Achieving Energy Savings in Municipal Construction in Long Beach, CA

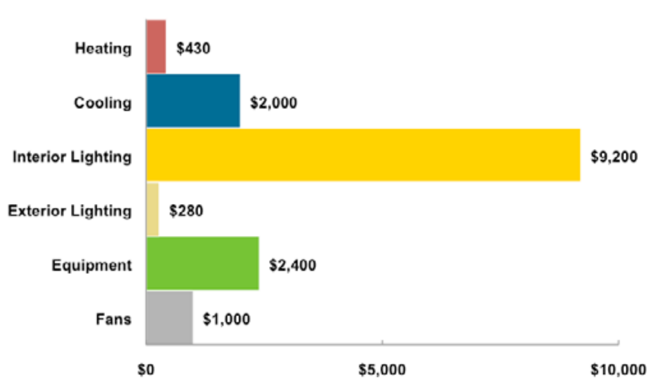
Overview

Long Beach Gas and Oil (LBGO), the public gas utility in Long Beach, California, partnered with the U.S. Department of Energy (DOE) to develop and implement solutions to build a new, low-energy modular office building that is at least 50% below 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) program.[3] The LBGO building, which demonstrates that modular construction can be very energy efficient, is expected to exceed the ASHRAE baseline by about 45%.

The new 15,000-square foot (ft^2) LBGO office building has two stories and houses private offices, open-plan cubicle offices, and a conference room and call center on the second floor. The building's modular nature allowed LBGO to realize the cost benefits of fast-tracked construction while saving substantial energy and reducing operational costs. The project was funded by the utility's ratepayer revenue, which imposed a tight budget limit.

The design process was a collaborative effort involving LBGO and its design-build team, Lawrence Berkeley National Laboratory (Berkeley Lab), and subcontractors Stantec (formerly Burt Hill) and LHB Inc. The team proposed efficiency measures based on computer modeling of the building in full compliance with ASHRAE 90.1-2007; in the modeled building, the lighting and cooling systems were the largest energy users, so increasing the efficiency of these systems was a top priority. Promising measures were modeled to estimate their energy performance, and each measure was evaluated for its feasibility within the budget.

Expected Energy Cost Reductions



West facade of the new modular office on the Long Beach Gas and Oil campus

Photo credit: Craig Beck, 4/7/12

Project Type	Commercial Office, New Construction
Climate Zone	ASHRAE Zone 3C, Warm Marine
Ownership	Owner occupied
Barriers Addressed	• Fixed capital project/fixed cost • Aligning corporate values to include sustainability
Square Footage of Project	15,000
Expected Energy Savings (vs. ASHRAE 90.1-2007)	~45%
Expected Energy Savings	~75,000 kWh/year
Expected Cost Reductions (vs. ASHRAE 90.1-2007)	~$15,000/year[1]
Actual Cost Reductions	To be verified
Project Simple Payback	~7.3 years
Expected Carbon Dioxide Emissions Avoided	~52 Metric Tons per year[2]
Construction Completion Date	February 2012

1. $0.204/kilowatt-hour, Los Angeles average price Nov 2011 – May 2012 (Bureau of Labor Statistics).
2. Calculated using EPA's Greenhouse Gas Equivalencies Calculator.
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 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.

In addition to meeting CBP's efficiency target, the building had to comply with the City of Long Beach's Green Building Policy, which requires that all new municipal buildings achieve Leadership in Energy and Environmental Design (LEED) Gold status. The city's policy also requires that new municipal buildings exceed ASHRAE 90.1-2007 by at least 10%; committing to the CBP's more ambitious 50% target offered the city an opportunity to demonstrate that much greater energy savings are feasible and cost-effective within LBGO's budget.

During the building's design and construction, the team learned lessons about working with modular buildings and ensuring follow-through on design details; a key lesson was that modular buildings can be attractive and very energy efficient while still cost-effective to build. DOE learned lessons from this project about energy efficient design in a cost-constrained environment. These lessons, described at the end of this case study, can help others in the commercial office market replicate the successes from this project.

