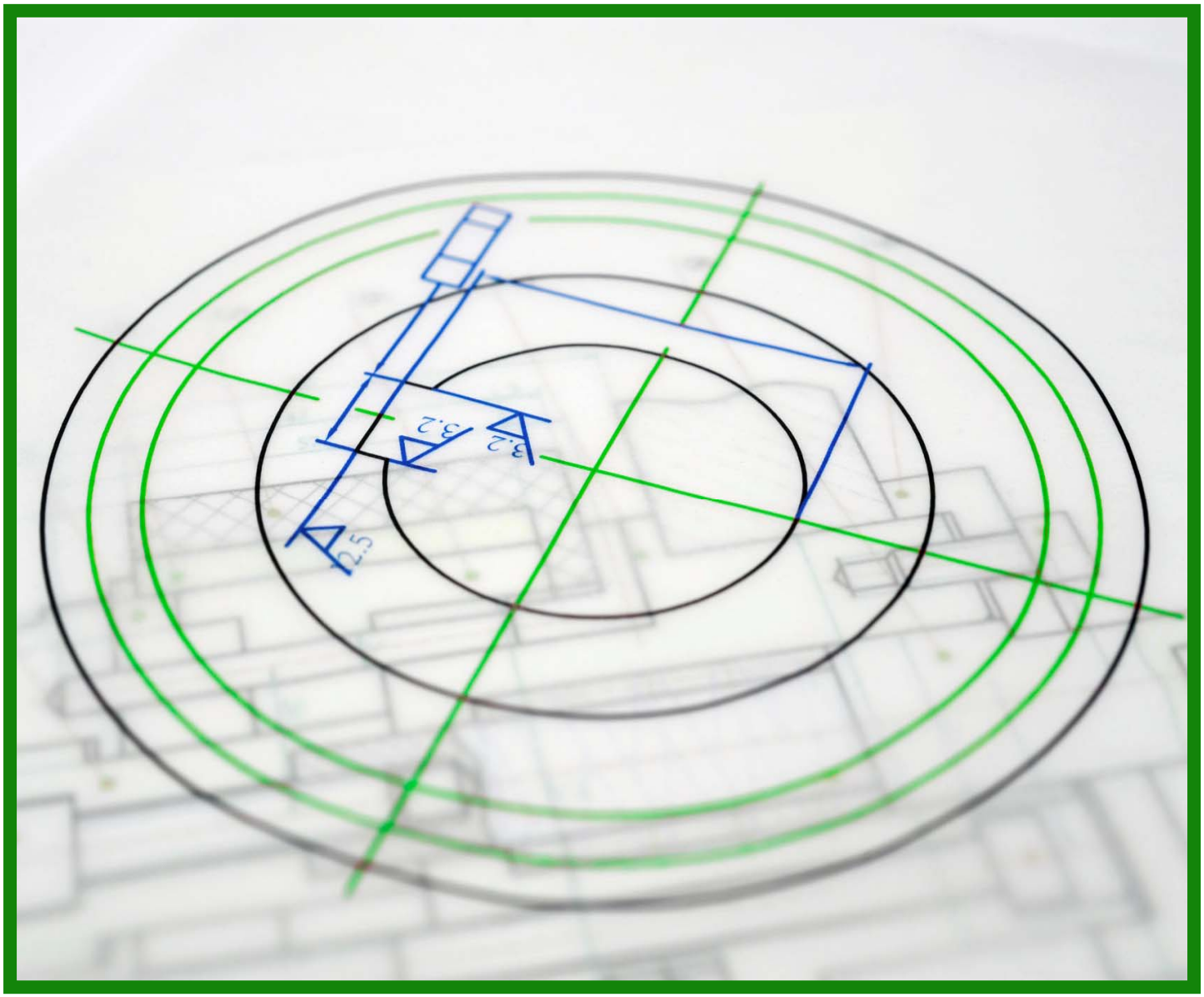

March 2012

Northwest Energy Efficiency Technology Roadmap Portfolio

Appendix B: Existing R&D Projects

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Introduction

This appendix to the 2012 Northwest 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 regional stakeholders.

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

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 itself in 2010, and the resource has since been revised annually. This R&D appendix appears with the 2012 iteration of the Roadmap Portfolio for the first time. Like the Roadmap Portfolio, this appendix is an evolving document and will change with future iterations of the Portfolio; as such, it reflects our best knowledge as of March 2012.

Appendix B Project Team:

Project Manager: **Joshua Binus**, Bonneville Power Administration

Project Coordinator: **James V. Hillegas**, Bonneville Power Administration

Graphics & Design: **David Moody**, Bonneville Power Administration

Research Assistance: **Ibrahim Iskin**, Portland State University, Department of Engineering and Technology Management; **E Source** (Peter Criscione, Katie Elliott, Mary Horsey, Bryan Jungers, Leland Keller, Ira Krepchin, Andrea Patterson, Essie Snell, Jay Stein, and Tim Stout)

Content Input: See complete list of workshop participants in the 2012 Northwest Energy Efficiency Technology Roadmap Portfolio.

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

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How to Use and Navigate Appendix B

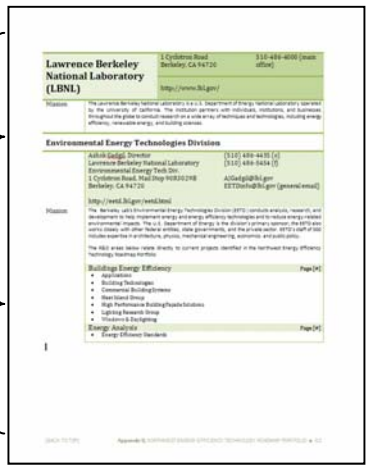
Appendix B is organized in a “nested” or “tiered” fashion that enable readers, at a glance, to do the following:

- 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.
- 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

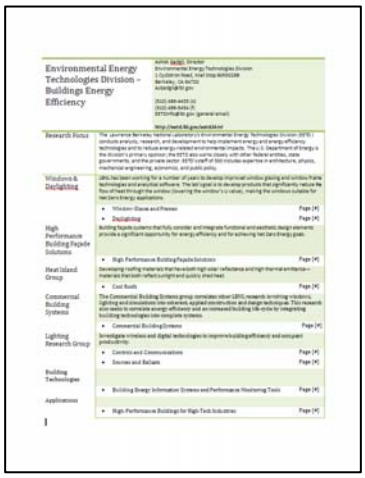
- These pages identify the institution or organization conducting the research.
- The pages also identified the applicable divisions, departments, or other second-tier sub-groups within the institution.
- Under the headings of each division or department are listed the research groups working on one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

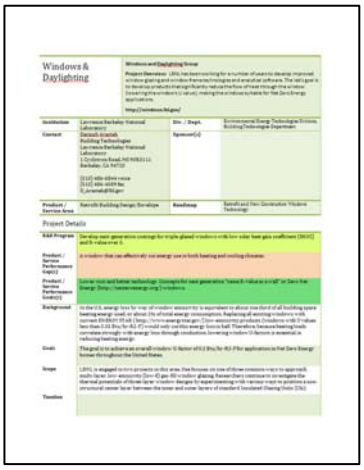
Note: Smaller organizations may not have a distinct Research Group Page; in these cases, the Institutional Page will flow directly into R&D Project Page(s)

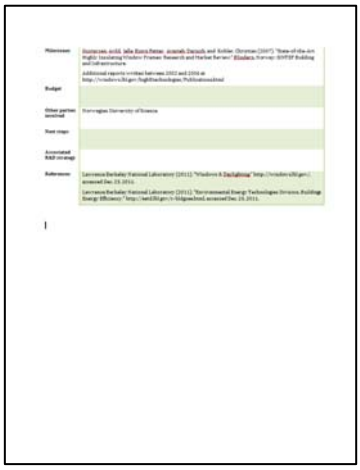


Level of detail on a given research project **increases**

R&D Project Pages

- R&D Project 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 Technology Roadmaps within the full Portfolio.





Research & Development Institution & Project Listings

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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 http://www.bnl.gov/cfn/ (631) 344-NANO (6266) (o) (631) 344-7072 (f) cfnuser@bnl.gov
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 3 • Transparent thin-film photovoltaic materials

Soft and Biological Nanomaterials	Oleg Gang P.O. Box 5000 Upton, NY 11973-5000 http://www.bnl.gov/cfn/research/Soft_and_Biological_Materials.asp	(631) 344-3645 (o) ogang@bnl.gov

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 Page 4

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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	Retrofit Building Design/Envelope	**Roadmap**	Retrofit and New Construction Windows

Project Details

R&D Program	Integral low-energy and photovoltaic windows.
Product / Service Performance Gap(s)	Concepts for next generation "same as R-value as a wall" or Zero Net Energy (ZNE) windows. Lower cost and better technology.
Product / Service Performance Goals(s)	Net energy producing 50% market skylights become alternative for lighting. Switchable window/photovoltaic 5% of replacement market.
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	
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	Page 7
	• Energy Innovation Small Grants Program (EISG)	
	Public Interest Energy Research (PIER) Program	Page 8
	• Buildings End-Use Energy Efficiency Research • Data Centers Research	

Energy Technology Systems Integration (ETSI) Program	Mike Gravely Energy Systems Research California Energy Commission 1516 Ninth Street, MS 43 Sacramento, CA 95814-5512 http://www.energy.ca.gov/research/integration/index.html	(916) 327-1370 (o) MGravely@energy.state.ca.us

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. • *[No current R&D projects identified as of Feb. 2012]*

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Public Interest Energy Research (PIER) Program	Panama Bartholomy Deputy Director California Energy Commission 1516 Ninth Street, MS-29 Sacramento, CA 95814-5512 http://www.energy.ca.gov/research/index.html	(916) 654-5013 (o) pbarthol @ energy.state.ca.us

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 9 • Improved Insulation for Buildings and Refrigeration — Page 11 • 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). • *[No current R&D projects identified as of Feb. 2012]*

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 Verificatoin Techniques

Project Details

R&D Program	M&V project for universal software.
Product / Service Performance Gap(s)	Need to be able to attribute energy performance improvements and effects. No tools for savings verification (M&V). Transform raw data into actionable insights. Feedback loops for energy-related system design and operation decisions.
Product / Service Performance Goals(s)	Low-cost savings verification techniques.
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.
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	New Construction Building Design/Envelope	**Roadmap**	New Construction Insulation

Project Details

R&D Program	Application technology "easy and cheap."
Product / Service Performance Gap(s)	Better modeling/technology. Easier to install.
Product / Service Performance Goals(s)	Affordable, widely available construction materials with outstanding insulating characteristics.
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^{tm} for Daylighting	**Public Interest Energy Research (PIER) Program** **Project Overview:** Developing and enhancing the Sensor Placement Orientation Tool (SPOT^{tm}) 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.
Product / Service Performance Gap(s)	Better light quality as perceived by users. More responsive controls, especially for horizontal daylighting. Easier to design, commission, and operate.
Product / Service Performance Goals(s)	Affordable, widely available daylighting options.
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^{tm} 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^{tm} 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^{tm} 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 http://www.cornell.edu/	(607)254-4636 (o) (607)255-5396 (f) info@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 http://www.graphics.cornell.edu/	(607) 255-7444 (o) (607) 255-0806 (f) pcg-info@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 team	Page 14
	• Green Building Design Computer Simulation Software	

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Green Building Design team	Dr. Donald P. Greenberg, Director 580 Rhodes Hall Cornell University Ithaca, NY 14853 http://www.graphics.cornell.edu/	(607) 255-7444 (o) (607) 255-0806 (f) pcg-info@graphics.cornell.edu

Research Focus	Software development team comprised of faculty from computer science, mechanical engineering and architecture departments.
Green Building Design Computer Simulation Software	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
	• Green Building Design Computer Simulation Software Page 15

Green Building Design Computer Simulation Software	**Green Building Design team** **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) pcg-info@graphics.cornell.edu	**Sponsor(s)**	
Product / Service Area		**Roadmap**	
Product / Service Area		**Roadmap**	

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
R&D Program	Need more accurate modeling to compare systems more easily.
Product / Service Performance Gap(s)	Don't currently optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, heat recovery. Not tied to building needs/loads. Current high-energy use for distribution of heat and cooling beyond actual vent need.
Product / Service Performance Goals(s)	Deliver of only what the space of occupant needs (long-term goal). Maximum efficient distribution of HVAC (don't use ducts if you don't have to) (long-term goal).
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 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.
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 as temperature, natural light, and total energy use to make building modeling more accurate and help cut down on consultation and labor expenses.

