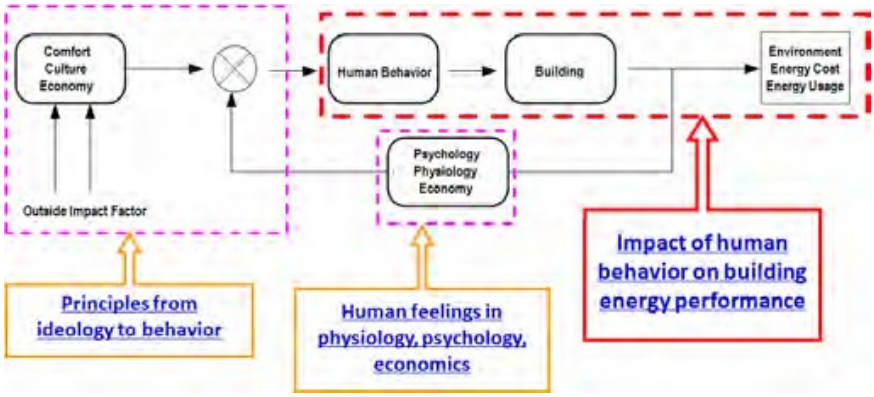
Selected Outcomes

U.S.-China Clean Energy Research Center (CERC)
Building Energy Efficiency (BEE)

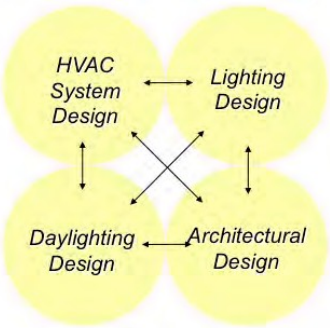
December 2015

1. Building Design

- ***1.1 Modeling Human Behavior in Energy Simulation Tools:*** CERC researchers from Lawrence Berkeley National Laboratory (LBNL) in the United States and Tsinghua University in China 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. The first Expert Meeting was successfully completed at LBNL from March 30 to April 1, 2015, with 72 participants from 16 countries. Annex 66 made great progress in developing and assigning a list of technical activities with clear scope and deliverables towards a final report.



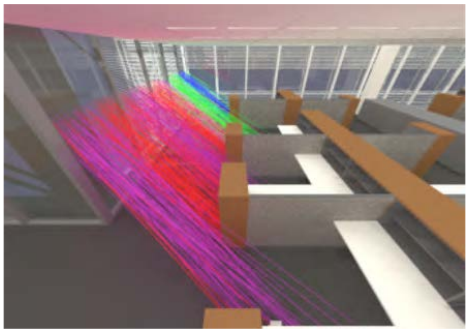
- ***1.2 Integrated Design - Developing protocols and design tools for very low energy buildings***: CERC researchers from LBNL (U.S.), Tsinghua University (China), and Bentley Systems (U.S.) studied actual energy performance of 51 high performance buildings in the United States, China, other regions 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.

2. Building Envelope

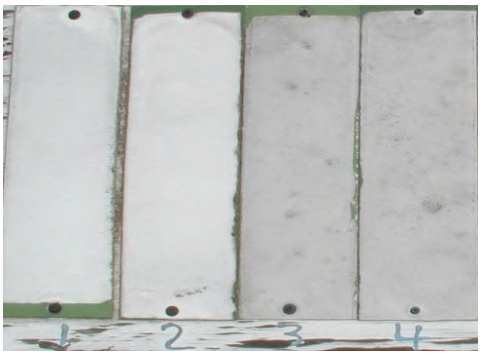
- ***2.1 Windows—Modeling tools to facilitate performance-based design of integrated facades for commercial buildings, resulting in perimeter energy reduction of 15%–30%:*** A full scale field test demonstrated that the grid electricity use of a south-facing perimeter office could be reduced to nearly zero demand during the daytime (5 W/m2-floor peak)—when energy costs are at their highest—if dynamic electro-chromic windows and on-site generation and storage are optimized with integrated demand-supply side controls. This simulation resulted in an estimated 63% reduction in utility grid costs compared to heuristic control of electro-chromic windows. The Lutron shading system, which uses open-loop wireless sensors to balance the demands of daylight admission, solar control, and glare mitigation—also completed a field test and will be demonstrated in a commercial office building in New York City this summer. The WINDOW, EnergyPlus, and COMFEN tools developed by LBNL enable end users to model any 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.



