Bernheim + Dean, Inc.
Sustainable Building Consultants

Energy Efficiency Report
West Berkeley Branch Library

Pacific Gas and Electric Company®

SAVINGS BY DESIGN

14 November 2013

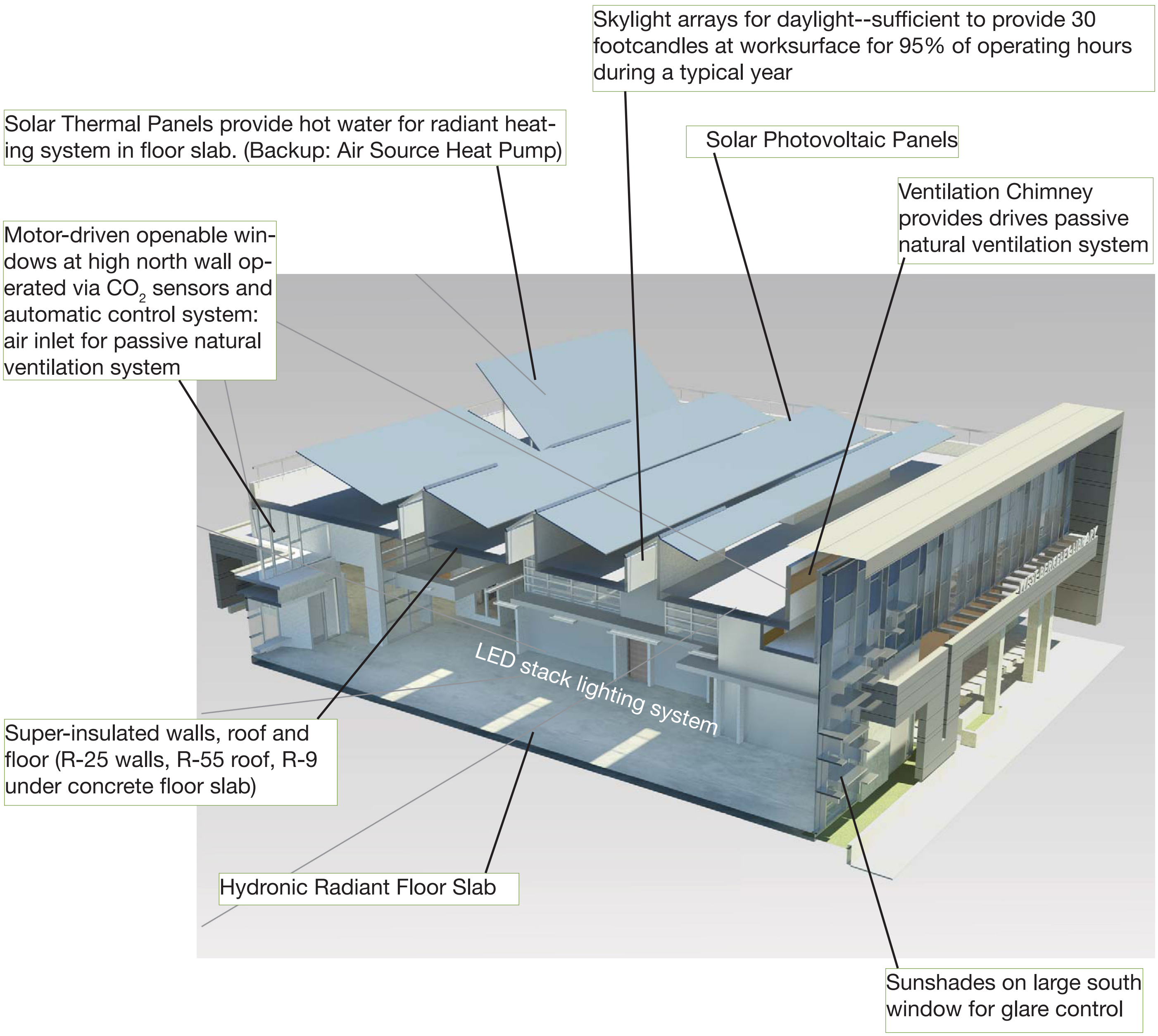


Fig. 1. Section-Perspective View through the Main Stacks & Reading Room--Energy Efficiency Features.

1.0 INTRODUCTION AND SUMMARY

This *Energy Efficiency Report* is submitted as part of the requirements of the PG&E Savings by Design program. Attached to this report as appendices are the summary of incremental cost for energy-saving measures that go beyond Title-24 requirements, and the UTIL-1 report with input files for the energy savings and incentive calculations.

The West Berkeley Branch Library Project was designed from 2010 through 2011 and was successfully bid on budget in March, 2012. Construction is scheduled for completion in December, 2013.

The building occupies a 12,000 sq. ft. lot on University Avenue near San Pablo Avenue in Berkeley, CA, a relatively tight urban site. There is a three-story hotel to the east and a five-story apartment building across the street to the south. The building itself is 9,300 sq. ft. and one-story, although it has a two-story main roof height to avoid shadows cast by the neighboring buildings on any solar photovoltaic panels located on the roof.

The design of the building incorporates many energy-efficiency features and systems. These are shown in the diagram of Fig. 1 and are described in detail in this report:

- Extra Insulation: R-25 walls (including effect of thermal bridging), R-55 roof, R-9 floor slab;
- Radiant floor slab heating with hot water from a solar thermal panel system, with an air source heat pump as backup, in lieu of standard rooftop VAV package air-handling unit.
- Passive natural ventilation using motor-driven openable windows and a “wind chimney” feature combined with openable rooftop skylight arrays, in lieu of a fan-driven fresh air delivery system;
- Skylight arrays for daylighting in addition to the natural ventilation function;
- LED stack lighting, in lieu of standard fluorescent stack lighting.

