Preliminary Technical Energy Audit Sample

Siemens Building Technologies, Inc. was pleased to present Long Beach Community College District (LBCCD) with this Preliminary Energy Assessment (PEA) Report for Liberal Arts Campus (LAC) and Pacific Coast Campus (PCC).

The overall objectives of this preliminary evaluation were to:

- Review phasing of buildings in the Master Construction Plans for the two campuses, and prioritize connection of buildings to the central plants being constructed
- Identify HVAC modifications necessary to connect the identified buildings to the central plants
- Identify other potential Facility Improvement Measures (FIMs) based on facility and staff operational and maintenance needs,
- Assess the preliminary costs and potential savings from these measures,
- Perform a “first-pass” financial assessment for the implementation of the FIMs, and,
- Present next steps to move the projects toward implementation.

The following steps were undertaken by Siemens to arrive at the recommendations listed in this report:

- Review of Master Construction Plans for LAC and PCC done by P2S
- Utility data analysis
- Mechanical and electrical plan review
- Facility personnel interviews
- Interviews with BMT and P2S
- On-site audits of buildings B, C, D, E, J, K, Q, R, O, W at LAC; and FF, GG, MM at PCC
- Control system front-end audit

The above steps and the feedback obtained from facility personnel indicated the following challenges within the existing infrastructure of the two campuses:

- Old and difficult-to-maintain air-side systems, leading to reactive rather than preventative maintenance
- Absence of infrastructure to tie in air-side systems to the new central plants on buildings B, C, D, E, J, K; and FF and GG
- Multiple HVAC system types, which are configured and controlled differently
- Several different control systems and front ends that do not communicate with each other, and in which facility personnel are not well-trained
- Inefficient and improperly programmed controls, which do not allow for segregating occupied and unoccupied spaces, leading to increased energy and operational costs
- Limited information regarding equipment operation at the front end, which does not allow for troubleshooting, scheduling or pro-active operation
- Lighting systems that are nearing the end of their useful life – failing lamps and ballasts
- Old, decentralized and inefficient irrigation system, only partially converted to reclaimed water
- Decentralized exterior lighting control system

This analysis and proposal provided LBCCD with a comprehensive plan to address the above problems without any upfront capital expenditure. Siemens recommended a comprehensive list of measures based upon preliminary analysis of the campuses.

Our preliminary estimates indicated that installation of the identified measures would cost in the range of $7.8 million to $8.6 million. Projected energy savings were in the range of $220,000 to $265,000.

The energy services program discussed in this preliminary study was a guaranteed program. This means that once the final engineering analysis had been conducted Siemens would stipulate how much LBCCD would save in terms of energy costs savings and operational cost savings, and provide reconciliation of the savings on an agreed-upon frequency. The financial guarantee was based on findings during the Final Energy Engineering phase.

The project was developed, analyzed, implemented and measured by members of the Siemens team identified in Section 5.0.

PRELIMINARY ENERGY ASSESSMENT

For

Long Beach Community College District

Prepared by:

Building Technologies, Inc.

December 2007

PRELIMINARY ENERGY ASSESSMENT FOR LONG BEACH COMMUNITY COLLEGE DISTRICT

Prepared for:

Long Beach Community College District
4901 E Carson St
Long Beach, CA 90808

Prepared by:

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Prashanth Navuduri, P.E.

December 2007

Confidentiality of Information

This Preliminary Energy Assessment Report package includes data that is proprietary and confidential and shall not be disclosed outside its recipient and shall not be duplicated, used, or disclosed, either in whole or in part, for any purpose other than its evaluation. This restriction does not limit in any way the recipient's right to use information contained in this data if it is obtained from another source.

Submitted by ________________________ ***Date*** ____________

Shaun Ayvazi

Business Development Manager, Performance Contracting

Submitted by ________________________ ***Date*** ____________

Prashanth Navuduri, PE

Senior Energy Engineer

Accepted by ________________________ ***Date*** ____________

Ann Marie Gabel

Vice President, Long Beach CCD

Acknowledgment

Siemens thanks LBCCD facility personnel for investing their time and effort in providing interviews, resources and direction, and in participating in job-walks, which helped immensely in the production of this proposal. Siemens particularly wishes to thank the following personnel for their participation and support:

- Mark Thissell, Director of Maintenance and Operations
- Tim Wootton, Deputy Director of Facilities and Maintenance
- Mark Garber, HVAC Mechanic
- Oscar Trejo, Electrician
- Roy Rubio, Irrigation Maintenance
- Butch Fitzgerald, Irrigation Maintenance

1 EXECUTIVE SUMMARY

Siemens Building Technologies, Inc. (Siemens) is pleased to present Long Beach Community College District (LBCCD) with this Preliminary Energy Assessment (PEA) Report for Liberal Arts Campus (LAC) and Pacific Coast Campus (PCC).

The overall objectives of this preliminary evaluation are to:

- Review phasing of buildings in the Master Construction Plans for the two campuses, and prioritize connection of buildings to the central plants being constructed
- Identify HVAC modifications necessary to connect the identified buildings to the central plants
- Identify other potential Facility Improvement Measures (FIMs) based on facility and staff operational and maintenance needs,
- Assess the preliminary costs and potential savings from these measures,
- Perform a "first-pass" financial assessment for the implementation of the FIMs, and,
- Present next steps to move the projects toward implementation.

The following steps were undertaken by Siemens to arrive at the recommendations listed in this report:

- Review of Master Construction Plans for LAC and PCC done by P2S. (see Appendix – A)
- Utility data analysis (see Section 4)
- Mechanical and electrical plan review
- Facility personnel interviews
- Interviews with BMT and P2S
- On-site audits of buildings B, C, D, E, J, K, Q, R, O, W at LAC; and FF, GG, MM at PCC
- Control system front-end audit

The above steps and the feedback obtained from facility personnel indicated the following challenges within the existing infra-structure of the two campuses:

- Old and difficult-to-maintain air-side systems, leading to reactive rather than preventative maintenance
- Absence of infra-structure to tie in air-side systems to the new central plants on buildings B, C, D, E, J, K; and FF and GG
- Multiple HVAC system types, which are configured and controlled differently
- Several different control systems and front ends that do not communicate with each other, and in which facility personnel are not well-trained
- Inefficient and improperly programmed controls, which do not allow for segregating occupied and unoccupied spaces, leading to increased energy and operational costs
- Limited information regarding equipment operation at the front end, which does not allow for troubleshooting, scheduling or pro-active operation
- Lighting systems that are nearing the end of their useful life – failing lamps and ballasts
- Old, decentralized and inefficient irrigation system, only partially converted to reclaimed water
- Decentralized exterior lighting control system

This analysis and proposal provides LBCCD with a comprehensive plan to address the above problems without any upfront capital expenditure. Siemens recommends the following measures:

Recommended Measures – Liberal Arts Campus			
System	No.	Measure	Applicable Buildings
CHW Loop	1	Extend chilled water loop and connect air-side systems to Central Plant	B, C, D, E
	2	Decommission/retire small air-cooled condensing units, chillers and chilled water pumps	B, C, D, E
Air handlers	3	Retrofit existing air-side equipment containing DX coils with Chilled Water coils and connect to CHW loop	B, C, E
	4a	Convert constant volume air-side systems to variable air volume systems – retrofit AHU motors with VFDs and install static pressure control for VFD operation	B, C, E
	5	Air handler refurbishment: Replace old motors, belts, sheaves, clean or replace condensate pans, clean or replace coils, repair or replace insulation	B, C, E
	6	Repair or replace dampers and recommission economizers in air handlers	B, C, E
	7	Replace 3-way CHW valves with 2-way valves	B, C, D, E
	8	Partially or completely eliminate pneumatic controls at air handlers	B, C, E
	9	Revise/improve schedule and sequence of operation for air handlers	B, C, E
Air handler zones	4b	Convert constant volume air-side systems to variable air volume systems – replace constant volume mixing boxes and pneumatic controls, with variable volume mixing boxes and electronic controls	B, C, E
	10	Replace pneumatic thermostats at zones with electronic controls	B, C, E
Controls	11	Add new Siemens controls and integrate to the new central front end. Provide efficient operating parameters and sequence of operation.	B, C, E, W
	12	Integrate controls and recommission existing controls	J, K, Q, R, O
	13	Recommission existing functional controls	D
Unitary eqpt	14	Replace unitary equipment with higher efficiency equipment which meets Title 24 stds at a minimum	W

Recommended Measures – Liberal Arts Campus			
System	No.	Measure	Applicable Buildings
Hot water systems	15	Replace old boilers with new low emission, higher efficiency boilers, piping and hot water pumps	B, E
	16	Replace old hot water pumps and std efficiency motors with new pumps and premium efficiency motors	B, E
	17	Replace old hot water piping and insulation with new pipe in mechanical spaces (asbestos present)	B, E
Pool	18	Provide automatic unwinders to facilitate deployment of pool covers	Pool
	19	Reduce pool water temperature (at least during unoccupied hours)	Pool
	20	Install controls to reduce pump speed during unoccupied hours	Pool
	21	Connect South Quad heating loop to pool heating loop for redundancy through the co-gen system plate and frame heat exchanger	Pool
Lighting	22	Provide a comprehensive lighting retrofit for 32 watt first generation T8 lamps to 28 watt third generation T8 lamps	B, C, D, E, J, K, Q, R, O, W
	23	Provide programmed start ballasts in areas with occupancy sensors to prevent lamp failures	B, C, D, E, J, K, Q, R, O, W
	24	Replace older metal halide lamps and ballasts with pulse start metal halide lamps and ballasts	Exterior, interior high bay lighting
	25	Add lighting controls – photocells on area and parking lot lighting and time-of-use controls for tennis court lighting, and integrate to front end	Exterior, interior high bay lighting
Water Systems	26	Retrofit/replace toilet, sink, urinal and showerhead fixtures with low flow fixtures	B, C, D, E, J, K, Q, R
Further investigation/ College input reqd.	27	Install photovoltaic system in a new carport structure in the Stadium parking lot	TBD
	28	Replace domestic water irrigation with reclaimed water in the North Campus. Improve irrigation controls.	Throughout campus
	29	Replace exterior lighting poles	TBD
	30	Electrically separate Stadium loads and convert rate schedule to exterior lighting schedule	Stadium
	31	Fleet improvements	Throughout campus

Recommended Measures – Pacific Coast Campus			
System	No.	Measure	Applicable Buildings
CHW / HW Loop	1	Extend chilled water loop and connect air-side systems to Central Plant	FF, GG
	2	Decommission/retire small air-cooled compressors and condenser fans	FF, GG
Air handlers	3	Replace package units with fan coil units with CHW and HW coils, or retrofit existing air-side equipment containing DX coils with chilled water coils, and furnaces with hot water coils, and connect to CHW and HW loop	FF, GG
	4	Add or recommission economizers in airside equipment	FF, GG, MM
	5	Provide 2-way CHW and HW valves on new or retrofitted air handlers	FF, GG
	6	Provide new DDC controls at air handlers	FF, GG
	7	Revise/improve schedule and sequence of operation for air side equipment	FF, GG, MM
Controls	8	Add new Siemens controls and integrate to the new central front end. Provide efficient operating parameters and sequence of operation.	FF, GG
	9	Recommission existing functional controls and integrate to front end	MM
Unitary eqpt	11	Replace unitary equipment with higher efficiency equipment which meets Title 24 stds at a minimum	MM
Lighting	13	Provide a comprehensive lighting retrofit for 32 W first generation T8 lamps to 28 W third generation T8 lamps	FF, GG, MM
	14	Provide programmed start ballasts in areas with occupancy sensors to prevent lamp failures	FF, GG, MM
	15	Replace older metal halide lamps and ballasts with pulse start metal halide lamps and ballasts	Exterior, interior high bay lighting
	16	Add lighting controls – photocells on area and parking lot lighting and time-of-use controls for tennis court lighting, and integrate to front end	Exterior interior high bay lighting
PV	17	Install photovoltaic system in MM building roof. Connect PV system to main feed near MM building	MM
Water Systems	18	Retrofit/replace toilet, sink, urinal and showerhead fixtures with low flow fixtures	FF, GG and MM

Recommended Measures – Pacific Coast Campus			
System	No.	Measure	Applicable Buildings
Further investigation/ College Input	19	Improve irrigation controls	TBD
	20	Replace exterior lighting poles	TBD
	21	Fleet improvements	TBD

Our preliminary estimates indicate that installation of the identified measures will cost in the range of $ 7.8 million to $ 8.6 million. Projected energy savings are in the range of $ 220,000 to $ 265,000. Further details on project financials, including project savings, incentives and payment options are provided in Section 7.

As the next step, Siemens proposes that LBCCD commit to a Final Energy Engineering phase for the implementation of the identified projects by signing a Letter of Intent (LOI). The deliverables from this phase will include: final "hard" costs, engineered specifications, final savings, measurements of existing conditions, further analysis of energy efficiency measures, performance measurement and verification (if required), and other detailed financial information. The final development will be performed in a phased approach as shown in Section 8.

The energy services program discussed in this preliminary study is a ***guaranteed program***. This means that once the final engineering analysis has been conducted Siemens will stipulate how much LBCCD will save in terms of energy costs savings and operational cost savings, and provide reconciliation of the savings on an agreed-upon frequency. The financial guarantee will be based on findings during the Final Energy Engineering phase. On behalf of LBCCD, Siemens can also apply for any available rebates from the utility.

Siemens stands ready to support LBCCD in implementing any or all of the recommended measures. With its bonding capabilities, financial strength, and reserves that come from being a public company listed on the New York Stock Exchange, Siemens has the backing and the ability to assist LBCCD in moving forward. Siemens provides turn-key implementation services, project financing and guaranteed savings.

On behalf of Siemens Building Technologies, Inc. we have welcomed the opportunity to audit your facilities and await your favorable review of these findings as we proceed to the comprehensive proposal stage of the energy services/performance contracting process.

Contents

2 INTRODUCTION

Siemens Building Technologies, Inc. (Siemens) is pleased to present Long Beach Community College District (LBCCD) with this Preliminary Energy Assessment (PEA) Report for Liberal Arts Campus (LAC) and Pacific Coast Campus (PCC).

LBCCD has made a significant investment in constructing central chilled water plants at both campuses, and this represents a forward-thinking approach, which addresses both the ageing infrastructure in existing buildings and future building additions, based on energy conservation and operational efficiency. The investment in the central plant includes new central plant equipment, centralized controls, and the piping infra-structure laid out through the campuses.