Decision Criteria

This building was selected for participation in the CBP program because it will serve as a model for energy efficient, modular municipal buildings in Long Beach. The subsections below describe the economic, operational, and policy criteria that affected the choice of energy efficiency measures for the building.

Economic

This project was funded through ratepayer utility revenue, a typical funding source for energy efficient new construction by utility providers. Reliance on this funding source meant a very tight budget; the sum total of the efficiency measures could not exceed the project's $4 million budget plus contingency funds. Therefore, energy efficiency measures were judged primarily on their first costs, though life-cycle costs were also considered. The efficiency measures of interest turned out to be within the project's budget, however, if the measures had exceeded the budget, life-cycle costs would have been used as a justification for seeking additional funds, i.e., by showing that an incremental addition to the first cost would reduce energy consumption and/or maintenance costs over the life of the project.

Because cost-effectiveness was a key criterion, LBGO sought proven cost and benefit data as a basis for their decisions about measures. The CBP team helped to collect and present data both from their experience and publications.

Efficiency measures with reduced maintenance costs were viewed favorably. For example, the CBP team developed, and LBGO selected, an energy efficient lighting layout that reduced the fixture and lamp count, thereby reducing capital and maintenance costs compared to the ASHRAE-90.1-2007-compliant baseline building.

Operational

LBGO preferred building systems that operate "out of the box" and do not require additional training or maintenance. For instance, efficiency measures such as a thermal break typically perform as expected with little or no maintenance over their lifetime. In contrast, a unique mechanical system that uses new technologies might require greater investment in maintenance or training. Some of the measures chosen based on LBGO's preference for building systems requiring minimal training and maintenance were:

- Roof monitors, which provide a low-maintenance daylighting option for the building's call center.
- T8 lamps in lighting fixtures, to match what LBGO has standardized in its existing facilities.

Another operational consideration was related to the building's location. LBGO rejected a mixed-mode ventilation scheme that included natural ventilation because of the building's proximity to the Long Beach airport and a busy highway, sources of noise and particulate matter that could enter the building via the natural ventilation louvers.

Policy

The City of Long Beach's commitment to sustainability addresses a number of areas, as summarized in the City of Long Beach Sustainable City Action Plan. City sustainability goals and policies that affected this building include:

- The Green Building Policy for municipal buildings, mentioned above.
- A 15% reduction in greenhouse gas emissions from city facilities and operations by 2020.
- A 25% reduction in electricity used for city operations by 2020.

Energy Efficiency Measures Snapshot

The following table lists energy efficiency measures (EEMs) proposed for this project. Measures not included in the project but that are potential considerations for future municipal projects in Long Beach are also included. Some notes about this table:

- EEMs were often modeled as a package and compared to the baseline ASHRAE-90.1-2007-compliant building. These packages, composed of efficiency measures for various end uses, are presented in the table.
- Whole-building percentage savings are shown by end use for each EEM package to give a sense of where the major energy saving opportunities lie. The values for each individual measure are generally quite small.
- This table does not compare strategies one to one. And, unlike Options #1 and #3, Option #2 (mixed-mode ventilation) was not modeled relative to an energy baseline with an all-electric HVAC system, for reasons explained on page 5, so savings for this strategy would likely be greater than those shown in the table.
- Additional EEMs for this building type that were not considered for this project can be found in the Advanced Energy Design Guide for Small and Medium Offices.

Energy Efficiency Measures

The Stantec team recommended the options in this table. LBGO chose Option #3.