The building’s energy performance was modeled through the design phases and is predicted to achieve *zero net energy (ZNE)* performance under the conditions and operation assumed in the input parameters of the model. The computer analysis for daylighting, computational fluid dynamics (CFD) for modeling natural ventilation air flow, and the whole building energy analysis were all carried out with the support of a grant from Pacific Gas & Electric Company.

The analysis during the design phase indicated that the building would achieve an *energy use intensity (EUI)* of 20 (kBtu/sq. ft. per year), well within the range of energy efficiency generally required for a building to be able to achieve a ZNE performance with an on-site renewable energy system.

The energy use modeling carried out for this Savings by Design submittal confirmed this level of performance. The site EUI as calculated by the required software, *Energy Pro*, is 25 and the building design was found to perform 35.9% better than the comparable building meeting the minimum Title-24 requirements. This performance level would qualify the project owner to a Savings by Design incentive award of $13,420.

The incremental cost for these five specific energy efficiency features was determined to be $478,486. 75% of this amount comes to $358,864, which is well above the incentive award amount determined as part of the *Energy Pro* analysis.

2.0 BUILDING DESCRIPTION

2.1 General

The 9.300 gross-square-foot branch library building is contained on one level on a 100' X 120' deep commercial property on University Avenue in Berkeley, CA. (See Fig. 2.) The building essentially occupies the entire site.

The roof is set at a height of two stories in order to avoid shading of the 175 solar photovoltaic panels by the three-story hotel to the east.

The overall floor plan, street elevation and principal building sections are shown in Figs. 3 and 4. The large Stacks & Reading Room on the west half of the building is thoroughly daylit by arrays of skylights on the roof. The placement of the skylights and the solar PV panels is worked out to avoid any shading of the PV panels by the skyllight shafts while at the same time giving the skylights the maximum "view" of the sky, the source of all the daylight.

The front of the building, facing University Avenue, is dominated by a three-story facade that rises a full story above the roof and aligns with the facade of the neighboring hotel. While the high facade is part of City of Berkeley zoning requirement in this commercial zone, this feature is actually part of an energy-efficiency feature: the passive natural ventilation system. (See section 2.3.)

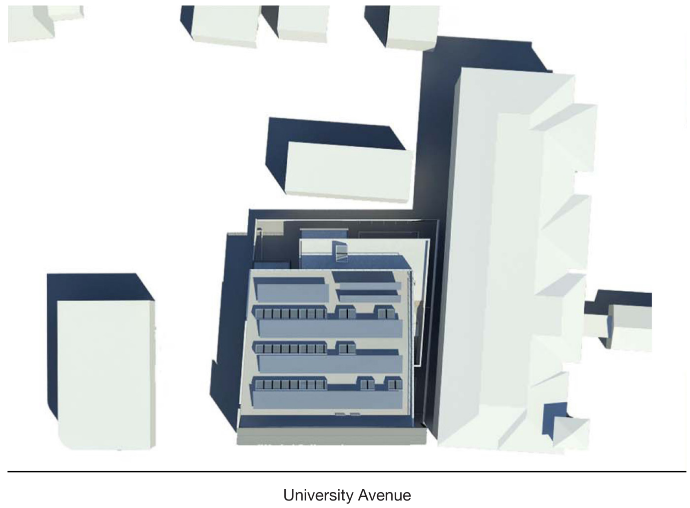


Fig. 2. Site and new library with surrounding build-

Fig. 3. Street Elevation at University Avenue

2.2 Building Envelope

The most significant energy-efficiency features of the building envelope are the added level of insulation and the extensive amount of daylighting introduced through the roof skylights. The daylighting design is discussed separately in section 2.4.

The building's wall framing is done with 2X8 microlams, which not only provide the straightness of wall plane for the heightened ceilings, but also create significant depth of cavity for the extra insulation. This 7-1/4" cavity is filled with Roxul *Comfortbatt* mineral fiber, which is both fireproof and non-toxic. Also, because of the thermal properties of the wood microlams, the thermal bridging effect is minimum, eliminating the need for an extra layer of rigid insulation on the outside of the framing layer while still achieving a total R-value of 25.5 including the thermal bridging effect.

The roof layer consists of a TJI (truss joist) system, which allows adequate space for a full 12" of Roxul *Comfortbatt* insulation. In addition, a thick layer of rigid styrofoam insulation is used between the roof sheathing and the TPO single ply roof membrane. The styrofoam is shaped to provide drainage of the flat roof to the various roof drains and averages 3" in thickness over the roof area. The net effect of this layer of materials is a roof R-value = 55.

The floor consists of a 4" concrete topping slab, which contains the hydronic tubing of the radiant heating/ cooling system, over 2" of rigid polystyrene, which sits above the 5" structural slab. The topping slab is isolated from the wall at the joint between the two by a 3/4" layer of rigid insulation. With this subfloor insulation, the R-value for the floor is R=9.

