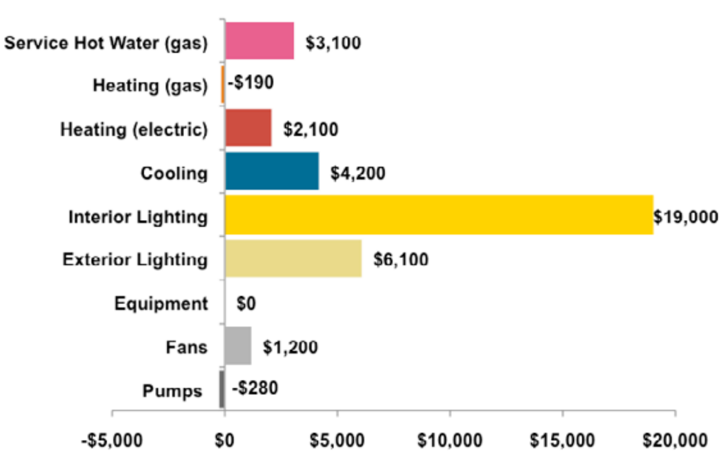
Keeping Energy Savings in the LOOP

Overview

Mesa Lane Partners (MLP) partnered with the U.S. Department of Energy (DOE) to develop and implement solutions to a build a new, low-energy mixed-use building that consumes at least 50% less energy than requirements set by Energy Standard 90.1-2007 of the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), and the Illuminating Engineering Society of America (IESNA), as part of DOE's Commercial Building Partnerships (CBP)[3] Program. Lawrence Berkeley National Laboratory (LBNL) provided technical expertise in support of this DOE program.

The privately developed 46,000-square-foot LOOP project, which is intended to provide affordable off-campus student housing in an underserved community next to University of California at Santa Barbara, will contain more than 7,000 square feet of retail space, a roof deck, an event space, a gym, and 48 apartments. The project developer, MLP, is aiming to exceed CBP requirement, targeting energy consumption that is at least 65% less than that required by the standard. If the LOOP meets this goal, it is expected to achieve Leadership in Energy and Environmental Design (LEED) Gold certification. To meet this goal, the project design incorporates a variety of energy efficiency measures (EEMs) that address the needs of the multiple use types that the project will house.

Expected Energy Cost Reductions



North-facing exterior of The LOOP, a 48-unit student housing complex with ground floor commercial units

Project Type	Mixed–Use: Housing and Retail, New Construction
Climate Zone	ASHRAE Zone 3C, Warm Marine
Ownership	Developed as investment property for future resale
Barriers Addressed	• Incorporating energy efficiency in an affordable housing project with a tight first-cost budget • Ensuring adequate occupant comfort using natural ventilation and no air conditioning
Square Footage of Project	46,380
Expected Energy Savings (vs. ASHRAE 90.1-2007)	~48%
Expected Energy Savings	• ~160,000 kWh/year of electricity • ~2,900 therms/year of natural gas
Expected Cost Reductions (vs. ASHRAE 90.1-2007 baseline)[1]	~$35,000/year
Actual Cost Reductions	To be Determined
Project Simple Payback	~6.3 years
Expected Carbon Dioxide Emissions Avoided[2]	~60 Metric Tons per year
Project Completion Date	To be Determined

1. Cost reductions calculated using $0.204/kilowatt hour and $0.978/therm (Bureau of Labor Statistics).
2. Natural gas emission factor of 11.7 lbs. carbon dioxide (CO^2)/therm (Bruso, 2011). Electricity emission factors of 630.89 lbs. CO^2/megawatt hour (Climate Registry, Utility Emission Factors).
3. The Commercial Building Partnerships (CBP) Program is a public/private, cost-shared initiative that demonstrates cost-effective, replicable ways to achieve dramatic energy savings in commercial buildings. Through the program, companies and organizations, selected through a competitive process, team with U.S. Department of Energy (DOE) and national laboratory staff who provide technical expertise to explore energy-saving ideas and strategies that are applied to specific building project(s) and that can be replicated across the market.

