Selected Outcomes

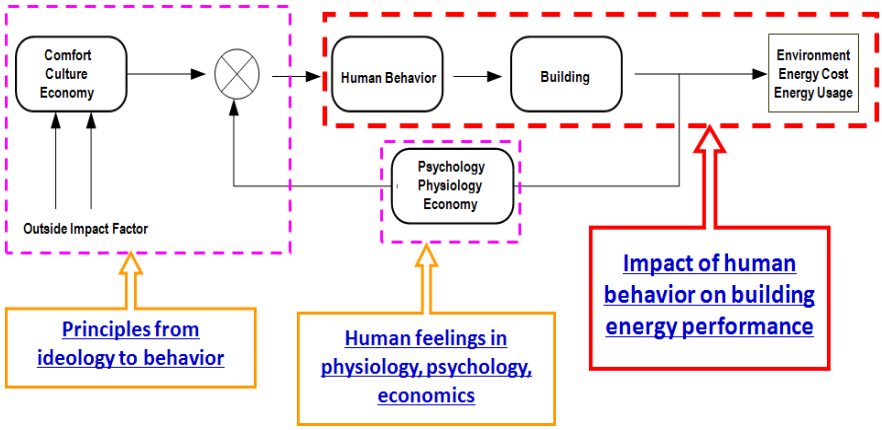
U.S. China Clean Energy Research Center (CERC)
Buildings Energy Efficiency Consortium (BEE)

January 2014

1. Building Design [Research Topic A]

- ***1.1 Human Behavior—Building energy modeling tools improved by integrating human behavior:***

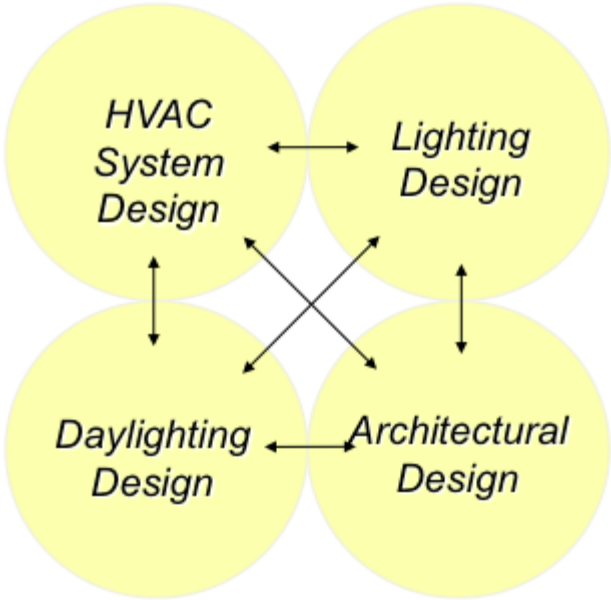
CERC researchers from Lawrence Berkeley National Laboratory (LBNL) and Tsinghua University studied human behavior in building energy systems. The studies determined that the largest variable in building operating efficiency, compared to design, is the human factor. Researchers developed new methods and simulation tools to characterize human behavior and quantify its relative impact on building energy performance. The tools and findings support the development of effective energy codes and efficient building designs that can significantly reduce energy consumption. Based on these results, the team improved the Designer's Simulation Toolkit (DeST) and EnergyPlus designer simulation tools to integrate human behavior into design calculations, potentially reducing energy use in new buildings up to 70% and pointing to opportunities for improved control systems in existing buildings. Building upon the CERC research, LBNL and Tsinghua University are jointly leading a new International Energy Agency (IEA) Energy Business Council (EBC) Annex 66 Definition and Simulation of Occupant Behavior in Buildings, with participants from 23 countries.