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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.
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	As of September 2010, a member of the team, Lars Schumann, was developing software to enhance simulation results by displaying them on large-scale multitouch devices.
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.

E Source	1965 North 57th Court Boulder, Colorado 80301-2826 http://www.esource.com	(303) 444-7788 (o) (303) 484-4279 (f) Email: https://www.esource.com/user/5471/contact
Mission	Facilitates interaction, networking, and information dissemination to utilities, major energy users, and others in the retail energy marketplace, with the goal of promoting efficient and environmentally sound energy use by enhancing members' operations, programs, and customer relationships.	
	Efficiency tools & services • EnFocus tool • Residential Energy-Use Study	Page 18

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EnFocus tool	**Efficiency tools & services** **Project Overview:** E Source's EnFocus system integrates geographic information system (GIS) data with utility billing records and could be used to categorize building stock and identify individual buildings. http://www.esource.com/esource/preview_list/27113?highlight=allsubs&plain=no

Institution	E Source	**Div. / Dept.**	
Contact	Michael Shepard, President 1965 North 57th Court Boulder, Colorado 80301-2826 (303) 345-9129 (o) (303) 484-4279 (f)	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Deep Retrofits for Residential & Commercial

Project Details

R&D Program	Categorize building stock for better, easier testing.
Product / Service Performance Gap(s)	Awareness / training / technology.
Product / Service Performance Goals(s)	Cheap, streamlined testing and retrofitting of existing buildings to achieve optimum savings at minimum total cost.
Background	
Goals	To help utilities integrate and improve demand-side management (DSM) , marketing, account management, and communications programs.
Scope	Tool facilitates microtargeting and demand-side management (DSM) program impact measurement by integrating utility billing, premises, and customer data within a geographic information systems (GIS) interface.
Timeline	
Milestones & Publications	Company reported this as one of their new tools at the 22nd Annual E Source forum "Advancing Energy Efficiency & Utility Customer Relationships," Denver, CO, Sep. 21-25, 2009.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	E Source (2009). "22nd Annual E Source Forum Agenda." http://www.esource.com/ee/event/agenda/25799, accessed Dec. 14, 2011. E Source (2009). "New Arrivals: The Latest Tools from E Source." http://www.esource.com/esource/preview_list/27113?highlight=allsubs&plain=no, accessed Dec. 14, 2011.

Residential Energy-Use Study	**Efficiency tools & services** **Project Overview:** Analytical pay-for-service tool that utility customers can use to take advantage of detailed market research data to analyze impacts on loads, residential customers program participation, user behavior, market segments, appliance saturation, and customer attitudes toward the utility. http://www.esource.com/Residential_Energy-Use_2011

Institution	E Source	**Div. / Dept.**	
Contact	Michael Shepard, President 1965 North 57th Court Boulder, Colorado 80301-2826 (303) 345-9129 (o) (303) 484-4279 (f)	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Deep Retrofits for Residential & Commercial

Project Details

R&D Program	Categorize building stock for better, easier testing.
Product / Service Performance Gap(s)	Awareness / training / technology.
Product / Service Performance Goals(s)	Cheap, streamlined testing and retrofitting of existing buildings to achieve optimum savings at minimum total cost.
Background	ESource collaborated with the Nielsen Company to conduct wide range of market studies for providing information about residential energy use. In 2011, tool users could take advantage of data back to 2009.
Goals	Goal of this consulting service is to provide information about the residential energy use in a given geographical context. This is not an R&D program, this is a resource that can be utilized.
Scope	Tool takes advantage of The Neilson Company's extensive market research assets (including a nation-wide sample of more than 32,000 survey respondents) to generate detailed and customized reports on residential appliance saturation, efficiency program participation, customer attitudes, and demographics.
Timeline	
Milestones & Publications	Consulting tool available for purchase at http://www.esource.com/Residential_Energy-Use_2011. Tailored reports provided according to customer requirements.
Budget	
Other parties involved	The Nielsen Company (http://nielsen.com/content/corporate/global/en.html).
Next steps	
Associated R&D strategy	
References	E Source (2011). "E Source Residential Energy-Use Study, 2011: Insights on Efficiency, Segments, and Appliance Saturation." http://www.esource.com/Residential_Energy-Use_2011, accessed Dec. 14, 2011.

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
	• Computers and Electronics • DC Power for Data Centers • Variable Refrigerant Flow Systems	
	High Voltage Direct Current (HVDC) (Program 162)	Page 26
	• High Voltage Direct Current (HVDC)	

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.
Computers and Electronics	Research involving electronics and computer components and systems such as gaming consoles and network devices.
	• Computers and Electronics Page 22
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 24
Variable Refrigerant Flow Systems	Conduct laboratory testing and modeling of advanced variable refrigerant flow systems.
	• Variable Refrigerant Flow Systems Page 28

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
Product / Service Area	Electronics	**Roadmap**	Component-Level Efficiency

Project Details

R&D Program	Responsive to gamers' needs.
Product / Service Performance Gap(s)	Responsive to user needs and preferences. Minimal user interaction required.
Product / Service Performance Goals(s)	Optimize sleep mode energy impacts without degrading user experience.
R&D Program	Broad research on component-level efficiency opportunities in electronics.
Product / Service Performance Gap(s)	Knowledge of the state of the art of existing component energy performance and potential beneficial interactions among components.
Product / Service Performance Goals(s)	Development of low loss components for electric devices.
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.
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." (see 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	Higher voltage conversion alternating current (AC) as an alternative to DC (230v).
Product / Service Performance Gap(s)	Evidence that direct current (DC) has predictable energy savings benefits compared to alternating current (AC), and under what conditions
Product / Service Performance Goals(s)	Investigate alternative—perhaps simpler—to direct current (DC) power, such as higher voltage AC, to see if they are as effective before committing to changing to DC power.
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.
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.

High Voltage Direct Current (HVDC)	**High Voltage Direct Current (HVDC) – Program 162** **Project Overview:** Ongoing research in the area of high voltage direct current technologies provides the opportunity to improve grid reliability, raise power transfer capabilities, and integrate renewable energy sources into the grid. http://portfolio.epri.com/ProgramTab.aspx?sId=PDU&rId=200&pId=6283

Institution	Electric Power Research Institute	**Div. / Dept.**	Power Delivery & Utilization
Contact	John Chan Program Manager Electric Power Research Institute 3420 Hillview Avenue Palo Alto, CA 94304 (650) 855-2452 (o) jchan@epri.com	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Direct Current (DC) Power Source

Project Details

R&D Program	Direct current (DC) loss reduction.
Product / Service Performance Gap(s)	Evidence that direct current (DC) has predictable energy savings benefits compared to alternating current (AC), and under what conditions.
Product / Service Performance Goals(s)	Investigate alternative—perhaps simpler—methods to direct current (DC) power, such as higher voltage alternating current (AC), to see if they are as effective before committing to changing to DC power.
Background	Both Flexible ac transmission system (FACTS) and high voltage direct current (HVDC) technologies offer opportunities to help alleviate power grid reliability issues and integrate renewable power sources into the existing alternating current (AC) system.
Goals	The program seeks to provide insights about and support for wider industry adoption of HVDC systems.
Scope	The scope of the program is to evaluate and test components; study electrical effects; develop conversion strategies and guidelines; provide experimental and theoretical analyses as well as practical technology demonstrations; address and resolving concerns of owners and operators.
Timeline	
Milestones & Publications	Project members promulgate their findings regularly by way of newsletters, conferences, and workshops, and consult with utilities considering applying these technologies. Other examples of important milestones and project reports include producing life extension guidelines for HVDC converter stations and transmission lines; producing an HVDC reference book; and ongoing component testing, among others. Annual program overviews for 2010 and 2011 can be found at http://portfolio.epri.com/ProgramTab.aspx?sId=PDU&rId=200&pId=6283.
Budget	$1.5 million (estimated 2012 program funding).

Other parties involved	
Next steps	The program is slated to continue through 2012.
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.." (see http://my.epri.com/portal/server.pt?open=512&objID=237&mode=2&in_hi_userid=2&cached=true.)
References	Rajagopalan, Satish, Fortenberry, Brian, Symanski, Dennis, and Tschudi, William (Nov. 2010). "DC Power for Data Centers." Palo Alto, CA: Electrical Power Research Institute. Electric Power Research Institute (2012). "Technology 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, Dec. 14)."Energy Efficiency Demonstration Webcast 14Dec2011 FINAL."

Variable Refrigerant Flow Systems	**End Use Energy Efficiency and Demand Response (Program 170)** **Project Overview:** Conduct laboratory testing and modeling of advanced variable refrigerant flow systems. http://my.epri.com/portal/server.pt?

Institution	Electric Power Research Institute (EPRI)	**Div. / Dept.**	Power Delivery & Utilization
Contact	Ron Domitrovic 942 Corridor Park Blvd. Knoxville, TN 37932 (865) 218-8061 (o) rdomitrovic@epri.com	**Sponsor(s)**	Bonneville Power Administration Southern California Edison
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Variable Refrigerant Flow

Project Details

R&D Program	More information about energy use; improve controls.
Product / Service Performance Gap(s)	VRF energy savings potential, control optimization not well understood.
Product / Service Performance Goals(s)	Need the equivalent of ASHRAE Manual chapter on VRF design, control and energy savings optimization. Clarify variable refrigerant flow system energy benefits, trade-offs, and optimal control strategies.
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 variable refrigerant flow 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.
Milestones & Publications	In early February 2012, Ron Domitrovic provided project update at 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." (see 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 Variable Refrigerant Flow 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.

EMerge Alliance	2400 Camino Ramon, Suite 375 San Ramon, CA 94583 http://www.emergealliance.org/	(925) 275-6617 (o) (925) 884-8668 (f) help@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*.	
	EMerge Alliance DC power distribution standards	Page 31

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	Direct current (DC) safety.
Product / Service Performance Gap(s)	Need safety education and training for designers, installers, code officials, end users. Need a good, affordable way to transmit control signals on a DC network.
Product / Service Performance Goals(s)	Work with state/local entities to invoke codes and standards.
R&D Program Needed	Electric system compatibility.
Product / Service Performance Gap(s)	Reduce cost. Increase efficiency. Better (CRI). Improve stability over time. Improve human interface. Full dimming while maintaining all of the preceding qualities.
Product / Service Performance Goals(s)	Solid state lighting that can operate on alternating current (AC) power without rectification, or an ultra-efficient direct-current-to-direct-current converter well-suited to solid state lighting driver applications.
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 (2012). "EMerge Alliance." http://www.emergealliance.org/, accessed Jan. 5, 2012.

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 34 • 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 http://energytrust.org/	(503) 445.7602 (o) Fred.Gordon@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 35

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 (3 of 3)

Project Details

R&D Program	Research to reduce maintenance.
Product / Service Performance Gap(s)	Don't currently have "on-board" diagnostics or data streams to collect. Don't have redundant or corrective hardware.
Product / Service Performance Goals(s)	Predictive maintenance in 100% of new sales (short-term goal). Initial self-healing/correcting (medium-term goal). Intelligent system with predictive, diagnostic controls & self-healing processes (long-term goal).
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.
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.

GrindPoint, 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 Energy Manager Page 38

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	Uninterruptible power supply (UPS)-photovoltaic (PV) integration (large or small).
Product / Service Performance Gap(s)	Lack of DC network infrastructure.
Product / Service Performance Goals(s)	Work with state/local entities to invoke codes and standards.
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. (2011, June 28). "New GridPoint Energy Manager Software Provides Comprehensive Visibility, Analysis, and Control of Energy Endpoints." 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.

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 39

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	Uninterruptible power supply (UPS)-photovoltaic (PV) integration (large or small).
Product / Service Performance Gap(s)	Lack of DC network infrastructure.
Product / Service Performance Goals(s)	Work with state/local entities to invoke codes and standards.
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.
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.

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iPower (Integrated Power Corp.)	Headquarters 504 Redwood Blvd Suite 230 Novato, CA 94947 http://www.ipowercorp.com/	(877) 88-iPower (884-7693) (o) (415) 884-5555 (o) (415) 884-5557 (f) info@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 http://www.ipowercorp.com/index.php?option=com_content&view=article&id=5&Itemid=4	(877) 88-iPower (884-7693) (o) (415) 884-5555 (o) (415) 884-5557 (f) info@ipowercorp.com
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 43
	• iPower® SHO Series Grid Tie Inverters	

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	Uninterruptible power supply (UPS)-photovoltaic (PV) integration (large or small).
Product / Service Performance Gap(s)	Lack of DC network infrastructure.
Product / Service Performance Goals(s)	Work with state/local entities to invoke codes and standards.
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.