This case study reports expected savings from the project's preliminary design recommendations, which are subject to change in final construction. After construction is complete, additional work is anticipated, to validate the performance of the project's EEMs.

The project team consists of MLP, LBNL, and private consultants Solarc. The team is using an integrated design process to develop EEMs for this project. The goal is to build a project that can be an example for other mixed-use student housing projects. This project is also a case study of how a private development that aims to turn a profit can also successfully save energy in a challenging cost environment.

All parties involved in the building design, including the owner, design team, general contractor, and the CBP team, contributed to identifying appropriate energy saving measures for the project. Promising EEMs were modeled and evaluated for efficacy, and the general contractor, who was brought on board early to participate in the integrated design process, provided cost estimates throughout to ensure that the project remained within budget.

The building's lighting design offered a major energy savings opportunity: three lighting EEMs are responsible for about half of the project's total energy savings. Another major source of savings will be a solar service hot water system installed on the roof, which will take advantage of the coastal sun. An alternative to traditional air conditioning will also save significant energy; the building will employ a single-sided natural ventilation design with fan assistance from inside and associated envelope features. Isla Vista's climate is mild with highs in the mid-70s. However, comfort is a concern in the summers because of stratification and heat build-up in the double-height spaces in the building's interior as well as occupant discomfort from direct solar gain. Therefore, the team emphasized controlling solar gain, providing airflow, and validating thermal comfort through modeling.

During the design process, the design team and MLP learned about low-cost energy efficiency solutions that are applicable to multi-unit residential and mixed-use projects.

Decision Criteria

Because a project goal was to offer affordable rents, minimizing first costs of EEMs was a primary criterion although the developer was open to EEMs with relatively short payback periods. Core and shell systems were provided for the retail spaces. However, because the retail tenants had not been selected during the design phase and therefore it was not known how the spaces would be customized by their future occupants and what end use equipment and systems might be installed, it was difficult to provide detailed space-specific EEMs for the retail portion of the project. Therefore, the team chose to focus on measures that would significantly reduce energy use in the core and shell of the building.

Economic

It was important to keep capital costs low to assure a timely return on investment for the developer as well as low rents for the affordable apartment units. Therefore, energy efficiency measures were judged based on:

- Utility rebates and other services to ensure affordability of EEMs.
- A simple payback of 3 years or less, taking into account utility rebates, first costs, installation costs, and energy cost reductions (utilities will be included in the rent students pay for the apartments); which the developer considered acceptable.
- Selecting "off the shelf" systems and components that did not require extensive maintenance or operational care (although operational and maintenance costs were not directly included in evaluating EEMs).
- An overall sustainability vision, which was very important for branding and marketing this site as a desirable location for students and business; this was considered key to the value of the project.

Operational

Because MLP planned to eventually sell the building, so emphasized the incorporation of EEMs with relatively low-impact, simple maintenance and operational needs, to ensure the project's overall economic sustainability. The team also wanted to take advantage of the relatively mild climate in Isla Vista and aspired to a building without a conventional air conditioning system. Related to these operational goals, MLP chose EEMs as follows:

- Utilization of fans that were already in the project for other purposes to assist with natural ventilation during periods of low airflow.
- Systems requiring minimal maintenance.
- Simple operational controls to ensure low operational and maintenance costs for future owners.

Reduced hallway lighting creates an esthetic ambiance.

