



Mid-CD Phase Energy Narrative

**Poudre River Public Library
Fort Collins, CO**

August 11, 2011

Prepared for:

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ARCHITECTURE
URBAN DESIGN
INTERIOR DESIGN

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EXECUTIVE SUMMARY

This document provides an energy performance estimate to the project team for the proposed renovation and expansion of the Poudre River Public Library. By renovating and upgrading an existing facility in lieu of new construction the library is demonstrating a commitment to the responsible use of resources. The results presented in this energy report show that the project team has enhanced this commitment through the proposed architectural, mechanical and electrical systems and strategies. **The proposed upgraded library achieves greater square footage, improved space planning, significantly improved energy performance and lower annual energy costs compared to the existing facility.** The current facility energy costs of \$2.01/sf/year are potentially decreased to \$0.98/sf/yr. In summary, even with a larger square footage the new facility will potentially achieve **net-savings in energy costs** based on the strategies described in this report.

This narrative focuses on the annual energy usage of the completed 40,000 sf library facility, including all work in both Phase 1 and Phase 2. The purpose of this energy modeling exercise is as follows:

- Identify the percentage energy savings in Energy Use Index (kBtu/sf/year) and Energy Cost Index (\$/sf/yr) as compared to the existing Poudre River Public Library.
- Identify the relative contribution to overall savings in energy use and energy cost of three key energy efficiency measures (EEMs)
 - EEM-1 LPD: Networked Lighting Controls
 - EEM-2 EPD: Plug Load Management
 - EEM-3 DCV: Upgraded CO2 sensor-based Demand Control Ventilation (DCV)
- Provide an energy model that can be used for post-occupancy building performance diagnostics after the renovation is complete.

Each EEM was modeled in isolation to identify their relative impact on the annual energy use and cost of the proposed design. In addition, a final Design Case incorporating all EEM was modeled. Table 1 below summarizes the annual energy use and cost results for each model scenario compared to the historical average energy use and cost for the existing library, as calculated from utility bills for the years 2005 – 2010.

Table 1. Summary Results for Annual Energy Use, Cost and Peak Demand

Scenario	Annual Energy Use		Facility Peak Demand		Annual Energy Costs	
	kBtu/sf/yr	% Savings vs. Existing	kW/Month	% Savings vs. Existing	\$/yr	% Savings vs. Existing
Existing Library (average)	139		217		\$68,394	
Design Case, No EEMs	91	35%	149	31%	\$54,375	20%
EEM-1 LPD	86	38%	125	42%	\$48,114	30%
EEM-2 EPD	84	40%	120	45%	\$45,282	34%
EEM-3 DCV	89	36%	138	36%	\$52,442	23%
Design Case, All EEMs	77	45%	95	56%	\$38,062	44%

As shown above, the Design Case with all EEMs achieves an annual savings of 45% in energy use, 56% in peak demand and 44% in energy costs against the historical 5-year average for the existing library.

The scope of proposed architectural envelope upgrades is limited - the new wall and window areas represent a small percentage of the overall building envelope, at 10% and 14% respectively. In analyzing the detailed energy model results and historical utility bills for the existing library it is apparent the key issues facing the existing library are high heating loads and peak demand charges, possibly due to the poor thermal performance of the existing envelope and operational issues with the existing HVAC equipment. Therefore in addition to the proposed boiler and HVAC controls upgrades, the following are highly recommended to achieve the magnitude of improved energy and cost performance indicated by the energy modeling results:

- The savings indicated for the Design Case, All EEMs model can only be realized with proper **commissioning** of all systems and controls prior to occupancy and the proposed **building performance diagnostics** in the immediate post-occupancy period.
- As a building type, libraries have a high equipment and lighting power load, and large numbers of transient occupants who use the equipment and need the lights but do not have the responsibility to turn them off after use. An **integrated lighting and plug load controls system**, such as the Power Link control system, **occupant awareness** (signage) and **staff training** of the need to turn off appliances when not in use, can help reduce peak demand, energy use and thus annual energy costs in a densely occupied public facility such as the Poudre River Library.

Fig. 1 below compares the annual energy use of each modeled scenario.

