Energy-Efficient Building Design for the Louisiana Capitol Complex: Overview of the Process & Results

by
David Y. McGee, Engineer Supervisor

Louisiana recently designed and began construction on buildings to house state government offices. All of the buildings are located in downtown Baton Rouge near the new state capitol building and are referred to as the Louisiana Capitol Complex. The first three of these new buildings, the LaSalle Building (364,700 sq. ft.), the Claiborne Building (465,000 sq. ft.) and the Galvez Building (340,000 sq. ft.), were chosen by the Louisiana Department of Natural Resources and U.S. Department of Energy for a demonstration project for energy-efficient building techniques. The overall project goal was to construct buildings that would qualify for an Energy Star rating. Qualification required each building's actual energy use to be 30% less than that of an equivalent building constructed to minimal ASHRAE (American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc.) 90.1-1989 standards.

Advanced software tools, including *PowerDOE* and Building Life-Cycle Costing program (BLCC), were used to model the energy consumption and emissions output of the buildings. Modeling results indicated that a 39% savings in energy consumption could be realized, i.e., in comparison to an equivalent building built to minimal ASHRAE 90.1-1989 standards, by utilizing conventional energy-efficient building technologies. Savings of this magnitude have been realized around the country in a wide range of building types including schools, offices, and commercial facilities.

This report describes the design procedures and software tools that were used, explains how they were implemented, and discusses their predicted results. In addition, some of the actual electricity consumption figures of the three buildings are presented.

THE DESIGN PROCESS AND PREDICTED RESULTS

The project's goal of achieving Energy Star compliance was constrained by the following conditions:

- Identify the most effective building concepts to support the missions of the owner.
- Create environmentally sensitive strategies for better buildings that are both pragmatic and repeatable in future facilities to serve as demonstration for future construction.
- Achieve the desired result with a "real world" budget and schedule.

With these conditions in mind, the measures-of-merit used in deciding what technologies to employ were total life-cycle costs, site life-cycle energy use measured at the meter, oxides of sulphur (SO_x) and oxides of nitrogen (NO_x) emissions (associated with acid rain and smog production), and carbon dioxide (CO_2) emissions, a greenhouse gas. Including these as measures-of-merit in the design criteria helps to determine the full impact of a building on its inhabitants and surrounding community.

Table 1 provides typical office building data reported by the Energy Information Agency in 1999 relative to size, function, and Louisiana climate. The annual energy consumption and expenditure data for typical office building classes reported below provide a baseline for comparison for the three new state buildings. The ranges of values are averaged to provide a mean reference value.

Table 1: Typical Office Bldg. Data for Size, Function and Louisiana Climate (1999)
U.S. Department of Energy, Energy Information Agency
Electricity Consumption and Expenditure Intensities, 1999 Building Annual

Building Class by Size, Use, Age, Climate, Occupancy, and Ownership	Electricity Consumption					Electricity Expenditures	
	kwhr[1] / sq. ft.	mwhr[2] / Worker	Distribution- kwhr / sq. ft.			$ / sq. ft.	$ / kwhr
			25th %	Median	75th %	Average	Cost
200,001 to 500,000 sq. ft.	14.7	11.3	5.1	10	20.4	0.95	0.064
Office	18.7	7.8	6	11.7	17.9	1.3	0.07
1990 to 1999	17.8	14.4	3.7	8.6	21.8	1.24	0.069
>2,000 CDD**3** & <4,000	15	12	3.3	9.8	22.1	1.02	0.068
49 to 60 Hours/ week	12	8.2	4	7.7	14.7	0.91	0.076
61 to 84 Hours / week	13.9	10.7	6.2	11.6	23.7	1.06	0.076
Federal Gov.	21	12.5	8.3	18.1	42.8	1.28	0.061
State Gov.	13.9	13.2	6.4	12.9	17.9	0.94	0.068
Average / year	**15.9**	**11.3**	**5.4**	**11.3**	**22.7**	**$1.09**	**$0.07**

1 - Kilowatt hour **2** - Megawatt hour **3** - Cooling Degree Days **4** - Heating Degree Days

Each building was modeled by M. S. Addison and Associates of Tempe, AZ, using *PowerDOE*. *PowerDOE* and its predecessor, DOE2.1E, calculated hour-by-hour building energy consumption over an entire year (8,760 hours) using weather data for the specific location. Life-cycle cost analysis was performed using an easy-to-use spreadsheet from the National Institute of Standards and Technology's widely used BLCC program. For more information on *PowerDOE* and the user-friendly BLCC program visit the DOE-2 Based Building Energy Use and Cost Analysis Software website at http://www.doe2.com.

A detailed description of the building being analyzed, including hourly scheduling of occupants, lighting, equipment, thermostat settings and equipment performance characteristics is input into the program. Discount rates were those established by the U.S. Federal Energy Management Program (FEMP) for the current analysis year. Energy prices were based on local utility contracts.