The logical next step consists of duly connecting existing and future buildings to the central plant in a planned sequence.

2.1 Objectives

At this point, there are points of connection laid out only to the L, M, N and A buildings at LAC and AA-BB-DD-EE, FF and GG buildings at PCC for hook-up to the central plants. As the construction of the plants progresses, there is a need to start adding other buildings so that there is a minimal load for satisfactory operation of the central plant.

This evaluation is aimed at analyzing the sequence, scheme and priority of adding other buildings on to the central plant in order that LBCCD may realize the value of the investment it has made in the central plants. The following points were kept in mind as the analysis progressed:

- Master construction plan for the two campuses, which determines the sequence in which existing buildings are expected to be modernized and future buildings, to be added
- Buildings to be modernized in the near future were not considered as scope and budgets for the modernization were not available. This group of buildings includes Buildings A, F, P, G, H, M, N, L, T and Z at LAC; and, Buildings AA, BB, DD, EE and JJ at PCC

The other objectives of this analysis were to:

- Identify air-side modifications in the remaining buildings (B,C,D,E,J,K,Q, R, O and W at LAC; and FF, GG and MM at PCC)
- Identify other facility improvement measures at these buildings which make sense from an economic, operational and energy efficiency standpoint, that can be undertaken along with the air-side modifications
- Assess the preliminary costs and potential savings from these measures,
- Perform a “first-pass” financial assessment for the implementation of the FIMs, and,
- Present next steps to move the projects toward implementation

2.2 Analysis Steps

The analysis steps included:

- Review of the Master Construction Plan for both campuses in conjunction with facility personnel and P2S (see Appendix-A)
- Utility data analysis, including electricity, gas and water usage and cost data (see Section 3)

- Mechanical and electrical plan review for buildings being analyzed
- Facility personnel interviews
- On-site audits of buildings B, C, D, E, J, K, Q, R and W at LAC; and FF, GG, MM at PCC
- Control system audit, including the Honeywell front end at the LAC Maintenance Shop, Alerton and Tek-air systems at Building D, exterior lighting time clocks and irrigation controls at LAC

The sections that follow present the findings.

Section 3 presents an overall utility analysis for the campuses. Section 4 presents a description of the existing lighting, HVAC, automation, irrigation, water and pool systems, along with existing systemic and operational inefficiencies noted during the audit. Sections 5 & 6 present a description of facility improvement measures recommended. Section 7 summarizes costs and savings, while Section 8 presents next steps following review of this Assessment.

2.3 Benefits of Siemens Recommended Measures

LBCCD will realize the following benefits by implementing the measures recommended in this PEA. The Siemens solution will:

- Address the addition of buildings to the central plant in a planned, phased manner
- Immediately address the problem of small loads on the central plants, which may result in operational problems for the new plants
- Modernize old and ageing air-side systems at buildings B, C, E, and W at LAC; and FF, GG, MM at PCC
- Provide a centralized control system with one front end, in which facility personnel will receive full training and operational support
- Realize energy and operational savings and environmental benefits by adding energy-efficient systems in place of inefficient systems for Bldgs B, C, D, E, J, K, Q, R, O and W
- Allow for energy efficient operation during low-occupancy hours in summers, weekends, nights and holidays
- Solve problems of failing lamps and ballasts, decentralized exterior lighting control, and maintenance-intensive irrigation systems
- Implement the recommended measures in an economically feasible, integrated manner, wherein energy and operational savings pay for the bulk of the costs of modernizing these systems

3 UTILITY DATA ANALYSIS

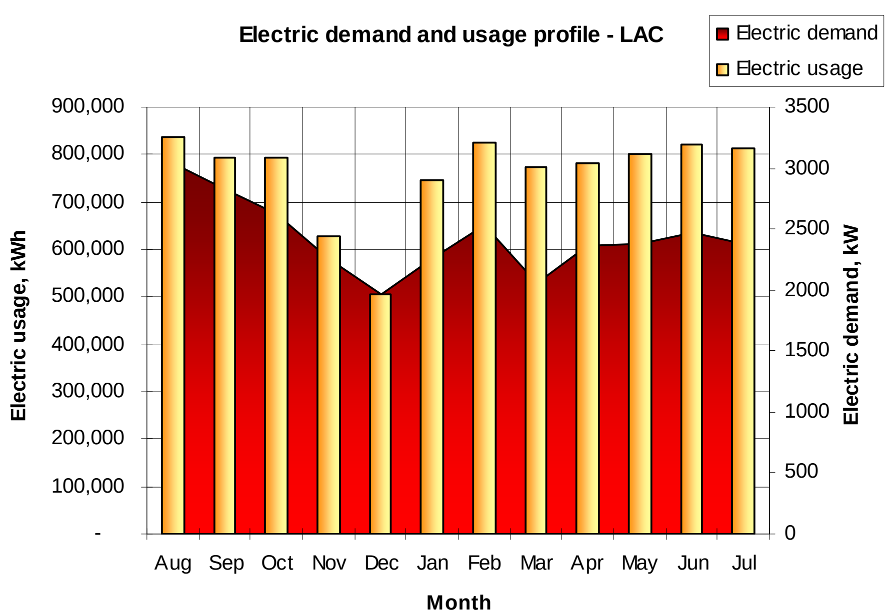
3.1 LAC

Electric service for LAC is provided by Southern California Edison. There are 7 meters on the campus. The main meter for the North side is located on the South side of Carson, while the South campus main meter is located at the Stadium.

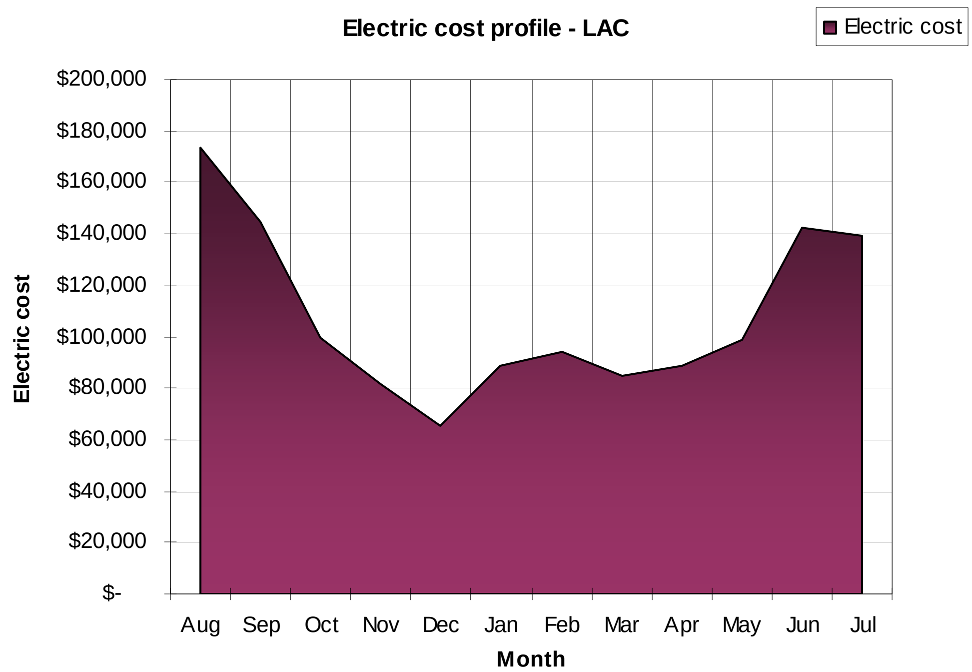
Water and gas service is provided by the City of Long Beach and only 10 months of utility data (between Dec 2006 and Sep 2007) was available at the time of report production. There are as many as 20 water meters and 10 gas meters at LAC, and only the main meters were analyzed for the utility analysis shown below.

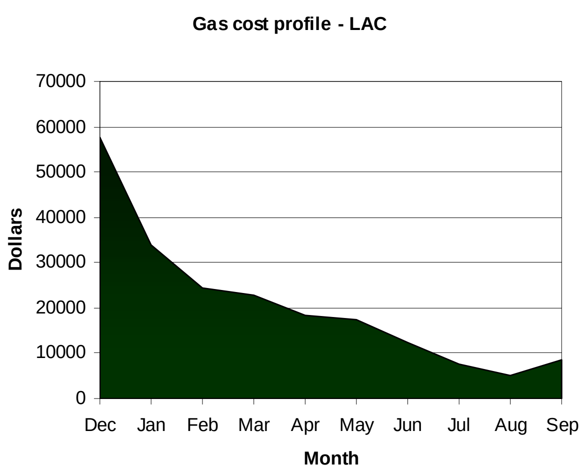
Utility	Energy use	Normalized energy use	Peak demand	Normalized energy demand	Utility cost	Normalized utility cost	Average utility rate	Overall normalized energy use
Electric	9,117,782 kWh	17.77 kWh/sf	3,035 kW	5.91 W/sf	$ 1,301,697	2.54 $/sf	0.14 $/kWh	60.66 kBtu/sf
Natural Gas	226,220 therm	0.44 therm/sf			$ 208,463	0.41 $/sf	0.92 $/therm	44.09 kBtu/sf
Water & sewer	27,558 CCF				$ 52,718		1.913 $/CCF	
Total					$ 1,562,878	2.94 $/sf		104.75 kBtu/sf

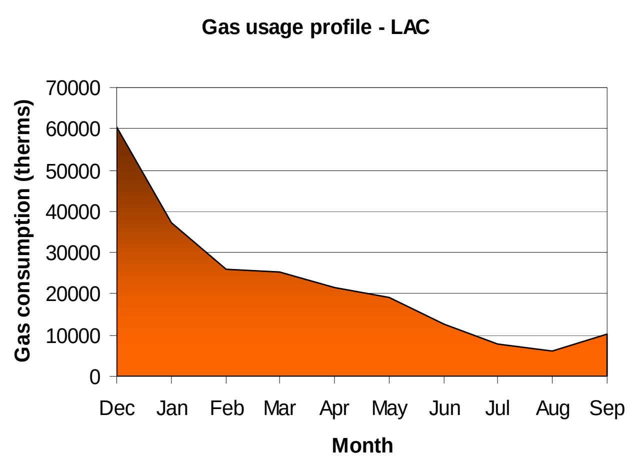
The following graphs show the electric, gas and water cost and consumption profiles, and estimate end use disaggregation.

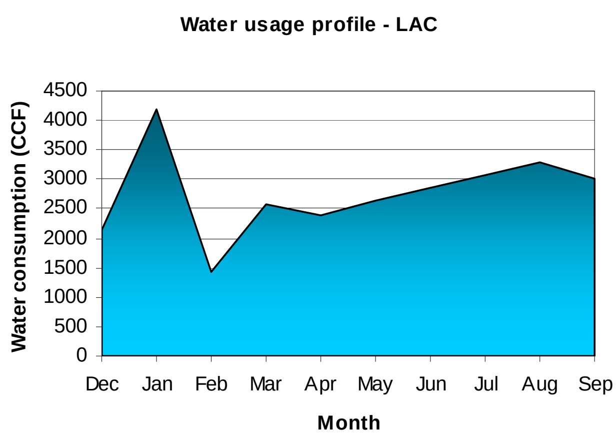


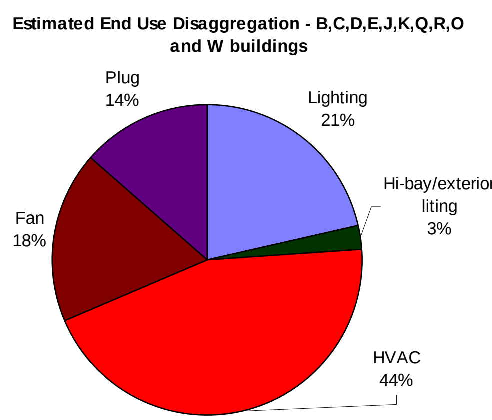
The graph above shows a base demand of close to 2,000 kW for the LAC campus, and no significant drop-off in the summer even though portions of the campus are likely not operating. This is due to the presence of large constant volume systems, which do not allow for segregation and partitioning of spaces based on occupancy.


Electric cost profile - LAC
Electric cost
$200,000
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
Electric cost
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
Month


Gas cost profile - LAC
70000
60000
50000
40000
30000
20000
10000
0
Dollars
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Gas usage profile - LAC
70000
60000
50000
40000
30000
20000
10000
0
Gas consumption (therms)
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Water usage profile - LAC
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Water consumption (CCF)
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Estimated End Use Disaggregation - B,C,D,E,J,K,Q,R,O and W buildings
Plug 14%
Lighting 21%
Hi-bay/exterior liting 3%
Fan 18%
HVAC 44%

3.2 PCC

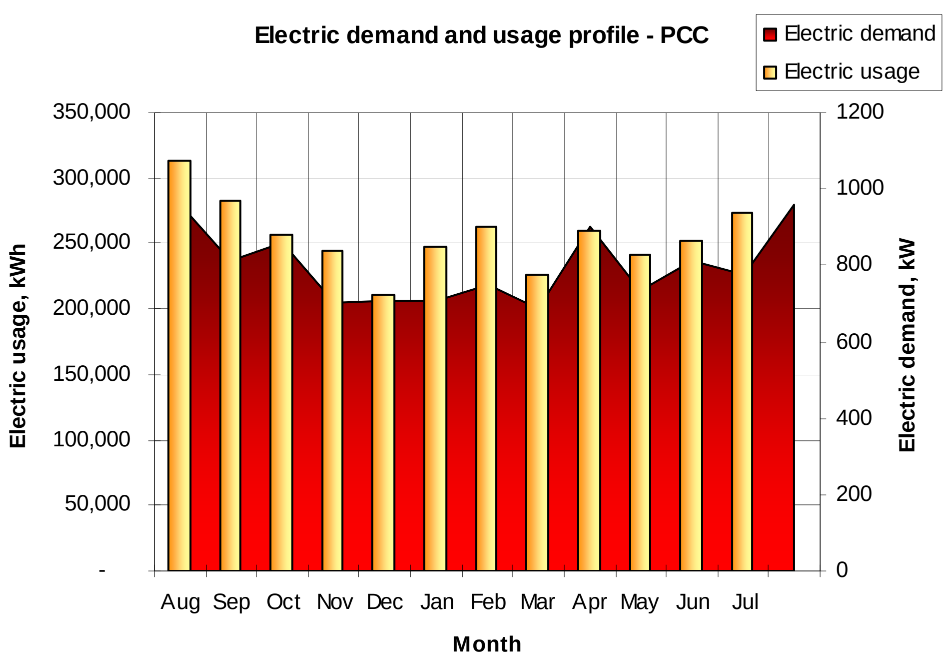
Electric service for PCC is provided by Southern California Edison. There are 5 meters on the campus. The main meters for the sites are located near the MM building for the northern part of the campus, and near the AA-BB-DD-EE building for the south side.