- ***2.2a Insulation—Developing sprayable liquid flashing*:** Dow Chemical (U.S) and Oak Ridge National Laboratory (ORNL) are developing sprayable liquid flashing technology that will contribute to increasing the air tightness of commercial and residential buildings in the United States and China. The product was demonstrated at several U.S. buildings and at the China Academy of Building Research in Beijing. The technology reduces energy consumption by decreasing air leakage through the building envelope, reducing heating and cooling loads. It is cost-effective through its short installation time and improved workmanship due to ease of use and is environmentally friendly given that its water-based formulation utilizes low volatile organic compound (VOC) technology. Dow launched the sprayable liquid flashing in September 2014 at the 2014 Construct Trade Show, which is organized by the Construction Specifications Institute. The liquid flashing was introduced under the name LIQUIDARMOR – CM, and in 2015 was selected as a R&D100 finalist. Dow is commercializing the product and training their agents and sellers. ORNL and Dow have begun the construction of a third test wall that will further evaluate the liquid flashing's capability to span gaps without a supporting material.

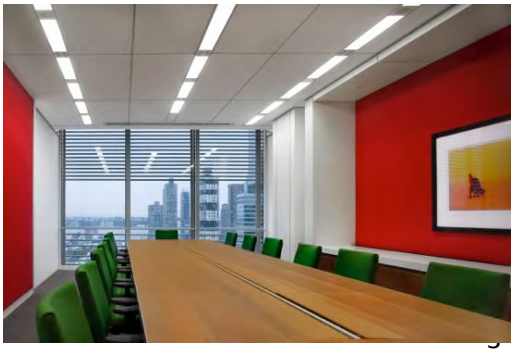
- ***2.2b – Developing new generation air barrier adhesives:*** *3M (U.S.)* and Oak Ridge National Laboratory (ORNL) have developed a new adhesive air barrier product that is differentiated and provides more durability, consistency and productivity than the prevailing rubberized asphalt adhesives in sheet air & vapor barriers and latex based coatings in liquid air barriers. The new adhesive, created under CERC-BEE and introduced in US markets under the name "3M 3015," is an air, water, and vapor barrier adhesive that has excellent adherence to common building materials without priming. This means that 3M 3015 provides up to 2 times faster installation than membranes that require priming, and can be used for residential and commercial construction, on both new and existing structures. It also allows for low temperature application to ~0°F. 3M and ORNL are installing 3M 3015 in demonstration buildings throughout the US and in China in order to expand market size.

- ***2.3 Cool Roofs—High-performance, long life, energy-saving cool roof materials developed for the Chinese and U.S. markets.*** CERC researchers from the United States (LBNL, ORNL, and Dow Chemical) and China (Chongqing University, Guangdong Provincial Academy of Building Research, and the China Academy of Sciences) are developing improved 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 climate change. LBNL's "Cool Roof Time Machine" (ASTM D7897-15) cuts prototype testing to 3 days from 3 years and has been shown to reduce annual cooling energy use by 5-20% on the top floor of a building in a hot-summer climate. Based on the findings from CERC research, LBNL has been awarded a three-year, $2.5M Cool Walls project by the California Energy Commission. In the CEC Cool Walls project, LBNL and industry will leverage the CERC research and expand the application of Cool Roofs to Cool Walls by developing metrics and protocols for exposure of wall products. These metrics and protocols will be available for use at the Chinese sites.



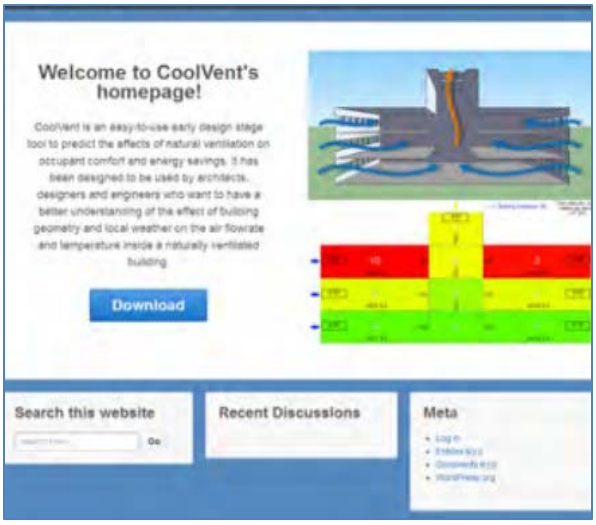
3. Building Equipment

- ***3.1 Advanced Lighting Controls— Technical specifications and functional requirements for Proof-of-Concept (POC) lighting control systems.*** CERC researchers from the United States (LBNL and Lutron) have developed two POC concepts to be implemented in a unique experimental design that combines a monitored advanced lighting controls demonstration at the China Academy of Building Research (CABR) in Beijing. The project includes a