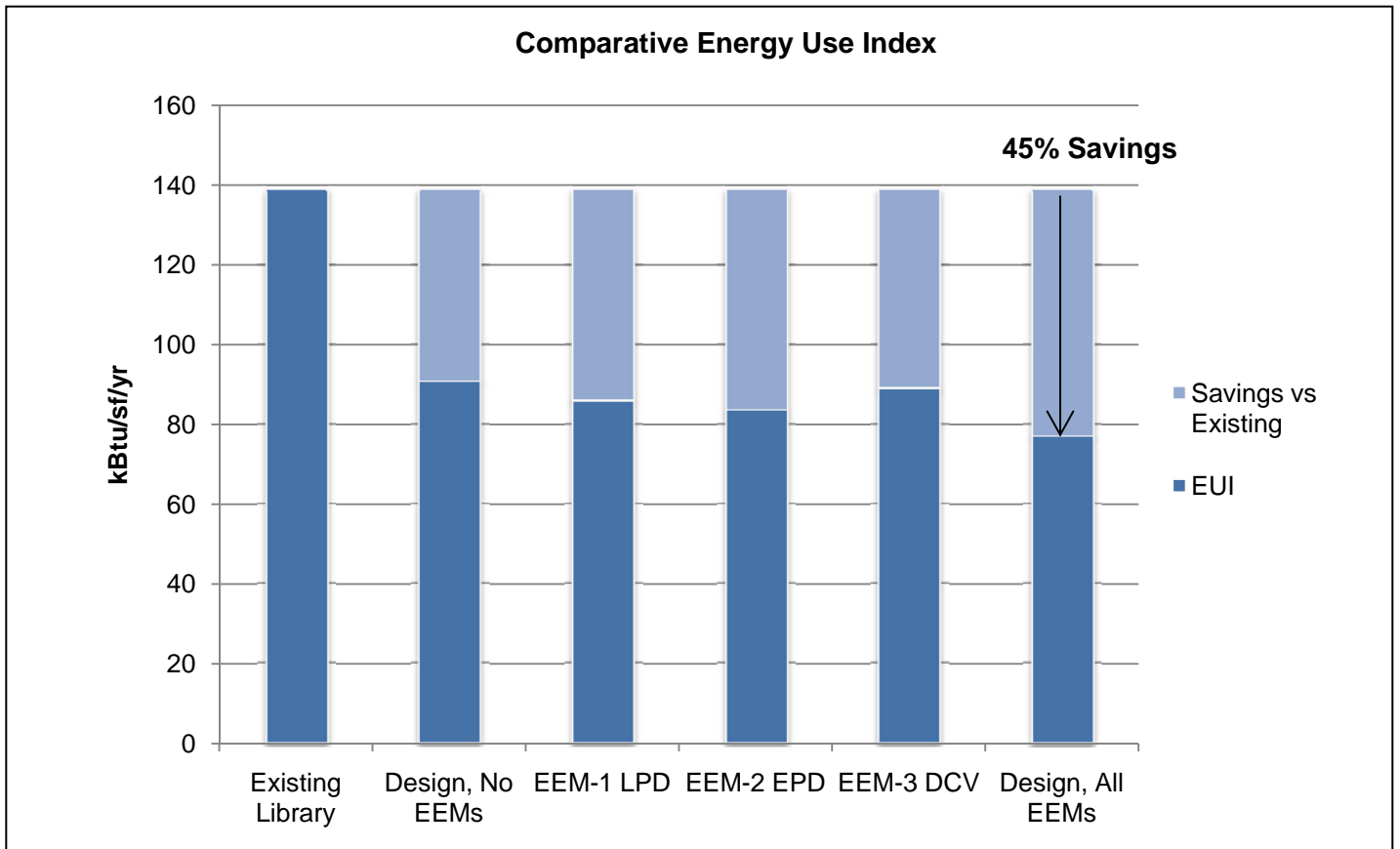


Figure 1: Annual Energy Use Index Comparison

Please note that energy model results are significantly affected by inputs to the model that will vary greatly under actual operating conditions such as patterns of occupancy, lighting, receptacles, domestic hot water use, and HVAC system set points. The data presented in this report is the result of a comparative energy model analysis, more commonly used during the design development phase to compare options against each other on a relative basis. These results are not predictive of *actual* energy use and costs once the project is completed and occupied. A calibration of the energy model results to actual operation parameters and utility bills will take place during the building performance diagnostic phase after renovations are complete and be documented accordingly.

Building Performance Diagnostics

As noted in the Executive Summary above, engaging in building commissioning is highly recommended for this project for a successful integration of the different phases, new and existing equipment and systems, and to achieve the magnitude of savings estimated for the 'Design Case with All EEMs'.

Building commissioning addresses the correct installation and tuning of systems and equipment during construction. To support ongoing utility accountability as a management tool for the Poudre River Public Library District (PRPLD), Ambient Energy will be providing building performance diagnostics during the post-occupancy period. The objective of these services is to provide PRPLD with actionable suggestions to tune the buildings for immediate performance improvements as well as create a framework for communication and proactive management around utilities that includes facilities, accounting, and library programming and management personnel.

Typically performed 3-6 months after occupancy, while the building is still within the warranty period, performance diagnostics of the Poudre River Library will cover lighting and lighting controls, mechanical and electrical systems and controls, process (receptacle) loads such as office equipment. A 'Diagnostic Energy Model' will be created based on updates to the energy model used in this energy analysis exercise and the final as-built design documents, and calibrated to the actual weather conditions and occupancy patterns. To support long term utility accountability, Ambient Energy will conduct a training session with the library facility manager, BAS technician, library representatives, and other staff regarding operational procedures and best practices.

The benefits of this performance diagnostics scope include the following:

- Reduced utility expense and reduced exposure to energy budget volatility
- Assistance in creating a framework for communication and proactive management of building energy use that includes facilities, accounting, and building users and management personnel
- Support for PRPLD management, staff, processes, equipment and data for ongoing utility accountability

ENERGY CONSERVATION AND MODELING

Energy Efficient Design and Systems Strategies

In addition to the EEMs described in this report the following proposed architectural, mechanical and electrical strategies will contribute to savings in energy use, cost and peak demand compared to the existing facility.