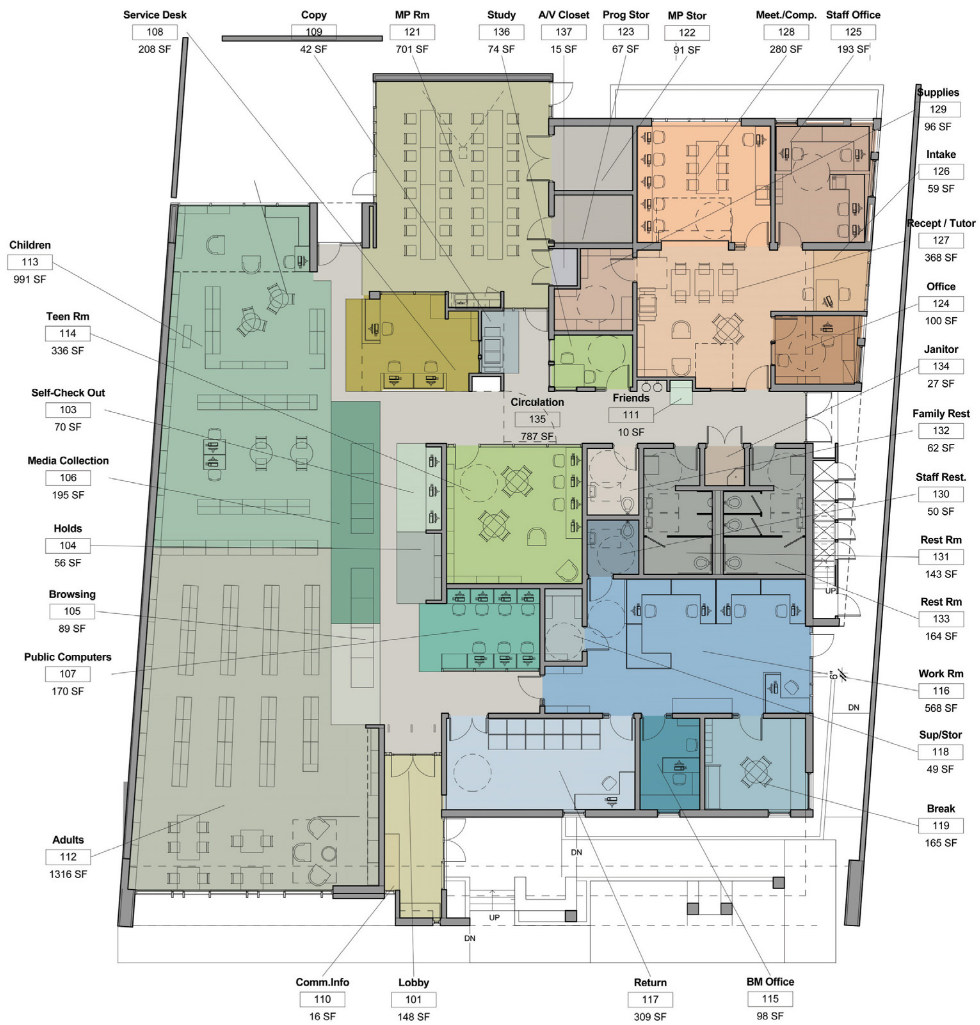
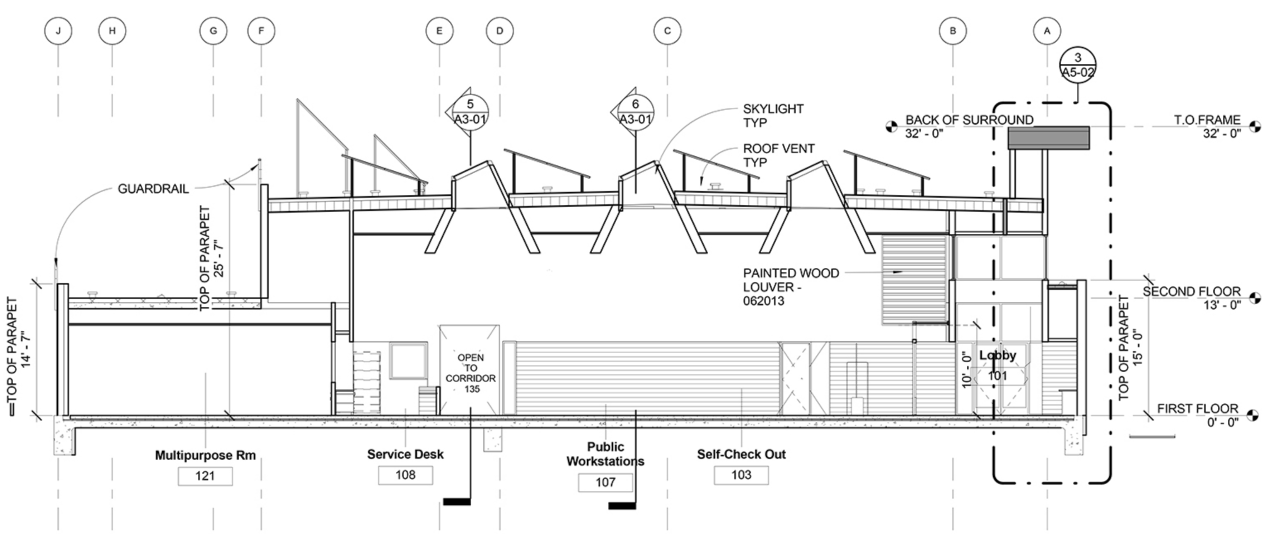


Fig. 4. Floor Plan (left) and main Section through the Stacks & Reading Room, looking east (below).



2.3 Heating, Ventilating and Air-Conditioning (HVAC) Systems

Because of the marine-type microclimate at the building site, the mechanical systems function to provide heating during the winter, cooling during peak temperature events in summer and early fall, and fresh air ventilation throughout the year. A large part of the cooling can be provided by the natural ventilation system in this particular climate zone, thus making the natural ventilation system the centerpiece of the building's overall HVAC system.

2.3.1 PASSIVE NATURAL VENTILATION SYSTEM

The building does not have a standard forced-air (fan-driven) system for delivering the minimum required fresh air, heated air or cooled air. Rather, the heating (and cooling for high temperature days) is provided by a radiant system that is described in section 2.3.3. The fresh air and most of the sensible cooling is provided by the passive natural ventilation system described in this section.