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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 45 • High Performance Thermoelectric Materials	

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

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 46

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.
Product / Service Performance Gap(s)	Increase efficiency.
Product / Service Performance Goals(s)	Thermoelectric generation mounted on LED driver chip to reduce power requirements and waste heat output.
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.
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 http://www.lbl.gov/	510-486-4000 (main office)
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 http://eetd.lbl.gov/eetd.html	(510) 486-4435 (o) (510) 486-5454 (f) AJGadgil@lbl.gov EETDinfo@lbl.gov (general email)
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 48
	• Applications • Building Technologies • Commercial Building Systems • Heat Island Group • High Performance Building Façade Solutions • Lighting Research Group • Windows & Daylighting	
	Energy Analysis	Page 66
	• Energy Efficiency Standards	

Buildings Energy Efficiency

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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.	
	• Window Glazes and Frames	Page 64
	• Daylighting	Page 55
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 57
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 52
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 53
Lighting Research Group	Investigates wireless and digital technologies to improve building efficiency and occupant productivity.	
	• Lighting Controls and Communications	Page 60
	• Lighting Sources and Ballasts	Page 62
Energy Information Systems	Works to develop energy information systems and performance monitoring and analysis technologies.	
	• Building Energy Information Systems and Performance Monitoring Tools	Page 50
Applications	Helps transfer new building technologies to the marketplace.	
	• High-Performance Buildings for High-Tech Industries	Page 59

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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	New Construction Building Design/Envelope	**Roadmap**	Labeling

Project Details

R&D Program	Energy information systems – numerous existing.
Product / Service Performance Gap(s)	Get stakeholders to adopt.
Product / Service Performance Goals(s)	Have labels (short-term goal).
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.
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	Retrofit Building Design/Envelope	**Roadmap**	Solar and/or Smart Roofing Technology

Project Details

R&D Program	Cool, photovoltaic, and/or solar water heating roofing.
Product / Service Performance Gap(s)	Technology, price, and standards. Need to match-up house locations with Google Maps, global positioning system (GPS), or equivalent, plus site-specific data collection by non-technical auditors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaics.
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	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home Technology

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
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.
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	Dariush Arasteh Building Technologies Lawrence Berkeley National Laboratory 1 Cyclotron Road, MS 90R3111 Berkeley, CA 94720 (510) 486-6844 (o) (510) 486-4089 (f) D_Arasteh@lbl.gov	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Core lighting.
Product / Service Performance Gap(s)	Better light quality as perceived by users. More responsive controls, especially for horizontal daylighting.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in part due to combination of better controls, better application, and more use of natural light. Affordable, widely-available daylighting options.
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.
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	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home Technology

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
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	
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 Technology

Project Details

R&D Program	Network/web energy usage research leading to better awareness of energy use of Googling, email, etc.
Product / Service Performance Gap(s)	Standard approaches to maintain reliability and performance with reduced energy use.
Product / Service Performance Goals(s)	Optimize energy use by serves, routes, personal computers, and other devised involved in Internet interactions without degrading user experience.
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.
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.

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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 Department
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 (Dimming, Occupancy Sensors)

Project Details

R&D Program	Dynamic control of occupancy-based lighting.
Product / Service Performance Gap(s)	50% energy reduction.
Product / Service Performance Goals(s)	Better human interface. Cheaper controls.
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.
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 Department
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	Solid state lighting (SSL) life extension. Improved light extraction.
Product / Service Performance Gap(s)	Better Color Rendering Index (CRI). Improve stability over time. Improve lumen maintenance. Increase efficiency. Reduce Cost.
Product / Service Performance Goals(s)	Target early, cost-effective applications. 200 lumens per watt (lm/W) for 3500° Kelvin Correlated Color Temperature(CCT).
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.
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	Dariush Arasteh Building Technologies Lawrence Berkeley National Laboratory 1 Cyclotron Road, MS 90R3111 Berkeley, CA 94720 (510) 486-6844 voice (510) 486-4089 fax D_Arasteh@lbl.gov	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Retrofit and New Construction Windows

Project Details

R&D Program	Develop next-generation coatings for triple-glazed windows with low solar heat gain coefficient (SHGC) and R-value over 5.
Product / Service Performance Gap(s)	A window that can effectively cut energy use in both heating and cooling climates.
Product / Service Performance Goals(s)	Lower cost and better technology. Concepts for next generation "same R-value as a wall" or Zero Net Energy (http://netzeroenergy.org/) windows.
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	
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	James McMahon, Director Lawrence Berkeley National Laboratory (510) 486-6049 (o) Environmental Energy Technologies Div. (510) 486-6996 (f) 1 Cyclotron Road, MS 90R4000 Berkeley, CA 94720 JEMcMahon@lbl.gov http://eetd.lbl.gov/eetd.html
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 Page 67

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	James McMahon 1 Cyclotron Road MS 90R4000 Berkeley, CA 94720 (510) 486-6049 (o) JEMcMahon@lbl.gov	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Interlock Devices to Manage Energy Use

Project Details

R&D Program	Requirement standards for sleep modes/stand-by.
Product / Service Performance Gap(s)	Not inconvenient for users. Designed-in, not added-on to systems.
Product / Service Performance Goals(s)	Develop low-cost systems that permit quick adoption.
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.
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 Corp.	One Microsoft Way Redmond, WA 98052-6399 http://www.corporateofficeheadquarters.com/2011/03/microsoft.html	Press Contact: Waggener Edstrom Worldwide: (503) 443-7000 (o) msrpr@wagged.com
Mission	A world-wide leader in information technology systems.	

Microsoft Research

	Peter Lee, Director Microsoft Research Redmond One Microsoft Way Redmond, WA 98052-6399 http://research.microsoft.com/en-us/default.aspx	Press Contact: Waggener Edstrom Worldwide: (503) 443-7000 (o) msrpr@wagged.com
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.	
	Networking Research Group — Page 70 • Desktop PC Energy Savings for Enterprises	
	Sensing and Energy Research Group — Page 73 • Energy-Efficient Enterprise and Cloud Computing	

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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 71

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	One Microsoft Way Redmond, WA 98052 (800) 642-7676 (o) http://research.microsoft.com/en-us/groups/nrg/	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Sleep Mode

Project Details

R&D Program	Responsive to late-night network updates.
Product / Service Performance Gap(s)	Minimal user interaction required. Responsive to user needs and preferences.
Product / Service Performance Goals(s)	Sleep mode more responsive to late-night network administrator updates.
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 April 2010, the project was six months into operational testing in a fully-operational enterprise environment at Microsoft Research's Redmond facility.
Milestones & Publications	Researchers published an update of the project at the June 2010 USENIX Annual Technical Conference. (http://www.usenix.org/events/atc10/).
Budget	
Other parties involved	Pradeep Padala (intern, University of Michigan), Joshua Reich (intern, Columbia 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.

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 74

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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.
Product / Service Performance Gap(s)	Site: Common protocols for remote terminal unit (RTU) sponsors. Enterprise, communicating data. Processing, synthesizing, and storing data.
Product / Service Performance Goals(s)	Integrating energy management into consumer services. Standards: Internet Protocol version 6 (IPv6) (http://www.ipv6.com/), Internet Engineering Task Force (http://www.ietf.org/).
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.
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.

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 http://bt.mit.edu/	Cambridge, MA 02139-4307 (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 76
	• Advanced Thermal Insulations • 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.
Advanced Thermal Insulations	Research on closed-cell foam insulation for appliances and buildings exhibited improved insulative ability and reduced environmental hazards. • Advanced Thermal Insulations Page 77
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 78

Advanced Thermal Insulations

Building Materials & Construction Group

Project Overview: Research on closed-cell foam insulation for appliances and buildings exhibited improved insulative ability and reduced environmental hazards.

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

Institution	MIT	**Div. / Dept.**	Building Technology Research Program
Contact	Leon Glicksman Principal investigator	**Sponsor(s)**	U.S. Department of Energy
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	New Construction Insulation

Project Details

R&D Program	Application technology "easy and cheap."
Product / Service Performance Gap(s)	Better modeling/technology. Easier to install. Better materials with higher energy efficiency value.
Product / Service Performance Goals(s)	Affordable, widely available construction materials with outstanding insulating characteristics.
Background	Building heating and cooling consumes a large percentage of energy used in the U.S. One contributing factor is insufficiently insulated appliances.
Goals	Develop advanced insulation technologies for new and renovated buildings as well as for appliances.
Scope	Produce closed-cell foam insulation that is less harmful to the environment; investigate composite insulation involving both foam and vacuum technology.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
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.

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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	Ellann Cohen Student	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Retrofit Insulation

Project Details

R&D Program	"Smart" material that fills all cavities and is mistake-free and inexpensive.
Product / Service Performance Gap(s)	Training/methods and technologies. Awareness—identification of need at a low cost, easier to install.
Product / Service Performance Goals(s)	Easier to use, affordable insulation products.
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 shallow retrofits to existing buildings.
Scope	Make use of silica aerogel (currently considered the material with the lowest thermal conductivity) to develop insulation in the form of thin film that can be easily applied to walls.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
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 http://web.mit.edu/cshub/index.html	(617) 253-4087 (o) (617) 253-6152 (f) jao@mit.edu
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 80 • The Edge of Concrete: A Life-Cycle Investigation of Concrete and Concrete Structures	

Concrete Building Technology Platform	Massachusetts Institute of Technology 77 Massachusetts Avenue, 5-418B http://web.mit.edu/cshub/research/projects.html	Cambridge, MA 02139-4307
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	Page 81

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	New Construction Building Design/Envelope	**Roadmap**	New Construction Insulation

Project Details

R&D Program	Application technology "easy and cheap."
Product / Service Performance Gap(s)	Better modeling / technology. Easier to Install. Better materials with higher energy efficiency value.
Product / Service Performance Goals(s)	Affordable, widely available construction materials with outstanding insulating characteristics.
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.
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 84
	• SurroundVision	
	Responsive Environments Research Group	Page 86
	• Beyond the Light Switch: New Frontiers in Dynamic Lighting	

Object-Based Media Group	V. Michael Bove Jr. Principal Research Scientist MIT Media Lab E15-432, 20 Ames Street Cambridge, MA 02139 http://obm.media.mit.edu/	(617) 253-0334 (o) vmb@media
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	Page 85

SurroundVision	**Object-Based Media Group** **Project Overview:** Investigating the 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	Santiago Alfaro PhD Candidate E15-432, 20 Ames Street Cambridge, MA 02139 (617) 253-0334	**Sponsor(s)**	
Product / Service Area	Electronics	**Roadmap**	Use and Virtualization

Project Details

R&D Program	User comfort with virtual reality (VR) goggles.
Product / Service Performance Gap(s)	Standard approaches to maintain reliability and performance with reduced energy use.
Product / Service Performance Goals(s)	Comfortable virtual reality goggles to replace larger and more energy-intensive screens.
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	Produce closed-cell foam insulation that is less harmful to the environment; investigate composite insulation involving both foam and vacuum technology.
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	
Next steps	
Associated R&D strategy	
References	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.

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 87

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	Matthew Aldrich Research Assistant Responsive Environments Group MIT Media Lab E15-432, 20 Ames Street Cambridge, MA 02139 (617) 452-5647 (o) maldrich@media.mit.edu	**Sponsor(s)**	Philips-Color Kinetics (http://colorkinetics.com/)
Product / Service Area	Lighting	**Roadmap**	Lighting Controls (Dimming, Occupancy Sensors)
Product / Service Area	Lighting	**Roadmap**	Cheaper, simple self-calibration

Project Details

R&D Program	Predictive modeling for dynamic lighting needs. R&D for cheaper, simpler self-calibration.
Product / Service Performance Gap(s)	Better human interface. Cheaper controls.
Product / Service Performance Goals(s)	50% reduction (25% of 80% goal) (long-term goal).
R&D Program	Cheaper, simple self-calibration.
Product / Service Performance Gap(s)	Cheaper controls. Better human interface.
Product / Service Performance Goals(s)	50% reduction (25% of 80% goal) (long-term goal).
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.

Timeline	Most recent website update: March 31, 2011.
Milestones & Publications	Suite of MATLAB tools created to calculate lux and color rendering index of virtual and measured light sources. Full list of project-related publications and news reports from 2010 to March 2011 at http://resenv.media.mit.edu/lighting.
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.