Utility	Energy use	Normalized energy use		Normalized energy demand	Utility cost	Normalized utility cost	Average utility rate	Overall normalized energy use
Electric	3,071,752 kWh	11.89 kWh/sf	958 kW	3.71 W/sf	$ 429,305	0.84 $/sf	0.14 $/kWh	40.59 Btu/sf
Natural Gas	44,822 therm	0.17 therm/sf			$ 41,172	0.16 $/sf	0.92 $/therm	17.35 Btu/sf
Water & sewer	8,745 CCF				$ 16,728		1.913 $/CCF	
Total					$ 487,204	1.00 $/sf		57.93 kBtu/sf

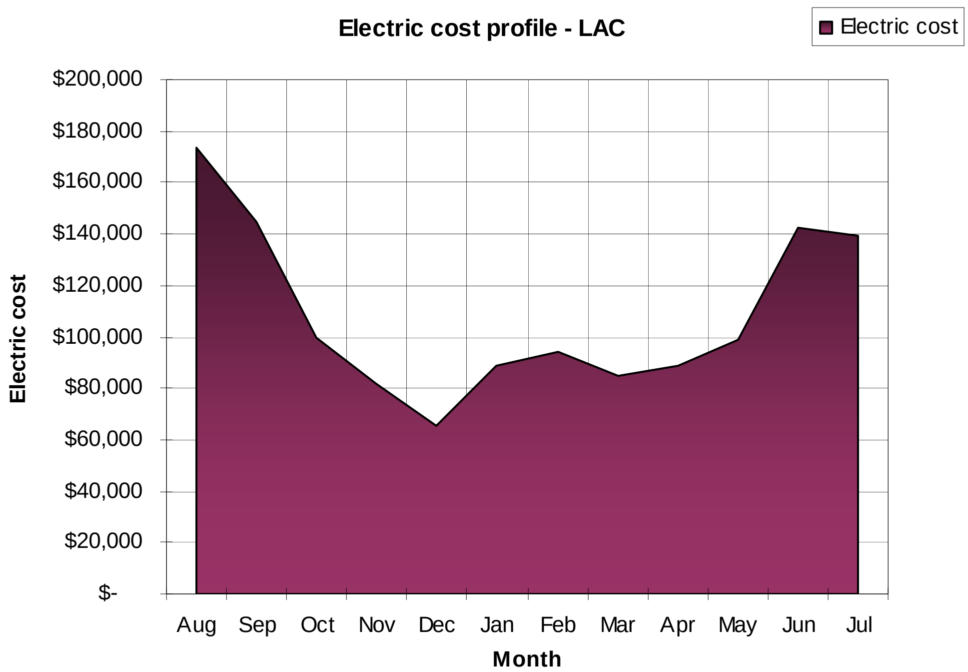
Water and gas service is provided by the City of Long Beach and only 10 months of utility data (between Dec 2006 and Sep 2007) was available at the time of report production. There are as many as 15 water meters and 10 gas meters at PCC, and only the main meters were analyzed for the utility analysis shown below.

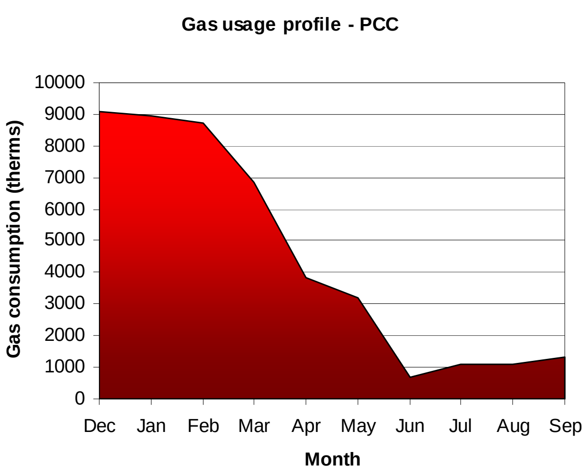
The normalized energy use of 57.93 kBtu/sf is considerably lower than that of LAC. This is due to the fact that PCC has more shop and warehouse-type spaces which are not air-conditioned.

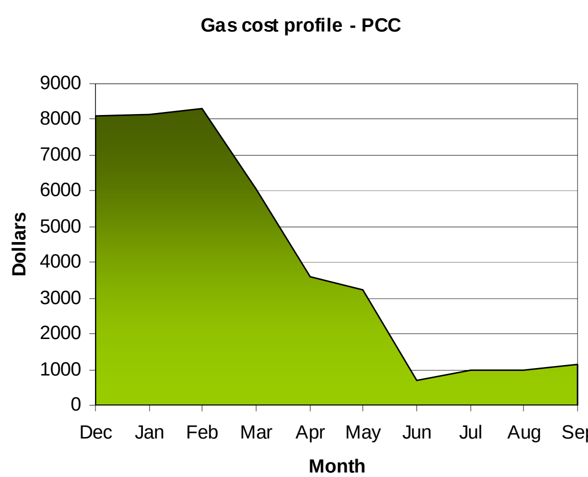
The following graphs show the electric, gas and water cost and consumption profiles, and estimated end use disaggregation.

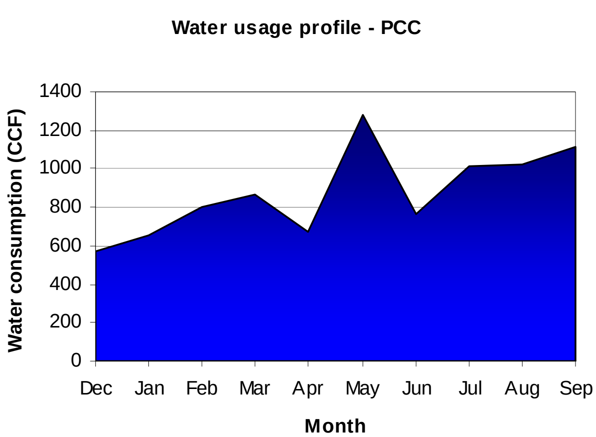


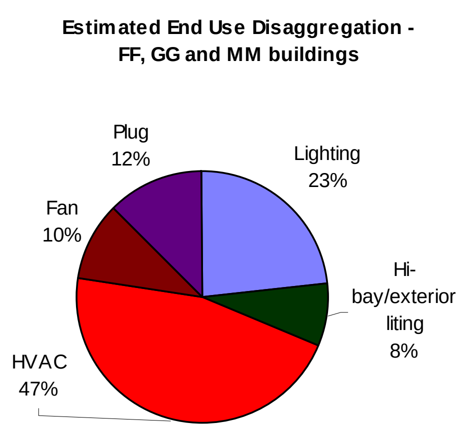
The graph above shows a base demand of close to 1,000 kW for the PCC campus, and no significant drop-off in the summer even though portions of the campus are likely not operating. This is attributable to the poor controls on the PCC campus and inefficient unitary equipment.


Electric cost profile - LAC
Electric cost
Electric cost
$200,000
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
Month


Gas usage profile - PCC
Gas consumption (therms)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Gas cost profile - PCC
Dollars
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Water usage profile - PCC
Water consumption (CCF)
1400
1200
1000
800
600
400
200
0
Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month


Estimated End Use Disaggregation -
FF, GG and MM buildings
Plug
12%
Lighting
23%
Fan
10%
Hi-
bay/exterior
liting
8%
HVAC
47%

4 DESCRIPTION OF EXISTING SYSTEMS

A brief description of the facilities including the building occupancy, lighting, and HVAC systems and controls is presented below.

4.1 Hours of Operation

As a post secondary educational facility, the bulk of the spaces are generally occupied Monday through Friday from 8:00 am to 10:00 pm. The Cafeteria area may be occupied up to 18 hours per day. Several classrooms are in use on Saturdays as well, while the Cafeteria and other areas may be in use on Sundays by reservation. HVAC equipment is programmed to run from 7:00 am to 10:00 pm, 6 days a week.

The facility maintenance staff programs the control system to schedule equipment off during Martin Luther King Day/ Presidents' Day/ Memorial Day/ Independence Day/ Labor Day/ Thanksgiving. In addition, equipment is scheduled off between Dec 20th and Jan 20th. HVAC equipment runs during summer, spring and fall breaks because the staff still uses their offices during this time.

4.2 Lighting Systems

4.2.1 Interior Lighting – LAC and PCC

Interior lighting in classrooms throughout both campuses consist of T8 lamps and electronic ballasts, which were upgraded during a lighting retrofit conducted approximately 9 years ago. The fixtures consist of various configurations including surface-mounted, recessed and in rare cases pendant fixtures. Fixtures are generally in good condition.

Lamps are typically 32 watt (F32T8/XL/SP41/ECO), 4100 K, GE brand. Ballasts are typically instant start, Advance brand. Facility personnel report that they are seeing substantial lamp and ballast failures of late, which is to be expected, considering the age of the systems. Ballast failures are reported to be higher in areas with occupancy sensors.

Typical electronic ballast

Classroom fluorescent lighting


Pendant mounted T8 fluorescent fixtures


Classroom surface-mount T8 fluorescent fixture


Surface-mount T8 fixtures in corridor

Exit light with failed lamp

Stairways, corridors, mechanical rooms and closets are served predominantly by compact fluorescent fixtures. In some cases, failed compact fluorescent lamps are being wrongly replaced by incandescent lamps.


Incandescent Lighting in Stairwell


Compact fluorescent lighting

The only other type of interior lighting is in the gym areas of building Q and R in LAC, and workshop areas of MM in PCC. These are typically metal halide high bay lighting (except in Building R which consists of 8-lamp compact fluorescent fixtures).


Metal halide lighting in Bldg MM


Compact fluorescent high bay lighting in Bldg R

4.2.2 Exterior Lighting – LAC and PCC

Exterior lighting in both campuses consists of general area lighting, parking lot lighting and building exterior lighting. Parking lot lighting is typically either high pressure sodium, 250 W or 400 W, or, metal halide, mainly 400 W. Building exterior lighting consists of metal halide, fluorescent and compact fluorescent lighting.

Lighting poles and fixtures are generally in good condition, but are of different types including cobra-head on the parking lights, and box-type, decorative, pumpkin-head and other types for area lighting.


Building exterior lighting fixture


250 W HPS Parking lot lighting in cobra-head fixture


Decorative pole in Stadium parking


New pole in South Quad area


Parking light pole in PCC


Pumpkin head fixture in PCC

Other exterior lighting includes tennis court and stadium lighting. Tennis courts consist of 400 W metal halide lighting, which works well. These may be replaced by 320 W pulse start metal halide lamps and ballasts. Stadium lighting consists of 8 poles: 3 containing 40 lamps, and 5 containing 20 lamps. These lamps are estimated to be 1000 W metal halide lamps.


Metal halide tennis lighting


Stadium lighting

4.2.3 Lighting Controls – LAC and PCC

Interior lighting in classrooms is predominantly controlled by occupancy sensors, which were installed during the lighting retrofit done about 9 years ago. As mentioned earlier, most of these areas have instant start ballasts. Siemens does not recommend installing instant start ballasts in areas with occupancy sensors, as this adversely affects lamp life.

In areas without occupancy sensors, control is typically accomplished by manual switches, operated by building occupants.

Typical ceiling occupancy sensor

Exterior lighting control is predominantly accomplished by time-clocks, which are programmed each season. Lighting typically runs 7 pm to 7 am, 7 days a week. Tennis court lights are operated manually by coaches. Typically, there are no photo sensors on any exterior lights.

Typical exterior lighting time clock

Time clocks in Bldg B for exterior lighting control

Lighting control for MM bldg exterior

Rooms with large windows in the AA-BB-CC-DD buildings also have daylighting controls, installed during the Honeywell energy project 9 years ago.

Daylighting controller

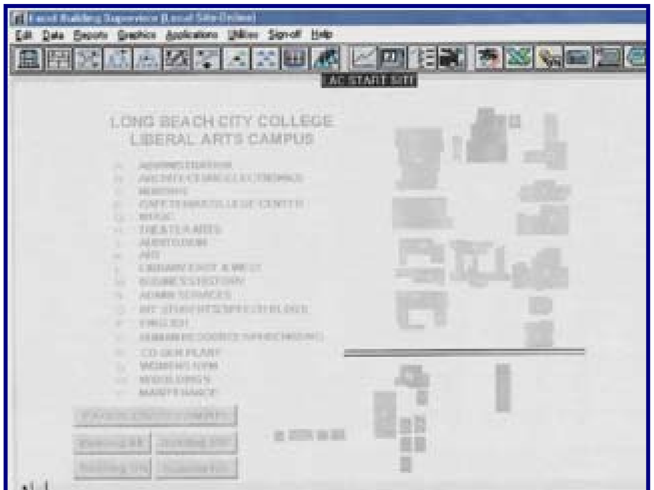
Room with daylighting controls in BB building

4.3 Building Automation Systems

LAC and PCC, as mentioned earlier, have several different control systems of varying age, complexity and level of control. The controls are part-pneumatic, part-electronic depending on the type of the system. The different control systems function differently and do not currently communicate with each other. Communication to remote devices is established by dial-up only.

4.3.1 LAC

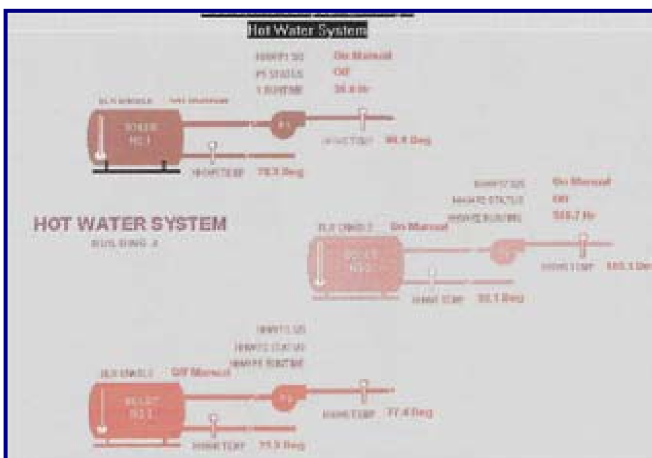
In LAC, Buildings B, C, E, J, K, Q, R are under a Honeywell control system, which was put in as part of an energy project approximately 9 years ago. At B, C and E, the end devices for air handlers and zones were left pneumatic, but electronic receiver-controllers and electronic-pneumatic transducers were installed to interface between the two modes of control. The receiver-controllers offer different levels of control (on-off only, on-off with temperature reset, full control) for different buildings, and communicate to the front end located at the Maintenance Shop. Chillers at B and C are electronically controlled, but do not interface with the front end.