Design

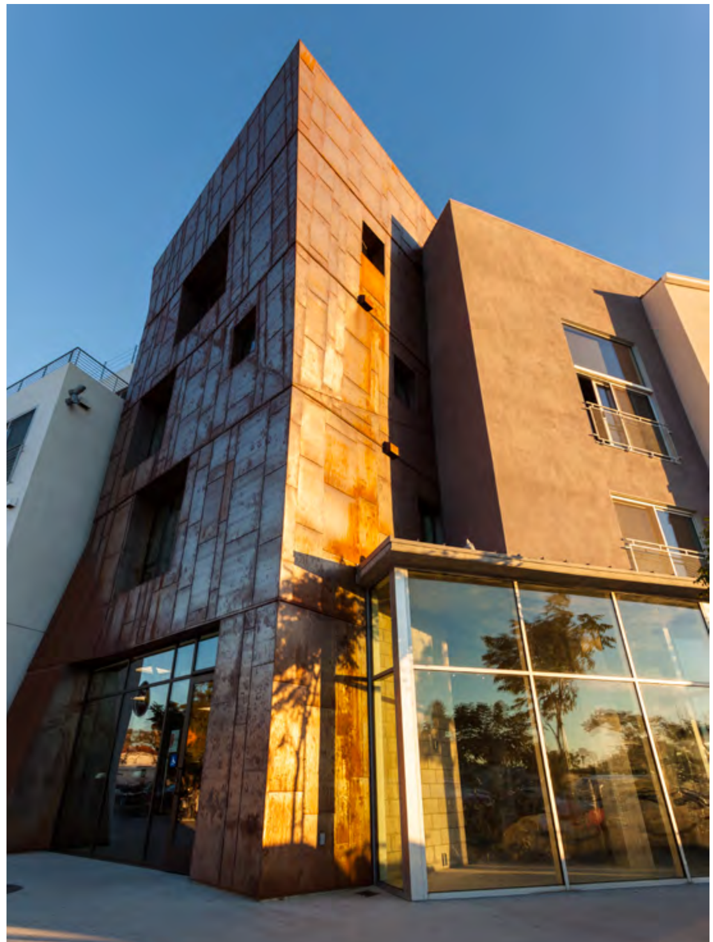
To keep project costs low and achieve deep energy savings, the team looked for EEMs that had multiple functions and benefits. Some of these benefits were energy savings in more than one building system. Examples of EEMs that met these criteria included:

- Fans for toilet exhaust were also used to improve airflow during periods of low airflow from the single-sided natural ventilation design.
- Solar shading on the envelope was achieved in part by balconies from units above, reducing the need for additional shading devices.
- The solar hot water heating system was designed both to provide heating to the service hot water system in the building and to preheat the hot water for hydronic heating, via fan coil units, of the living spaces.

Policy

No formal energy savings policy was set for the project, but MLP set a goal of 50–65% energy savings. MLP was very motivated to produce a sustainable, green building design in keeping with their corporate mission statement. The developer's goal was to sustainably construct a new low-energy, affordable housing and retail building that met the developer's commitment to:

- Create wealth through profit and sustainable growth.
- Develop, from the ground up, responsible projects that respect the environment and society's needs.
- Promote the health of future occupants, well-being of the wider community, and preservation of the local and global environment.
- Innovate and drive change by inspiring others to follow their example.



Design increases natural lighting exposure to meet 50% reduction in lighting power density for residential spaces.

Energy Efficiency Measures Snapshot

The following table lists EEMs that were proposed for this project. All measures included in this project will also be considered for future MLP developments. Some notes about this table:

- Rebates were not included in EEM cost calculations. Life-cycle costs were not included in the costs, the cost of conserved energy (CCE), or net present value (NPV) calculations.
- Energy savings are shown for packages of measures rather than for individual measures to capture the overall impacts of these measures on the whole-building design option.
- The analysis uses rates of $0.204/kilowatt hour (kWh) of electricity and $0.978/therm of natural gas, equivalent to the average May 2012 rates in the Los Angeles area.
- Reducing artificial lighting density levels with dimming fixtures when daylighting is available and providing interior roll shades to prevent glare represented no additional cost over traditional lighting systems.
- Additional EEMs for this building type that were not considered for this project can be found in the Advanced Energy Design Guide (AEDG) for Small Retail Buildings and the AEDG for Highway Lodging (aedg.ashrae.org).
- The EEMs are presented ranked by estimated annual savings within each end use.