Incorporating human behavior in modeling tools to improve building operating efficiency

- ***1.2 Integrated Design—Protocols and design tools for very low energy buildings:***

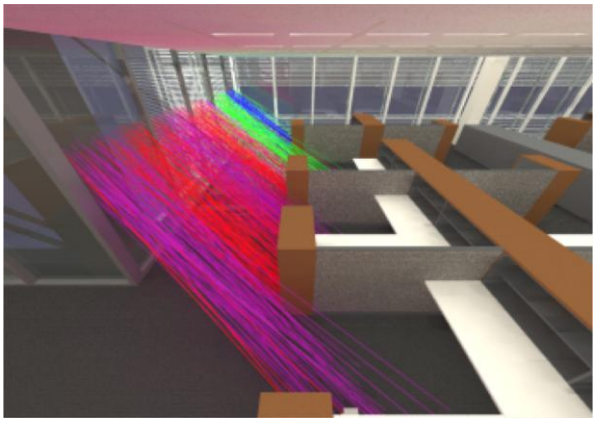
Building integrated design and operations are key to achieving energy savings. CERC researchers from LBNL, Tsinghua University, and Bentley Systems studied actual energy performance of 51 high performance buildings in the United States, China, other regions of Asia, and Europe, and determined that: 1) buildings with high performance ratings did not necessarily consume less energy; 2) energy use intensities of these buildings vary by a factor of more than ten; 3) there is no a single factor determining energy use in buildings; 4) simply adding more building technologies may not lead to low energy use and; 5) integrated design, operations, and human behavior in buildings is the key to achieving superior energy performance. Based on these results, CERC researchers provided guidance to improve the design of very low energy use demonstration buildings in China.



Design tools that help increase energy savings

2. Building Envelope [Research Topic B]

- ***2.1 Windows—Window modeling tools facilitate performance-based design of integrated facades for commercial buildings, resulting in perimeter energy reduction of 15%–30%:*** LBNL researchers trained researchers at Tongji University and Saint-Gobain Research Shanghai, on the use of recently developed modeling tools for advanced switchable chromogenic windows and optically-complex fenestration systems, such as shading and daylighting systems. WINDOW, EnergyPlus, and COMFEN tools enabled end users to model any arbitrary combination of glazing and shading layers based on measured spectral and light-scattering (bidirectional scattering distribution function) solar-optical data, improving engineering confidence in specifying such systems in both the United States and China. The software

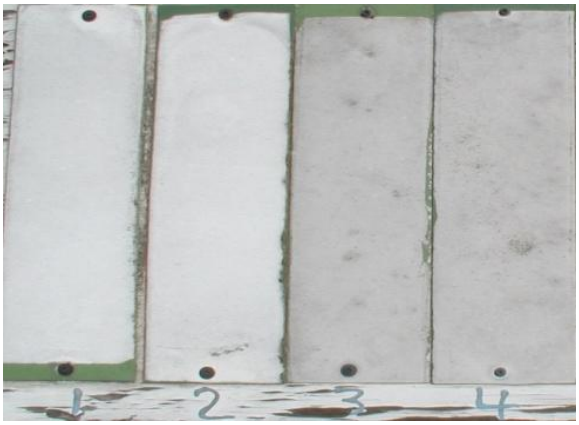

Advanced switchable chromogenic windows

tools were used in the planning stages of a low-energy demonstration of Sage Electrochromic windows in the new Saint-Gobain Research Shanghai headquarters building.

- ***2.2 Insulation—Dow Chemical and ORNL are developing a sprayable liquid flashing:*** this new material will contribute to increasing the air-tightness of commercial and residential buildings in the United States and China; reduce energy consumption by decreasing heating and cooling loads due to air leakage through the building envelope; achieve cost-effectiveness through shorter installation time and improved workmanship due to ease of use; be environmentally friendly given that its water-based formulation utilizes low volatile organic compound (VOC) technology and; likely attain a patent.