LAC Honeywell System Front end

On-off/Discharge air monitoring control in K

On-off control in J



Hot water system: On-off & temp. control


Pneumatic AHU control devices in B


Electronic control for chillers in B

Building D was completely modernized 8 years ago and has its own independent control systems. An Alerton control system provides comfort control to the zones and is all-electronic, including at the zone mixing boxes. In addition to the Alerton system is a sophisticated pneumatic Tek-air control system for the laboratory fume hoods. This system controls the room pressurization and fume hood exhaust fan operation for laboratories, based on the number of fume hoods in operation and extent of sash opening, by maintaining a net negative pressure in lab spaces and constant face velocity across the fume hood. There are separate front ends for both these systems, which are both located in Building D.


Alerton system front end in Bldg D

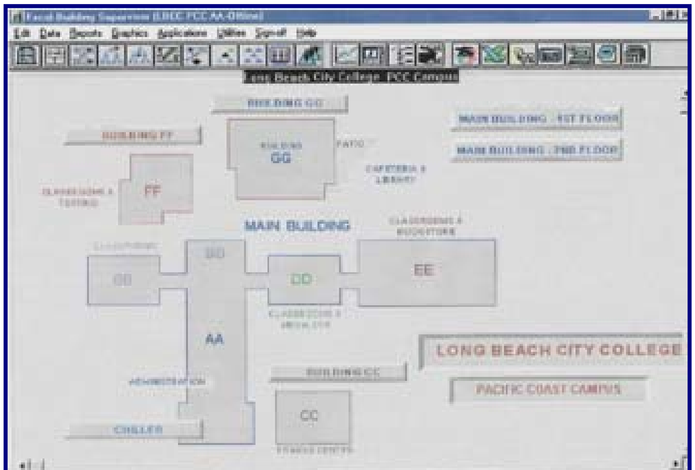

Mixing Box in Bldg D with Alerton electronic control

4.3.2 PCC

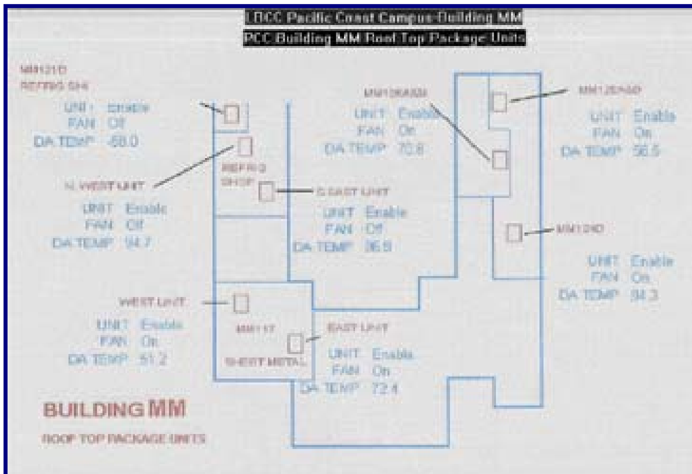
In PCC, Buildings FF and GG, have unitary rooftop equipment, and MM has unitary equipment as well, except for a single multizone unit. These buildings are integrated into the Honeywell front end located at LAC.

The predominant level of control is on-off only, with display of space and discharge air temperature available in certain units only.

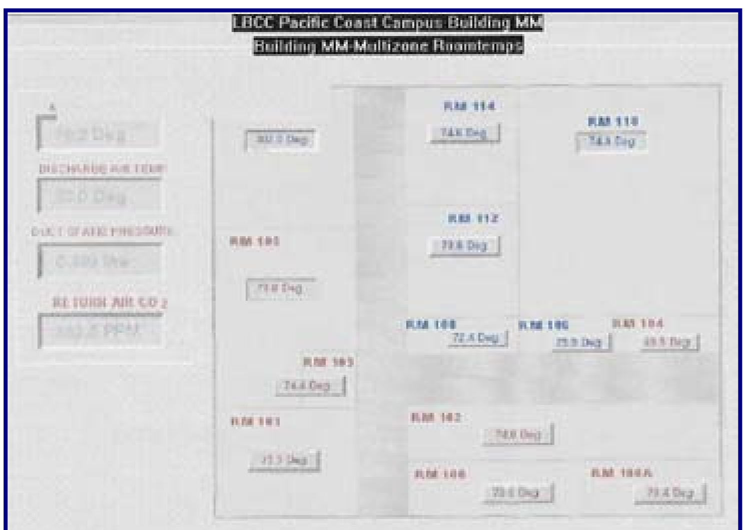
The multizone unit in MM is either heating or cooling only, because it is a single-duct system. Heating requirements are satisfied by a rudimentary morning warm-up sequence, after which the heating is disabled, and the unit functions as a cooling-only unit. This causes comfort problems in zones that require heating during the day.



PCC Honeywell System front end



Pkg unit on-off control at MM



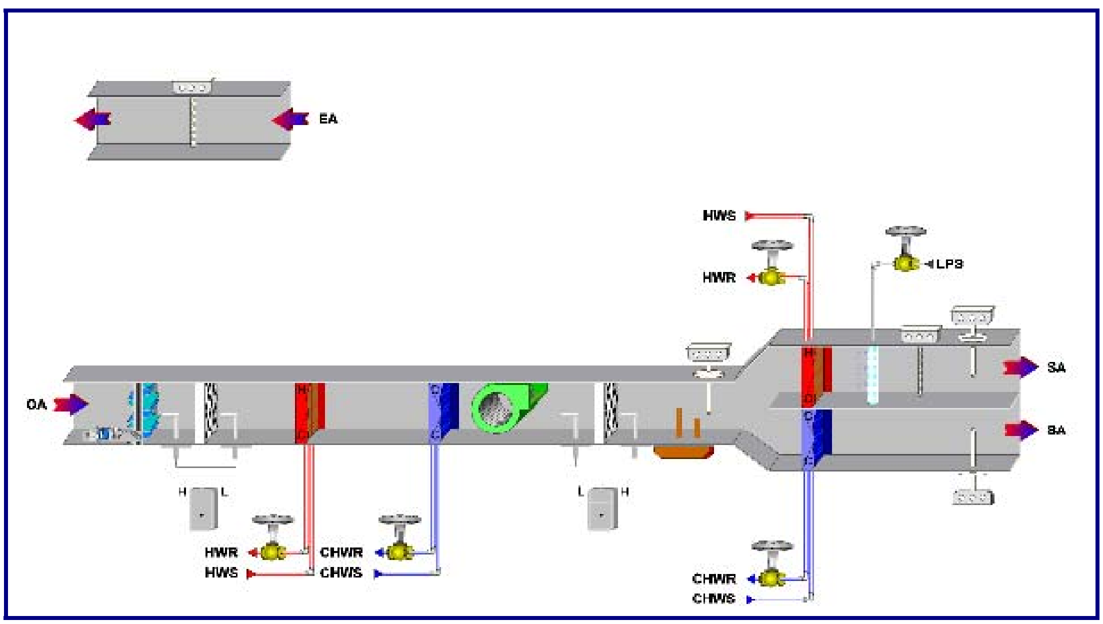
Multizone unit control at MM

4.4 Building HVAC Systems

4.4.1 LAC – B, C and E Buildings

Air handlers

Air needs in Building B, C and west part of E are served by constant volume dual duct air handlers, located on the roof of each building. In a dual duct system, warm and cool air are supplied to spaces by two ducts run throughout the building – referred to as hot and cold "decks." At the spaces, the hot and cool air streams are mixed in "mixing boxes" before being delivered to the space. In a constant volume system, there is a constant volume of air being delivered whether the zone requires little or substantial cooling. This wastes a lot of fan energy, as well as cooling and heating energy.



Schematic of Dual Duct System

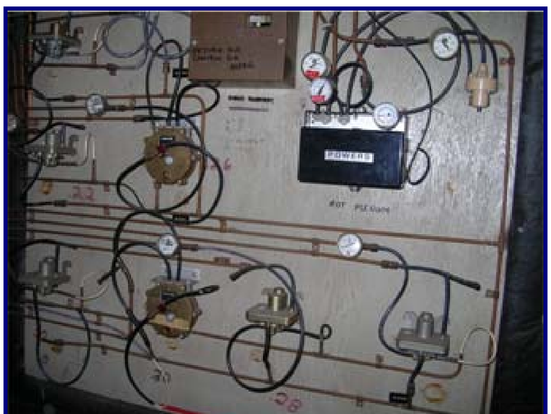
Bldg	AHU type, size	Motor size	Cooling type/ coil condition	Heating type/ coil condition	Controls	Econ.?
B	Dual duct const vol., 75 tons	30 hp	DX – repl 9 years ago, need cleaning	HW – old, need replacement	Pneumatic	Disabled
C	Dual duct const vol., 80 tons	20 hp	DX – repl 9 years ago, need cleaning	Inline furnace in hot deck	Pneumatic	Disabled
E	Dual duct const vol., 50 tons	30 hp	DX – repl 9 years ago, need cleaning	HW – old, need replacement	Pneumatic	Disabled

All fans are constant volume and scheduled to run from 7 am to 7 pm, 6 days a week.


Dual duct air handler on Bldg "B" roof


Dual duct air handler on Bldg "C" roof

Dual duct air handler serving west side of Bldg "E"


Typical AHU pneumatic controls

The E building may be in use on Sundays by reservation, and the air handler is scheduled on in that case.

Air distribution

Ductwork in the buildings is approximately 35 years old, and it was difficult to ascertain its condition during the audit. Mixing boxes are also 35 years old and constant volume, with pneumatic controls. Thermostats at zones are all pneumatic, controlled by occupants, and in many cases, in poor condition.


Typical const vol. mixing box with pneumatic actuator


Typical pneumatic thermostat

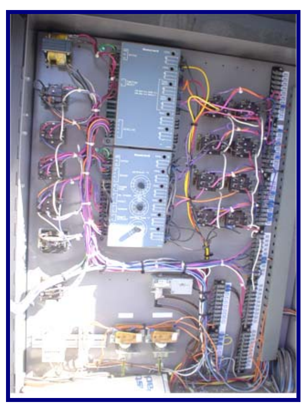
Cooling System

Air-cooled Carrier dual condensing units serve the air handler DX coils. These are in good condition and are controlled by a Carrier load analyzer control panel located on the roof.


Air-cooled Carrier dual compressor units on Bldg B roof


Air-cooled dual compressor Carrier units on Bldg C roof


Air-cooled dual compressor units on Bldg “E” roof



Heating System

One (1) 35-year old Bryan boiler (2,000,000 Btuh input, 80% nameplate efficiency) serves the hot water coils in Bldg B. One (1) Peerless boiler (1,470,000 Btuh input, 80% nameplate efficiency) serves Bldg E (west side). The hot water pumps in Bldg B and E are both 3 hp, and have been rebuilt a couple of times. Piping and insulation are 35 years old as well, and the insulation contains asbestos. In Bldg C, heating is accomplished by an inline furnace in the hot deck, which was replaced 9 years ago.

35-year old Bryan boiler serving Building B

Hot water pump in Bldg B

Peerless boiler serving Bldg E (west side)

Hot water pump in Bldg E

Hot water piping and asbestos-containing insulation

Unitary equipment

Unitary HVAC equipment serves the cafeteria (east portion) of Bldg E. There are 4 units on the roof, of which 2 units serving the "Saga" room and the faculty dining area have been non-functional for the past 8 years. One of these units is scheduled to be replaced by a heat pump from another building, which is being connected to the central plant. The other two units are Carrier gas packs, approximately 10 years old.

Carrier gas-electric unit serving cafeteria


Old gas-electric package unit in Bldg E – East Side

4.4.2 LAC – D Building

Building D was completely modernized 9 years ago and has more modern, energy-efficient systems.

Air handlers

Building D is served by five 9-year old air handlers, located on the roof. As shown below, 4 of the air handlers are variable air volume, a configuration, which when controlled effectively, reduces the energy usage associated with constant volume systems, like those at buildings B, C and E.

ID	AHU type, size	Motor size	Cooling type/ coil condition	Heating type/ coil condition	Controls	Serves
AH1	Single duct VAV	15 hp	CHW – repl 9 years ago, need cleaning	HW – repl 9 years ago, need cleaning	Elec.	Offices
AH2	Single duct VAV	50 hp	CHW – repl 9 years ago, need cleaning	HW – repl 9 years ago, need cleaning	Elec.	Classrooms
AH3	Single duct VAV, 100% OA	40 hp	CHW – repl 9 years ago, need cleaning	HW – repl 9 years ago, need cleaning	Elec.	Labs
AH4	Single duct VAV, 100% OA	40 hp	CHW – repl 9 years ago, need cleaning	HW – repl 9 years ago, need cleaning	Elec.	Labs
AH5	Constant volume	5 hp	CHW – repl 9 years ago, need cleaning	HW – repl 9 years ago, need cleaning	Elec.	Planetarium (seldom used)

AH-1 and AH-2

Air handlers (Bldg D) serving labs

Air distribution

Ductwork in the buildings was completely replaced during the remodeling done 8-9 years ago, and is in good condition. Mixing boxes are also VAV boxes, with electronic controls. Thermostats at zones are all electronic and controlled through the Alerton control system. The only pneumatic controls are for the fume hood exhaust system (see below), controlled by a Tek-air control system.

Typical VAV mixing box w. HW reheat

Fume hood and lab exhaust system

Bldg D has a sophisticated fume hood control system. One objective of the control system is to minimize air flow, while satisfying exhaust requirements for laboratories, and this is achieved by face velocity control by the Tek-air system. Basically, each bank of fume hoods is served by a variable speed exhaust fan located on the roof. The fume hood controller seeks to keep the face velocity of exhaust air constant across the fume hood. When the fume hood sash is lowered, the area reduces, which increases the velocity, if the flow were kept constant. In order to maintain a constant velocity, the flow is reduced by reducing the exhaust fan speed on the roof, which reduces fan energy consumption.

In addition to fume hood control, the Tek-air system seeks to maintain a slight negative pressure in lab spaces with respect to corridors. This room pressure control is achieved by constantly manipulating the amount of supply air, room exhaust and fume hood exhaust using pneumatic Tek-air valves.