Emissions factors for NO_x, SO_x, and CO_2, expressed as a function of the amount of electricity and natural gas used, were obtained from two sources:

1. The FEMP web site provides information on the EMISS program developed by the National Institute of Standards and Technology:
   (URL: http://www.eere.energy.gov/femp/information/download_blcc.cfm#emiss).

2. The National Resources Defense Council web site provides data on electric utility emissions by the utility company: (URL: http://www.nrdc.org/air/pollution/benchmarking/default.asp).

Baseline levels for utility costs, energy use, emissions levels and peak demand were determined by designs that were minimally compliant with AHSRAE 90.1-1989, the national standard energy code at the time. Design team members identified a variety of alternative design concepts and technologies including: Siting and orientation; envelope materials and insulation levels; fenestration amount and interior shading/light shelf; the glazing's solar/thermal and daylighting properties; ceiling and interior finish colors; high efficiency indoor lighting; occupancy sensor lighting controls; and automatic dimming controls. Because the HVAC systems would be served by an existing central chilled water plant, HVAC system alternatives focused on heat recovery, two-speed vs. variable speed drives, chilled water pumping control, and air-side economizer types.

A challenge associated with energy efficient building design is the interaction that occurs between design alternatives. It is important to demonstrate both the separate performance of individual design alternatives and the collective performance of the group of recommended features; therefore, care must be taken regarding how the computer simulations are run. This project proceeded by modeling one design alternative at a time on top of design alternatives previously accepted. Only the designs that provided good economic and environmental performance were retained, thus "growing" the design package item-by-item. The incremental and cumulative performance of each alternative was reported.

Typical summary results from the *PowerDOE* simulations for the Galvez building are shown in **Table 2**. Each row of recommended measures incorporates all previous recommended measures. The 25-year life-cycle costs are reported as undiscounted dollars indicating future operations budget impacts.

Table 2: Typical Results – Galvez Building, Louisiana State Capitol Complex, 12/20/00

Only RECOMMENDED measures are shown	Annual Energy, Demand, & Costs				Cumulative Results (% savings)		
	Site Electricity	Peak Demand	Savings	Annual Utility	25 Year LifeCycle	Annual Savings	
Measure Description	**mwhr**	**kw**	**%**	**Cost ($)**	**Cost ($)**	**$**	**%**
Min 90.1 Compliance	7,238	2,836	n/a	$563,089	14,077,225	n/a	
0+Reoriented Building	7,125	2,779	-2%	$554,469	13,861,725	8,620	-2%
1a+Window Setback	7,044	2,744	-3%	$548,788	13,719,700	14,301	-3%
1b+Precast Skin	6,872	2,670	-6%	$532,177	13,304,425	30,912	-5%
1c+Light Surface Color	6,836	2,648	-7%	$529,378	13,234,450	33,711	-6%
1d+East Patio Shading	6,826	2,641	-7%	$528,663	13,216,575	34,426	-6%
1e+Increased Wall Insulation	6,805	2,627	-7%	$526,236	13,155,900	36,853	-7%
2a+Increased Roof Insulation	6,795	2,620	-8%	$525,266	13,131,650	37,823	-7%
2b+Dbl Low-e Bronze Glass	6,566	2,503	-12%	$505,914	12,647,850	57,175	-10%
3c+Reduced Lighting Density	6,124	2,337	-18%	$471,737	11,793,425	91,352	-16%
4a+Daylighting Controls	5,355	2,023	-29%	$412,231	10,305,775	150,858	-27%
4b+Occupancy Sensors	5,108	1,966	-31%	$396,539	9,913,475	166,550	-30%
4c+Heat Recovery Ventilator	4,777	1,788	-37%	$371,866	9,296,650	191,223	-34%
5a+VS Drive Pump Control	4,704	1,756	-38%	$365,942	9,148,550	197,147	-35%
5b+CO2-Controlled Vent Air	4,689	1,755	-38%	$365,309	9,132,725	197,780	-35%
5c+Central Chiller Plant	4,617	1,722	-39%	$359,356	8,983,900	203,733	-36%
Electricity kwhr / sq. ft. / year	13.6			$1.056 / sf	(-5,093,325)		

Projected savings were 36% for energy, annual utility cost, and annual emissions, and 39% for peak electrical demand. These significant reductions will yield a 25-year savings of 1.9 million dollars (discounted) or 5.1 million dollars of avoided utility costs. Expected use and consumption for all three buildings is shown in **Table 3**.