Energy Efficiency Measures

	Implementing in this Project	Will Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost, $	Cost of Conserved Energy (CCE),[4] $/kWh	Simple Payback
			kWh/year	$/year			
Envelope: 2% Whole-Building Savings							
Improve the building envelope exterior wall insulation using phase-change material. Also improve insulation of roof, exterior doors, windows, and reduce filtration rate to 0.15 air changes per hour (ACH).*	Yes	Yes	9,000	$2,800	$84,000	$0.66	30
Lighting: 24% Whole-Building Savings							
Reduce interior lighting power density by 50% in residential areas and 40% in retail areas under ASHRAE 90.1-2007. Use 0.9 watts per square foot (W/ft^2) for retail and 0.5 W/ft^2 for residential. Corridors and stairs have 0.25 W/ft^2 with occupancy sensors.	Yes	Yes	82,000	$17,000	$21,000	$0.02	1.2
Reduce exterior lighting power by 50% of the exterior lighting power under the ASHRAE standard (use 2,219 W for exterior lighting).	Yes	Yes	30,000	$6,000	$7,800	$0.02	1.3
Utilize daylighting by installing fixtures that dim when daylighting is available, to reduce artificial lighting density levels. Provide interior roll shades to prevent glare.	Yes	Yes	9,200	$1,900	$0	$0.00	0
HVAC: 4% Whole Building Savings							
Adopt single-sided natural ventilation for summer cooling in residential areas.*	Yes	Yes	21,000	$4,200	$0	$0.00	0
Domestic Hot Water: 18% Whole-Building Savings							
Use solar thermal panels to pre-heat hot water, reducing natural gas energy consumption from the boiler. Optimize inclined angle of solar panel installation to 35°. Determine number of solar thermal panels to achieve the most cost-effective benefits.*	Yes	Yes	78,000	$2,600	$100,000	$0.09	38
Improve hot water boiler efficiency to 95% by using condensing boiler for service hot water system.	Yes	Yes	14,000	$460	$9,200	$0.05	20

* EEM is climate-dependent
4. CCE evaluated with 5% discount rate for 25 years (Meier, 1984)

Energy Use Intensifies by End Use

Two energy models were created to compare the proposed design with that of a typical code-compliant building. Version 6 of EnergyPlus, an energy analysis and thermal load simulation program, was used to model the two designs. Model 1 is the ASHRAE 90.1 2007 code-compliant baseline model. Model 2 represents the LOOP building with the proposed EEMs. The priority in energy modeling was to determine whether the CBP 50% savings target was achievable. Lighting efficiency measures contributed substantially, representing almost half of the total savings.

The envelope design was key to reducing heating, ventilation, and air conditioning (HVAC) energy use. The envelope EEM package by itself, without the associated reductions in HVAC system cost, did not make a compelling business case. However, the envelope EEMs were essential to the performance of the natural ventilation system, enabling the project to be built without air conditioning. The glazing was selected to reduce solar gain, and solar shading was incorporated in each unit. Phase-change material at strategic locations in the interior wallboards provided thermal mass benefits. Santa Barbara experiences a significant diurnal temperature swing; in warmer summer months, the phase-change material can increase thermal mass during the cooler nights, which would last into the next day, providing an interior comfort benefit. The combination of these envelope measures made the natural ventilation scheme viable.

The primary lighting EEMs were occupancy sensors for corridors and stairs, daylighting dimming fixtures for apartments, and decreasing exterior lighting from 4,500 Watts (W) in the baseline model to 2,219 W in the proposed design. Because the lighting power densities in the proposed model were much lower than those in the baseline model, the proposed model had a corresponding slight increase in heating energy as a result of the loss of heat output from exterior fixtures.