Fume hood VAV exhaust fan system

Fume hood system with VAV controls

Pneumatic Tek-air valve for lab exhaust

Cooling System

Two 170-ton air-cooled York dual-compressor chillers serve the air handler chilled water coils. The chilled water pumps are 10 hp each, and constant volume. These are in good condition and are controlled through the Alerton control system. At present no chilled water reset is being performed, and the chillers produce constant 45 F water.


Air-cooled chillers serving Bldg D


Chilled water pumps (10 hp)

Heating System

Two (2) 8-year old Thermal Solutions non-condensing boilers (2,000,000 Btuh input, 88% nameplate efficiency) serve the hot water coils in the air handlers. The hot water pump in Bldg D is 5 hp, and is in good condition. Piping and insulation are generally in good condition.

4.4.3 LAC – J Building

The J-building consists of an auditorium area, dressing rooms, rest rooms, foyer and small offices. The building is approximately 50 years old, and most of the equipment and infra-structure is also of that age.

Air handlers and air distribution

There are total of 5 air handlers that are enabled and disabled through the central Honeywell control system. 1 air handler is located in the basement, two serve the foyer and two others serve the main auditorium space. Air distribution in the main auditorium consists of an under floor return system.


Fan coil units with HW coils for main auditorium


Underfloor return grille in main auditorium


Air handler in J Bldg


Foyer air handler

Heating System

There is no cooling in the building, and heating is accomplished by fan coil units with HW coils, served by 50 year old boilers (1 x 1,050,000 Btuh, 64% nameplate efficiency, 2 x 1,500,000 Btuh, 75% nameplate efficiency) located in the basement. Boilers typically run 5 months out of the year, after which they are disabled. The hot water insulation is in poor condition and contains asbestos. One of the larger boilers recently exploded due to a gas leak and has been de-commissioned. There are 3 hot water pumps, each ¾ hp in size, in which the motors and belts were replaced recently.


HW boilers at J Bldg


HW pumps at J Bldg

The consensus among facility personnel is that this building needs complete remodeling which addresses all of the ageing systems. Adding cooling coils to 50-year old equipment and air distribution systems is likely not going to solve the comfort problems in this building. A recent P2S proposal looked at the feasibility of simply replacing the 50-year old boilers in this building, but was cancelled after contractor estimates for replacement substantially exceeded the proposal estimates.

Siemens will work hand-in-hand with the campus to determine the best approach to modernizing the building. A comprehensive approach would be to replace air handling equipment and coils, refurbishing or replacing damaged air distribution, and replacing the old HW system. These measures will likely be high-capital, high payback items.

4.4.4 LAC – K Building

The K (Art) building consists of classrooms, lecture halls, rest rooms, common areas and small offices. The building was rebuilt in 1994 except for a couple of areas, and most of the equipment and infra-structure was modernized at that time.

HVAC systems

The building is served by 20 rooftop gas-electric package units varying in size between 2.5 to 7.5 tons. In addition, there is one split unit, serving the lecture hall, with a ground-mounted outdoor portion, and three rooftop furnaces. All these units are enabled and disabled through the Honeywell control system.

Typical rooftop gas-electric unit on K Bldg roof

Ground-mounted outdoor portion of Lecture Hall split unit

4.4.5 LAC – Q and R Building

The Q and R (gym) buildings consist of locker rooms, training rooms, activity areas, common areas and small offices. The buildings are 50 years old, and most of the air distribution infrastructure is also that old.

Air handlers and air distribution

Air distribution consists of fan coil units, unit heaters and small air handlers with heating coils. Locker rooms in both buildings consist of overhead heating only fan coil units. 50 year old heating-only air handlers provide heating and ventilation to the Weight Room in R, and the Dance Studio in Q. The basketball and volleyball areas are served by unit heaters suspended from the roof.

50 year old air handler for dance studio

50 year old air distribution system

Damaged thermostats at Q and R buildings

Window shakers for training room

50 year old unit heater and piping


Fan coil unit with heating coil for locker rooms


Air handler in Q bldg

Heating System

There is no cooling in the buildings except for a couple of areas (see below). Heating is accomplished by three (3) recently installed Raypak hot waer boilers (2,000,000 Btuh, 84% nameplate efficiency) located in the R-building. This heating plant will also serve the South Quad building, currently under construction. One other boiler (1,530,000 Btuh, 84% nameplate efficiency) serves the domestic hot water loop for Q, R and the South Quad. Two variable speed 10 hp hot water pumps serve the space heating needs for the three buildings, and 1 x 2 hp serves the domestic hot water loop.

Cooling is present only in the following areas: R-building Human Performance Lab, which has window shakers, Q-building Training room, which has an 8-year old heat pump, Athletic department office, which has a 15-year old split unit, and the Nurse's Office, which has a window shaker unit.


Q, R and South Quad heating plant


HW pumps in heating plant

These buildings are similar in modernization needs to the J building. The buildings are slated to be added to the central plant chilled water loop, but simply adding cooling coils to 50-year old equipment and air distribution systems is likely not going to solve the comfort problems in this building.

Siemens will work hand-in-hand with the campus to determine the best approach to modernizing the building. A comprehensive approach would be to replace air handling equipment and coils, piping, and refurbishing or replacing damaged air distribution. These measures will likely be high-capital, high payback items.

4.4.6 LAC – Auxiliary Buildings (O, W)

These buildings were intended to be temporary buildings and trailers, but are still in use around the campus. Bldg W is air-conditioned by Bard wall packs which are 30+ years old. Bldg O has Bard units which are 20 years old.

As such, these old units are inefficient and are simply enabled and disabled through the Honeywell control system.

4.4.7 PCC – MM Building

The MM (Trade and Industrial) building consists of shop areas, offices, common areas, classrooms and restrooms.

HVAC equipment

Heating, ventilation and cooling are accomplished pre-dominantly by seven (7) rooftop gas-electric package equipment. These units are 20+ years old and in need of replacement.

There is also one (1) newer Carrier DX unit with gas furnace, which serves multiple zones in Rooms 100-114. This unit can either perform heating or cooling, as there is only a single duct serving each zone. To satisfy heating needs, the control sequence enforces a morning warm-up during the cold season to pre-heat the building prior to occupancy. Once the warm-up is done, the unit is set to cooling mode for the rest of the day. At the time of the audit, the outside air dampers were completely closed. Unit heaters serve shop areas.

Control is limited to enable-disable only for the package units, and this is accomplished from the Honeywell front end.

Old rooftop equipment on MM roof

Old Rheem unit on MM roof

Carrier heating or cooling only unit

Typical unit heater serving shop areas

4.4.8 PCC –GG Building

The GG (Cafeteria, Library and Learning Center) building consists of a library area, small offices, common areas, classrooms and cafeteria area. The building was remodeled in the early 90s.

HVAC equipment

Heating, ventilation and cooling are accomplished by eight (8) rooftop package gas-electric Carrier units and one (1) heat pump, between 2 to 15 tons. The units are from the early 90's and reaching the end of their useful life.

Control is limited to enable-disable only for the package units, and this is accomplished from the Honeywell front end.


Rooftop gas-electric package units on Bldg GG


Carrier rooftop units on Bldg GG

4.4.9 PCC –FF Building

The FF (Assessment and Senior Center) building consists of a classrooms, small offices, common areas, and restrooms.


FF bldg roof with 3 heat pumps

HVAC equipment

Only part of the building is air-conditioned and this is accomplished by three (3) rooftop heat pumps, which are approximately 7 years old. Unit heaters serve heating needs in other areas.

One classroom is served by a fan coil unit with a steam coil, which is served by steam boilers located in the AA-BB-DD-EE building.

Control is limited to enable-disable only for the package units, and this is accomplished from the Honeywell front end.

4.5 Pool Systems

The swimming pool at LAC is a year-round, heated, partially covered pool. It is typically occupied from 6 am to 10 pm throughout the year. The pool systems were modernized 4 years ago, and are generally in good condition. It is maintained at a relatively high set point of 82 F.

Pool Cover

Manually deployable covers are available on site, and the intent is that the coaches deploy them at the end of the day, but facility personnel indicate that this is seldom done. Evaporation from the pool surface is the biggest heat loss phenomenon in a pool and not using the pool cover increases gas and water use by approximately 40%.

Manual pool cover

Pool filtration system

The pool water is filtered by three (3) EPD Commercial sand filters, which were installed 4 years ago. These are efficient and in good condition.

Pool sand filtration system

Pool boiler

The pool heating water system consists of a 2,000,000 Btuh boiler (88% efficiency) which is located outside the R building. The heater is in good condition. Facility personnel report that this heater is not adequate to maintain 82 deg F on the coldest days, resulting in occupant complaints. The South Quad heating plant is located in the R-building as well, in close proximity to the pool. There is a plan to use the South Quad heating plant to provide back-up heating, by utilizing the plate and frame heat exchanger in the abandoned cogeneration plant.

Pool heater

Pool pump

Pool Pump

The pool circulation pump is 4 years old and consists of a 25 hp premium efficiency motor. The pump runs 24/7, throughout the year.

4.6 Irrigation Systems

4.6.1 LAC

Irrigation water

The South side of LAC uses reclaimed water for irrigation, while the north side has no reclaimed water, and domestic water is used for irrigation. The main for the reclaimed water is located on Lew Davis St north of the Stadium, while the domestic water main for the North side is located on Clark St north of Carson.

Facility personnel indicate that the water pressure for the North side is low, and consequently the remotest stations do not receive enough water, leading to dry areas. The reclaimed water pressure on the South side system is adequate.

Areas with dried and overwatered spots

Area with irrigation water being wasted (common throughout campus due to old distribution system)

Area with reclaimed water run-off (needs immediate attention from personnel)

Irrigation water distribution

Distribution piping on the South side was modified when the South side was converted to reclaimed water a few years ago. The system consists of a mixture of original galvanized steel main lines, which are old and not designed for "gray" water, and newer reclaimed water lines which run out to the distribution devices.

On the North side, piping is original galvanized steel piping, and would need to be redesigned and replaced when the system is converted to reclaimed water.

Valves and heads on both sides of Carson are replaced as they fail, resulting in high maintenance costs. On the South side, since the system uses reclaimed water, there is no run-off allowed, but the old distribution system results in frequent leaks and creates run-off, which in turn results in increased maintenance issues that need immediate attention.

Irrigation controls

The irrigation controls in LAC are decentralized with around 20 Sterling-24 control panels located throughout the campus, which serve 24 stations each. Facility personnel manually adjust irrigation schedules on each of these 20 stations every season.

There are no automatic controls for head or valve adjustment, or leak detection.


Sterling 24 decentralized irrigation control


Older style valves present throughout LAC (replaced as they fail)


New irrigation valve replacing old valves

4.6.2 PCC

The irrigation system at PCC was not audited during this phase of the project as:

- The majority of the irrigation system issues were identified by facility personnel to be at LAC
- Since this is a capital-intensive measure with a lengthy payback, a phased approach involving work on one campus at a time, would make more economical sense.

4.7 Water systems

Siemens investigated the water systems in the restrooms in Buildings B, C, D, E, J, K, Q and R in LAC and FF, GG and MM in PCC. Domestic fixtures located in public restrooms offer good water savings opportunities.. Water savings are dictated by the amount of water that can be saved per fixture (gallons per flush for toilets and urinals, or gallons per minute for sinks and showers) and the frequency of fixture use. Facility demographics determine the frequency of fixture use. An engineering survey of the public bathrooms of each building yielded the following results.

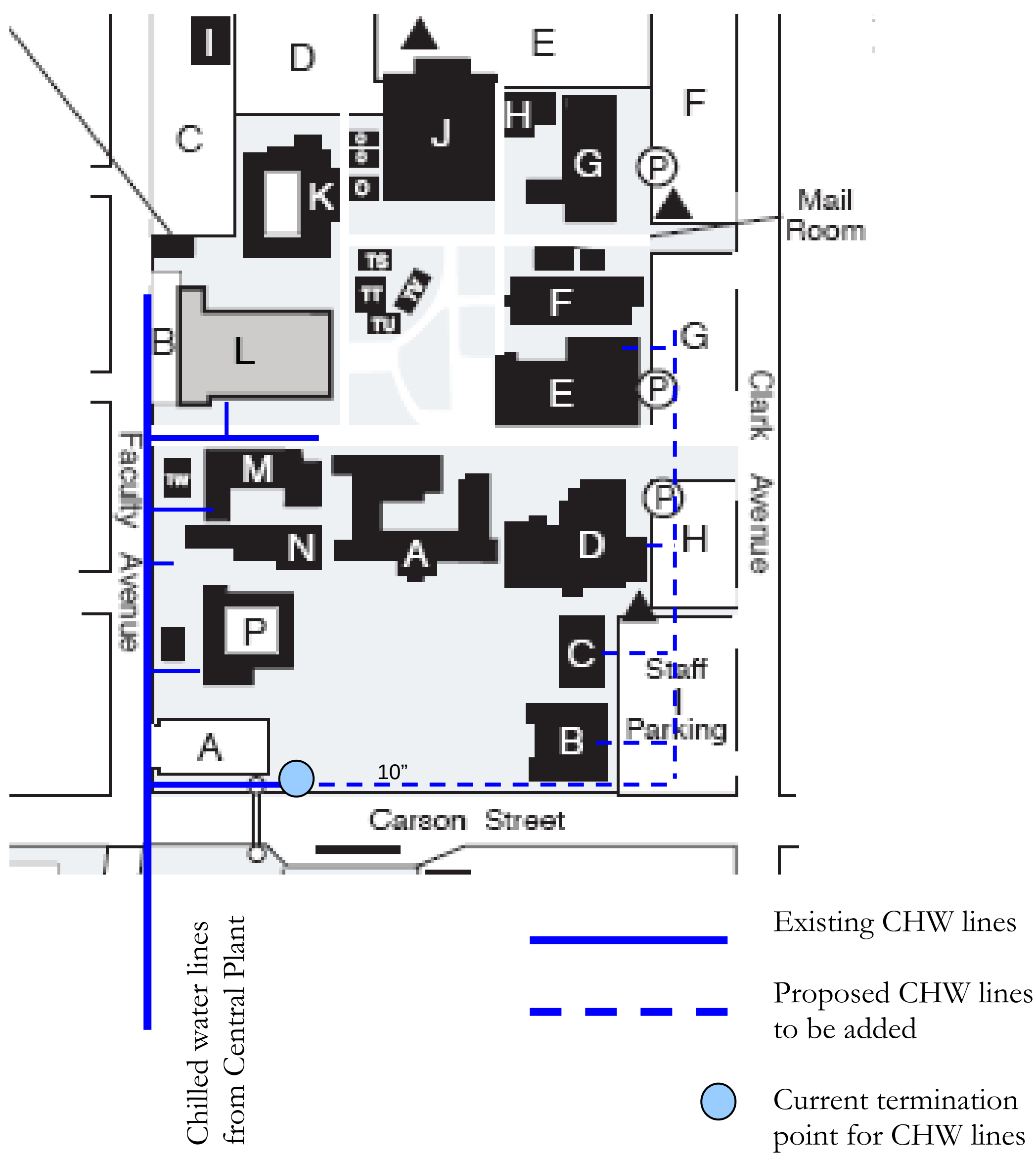
A total of 131 toilets, 69 urinals, and 146 bathroom sinks and 84 showerheads were identified during the survey. All toilets and urinals surveyed were located in public bathrooms. 50 of the toilets are Ultra Low Flush (ULF) types that use 1.6 gallons per flush (gpf). The remaining 81 toilets use an average of 3.5 gallons per flush. 15 of the urinals are Ultra Low Flush (ULF) types that use 1.0 gallons per flush (gpf). The remaining 54 urinals use an average of 1.5 gallons per flush. The sink faucets usage varied from building to building. The showerheads use an average of 2.5 gallons per minute (gpm). All of the sink faucets, showerheads and non-ULF toilets and urinals are good candidates for water saving retrofits.