- Architecture:
 - The proposed new infill envelope on L1 includes high-performance glazing tuned according to function (daylight vs. vision) and external horizontal shading
- Mechanical Systems:
 - New high-efficiency condensing boiler
 - New VAV controls, thermostats
 - VFD controls on all fans
- Electrical Systems
 - Reduced lighting power density with daylight controls
- Plumbing Systems
 - Water use reduction goals and strategies per the LEED NC v2009 rating system will be applied to all new plumbing fixtures

In addition to those listed above, these additional strategies are recommended to be considered:

- General:
 - Occupant awareness programs / training to control use of equipment and electric lighting
 - Commissioning of all HVAC, electrical and plumbing equipment and control systems
- Architecture
 - Incorporating the recommendations listed in the daylight Recommendations Memo by Ambient Energy dated July 20, 2011, regarding the glazing type and tuning per function (daylight vs vision)
- Receptacle Equipment and Appliances:
 - Switched or scheduled electrical receptacles to minimize consumption during unoccupied hours
 - ENERGY STAR equipment (applicable to all new computers, monitors, television screens, refrigerators, copiers/printers)
- Mechanical and Electrical Systems:
 - High efficiency LED site lighting and building exterior lighting
 - “Photocell on, time-clock off” sequence for exterior lighting systems

Energy Benchmarks

Energy benchmarks are a useful tool for establishing and tracking progress towards energy goals. As the project is not pursuing a LEED certification, the energy performance of the existing facility has been used as a reference for the project’s energy performance goals. In addition, the project can be compared to the average energy performance of Colorado public libraries as documented in the database compiled by Denver Public Libraries. *Table 2* below identifies these benchmarks.

Table 2: Project Benchmarks

Scenario	Energy Use Index (kBtu/sf/yr)	Energy Cost Index (kBtu/sf/yr)
Existing Poudre River Library	139	\$2.01
Average CO Libraries	57	\$1.84
Design Case with all EEMs	77	\$0.98

It must be noted that the integration of the new and existing building and systems in the Poudre River Library causes a higher EUI than would be achieved with a new building, however the conservation of resources resulting from reuse of an existing building achieves a greater level of sustainability for the project overall.

Energy Efficiency Measures (EEMs)

The impact on modeled building performance of several EEMs was analyzed to identify opportunities to further improve the energy use performance of the Design Case. The EEMs are summarized and explained in more detail in *Table 3* below.

Table 3. Energy Efficiency Measures (EEMs)

EEM	Alternative	Proposed Design
1 Networked Lighting Controls	Whole building lighting power density 1.1 W/sf, 42.6kW total lighting power load, 20.5 kW of lights under photosensor control in perimeter zones (0-100% dimmable fixtures, 30fc threshold Occupancy sensors in interior zones	Whole building lighting power density 1.1 W/sf, 42.6kW total lighting power load. No daylight controls, occupancy sensors in storage, janitor, elec/mech rooms
2 Plug Load Management	Whole building receptacle load 0.55 W/ft ² with power management controls	Receptacle loads: 2.0 W/sf in staff/admin areas, 1.5 W/ft ² in public access areas
3 Upgraded Demand Control Ventilation (DCV)	DCV based on CO2 levels in each densely occupied space. Ventilation minimum of 7-15% OA. Min requirements per ASHRAE 62.1-2007: 5 cfm/person. 0.12 cfm/sf, 6,393 cfm	DCV based on CO2 levels in each densely occupied space, 14,957 cfm. Ventilation minimum of 50% OA per ECube Inc Retro-commissioning report 06/2010

Detailed Energy Results

The correlation between modeled and actual annual energy performance of any building is highly dependent on assumptions made about patterns of occupancy, lighting and receptacle use, as well as general occupant behavior (e.g. use of internal blinds). Therefore all data presented in this report should be considered comparative and not predictive. *Table 4* describes the modeled scenarios; *Table 5* and *Table 6* document detailed annual energy use and cost results.

Table 4. Energy Model Descriptions and Scope

Model	Architectural Upgrades, Phase 1 and 2	HVAC Upgrades, Phase 1 and 2	Current DCV air flow, controls	Lighting Controls	Plug Load Management	Upgraded DCV air flow, controls
Design Case, No EEMs	X	X	X			
EEM 1 LPD	X	X	X	X		
EEM 2 EPD	X	X	X		X	
EEM 3 DCV	X	X				X
Design Case, All EEMs	X	X		X	X	X

Table 5. Summary Energy Use Results

Model	Annual Electricity	Annual Natural Gas	Energy Usage Index	Facility Peak Demand	% Savings	
	kWh/yr	MMBtu/yr	kBtu/sf/yr	kW/mo	Peak Demand	Energy Use
Existing Library (average)	826,248	1,924	139	217		
Design Case, No EEMs	459,715	1,946	91	149	31.3%	34.7%
EEM-1 LPD	377,189	2,038	86	125	42.4%	38.2%
EEM-2 EPD	334,547	2,091	84	120	44.7%	39.9%
EEM-3 DCV	452,251	1,900	89	138	36.3%	36.0%
Design Case, All EEMs	244,405	2,148	77	95	56.2%	44.6%

Table 6. Summary Energy Cost Results

Model	Energy Costs	Energy Cost Index	% Savings
	\$/yr	\$/sf	Energy Cost
Existing Library (average)	\$68,394	\$2.01	
Design Case, No EEMs	\$54,375	\$1.41	20.5%
EEM-1 LPD	\$48,114	\$1.24	29.7%
EEM-2 EPD	\$45,282	\$1.17	33.8%
EEM-3 DCV	\$52,442	\$1.36	23.3%
Design Case , All EEMs	\$38,062	\$0.98	44.3%

Fig. 2, Fig. 3 and Fig. 4 compare the relative contribution of each end use category to the total annual energy use in the 'Design Case with No EEMs' and 'Design Case with All EEMs' models respectively. Note exterior lighting has not been modeled due to insufficient data available at the time of the modeling exercise. Fig. 5 compares the percentage of annual electrical and natural gas use for the existing building and each modeled scenario.