MountainLogic, Inc.	Scott Elliott, CEO mountainlogic@gmail.com http://mountainlogic.com/
Mission	Company with offices in Portland, OR, and Seattle, WA, manufactures energy efficient, automated residential atmosphere controls.
Residential Predictive Occupancy Zoned HVAC Demonstration	Demonstrate feasibility of low-cost, wireless retrofit predictive occupancy residential zone control solution for central forced air HVAC systems. • Residential Predictive Occupancy Zoned HVAC Demonstration Page 90

Residential Predictive Occupancy Zoned HVAC Demonstration

Project Overview: Demonstrate feasibility of low-cost, wireless retrofit predictive occupancy residential zone control solution for central forced air HVAC systems.

http://mountainlogic.com/

Institution	MountainLogic, Inc.	**Div. / Dept.**	
Contact	Scott Elliott mountainlogic@gmail.com	**Sponsor(s)**	Bonneville Power Administration
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Modeling, Lab, and Field Testing (1 of 2)

Project Details

R&D Program	Predictive occupancy zoned HVAC system.
Product / Service Performance Gap(s)	Don't currently optimize use of ambient or indoor conditions. Not tied to building needs / loads. Current high-energy use for distribution of heat and cooling beyond actual vent need.
Product / Service Performance Goals(s)	Quantify and deliver predicable energy savings from HVAC distribution zone control systems.
Background	HVAC zone controls provide the opportunity for residential energy savings because they are able to distribute heating or cooling only to occupied areas, thereby replacing single-unit residential atmospheric controls that provide unneeded heating and cooling in unoccupied rooms. Wireless systems offer the additional attraction of stringing new wires in the building. This is BPA Technology Innovation office Project #248.
Goals	Goals include: 1) demonstrate basic functionality, efficacy, and user acceptance; 2) assess user interface effectiveness and acceptance, 3) conduct field trials to measure and demonstrate energy savings; 4) evaluate energy savings with demand response cues; 5) publish results.
Scope	ZigBee wireless thermostats with occupancy sensors provide user-friendly controls, and ZigBee wireless register/dampers replace existing air registers provide zone airflow control. The thermostat controls also offer the possibility of demand response and predictive demand. Project is currently at a technology readiness level of 6 (TRL-6) in preparation for pilot testing, and with placement of units in homes for functional testing and debugging, the project will be able to achieve TRL-7 and be ready for user acceptance and energy savings demonstrations.
Timeline	Performance period: Nov. 22, 2011 through Sep. 30, 2012.
Milestones & Publications	Stage 1 Nov 4 2011 - March 14 2012: Submit detailed project plan; install systems in 10 pilot homes and conduct tests; identify 79 test homes and 89 reference homes. Stage 2 April 25 2012 – May 3 2012: Install equipment in 79 test homes and 89 reference homes; generate Stage 2 report. Stage 3 May 10 2012 – Sep. 28 2012: Conduct field testing; post test user survey; receive final technical review; compose final project report. Presentation delivered at BPA TI R&D Summit, Jan. 31-Feb. 2, 2012.
Budget	$628,725 (BPA TI = $254,770, MountainLogic = $373,955)

Other parties involved	
Next steps	
Associated R&D strategy	
References	"Technology Innovation Project #248, Residential Predictive Occupancy Zoned HVAC Demonstration." Nov. 22, 2011.

National Institute of Standards and Technology (NIST)	100 Bureau Dr. Gaithersburg, MD 20899 http://www.nist.gov/index.html	(301) 975-NIST (6478) (o) (301) 975-2000 (o) inquiries@nist.gov

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 http://www.nist.gov/el/building_environment/	(301) 975-5864 (o) hunter.fanney@nist.gov

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.

Heat Transfer and Alternative Energy Systems Group Page 93

- Measuring Performance of Net-Zero Energy Homes Project
- Net-Zero Energy, High-Performance Buildings Program
- Whole Building Energy Modeling and Measurements Project

HVAC&R Equipment Performance Group Page 100

- Design and In-Situ Performance of Vapor Compression System Project

Mechanical Systems and Controls Group Page 103

- Fault Detection and Diagnostics for Commercial Heating, Ventilating, and Air-Conditioning Systems
- Fault Detection and Diagnosis for Air-Conditioners and Heat Pumps

Heat Transfer and Alternative Energy Systems Group

William M. Healy, Leader
Heat Transfer and Alternative Energy Group
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william.healy@nist.gov

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

Research Focus	Advance building energy efficiency measurement science, standards, and technology to help promote innovation and competitiveness.
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 94
Net-Zero Energy, High-Performance Buildings Program	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.
	• Net-Zero Energy, High-Performance Buildings Program Page 96
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 98

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Measuring Performance of Net-Zero Energy Homes Project	**Heat Transfer and Alternative Energy Systems Group** **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	New Construction Building Design / Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
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	Establish comprehensive test facility and develop the necessary measurement science by 2014 to analyze Net Zero Energy home performance monitoring systems, evaluate integrated performance metrics, and validate building energy and ventilation models.
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.
Timeline	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.
Milestones & Publications	
Budget	

Other parties involved	
Next steps	
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 Jan. 23, 2012.

Net-Zero Energy, High-Performance Buildings Program	**Heat Transfer and Alternative Energy Systems Group** **Project Overview:** 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. http://www.nist.gov/el/building_environment/heattrans/netzero.cfm

Institution	National Institute of Standards and Technology	**Div. / Dept.**	Energy and Environment Division
Contact	William Healy 100 Bureau Drive, M/S 8632 Gaithersburg, MD 20899-8632 (301) 975-4922 (o) william.healy@nist.gov	**Sponsor(s)**	
Product / Service Area	New Construction Building Design / Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
Background	Building energy consumption and emissions are a significant barrier to energy efficiency in the U.S. The development of measurement science for net-zero energy buildings is complex, which makes it difficult to devise functional and effective solutions. NIST researchers are uniquely situated among other federal research laboratories to contribute to the development of measurement science for net-zero energy buildings and disseminate these findings to other institutions and private industry.
Goals	To build upon the NIST Engineering Laboratory's core competency in energy-efficient and intelligent operation of buildings with healthy indoor environments, as well as the laboratory's strategic to help develop Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure, particularly in the area of developing energy-efficient buildings.
Scope	To help the U.S. building industry achieve net-zero energy, high-performance buildings, NIST will focus on four thrust areas: 1) Building Envelope Load Reduction; 2) Equipment Efficiency; 3) On-Site Energy Generation; 4) Whole Building Metrics.
Timeline	
Milestones & Publications	A wide array of milestones and publications available at http://www.nist.gov/el/building_environment/heattrans/netzero.cfm.
Budget	

Other parties involved	
Next steps	
Associated R&D strategy	Efforts accord with the mission and goals of a number of federal and international bodies, including: the U.S. Office of Budget and Management, which established federal priorities for research into energy efficiency for fiscal year 2012; the National Science and Technology Council (NSTC); American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); and the American Institute of Architects' 2030 Challenge. NIST will help develop standards applicable to new building design, building retrofits, and building components and systems performance.
References	National Institute of Standards and Technology (2012). "Net-Zero Energy, High-Performance Buildings Program." http://www.nist.gov/el/building_environment/heattrans/netzero.cfm, accessed Jan. 23, 2012.

Whole Building Energy Modeling and Measurements Project	**Heat Transfer and Alternative Energy Systems Group** **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	New Construction Building Design / Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
Background	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. 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.
Scope	In fiscal year 2012, project staff will develop measurement tools and methods to decrease uncertainty in energy audits. They will also contribute to the development and testing of continuous energy monitoring tools.
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	
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 Jan. 23, 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 Page 101

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**	Net Zero Energy Home
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Modeling, Lab, and Field Testing (1 of 2)

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
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.
Product / Service Performance Gap(s)	Don't currently optimize use of ambient or indoor conditions, e.g., economizer, indoor ventilation controls, heat recovery. Not tied to building needs / loads. Current high-energy use for distribution of heat and cooling beyond actual vent need.
Product / Service Performance Goals(s)	Controls to meet indoor air needs—no excess vented air beyond occupant needs (long-term goal). Delivery of only what the space of occupant needs (long-term goal). Maximum efficient distribution of HVAC (don't use ducts if you don't need them) (long-term goal).
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.
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, testing will commence on a 7.5-ton rooftop unit (RTU) and a window air conditioner 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.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
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
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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 104
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 106

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	**Roadmap**	Fault Detection and Predictive Maintenance (3 of 3)

Project Details

R&D Program	Research to reduce maintenance.
Product / Service Performance Gap(s)	Don't' currently have "on-board" diagnostics or data streams to collect. Don't have redundant or corrective hardware.
Product / Service Performance Goals(s)	Predictive maintenance in 100% of new sales (short-term goal). Initial self-healing / correcting (medium-term). Intelligent systems with predictive diagnostic controls & self-healing processes.
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.
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 Daniel Veronica, Principal Investigator daniel.veronica@nist.gov	**Sponsor(s)**	
Product / Service Area	Heating, Ventilation, and Air Conditioning	**Roadmap**	Fault Detection and Predictive Maintenance (3 of 3)

Project Details

R&D Program	Research to reduce maintenance.
Product / Service Performance Gap(s)	Don't' currently have "on-board" diagnostics or data streams to collect. Don't have redundant or corrective hardware.
Product / Service Performance Goals(s)	Predictive maintenance in 100% of new sales (short-term goal). Initial self-healing / correcting (medium-term). Intelligent systems with predictive diagnostic controls & self-healing processes.
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.
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 Jan. 23, 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.

National Renewable Energy Laboratory (NREL)	1617 Cole Blvd. Golden, CO 80401-3305 http://www.nrel.gov/	(303) 275-3000 (o)
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 http://www.nrel.gov/science_technology/	(303) 275-3008 (o) (303) 275-3097 (f) (303) 275-3094 (Admin. Assistant) Dana.Christensen@nrel.gov
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 109 • Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing • Integrated Daylighting and Energy Analysis Toolkit (IDEAKit) • Windows National Center for Photovoltaics — Page 116 • 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/).
Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing	Project funded 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 110
Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)	Project funded 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 112
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.
	• Electrochromic Research Activities - Advanced Prototypes for Electrochromic Windows Page 114

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	David Christensen 1617 Cole Blvd. Golden, CO 80401-3305 (303) 275-3015 (o) david_christensen@nrel.gov	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Retrofit and New Construction Windows

Project Details

R&D Program	Add a small photovoltaic (PV) panel to electrochromic windows that will increasing lighting proportionally or insulate during the cooling season.
Product / Service Performance Gap(s)	Lower cost & better technology. Concepts for next generation "same R-value as a wall" or zero net energy windows. Address seamless photovoltaic integration into fenestration. Electrochromic issues such as cost, life, performance.
Product / Service Performance Goals(s)	Switchable window/photovoltaic 5% of replacement market (short-term goal). Net energy producing 50% market skylights become alternative for lighting (long-term goal).
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.
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 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	Dynamic control of occupancy-based lighting.
Product / Service Performance Gap(s)	Better human interface. Cheaper controls.
Product / Service Performance Goals(s)	50% reduction (25% of 80% goal) (Long-term goal).
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.
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	SSRU, LLC, software development company of Fort Collins, CO (http://www.ssuru.com/about-us/).

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 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	New Construction Building Design/Envelope	**Roadmap**	Daylighting Walls

Project Details

R&D Program	Develop easier, cheaper daylighting models that determine energy savings benefits.
Product / Service Performance Gap(s)	Measurable. Design cost / complexity.
Product / Service Performance Goals(s)	Easier, cheaper daylight modeling tools that give energy benefits.
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.
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.