The code-compliant baseline was modeled with a standard packaged rooftop air conditioning (PSZ_AC) system for the retail space and individual packaged terminal air conditioners (PTAC) for residential spaces. The proposed design for the retail space was modeled with a PSZ-AC system similar to that used in the baseline for retail, but the proposed design for the residential spaces did not use air conditioning, so those spaces were modeled with hydronic heating fan coil units and natural ventilation. The natural ventilation model assumes that each tenant will fully open the sliding glass door to the unit balcony to regulate the inside temperature once it reaches 72.5°F. As a result, stack-driven flow will come in through the door, and hot air will exit through the exhaust fans that double as bathroom fans. During the iterative design of the project, LBNL modelers used the 80% acceptability range of the ASHRAE Standard 55 adaptive thermal comfort standard to identify "hot spots" (rooms that too often exceeded the comfort range criteria). A parametric analysis was performed on the hot spots to vary the area of the exhaust fan duct and the height of the exhaust fan outlet and determine the configuration that would minimize the number of hours of discomfort from overheating. Based on the findings of the parametric analysis, recommendations for addressing the hot spots were made to the design team. Single-speed, on/off fans that respond to outside air and cooling set points were used in the proposed system.

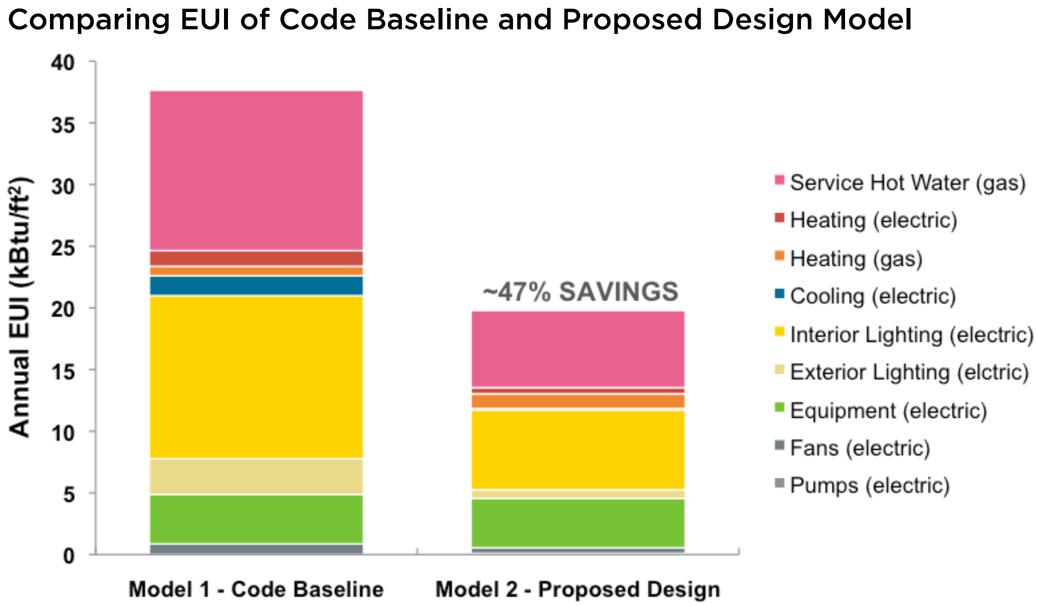
A large portion of the LOOP's energy savings is due to the solar service hot water system. The baseline model used a stand-alone service hot water gas-fired boiler, but the proposed design used solar panels installed on the roof to preheat the service hot water and decrease the load on the condensing boiler. The water can also be used at times to preheat the water for the hydronic heating that serves the apartment units. Water will be looped through flat plate collectors installed at 35° from horizontal. (As a rule of thumb, panels should be installed at an angle close to the latitude of the location). For the solar service hot water system, two pumps would be necessary to force the water through two systems, in contrast to the baseline model with its stand-alone service hot water boiler that requires no pumps. Therefore, some increase in pumping energy is expected in the proposed design even though overall the energy savings from the solar hot water system are significant.