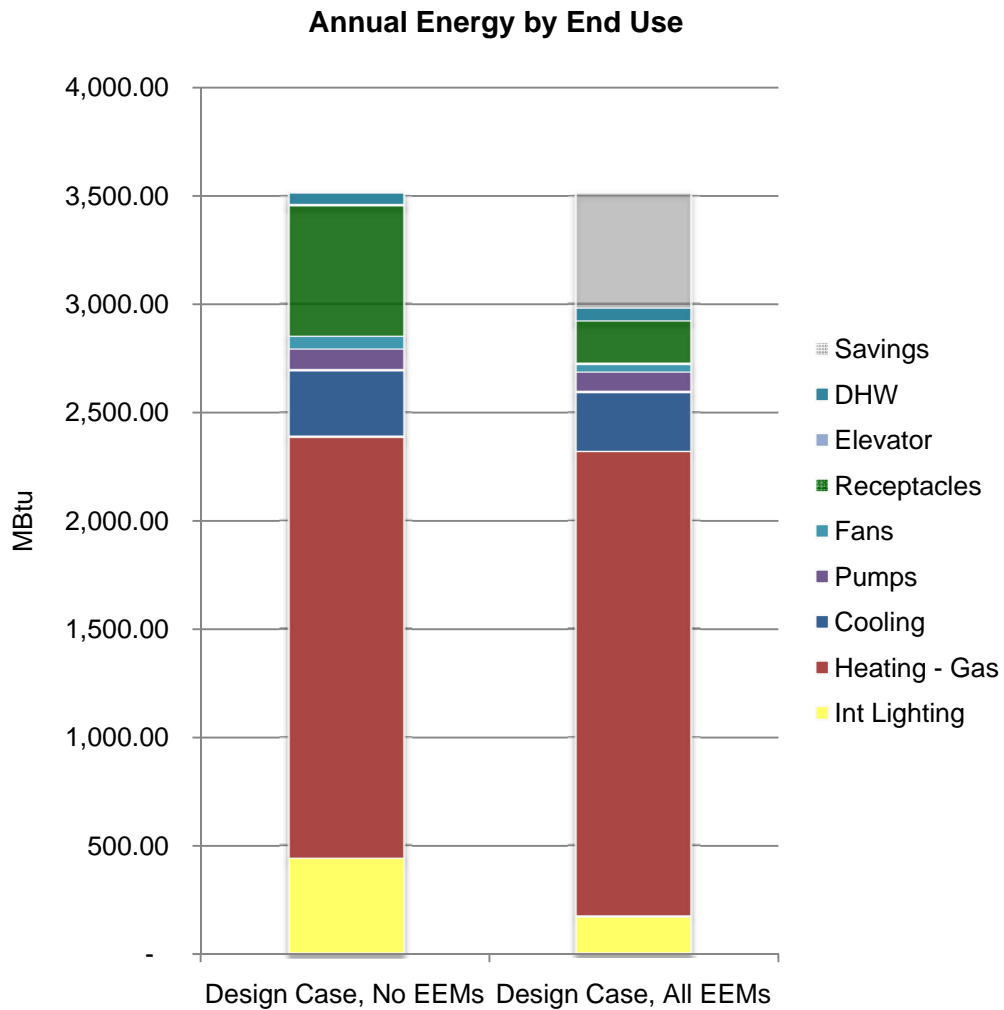


Figure 2: Annual Energy Comparison, by End Use. Note: MBtu = 10³ kBtu

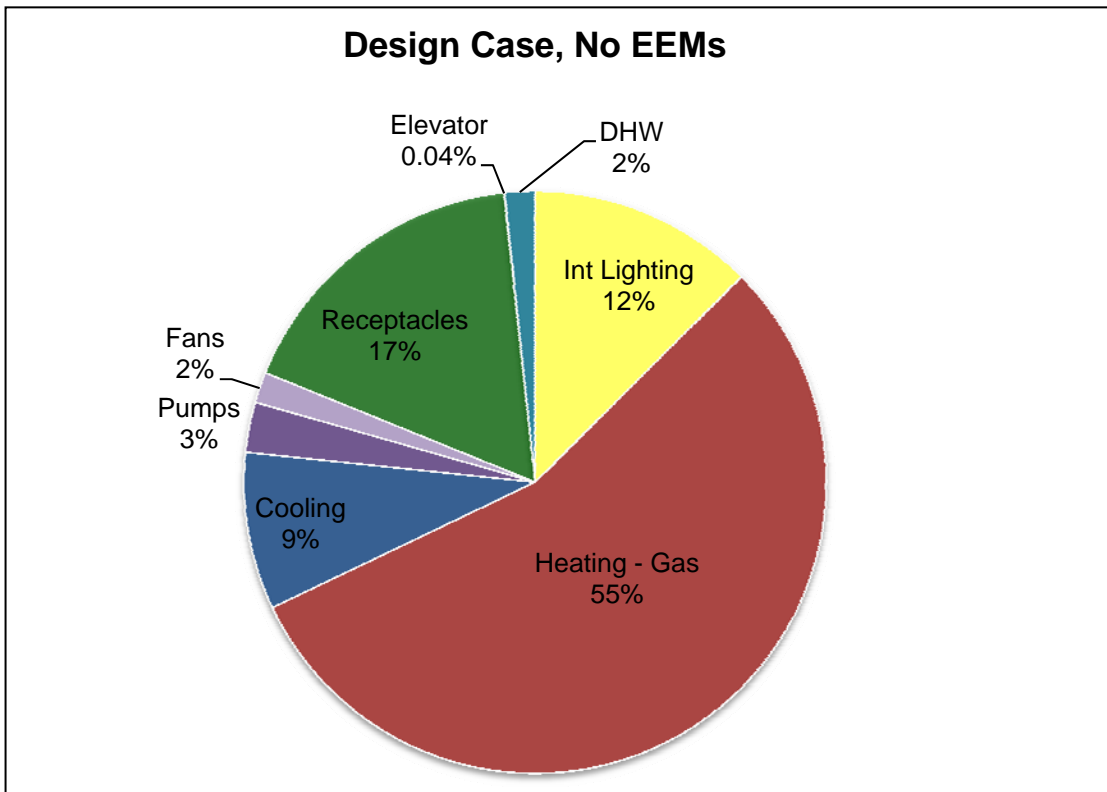


Figure 3: 'Design Case with No EEMs' Annual Energy Use Contributions

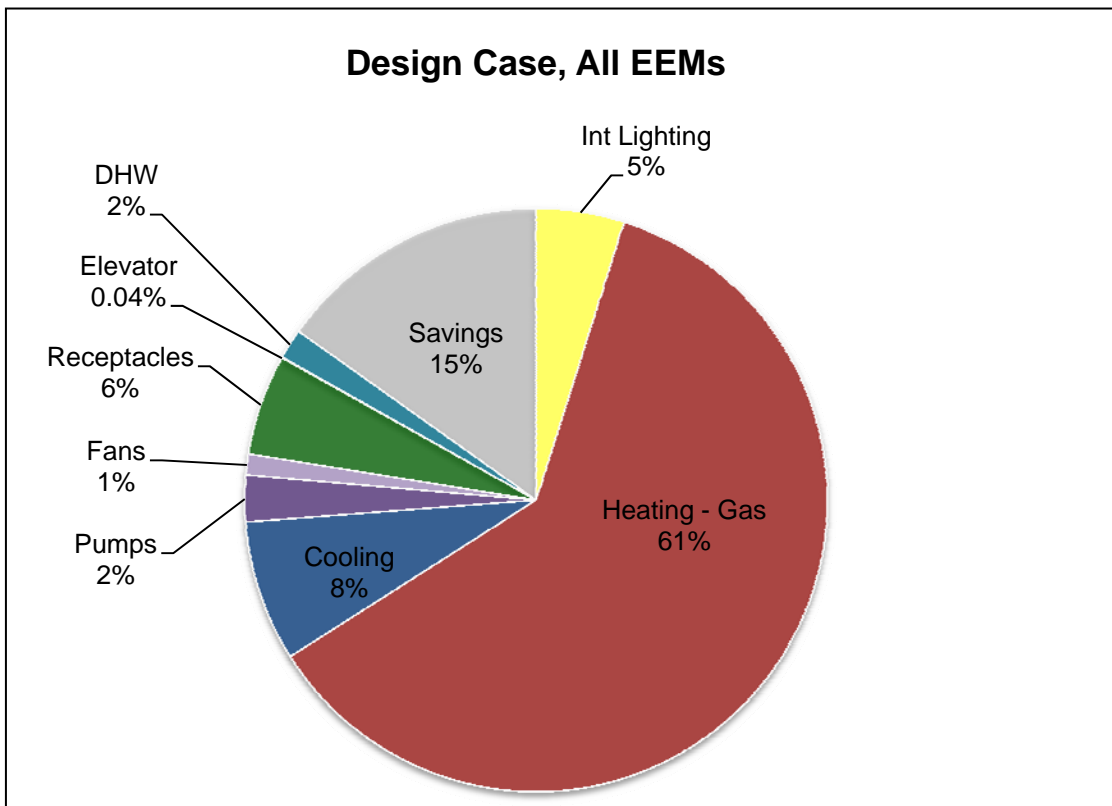


Figure 4: 'Design Case with All EEMs' Annual Energy Use Contributions

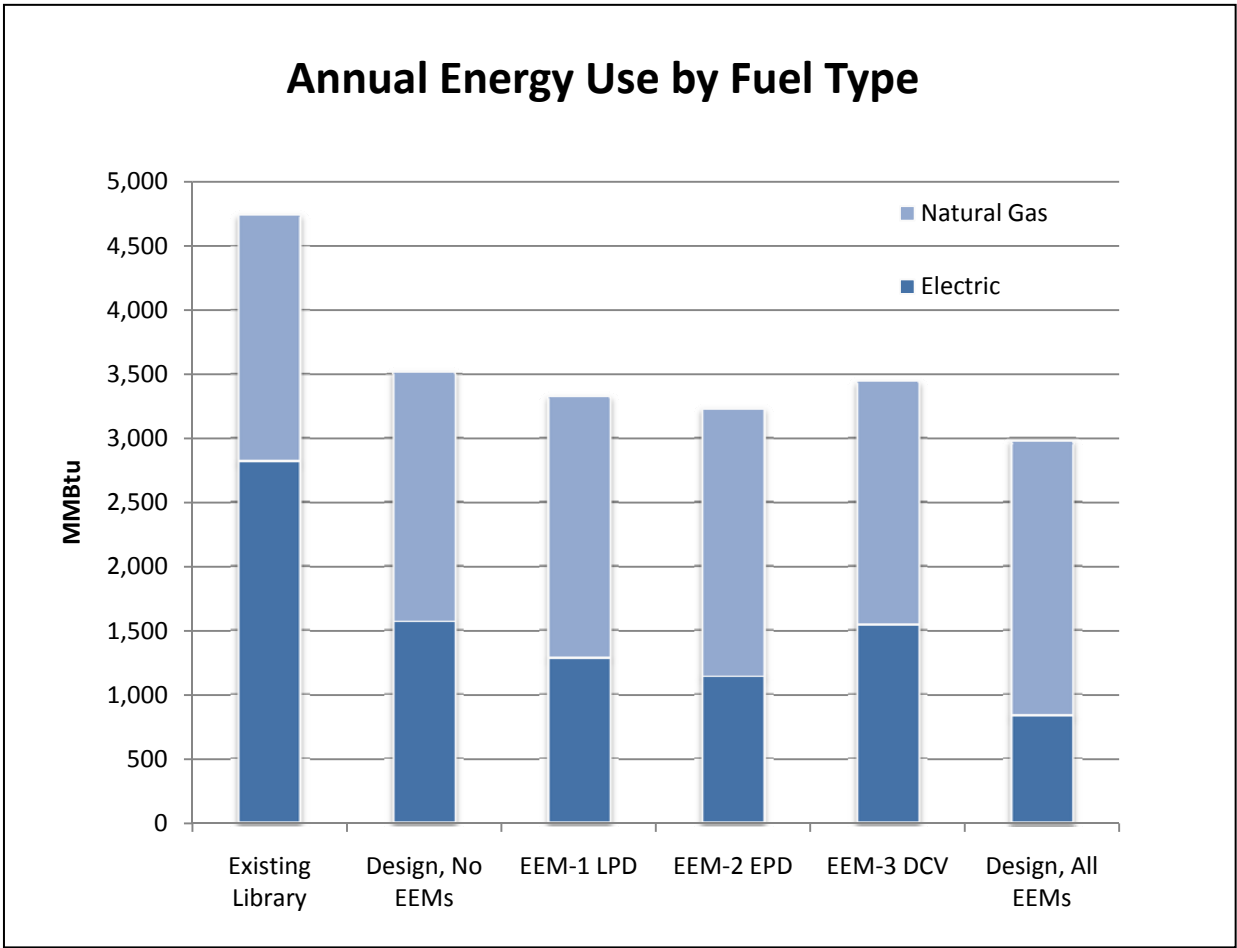


Figure 5: Annual Energy Comparison, by Fuel Source

APPENDICES

- A. Energy Modeling Methodology and Description**
- B. Common Model Input Parameters**
- C. Detailed Design Case and Base Case Input Parameters**
- D. Wall Layers R-value Calculation Table**

Appendix A. Common Model Input Parameters

Inputs common to all models

For a more accurate comparison of relative energy performance, the following project parameters are consistent in each building model scenario.

Table A1. Summary Common Model Inputs

Model Input Parameter	Proposed Design Input
Size	38,685 sf