Liquid sprayable flashing technology

- ***2.3 Cool Roofs—High-performance, long life, energy-saving cool roof materials are being developed for the Chinese and U.S. markets.*** CERC researchers from the U.S. (LBNL, ORNL, and Dow Chemical) and China (Chongqing University [CU], Guangdong Provincial Academy of Building Research [GPABR] and China Academy of Sciences [CAS]) are developing improved white (cool) roof coatings with superior reflectance, durability, and self cleaning properties for U.S. and Chinese markets, and quantifying how they can save energy, cool cities, and slow global warming. Dow and ORNL have made substantial progress incorporating superhydrophobic (water repellent) materials in high-albedo elastomeric roof coatings with potential to stay clean in polluted urban environments. To speed up prototype testing and improvement, LBNL has developed a calibrated laboratory device that rapidly measures the soiling resistance of roof coatings. In 2012, LBNL, GPABR and CU measured and simulated building energy savings attained by reducing roof solar heat gain (the 'direct' benefit). In 2013, LBNL and CAS started modeling the ability of cool roofs to lower outside air temperatures in Chinese cities (the 'indirect' benefit), and to cool the planet by reflecting more sunlight to space ('global cooling').



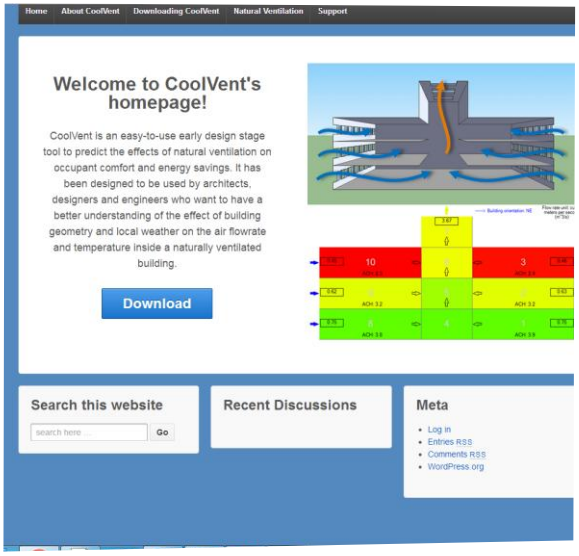
Cool roof coatings

3. Building Equipment [Research Topic C]

- ***3.1 Advanced Lighting Controls—LBNL researchers produced technical specifications and functional requirements for the Proof-of-Concept (POC) lighting control systems:*** Industrial partner Lutron has developed two Proof-Of-Concepts to be tested in Year 2: a dimmable, fully automated lighting control system for maximum energy savings and added functionality and; a simpler, less expensive switching system that will be semi-automatic and tailored to the requirements of the Chinese building market. In the proposed work for Year 2, the project will implement a unique experimental design that combines a monitored advanced lighting controls demonstration at the CARB in Beijing with a detailed testing program at LBNL's unique FlexLab facility. [Promising - cases for the two POCs will be initially tested at FlexLab in summer 2014 and lessons learned from these tests will be used to inform the operational sequences demonstrated at CABR Building later in Year 2. Conversely, the lessons learned from the demonstration at CABR will be captured and used to inform U.S. efforts to upgrade and modernize its commercial lighting building infrastructure.] It is estimated that 40 Terra Watt-hour (TWh) of lighting energy can be saved annually in the U.S. at 25% penetration of lighting controls, with energy savings of 15 TWh/yr in China, for a total of 55 TWh in U.S. and China and 38 Million Metric Ton (MMT) of avoided carbon dioxide annually.