	Implemented in this Project	Will Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost, $	Cost of Conserved Energv (CEE)[4] $/kWh	Simple Payback Years
			kWh/yr	$/yr			
Option #1 - Variable Refrigerant HVAC System (~50% Whole-Building Savings[5])			84,000	$17,000	$150,000	$0.11	8.8
Envelope (~15% Savings)							
Improve envelope U-value with thermal break at top of first- and second-floor modules. Include R-13 batt insulation around perimeter C-channels.	Yes	Yes					
Improve glass performance by decreasing the solar heat gain coefficient from 0.36 to 0.27.	Yes	Yes					
Lighting (~27% Savings)							
Incorporate clerestories and daylighting controls, including vacancy sensors for perimeter and occupancy sensors for open offices.	Yes	Yes					
Reduce number of exterior fixutres.[6]	Yes	Yes					
HVAC (No Savings)							
Incorporate a variable refrigerant flow (VRF) system for heating and cooling with an integrated energy efficiency ratio (EER) of 14.5 & a coefficient of performance (COP) of 3.25.	No	Yes					
Plug Load (~7% Savings)							
Install ENERGYSTAR equipment (computers, printers, refrigerators, microwaves) and computer energy management software.	Yes	Yes					
Option #2 – Mixed-Mode (~48% Whole-Building Savings[5])			79,000	$16,000	$230,000	$0.17	14
Envelope (~22% Savings)							
Improve envelope U-value with thermal break — same as Option #1.	Yes	Yes					
Improve glass performance — same as Option #1.	Yes	Yes					
Lighting (~19% Savings)							
Incorporate daylighting — same as Option #1.	Yes	Yes					
Reduce number of exterior fixutres.	Yes	Yes					
HVAC (No Savings)							
Include 2 VRF heat pumps on rooftop with EER of 16.5 & COP of 3.6, and 12 interior fan coil units to cool outside air coming from louvers.*	No	Yes					
Include 12 commercial-grade, ENERGY STAR-certified ceiling fans.*	No	Yes					
Incorporate natural ventilation, automated louvers, and controls.*	No	Yes					
Plug Load (~7% Savings)							
Install ENERGY STAR equipment & computer energy management software — same as Option #1.	Yes	Yes					

Energy Efficiency Measures

The Stantec team recommended the options in this table. LBGO chose Option #3.

	Implemented in this Project	Will Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost, $	Cost of Conserved Energv (CEE)[4] $/kWh	Simple Payback Years
			kWh/yr	$/yr			
Option #3 - Reduced Cooling Loads (~45% Whole-Building Savings[5])							
Envelope (<10% Savings)			75,000	$15,000	$110,000	$0.09	7.3
Improve envelope U-value with thermal break — same as Option #1.	Yes	Yes					
Improve glass performance — same as Option #1.	Yes	Yes					
Lighting (~27% Savings)							
Incorporate daylighting — same as Option #1.	Yes	Yes					
HVAC (~2% Savings)							
Incorporate a rooftop unit (RTU) system (constant volume) with an EER of 12.	Yes	Yes					
Plug Load (~7% Savings)							
Install ENERGY STAR equipment; computer energy management software — same as Option #1.	Yes	Yes					

* EEM is climate-dependent.
4. CCE calculated using a 5% discount rate for 25 years (Meier, 1984).
5. Savings were calculated compared to an electric HVAC system.
6. Existing exterior lighting is nearly sufficient, so fewer fixtures are required than in the baseline building.

Energy Use Intensities By End Use

EnergyPlus software was used to model four design alternatives, to inform the decision-making process. LBGO was committed to achieving the CBP energy savings goal to the extent possible given the utility's first-cost constraints. The priority in energy modeling was to evaluate several different whole-building options, determine whether the CBP's 50% savings target could be met, and then discuss the economic feasibility of each efficiency measure to determine whether all measures could be incorporated into the project.