Table 3: Summary of Each Building's Projected Electricity Use

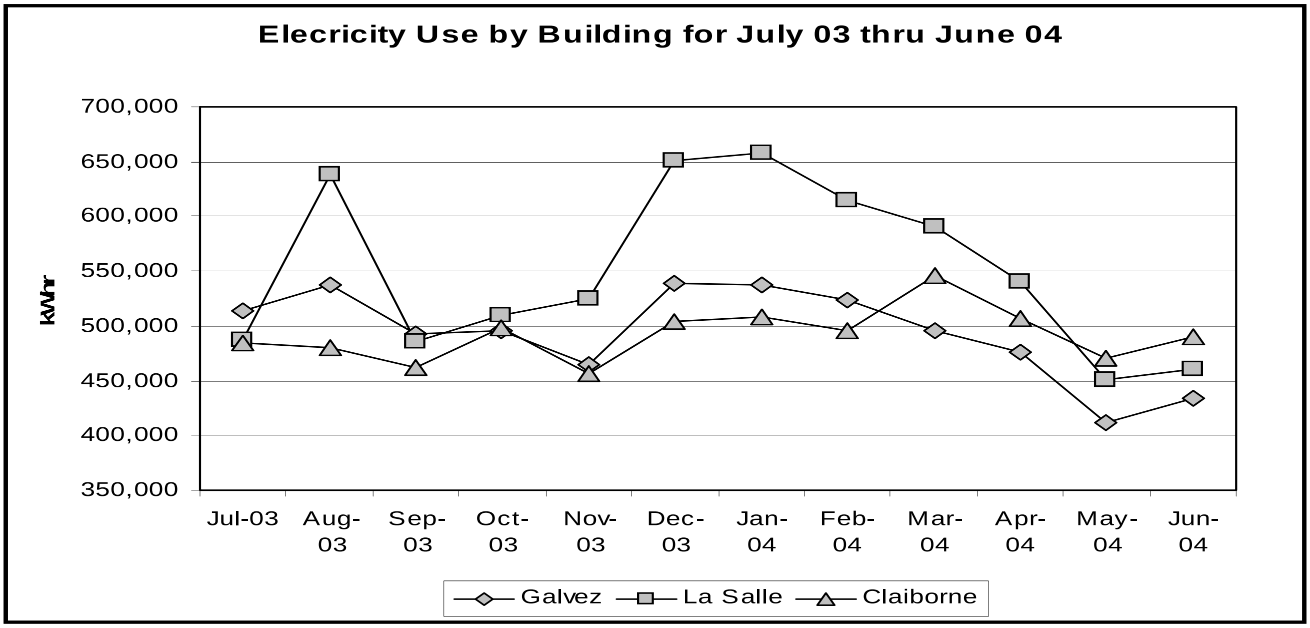
Simulation Projections	Area Lights	Misc Equip	Space Heating	Space Cooling	Heat Reject	Pumps & Aux	Vent Fans	Hot Water	Total	kwhr / sq. ft.
Building	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**kwhr**	**year**
LaSalle	622,520	1,586,445	55,720	569,309	25,612	206,896	255,543	57285	3,379,330	**9.27**
Claiborne	1,027,943	2,169,632	21,479	826,620	40589	298,138	252,369	Nat. Gas	4,636,770	**9.3**
Galvez	745,029	1,653,000	30,916	621,947	30,925	204,103	347,480	56,895	3,690,295	**9.71**

Actual electrical consumption for the three buildings, as reported by the Office of State Buildings, is shown in **Table 4**, and graphically in **Figure 1**.

Table 4: Monthly Electricity Consumption in kwhr

Month	3-Jul	3-Aug	3-Sep	3-Oct	3-Nov	3-Dec	4-Jan	4-Feb	4-Mar	4-Apr	4-May	4-Jun	Year Total
Galvez	514,200	538,200	492,600	496,200	465,000	539,400	538,200	523,200	496,200	475,800	411,000	434,400	**5,924,400**
kwhr/sq. ft.	1.51	1.58	1.45	1.46	1.37	1.59	1.58	1.54	1.46	1.4	1.21	1.28	**17.42**
La Salle	486,868	639,010	486,016	509,281	524,445	650,492	657,806	615,229	590,775	539,749	450,337	460,155	**6,610,163**
kwhr/sq. ft.	1.33	1.75	1.33	1.4	1.44	1.78	1.8	1.69	1.62	1.48	1.23	1.26	**18.12**
Claiborne	485,016	480,837	461,423	498,472	456,722	503,352	508,014	494,998	545,396	507,031	470,739	489,691	**5,901,691**
kwhr/sq. ft.	0.97	0.96	0.93	1	0.92	1.01	1.02	0.99	1.09	1.02	0.94	0.98	**11.83**

Figure 1: Electrical use by Building for each Month from Office of State Buildings



CONCLUSION

When design criteria include environmental measures-of-merit and total building impacts are weighed over the life of the facility, owners and design teams tend to make better choices and tend to be more motivated to identify environmentally superior solutions.

Advances in simulation and economic analysis tools make this extra effort both affordable and reliable. Future software developments will further facilitate the life-cycle environmental building design process and further reduce the cost of identifying “optimal” design solutions.

This project predicted that substantial energy savings and associated emissions reductions could be realized by making use of affordable, conventional energy efficiency building technologies. The actual results, however, have been less than what was predicted. Currently, only the Claiborne Building is performing close to expectations, but the elements needed for success are there; they just need to be tuned to work together as originally intended.