Hours of Operation	Mon-Thurs: 9.30AM – 9PM Fri: 10AM – 6PM Sat: 10AM – 5PM Sun: 1PM - 5PM
Location	Fort Collins, CO
Weather File	Fort Collins AWS
Occupancy	32 staff, total 1000 peak occupants at any one time
Setpoint Temperatures	Heating Setpoints: Occupied: 72 F Unoccupied: 60 F Cooling Setpoints: Occupied: 75 F Unoccupied: 80 F
ASHRAE Design Conditions	Summer: 93 F DB / 64 F WB Winter: -2 F DB

Utility Rates

The project is in the service territory of the City of Fort Collins (electric) and Asgard LLC (gas), and is charged under the following utility rates:

Table A2. Utility Rate

Utility Rates	
Electric Source:	City of Fort Collins, E300-310 Tariff, Jan 1st 2011
\$19.46	per month
\$0.026	/kWh
\$5.11	/kW Facility Demand
\$13.57	/kW Coincident Peak
Fuel Source:	Asgard LLC Tariffs, historical rates (2005-2010 average)
\$6.20	/MMBtu

Schedules

The following schedules were applied to each major zone, based on typical use and occupancy patterns seen in public libraries.

Table A3: Main Library Area Schedule

Hour of Day	Occupancy (% of Maximum Load)				Lighting, Receptacles (% of Maximum Load)				HVAC Systems			
	Mon-Th	Fri	Sat	Sun	Mon-Th	Fri	Sat	Sun	Mon-Th	Fri	Sat	Sun
1	0	0	0	0	5	5	5	5	Off	Off	Off	Off
2	0	0	0	0	5	5	5	5	Off	Off	Off	Off
3	0	0	0	0	5	5	5	5	Off	Off	Off	Off
4	0	0	0	0	5	5	5	5	Off	Off	Off	Off
5	0	0	0	0	5	5	5	5	Off	Off	Off	Off
6	0	0	0	0	5	5	5	5	Off	Off	Off	Off
7	0	0	0	0	5	5	5	5	Off	Off	Off	Off
8	0	0	0	0	5	5	5	5	On	Off	Off	Off
9	5	0	0	0	90	5	5	5	On	On	On	Off
10	10	10	20	0	90	90	90	5	On	On	On	Off
11	25	20	50	0	90	90	90	5	On	On	On	Off
12	20	50	50	0	90	90	90	5	On	On	On	On
13	20	50	50	50	90	90	90	90	On	On	On	On
14	20	50	50	50	90	90	90	90	On	On	On	On
15	20	50	50	50	90	90	90	90	On	On	On	On
16	20	50	50	50	90	90	90	90	On	On	On	On
17	20	20	20	50	90	90	90	90	On	On	On	On
18	10	10	0	0	90	90	5	5	On	On	On	On
19	10	0	0	0	90	90	5	5	On	On	Off	Off
20	10	0	0	0	90	5	5	5	On	Off	Off	Off
21	5	0	0	0	90	5	5	5	On	Off	Off	Off
22	0	0	0	0	90	5	5	5	On	Off	Off	Off
23	0	0	0	0	5	5	5	5	Off	Off	Off	Off
24	0	0	0	0	5	5	5	5	Off	Off	Off	Off