In general, LBGO was supportive of the daylighting measures suggested, so these were included in each of the four models that are summarized below. Each of the EEM packages modeled also included a thermal break and improved glass. The thermal break was modeled for the entire exterior wall assembly in the form of insulation around the perimeter of the building where the first floor meets the ceiling and the second floor meets the roof. Glass appropriate for the climate was modeled, to reduce the solar heat gain (and thus reduce the peak cooling load) while maintaining visible transmittance and diffuse light to reduce glare in the building. The daylighting strategy reduced the energy required for interior lighting in two ways: 1) by providing daylight to more of the building through the installation of roof monitors, and 2) by installing controls to turn artificial lights off when daylight provides adequate light levels.

Because the HVAC strategy was chosen at the end of the predesign phase, the models focused on different ventilation schemes. Specifically, the Stantec team modeled a variable refrigerant flow (VRF) case (Model 2), a mixed-mode ventilation case (Model 3), and an efficient rooftop unit (RTU) with reduced cooling demand case (Model 4). Although the mixed-mode scheme saved the most energy, it was eliminated because of the noise and pollution concerns related to natural ventilation that were mentioned earlier.

During the design development phase, the building baseline was updated to reflect LBGO's decision to use an all-electric HVAC system, and the energy savings for the VRF and RTU schemes were calculated with this all-electric baseline. The savings for the mixed-mode system were not recalculated with the all-electric baseline because LBGO had already decided not to pursue the mixed-mode scheme. Thus, the savings for the mixed-mode system (Model 3), which are not calculated against the all-electric baseline, appear smaller than the savings for the VRF system, which are calculated against the all-electric baseline. In general, a system using natural ventilation would be expected to produce the greatest savings because natural ventilation is the most efficient way to cool a building.

Model 1 – Code Compliant Baseline (All-electric)

The first model represented the all-electric prescription in the program-defined ASHRAE Standard 90.1-2007 code-referenced baseline. The LBGO baseline building has an annual energy use intensity (EUI) of about 38 kilo British thermal units (kBtu)/ft^2.

Model 2 – Proposed Design with a Variable Refrigerant Flow Mechanical System

Model 2 represents the LBGO office building with a thermal break, improved glass, and daylighting as described above. This model also includes a VRF mechanical system to provide both heating and cooling. The VRF system allows for simultaneous heating of one space and cooling of another according to the temperature needs of each. This system consists of one fan coil unit for each of the 14 interior zones. This building model has an estimated annual EUI of 19 kBtu/ft^2, which is ~50% better than the Model 1 baseline. Savings result from lowering internal loads via the daylighting, envelope, and plug load measures, and installing a higher-efficiency mechanical cooling system than the baseline system in Model 1.

Model 3 – Proposed Design with a Mixed-Mode Ventilation Scheme

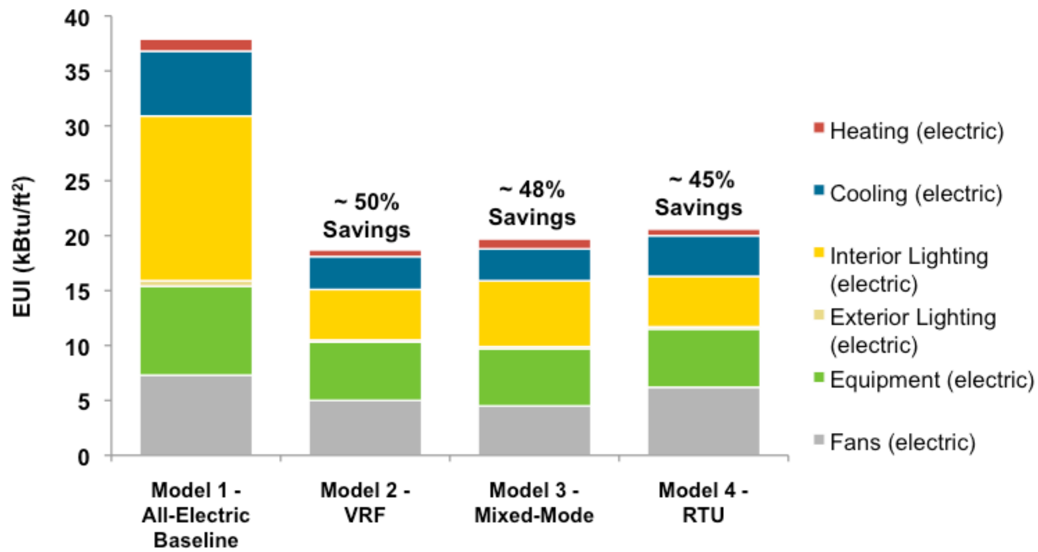
Model 3 represents the LBGO office building with a thermal break, improved glass, and daylighting as described above, as well as a mixed-mode ventilation system. The mixed-mode system naturally ventilates the building through automated louvers and uses a variable refrigerant mechanical system similar to the one included in Model 2 for heating and to meet cooling requirements that cannot be met by natural ventilation alone. This building model has an estimated annual EUI of 20 kBtu/ft^2, which is ~52% better than the ASHRAE-compliant baseline building with a gas/electric HVAC system and ~48% better than the all-electric baseline of Model 1. Savings result from lowering internal loads via the daylighting, envelope, and plug load measures, and a reduced reliance on fan energy in the mechanical cooling system compared to the features of Model 1.

