AE Senior Thesis Final Report

Energy Efficient Mechanical System Alternatives

Miller Children's Hospital Pediatric Inpatient Addition

Long Beach, CA

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Mechanical Option

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Miller Children's Hospital Pediatric Inpatient Addition

Long Beach, CA

Project Information

Building: 4-story addition includes 7 operating rooms, a new pediatric imaging center, 48 neonatal intensive care beds, and 24 general pediatric beds
Size: 127,129 sq. ft.
Cost: $151,000,000 (estimated)
Completion: Fall 2009
Delivery Method: Design-bid-build

Project Team

Architect: Taylor Architects
Interior Design: Taylor, Ford Design
Engineers:
MEP:JBA Consulting Engineers
Structural: Taylor & Gaines
Civil: Moffatt & Nichol
Contractor: Turner Construction

Mechanical System

- 7 AHUs located in roof mechanical penthouse plus 1 existing AHU serve separate levels
- Each space served with reheat coil
- Steam and chilled water supplied from central plant located on site
- HEPA filters used for operating rooms
- VFDs reduce energy consumption

Architectural Design

- Creates a "Safe Haven" for patients
- "Castle" architectural theme appeals to children
- Utilizes a green roof system
- Exterior features include metallic panels, metal cladding on columns, and stucco

Electrical System

- 4000A switchboard serves 480Y/277V, 3-phase, 4-wire system
- Emergency system comprised of (2) 750kW diesel generators
- Operating rooms require special light fixtures for maximum light output
- Color-Kinetic lighting uses primary colors for a welcoming feeling experience for children

Structural System

- Curtain wall system with steel supporting upper levels
- Steel frame construction utilizes proprietary system called SidePlate
- 3 ft deep mat foundation supports columns
- Cast-in-place concrete foundation retaining walls

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1.0 Acknowledgements

To those who generously gave their time to help obtain information and resources for this report, a special thanks to:

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Also, a special thanks to my parents for all their support over the years

2.0 Executive Summary

The purpose of this report is to explore redesign options for the Miller Children's Hospital Pediatric Inpatient Addition, located in Long Beach, CA. The facility has been estimated to have high energy consumption and operation costs due to its function as a hospital facility in a warm climate. The two redesign options explored in this report are combined heat and power and photovoltaic electricity production. The main goals of the redesign are to reduce energy consumption, decrease operation costs, and cut back on emissions while exercising good design practices.

The proposed combined heat and power system proposed uses a 1,075 kW reciprocating engine generator to produce electricity for the building. The engine will operate along the building demand curve and recover exhaust heat that will be used for hot water reheat coils and domestic water throughout the building. The initial cost of the system is approximately $1,840,000 with an overall building operation savings of approximately $320,000 per year. The payback period for the proposed system is less than 6 years. An acoustics analysis was also done to measure the noise levels caused by the engine of various spaces in the Miller Children's Hospital, the Pediatric Inpatient Addition, and outdoors. All noise levels fall within the recommended limits due to the layout of the new cogeneration plant spaces.

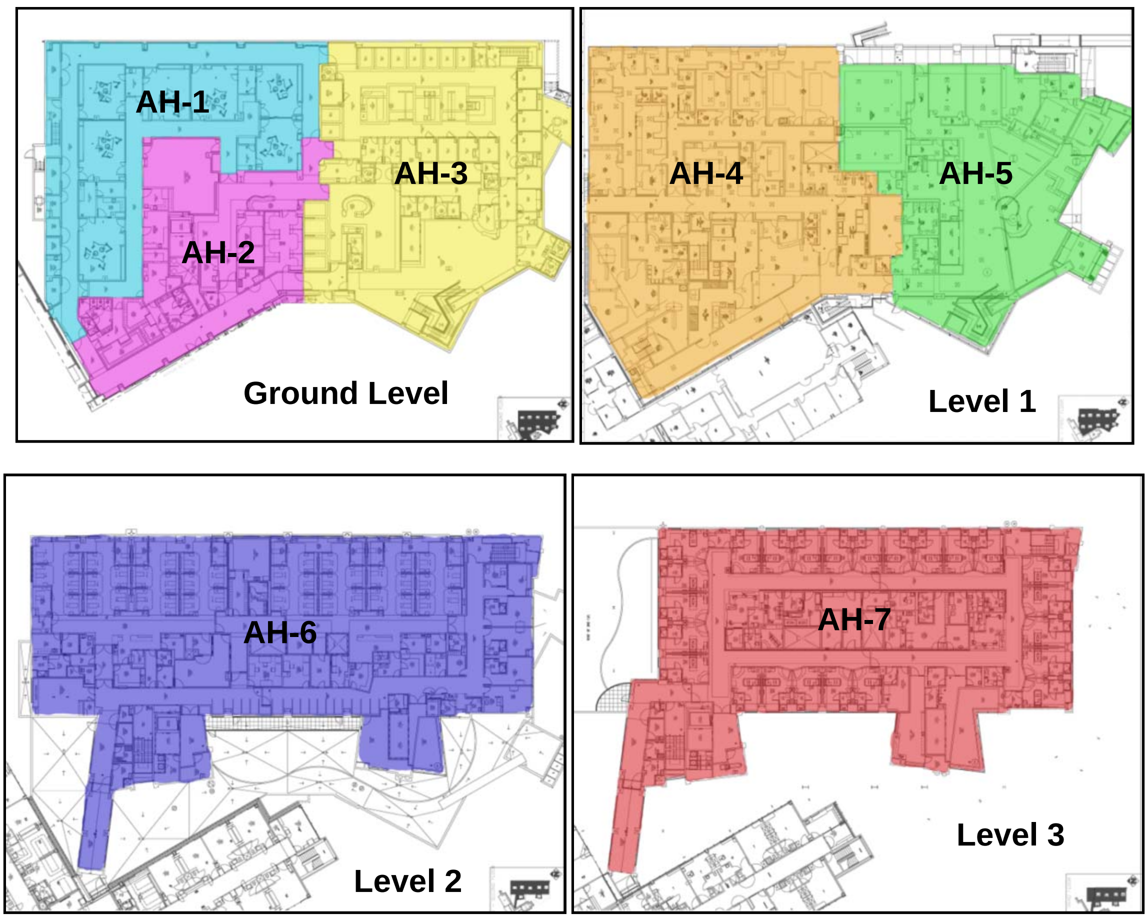
Finally, two photovoltaic panel arrays totaling 900 panels were installed on the roof of the Miller Children's Hospital and the Pediatric Inpatient Addition generating 245,631 kWh of electricity and a maximum power output of 140 kW AC. The initial cost of the system is estimated to be $1,482,250. The incentives package, including performance based incentives and state and federal tax breaks, totals $1,192,200. This reduces the initial cost of the photovoltaic system down to $290,000. With an annual electric savings of approximately $46,000 per year, the proposed system will have a payback period of just over 6 years.

3.0 Building Overview

The Pediatric Inpatient Addition to Miller Children's Hospital is a 4-story, 127,000 sq. ft. facility. Operating rooms are located on the ground floor, which is actually below grade. The first floor consists of the main lobby with gift shop and sanctuary, conference and office spaces, and physicians' rooms. The second floor houses the neonatal intensive care unit. Finally, the patient rooms are located on the third floor with mechanical penthouse on the roof above.

The building utilizes a constant air volume with reheat system. Seven AHUs located on the roof of the tower supply air to the 4 levels of the building through two centrally-located mechanical shafts. Figure 3-1 below shows the areas for each AHU.

Figure 3-1: AHU Areas



The central plant for the Pediatric Inpatient Addition is located on the site but was part of a separate drawing package. The central plant houses the chillers, cooling towers, and pumps as well as other electrical equipment. Two 500-ton centrifugal water chillers supply chilled water to the AHUs and fan coil units for the building. Two induced-draft cooling towers, located on the roof of the central plant, cool condenser water from 95˚F to 85˚F. Hot water is supplied to the reheat coils throughout the building with two, 2,000 MBh gas-fired boilers housed in the rooftop mechanical room of the tower.

4.0 Existing Mechanical Equipment Summary

As stated earlier, the mechanical equipment for the Pediatric Inpatient Addition is primarily located in two areas: the central plant and the tower roof. The central plant houses the chillers, cooling towers, and chilled water pumps. The air handling units, boilers, and hot water pumps are located on the tower roof. This section summarizes the major equipment that comprises the mechanical system for the building.