The natural ventilation system is deemed "passive" since the required fresh air supply and movement through the spaces is done by natural forces of pressure difference and air bouyancy rather than electric-powered fans. These natural forces are controlled by the automatic operation of designated openable windows on the north side of the building and the design of the air outlets at the upper part of the building.

In particular, the shape and design of the tall front of the building creates a "ventilation chimney" on the side of the building opposite the openable windows on the north side (the air inlets). Since the prevailing winds are always from the south and southwest, there is almost always a negative pressure area on the back side of this "chimney". When the air outlets are located on this side of the "chimney", a natural draft is created across the interior building spaces.

See Fig. 5 for a diagram of this concept. The space was carefully studied for technical feasibility using computational fluid dynamics (CFD) analysis. The air flow was found to follow exactly the desired path no matter what ceiling configuration is in place. See Fig. 6.

More detailed design was necessary to ensure that the system could maintain comfortable conditions under all daily outdoor conditions while providing the fresh air required by the occupants.

Air Inlets.

In the main space, the Stacks & Reading Room, the air inlets are at the motor-driven openable windows at the upper part of the window wall on the north side of the space. The window opening is controlled by the Building Management System (BMS) in response to CO_2 sensors located in the space. Building users control only a limited number of openable windows at floor level, which is intended for the psychological effect of a sense of control over comfort, thus providing motivation to allow a wider range of temperature swing.

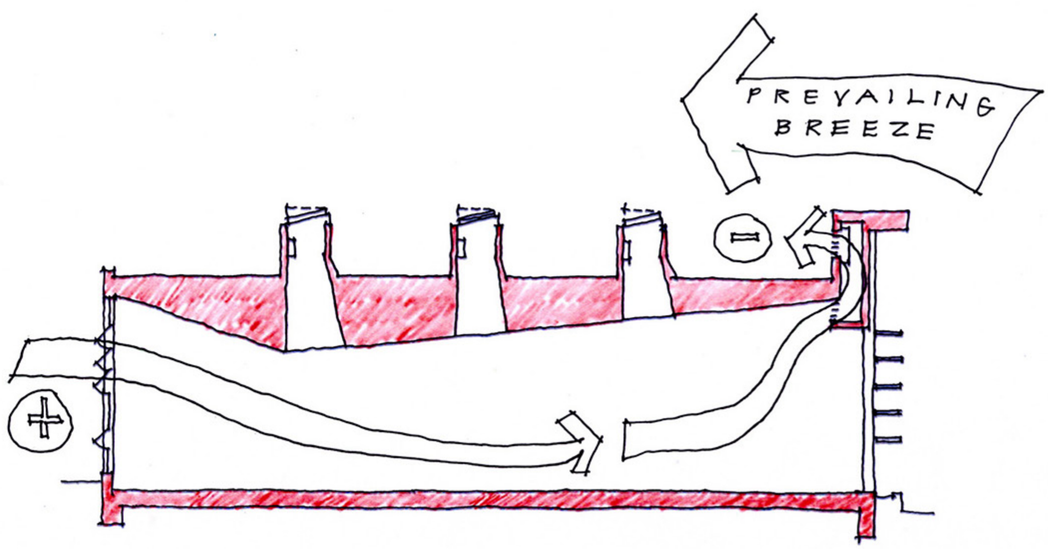


Fig. 5. Basic Concept for Passive Natural Ventilation System

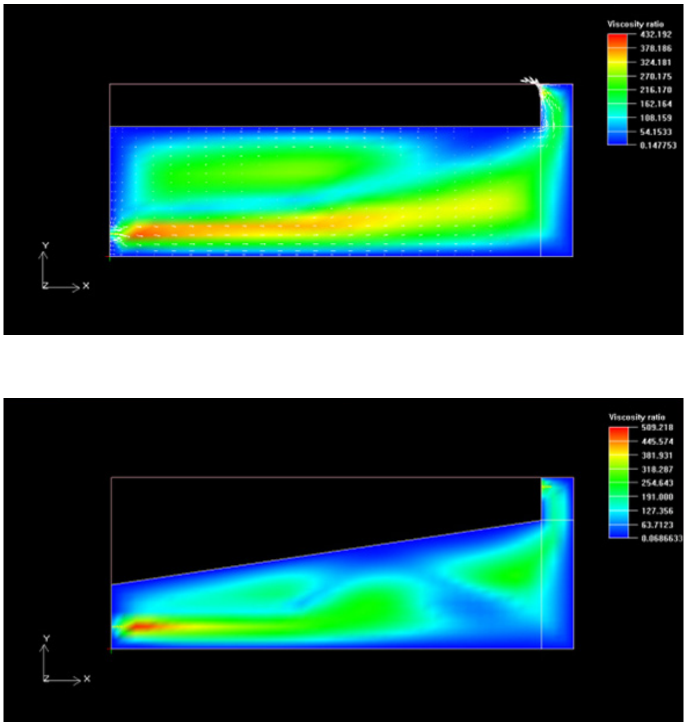


Fig. 6. Images from CFD Analysis of Main Space for Different Ceiling Configurations.

Fig. 7. *Runtal* hydronic convectors (bar type) located at upper motor-driven openable windows.

To avoid the possibility of cold drafts from these upper windows, hydronic *Runtal* convectors are installed in front of the windows. These convectors provide virtually instantaneous warming of incoming fresh air, preventing uncomfortable downdrafts in the heating season. See Fig. 7.

Similar automatic, motor-driven windows with Runtal convectors at the face of the opening are used in all of the other spaces, adapted to the shape and window locations.

<u>Air Outlets.</u>

The primary air outlet for the building is the "ventilation chimney". At periods of higher cooling demand, designated skylights open to provide additional outlet area and air flow. (See section 2.3.2 for a description and illustration of the mixed mode operation of the building's ventilation and cooling system.) A detail section through the "ventilation chimney" is shown in Fig. 8.