National Center for Photovoltaics	1617 Cole Blvd. Golden, CO 80401-3305 http://www.nrel.gov/buildings/	(303) 275-3000 (o)

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 117

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	Retrofit Building Design/Envelope	**Roadmap**	Retrofit and New Construction Windows

Project Details

R&D Program	Cool/photovoltaic/solar water heating roofing.
Product / Service Performance Gap(s)	Technology, prices, and standards. Need to match up home locations with Google Maps, Global Positioning System (GPS), or equivalent, plus site-specific data collection by non-technical auditors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaic systems.
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.
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 Page 120 • Appliances • Hygrothermal Property Measurements • R30/30 Roofing Systems • Reflective Roof Systems • Residential Attics and Cathedral Ceilings • Vegetative Roofing System Cooling Heating & Power Technologies Program Page 131 • Cooling Heating & Power Technologies

Building Technologies Research and Integration Center

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.
Appliances	Research to support the U.S. Department of Energy's Energy Efficiency and Renewable Energy Program (http://www.eere.energy.gov/) by analyzing both energy- and non-energy-related attributes of household technologies and these attributes impact consumers' purchasing decisions.
	• Appliances — Page 121
Hygrothermal Property Measurements	To develop technologies, techniques, and modeling systems that aid in understanding and addressing moisture transfer, thereby increasing a building's energy efficiency, indoor air quality, functional lifespan.
	• Hygrothermal Property Measurements — Page 122
R30/30 Roofing Systems	To develop marketable roofing systems that have an average service life of 30 years and a thermal resistance (R-value) of 30h.ft2.oF/Btu ("R30/30").
	• R30/30 Roofing Systems — Page 123
Reflective Roof Systems	To produce more energy efficient houses by increasing knowledge of attic air distribution, ventilation, and thermal performance that will enable the development of improved insulation and duct sealing systems.
	• Reflective Roof Systems — Page 125
Residential Attics and Cathedral Ceilings	To produce more energy efficient houses by increasing knowledge of attic air distribution, ventilation, and thermal performance that will enable the development of improved insulation and duct sealing systems.
	• Residential Attics and Cathedral Ceilings — Page 127
Vegetative Roofing System	Project initiated to quantify thermal performance of different kinds of vegetative roofing systems in comparison to black and white roofs.
	• Vegetative Roofing System — Page 129

Appliances

Building Technologies Research and Integration Center

Project Overview: Research to support the U.S. Department of Energy's Energy Efficiency and Renewable Energy Program (http://www.eere.energy.gov/) by analyzing both energy- and non-energy-related attributes of household technologies and these attributes impact consumers' purchasing decisions.

http://www.ornl.gov/sci/ees/etsd/btric/appliances.shtml

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction Zero Net Energy by 2030.
Background	Developing energy efficient appliances that consumers are interested in purchasing will contribute significantly to reducing the electricity and natural gas demands of buildings.
Goals	The team partners with manufacturers to develop appliances that are more energy efficient and long-lasting, while also meeting end-user's needs.
Scope	By applying a market-focused approach to technology assessment, the team develops business plans linked directly to market-readiness and acceptance.
Timeline	Project appears to be ongoing.
Milestones & Publications	Team has provided market evaluations of a number of household technologies, including: demand response appliances; the General Electric Hybrid Water Heater; heat pumps; heating, ventilation, and air conditioning systems; and waste heat recovery systems.
Budget	
Other parties involved	Team has partnered with major appliance manufacturers, including General Electric and Whirlpool.
Next steps	
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "Appliances." http://www.ornl.gov/sci/ees/etsd/btric/appliances.shtml, accessed Jan. 4, 2012.

Hygrothermal Property Measurements	**Building Technologies Research and Integration Center** **Project Overview:** To develop technologies, techniques, and modeling systems that aid in understanding and addressing moisture transfer, thereby increasing a building's energy efficiency, indoor air quality, functional lifespan. http://www.ornl.gov/sci/ees/etsd/btric/res_walls_hygrothermal.shtml

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction Zero Net Energy by 2030.
Background	Moister transfer through materials involves complex interactions between different kinds of materials in different climates. Understanding this dynamic will help prolong the life of building materials while also making structures more energy efficient and improving indoor air quality.
Goals	These research efforts have three primary goals: 1) Develop laboratory facilities building materials hygrothermal properties; 2) Devise testing methods and standards; 3) Help devise accurate models by characterizing material properties and durability.
Scope	The ORNL laboratory will allow for testing of "hygroscopic (low moisture content) and capillary (high moisture content) regimes, water vapor permeability, liquid diffusivity, liquid uptake, two-dimensional distributions of moisture using nuclear magnetic resonance or gamma-ray methods, thermal conductivity, specific heat, and air-flow permeability."
Timeline	Research on moister transfer in buildings has been ongoing at the Large Scale Climate Simulator, in outdoor tests, and in computer simulations.
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "Hygrothermal Property Measurements." http://www.ornl.gov/sci/ees/etsd/btric/res_walls_hygrothermal.shtml, accessed Jan. 4, 2012.

R30/30 Roofing Systems

Building Technologies Research and Integration Center

Project Overview: To develop marketable roofing systems that have an average service life of 30 years and a thermal resistance (R-value) of 30h.ft2.oF/Btu ("R30/30").

http://www.ornl.gov/sci/ees/etsd/btric/res_r30_roof_system.shtml

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Division Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Solar/Smart Roofing
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Cool/photovoltaic/solar water heating roofing.
Product / Service Performance Gap(s)	Technology/price/standards. Need to match up home locations with Google Maps, global positioning system (GPS), or equivalent, plus site-specific data collection by non-technical authors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaics.
R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction Zero Net Energy by 2030.
Background	Traditional roofing systems tend not to last long, contributing to large amount of re-roofing work and a significant amount of solid wastes generated. Improving energy efficiency of low-slope roofing systems involves increasing moisture and wind tolerances.
Goals	The three primary goals of this project are: 1) Develop Internet-based moisture control design tool; 2) Devise more energy-efficient and environmentally sound re-roofing alternatives; 3) Investigate causes of roofing system failure during major wind events.
Scope	Design and testing of new techniques to enhance roofing system drying potential and comparing these systems to current practices; testing a variety of roofing systems to enhance thermal performance, including efficient skylights, vegetative coverings, and photovoltaic-integrated roofing surfaces.

Timeline	Projects appear to be ongoing.
Milestones & Publications	Research thus far has led to the development of a design guide, "Moisture Control In Low-Slope Roofing: A New Design Requirement" (http://www.ornl.gov/sci/roofs+walls/wetroof/wetroof01.html).
Budget	
Other parties involved	Various private roofing firms.
Next steps	Team is seeking a partnership to demonstrate the performance and sustainability potential of green roofs
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "R30/30 Roofing Systems." http://www.ornl.gov/sci/ees/etsd/btric/res_r30_roof_system.shtml, accessed Jan. 4, 2012.

Reflective Roof Systems

Building Technologies Research and Integration Center

Project Overview: To produce more energy efficient houses by increasing knowledge of attic air distribution, ventilation, and thermal performance that will enable the development of improved insulation and duct sealing systems.

http://www.ornl.gov/sci/ees/etsd/btric/res_reflective_roof_system.shtml

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

Project Details

R&D Program	Cool/photovoltaic/solar water heating roofing.
Product / Service Performance Gap(s)	Technology/price/standards. Need to match up home locations with Google Maps, global positioning system (GPS), or equivalent, plus site-specific data collection by non-technical authors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaics.
Background	Since light-colored roofing materials have a high solar reflectance and dark-colored materials have a low solar reflectance, light-colored materials are better able to reflect sunlight. This lowers roof temperature, prolongs the life of roofing materials, and decreases the need for air conditioning inside the building. Research conducted in partnership with the Roof Coating Manufacturers Association (http://www.roofcoatings.org/) and five individual roofing manufacturers.
Goals	There are two primary goals with this project: 1) Quantify long-term energy and durability benefits of reflective roofing materials; 2) Help consumers choose an appropriate roofing material by developing fair and accurate procedures.
Scope	Project has included a three-year study of 24 different white and aluminum coatings involving measurement of solar reflectance, infrared emittance, and thermal performance of each coating, a similar study of eighteen different low-slope roofing systems, and an evaluation of high- and low-slope bare and painted metal roofs.
Timeline	Research ongoing since 1997.
Milestones & Publications	Publications listed at http://www.ornl.gov/sci/ees/etsd/btric/publications.shtml.
Budget	
Other parties involved	Roof Coating Manufacturers Association (http://www.roofcoatings.org/) and five individual roofing manufacturers.

Next steps	
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "Reflective Roof Systems." http://www.ornl.gov/sci/ees/etsd/btric/res_reflective_roof_system.shtml, accessed Jan. 4, 2012.

Residential Attics and Cathedral Ceilings

Building Technologies Research and Integration Center

Project Overview: To produce more energy efficient houses by increasing knowledge of attic air distribution, ventilation, and thermal performance that will enable the development of improved insulation and duct sealing systems.

http://www.ornl.gov/sci/ees/etsd/btric/res_attics_cathedral_ceilings.shtml

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	Patrick Hughes, BTRIC Director Energy & Transportation Science Division Oak Ridge National Laboratory P.O. Box 2008, MS-6070 Oak Ridge, TN 37831-6070 hughespj1@ornl.gov	**Sponsor(s)**	Single Ply Roofing Institute (SPRI) (http://www.spri.org/)
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Solar/Smart Roofing
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Cool/photovoltaic/solar water heating roofing.
Product / Service Performance Gap(s)	Technology/price/standards. Need to match up home locations with Google Maps, global positioning system (GPS), or equivalent, plus site-specific data collection by non-technical authors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaics.
R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing
Product / Service Performance Goals(s)	All new construction Zero Net Energy by 2030.
Background	Housing roofs and ceilings are a significant source for heat loss or gain. Improving attic insulation and ducting efficiency can improve overall housing energy efficiency by up to 30 per cent.
Goals	The two primary goals with this project are: 1) Improve understanding of residential attic and cathedral ceiling thermal performance and ducting performance; 2) Use this information to create a practical technical handbook outlining cost-effective methods to increase energy efficiency.
Scope	Conducted laboratory studies within Large Scale Climate Simulator (LSCS) by developing test module to simulate standard residential construction; used module to evaluate performance of different types of ducting and attic insulation in various climate conditions. Also evaluated steel-framed attic systems in comparison to wood framing.

Timeline	Project appears to be ongoing.
Milestones & Publications	Initial laboratory studies have validated ASHRAE 152P duct efficiency standard. Publications listed at http://www.ornl.gov/sci/ees/etsd/btric/publications.shtml.
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	
References	Oak Ridge National Laboratory (2012). "Residential Attics and Cathedral Ceilings." http://www.ornl.gov/sci/ees/etsd/btric/res_attics_cathedral_ceilings.shtml, accessed Jan. 4, 2012.

Vegetative Roofing System	**Building Technologies Research and Integration Center** **Project Overview:** Project initiated to quantify thermal performance of different kinds of vegetative roofing systems in comparison to black and white roofs. http://www.ornl.gov/sci/ees/etsd/btric

Institution	Oak Ridge National Laboratory	**Div. / Dept.**	Energy and Transportation Science Division
Contact	André O. Desjarlais Building Envelope Research Program Manager Oak Ridge National Laboratory P. O. Box 2008, MS 6070 Oak Ridge, TN 37831-6070 desjarlaisa@ornl.gov	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Solar/Smart Roofing

Project Details

R&D Program	Cool/photovoltaic/solar water heating roofing.
Product / Service Performance Gap(s)	Technology/price/standards. Need to match up home locations with Google Maps, global positioning system (GPS), or equivalent, plus site-specific data collection by non-technical authors, possibly the homeowner.
Product / Service Performance Goals(s)	Products readily available in marketplace at low cost. Intelligent buildings with photovoltaics.
Background	In light of recent growth in the interest in and application of green/vegetative roofing systems, ORNL developed this research project to compare directly the thermal performance of various kinds of low-slope vegetative roofing systems with standard black and white roofing systems. Project carried out in partnership with Single Ply Roofing Institute (SPRI) (http://www.spri.org/).
Goals	Provided quantitative information about the thermal insulative properties of vegetative roofing systems relative to standard roofing systems.
Scope	Evaluation of the cooling and heating loads per unit area of three different kinds of vegetative roofing systems, compared to black and white roofing systems and a test roof section containing growing media but not plants.
Timeline	First phase of project findings reported in 2010, research ongoing to develop predictive model.
Milestones & Publications	Project results reported in 2010 include the finding that vegetative roofing systems reduced temperature and temperature fluctuations relative to non-vegetative systems. Publications listed at http://www.ornl.gov/sci/ees/etsd/btric/publications.shtml
Budget	
Other parties involved	Single Ply Roofing Institute (SPRI) (http://www.spri.org/).

Next steps	Future research will use 2010 data to develop a model, and, when validated, this model will serve to forecast thermal insulation levels for various kinds of vegetative roofing systems in varied climates.
Associated R&D strategy	
References	Desjarlais, André O., Zaltash, Abdi, Atchley, Jerald A., and Ennis, Michael (2011). "Vegetative Roofing Systems." *Proceedings of the 25th RCI International Convention, March 23-30, 2011*. http://www.ornl.gov/sci/ees/etsd/btric/pdfs/ThermalPerfofVegetatedRoofSystems_Mar2010.pdf, accessed Jan. 3, 2011.