Model 1 – Code Baseline

Model 1 is the baseline, representing the prescriptive specifications of Standard 90.1-2007 and ASHRAE 62.1-2007. The envelope of the baseline model is standard with a 0.25-air-change-per-hour infiltration rate. For lighting, the model assumes a 1.5 W/square foot (ft^2) lighting load density, 4,500 W of exterior lighting, and no occupancy sensors or daylighting dimming fixtures. The baseline building is conditioned by a PSZ-AC in commercial spaces and PTAC in residential spaces. A stand-alone hot water boiler provides service hot water with no pumps. The LOOP baseline has an annual energy use intensity (EUI) of approximately 38 kilo British thermal units (kBtu)/ft^2.

Model 2 – Proposed Design

Model 2 incorporates the EEMs selected for the LOOP design. Envelope EEMs include reduced U-value and infiltration rates and improved glazing and solar shading. Phase-change material wallboards were included in the modeling, but limitations in EnergyPlus version 6 prevented the model from fully characterizing the thermal comfort effects of this measure. The impacts of the phase-change material are expected to be more significant than modeled (the issues that led to underestimation have been corrected in the current EnergyPlus version 7 or later). As mentioned previously, the proposed design also includes measures to reduce lighting load: occupancy sensors, daylighting dimming fixtures, and decreased exterior lighting wattage. Also as noted earlier, the residential spaces have natural ventilation, hydronic heating fan coils, and no air conditioning. Natural ventilation was modeled using a simplified object in EnergyPlus that calculates ventilation rates from wind and stack effects rather than an airflow network, which is more complex and time intensive. Service hot water was modeled as a solar thermal panel water loop with a condensing boiler and two pumps interconnected to the hydronic heating system. This proposed design model has an annual EUI of approximately 20 kBtu/^{ft2}, which is about 47% better than Model 1.



Expected Annual Energy Use and Percent Savings by End Use

End Use Category	Model 1 – Code Baseline Annual EUI ($kBtu/ft^2$)	Model 2 – Proposed Design Annual EUI ($kBtu/ft^2$)	Model 2 – Proposed Design Percent Savings Over 90.1-2007
Service Hot Water (gas)	13	6.3	52%
Heating (electric)	1.3	0.5	61%
Heating (gas)	0.8	1.2	-56%
Cooling (electric)	1.6	0.1	94%
Interior Lighting (electric)	13	6.5	51%
Exterior Lighting (electric)	2.9	0.7	75%
Equipment (electric)	4.0	4.0	0%
Fans (electric)	0.9	0.4	49%
Pumps (electric)	0.0	0.1	-100%
Total	**~38**	**~20**	**~47%**

Expected Building Energy Savings from Implemented EEMs by End Use

Electricity End Use Category	Energy Savings
Heating	11,000 kWh
Cooling	21,000 kWh
Interior Lighting	91,000 kWh
Exterior Lighting	30,000 kWh
Equipment	0 kWh
Fans	5,700 kWh
Pumps	-1,400 kWh
Electricity Total	**~160,000 kWh**

Gas End Use Category	Energy Savings
Service Hot Water	3,100 therms
Heating	-200 therms
Natural Gas Total	**~2,900 therms**

Lessons Learned

As part of the CBP work on the LOOP, MLP, LBNL, and Solarc learned lessons that can help others achieve similar results in future mixed-use student and multi-family housing projects. This case study was written as the project is midway through its design phase, so the lessons below represent the team's insights to date. Additional lessons will be documented after the building is constructed and operating, with building energy use analyzed and EEM performance verified.

> "When designing affordable housing, low maintenance and operating costs are as important as first costs."
>
> — Neil Dipaola, CEO
>
> Mesa Lane Partners

Invest strategically in areas with the greatest potential to save energy

Developing an affordable housing project can be a challenge, especially in challenging economic times. Good cost estimates early and often throughout the project help the project stay within budget. Focusing analysis and energy savings measures on the project's biggest energy saving potentials will deliver the most benefit. In residential spaces, large energy savings often result from EEMs for lighting and service hot water because these are heavily used end uses. While falling short of the 50–65% savings goal, lowered lighting power density, dimmable fixtures, occupancy sensors on corridor lighting, and solar service hot water heating allowed the LOOP project to achieve nearly 50% savings. Taking advantage of utility rebates can help cover some of the cost of EEMs. Some local utilities also provide design assistance for energy savings, which helps keep projects affordable.