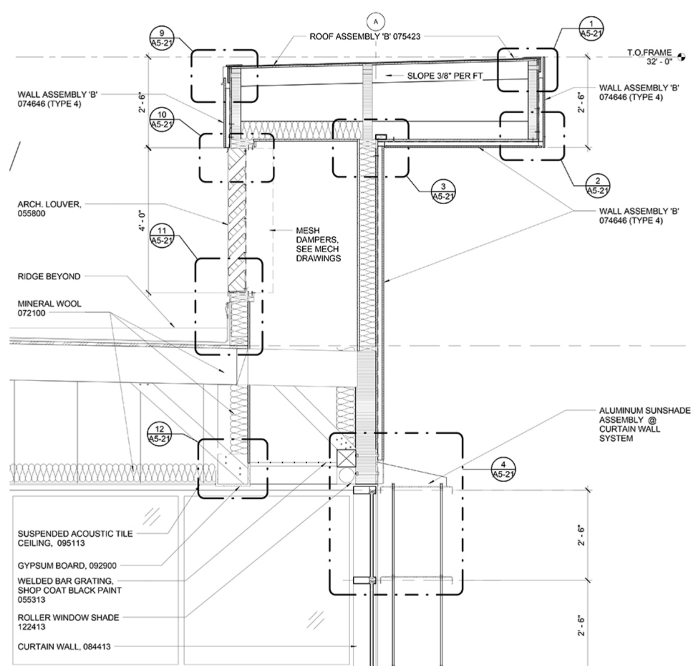


Fig. 8. Detail Drawing of "Ventilation Chimney".

2.3.2 COOLING SYSTEM

Because of the marine-type microclimate, much of the space sensible cooling can be accomplished with the passive natural ventilation described in the previous section. Generally, the indoor temperature rises due to the presence of people and equipment and high insulation value of the building envelope.

However, for most of the year, the outside air temperature is low enough to provide cooling even as the interior of the building warms up. As temperature conditions require, the amount of once-through outdoor air can be increased through a number of mechanisms designed into the system.

Only when the outdoor air temperature becomes too high to provide cooling, even at the maximum air flow through the building--a rate occasion in this microclimate--does the building's mechanical system become engaged to provide chilled water through the radiant slab.

All of these operating modes are controlled by the BMS and is generally referred to as a *Mixed-Mode Cooling System*. The BMS is a smart system that also measures ongoing weather conditions and can predict expected termperature conditions. This allows the system in the case of anticipated high temperature days to call for the operation of the natural ventilation system at night, thus precooling the building in advnace. The microclimate is characterized by cool nights even during periods of hot days, allowing this "night purge" operation to shave peak cooling demand and reduce peak electric demand.

There are also periods of the year, principally in late spring and early fall, when high pressure systems cause warm San Joaquin Valley air to circulate into the Bay Area, producing a two to five day cycle of steadily increasing outdoor air temperatures. These rare high air temperature events (85-95 degrees F) typically have higher night air temperatures than normal, requiring a backup approach to handle this extreme condition.

Mixed-Mode Cooling System

The *Mixed-Mode Cooling System* defines a sequence of operation of the elements of the natural ventilation air supply system and the design backup system to provide comfortable indoor air conditions under varying outdoor weather conditions. The building's control system will manage this operation to ensure a modern comfortable interior environment in all spaces for all outdoor weather conditions.

Refer to Figs. 9a and 9b for a diagram of each operating mode of the building under the conditions described. For simplicity of explanation, the large reading room space is used for this illustration, but the other spaces operate in a similar manner, using the corresponding features of the natural ventilation air supply system.

<u>Mode 1</u>

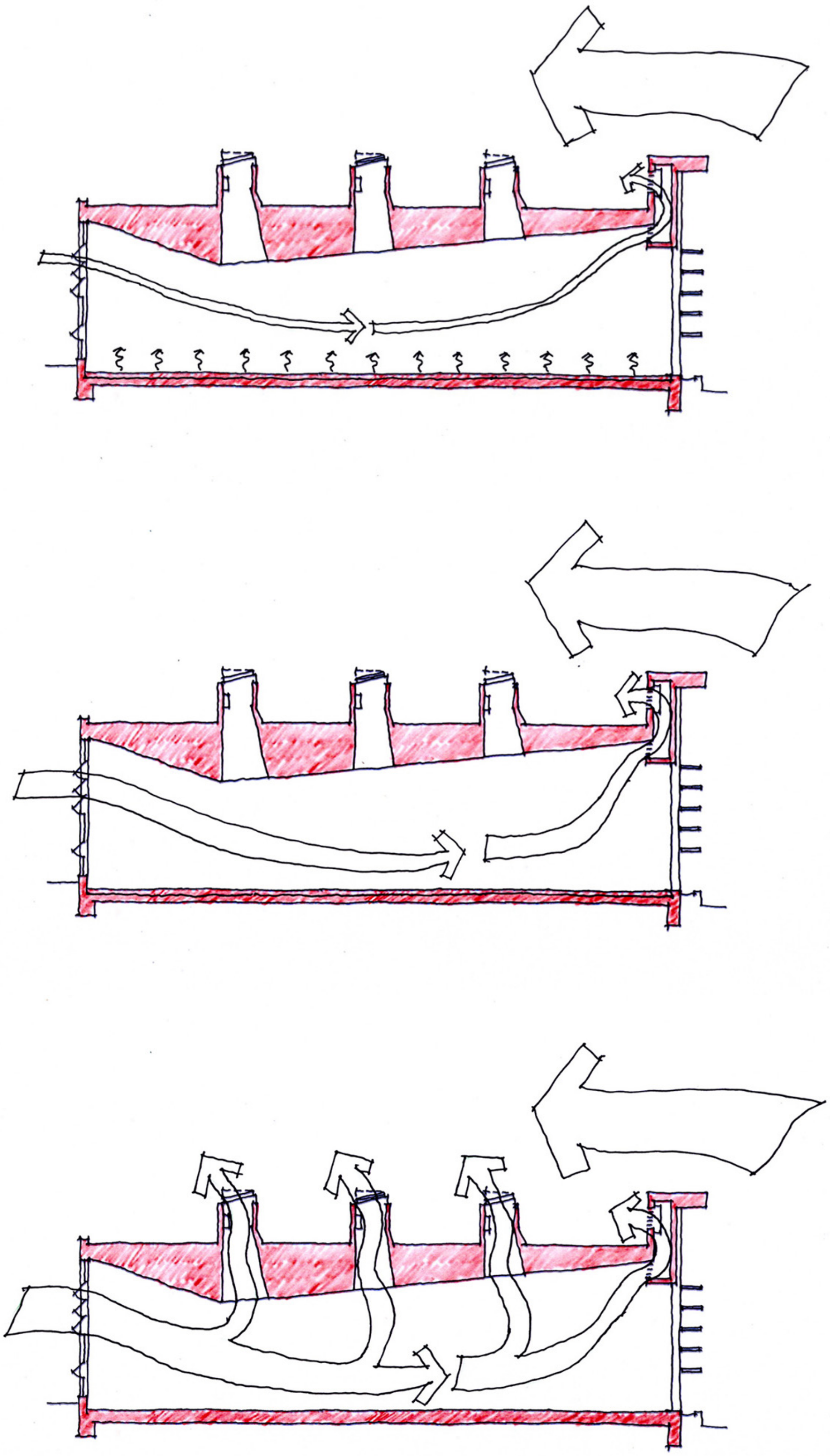
Cool outside air conditions and the building is operating in heating (winter) mode. Air intake is a minimum, for fresh air requirements only.