4.1 Chilled Water System

The chilled water system for the Pediatric Inpatient Addition is located in the central plant. Two centrifugal water cooled chillers supply chilled water to the rooftop AHUs as well as various fan coil units located throughout the building. The chiller data can be found in Table 4-1 below. The induced draft cooling towers are located on the roof of the central plant and are fitted with variable frequency drives. The cooling tower data can also be found on the following page in Table 4-2. See the HVAC Schematic Diagrams section and Appendix to view the chilled water and condenser water flow diagrams.

Table 4-1: Chiller Data

Centrifugal Water Cooled Chiller												
Quantity	Nominal Size (tons)	Evaporator				Condenser			Full Load Capacity (kW/ton)	NPLV (kW/ton)	Refrigerant Type	VFD
		GPM	EWT	LWT	Max ΔP (ft)	GPM	EWT	Max ΔP (ft)				
2	500	1000	56	44	12	1500	85	16	0.566	0.501	HFC-134A	Yes

Table 4-2: Cooling Tower Data

Induced Draft Cooling Tower								
Quantity	GPM	EWT ˚F	LWT ˚F	EAT ˚F WB	Fan Motor			
					HP	Volts	Phase	VFD
2	1500	95	85	78	25	460	3	Yes

4.2 Hot Water System

The hot water system for the Pediatric Inpatient Addition is located in the mechanical room on the tower roof. Two copper finned tube gas-fired hot water boilers supply hot water to 145 reheat coils located throughout the building. The boilers also supply hot water to the heating coil for AH-3. Boiler data can be found in Table 4-3 below. See the HVAC Schematic Diagrams in Appendix A to view the hot water flow diagram.

Table 4-3: Hot Water Boiler Data

Copper Finned Tube Hot Water Boiler			
Quantity	Input (MBH)	Heat Output (MBH)	Thermal Efficiency
2	2000	1740	0.87

4.3 Air Handling Units

As previously stated, the air handling units for the Pediatric Inpatient Addition are located on the roof of the tower and serve the four levels of the building. The units supply a constant air volume with zone reheat to maintain pressure differences between spaces. AH-3 supplies 100% OA and the others supply mixed air. Data for each of the 7 AHUs can be found in Tables 4-4 through 4-6 on the following page. Fan data for the supply and return fans is located in Table 4-4, cooling coil data is located in Table 4-5, and heating coil data is located in Table 4-6. Note that only one air handling unit has a heating coil: AH-3.

Table 4-4: AHU Fan Data

Air Handling Unit Fans										
AHU	Supply Fan				Return/Exhaust Fan				Min OA CFM	Volts/ Phase
	CFM	Total Static Pressure (in. WC)	Fan RPM	Motor HP	CFM	Total Static Pressure (in. WC)	Fan RPM	Motor HP		
1	20,000	6.0	1476	40	19,000	1.5	829	10	6,000	460/3
2	7,000	5.0	1852	10	6,000	1.5	1238	5	1,500	460/3
3	15,000	5.0	1258	25	-	-	-	-	15,000	460/3
4	20,000	5.0	1397	30	16,000	1.5	756	7.5	5,000	460/3
5	18,000	5.0	1340	25	16,700	1.5	965	10	4,000	460/3
6	20,000	5.0	1397	30	17,000	1.5	773	10	6,000	460/3
7	18,000	5.0	1340	25	15,000	1.5	900	10	5,000	460/3

Table 4-5: AHU Cooling Coil Data

Air Handling Unit Cooling Coil										
AHU	Air Side					Water Side				Face Velocity (fpm)
	Entering Temp. (˚F)		Leaving Temp. (˚F)		Max. ΔP (in. WC)	GPM	Entering Temp. (˚F)	Leaving Temp. (˚F)	Max. ΔP (ft. WC)	
	D.B.	W.B.	D.B.	W.B.						
1	79.5	65.5	52.4	52.1	1.0	121.6	45	58	10	430
2	81.4	66.3	52.8	52.5	1.0	44.4	45	58	10	453
3	90	71	53.6	53.4	1.0	130	45	58	10	437
4	78.8	64.8	52.3	52.1	1.0	114.5	45	58	10	424
5	78.3	64.7	52.4	52.2	1.0	101.5	45	58	10	443
6	79.5	65.5	52.5	52.3	1.0	120.4	45	58	10	424
7	79.1	65.1	52.5	52.2	1.0	105	45	58	10	443

Table 4-6: AHU Heating Coil Data

Air Handling Unit Heating Coil								
AHU	Air Side			Water Side				Face Velocity (fpm)
	Entering Temp. D.B. (˚F)	Leaving Temp. D.B. (˚F)	Max. ΔP (in. WC)	GPM	Entering Temp. (˚F)	Leaving Temp. (˚F)	Max. ΔP (ft. WC)	
3	38	83.5	0.3	61.4	180	156	5	436

4.4 Water Pumps

Water pumps for the chilled water loop and condenser water loop are located in the pump room in the central plant for the Pediatric Inpatient Addition. The condenser water loop has two centrifugal pumps, with one as a standby. The chilled water loop uses two primary pumps and two secondary pumps, with one secondary as a standby. The hot water loop has two primary and two secondary pumps as well. All ten centrifugal pumps are suction frame mounted. The water pump data for these pumps is listed below in Table 4-7.

Table 4-7: Water Pump Data

Centrifugal Water Pump								
Pump	Quantity	GPM	Total Head (ft.)	Motor				VFD
				HP	Volts/ Phase	RPM	Min. Efficiency	
Condenser Water	2	1500	60	40	460/3	1750	0.8	No
Primary Chilled Water	2	1000	50	20	460/3	1750	0.81	Yes
Secondary Chilled Water	2	750	70	20	460/3	1750	0.78	Yes
Primary Hot Water	2	90	20	1	460/3	1750	0.67	No
Secondary Hot Water	2	240	60	7	460/3	1750	0.76	Yes

5.0 Existing Electrical System Summary

The electrical system for the Pediatric Inpatient Addition is served through the central plant located on-site. The central plant houses the main distribution panel, motor control center, switchgear, transformers, and emergency generators. Electricity is supplied by Southern California Edison electric utility company through a pad-mounted transformer at 480Y/277V 3-phase, 4-wire secondary and is backed up by two 750 kW emergency generators. The Pediatric Inpatient Addition is tied into the existing Miller Children's Hospital through a 10,000 kVA transformer, although serves no power to the Miller Children's Hospital. The hospital is considered a non-conforming building by California code. Even though the Pediatric Inpatient Addition was designed with enough capacity to theoretically serve the entire hospital in addition to itself, California code does not allow a non-conforming building to be served by a conforming building. Therefore, the 10,000 kVA transformer is essentially a redundant transformer and was installed for owner preference only. This electrical system single line diagram for the Pediatric Inpatient Addition can be seen in Figure B-1 of Appendix B.

6.0 Annual Energy Consumption

The annual energy consumption for the Pediatric Inpatient Addition was calculated using *BCHP Screening Tool*. *BCHP Screening Tool* is a program created by the Department of Energy specifically for CHP analysis and can calculate the energy loads on the building as well as annual energy consumption, much like Trane's *Trace 700*, which was used in previous technical reports. An energy analysis was not performed by the engineer on the project. The reason for this is because the energy consumption of the building was not the primary element driving the design. The importance of patient health and safety exceeds the need to reduce energy consumption. The building was designed in accordance with OSHPD standards, which exempt medical facilities from meeting many energy consumption requirements. The annual electric energy consumption for the Pediatric Inpatient Addition is approximately 5,915,000 kWh, and the gas consumption is 38,000 therms. The percent breakdown can be seen in Figure 6-1 below.