5 RECOMMENDED MEASURES – LAC

5.1 Chilled water loop extension

This measure recommends the extension of the chilled water loop to serve Buildings B, C, D and part of E. This would enable the air-side systems in these buildings to be connected and served by the central plant instead of less efficient air-cooled systems. The existing air-cooled systems may then be disconnected and retired.

For purposes of this PEA, Siemens evaluated this measure as proposed in the Master plan provided in Appendix – A as designed by P2S. Siemens would also recommend an alternative proposal consisting of providing a reverse return chilled water loop in the final engineering phase.



The measure would involve the following steps:

- Extend the 10" chilled water line from the current termination point to Buildings B, C, D and E as shown below
- Sizing of piping to these buildings will be based on detailed load calculations to be performed during final engineering, but for purposes of the PEA, the original Master Plan sizing and piping routing performed by P2S is shown below:

Building	Master plan GPM	CHW pipe sizing
B	258	4"
C	138	4"
D	652	6"
E	258	4"

- This would involve trenching, pipe lay-in and backfill along the path shown in the diagram above from near the M and A buildings to Buildings B, C, D, and E
- Buildings B, C and E have air handlers with existing DX coils. These AHUs will be retrofitted with CHW coils (see below).
- Building D already has CHW coils which were replaced only 9 years ago. While these are 12 deg F delta T coils, throttling the flow to the building would allow for operating them close to the 14 deg delta T of the central plant, without the need for replacing coils.
- Extend CHW lines from building points of connection to air handlers in B, C and E, and the existing chilled water loop in D.
- Decommission and retire air-cooled condensing units in B, C and E (west), and air-cooled chiller in D.

Benefits

- Realizes the original design intent behind construction of central plant
- Adds loads to central plant necessary for its proper operation
- Provides cooling needs from central plant instead of less efficient air-cooled equipment
- Reduced maintenance due to retirement of decentralized cooling equipment
- Improved comfort for occupants

5.2 Air handler improvements

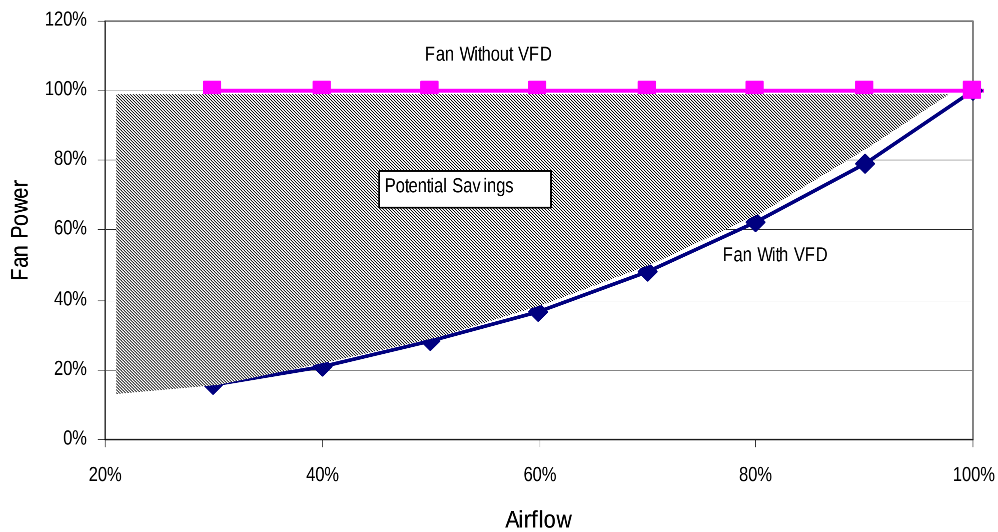
This measure addresses the old, constant volume air-side systems in Buildings B, C and E. In addition to putting these equipment on the central plant by replacing DX coils with CHW coils, the energy and operational efficiency of these equipment can be dramatically improved by converting these constant volume systems, with variable air volume (VAV) systems.

VAV systems enable fan energy savings by reducing the amount of air supplied during low load conditions and decrease both the heating and cooling loads by reducing the total amount of air that is conditioned. The conversion from constant volume to variable volume will include the zone upgrades (see Section 5.3).

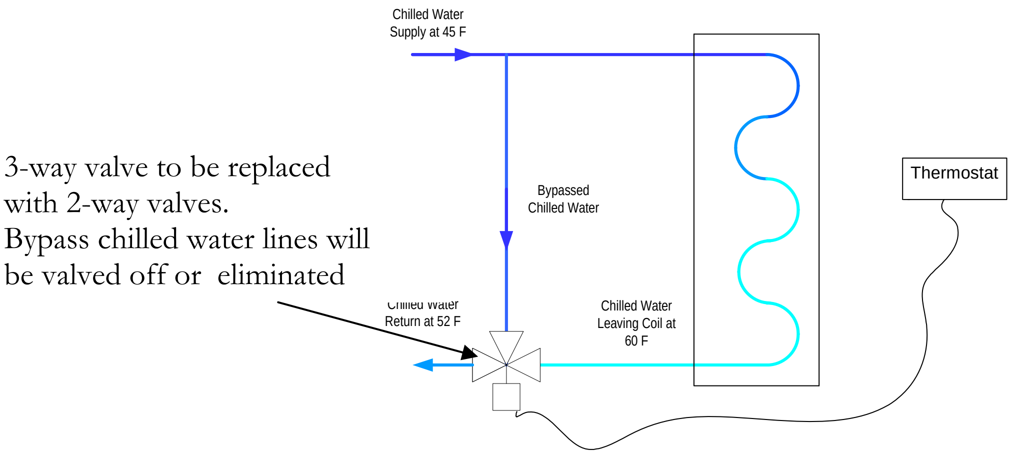
When a zone needs cooling, the hot-deck damper will be closed, and the cold deck damper will be open with the modulating damper controlling the amount of air entering the zone based on the thermostat. When a zone needs heat, VAV damper will be at its minimum position and the mixing damper will modulate to adjust the supply air temperature based on the needs of the space.

This modification to a true variable air volume unit enables fan savings. The variable speed drive on the fans will modulate the speed of the fan based on the amount of air needed by the air-handling unit. The theoretical fan power savings varies as a cubic function of the airflow delivered by the fan. The figure below provides a visual representation of the fan energy savings potential versus airflow.

Example of VAV Conversion Savings



At Building D, which already has chilled water coils, in order to realize savings from variable flow pumping at the central plant, the 3-way chilled water valves will be replaced with 2-way modulating chilled water valves. Buildings B, C and E will have new chilled water coils and new 2-way valves installed. The conversion of the chilled water distribution from constant volume will dramatically reduce the amount of pumping energy used by the college. The power required to pump the chilled water varies as a cubic function to the amount of water distributed.



This measure also recommends repairing and replacing the economizer dampers on the units at buildings B, C, D and E. Some of these economizer dampers are no longer functioning. Properly functioning economizer dampers enable the HVAC systems to cool the facility with outside air when conditions permit, reducing the number of hours the chiller must operate.

In addition, thorough maintenance of all other parts of the air handlers at B, C, D and E will be performed including:

- Replacement of old fan motors with new premium efficiency motors
- Fan blade cleaning and maintenance
- Replacement of fan belts and sheaves
- Clean coils in building D (other buildings will have new CHW coils installed)
- Repair or replace damaged insulation in Building D (other buildings will have new piping)
- Clean or replace condensate pans

Finally, pneumatic controls in air handler rooms will be demolished and new electronic controllers will be provided. See Section 5.4.

Benefits

- Complete modernization and refurbishment of 30-year old air handlers
- Substantial energy savings due to VAV conversion, by minimizing air flow to zones which have low loads
- Reduced maintenance
- Improved comfort for occupants
- Central control of air handlers

5.3 Air handler zone improvements

The conversion of air handlers from constant volume to variable volume, described in Section 5.2 will include the addition of air flow stations to each zone mixing box and replacing the existing constant volume mixing boxes with new VAV mixing boxes, pre-fitted with electronic controls which will interface with the central control system (See Section 5.4). This applies to Buildings B, C and E.

In addition, zone thermostats which are currently pneumatic will be changed to electronic, and will interface with the central control system.

Benefits

- Modernization of zone mixing boxes
- Reduced maintenance
- Improved comfort for occupants
- Central control of air handlers which will enable remote temperature control and troubleshooting

5.4 Control system improvements

The problems on the campus caused by multiple control systems, limited information at central front ends, lack of operator training, and inefficient sequence of operation needs to be addressed in a phased manner. Siemens recommends the following approach:

Phasing of the work

<u>Phase 1: (already in the works):</u>

- Controls for central plant
- New central front end at Maintenance Shop
- Operator training for new central front end
- Integrate buildings J, K, Q, R and O to central plant front end

<u>Phase 2:</u>

- Conversion of pneumatic controls at zones and air handler rooms to all-electronic at buildings B, C, E and W (addressed in this PEA)
- Controls on new buildings – South Quad and L – to be Siemens and integrated to front end
- Updated sequences for buildings B, C, D, E, J, K, Q, R, O and W (addressed in this PEA)
- Additional operator training for building controls (addressed in this PEA)

<u>Subsequent Phases:</u>

- Buildings that will be demolished or modernized including A, M/N, P and G/H will have new Siemens controls at zone and air-side equipment level installed during modernization. These will be integrated to the front end as new controls are installed.
- Buildings K and O will have new controls installed when the mechanical equipment there is replaced.
- This approach does not address only buildings J, Q and R. The mechanical systems in these buildings are 30-50 years old, so simply modernizing the controls will not solve the problems in these buildings. This will need to be decided on by the campus.

Control strategies to be implemented

The new control system will be programmed to optimize operation of the system as a whole, and the following strategies will be implemented:

- 365-day scheduling, allowing for system turndown during weekends, holidays, summertime operation etc
- Optimal sequencing of central plant equipment
- Supply air reset
- Chilled water reset
- Hot water reset
- Morning warm-up or cool-down
- Economizer operation
- Static pressure optimization for air-side systems

Benefits

- Integration of multitude of control systems to a central location
- Additional information to operators for complaint response, troubleshooting and control
- Modernization of old controls
- Reduced maintenance
- Improved comfort for occupants
- Substantial energy savings due to proper sequencing and control strategies

5.5 Unitary equipment upgrades

Siemens recommends replacing and upgrading the Bard units at Building W, to improve or maintain the comfort levels while reducing the associated utility costs, and meeting Title 24 efficiency standards. Building O also has 20 year old Bard units, but replacing these units is a high-payback item, and it is not clear if these portables are expected to remain. If they are scheduled to remain on campus, the O units may be replaced in this or a later phase. The scope includes:

- Remove and properly dispose of existing unit
- Provide and install new high efficiency unit of equal capacity
- Provide and install new electrical connections between the unit and the existing disconnect

Benefits

- Modernization of old units
- Reduced maintenance
- Improved comfort for occupants
- Energy savings due to improved efficiency

5.6 Hot water system upgrades

Currently, buildings B, E and J are served by boilers which are about 30 or so years old and no longer meet the emission guidelines established by the Air Quality Management District. The measure includes the removal of the existing boilers and the installation of new high efficient natural gas boilers. The improved efficiency of the new boilers will reduce the amount of natural gas used to heat the gym and the improved emissions will reduce the pollution generated.

Also recommended is removal and replacement of the old hot water pumps and motors with new pumps and premium efficiency motors. Finally, the piping in these buildings is old and contains asbestos and damaged insulation. Siemens recommends replacing the piping and insulation within the boiler room to be replaced after due abatement of asbestos by the campus.

Benefits

- Modernization of old units
- Reduced maintenance
- Hazardous material abatement
- Improved comfort for occupants
- Energy savings due to improved efficiency

5.7 Pool upgrades

Pool equipment is overall in good condition and operational – and the Siemens recommended measures listed below are aimed at operational improvements and energy efficiency. The following measures are recommended:

- Reduce pool water temperature from 82 deg F to 78-80 F. This is dependent upon occupants being accepting of this change. Even if an 82 F set point is desired during winter months, a seasonal change to a lower heating set point would result in substantial gas savings.

- Install automatic unwinders for easier deployment of pool covers. Currently, pool users are entrusted with the responsibility of deploying covers. Since they need to be manually installed, users may be less likely to deploy them. Siemens recommends installing an automatic unwinder on the pool reels for easier deployment of pool covers. Educating the occupants on the amount of gas wasted by not deploying pool covers will also be done as part of this measure with help from the campus. This measure would result in up to 40% savings in gas usage during unoccupied hours.

- Facility personnel report that the pool heater is not adequate to maintain 82 deg F on the coldest days, resulting in occupant complaints. Assuming that an 82 deg F setpoint is necessary during cold days, Siemens concurs with the facility personnel plan of using the South Quad heating plant to provide back-up heating, by utilizing the plate and frame heat exchanger in the abandoned cogeneration plant.