<u>Mode 2</u>

Comfortable outdoor air conditions and the building is operating in swing season mode, no heating system operation. Air intake increases beyond the minimum and only the ventilation chimney drives the airflow pasively since sufficient air quantity and air movement are provided to maintain comfort conditions.

<u>Mode 3</u>

Outside air temperature increases and the building is operating in cooling mode. The draft from the ventilation chimney does not provide enough air quantity and air movement to maintain comfort conditions within the space, so the operable skylights are opened automatically to allow increased airflow through all spaces. The interior room air temperature is still within the expanded thermal comfort range due to the air movement.

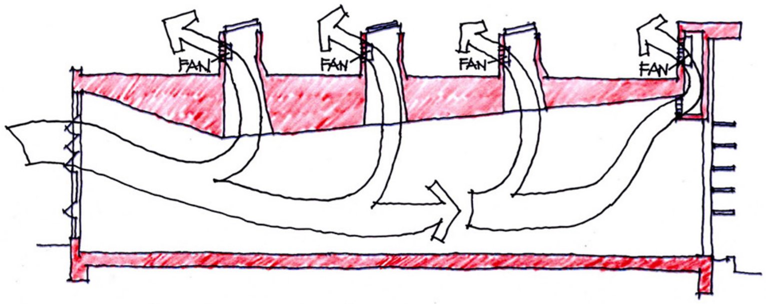


Mode 1. Heating Season. Minimum outside air admitted.

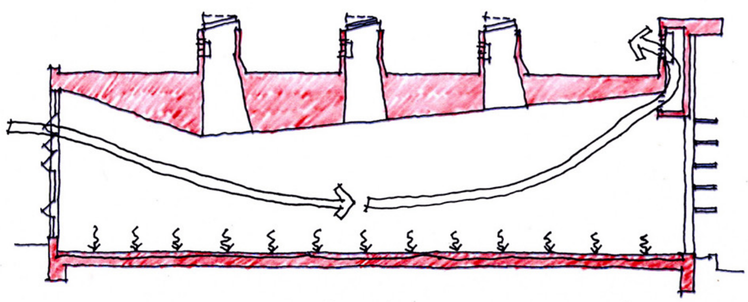
Mode 2. Swing Season. Varying amounts of outside air via wind chimney only.

Mode 3. Early Cooling Season. Increased amounts of outside air for cooling via wind chimney and venting skylights.

Fig. 9a. Mixed Mode System



Mode 4. Cooling Season. Maximum air movement via roof fans. (Skylights are closed.)
Mode 4a. (Same Diagram). Use of "night purging" using natural ventila-



Mode 5. Peak Cooling Events. Minimum outside air. Cool space using chilled water in radiant slab from backup air source heat pump .

Fig. 9b. Mixed Mode System

<u>Mode 4</u>

Outside air temperatures increase further and/or the outside wind speed drops and the natural draft of the wind chimney and the operable skylights is insufficient to provide the maximum airflow for occupant comfort. Low power backup fans located in the ventilation chimney shafts and in the skylight shafts operate to produce the maximum airflow required for comfort.

<u>Mode 4a</u>

For weather patterns such as that described for Mode 4, the system will operate its night purging function, allowing full natural ventilation of the spaces at night until the interior temperature drops to 65 deg F. The building will operate with minimal outside air at the start of the next day, maintaining a cool interior until the internal loads cause the temperature to rise to a preset temperature like 72 deg F. At this time, the building will cycle through Modes 2, 3 and 4 as required through the day to maintain comfortable interior conditions.

<u>Mode 5</u>

This operating mode is used only for the extreme weather events described above. When the interior temperature rises to a point outside even the expanded comfort zone, the building switches to a conventional building cooling mode.