Figure 6-1: Annual Energy Consumption

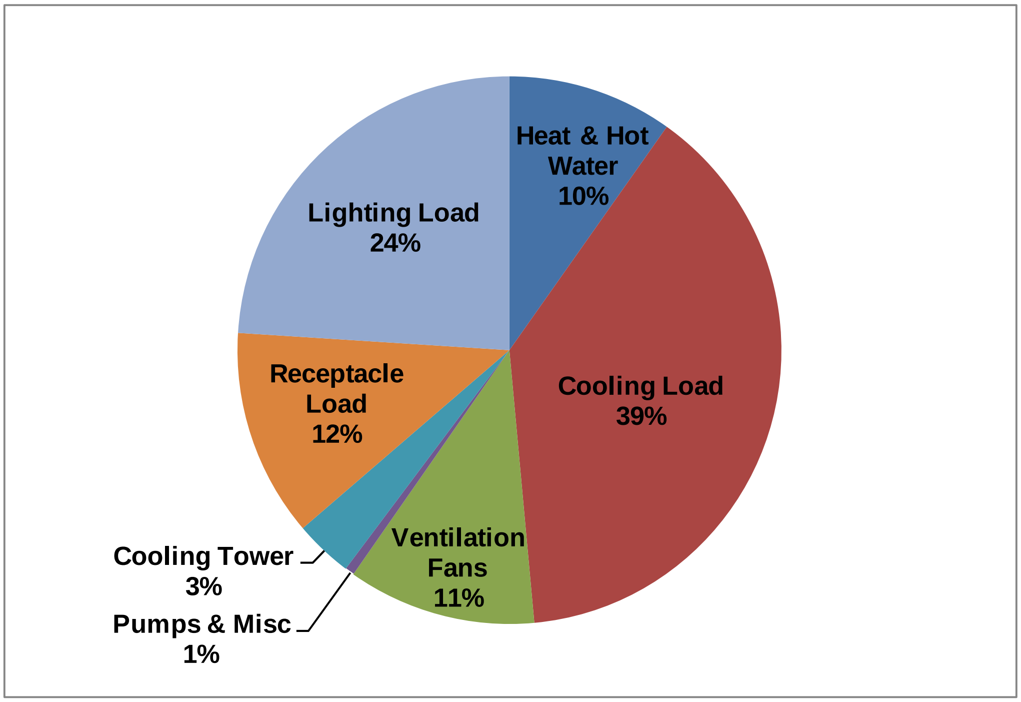


Figure 6-1 shows the percent breakdown of the annual total energy consumption for the Pediatric Inpatient Addition. The mechanical systems comprise 64% of the entire building energy consumption.

7.0 Design Goals

The Pediatric Inpatient Addition's mechanical systems were designed with great care toward patient health and safety. As this is the number one priority in hospital and medical facility design, they often consume a large amount of energy to operate. Often times, many energy saving techniques are abandoned because achieving both occupant safety requirements and also reduced energy requirements causes the initial cost to rise significantly. Although the system was designed very well in terms of initial cost, maintainability, and space requirements, operational costs for the Pediatric Inpatient Addition are quite high, primarily due to the constant volume air system designed to maintain proper pressure differences between sensitive spaces. Some of the energy requirements set forth by ASHRAE Standard 90.1 were not met for this very reason. The three main design goals of the mechanical redesign for this report will be to reduce energy consumption, reduce operation costs, and cut back on emissions.

8.0 Mechanical Depth – Combined Heat and Power

Combined Heat and Power (CHP), also known as Cogeneration, is the sequential production of power and useful thermal energy from a single energy source. CHP facilities generate electricity and steam on-site and recover heat that would normally be wasted by the electric utility provider. CHP also offers dramatic advantages in efficiency and much lower air pollution. Typically hospital facilities, such as the Miller Children's Hospital Pediatric Inpatient Addition, are good candidates for CHP technologies as they have relatively constant load profiles and large electric consumption which makes them better fit for on-site electricity generation and recovering heat for reheat coils and domestic hot water for the facility. For the mechanical depth of this report, Combined Heat and Power technologies will be researched for use in the Pediatric Inpatient Addition, and a determination will be reached as to the feasibility of CHP for this particular application.

8.1 CHP Screening

The purpose of CHP screening is to determine if site conditions indicate that further study of CHP is warranted, and it is really the starting point in the exploration of CHP feasibility. The screening is based on general site information and some assumptions that will impact the decisions about implementing CHP technology. This screening essentially looks at the general factors affecting CHP including spark spread, energy costs, energy consumption, and economics.

The spark spread is used to determine the feasibility of CHP for different applications and is the difference between electricity of fuel (gas) rates in \$/MMBtu. The higher spark spread favors CHP. The following table (Table 8-1) lists the current energy rates and estimated energy consumption for the Pediatric Inpatient Addition.

Table 8-1: Energy Cost and Consumption

	Energy Costs	Energy Consumption
Electricity	\$0.187/kWh	5,915 MWh
Natural Gas	\$8.01/MMBtu	3,811 MMBtu

Table 8-1 lists the cost and estimated consumption for the Pediatric Inpatient Addition and is used to determine the spark spread for screening. Note: The cost of electricity includes electric demand charges and electric usage for on-peak, mid-peak, and off-peak hours. See utility rate schedules and annual operational cost in Appendix D for more information.

The spark spread calculation for the Pediatric Inpatient Addition is as follows:

Natural Gas: \$8.01/MMBtu

Electricity: (\$0.187/kWh)*(1 kWh) / (0.003413 MMBtu) = \$54.79/MMBtu

Spark Spread = \$54.79/MMBtu - \$8.01/MMBtu = \$46.78/MMBtu

Table 8-2: General Factors Affecting CHP

Factors Favoring CHP Feasibility:	Spark Spread \$/MMBtu > 12	Elec. Cost \$/kWh	NG Cost \$/MMBtu	Elect. Load Avg/peak	Thermal Load Avg/peak
	> 12	> 0.05	< 4.00	> 0.7	> 0.7
Value for Site:	46.78	0.187	8.01	0.74	0.25

Table 8-2 shows the general factors that affect CHP as part of the screening process. The cost of natural gas and thermal load are higher than ideal but the large spark spread warrants further analysis of CHP for the Pediatric Inpatient Addition. The factors were taken from Department of Energy's Federal Energy Management Program.

The CHP screening analysis favors CHP in the majority of factors, especially the spark spread. This is because Long Beach Gas and Oil Department offers a lower natural gas rate for electric generation. See Appendix D for natural gas and electric rates. A further analysis can now be done with the detailed energy analysis.

8.2 Detailed Energy Analysis

The next step in the CHP design is to do a comprehensive energy analysis to determine daily electricity peak loads for different days of the year, overall monthly peak loads, yearly electric consumption, and yearly fuel consumption. Comparing the CHP values to the base case (without CHP) will make it easier to determine if CHP can be implemented into this particular facility. For this analysis, a program called *BCHP Screening Tool* was used. *BCHP Screening Tool* is a program created by the Department of Energy specifically for CHP analysis. Building energy loads and equipment, weather data and other parameters, are inputted into the program and then it calculates the data for both CHP and the base case scenarios. This data can be used to size equipment, determine equipment operation parameters, yearly energy costs, etc.

From CHP analysis, the estimation of the peak electric load, occurring on September 6 at 5:00 pm, is 900 kW. With a 15% over-sizing, the design generator size will be 1,035 kW. Also the load profiles for four typical days of the year (one in each season) were generated to see the percent difference between the peak and the lowest demand. These can be seen in Appendix C of this report. Because the Pediatric Inpatient Addition is located in Long Beach, CA, the hot water load (for both reheat coils and domestic hot water) is relatively small compared to the cooling load. Therefore, a steam turbine is not recommended because of the relatively high heat value and fuel consumption. A reciprocating engine is better suited for this application because of its low operating rpm, fuel consumption, and cost.

The daily demand curves for the Pediatric Inpatient Addition are not as drastic as, say an office building, where the loads can drop to 10% of the peak load during night times. This allows for several options for operating conditions the generator. Using BCHP Screening Tool, these options were analyzed to determine the optimal operation condition for the generator. The first scenario analyzed was a base-load electricity generation on-site of around 400-500 kW. The peak loads would then be purchased from Southern California Edison as usual. Even with the base-load, the generator still produced enough hot water to run the building. However, this scenario still purchased too much electricity from the utility, especially during peak hours and was not cost-effective. The second scenario was to run the generator at full output (around 1 MW), fulfill the building's heating loads, and purchase no electricity from the utility. Unfortunately, this scenario produced too much waste heat and consumed too much natural gas fuel to be cost-effective as well.

The operation of the generator that produces the most annual savings is to size the generator for the peak load, and run it along the demand curve, revving it down during off-peak hours and operating at near full-output for peak hours of the day. This allows for very little electricity purchased from the utility, lower fuel consumption, and fulfilling heating loads for the building. This scenario produces the best conditions for CHP for the Pediatric Inpatient Addition and a cost-analysis can now be performed to determine yearly energy savings and payback period for the system.