Cooling Heating & Power Technologies Program	Denise Overton Project Management Specialist http://www.coolingheatingpower.org	Contact: http://www.coolingheatingpower.org/contact/form.php

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 Page 132

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	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction Zero Net Energy by 2030.
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) Lighting Research Center Rensselaer Polytechnic Institute 21 Union St. Troy, NY 12180 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 • *[No specific current R&D projects listed as of Feb. 2012]* DesignWorks • *[No specific current R&D projects listed as of Feb. 2012]* Energy Efficiency • *[No specific current R&D projects listed as of Feb. 2012]* Health & Vision Page 134 • Quantifying the Impact of Light on K-12 Students' Performance and Well-being Lighting Metrics • *[No specific current R&D projects listed as of Feb. 2012]* Solid-State Lighting Page 137 • Estimating LED Life • Improving LED Light Output and Efficacy Through SPE™ • Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting Transportation Lighting and Safety Page 144 • Outdoor Lighting

Health & Vision	110 Eighth Street Troy, NY USA 12180 http://www.lrc.rpi.edu/researchAreas/healthVision.asp	(518) 276-6000 (o)
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.	
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 135

Quantifying the Impact of Light on K-12 Students' Performance and Well-being	**LHealth & Vision 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**	Lighting (General)

Project Details

R&D Program	Human factors—research on parameters for optimizing?
Product / Service Performance Gap(s)	Better light quality as perceived by users.
Product / Service Performance Goals(s)	Design lighting and luminaires to optimize the effectiveness for the task from the user's point of view.
R&D Program	Study health impacts of lighting.
Product / Service Performance Gap(s)	Optimize use of fluorescent, solid state lighting, halogen infrared technology by application.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in new buildings (through combination of more efficient light sources, more efficient luminaires, better controls, better application, and more use of natural light (long-term goal).
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

Professor Nadarajah Narendran, Ph.D.
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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.
	• Electronic Walls and Ceilings Offer Adaptable Solid-State Lighting Page 138
Estimating LED Life	Continued research into issues relating to longevity of LED lighting systems, such as component integration, optics, housings, and installation methods.
	• Estimating LED Life Page 140
Improving LED Light Output and Efficacy Through SPE™	Ongoing research and development of systems incorporating the Scattered Photon Extraction (SPE™) system to improve LED light output and efficacy.
	• Improving LED Light Output and Efficacy Through SPE™ Page 142

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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.
Product / Service Performance Gap(s)	Reduce cost. Increase efficiency. Improve stability over time.
Product / Service Performance Goals(s)	Standardized, affordable, reliable solid state lighting components allowing fixture designers wide freedom to innovate and meet consumer needs.
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	Research program received seed money in 2004; full-scale mock-up built in 2005; field study commenced in 2009 and scheduled to be completed in Fall 2011.
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 is scheduled to be completed Fall 2011.
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	
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 LED 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	Solid state lighting life extension.
Product / Service Performance Gap(s)	Better Color Rendering Index (CRI). Improve stability over time. Improve human maintenance.
Product / Service Performance Goals(s)	Target early, cost-effective applications.
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	Evaluate LEDs 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	
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.

Improving LED Light Output and Efficacy Through SPE™	**Solid State Lighting** **Project Overview:** Ongoing research and development of systems incorporating the Scattered Photon Extraction (SPE™) system to improve LED light output and efficacy. http://www.lrc.rpi.edu/programs/solidstate/speLED.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)**	U.S. Department of Energy High-Efficiency, Nitride-Based Solid-State Lighting program (http://www.lrc.rpi.edu/programs/solidstate/cr_nitridebasedssl.asp)
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	Improved light extraction.
Product / Service Performance Gap(s)	Better Color Rendering Index)(CRI). Improve stability over time. Increase efficiency.
Product / Service Performance Goals(s)	200 lm/W for 3500 Correlated Color Temperature (CCT) (50% of 80% goal (long-term goal)
Background	Standard white LEDs lose a significant amount of light through the scattering of photons back toward the semiconductor.
Goals	Identify optimally-shaped optics and determine placement of the phosphor away from the die so as to increase LED lumens and lifespan.
Scope	Research in this area includes applying the Scattered Photon Extraction (SPE™) method to improve color uniformity, evaluate multiple-phosphor LED packages, and develop luminaries.
Timeline	
Milestones & Publications	Researchers at LRC developed a way to improve light output and efficacy of white LEDs, the Scattered Photon Extraction (SPE™) method, in 2004. Since developing this method, LRC research teams continue to apply it to improve LED lights, including: • improve the spatial color uniformity of mixed-color LED systems (http://www.lrc.rpi.edu/programs/solidstate/cr_mixedColorLEDs.asp) • optimize performance through optical ray-tracing (http://www.lrc.rpi.edu/programs/solidstate/cr_optimizingPhosphor.asp) • understand the effects of phosphor layer order in multiple-phosphor LED packages (http://www.lrc.rpi.edu/programs/solidstate/cr_multiPhosphor.asp) • develop a snap-in LED module for outdoor luminaires (http://www.lrc.rpi.edu/programs/solidstate/cr_snapInPVLED.asp) • design a better recessed downlight

	(http://www.lrc.rpi.edu/programs/solidstate/cr_SPEDownlight.asp) • analyze phosphor treatments to close the LED "green gap" (http://www.lrc.rpi.edu/programs/solidstate/cr_greenPhosphor.asp) Research in this area has led to two patents: • U.S. Patent 7,703,942; April 27, 2010. High-efficient light engines using light emitting diodes. • U.S. Patent 7,750,359 B2; July 6, 2010. Package design for producing white light with short-wavelength LEDs and down-conversion materials.
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). This particular initiative was sponsored by the U.S. Department of Energy's High-Efficiency, Nitride-Based Solid-State Lighting program (http://www.lrc.rpi.edu/programs/solidstate/cr_nitridebasedssl.asp).
References	Lighting Research Center (2012). "Improving LED Light Output and Efficacy Through SPE™." http://www.lrc.rpi.edu/programs/solidstate/speLED.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 http://www.lrc.rpi.edu/programs/transportation/index.asp	(518) 687-7100 (o) (518) 687-7120 (f) bulloj@rpi.edu

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 145

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.
Product / Service Performance Gap(s)	Better light quality as perceived by users.
Product / Service Performance Goals(s)	Make mesopic lighting standards accessible to appropriate users.
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	
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 148

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	New Construction Building Design/Envelope	**Roadmap**	Manufactured Housing

Project Details

R&D Program	Innovative shop floor technologies similar to auto industry.
Product / Service Performance Gap(s)	Follow codes / code improvement. Panels that can be easily installed – spray-on. Elimination of duct work.
Product / Service Performance Goals(s)	Cheap, streamlined construction and installation of energy-efficient manufactured housing – reflecting best practices in other manufacturing industries.
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.
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.

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

California Lighting Technology Center

	Michael Siminovitch, Ph.D Director 633 Pena Drive Davis, CA 95618 http://cltc.ucdavis.edu/content/view/716/420/	(530) 747-3835 (o) (530) 747-3812 (f) mjsiminovitch@ucdavis.edu
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.	
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 152
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 153
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 155
Solatube Product Development	Project goal is to determine effective ways to reduce the glare of Tubular Daylighting Devices (TDDs).	
	• Solatube Product Development	Page 156

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	Core lighting project.
Product / Service Performance Gap(s)	Better light quality as perceived by users. More responsive controls, especially for horizontal daylighting.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in part due to combination of better controls, better application, and more use of natural light. Affordable, widely-available daylighting options.
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.
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.

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	Cheaper and simpler self-calibrating dimming controls.
Product / Service Performance Gap(s)	More responsive controls, especially for horizontal daylighting. Easier to design, commission, and operate.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in part due to combination of better controls, better application, and more use of natural light. Affordable, widely-available daylighting options.
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	
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.
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 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	Skylight design.
Product / Service Performance Gap(s)	Better light quality as perceived by users. More responsive controls, especially for horizontal daylighting. More responsive, reliable, long-lived controls for vertical daylighting. Easier to design, commission, and operate.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in part due to combination of better controls, better application, and more use of natural light. Affordable, widely-available daylighting options.
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	
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.

Solatube Product Development	**Project Overview:** Project goal is to determine effective ways to reduce the glare of Tubular Daylighting Devices (TDDs). http://cltc.ucdavis.edu/content/view/113/139/

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)**	California Energy Commission Public Interest Energy Research (CEC PIER)
Product / Service Area	Lighting	**Roadmap**	Daylighting

Project Details

R&D Program	Skylight design.
Product / Service Performance Gap(s)	Better light quality as perceived by users. More responsive controls, especially for horizontal daylighting. More responsive, reliable, long-lived controls for vertical daylighting. Easier to design, commission, and operate.
Product / Service Performance Goals(s)	80% reduction in average lighting electric use in part due to combination of better controls, better application, and more use of natural light. Affordable, widely-available daylighting options.
Background	Tubular Daylighting Devices (TDDs) do an effective job of capturing daylight through rootop transparent domes, and routing the light into interior rooms through reflective tubes. However, the light that comes into rooms can often be harsh, creating visual discomfort.
Goals	Project goals are to devise direct/indirect TDD diffuser options with which to conduct detailed photometric analyses; create two or three prototypes of commercially viable diffuser options for testing; perform detailed photometric testing and analysis on one commercially viable solution so as to quantify data required to support commercial launch; produce guidelines to support application and use of the diffuser.
Scope	CLTC has partnered with Solatube International Inc. devise and test technologies to reduce glare, including a direct/indirect diffuser. CLTC's research has included quantifying Solatube TDD performance; devising diffuser tests and simulations using HDR imaging and ray-tracing software; and providing recommendations for further testing and development of promising diffuser options.
Timeline	
Milestones & Publications	Analysis and testing thus far provided a diffuser solution that was an improvement over previous TDD performance, but the variability of light intensity and direction makes consistent product performance difficult. The technology is promising, but this research project ended before product could be refined sufficiently to make it available as a commercially-viable project.
Budget	
Other parties involved	Solatube International Inc. (http://www.solatube.com/).
Next steps	
Associated R&D strategy	
References	California Lighting Technology Center (2012). "Solatube Product Development ." http://cltc.ucdavis.edu/content/view/113/139/, accessed Jan. 20, 2012.

University of California Davis	One Shields Ave. Davis, CA 95616 http://www.ucdavis.edu/index.html	(530) 752-1011 (o)
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/). HVAC Maintenance, Fault Detection & Diagnostics — Page 157 • Fault Detection and Diagnostics: The Path to Commercialization	

HVAC Maintenance, Fault Detection & Diagnostics

Kristin Heinemeier
1450 Drew Avenue, Suite 100
Davis, California 95618

(530) 754-7667 (o)
kheinemeier@ucdavis.edu

Research Focus	Research and develop technologies and best practices to improve energy efficiency of HVAC units through advanced fault detection and diagnostics (FDD) systems.
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 158

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Fault Detection and Diagnostics: The Path to Commercialization	**HVAC Maintenance, Fault Detection & Diagnostics** **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	**Roadmap**	Fault Detection and Predictive Maintenance (3 of 3)

Project Details

R&D Program	Research to reduce maintenance.
Product / Service Performance Gap(s)	Don't' currently have "on-board" diagnostics or data streams to collect. Don't have redundant or corrective hardware.
Product / Service Performance Goals(s)	Predictive maintenance in 100% of new sales (short-term goal). Initial self-healing / correcting (medium-term). Intelligent systems with predictive diagnostic controls & self-healing processes.
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	
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.