The outside air intake is reduced to a minimum to satisfy fresh air needs and the building's air source heat pump, normally used as the backup to the solar thermal heating system (see Section 2.3.3 below), is operated in reverse as an air conditioning unit. Chilled water is produced and circulated through the radiant slab system, providing a cool surface that reduces internal air temperature and increases the occupants' radiant heat loss (thereby cooling them).

2.3.3 SPACE HEATING

The space heating system is a radiant heating system using the concrete floor slab and hot water circulating through encased piping. A solar thermal system provides the hot water to the radiant heating system and utilizes three residential-size air source heat pumps as a backup during low production days.

The solar panel sizing and layout studies showed that the requisite number of solar thermal panels could be accommodated on the roof. The solar access requirements are different than for the photovoltaic system since the heating load is experienced primarily when the sun is at low angles. Based on the heating load analysis, it was determined that 18 standard solar thermal panels tilted at an angle of 45 degrees would be optimal for the system design.

The West Berkeley Branch Library therefore uses no natural gas as an energy source and is operationally a *net zero carbon* building in addition to *net zero energy.*

2.4 Daylighting

Daylighting is the basis of the design of the lighting for this building. Like natural ventilation, this is one of the two principal design approaches for reducing the energy demand for this project in this particular location.

Because of the urban conditions surrounding the site, the only source of daylight is via the roof. A series of skylight arrays are used to provide glare-free light to the public spaces below. The skylights are standard size curb-mounted type with clear insulated glass and interior white shades that are activated when direct sun is detected entering the space. See Fig. 10 for an illustration of a typical skylight array of this type.

The number and spacing of the skylights was determined by the requirement of providing a minimum of 30 footcandles on a horizontal surface at 30" above the floor for 95% of the operating hours of the building. In addition, to prevent glare conditions, the size of the skylight openings would be limited by the requirement of no more than 300 footcandles for the same period. Computer simulation of the Stacks & Reading Room

Fig. 10. Illustration of curb-mounted skylight arrays. (Note: not actual installation on this project)

using Radiance software provided verification that the design criteria were satisfied by the design.

2.5 Domestic Hot Water

Hot water will be supplied for washing in the toilet rooms, custodial room, and in the Staff Break Room via local electric flash heaters. This is both more energy efficient, supplying hot water at point of use, and more serviceable for the library.

2.6 Plug Load

The "Receptacle" or Plug Load for the building appears to be the largest electrical load in the building. For analysis purposes and to estimate the needed number of solar photovoltaic panels to achieve *zero net energy* performance, the design team carried out a small research project on actual plug load demand in the existing branch library. This involved a careful study of the actual average energy use over an extended period of time of each major piece of plug load equipment using a metering device attached to each item. This included public computers, printers, staff computers, copy machines and other plug-in equipment present in the existing library.

in addition to the inventory of existing equipment, new equipment was identified, including new audio-visual equipment not currently available at the existing library and the plug-in equipment that would be located in the new IT Room for the library computer system.

In order to provide some basis for estimating the quiescent load and the actual average power demand of the new types of IT equipment, a comparable new Cisco switch was metered at the Central Library. The average power demand over a 15 day period was found to be 80 watts compared with the power listing of 150 watts, or approximately 1/2 of the listed load. This measurement provides some guide to estimating actual loads for the new IT equipment.

The plug load created by both existing and new equipment will be reduced by the utilization of power controls tied to occupancy sensors and timers. In addition, the design team is working with the client to select energy efficient equipment, such as Energy Star rated equipment, to ensure the lowest possible plug load for a particular type of equipment.

Given all these factors, the plug load total for the new building is therefore at best an estimate based on the metered results of the existing equipment, projections and rough estimates for new equipment and the effect of the power controls on the current pattern of use.

The final estimated plug load for the completed building is approximately 6.7 kW average during operating hours and a total annual energy use (converted from kWhr to MBtu) of 59.2 MBtu for 9,300 gross sf of building or 6.4 kBtu/sf. (As an interesting comparison, EnergyPro software sets the plug load for a building of this type, located in this climate zone, at 13.4 KBtu/sf, almost double the expected total based on the team's measurements and research.)

2.7 Energy-Efficient Electric Lighting Design

Electric light fixtures were selected with the highest efficiency rating possible, with a minimum of 85%.

All electric lighting will dim in response to daylight availability. During dark days and evening hours, the light fixtures are designed to illuminate white surfaces to reduce the perception of visual glare and to minimize the users' tendency to turn on electric lights to overcome such glare.

The design team avoided the use of indirect or uplighting for ceiling surfaces and instead opted for light focused on objects related to visual tasks. To avoid any feeling of gloominess, some uplighting is employed in the public reading areas only.

Stack lighting was a focus of major lighting design effort, where several options were studied for energy efficiency, high quality of light on the shelf contents and a consistent architectural approach to the overall lighting of the major spaces. The result was the choice of a LED stack light system, with one row of LED lights attached to each side of the double-sided shelving units. While the number of light fixtures is double the normal count in a traditional stack lighting design, the energy use is much lower and the architectural lighting quality of the installation is exceptional.

For exterior lighting, the design approach was again to focus the light to the visual needs and to avoid over-design for unnecessary lighting of exterior spaces. Therefore, the exterior lighting is focused in the entry area along University Avenue to denote the public nature of the building and its place on this commercial street.