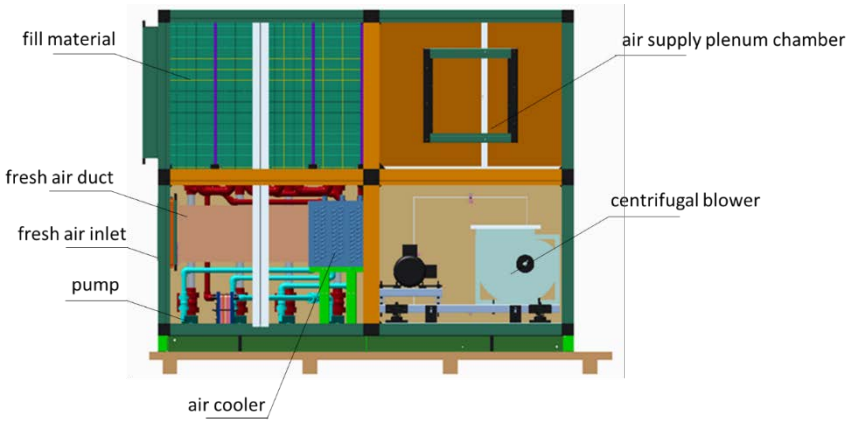


dimmable, fully automated lighting control system for maximum energy savings and added functionality and a simpler, less expensive switching system that will be semi-automatic and tailored to the requirements of the Chinese building market. LBNL also installed Lutron's 3rd generation Quantum lighting controls system in the FLEXLAB testing facilities and conducted a comprehensive experimental regime involving a wide variety of parameters to ascertain the system reporting accuracy relative to explicit external monitoring and sensing data. Lessons learned from CABR and FLEXLAB will be used to inform U.S. and China efforts to upgrade and modernize its commercial lighting building infrastructure. It is estimated that 40 terawatt hours (TWh) of lighting electricity can be saved annually in the United States at 25% penetration of lighting controls, with electricity savings of 15 TWh/yr in China, for a total of 55 TWh and annual emissions reductions of 38 million metric tonnes of CO_2.

- ***3.2 Natural Ventilation—Tailored software package to improve design and optimize control and occupant comfort of hybrid ventilation in commercial buildings.*** CERC researchers from Massachusetts Institute of Technology (MIT) in the United States, 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 software tool 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 the 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 office building in Massachusetts and new developments in Zhuhai, Wuhan, and Chongqing. The tool is being used in major U.S. universities and in architectural firms including Skidmore, Owings & Merrill. The work will be highlighted through a new IEA Annex on ventilative cooling.



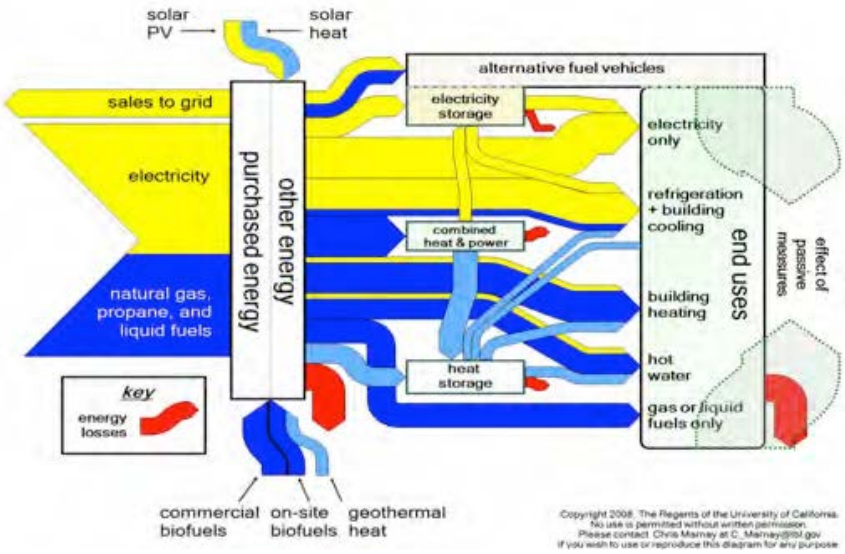
- ***3.3 Wet Bulb Evaporative Chiller—Efficient cooling strategies for some U.S. and Chinese regions.*** CERC researchers from UC Davis Western Cooling Efficiency Center (WCEC) in the U.S. teamed with Tsinghua University in China to develop an evaporative sub wet-bulb evaporative chiller model to predict performance in multiple climates. The project commenced in May 2014. The WCEC lab upgraded their electrical system and instrumentation to receive the Tsinghua chiller, which was delivered in April 2015. Early stage lab testing has demonstrated production of chilled water (55-60°F) and chilled ventilation air (65-75°F) in climate conditions typical of Western United States. Lab tests demonstrated coefficient of performance between 5 and 8. Continuing work includes chiller design and testing. WCEC identified a potential application for the technology at dairy farms.