Model 4 – Proposed Design with a Rooftop Unit Mechanical System

Model 4 represents the LBGO office building with a thermal break, improved glass, daylighting as described for Models 2 and 3, and a RTU. Model 4 focuses on reducing cooling loads in the building through lighting system measures and reduced plug loads. Model 4 focuses on reducing cooling loads in the building through lighting system measures and reduced plug loads. This building model has an estimated annual EUI of 21 kBtu/ft^2, which is ~45% better than the Model 1 baseline. Savings result from lowering internal loads via the daylighting, envelope, and plug load measures and a reduced reliance on fan energy in the mechanical cooling system.

Model 4, with a savings of ~45% relative to a building compliant with ASHRAE 90.1-2007, was selected for a variety of reasons. The RTU system offered attractive energy savings. The cost estimates from the contractor for the Model 2 VRF system exceeded the available budget. And noise and pollution concerns made the Model 3 mixed-mode scheme with natural ventilation unattractive.

Comparing EUI of Code Baseline and Proposed Design Models



Expected Annual Energy Use and Percentage Savings by End Use

End Use Category	Model 1 - All-Electric Baseline	Model 2 - VRF System		Model 3 - Mixed-Mode		Model 4 - RTU	
	Annual EUI (kBtu/ft²)	Annual EUI (kBtu/ft²)	Percent Savings vs. 90.1-2007	Annual EUI (kBtu/ft²)	Percent Savings vs. 90.1-2007	Annual EUI (kBtu/ft²)	Percent Savings vs. 90.1-2007
Heating (electric)	1.1	0.6	49%	0.9	21%	0.6	38%
Cooling (electric)	5.9	3.0	49%	2.9	51%	3.7	38%
Interior Lighting (electric)	15	4.6	70%	6.0	60%	4.6	70%
Exterior Lighting (electric)	0.5	0.2	64%	0.2	64%	0.2	64%
Equipment (electric)	8.1	5.3	34%	5.2	37%	5.3	34%
Fans (electric)	7.3	5.0	32%	4.5	39%	6.2	17%
Total Savings	**~38**	**~19**	**~50%**	**~20**	**~48%**	**~21**	**~45%**

Expected Building Energy Savings from Implemented EEMs by End Use

Electricity End Use Category	Energy Savings
Heating	2,100 kWh
Cooling	9,800 kWh
Interior Lighting	45,000 kWh
Exterior Lighting	1,400 kWh
Equipment	12,000 kWh
Fans	5,100 kWh
Electricity Total	**75,000 kWh**

The building was substantially completed in February 2012 and projected to achieve LEED Gold. LHB installed meters in the building in April 2012 to measure and verify performance of the EEMs installed in the building.