APPENDIX

SavingsByDesign

UTILITY INCENTIVE WORKSHEET UTIL-1

Project Name: *City of Berkeley West Branch Library*

Date: *11/13/2013*

Step 1 ANNUAL TDV ENERGY USE (kBtu/sqft-yr)

ENERGY COMPONENT	Standard	Proposed	Margin
Space Heating	25.23	2.97	22.26
Space Cooling	46.82	24.04	22.78
Indoor Fans	0.36	2.02	-1.66
Heat Rejection	0.00	0.00	0.00
Pumps	0.00	0.00	0.00
Domestic Hot Water	15.63	15.63	0.00
Lighting	78.80	34.73	44.07
Receptacle	77.08	77.08	0.00
Process	0.00	0.00	0.00
Process Lighting	0.00	0.00	0.00
TOTALS:	243.92	156.47	87.45

Step 2 PERCENT BELOW TITLE 24

Adjusted TDV Energy Use
(Excludes Process Energy)

Standard Design		Proposed Design		Margin
243.92	-	156.47	=	87.45

Margin		Standard Design		% Below Title 24*
87.45	/	243.92	=	35.9 %

Incentive Eligibility — Yes / No
Owner Incentive (>=10%) — ☑ Yes ☐ No

Conditioned Floor Area = 9,165.0 ft² **sq. ft.**

Step 3 ANNUAL SITE ENERGY USE

Average 2pm - 5pm Peak Demand (kW)	Standard	Proposed	Margin
	33.0	25.2	7.9

The values shown here are based upon the results of an EnergyPro Compliance energy analysis that uses Title 24 profiles as specified in the Alternative Calculation Method manual.

ENERGY COMPONENT	Standard Electricity (kWh)	Standard Natural Gas (therms)	Proposed Electricity (kWh)	Proposed Natural Gas (therms)	Margin Electricity (kWh)	Margin Natural Gas (therms)
Space Heating	14,826	0	1,725	0	13,101	0
Space Cooling	16,876	0	7,111	0	9,765	0
Indoor Fans	167	0	936	0	-768	0
Heat Rejection	0	0	0	0	0	0
Pumps	0	0	0	0	0	0
Domestic Hot Water	7,067	0	7,067	0	0	0
Lighting	36,107	0	16,104	0	20,004	0
Receptacle	36,563	0	36,563	0	0	0
Process	0	0	0	0	0	0
Process Lighting	0	0	0	0	0	0
TOTALS:	111,607	0	69,505	0	42,101	0

Step 4 POTENTIAL OWNER INCENTIVE CALCULATION

Pacific Gas and Electric Company

	% Below Title-24* (from step 2)	Incentive Rate		Savings (from Step 3)		Subtotal
Electricity (kWh)	30.0 %	30.0 ¢/kWh	X	42,101 kWh	=	$12,630
Electricity (kW)		= 100.00 $/kW	X	7.9 kW	=	$790
Natural Gas		= 100.0 ¢/therm	X	0 therm	=	$0

Owner Incentive ($150,000 max) = $13,420

Potential incentives indicated on this report are available only through the Whole Building Approach Element of the Savings By Design Program for new construction and are NOT GUARANTEED. Projects MUST receive prior, written approval from The Utility during conceptual or early design development and must meet all other program requirements to qualify. Potential incentives are subject to program limitations based upon the incremental cost of the measures.

*% Below in this equation is limited to 30%.

Incremental Measure Cost Table

Project Name: West Berkeley Library NZE Savings By Design
Project Number: SBD #105926

Energy Efficiency Measure <1>	Title 24 Baseline Cost	Estimated Actual Cost	Difference	Comment
1. Lighting				
1.1 Stack Lighting	$ 39,690.00	$ 51,030.00	$ 11,340.00	LED Stack Light in lieu of standard flourescent stack lights.
1.2 Skylilght System for Daylighting and Natural Ventilation		$ 128,010.75	$ 128,010.75	Skylights in lieu of No-Skylights. System includes automatically controlled shades for glare control, activated by direct sunlight sensors, and openable motorized skylights tied to air sensors.
1.3 Extra Framing for Skylights and Daylight-Diffusing reflecting panels		$ 44,625.00	$ 44,625.00	Includes extra glulam beams on either side of skylight arrays, framing of suspended daylight-diffusing panels.
2. HVAC System:				
2.1a Standard HVAC package units	$ 292,950.00		$ (292,950.00)	*This is the standard system that would have been used in a Title-24 (base design) building of this type.* Complete with ductwork, registers, piping for natural gas, etc.
2.1b Radiant floor slab system (heating and cooling).		$ 390,600.00	$ 390,600.00	*This is the primarily passive system designed to minimize use of fans and to allow wider range of temperature setpoints due to inherent comfort level of the alternative system approach.* Includes topping slab, all plumbing, pumps, backup air-source heat pump. (Solar thermal panels for heating not allowed to be included in cost.)
2.2 Natural ventilation system: "Wind Chimney" structure--motorized dampers and architectural louvers only		$ 48,636.00	$ 48,636.00	8-ft high "Wind Chimney" at south end of roof creates natural draft (no fans) for passive ventilation. (Includes only backup mechanical dampers with architectural louvers and exhaust fan no. 1 with ductwork. Six motorized dampers with 4'X6' architectural louvers.)
2.3 Natural ventilation system: Runtal heating convector units at openable windows		$ 73,080.00	$ 73,080.00	Runtal heating convectors preheat air of BMS-controlled ventilating windows at north side of building. (300 sq. ft. of Runtal convectors at windows. Includesplumbing runs.)
3. Building Envelope				
3.1 Sub-slab insulation		$ 17,967.60	$ 17,967.60	Not required for Title-24. (9300 sq. ft. of 2" thick rigid insulation board under concrete slab.)
3.2 Wall insulation	$ 15,582.00	$ 32,722.20	$ 17,140.20	7" Roxul mineral wool versus 5-1/2" fiberglass batts.
3.3 Roof insulation	$ 14,647.50	$ 54,684.00	$ 40,036.50	12" Roxul mineral wool plus 3" rigid insulation board versus 9" fiberglass batts
Totals	**$ 362,869.50**	**$ 841,355.55**	**$ 478,486.05**	