The benefits of natural ventilation are worth the effort

Although the LOOP is located in a very mild climate, its approach to maximizing natural ventilation can be applied in other climates. Opting for natural ventilation and forgoing mechanical air conditioning is a major decision, even in Isla Vista's mild, year-round climate. Designing an effective natural ventilation system requires careful attention to comfort but can yield big energy use and capital cost reductions. The LOOP project team stretched funds by making strategic investments in ventilation system performance analysis; for example, in addition to overall energy modeling for the whole building, deep, detailed analysis was done for representative units, including units with the greatest cooling challenges so that solutions could be targeted at making sure those units provide adequate thermal comfort. Modeling a naturally ventilated space is not easy, and not all energy simulation programs can do so. Choosing a design team with this expertise and familiarity with the appropriate thermal comfort standards is an important prerequisite to designing a successful natural ventilation system.

Design synergies maximize energy savings and economic benefit

To maximize the benefit from the developer's capital investment and achieve deep energy savings, the project targeted EEMs that serve multiple functions and provide multiple benefits to the building. For example, some shading elements double as balconies for the units above (in other projects, shading elements could provide area for mounting photovoltaics). External shading was strategically placed to prevent glare, improve comfort, and control solar gain. Other building system components in this project serve multiple functions, such as the restroom exhaust fans, which provide ventilation to increase airflow through the units during periods when natural ventilation is minimal. Design synergies such as these maximize the benefit from the investment in each EEM.

Tenants can help too

It is important to take advantage of opportunities for tenants to reduce energy use. Both residential and retail tenants contribute to a building's energy use. Residential end uses that impact energy use include lighting and appliances (e.g., TVs, microwaves), and retail tenants use lighting as well as other equipment; in particular, the commercial kitchen equipment of food service tenants can use considerable energy. Educating tenants about their energy use impacts and options for reducing energy use will not only help them to conserve energy but can increase their awareness of the building's base systems. Educated tenants can help maintain and improve a project's efficiency measures, which benefits not only the tenants themselves, but the project's bottom line and long-term attractiveness if it is to be sold in the future. MLP has branded the LOOP as a sustainable building, which is the first step in educating prospective tenants about the project's sustainability features. An education campaign can take this a step further by encouraging good plug load procurement and usage practices. Further efforts can include providing retail tenants with information about utility design assistance and incentive programs, which can encourage them to undertake sustainable design.

This project demonstrates that student, multi-family housing, and core and shell retail projects can demonstrate whole-building energy savings and success, even when challenged with a tight construction budget.

References and Additional Information

ANSI/ASHRAE Standard 55-2010. *Thermal Environmental Conditions for Human Occupancy*. Atlanta GA. ISSN 1041-2336

Bruso, X. 2011. *Greenhouse Gas Emission Factors Info Sheet*. http://www.pge.com/includes/docs/pdfs/shared/environment/calculator/pge_ghg_emission_factor_info_sheet.pdf

Bureau of Labor Statistics. *Average Energy Prices in the Los Angeles Area*. http://www.bls.gov/ro9/cpilosa_energy.htm

Climate Registry Electricity Emission Factors: www.climateregistry.org/resources/docs/PUP_Metrics-June-2009.xls

EnergyPlus Energy Simulation Software: http://apps1.eere.energy.gov/buildings/energyplus/energyplus_about.cfm

Meier, A. K. 1984. The Cost of Conserved Energy as an Investment Statistic. Berkeley CA: Lawrence Berkeley National Laboratory Report ESL-IE-84-04-109. http://repository.tamu.edu/bitstream/handle/1969.1/94751/ESL-IE-84-04-109.pdf?sequence=1

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
www.eere.energy.gov

CSO 25194 • March 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.