8.3 CHP Operation Costs

The next step in the CHP design is to determine yearly building operation costs for the base case and CHP case for the Pediatric Inpatient Addition. For this, the energy rates used for the spark gap will be used in conjunction with the *BCHP Screening Tool* output to determine operation costs for the facility. The annual operation cost breakdown for the Pediatric Inpatient Addition can be seen in Appendix D. The overall cost of operation is as follows:

Base Case Estimate = $1,135,078/year

CHP Estimate = $726,721/year

Savings = **$408,357/year**

The annual operation and maintenance costs of the generation equipment are calculated as:

($0.0110/kWh)*(5,914,738 kWh/year) = $65,062/year

Total Savings = $408,357 - $65,062 = **$343,295/year**

8.4 Equipment Selection

The generator selected is a *Caterpillar* reciprocating engine generator Model # G3606 T 130 LE with a maximum electric capacity of 1,075 kW. The performance data is listed below in Table 8-3.

Table 8-3: *Caterpillar* Engine Specifications

***Caterpillar* Engine**				
Model No. G3606 T 130 LE				
Electric Capacity	1,075 kW			
Fuel Rate	10.64 MMBtu/h (HHV)			
Heat Recovery	2.03 MMBtu/h			
% Efficiency	**Electrical**	**Thermal**	**Overall**	
	34.47%	19.03%	53.50%	
Emission Rates	**CO2**	**CO**	**Nox**	**Sox**
(lb/MMBtu)	110	0.082	0.179	0.0034

Table 8-3 lists the specifications for the G3606 reciprocating engine chosen for the CHP analysis. The values listed are at 100% load and speed and may vary under different operating conditions.

The heat recovery method will be two-fold, the heat obtained from the exhaust and the water jacket. This recovered heat will fulfill all the building's hot water loads for reheat coils and domestic hot water.

Table 8-4: Heat Recovery Data

Heat Recovery Heat Exchanger Operation			
	Jacket (MBtuh)	**Exhaust (MBtu/h)**	**Total (MBtuh)**
Annual Operating Hours	8,760	8,760	8,760
Minimum Heat Recovery	0.54	0.45	0.98
Maximum Heat Recovery	0.84	0.92	1.77
Mean (Average) Heat Recovery	0.71	0.71	1.42

Table 8-4 lists the heat recovery values obtained by the jacket and exhaust from the generator. The amount of heat obtained fulfills all the heating loads for the building, essentially negating the need for a boiler.

The annual energy use of the system is outlined on the following page in Figure 8-1, which shows the equipment, annual operating hours, energy inputs, and energy usage for the building.

Figure 8-1: CHP System Schematic

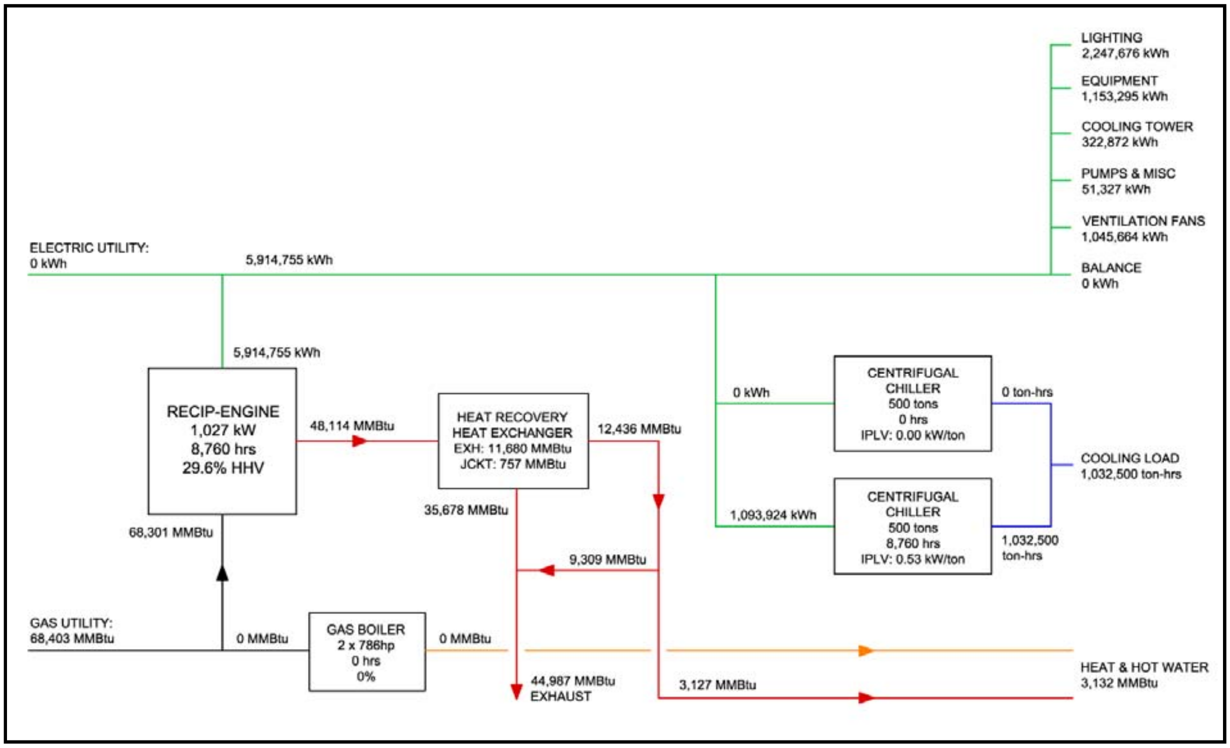


Figure 8-1 shows the schematic design for the CHP system for the Pediatric Inpatient Addition. The generator operates constantly producing 5,914,755 kWh of electricity with a total heat recovery of 12,436 MMBtu. These values are for a typical year and do not include times when the generator is off-line for maintenance or repairs.

8.5 Central Plant Redesign

The existing central plant for the Pediatric Inpatient Addition houses the chillers, cooling towers, circulation pumps, emergency generators, transformers, and other electrical equipment. The total square footage is 4,700 sq. ft (excluding roof area for the cooling towers). The proposed redesign of the central plant is to expand onto unused property area and include space for the generator and heat recovery equipment. The electrical transformer yard and the emergency generator room are relocated and a new generator room has been added. The chiller room, pump room, and switchgear will remain in their same original locations. The total square footage of the new cogen plant is 5,880 sq. ft. (excluding roof area for the cooling towers) for an additional floor area of 1,180 sq. ft. The central plant redesign can be seen in Figures 8-2 and 8-3 on the following page.

Figure 8-2: Existing Central Plant

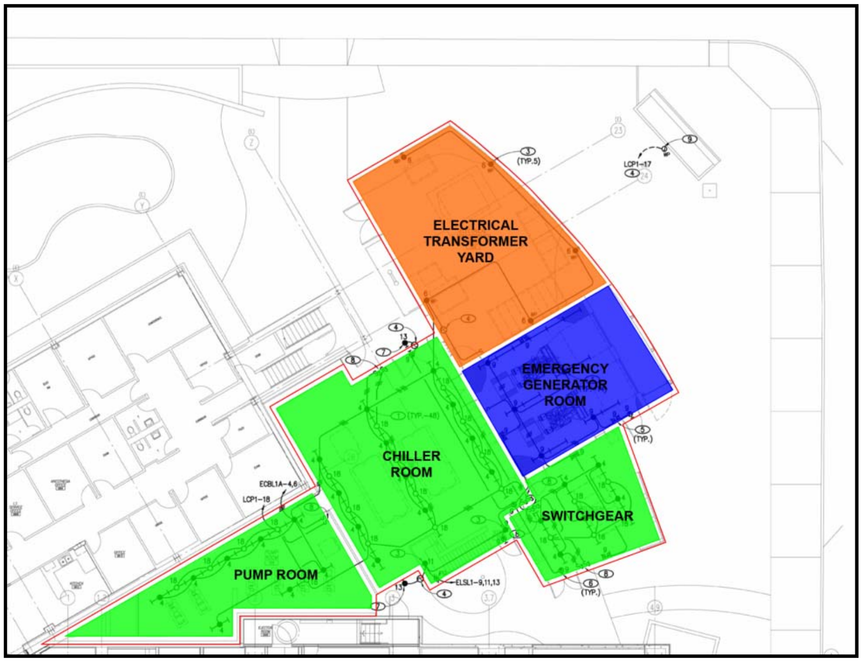


Figure 8-2 shows the existing central plant for the Pediatric Inpatient Addition. The central plant has a total floor area of 4,700 sq. ft.