Table A4: Admin/Staff Areas Schedule

Hour of Day	Occupancy (% of Maximum Load)				Lighting, Receptacles (% of Maximum Load)				HVAC Systems			
	Mon-Th	Fri	Sat	Sun	Mon-Th	Fri	Sat	Sun	Mon-Th	Fri	Sat	Sun
1	0	0	0	0	5	5	5	5	Off	Off	Off	Off
2	0	0	0	0	5	5	5	5	Off	Off	Off	Off
3	0	0	0	0	5	5	5	5	Off	Off	Off	Off
4	0	0	0	0	5	5	5	5	Off	Off	Off	Off
5	0	0	0	0	5	5	5	5	Off	Off	Off	Off
6	0	0	0	0	5	5	5	5	Off	Off	Off	Off
7	0	0	0	0	5	5	5	5	Off	Off	Off	Off
8	0	0	0	0	5	5	5	5	On	Off	Off	Off
9	25	25	25	0	90	5	5	5	On	On	On	Off
10	25	25	25	0	90	90	90	5	On	On	On	Off
11	25	25	25	0	90	90	90	5	On	On	On	Off
12	25	25	25	25	90	90	90	5	On	On	On	On
13	25	25	25	25	90	90	90	90	On	On	On	On
14	25	25	25	25	90	90	90	90	On	On	On	On
15	25	25	25	25	90	90	90	90	On	On	On	On
16	25	25	25	25	90	90	90	90	On	On	On	On
17	25	25	25	25	90	90	90	90	On	On	On	On
18	25	25	25	25	90	90	5	5	On	On	On	On
19	25	25	0	0	90	90	5	5	On	On	Off	Off
20	25	0	0	0	90	5	5	5	On	Off	Off	Off
21	25	0	0	0	90	5	5	5	On	Off	Off	Off
22	0	0	0	0	90	5	5	5	On	Off	Off	Off
23	0	0	0	0	5	5	5	5	Off	Off	Off	Off
24	0	0	0	0	5	5	5	5	Off	Off	Off	Off

Equipment Inventory

The following equipment list was used to calculate the whole building equipment power density (W/sf). This list was compiled based on a review of 50% CD design submittal and reference to similar library facilities.

Table A5: Assumed Equipment Inventory

Equipment	Qty	VA	Watts	Total Watts
Server	1	150	135	150
Receptacles	64		270	17280
Printer	2	1000	900	1800
LCD	17	750	675	11475
Ceiling Projector	2	1000	900	1800
Refrigerator	1	960	864	864
Microwave	1	1500	1350	1350
Coffee Maker	1	1500	1350	1350
Vending Machine	1	1200	1080	1080
Copiers	3	1500	1350	4050
Book Sorter	1	15380	13842	13842
Book Sorter Duplex Receptacles/PC	1	180	162	162
Security Gate	1	120	108	108
Security Control Panels	1	1500	1350	1350
Exterior Wireless Access	1	500	450	450
Hand Dryer	7	1500	1350	9450
Drinking Fountains	4	260	234	936

Appendix B. Detailed Input Parameters

Model Inputs

Table B1 identifies the model input parameters of the 'Design Case with No EEMs' and each other modeled scenario except where an EEM variable supersedes the information. The inputs are based on information documented in the 50% CD Design Submittal dated July 8, 2011, the Retro-Commissioning Report by E Cube dated July, 2010 and correspondence with the design team.

Table B1. Model Inputs

Input	Proposed Design Value
Conditioned Area (sf)	38,685 sf
Unconditioned Area (sf)	38,685 sf
Total Area (sf)	38,685 sf

<i>Architectural Inputs</i>	
Exterior Wall Construction	Existing Wall Assembly: R-2.82, U-0.36 10" Concrete, 5/8" gyp board New Wall Assembly: R-15.67, U-0.06 3-5/8" 16"O.C metal stud w/ R-19 batt insulation on gyp board, grade beam, 1" air gap, 4" brick veneer
Roof Construction	Existing roof (per 1975 as-buit drawings) 8" Concrete Deck, built-up roofing , assembly U-0.51
Floor/Slab Construction	Slab: 4" concrete, uninsulated (Assembly U-0.13)
Window-to-gross wall ratio	WWR: 66% total per design North-76% East-75% South-65% West-48%
Fenestration type	Fixed, w/ thermally broken aluminum frames Type 1 (Existing): 3/8" Tempered, Bronze Tinted, Monolithic Type 2 (Vision): PPG, 1" IGU Solarban 80 (2) Optiblue/Clear Type 3 (Daylight): PPG, 1" IGU Solarban 60 (2) Clear/Clear Type 4 (Skylight, existing): 3/8" Clear, Monolithic
Fenestration U-factor (assembly, winter)	Type 1: U-1.00 Type 2: U-0.29 Type 3: U-0.29 Type 4: U-1.00
Fenestration SHGC	Type 1: SHGC-0.52 (SC-0.61) Type 2: SHGC-0.23 (SC-0.27) Type 3: SHGC-0.38 (SC-0.44) Type 4: SHGC-0.84 (SC-0.97)
Fenestration Visual Light Transmittance	Type 1: Tvis-37% Type 2: Tvis-34% Type 3: Tvis-70% Type 4: Tvis-91%
Shading Devices	3ft exterior horizontal overhang on all south, east, west glazing as indicated on drawings