Advanced lighting control technology

- ***3.2 Natural Ventilation—Tailored software package improves design and optimizes control and occupant comfort of hybrid ventilation in commercial buildings:*** CERC researchers from Massachusetts Institute of Technology (MIT) in the U.S. working in collaboration with Chinese universities and developers (Chongqing University, Tongji University, Shenzhen Institute of Building Research) developed an upgraded building design software tool that promotes the use of natural ventilation systems, which can increase energy efficiency and improve indoor climatic conditions. Although natural ventilation has great potential to reduce energy use for cooling, applications have been limited by a lack of design tools and control algorithms for architects and engineers. The design software tool by MIT strives to satisfy this need. The software tool



Software tools to encourage natural ventilation systems

simulates ventilation fans and chimneys, air conditioning units and different fenestration configurations, predicting the effects on internal temperatures and airflow rates in buildings. In addition, it optimizes the control of common ventilation strategies which take advantage of thermal mass in the building, considering energy consumption and thermal comfort standards. The tool has been successfully used in the design and control of a new office building in central Tokyo. The tool will be applied to the design of the first net zero energy office building in Massachusetts and new developments in Zhuhai, Wuhan, and Chongqing. The tool is also being used in major U.S. universities and in architectural firms including SOM. The work will be highlighted through a new IEA annex on ventilative cooling and a new web site.

4. Renewable Energy Utilization / Distributed Generation [Research Topic D]

- ***4.1 Ground Source Heat Pump—Improved efficiency and cost of ground-source heat pumps reduced system energy use by more than 30%:*** CERC researchers from the U.S. (ORNL & ClimateMaster) and China (Chongqing, Tainjin & Tongji Universities) evaluated emerging ground-source heat pump (GSHP) technologies in both the United States and China, pointing to technology advancements in heat exchangers and improvements in GSHP efficiency and cost. Researchers identified alternative ground heat exchangers that require 21%–36% less drilling depth compared with conventional ground heat exchangers while retaining the same performance. Through in-depth case studies of various GSHP systems in both countries, best practices are identified for improving operational energy efficiency and performance monitoring for GSHP systems. By participating in demonstrations in the other's territory, this work also established a foundation for commercial cooperation in areas of mutual benefit. (AR 2012-2013, page F16, Appx F: BEE project number D2)

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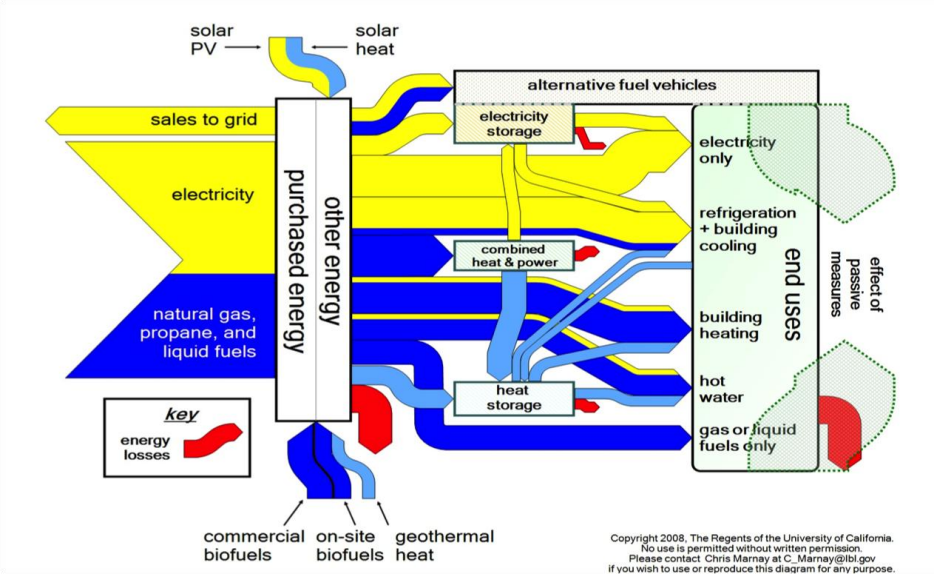
- ***4.2 Building Integrated Renewable Energy and Micro Grid—Optimized renewable energy technology selection, integration, and operation in real time:*** Researchers at LBNL, Tongji University, and industry partners at C3 and XingYe in China used LBNL's Distributed Energy Resources Customer Adoption Model (DER-CAM) tool to assess the potential of solar