Note: All savings shown in this case study are estimated. These figures illustrate the expected savings resulting from the various mechanical schemes.

Lessons Learned

During the design and construction process for the new LBGO office building, the CBP team learned lessons that can help guide future commercial office building projects, whether modular or traditional construction. The key lessons are summarized here.

> "LBGO believes new construction strategies to create energy efficient buildings, partnered with clean natural gas as an energy source, will achieve widespread financial and environmental benefits."
>
> — Craig Beck
>
> Business Operations Manager, LBGO

Establish collaboration and coordination expectations for the design-build team

LBGO was interested in a modular building because of the potential for accelerated project delivery and associated cost savings. However, because LBGO was not familiar with the unique aspects of design-build for a modular building, contract documents were not as focused on integrated design as they could have been. As a result, only some members of the design-build team were engaged throughout project design, and some decisions were made that had to be revisited later. The net effect was that LBGO did not receive the full benefit of coordination between the design and construction phases that is normally associated with a design-build project.

In future projects, LBGO will set clear collaboration expectations for the design-build team, including frequency of team meetings and meeting attendance.[7] LBGO will also engage the entire design-build team early and align the team around a common set of sustainability and energy goals. Once expectations are clear and goals are set, LBGO will engage the design-build contractor throughout the design process to ensure that all team members buy in to the design and address relevant constraints as they arise. With these clear expectations, LBGO expects to achieve even greater efficiency in future projects.

Follow through on design

Most EEMs considered for the project were vetted by the design team during the detailed design phase. When the project team decided to pursue a daylighting strategy, roof monitors were added to the building over the call center. The design team intended for these monitors to face north. However, the architect drew them facing south. As a result of the project's compressed schedule, the design drawings that went to the modular contractor were not updated to reflect the correct design, and the monitors were installed facing south. Thus, a post-construction solution had to be found to mitigate glare concerns. This particular issue was addressed by installing a film over the clear glass in the south-facing monitors to diffuse the sunlight. Failure to follow through on design can have a profound effect on energy efficiency and occupant comfort. This mistake could have been avoided by explicitly including in the project schedule a thorough review of the drawings before they were sent to the contractor.

Modular buildings can be both attractive and energy efficient

LBGO and the City of Long Beach municipality were both attracted to a modular building because of the shorter construction duration and streamlined delivery compared to traditional building construction. A modular building was also cost-effective. The LBGO project was intended as a pilot for other LEED Gold modular municipal buildings to be built in the city. This project proved to the City of Long Beach that modular buildings can achieve LEED Gold or better and be attractive, from both an architectural and an energy perspective. The building that was built is projected to more than quadruple the minimum 10% efficiency relative to the ASHRAE 90.1-2007 standard that is required by the city's Green Building policy, and this result was achieved within the project's tight budget. Furthermore, the final product does not look "like a trailer" as some were worried it would. Rather, it looks like a custom building with unique external and interior features, such as the sawtooth roof monitors. These features not only provide distinctive visual character and a pleasant working environment, they also reduce cooling demand and energy consumption. Finally, the modular construction saved time and will save money over the life of the building.

Lower partitions and clear interior glass for the private offices allows daylight to penetrate deeper into the building, saving energy while maintaining visual comfort for cubicle occupants

Photo credit: Patrick Rogers Studios, 2012

7. One model for such language is the American Institute of Architects' Integrated Project Delivery Contract Documents

References and Additional Information

The 50% Advanced Energy Design Guide for Small to Medium Office Buildings can be downloaded for free at https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download

American Institute of Architects' Integrated Project Delivery Contract Documents: http://www.aia.org/contractdocs/AIAS076706

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

City of Long Beach Sustainable City Action Plan: http://www.longbeach.gov/civica/filebank/blobdload.asp?BlobID=26498

Greenhouse Gas Equivalencies Calculator: http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

Meier, A. K. 1984. "The Cost of Conserved Energy as an Investment Statistic" 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

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