University of California, San Diego	9500 Gilman Dr., La Jolla, CA 92093 http://www.ucsd.edu/	(858) 534-2230 (o)
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 Professor and Qualcomm Endowed Chair EBU3B Room 2120, 9500 Gilman Drive La Jolla, CA 92093-0404 http://www-cse.ucsd.edu/	(858) 822-4391 (o) rgupta@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 161
	• SleepServer	

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 162

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	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**	Sleep Mode

Project Details

R&D Program	Responsive to late-night network updates.
Product / Service Performance Gap(s)	Minimal user interaction required. Responsive to user needs and preferences.
Product / Service Performance Goals(s)	Optimize sleep mode energy impacts without degrading user experience. Reduce overall energy use by 65% relative to "always on" baseline.
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	
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.
Associated R&D strategy	
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 http://www.ucsb.edu/	(805) 893-8000 (o) http://www.ia.ucsb.edu/util/contact.aspx
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 http://iee.ucsb.edu/	(805) 893-4191 (o) (805) 893-7119 (f) information@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 165 • Economically viable Zero Net Energy building systems Lighting Solutions Group — Page 167 • Solid State Lighting	

Buildings & Design Solutions Group	Igor Mezic Solutions Group Head http://iee.ucsb.edu/research/building-systems	(805) 893-7603 (o) mezic@engineering.ucsb.edu

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 Page 166

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	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home Technology

Project Details

R&D Program	Predictive modeling to determine what knobs to have and control.
Product / Service Performance Gap(s)	Effective design.
Product / Service Performance Goals(s)	Easy-to-use tools and techniques to optimize contributions of energy efficiency and renewable generation on an individual dwelling unit scale.
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 http://iee.ucsb.edu/research/lighting-displays	(805) 893-8511 (o) denbaars@engineering.ucsb.edu

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 166

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.
Product / Service Performance Gap(s)	Better Color Rendering Index (CRI). Improve stability over time. Improve lumen maintenance. Increase efficiency.
Product / Service Performance Goals(s)	200 lumens per watt (lm/W) for 3500° Kelvin Correlated Color Temperature(CCT).
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.
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 — Page 170 • Appliances R&D • Advanced Controls R&D • Building Energy Software Tools Directory • Envelope Materials R&D • Envelope Systems R&D • Lighting R&D • Whole Building Design R&D	
	SunShot Initiative — Page 196	

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.	
Advanced Controls R&D	Research to optimize building energy performance by developing technologies to provide real-time monitoring and control.	
	• Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways	Page 173
	• Wireless Controls R&D (Wireless End-User Power Metering, Ambient Power Harvesting, Wireless Sensing and Control for HVAC Terminal Boxes, Wireless Infrastructure for Performance Monitoring, Diagnostics, and Control for Small Commercial Buildings)	Page 194
Appliances R&D	Supports research and development of energy-efficient appliances including refrigerators, clothes washers and dryers, and water heaters.	
	• Appliances R&D	Page 175
Building Energy Software Tools Directory	Directory of 405 software tools (as of Dec. 2011, and counting) used to track and evaluate energy efficiency, renewable energy, and sustainability.	
	• Building Energy Software Tools Directory	Page 177
Envelope Materials R&D	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.	
	• Cool Roofs	Page 183
	• Hygrothermal Property Measurements	Page 185
	• Improved Performance and Application of Conventional Insulation Materials	Page 186
Envelope Systems R&D	Help propel research in the full range of building envelope systems (roof, wall, and foundation); 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.	
	• Advanced Envelope Systems	Page 171
	• Building Envelope Moisture Control Technologies	Page 179
	• Residential Attic and Cathedral Ceiling Research	Page 190
Lighting R&D	Collaborates with manufacturers and other research and development institutions to devise technologies and best practices for advanced, energy efficient lighting systems.	
	• Commercial Lighting Solutions	Page181
	• Next Generation Luminaires™ (NGL) Solid State Lighting (SSL) Design Competition	Page 188
	• Solid State Lighting	Page 192

Advanced Envelope Systems	**Building Technologies Program (BTP), Envelope Systems R&D** **Project Overview:** lorem http://www1.eere.energy.gov/buildings/systems_advanced.html		
Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Envelope Systems R&D (http://www1.eere.energy.gov/buildings/systems_rd.html) program providing test facilities and protocols so that designers and builders can evaluate the energy efficiency of new wall systems.
Goals	Establish the technology base requirements for high thermal performance wall systems and work with the building industry, product manufacturers, and code groups to increase the availability and use of innovative materials.
Scope	Initiative includes efforts to replace non-chlorofluorocarbon (CFC)/ hydrofluorocarbon (HCF) products, develop high-performing thermally broken steel-stud wall systems, and provide Internet-based database of products, performance, and specifications.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	

Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Envelope Systems R&D." http://www1.eere.energy.gov/buildings/systems_rd.html, accessed Jan. 12, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Advanced Envelope Systems." http://www1.eere.energy.gov/buildings/systems_advanced.html, accessed Jan. 12, 2012.

Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways	**Building Technologies Program (BTP), Advanced Controls R&D** **Project Overview:** Research to optimize building energy performance by developing technologies to provide real-time monitoring and control. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/pnnl-15149_market_assessment.pdf

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Research was needed to identify R&D options, provide market assessments, and evaluate energy savings from advanced building controls and sensors, so as to help develop a focused, five-year R&D roadmap.
Goals	To provide: market analysis; current and potential technology applications; hardware options; networking issues; and outline a process for installing building control monitors.
Scope	Integrating previous findings on the above issues.
Timeline	Report published in April 2005.

Milestones & Publications	Building Technologies Program staff reported that the findings of the following report were being integrated into the development of a formal five-year R&D plan: Brambley, M.R., *et al.* (2005, April). "Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways." Richland, WA: U.S. Department of Energy, Pacific Northwest National Laboratory.
Budget	
Other parties involved	Pacific Northwest National Laboratory
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	Brambley, M.R., *et al.* (2005, April). "Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways." Richland, WA: U.S. Department of Energy, Pacific Northwest National Laboratory. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/pnnl-15149_market_assessment.pdf, accessed Jan. 12, 2012.

Appliances R&D

Building Technologies Program (BTP)

Project Overview: Supports research and development of energy-efficient appliances including refrigerators, clothes washers and dryers, and water heaters.

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

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	The DOE's Buildings Energy Data Book (http://buildingsdatabook.eren.doe.gov/) indicates that appliances account for a significant amount of energy consumption in the average American household.
Goals	Ongoing research and development sponsored by DOE's Building Technologies Program (BTIP) seeks to create energy efficient refrigerators, clothes washers and dryers, water heaters, and other appliances and to foster the adoption of these appliances.
Scope	BTIP works with industry to develop technologies, enhanced appliance controls, and strategies for appliance integration.
Timeline	Projects are ongoing.
Milestones & Publications	BTIP worked with manufacturers and staff at t he Oak Ridge National Laboratory to develop a "Drop-in" residential heat pump water heater (HPWH) capable of being much more efficient than conventional electric water heaters; for more details see http://www1.eere.energy.gov/buildings/water_heating.html.
Budget	
Other parties involved	Oak Ridge National Laboratory and various manufacturers.

Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Building Technologies Program (2012). "Appliances R&D." http://www1.eere.energy.gov/buildings/appliances_rd.html, accessed Jan. 12, 2012. U.S. Department of Energy Building Technologies Program (2012). "Water Heating R&D." http://www1.eere.energy.gov/buildings/water_heating.html, accessed Jan. 12, 2012.

Building Energy Software Tools Directory	**Building Technologies Program (BTP)** **Project Overview:** Directory of 405 software tools (and counting, as of Dec. 2011) used to track and evaluate energy efficiency, renewable energy, and sustainability. http://apps1.eere.energy.gov/buildings/tools_directory/

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	Mail Stop EE-2J 1000 Independence Ave, SW Washington, DC 20585 (202) 586-9127 (o) Email: http://www1.eere.energy.gov/buildings/contacts.html	**Sponsor(s)**	
Product / Service Area	Retrofit Building Design/Envelope	**Roadmap**	Labeling Technology
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	Test –new tools for modeling that are attempting new approaches to computer applications.
Product / Service Performance Gap(s)	Get stakeholders to adopt.
Product / Service Performance Goals(s)	20% of homes meet standard (medium-term goal).
R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	DOE developed this resource to centralize the listing of Office of Building Technology, State and Community Program (BTS) software tools used to analyze and rank energy efficiency technologies and renewable energy strategies in new and existing buildings. There were fifty tools listed in the first version of the directory (August 1996), many of which were sponsored by DOE at one time or another.
Goals	To provide a regularly-updated directory of software tools available to researchers, designers, architects, engineers, builders, code officials, and other professionals involved in building life-cycle planning and evaluation.
Scope	The directory contains an array of internationally-produced modeling software tools developed for the PC, Mac, and UNIX platforms and the Internet. The tools are grouped in a variety of subject areas, including Whole Building Analysis; Codes, Standards, Materials, Components, Equipment, & Systems; and Other Applications (i.e., Atmospheric Pollution, Energy Economics, Indoor Air Quality, and many others).

Timeline	DOE provides ongoing directory updates as new tools are available.
Milestones & Publications	The directory includes more software programs (405) than can be accurately and efficiently linked to proposed R&D programs within the Labeling Technology Roadmap. One can search the directory at http://apps1.eere.energy.gov/buildings/tools_directory/.
Budget	
Other parties involved	Various international entities and organizations are involved in producing the tools listed in this directory.
Next steps	DOE provides ongoing directory updates as new tools are available.
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy (2011). "Building Energy Software Tools Directory." http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm, accessed Dec. 19, 2011.

Building Envelope Moisture Control Technologies	**Building Technologies Program (BTP), Envelope Systems R&D** **Project Overview:** lorem http://www1.eere.energy.gov/buildings/systems_control.html

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Envelope Systems R&D (http://www1.eere.energy.gov/buildings/systems_rd.html) program providing strategies and technologies to address the energy efficiency and other issues related to moisture.
Goals	Devise approaches and tools to manage moisture in building envelopes and thereby enhance energy efficiency (as well as prolonging material life).
Scope	Project seeks to characterize moisture control in building envelope systems and also develop a specialized hygrothermal-durability model to predict long-term performance and develop wall system moisture management guidelines applicable to climate zones across North America.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	

Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Envelope Systems R&D." http://www1.eere.energy.gov/buildings/systems_rd.html, accessed Jan. 12, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Building Envelope Moisture Control Technologies." http://www1.eere.energy.gov/buildings/systems_control.html, accessed Jan. 12, 2012.

Commercial Lighting Solutions	**Building Technologies Program (BTP), Commercial Building Initiative** **Project Overview:** Interactive web-based tool designed as part of the Commercial Building Initiative (http://www1.eere.energy.gov/buildings/commercial_initiative/about.html) to help building owners improve energy efficiency through lighting solutions. http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=168

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	U.S. Department of Energy Building Technologies Program (BTP) Mail Stop EE-2J 1000 Independence Ave, SW Washington, DC 20585 (202) 586-9127 webmasterbtp@nrel.gov	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Luminaires

Project Details

R&D Program	Review and audit of various luminaire designs for various lighting applications.
Product / Service Performance Gap(s)	Market needs to be rewarded for efficient luminaires. Change common metrics from source efficacy to luminaire efficacy. Use Fitted Target Efficacy (FTE) (lm/W) for outdoor lighting.
Product / Service Performance Goals(s)	In residential sector, begin shifting emphasis from efficient sources to efficient luminaires.
Background	Out of the estimated 18% of total U.S. energy use that commercial buildings consume; lighting consumes 25% of the commercial sector's energy use, making it the largest single component and accounting for 42% of the cooling load of commercial buildings.
Goals	Develop an easy-to-use Internet application to improve energy efficiency in commercial buildings by improving lighting efficiency by at least 30% over ASHRAE 90.1-2004.
Scope	The Commercial Lighting Solutions Internet application, currently in Beta testing, allows users to test building re-lamping and retrofit options to determine energy saving estimates. The tool can also be used to determine eligibility to receive the 179D Tax Deduction, as established by the Energy Policy Act of 2005.
Timeline	Beta testing appears to be ongoing since 2009.
Milestones & Publications	The Beta version of the Commercial Lighting Solutions app was launched in May 2009. Commercial Lighting Solutions is the first commercial technology solution launched within the DOE's Net-Zero Energy Commercial Building Initiative (CBI) (http://www1.eere.energy.gov/buildings/commercial_initiative/index.html).
Budget	

Other parties involved	DOE partnered with designers, architects, and commercial end-users to develop this application.
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2009, May 5). "DOE Releases Commercial Lighting Solutions Web Tool for Commercial Buildings." http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=168, accessed Jan. 17, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Commercial Lighting Solutions (beta)." https://www.lightingsolutions.energy.gov/comlighting/login.htm;jsessionid=F69C1181726235B410505D343FA08F32.jvm3, accessed Jan. 17, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Commercial Building Initiative." http://www1.eere.energy.gov/buildings/commercial_initiative/about.html, accessed Jan. 17, 2012.