<i>Electrical Inputs</i>	
Interior Lighting Power (W, W/sf)	Total interior lighting load: 42.7 kW, 1.1 W/sf
Daylighting Controls	20.5 kW of lights under photosensor control (perimeter zones) modeled directly in the building simulation 0-100% dimmable fixtures, 30fc threshold.
Other Lighting Control Credits	Additional lighting controls not modeled: Occupancy sensors in all rooms except IT, MECH/ELEC, Janitorial
Exterior Lighting Power (W)	Not Modeled
Receptacle Equipment Power Density (W/sf)	Total equipment load: 57.7 kW Library Spaces: 2.0 W/sf Admin Spaces: 1.5 W/sf (assumed comparable to GVRL)
Process Equipment: Elevator	Elevator peak demand 2.9 kW

<i>Mechanical Inputs</i>	
Primary HVAC System Type	AHU-Lower (level 1) and AHU-Upper (level 2): Overhead VAV air distribution, VAV boxes, packaged chiller, HW heat finned tube radiators in perimeter zones (AHU Lower 376.8kBtuh, AHU Upper 219.8kBtuh)
Other HVAC System Type	Ceiling mounted cabinet unit heater in each vestibule
Fan Supply Volume (cfm)	VSD on supply and return fans AHU Lower Supply: 10,300 cfm, 15 hp Return: 10,000 cfm, 5 hp AHU Upper Supply: 22,600 cfm, 25 hp Return: 22,000 cfm, 7.5 hp
Fan Power (kW)	AHU Lower Supply: 11.2kW, 0.0011 kW/ cfm AHU Lower Return: 3.7kW, 0.0004 kW/ cfm AHU Upper Supply: 18.6kW, 0.0008 kW/ cfm AHU Upper Return: 5.6kW, 0.0005 kW/ cfm
Ventilation/Exhaust	Ventilation minimum 50% OA per ECube Inc Retro-commissioning report 06/2010, 14,957 cfm. Restroom EF1: 1,330 cfm, 0.25 hp EF2: 225 cfm. Intermittent fans not modeled
Economizer Control	100% OA Economizer with high limit of 65F
Demand Control Ventilation	CO2 sensors in all high-occupancy spaces (multi-purpose room, main library space) 50% OA at minimum damper position per ECube Inc Retro-commissioning report 06/2010
Unitary Equipment Heating Efficiency	Trane FFEB020 CUH @ 96% efficiency
Chiller Parameters	100 ton McQuay packaged unit with (2) compressors @ 60 hp each
Chilled water loop and pump parameters	(2) B&G pumps, constant speed, 1.0 hp each. AHU Lower 31 gpm @ 24.1 W/gpm, AHU Upper 101 gpm @ 7.1 W/gpm
Boiler parameters	(2) P-K C900 high efficiency boilers @ 900 MBH, 43 gpm (ea), 96% thermal efficiency. HW supply temp based on OA reset: 180degF supply temp at/below 20degF OA, 150degF supply temp at/above 50degF OA
Hot water loop and pump parameters	(2) primary hot water pumps 70 gpm, 20 ft head, 1 HP (each pump) Premium efficiency (VFD)
Service Water	Gas-fired instantaneous water heater Thermal Efficiency 96%, Pump Power 0.08 kW Assuming 0.082 gal/hr/person with upgraded water efficient fixtures

Appendix C. Wall Layers R-value Calculation Table

Based on the information contained in the 50% CD Design Submittal dated July 8, 2011, and the envelope analysis submitted by Ambient Energy dated July 20, 2011 the following wall assemblies were used as inputs in each energy model.

Table C1: Assumed Opaque Assemblies

	1	2	3	4	5	6	7	8	R-value	U-value
Existing Wall Type	Interior Air Film	5/8" gypsum board	10" Concrete @ 105 lb/ft ³ Density ⁽¹⁾	Exterior Air Film						
R-value	0.68	0.56	1.4	0.17					2.82	0.36

New Wall Type (above grade)	Interior Air Film	5/8" gypsum board	Assembly: 2.5"- 16"O.C metal stud with R-11 batt insulation ⁽²⁾	1/2" gypsum sheathing	1.5" Rigid or Spray Insulation	2" air layer ⁽³⁾	4" Brick Veneer	Exterior Air Film		
R-value	0.68	0.56	3.9	0.4	7.50	1.23	1.20	0.17	15.67	0.06

New Wall Type (below grade)	Interior Air Film	5/8" gypsum board	Assembly: 2.5"- 16"O.C metal stud with R-11 batt insulation ⁽²⁾	1/2" gypsum sheathing	5" Concrete @ 105 lb/ft ³ Density ⁽¹⁾	2" air layer ⁽³⁾	4" Brick Veneer	Exterior Air Film		
R-value	0.68	0.56	3.9	0.4	0.70	1.23	1.20	0.17	8.87	0.11

Source:1. ASHRAE 90.1-2007, TABLE A3.1B Assembly U-Factors, C-Factors, Ru, Rc, and HC for Concrete

2. ASHRAE 90.1-2007, TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

3. ASHRAE Handbook - Fundamentals 2005 25.4 Table 3 Thermal Resistances of Plane Air Spaces ft²·°F·h/Btu