Figure 8-3: Proposed Cogen Central Plant Redesign

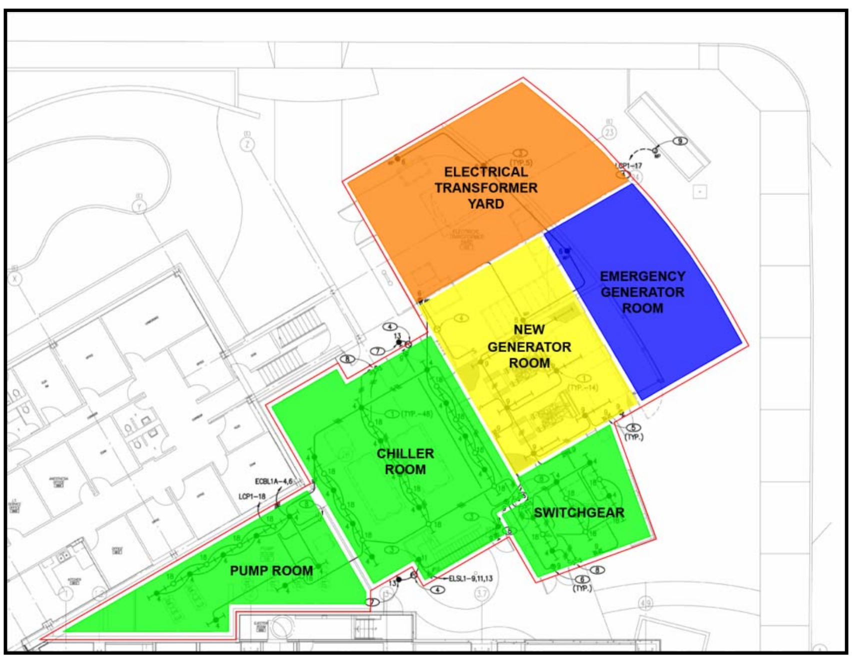


Figure 8-3 shows the proposed cogen central plant for the Pediatric Inpatient Addition. The cogen plant has a total floor area of 5,880 sq. ft.

8.6 Electrical System Integration

The generator for the CHP configuration will tie into the existing electrical system directly at the 10,000 kV transformer discussed previously in section 5.0. This can be seen in Figure B-1 of Appendix B. As this transformer is not used, the location is ideal to supply electricity to the system. The key switch (see Figure B-2) allows for two breakers to be open at once, allowing the building owner to manually switch from on-site power to utility power. This will occur when the generator is not operating for regular maintenance or repair purposes. Other changes to the system include moving the fire pump from the utility side to the generator side of the electrical system. With this, the fire pump can be run from generated power or utility power, with back-up generation for both scenarios. In addition, the two 750 kW emergency generators, by code, are not required with the cogen scenario because the on-site generator is the main power source with the utility as a back-up. Even with the cost savings of omitting the emergency generators from the design, however, this is not recommended. Therefore, the emergency generators were left in as a precautionary measure in the event that the generator would fail and also the utility power supply would fail.

8.7 Overall CHP Cost Breakdown

The ultimate goal of the CHP analysis is to reduce building operational costs enough to offset the increased initial cost of the added mechanical and electrical equipment in a short amount of time. The payback period for a system such as this should be approximately 5 years or less. Table 8-5 on the following page is a cost breakdown of the CHP system.

Table 8-5: CHP Costs

Cogen Equipment		
Nominal Capacity = 1,075 kW		
Item	**Equipment Costs per kW**	**Total $**
Generator Set Package	$281	$302,075
Heat Recovery	$87	$93,525
Interconnect/Electrical	$38	$40,850
Labor/Materials	$364	$391,300
CM and Engineering Fees	$224	$240,800
	SubTotal =	$1,068,550
Central Plant Expansion		
Area = 1,180 sf		
Item	**Cost per sq. ft.**	**Total $**
Substructure	$84.32	$99,500
Shell	$136.44	$161,000
Interiors	$23.31	$27,500
Services	$86.44	$102,000
Contractor Overhead/Profit	$82.63	$97,500
Architectural Fees	$28.81	$34,000
	SubTotal =	$521,500

Table 8-5 lists the initial costs for the cogen system equipment and central plant expansion. The equipment costs were taken from the *Catalogue of CHP Technologies*. The central plant expansion cost was determined using R.S. Means.

The total cost of the proposed cogen system is $1,590,050. The cogen equipment costs were obtained from the EPA Combined Heat and Power Partnership's *Catalogue of CHP Technologies*. The cost estimate figures table used can be found in Appendix D of this report. The central plant expansion costs were obtained by using R.S. Means *Cost Works*, which is an online form of the catalog. The square foot cost estimator was used and the cost breakdown of the items can also be found in Appendix D of this report. For general cost estimate purposes, the central plant building type was generalized as a factory, 1-story with concrete block and steel frame. With an annual operation savings of $343,295 (see section 8.3 of this report) the estimated payback period for the CHP system is less than 5 years.

8.8 Emission Totals

The use of CHP technology can significantly reduce emissions if implemented properly. Several factors affect this including engine or turbine type, percent load and speed, and fuel type. The emissions for both the on-site electric generator and the utility generator are listed below in Table 8-6.

Table 8-6: CHP Emissions

Pounds of Emissions per Year		
	On-Site Generation	Utility Generation
Nox	12,234	5,951
Sox	232	5,029
CO2	3,761	3,782

Table 8-6 shows the emissions for the proposed CHP system as well as the utility generated emissions in lbs per year. The proposed CHP design reduces emissions on both Sox and CO2 but is higher when it comes for the production of Nox. These values were obtained from the *BCHP Screening Tool* program output.

The CHP case actually produces more Nox than simply purchasing electricity from the utility. Two reasons for this exist. First, the operation sequence for the generator in the proposed cogen application is less efficient when it operates at part-load. This results in a greater emissions production per unit of energy generated than if it were operating at 100% output, although it consumed much less fuel. The utility electric generation, on the other hand, has much more control and can operate their generation equipment at nearly the highest efficiency, intern producing less emissions per unit of energy than the cogen system. The second reason is that the state of California has strict guidelines on emissions for utilities and therefore must use particulate filters and catalytic reductions to reduce emissions.

Caterpillar offers such catalytic reduction systems available for the G3600 series engines. The systems work by treating the exhaust gas after it leaves the engine with no impact on engine performance. They boast to reduce Nox emissions up to 90%. However, a typical catalytic reduction system uses a toxic reagent, such as ammonia, which reacts with the catalyst to reduce Nox. Some ammonia may be vented into the air during this process, and it must be stored on-site. This produces the potential risk of a spill. In addition these systems are quite expensive and significantly drive up the cost of the initial cogen system. The approximate price range for a catalytic reduction system is $175,000 to $250,000 with another $25,000 per year in operating costs, according to an article in the *Distributed Energy Journal for Onsite Power Solutions*. A catalytic reduction system may be too risky to install in a hospital facility such as the Pediatric Inpatient Addition.

8.9 Conclusions and Recommendations

The final results for the CHP analysis for the Pediatric Inpatient Addition are summarized below.

CHP Equipment Costs = $1,068,550

Central Plant Expansion = $521,500

Total proposed CHP System = $1,590,050

Annual Savings (less system maintenance costs) = $343,295

Payback Period: 4.6 years

At first glance, the combined heat and power system for the Pediatric Inpatient Addition appears to be an attractive solution to reducing energy consumption. However, obstacles exist that make the design process more difficult and increase the initial cost of the system, increasing the payback period. Adding a catalytic reduction system to the cogen equipment would add approximately $250,000 to the initial cost of the project. In addition, the $25,000/year maintenance cost would reduce the annual savings. The payback period would change from 4.6 years to 5.8 years. Add on the increased risk of toxic agents on-site and possibly venting into the air, and the proposed system has more drawbacks than what was initially thought.