4. Renewable Energy Utilization / Distributed Generation

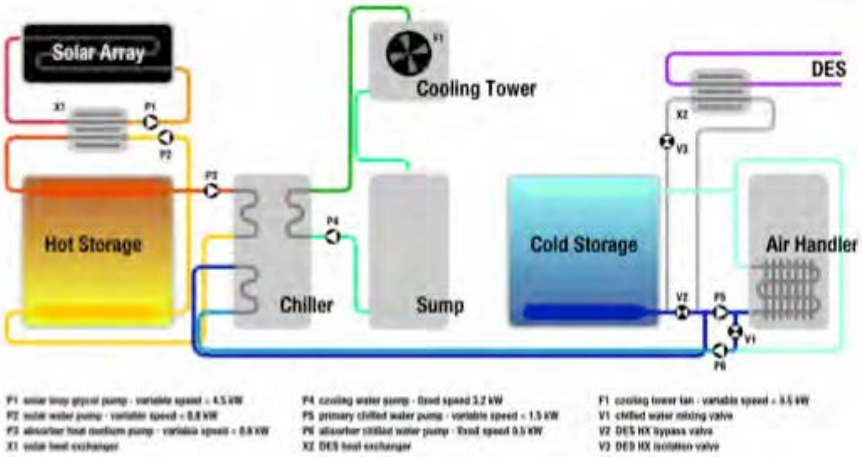
- ***4.1 Ground Source Heat Pump—Improved energy efficiency and cost of ground source heat pumps, reducing its system energy use by up to 30%:*** CERC researchers from the U.S. (ORNL and ClimateMaster) and from China (Chongqing University, Tainjin University, and Tongji University) evaluated emerging ground source heat pump (GSHP) technologies in both countries, focusing on 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 to conventional ground heat exchangers while retaining the same performance. CERC researchers have designed, built, and instrumented a first-of-a-kind test bed for distributed GSHP (DGSHP) systems. This 12-ton DGSHP system has a dedicated mechanical system capable of emulating various ground sources. The test bed is instrumented and monitored through more than 100 sensors. ORNL has completed and commissioned the DGSHP system test bed, which will be used to test proposed smart controls for central pumping and water heating. ClimateMaster is in negotiation with other demonstration sites for demonstrating its advanced GSHP units, which are demonstrated at China Academy of Building Research (CABR) in Beijing.

- ***4.2 Building Integrated Renewable Energy and Micro Grid—Optimized renewable energy technology selection, integration, and operation in real time.*** CERC researchers at LBNL in the U.S. and CERC researchers and partners at Tongji University, C3, and XingYe in China used LBNL's Distributed Energy Resources Customer Adoption Model (DER-CAM) tool to assess the potential of solar thermal technology in 11 diverse climate cities in China. Unlike simple technical assessments, DER-CAM 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. This open-access web service permits optimization of energy system equipment selection and operation for buildings and small district microgrids. Depending on the data quality, these estimates can be extrapolated to markets or regions. In the United States, this approach has been used to establish a standard set of representative commercial buildings based on U.S. DOE's Reference Buildings. Researchers have developed a preliminary scheme to do real-time optimization and have identified issues of real-time optimization interruption.

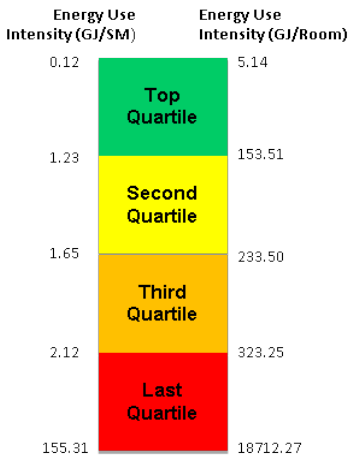


5. Whole Building

- ***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 of 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 buildings in New Mexico and one on the Tianjin University campus. Plans are to use the same technology in future Ministry of Housing and Urban-Rural Development (MOHURD) demonstration buildings.

6. Policy, Market Promotion

- ***6.1 Integrated Building Design & Operation—Commercial building energy use tool.*** CERC researchers from ICF International (U.S.) and Tsinghua University (China) developed benchmarking tools for hotels and commercial offices. The tools take into account key drivers of energy use, including building size, location, and number of workers, and incorporate data from hundreds of Chinese hotels and offices. An on-line version of the China Building Energy Benchmarking Tool has been completed. The China Building Energy Benchmarking Tool is based on the U.S. ENERGY STAR Portfolio Manager model and provides a peer rating of a building's energy performance for hotels, commercial offices, hospitals, and shopping malls in Beijing. The tool is being tested and will be available to the public in June 2015. There is significant potential for energy and CO2 emissions reductions identified by the tools, which can lead to market opportunities for green technology suppliers in both the U.S. and China.