- Title 24 states the following for pool circulation pumps:

B. The circulation pump shall have a time switch that allows the pump to be set to run in the off-peak electric demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

Currently, the circulation pump runs 24/7. Siemens recommends either cycling the pump off for a pre-determined period of time every night or slowing the pump down using a VFD through a control sequence. This will require further investigation as to backwash flow requirements and will be confirmed during final engineering.

Benefits

- Redundancy
- Energy savings due to improved efficiency

5.8 Lighting upgrades

This FIM addresses retrofit strategies for fluorescent lighting systems using T12 lamps, first generation T8 lamps, lighting controls, exit sign lighting, and incandescent lighting. Fixture quantities and types are based on a detailed room-by-room lighting audit.

Fluorescent lighting systems. The existing fluorescent lighting systems will be upgraded to utilize third generation T8 lamps and programmable electronic ballasts. The new third generation T8 lamps and ballasts use 19 percent less energy and have rated lamp lives 50 percent longer than the first generation T8 lamps currently used by the campus. As part of the space-by-space assessment the lighting retrofit will be selected to provide lighting levels in accordance with IES recommendations to ensure proper lighting levels while minimizing energy consumption.

Incandescent lighting. Incandescent light bulbs are an inefficient lighting source when compared to other means of illuminating a space. The incandescent bulbs use excessive amounts of energy, and require extensive maintenance to ensure fixtures are operational. The remaining incandescent fixtures will be retrofitted to utilize compact fluorescent lamps.

Metal halide lighting. The gymnasiums, tennis court lights and other high bay areas are illuminated with 400 watt metal halide lighting. These fixtures will be replaced with pulse start metal halide lamps, which provide comparable lumens for reduced wattage.

Exit sign lighting. The existing exit signs not illuminated with light-emitting diodes (LEDs) will be replaced with new signs using LEDs. LEDs are ideal for exit signs because they use very little energy, as low as 1.0 watt per illuminated face, and maintenance free life expectancies are over twenty years. LED exit signs compliant with the U.S. EPA's Energy Star Exit Sign Program use 5 watts or less per illuminated face. Traditional incandescent exit signs use 40 watts per illuminated face and require annual maintenance to replace the bulbs, while CFL exit signs use 7 to 9 watts per sign and last about 15 months.

Exterior lighting controls. Currently exterior lighting is manually programmed through mechanical time clocks throughout the campus. Siemens recommends installing photocells on exterior lights, and also provide overrides through the central control system by taking control of the mechanical time-clock points.

Benefits

- Resolution of problems with failing lamps and ballasts
- Reduced maintenance costs
- Centralized control for exterior lighting
- Energy savings due to improved efficiency

5.9 Water conservation measures

The 73 non-ULF toilets in the campus found during the site audit will be replaced with 1.6 gpf toilets. New 1.6 gpf china will be installed and existing flushometers will be retrofitted with of-the-shelf toilet flushometer kits that are 1.6 gal/flush. The 46 non-ULF urinals identified in the audit will have the flushometers retrofitted with 1.0 gal/flush flushometer kits. All bathroom sink faucet aerators will be replaced with 0.5 gpm faucet flow restrictors. All showerheads will be replaced with 2.0 gpm new showerheads.

A toilet replacement and flush-valve retrofit and maintenance upgrade includes installation of a water-saving flushometer kit, which includes the following components:

- ULF Toilet Installation
    - Toilets: 1.6 gallons per flush in kind replacement
    - New outlet seals will be installed
    - New toilet seats with stainless steel hardware will be installed
    - Reuse of existing flushometer valve and trim
    - Replace flushometer Diaphragm assembly with new 1.6 gpf Sloan diaphragm
    - Provide new relief valve, handle repair kit, O-ring at stop, friction ring and slip joint washer, and vacuum breaker
- Urinal Retrofit
    - Replace flushometer Diaphragm assembly with new 1.0 gpf Sloan diaphragm
    - Provide new relief valve, handle repair kit, O-ring at stop, friction ring and slip joint washer, and vacuum breaker
- Sink Retrofit
- Showerhead Retrofit

Benefits

- New fixtures
- Reduced water consumption and cost
- Reduced maintenance

5.10 Measures requiring further investigation

5.10.1 Photovoltaic systems

Siemens investigated the feasibility of installing PV panels on LAC building roofs. Most LAC roofs have rooftop equipment such as large air handlers, exhaust fans or penthouses. Besides the area this equipment takes up, they also cause substantial shading thereby rendering them poor candidates for PV panel installation.

The best candidates for a PV system would be the stadium parking lot with a carport configuration for supporting PV panels or the Tech building.

- There is substantial area available at the parking lot, with minimal shading, access to the optimal south orientation and close proximity to the main electrical feed for the southern part of the campus. Carport PV systems, would cost on an average an additional $2-$3/watt of PV capacity depending on the architectural design chosen, as compared to roof-mount PV systems.
- The Tech building offers a roof configuration but will need electrical wiring and conduit from the main Stadium meter, which would lead to increased costs.

Siemens requires campus input on either option to proceed with this measure. This measure will be investigated during final design.

Benefits

- Renewable energy source
- Hedge against future utility rate increases
- Availability of incentives to offset costs
- Shade structure for cars
- Low maintenance

5.10.2 Irrigation system improvements

Section 3.6.1 described some of the challenges with the irrigation system infra-structure at LAC. Siemens recommends a phased approach to modernize the irrigation system at LAC as follows:

South side improvements:

This side already has reclaimed water; however, the piping infra-structure is old and consists of pre-dominantly galvanized piping.

- Siemens recommends redesigning the distribution system and adding new PVC piping for reclaimed water distribution.
- As part of the piping replacement, old valves will be replaced with modern valves and damaged heads will be replaced.
- Siemens also recommends the addition of central satellite-based irrigation control systems for central control

The improvements in the South side are likely to produce mainly maintenance and operational savings, along with some water savings. Impact to campus activities will be less as compared to North side improvements.

North side improvements:

This side of the campus has no reclaimed water, as well as ageing piping and distribution infra-structure.

- Siemens recommends a conversion to reclaimed water, hand-in-hand with piping distribution redesign and improvement. The important step of providing a reclaimed water main line by extending the reclaimed main from the south side of the campus has already been done as part of the Central plant project.

- As part of the piping replacement, old valves will be replaced with modern valves and damaged heads will be replaced.

- Siemens also recommends the addition of central satellite-based irrigation control systems

The improvements in the South side are likely to produce substantial water savings (50% or more) in addition to maintenance and operational savings. Impact to campus activities will be high, but can be minimized by phasing of piping replacements in increments.

Siemens needs additional campus input regarding prioritization and phasing of this measure. This measure also requires in-depth analysis, which will be completed during final engineering.

Benefits

- Substantial energy and operational savings
- Replacement of old piping infra-structure
- Centralized control
- Environmental benefits through use of reclaimed water

5.10.3 Exterior lighting pole replacement

Siemens investigated the condition of exterior lighting poles and considered potential energy savings. The exterior lighting poles are of different styles throughout the campus, but barring the stadium parking lot poles, others seem to be in fair condition. Most exterior lighting consists of efficient HPS and metal halide lamps. Retrofit to pulse-start metal halide may be possible in some cases, but savings from such cases is minimal.

Replacement of poles would likely be a high-capital expense item with limited savings to offset costs. Siemens needs additional campus input to proceed further.

5.10.4 Stadium electrical isolation

The stadium electrical room contains the main campus electrical meter for the South side of LAC. This meter also serves the stadium lighting, which is only turned on at night. Since there is one meter for all loads, the demand set by the high-wattage stadium lights reflects on the electricity bill for the entire south campus. Additionally, the campus is paying a higher rate (13 c/kWh) for the electricity consumed by the stadium lighting, as Edison allows a much lower rate (6-10 c/kWh) for exterior lighting that is only in use after dark.

Siemens recommends:

- Investigating the electrical distribution from the stadium main meter

- Isolating stadium lighting electrical load from the rest of the campus load

- Working with SCE to install a separate meter on the stadium lighting load
- Converting the rate schedule on the stadium lighting load from ToU rates to an AL (area lighting) rate schedule

This requires an in-depth investigation in conjunction with Edison and will be completed during final engineering.

Benefits

- Substantial energy cost savings

5.10.5 Fleet improvements

Siemens recommends converting the older gasoline-based maintenance vehicles on LAC to new CNG (compressed natural gas)-based vehicles.

Natural gas is one of the cleanest burning alternative fuels available and offers a number of advantages over gasoline. According to the Alternative Fuels Data Center, in light-duty applications, air exhaust emissions from natural gas vehicles are much lower than those from gasoline-powered vehicles. In addition, smog-producing gases, such as carbon monoxide and nitrogen oxides, are reduced by over 90 percent and 60 percent, respectively and carbon dioxide, a greenhouse gas, is reduced by 30-40 percent. NGVs produce only a tiny fraction of these types of emissions and emit virtually no particulate matter. In addition to being cleaner than conventional vehicles, Natural gas vehicles reduce the nation's extreme dependence on imported oil, and the fuel cost is generally less than the cost of gasoline or diesel fuel.

Siemens would:

- Install natural gas refueling station near the maintenance shop
- Provide and install natural gas compressor
- Provide and install a natural gas meter
- Provide electrical connections
  - Includes extending electrical service to equipment
- Provide natural gas connections
  - Includes extending natural gas service to equipment

Siemens will investigate this measure if this is in the interest of the campus.

Benefits

- Gasoline cost savings
- Environmental benefits

6 RECOMMENDED MEASURES – PCC

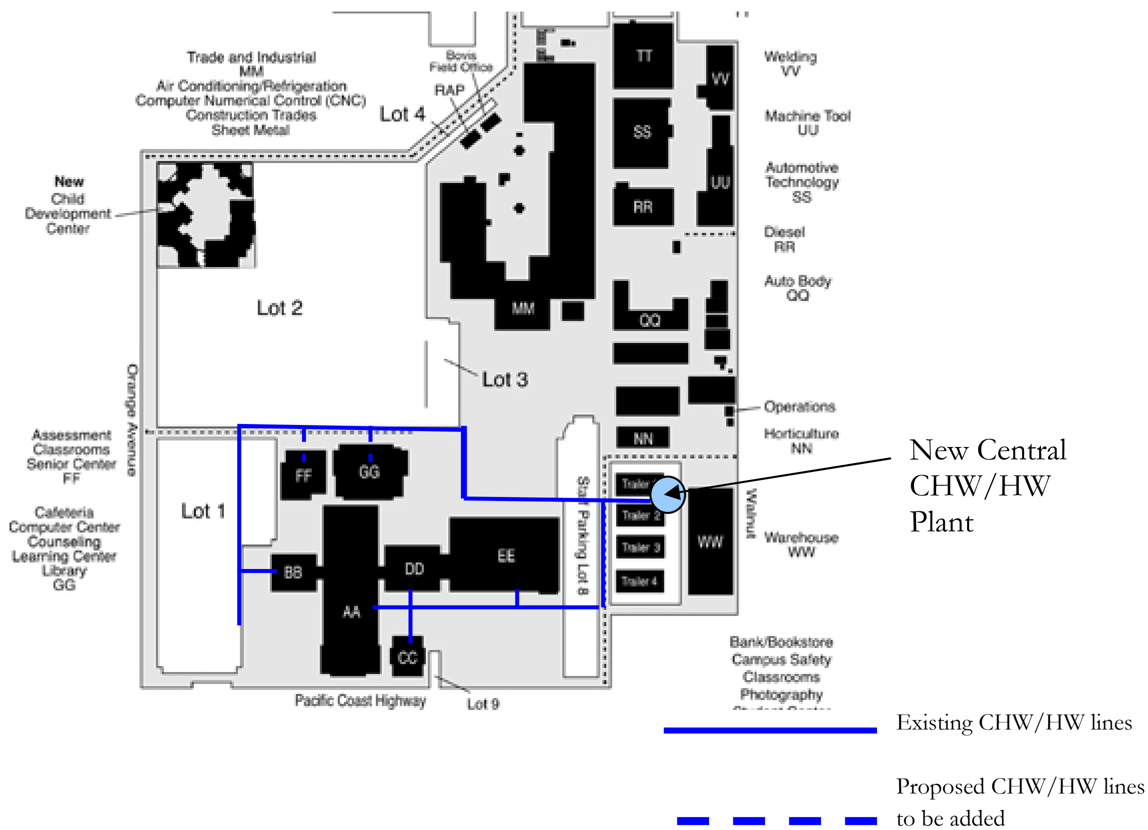
6.1 Chilled water loop extension

As with LAC, this measure recommends the extension of the chilled water loop – on this campus, to serve Buildings FF and GG. This would enable the air-side systems in these buildings to be connected and served by the central plant instead of less efficient air-cooled systems. The existing air-cooled systems may then be disconnected and retired.

For purposes of this PEA, Siemens evaluated this measure as proposed in the Master plan provided in Appendix – A as designed by P2S. Siemens would also recommend an alternative proposal consisting of providing a reverse return chilled water loop in the final engineering phase.

The measure would involve the following steps:

- Extend the chilled water loop from the current stub-out locations at the FF and GG buildings (assumed to be 25' away in this PEA)



- This would involve pipe lay-in from the point of connection near the FF and GG buildings to Buildings FF and GG equipment

- Buildings FF and GG have rooftop package gas-electric equipment. These units will be either be retrofitted with CHW/HW coils or replaced with fan coil units (see below).
- Remove and retire compressors and furnaces in FF and GG

The pipe sizing based on the P2S master plan to Buildings FF and GG is as follows:

Building	Master plan GPM	CHW pipe sizing
FF	80	4"
GG	240	4"

Benefits

- Realizes the original design intent behind construction of central plant
- Adds loads to central plant necessary for its proper operation
- Provides cooling needs from central plant instead of less efficient air-cooled equipment
- Reduced maintenance due to retirement of decentralized cooling equipment
- Improved comfort for occupants

6.2 Air handler improvements

This measure addresses the old gas-electric rooftop equipment in Buildings FF and GG. Siemens recommends:

- Demolishing and removing rooftop units 7 ½ tons or less, and replacing them with fan coil units with CHW/HW coils to serve the same areas
- Removing air compressors, DX coils and furnaces for units larger than 7 ½ tons and retrofitting the unit with CHW/HW coils to serve the same areas
- Add or recommission economizers in the new equipment
- Add new DDC controls for each new unit and interface with central front end
- Units with fans larger than 7 ½ hp will be set up for VAV operation

Benefits

- Replacement of old units
- Substantial energy savings due to units being served by central plant
- Reduced maintenance
- Improved comfort for occupants
- Central control of air handlers

6.3 Control system improvements

Siemens recommends adding new DDC controls for air-conditioning systems and zones at the FF, GG and MM buildings. This will enable standardization, centralized control, improved scheduling and remote parameter resetting for all units at these buildings.