While hospital facilities such as the Pediatric Inpatient Addition are good candidates for CHP technology, it is important to note that an efficient cogen system utilizes all the recovered heat produced by the generator for building use. The Pediatric Inpatient Addition, because of its warm climate location, unfortunately can only utilize about one quarter of the recovered heat. And the size of the electric demand (approximately 1 megawatt) on the building rules out the possibility of absorption cooling. Even with these few problem areas, CHP utilization can still save a great deal of money in the long run. The system can effectively reduce the annual utility costs by almost 30%, and it does consume less energy due to the recovered heat use elsewhere in the building. Based on this CHP feasibility study, the Pediatric Inpatient Addition should install the proposed cogen system.

9.0 Acoustics Breadth – Acoustical Effects of CHP

One of the problems with CHP is the increased noise of running the engine or turbine, and especially in replacement configurations where the building construction materials were not designed to properly control noise transmission through the walls, floor, etc. The acoustics breadth of this report will analyze the transmission loss through various walls and determine NC levels at particular points in the existing Miller Children's Hospital, the Pediatric Inpatient Addition, and the outside. *Trane Acoustics Program* was used to determine these values. This program aids designers in accurately modeling the sound reaching different points in the building. It analyzes noise from mechanical equipment, diffusers, duct breakout, etc. and then compiles the data into various reports including NC and RC graphs.

9.1 Acoustics Analysis

There are six total points of interest that will be studied for this analysis. The noise levels calculated for these points will determine if soundproofing will need to be added to the wall surfaces of the new generator room of the central plant. The points are as follows and are indicated in Figure 9-1 on the following page:

- **Point 1** – Noise level from the generator room through the chiller room, pump room and to an adjacent storage room in the Pediatric Inpatient Addition
- **Point 2** – Noise level from the generator room through the chiller room, pump room and into an adjacent office in the Miller Children's Hospital

- **Point 3** – Noise level from the generator room through the chiller room and into an exam room in the Miller Children's Hospital
- **Point 4** – Noise level from the generator room through the switchgear and to an outside location
- **Point 5** – Noise level from the generator room through the emergency generator room and to an outside location
- **Point 6** – Noise level from the generator room through the electrical transformer yard and to an outside location

Figure 9-1: Transmission Loss Calculation Points

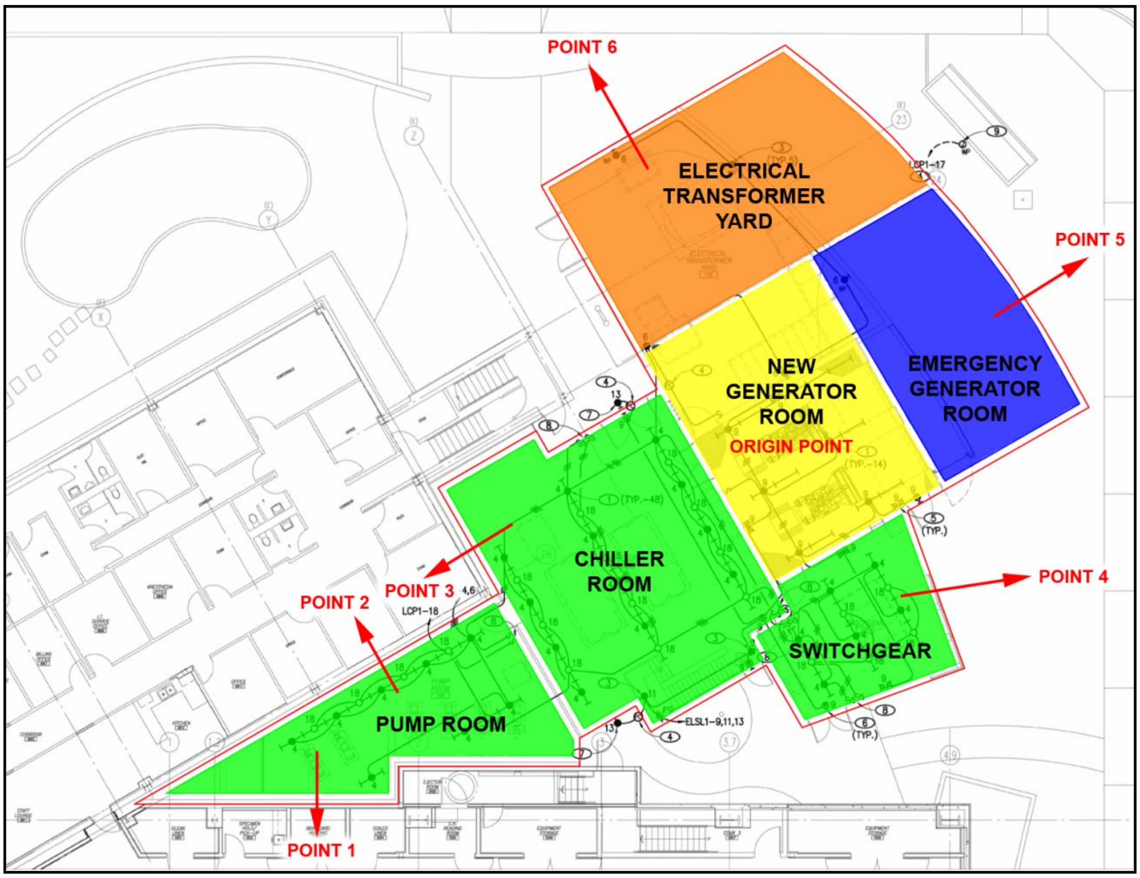


Figure 9-1 shows the points of interest for transmission loss calculations. All paths start from the new generator room and travel to each point. dB levels will then be determined for each space.

The noise levels for the various types of mechanical equipment in the central plant can be found in Table 9-1 on the following page. These are the values used to calculate the noise levels in each area. The noise levels for each point are listed in Table 9-2 below.

Table 9-1: Equipment Noise Levels

	Octave Band Data (dB)						
Equipment	**63 Hz**	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Reciprocating Engine	109	111	110	111	111	109	105
Centrifugal Chiller	74	77	74	74	75	75	74
Cooling Tower	108	108	105	102	99	96	92
Condenser Water Pump	96	97	99	99	102	99	95
Chilled Water Pump	93	94	96	96	99	96	92
Electric Transformer	89	91	86	86	80	75	70

Table 9-1 shows the equipment noise levels in dB for the calculation of transmission loss. The values were taken from the *Trane Acoustics Program* explained above and are general values for each type of equipment.

Table 9-2: Calculated Noise Levels

	Total dB Levels							NC Level	dB Rating
	63 Hz	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**		
Point 1	40	33	30	24	23	19	15	21	28
Point 2	39	32	28	23	21	16	12	19	26
Point 3	46	39	30	21	14	9	5	19	27
Point 4	22	16	21	15	10	5	5	< 15	17
Point 5	18	13	19	12	8	5	5	< 15	15
Point 6	54	53	46	44	36	29	22	39	45

Table 9-2 shows the final dB noise levels for each point due to the mechanical and electrical equipment located in the central plant. The levels are well within the acceptable level and no changes need to be made.

The construction materials used for the analysis were generalized using the *Trane Acoustics Program*. Typical wall construction for the central plant is 6” painted concrete block with or without resiliently mounted gypsum wall board depending on the particular application. For the detailed acoustics data for each of the six paths, see Figures F-1 through F-6 (each corresponding to their respective point) of Appendix F.

9.2 Conclusions and Recommendations

The Pediatric Inpatient Addition, Miller Children’s Hospital, and the central plant are essentially three separate buildings. This results in a high sound transmission loss through their adjacent walls due to the fact that it must travel through the exterior wall of the central plant and then through the exterior wall of the Miller Children’s Hospital or Pediatric Inpatient Addition to reach any space. Also, the location of the new generator room helps in that it is essentially surrounded by other rooms in the central plant. This helps to keep the generator noise from escaping the central plant by creating a spatial barrier. The wall of the new generator room that is exposed to the exterior electrical transformer yard (see Figure 9-1 above) yields the highest noise transmission and thus Point 6 has the highest NC level. This is also due in part to the presence of the utility provided electrical transformer that also adds to the noise level.

The following are the recommended NC levels for hospitals and clinics according to Architectural Acoustics: Principals and Design by Mehta, Johnson, Rocafort:

Private rooms and operating rooms: 25-35

Wards, corridors and public spaces: 30-40

The NC levels for the surrounding areas due to the mechanical and electrical equipment fall well within the acceptable levels and no soundproofing is necessary for the new generator room.