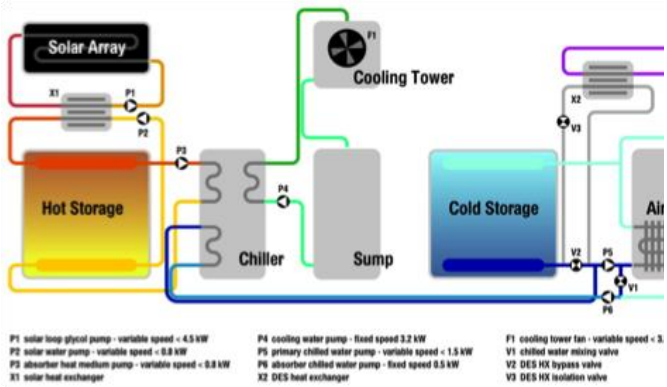


Market assessment tools that provide valuable information on the potential uptake of emerging technologies

thermal technology in 11 diverse climate cities in China. This policy analysis or market assessment tool is a powerful source of estimated market potential for emerging technologies. Unlike simple technical assessments, this approach is able to gauge the outcome of competition between alternative available technologies for certain building types of certain sizes in specific climate and economic conditions. If sound data that provides information on the makeup of the building fleet is available, it can be extrapolated to markets or other regions. The approach is particularly powerful for assessing the potential for penetration of technologies in the highly heterogeneous commercial building sector. On the U.S. side, this approach has been used to establish a standard set of representative commercial buildings based on U.S. DOE's Reference Buildings. C3 Energy is commercializing this capability as a means of offering energy efficiency and on-site generation investment suggestions to electricity utility customers.

5. Whole Building [Research Topic E]

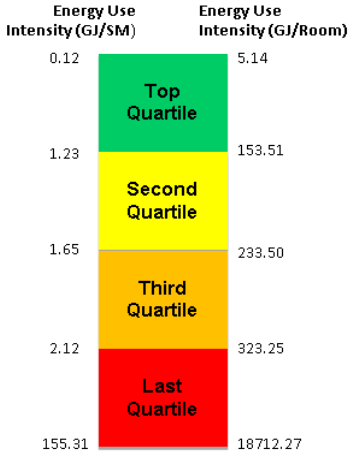
- ***5.1 Energy Systems and Technology for Demonstration Projects—Optimization and evaluation of energy system and operation:*** Researchers at LBNL (U.S.) and Tianjin University (China) have developed a Web-based tool to make a simple investment and planning version of DER-CAM for the optimization and control of building equipment and microgrids. The model, called WebOpt, is freely available on the web and has a Chinese language interface. There are over a hundred users applying the Chinese version. DER-CAM is currently being extended to optimize overall building control using a cloud tool that optimizes the operation of complex buildings as a software service. This integrated approach has been demonstrated to lower energy costs by 30% at a University of New Mexico campus building, which implements the optimized schedules directly in its building energy management system. The demonstration is being extended to four additional NM buildings, and one on the Tianjin University campus. Plans are to use the same technology in future MOHURD demonstration buildings.



Tools that help optimize and evaluate energy systems

6. Policy, Market Promotion [Research Topic F]

- ***6.1 Integrated Building Design & Operation—Commercial building energy use tool developed:*** Benchmarking tools for hotels and commercial offices in China were completed by CERC researchers from ICF International (U.S.) and Tsinghua University (China). The tools account for key drivers of energy use, including size, location, and number of workers, and incorporate data from hundreds of Chinese hotels and offices. Researchers are now utilizing the tools to identify the key design, technology, and operations and management (O&M) characteristics of very low-energy buildings in China. These will help inform new policies for designing and operating more efficient buildings. There is significant potential for energy and CO_2 emissions reductions identified by the tools, which can lead to market opportunities for green technology suppliers in both the United States and China.



Benchmarking tools developed for commercial buildings