Cool Roofs

Building Technologies Program (BTP), Envelope Materials R&D

Project Overview: Develop roofing products and technologies to improve building energy efficiency.

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

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Research has shown that replacing conventional, dark roofing materials can significantly reduce building energy use, lower peak energy demands, and provide other benefits. Since the mid-1980s, the DOE's Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory have been engaged in R&D on light-colored roofing products and solar radiation roof control coatings.
Goals	To develop and evaluate materials and systems to maximize solar reflectance (to reflect, rather than absorb, sunlight) and thermal emittance (cooling efficiency) so as to bring about reduced air conditioning needs inside of buildings, which will, in turn, increase building energy efficiency and reduce peak demand.
Scope	Initiatives involve software systems to design, monitor, and evaluate roofing systems; improved roofing materials; and best practices.
Timeline	
Milestones & Publications	Software tools, publications, ENERGY STAR-compliant materials, and other resources can be found at http://www1.eere.energy.gov/buildings/cool_roofs.html.
Budget	
Other parties involved	Lawrence Berkeley National Laboratory (http://www.pnl.gov/) and Oak Ridge National Laboratory (http://ornl.gov/).

Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Cool Roofs." http://www1.eere.energy.gov/buildings/cool_roofs.html, accessed Jan. 12, 2012.

Hygrothermal Property Measurements	**Building Technologies Program (BTP), Envelope Materials R&D** **Project Overview:** Project to develop a laboratory to provide measurements of hygrothermal properties of building materials that can then be incorporated into models. http://www1.eere.energy.gov/buildings/envelope_hygrothermal.html

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	U.S. Department of Energy Building Technologies Program (BTP) Mail Stop EE-2J 1000 Independence Ave, SW Washington, DC 20585 (202) 586-9127 http://www1.eere.energy.gov/buildings/contacts.html	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Accurate data is needed on building material moisture transport so that accurate models can be developed, in order to improve overall building energy efficiency.
Goals	Develop laboratory to measure hygrothermal properties accurately, and then transfer this data into modeling software.
Scope	Measure such properties as: moisture capacity of a given building material as a function of temperature and relative humidity; water vapor permeability; liquid diffusivity; liquid uptake; and two-dimensional distributions of moisture.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Hygrothermal Property Measurements ." http://www1.eere.energy.gov/buildings/envelope_hygrothermal.html, accessed Jan. 12, 2012.

Improved Performance and Application of Conventional Insulation Materials	**Building Technologies Program (BTP), Envelope Materials R&D** **Project Overview:** Improve building energy efficiency by improving systems and practices to apply and use conventional insulation materials. http://www1.eere.energy.gov/buildings/envelope_conventional.html

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Applying and using conventional insulation materials can result in significant energy efficiency.
Goals	Evaluate existing materials to produce and update fact sheet and related data; encourage the adoption of best practices.
Scope	Scope of the project is to: 1) evaluate existing and advanced insulation materials using at the Oak Ridge National Laboratory; 2) devise new ways to test material thermal and other properties; 3) serve as a conduit for the dissemination and sharing of data; 4) encourage adoption of best practices and systems.
Timeline	Ongoing research in this area supports the ASTM C-16 Committee on Thermal Insulation (http://www.astm.org/COMMIT/COMMITTEE/C16.htm).
Milestones & Publications	DOE's Insulation Fact Sheet (first published in 1998, in 2002) promotes appropriate use of insulation materials; recommendations from this fact sheet are often used in building codes and manufacturer's literature. Fact sheet at: http://www.ornl.gov/sci/roofs+walls/insulation/ins_08.html.

Budget	
Other parties involved	Oak Ridge National Laboratory (http://ornl.gov/).
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Improved Performance and Application of Conventional Insulation Materials." http://www1.eere.energy.gov/buildings/envelope_conventional.html, accessed Jan. 12, 2012.

Next Generation Luminaires™ (NGL) Solid State Lighting (SSL) Design Competition	**Building Technologies Program (BTP), Lighting R&D** **Project Overview:** Annual DOE-sponsored competition to promote the design and development of energy-efficient solid state lighting. http://www.ngldc.org/

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	U.S. Department of Energy Building Technologies Program (BTP) Mail Stop EE-2J 1000 Independence Ave, SW Washington, DC 20585 (202) 586-9127 ngl@pnl.gov	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Luminaires

Project Details

R&D Program	Review and audit of various luminaire designs for various lighting applications.
Product / Service Performance Gap(s)	Market needs to be rewarded for efficient luminaires. Change common metrics from source efficacy to luminaire efficacy. Use Fitted Target Efficacy (FTE) (lm/W) for outdoor lighting.
Product / Service Performance Goals(s)	In residential sector, begin shifting emphasis from efficient sources to efficient luminaires.
Background	DOE (represented by the Pacific Northwest National Laboratory (PNNL)) has worked with co-sponsors Illuminating Engineering Society (IES) and International Association of Lighting Designers (IALD) to organize and hold this competition since 2008.
Goals	The goal of this program is to encourage technical innovation in solid state lighting design, functionality, and energy efficiency by promoting and recognizing advanced light-emitting diode (LED) luminaires for commercial, industrial and institutional uses.
Scope	Evaluators grade entrants based upon color appearance and rendering; appropriate illuminance and luminance; serviceability and replacement; energy efficiency; product depreciation data; dimmability; cost; and aesthetic appearance and style. Luminaire categories cover both indoor and outdoor applications, and include: track; recessed; wall washing; decorative wall grazing; decorative pendant; decorative wall; general illumination; industrial; street and area; and others.
Timeline	Project is ongoing, with notable products recognized annually.
Milestones & Publications	In its first year, twenty-two products were recognized from 68 entries. Entries nearly doubled in 2009, as the amount of commercial light-emitting diode (LED) products on the market grew to 126 (from sixty companies); fourty-three of these were recognized as winners and four were named as "best in class." In 2010, forty-two of 138 products were recognized, four of which received "best in class" designations. 2011 competition winners identified at http://www.ngldc.org/10/winners.stm.

Budget	
Other parties involved	Illuminating Engineering Society (IES) (http://www.iesna.org/); International Association of Lighting Designers (IALD) (http://www.iald.org/); Pacific Northwest National Laboratory (http://www.pnl.gov/).
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Next Generation Luminaires." http://www.ngldc.org/, accessed Jan. 12, 2012.

Residential Attic and Cathedral Ceiling Research	**Building Technologies Program (BTP), Envelope Systems R&D** **Project Overview:** lorem http://www1.eere.energy.gov/buildings/systems_ceiling.html		
Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Envelope Systems R&D (http://www1.eere.energy.gov/buildings/systems_rd.html) program to devise systems and technologies to reduce energy losses through ceilings and attic ducting.
Goals	Previous research has quantified typical attic duct inefficiencies; this project will assess the energy efficiency gains from an innovative duct system installed in a conventional residential attic.
Scope	Project will lead to increased understanding of thermal performance in residential attics and cathedral ceilings (including duct work), and apply this knowledge to develop a design and renovation best practices guide to improve energy efficiency.
Timeline	
Milestones & Publications	
Budget	
Other parties involved	

Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Envelope Systems R&D." http://www1.eere.energy.gov/buildings/systems_rd.html, accessed Jan. 12, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Residential Attic and Cathedral Ceiling Research." http://www1.eere.energy.gov/buildings/systems_ceiling.html, accessed Jan. 12, 2012.

Solid State Lighting	**Building Technologies Program (BTP), Lighting R&D** **Project Overview:** Program to help spur the development and introduction of cost-effective solid state lighting systems. http://www1.eere.energy.gov/buildings/ssl/sslbasics_randd.html

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	Lighting	**Roadmap**	Solid State Lighting

Project Details

R&D Program	The DOE Office of Energy Efficiency & Renewable Energy provides an annually-updated Solid State Lighting Manufacturing R&D Roadmap (http://www1.eere.energy.gov/buildings/ssl/projects.html) that address ongoing work in at least the following areas identified in the Northwest Energy Efficiency Roadmap Portfolio: Improved light extraction; better fixture design; solid state lighting heat dissipation; substrate growth.
Product / Service Performance Gap(s)	Reduce cost. Increase efficiency. Better Color Rendering Index (CRI). Improve stability over time. Improve human maintenance.
Product / Service Performance Goals(s)	Standardized, affordable, reliable solid state lighting components allowing fixture designers wide freedom to innovate and meet consumer needs. 200 lm/W for 3500 Correlated Color Temperature (CCT) (50% of 80% goal) (long-term goal). Target early, cost-effective applications.
Background	Lighting R&D (http://www1.eere.energy.gov/buildings/lighting.html) program focused on working with partners in industry, academia, and government to direct DOE funding to an array of promising solid state lighting projects.
Goals	To spur research and development in a wide array of areas applicable to solid state lighting and thereby get energy efficient technologies into the marketplace as quickly as feasible.
Scope	DOE takes two complementary approaches. One is to foster core technology research at universities, national laboratories, and other research institutions to fill technology gaps and overcome technical barriers. The second is to work primarily with industry to apply the core technology research so as to introduce new technologies into the marketplace or enhance existing technologies.
Timeline	
Milestones & Publications	The DOE, in partnership with stakeholders, has developed a mult-year funding and research plan (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2011_web.pdf) and a manufacturing roadmap (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_manuf-roadmap_july2011.pdf, updated annually) to foster development of solid state lighting technologies.
Budget	

Other parties involved	National laboratories, universities, research institutions, and various manufacturers.
Next steps	Manufacturing Roadmap is updated annually, the most recent version is from July 2011.
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Lighting R&D." http://www1.eere.energy.gov/buildings/lighting.html, accessed Jan. 12, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Solid State Lighting R&D Projects." http://www1.eere.energy.gov/buildings/ssl/projects.html, accessed Jan. 12, 2012. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2011, July). "Solid State Lighting Research and Development: Manufacturing Roadmap." http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_manuf-roadmap_july2011.pdf, accessed Jan. 12, 2012.

Wireless Controls R&D	**Building Technologies Program (BTP), Advanced Controls R&D** **Project Overview:** Research to optimize building energy performance by developing wireless technologies to provide real-time monitoring and control. http://www1.eere.energy.gov/buildings/wireless_rd.html

Institution	U.S. Department of Energy	**Div. / Dept.**	Office of Energy Efficiency & Renewable Energy
Contact	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	**Sponsor(s)**	
Product / Service Area	New Construction Building Design/Envelope	**Roadmap**	Net Zero Energy Home

Project Details

R&D Program	2030 Challenge.
Product / Service Performance Gap(s)	Effective design. New technology. Architect and engineers, installers, code/manufacturing.
Product / Service Performance Goals(s)	All new construction zero energy by 2030 (long-term goal).
Background	Wireless building controls offer the potential of saving both costs and time associated with wired controls, while also offering users greater flexibility.
Goals	To provide wireless control systems that are easier to use that facilitate personalized indoor environments such as tailored heating and lighting levels.
Scope	DOE-sponsored research on wireless controls at the Pacific Northwest National Laboratory (http://www.pnl.gov/) is progressing in the following categories: Wireless End-User Power Metering; Ambient Power Harvesting; Wireless Sensing and Control for HVAC Terminal Boxes; Wireless Infrastructure for Performance Monitoring, Diagnostics, and Control for Small Commercial Buildings
Timeline	
Milestones & Publications	
Budget	
Other parties involved	Pacific Northwest National Laboratory (http://www.pnl.gov/); Southern California Edison (http://www.sce.com/); Hines GS Properties, Inc. (http://www.hines.com/home/default.aspx); Inovonics Wireless Corporation http://www.inovonics.com/); NorthWrite Inc. (http://www.northwrite.com/); Sensor IQ (http://sensoriq.com/technology.html); Trane

	(http://www.trane.com/index.aspx); Texas A&M University Energy Systems Laboratory (http://esl.eslwin.tamu.edu/)
Next steps	
Associated R&D strategy	The DOE's Office of Energy Efficiency and Renewable Energy (EERE) oversees the maintenance of the directory. The EERE's mission is to invest in "clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil" (http://www.eere.energy.gov/).
References	U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (2012). "Wireless Controls R&D." http://www1.eere.energy.gov/buildings/wireless_rd.html, accessed Jan. 12, 2012.

SunShot Initiative	Ramamoorthy Ramesh, Director U.S. Department of Energy– SunShot Initiative 1000 Independence Avenue, SW Washington, DC, 20585 http://www1.eere.energy.gov/solar/sunshot/	(202) 287-1862 (o) solar@ee.doe.gov

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)