10.0 Electrical Breadth – Photovoltaic Panels

The Miller Children's Hospital Pediatric Inpatient Addition is located in Long Beach, CA, which receives very large amounts of daylight throughout the year. This makes it an ideal facility to incorporate the use of renewable energy through photovoltaic solar panels. In addition to its exceptional location, the state of California offers incentives for businesses who implement renewable energy sources into their buildings through the California Solar Initiative Program.

As part of the electrical breadth for this report, a cost-feasibility study will be performed as well as an explanation of integrating PV panels into the existing electrical system and sizing requirements.

10.1 PV System Sizing

The PV panels used for the analysis are *BP Solar* monocrystalline photovoltaic modules model BP 175B. With its high 14% nominal efficiency, the panels are particularly suited for applications that need a maximum energy generation from a limited array area. The panels can power DC loads or AC loads with an inverter. The first step in sizing the PV system is to calculate the amount of roof area that can be used for the panels.

Unfortunately, the roof of the Pediatric Inpatient Addition is where the rooftop air handling units are located. However, there is some upper and lower roof area that receives direct sunlight and will be able to house a portion of the system. In addition, the adjacent Miller Children's Hospital has a large amount of roof area and would be ideal to locate the system. The PV roof area is highlighted in Figure 10-1 below. A more clear satellite image of the area is located in Appendix G for reference.

Figure 10-1: Photovoltaic Solar Panel Coverage

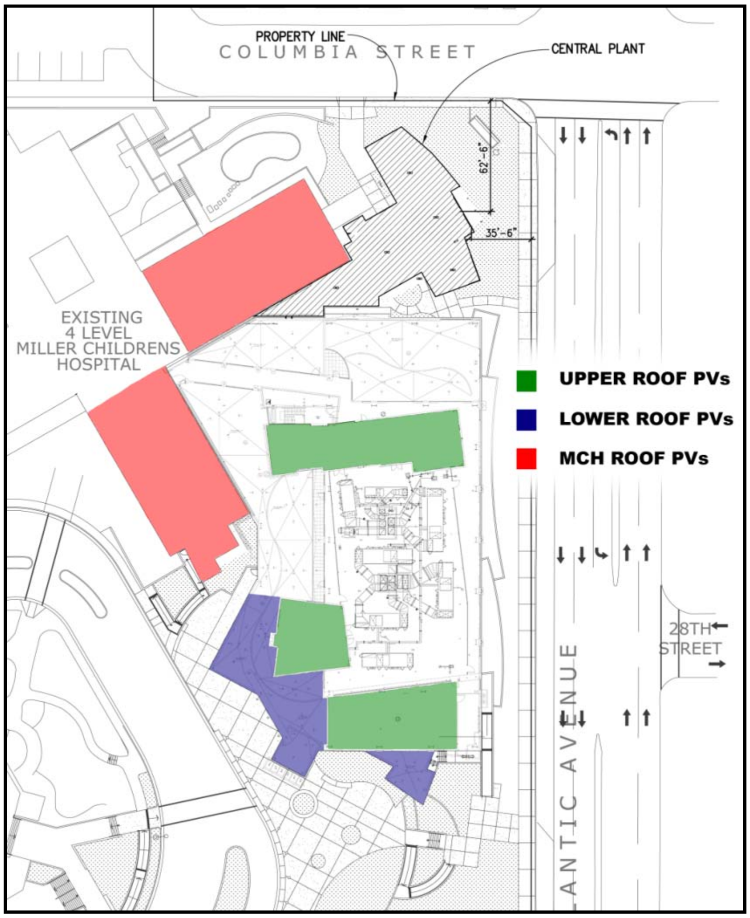


Figure 10-1 shows the roof area that will be used for the proposed PV system. Approximately 80% of the Pediatric Inpatient Addition and 60% of the Miller Children's Hospital roof area will be usable area due to other mechanical equipment, etc. located there.

The total roof area exposed to direct sunlight is:

Pediatric Inpatient Addition Upper Roof = 7,700 sf

Pediatric Inpatient Addition Lower Roof = 3,240 sf

Miller Children's Hospital Roof = 11,060 sf

Assuming a usable area of 80% for the Pediatric Inpatient Addition and 60% for the existing Miller Children's Hospital (the Miller Children's Hospital has more rooftop mechanical equipment), the usable PV area is:

Pediatric Inpatient Addition Upper Roof = 6,160 sf

Pediatric Inpatient Addition Lower Roof = 2,592 sf

Miller Children's Hospital Roof = 6,636 sf

Total Usable PV Area = 15,388 sf

Assuming 80% panel coverage of usable PV area (recommended by the manufacturer), the total panel coverage is:

Total Panel Coverage = (15,388 sf)*0.8 = 12,310 sf

With an individual panel area of 13.56 sf, the number of panels will be:

12,310 sf / (13.56 sf/panel) = 907 panels – Use 900 panels

Each panel has a nominal efficiency of 13.5% for a maximum possible power generation of 175 watts. The nominal PV array power is:

(900 panels)*(0.175 kW/panel) = 157.5 kW

RETScreen International software was used to determine the solar resource and system load, and to run a cost analysis for the Pediatric Inpatient Addition PV system. The software can be used to evaluate energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of energy efficient and renewable technologies including wind energy, small hydro, photovoltaics, combined heat and power, and various others.

The weather data for Long Beach was inputted into the program along with the PV panel data including nominal efficiency, temperature coefficients and inverter efficiency. The system characteristics can be seen in Figure 10-2 on the following page.

Figure 10-2: PV System Characteristics

RETScreen® Energy Model - Photovoltaic Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		Pediatric Inpatient Addition	See Online Manual
Project location		Long Beach, CA	
Nearest location for weather data	-	Long Beach, CA	Complete SR&SL sheet
Latitude of project location	°N	33.8	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.98	
Annual average temperature	°C	17.3	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	User-defined	
PV module manufacturer / model #		BP 175B	See Product Database
Nominal PV module efficiency	%	14.0%	4.0% to 15.0%
NOCT	°C	47	40 to 55
PV temperature coefficient	% / °C	0.50%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	157.50	
PV array area	m²	1,125.0	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	141.8	
Inverter capacity	kW (AC)	140.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	218.3	
Overall PV system efficiency	%	11.0%	
PV system capacity factor	%	17.8%	
Renewable energy collected	MWh	272.924	
Renewable energy delivered	MWh	245.631	
	kWh	245,631	
Excess RE available	MWh	0.000	
			Complete Cost Analysis sheet

Version 3.2 NRCan/CETC - Varennes

Figure 10-2 shows the system characteristics defined for the PV system for the Pediatric Inpatient Addition. The program then calculates the renewable energy delivered in kWh from the weather data and PV panel parameters.

10.2 Cost Estimate and Payback

The initial cost of the PV system for the Pediatric Inpatient Addition is calculated as:

Development and Engineering Fees: $70,000

PV Modules: ($1,050/panel)*(900 panels) = $945,000

Module Support Structure: ($10/sq. ft.)*(12,310 sq. ft.) = $123,100

Inverter: ($720/kW AC)*(140kW AC) = $100,800

System Installation: ($1,500/kWp)*(157.5kWp) = $236,000

The total initial cost of the proposed PV system is $1,482,250. With an electricity savings of approximately $46,000/year, the payback period for the system would be over 30 years. However, the state of California offers incentives for renewable energy generation. These incentives are outlined below:

California State Rebate (Performance Based Incentive): $478,980

Federal Investment (10%) Tax Credit: $197,582

State Solar Energy (7.5%) Tax Credit: $148,187

Federal Accelerated Depreciation (34% tax rate): $328,770

State Depreciation Savings (8% tax rate): $38,679

The total incentives package for the proposed PV system is $1,192,198. The payback period for the PV system is less than 7 years and the net system cost by year can be seen below in Table 10-1.

Table 10-1: Net PV System Cost by Year

Year	Total System Cost	SCE PBI Program	10% Federal Tax Credit	7.5% State Tax Credit	Federal Depreciation Savings	State Depreciation Savings	Estimated Energy Savings	Net System Cost
1	($1,482,250)	$478,980	$196,123	$147,092	$197,262	$7,736	$45,933	($409,124)
2					$52,603	$12,377	$45,478	($298,665)
3					$31,562	$7,426	$45,028	($214,649)
4					$18,937	$4,456	$44,582	($146,674)
5					$18,937	$4,456	$44,141	($79,140)
6					$9,469	$2,228	$43,704	($23,740)
7	Break even in 7 years						$43,271	$19,531
8							$42,843	$62,374
9							$42,419	$104,793
10							$41,999	$146,792

Table 10-1 shows the net cost for the proposed PV system on a yearly basis. The system will pay for itself entirely in 7 years. Net system costs after 7 years reflect earnings. The model assumes 1% module degradation and does not factor in the time value of money.