Control strategies to be implemented

The new control system will be programmed to optimize operation of the system as a whole, and the following strategies will be implemented:

- 365-day scheduling, allowing for system turndown during weekends, holidays, summertime operation etc
- Optimal sequencing of central plant equipment

- Supply air reset
- Chilled water reset
- Hot water reset
- Morning warm-up or cool-down
- Economizer operation
- Static pressure optimization for VAV air-side systems

Benefits

- Integration of multitude of control systems to a central location
- Additional information to operators for complaint response, troubleshooting and control
- Modernization of old controls
- Reduced maintenance
- Improved comfort for occupants
- Substantial energy savings due to proper sequencing and control strategies

6.4 Unitary equipment upgrades

This project includes the replacing and upgrading the mechanical systems at Building MM, to improve or maintain the comfort levels while reducing the associated utility costs, and meeting Title 24 efficiency standards. The scope includes:

- Remove and properly dispose of existing unit
- Provide and install new high efficiency unit of equal capacity
- Provide and install new electrical connections between the unit and the existing disconnect

Benefits

- Modernization of old units
- Reduced maintenance
- Improved comfort for occupants
- Energy savings due to improved efficiency

6.5 Lighting upgrades

As with LAC, this FIM addresses retrofit strategies for fluorescent lighting systems using T12 lamps, first generation T8 lamps, interior and exterior lighting controls, exit sign lighting, and incandescent lighting. Fixture quantities and types are based on a detailed room-by-room lighting audit.

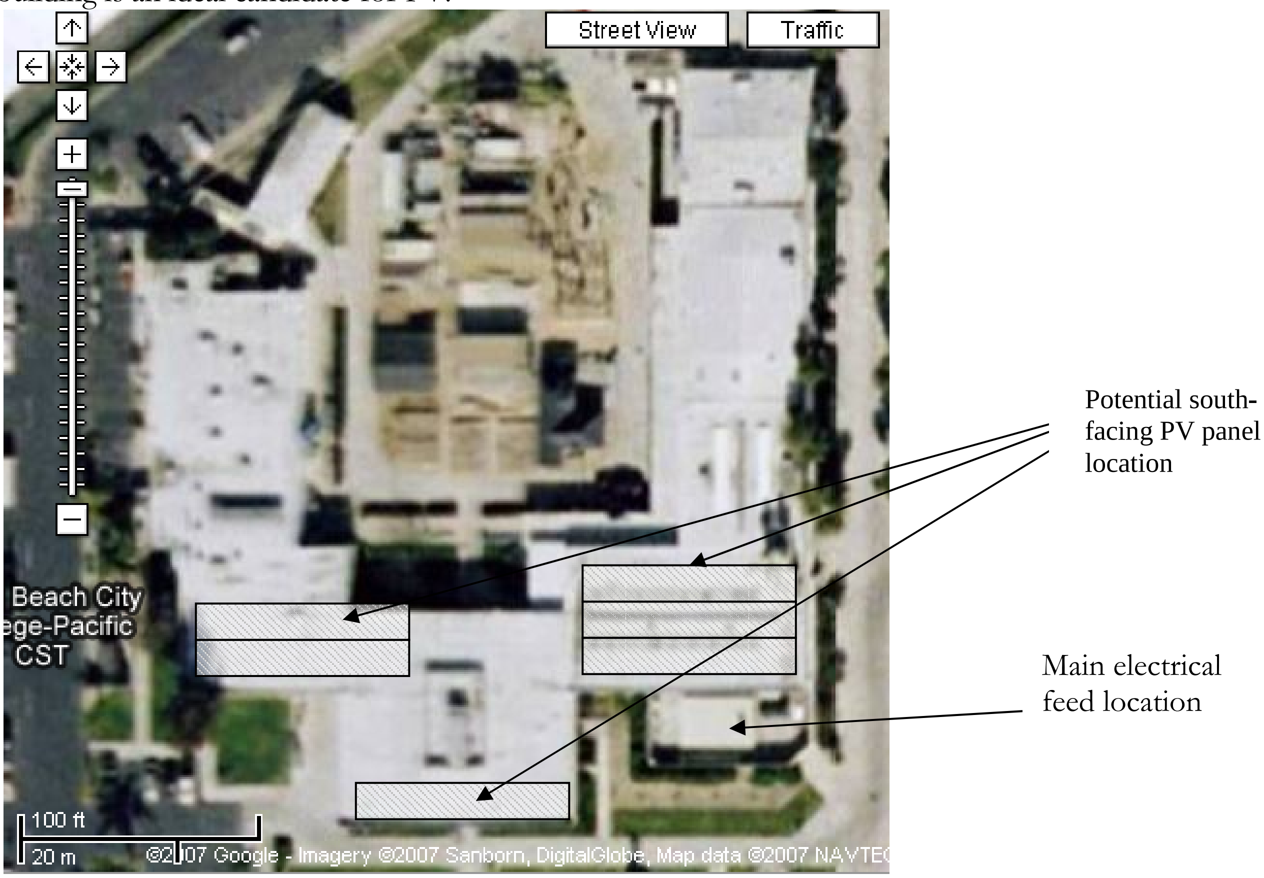
See Section 5.8 for a detailed description of these measures.

Benefits

- Resolution of problems with failing lamps and ballasts
- Reduced maintenance costs
- Centralized control for exterior lighting
- Energy savings due to improved efficiency

6.6 Photovoltaic system

Siemens investigated the feasibility of adding a new PV system at the MM building roof. This building has rooftop units interspersed throughout the roof, but the areas shown shaded below offer good prospects for location of PV panels. Added to this, the main electrical feed for interconnection purposes is located just south of the MM building in close proximity: hence this building is an ideal candidate for PV.



Assuming that some of the adjoining trees can be trimmed and the abandoned solar hot water heating system can be demolished, an area of approximately 12,000 sf is available for the installation of solar panels, which translates to approximately 110 kW-dc of PV capacity. Siemens recommends installing a non-penetrating sub-structure for support of panels.

Benefits

- Renewable energy source
- Hedge against future utility rate increases
- Availability of incentives to offset costs
- Shade structure for cars
- Low maintenance

6.7 Water conservation measures

The 8 non-ULF toilets in the campus found during the site audit will be replaced with 1.6 gpf toilets. New 1.6 gpf china will be installed and existing flushometers will be retrofitted with of-the-shelf toilet flushometer kits that are 1.6 gal/flush. The 8 non-ULF urinals identified in the audit will have the flushometers retrofitted with 1.0 gal/flush flushometer kits. All bathroom sink faucet aerators will be replaced with 0.5 gpm faucet flow restrictors. All showerheads will be replaced with 2.0 gpm new showerheads.

See Section 5.9 for further details on retrofit scope of work.

6.8 Measures requiring further investigation

6.8.1 Irrigation system improvements

Siemens has not investigated the irrigation systems at PCC. Input from facility personnel indicates that the piping infra-structure on PCC is also in poor shape, but the irrigation controls are in better shape than LAC.

Siemens recommends modernizing the LAC systems in the first phase, and once this is done, to implement a similar strategy for modernizing the PCC systems.

6.8.2 Exterior lighting pole replacement

As with LAC, Siemens investigated the condition of exterior lighting poles and considered potential energy savings. The exterior lighting poles are of different styles throughout the campus, most poles seem to be in fair condition. Most exterior lighting consists of efficient HPS and metal halide lamps. Retrofit to pulse-start metal halide may be possible in some cases, but savings from such cases is minimal.

Replacement of poles would likely be a high-capital expense item with limited savings to offset costs. Siemens needs additional campus input to proceed further.

6.8.3 Fleet improvements

As with LAC, Siemens recommends converting the older gasoline-based maintenance vehicles to CNG (compressed natural gas)-based vehicles.

See Section 5.9.5 for more information on this measure.

Benefits

- Gas cost savings
- Environmental benefits

7 PRELIMINARY PROJECT FINANCIALS

Siemens evaluated the preliminary utility and operational cost savings, and implementation budgets for the measures as shown below. At this stage in the process, these costs and savings are to be construed as preliminary only and roughly within ± 15% of final implementation costs.

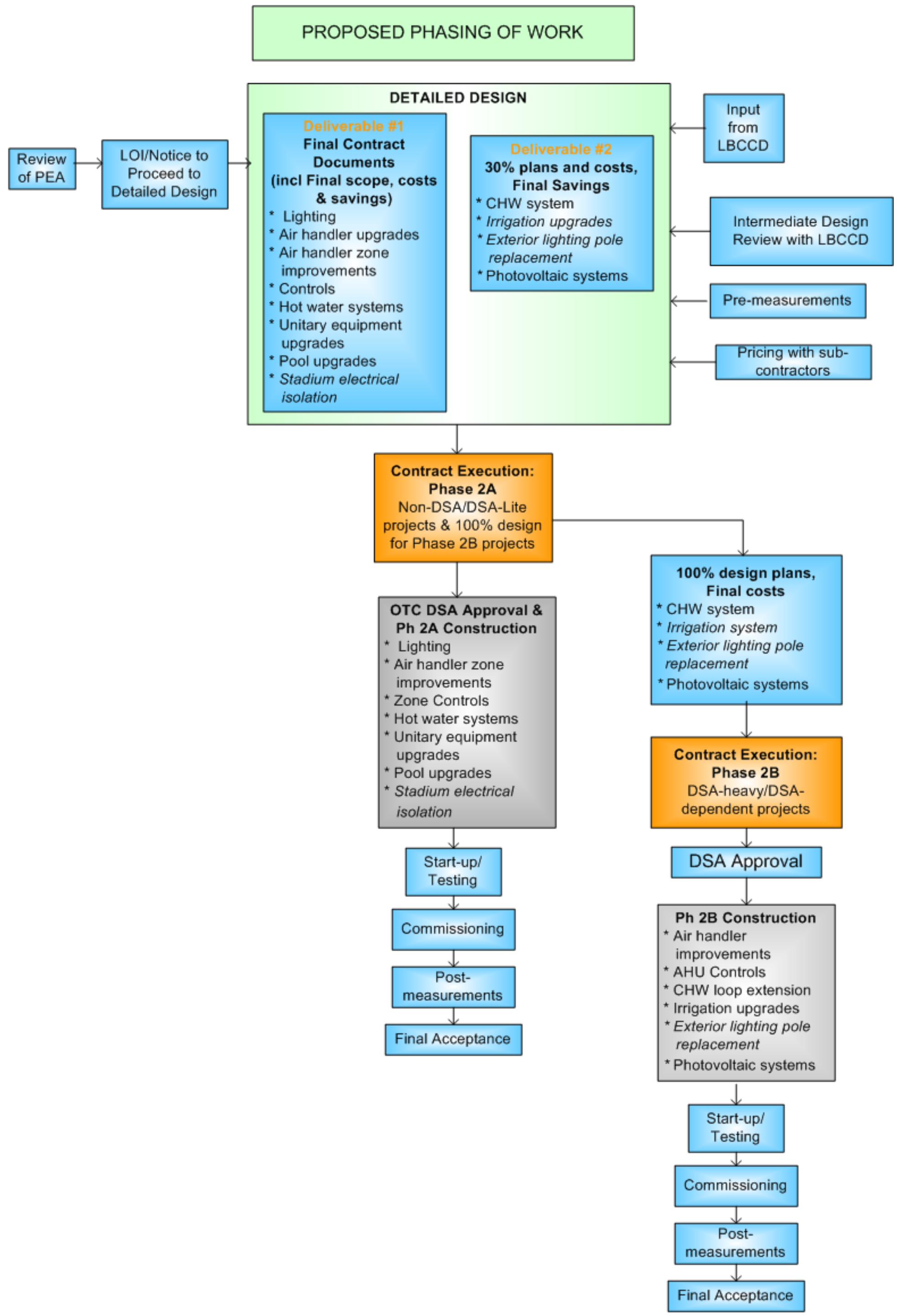
Measure	Campus	Estimated utility savings range	Projected operational/CIP budget savings	Projected budget	Projected incentives
HVAC Upgrades: ▪ Chilled water/Hot water loop extension ▪ Air handler upgrades ▪ Air handler zone upgrades ▪ Controls upgrades ▪ Unitary equipment upgrades ▪ Hot water systems upgrades	LAC/PCC	$ 140,000 - 170,000	TBD	$ 6.0 -$ 6.6 million	$ 30,000 †
Pool upgrades	LAC	$ 12,000 - $ 15,000	TBD	$ 75,000 – $ 85,000	$ 4,000
Lighting upgrades ▪ Interior lighting ▪ Exterior and high-bay lighting ▪ Lighting controls	LAC/PCC	$ 40,000 - $ 48,000	TBD	$ 420,000 - $ 450,000	$ 13,000
Water conservation measures	LAC/PCC	$ 8,000 - $ 10,000	TBD	$ 120,000 - $ 150,000	$ 10,000
Photovoltaic system addition	PCC	$ 20,000 - $ 22,000	TBD	$ 1.2 - $ 1.3 million	$ 293,000
TOTAL		$ 220,000 - $ 265,000		$ 7.8 - $ 8.6 million	$ 350,000

† Incentive amount does not include retiring air-cooled condensers and chillers – this may have been covered in the Phase I Central Plant project.

8 NEXT STEPS

8.1 Proposed Phasing of the Work

Siemens proposes phasing the work as follows:



As shown above, the next step following the review of this PEA is for the college to authorize Siemens to move forward to the Detailed Design phase by signing a Letter of Intent. A sample Letter of Intent is provided in Appendix-C.

8.2 Projected Schedule

A projected schedule for the above phases is as follows:

▪ LOI Signature: Jan 2008	
▪ Detailed Design: Apr 2008	
▪ Phase 2A Contract Execution: May 2008	
▪ Phase 2A Construction: June 2008	Phase 2B 100% Design: July 2008
▪ Phase 2A Construction Completion: Sep 2008	Phase 2B Contract Execution: Aug 2008
▪ Phase 2A Commissioning: Oct 2008	Phase 2B DSA Approval: Feb 2009
▪	Phase 2B Construction: Mar 2009
▪	Phase 2B Construction Completion: Sep 2009

APPENDIX –A CHILLED WATER MASTER PLAN DOCUMENTS

APPENDIX –B SAMPLE LETTER OF INTENT