The federal accelerated depreciation and state depreciation savings occur over a 5-year period. Without the legal provision for solar equipment, the depreciation for such equipment would be taken over the standard 20-year period. The Modified Accelerated Cost Recovery System (MACRS) uses a 200% declining balance method with depreciation deductions for years 1 through 6 of 20%, 32%, 19.2%, 11.52%, 11.52%, and 5.76% respectively.

10.2 Electrical System Integration

The electrical system characteristics are outlined in Figure 10-2 above. The total inverter capacity required is 140kW AC. The PV array will be broken up into two separate components, one for each Pediatric Inpatient Addition roof area segments and one for the Miller Children's Hospital roof area segment, and each with its own inverter. The inverters chosen for this system are *Solectria* PVI Gridtie Inverters and can be found in a number of different sizes. These inverters take DC current from the PV array and convert it into 480V AC current to be fed into the building's main distribution panel. The power generated will then be used for the building loads, or if need be, fed back into the utility grid. Figure 10-3 outlines this process.

Figure 10-3: Commercial PV Inverter Diagram

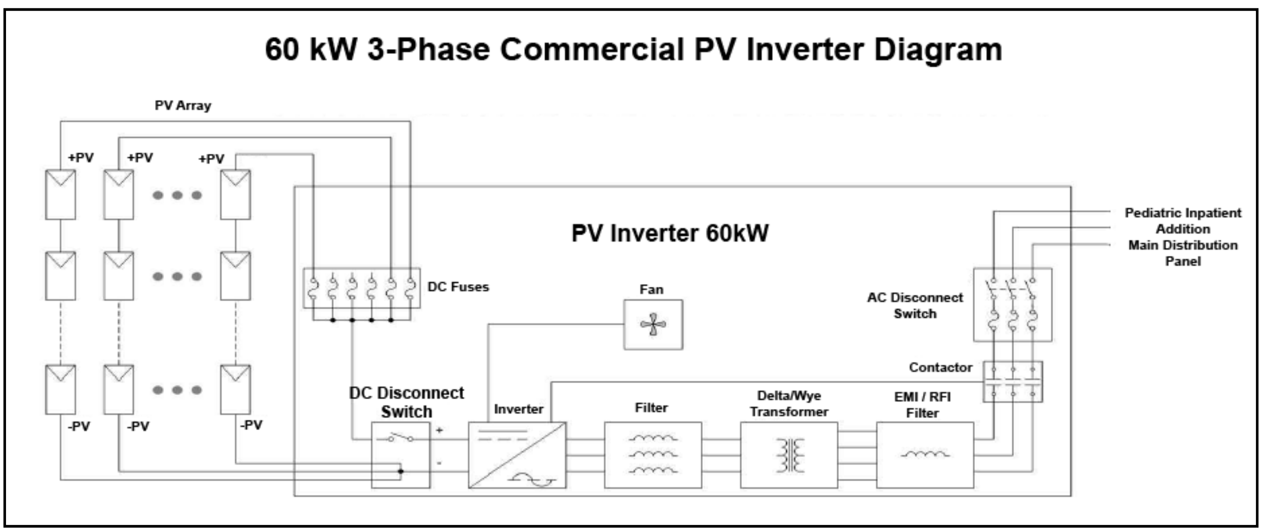


Figure 10-3 shows the components of the PV Inverter. The PV current is converted from DC to AC to be fed through the building's main distribution panel to the building loads or the utility grid.

Two *Solectria* PVI Gridtie Inverters will be used for the proposed PV system. One will be a 60 kW inverter serving the Miller Children's Hospital roof PV array, and the other will be an 82 kW inverter serving the Pediatric Inpatient Addition upper and lower roof PV arrays. The main distribution panel for the Pediatric Inpatient Addition will tie the PV arrays into the building and utility electrical grids. See Figure B-3 of Appendix B for the new electrical system single line diagram. The two PV arrays will be connected through a spare breaker on the main distribution panel (#4 in Figure B-3). The new breaker size is calculated as:

Total PV array inverter power (watts): 60,000W + 82,000W = 142,000 W

Total PV array inverter power (volt-amps) (142,000W)/(0.98 PF) = 144,898 VA

Total PV array amperage: (144,898VA)/(480V*1.73) = 174.5 A

Breaker size: 200A

The two separate PV inverters will be connected through a new PV panel board located in the Main Normal Power Electrical Room on the first level of the Pediatric Inpatient Addition. The feeder and conduit size from this panel board is calculated using NEC 2005 Table 310-16 and Table 250-122. For a 200 A distribution feeder, the feeder size will be (4) #3/0 and (1) #6 ground through 2" conduit. Conductor temperature rating will be 75°C copper. The distance from the new PV panel board to the main distribution panel is 240 ft. The voltage drop is calculated as:

% V-Drop = (200A)*(240ft)*(2 runs)*0.045*1.73*(100%) / [(480V)*1000]

% V-Drop = 1.56%

Since the voltage drop for the feeder is less than 2%, the feeder size configuration listed above will be adequate.

10.3 Conclusions and Recommendations

The proposed PV system for the Pediatric Inpatient Addition can effectively reduce electric utility usage and yield approximately $45,000 a year in energy savings. The incentives set in place for the state of California for renewable energy production makes the use of photovoltaic panels an attractive solution to high electricity costs. Although, without the incentives package, it is determined that the energy production cost for the PV system would be significantly more than the cost of electricity purchased directly from the utility. It is also important to note that the decision to implement a PV array system is still risky in that the amount of money reserved for the Performance Based Incentive Program fluctuates from year to year and could be cut off at some point in the future if funds run out. However, the non-renewable energy savings and reduction in greenhouse gas emissions from using photovoltaic array power systems is a great advantage. Based on the results from this analysis, it is recommended that the proposed PV system for the Pediatric Inpatient Addition be installed.

11.0 Summary and Recommendations

The Miller Children's Hospital Pediatric Inpatient Addition is an excellent facility to explore the use of energy efficient designs that can reduce energy consumption, decrease annual operation cost, and reduce greenhouse gas emissions. The proposed CHP system could potentially save the Miller Children's Hospital approximately $320,000 per year on utility costs alone, money that could be better used for patient care or medical research. It is shown that the system will have a payback period of approximately 6 years. Although it is clear that the system does have some problem areas, and more research will need to be done on emission reductions to ensure that the facility meets emissions standards for California and is safe to install in a medical facility such as this. Based on the results from the CHP analysis, it is recommended that the cogeneration system be installed.

The proposed photovoltaic system for the Pediatric Inpatient Addition is a renewable energy source that creates zero greenhouse gas emissions and produces safe, clean power to reduce the overall electric consumption of the building. The system saves the Miller Children's Hospital approximately $45,000 per year with a 7-year payback period. The incentives set in place by the state of California and federal government allows for the system to cost-effectively pay for itself in a reasonable time period. Perhaps the greatest advantage of this system is that the building ultimately consumes less non-renewable energy resources by utilizing "free" energy from the sun. Based on the PV analysis, it is in the best interest of the Miller Children's Hospital to install the proposed photovoltaic system.

12.0 References

City of Long Beach CA. “Gas Rates: Electric Generation.” Effective Nov. 1 2007. Visited 27 Feb. 2008. http://www.longbeach.gov/lbgo/.

City of Long Beach CA. “Gas Rates: Large Commercial and Industrial.” Effective Nov. 1 2007. Visited 27 Feb. 2008. http://www.longbeach.gov/lbgo/.

Combined Heat and Power Partnership, Catalogue of CHP Technologies. U.S. Environmental Protection Agency, Washington, D.C. 2008.

Department of Energy. BCHP Screening Tool v2.0.1. GARD Analytics, Park Ridge, IL. 1999-2002.

Google Maps. “2801 Atlantic Ave. Long Beach, CA.” Visited 26 Mar. 2008. http://maps.google.com.

JBA Consulting Engineers. 2006, Electrical Construction Documents. JBA Consulting Engineers, Costa Mesa, CA. 2006.

JBA Consulting Engineers. 2006, Mechanical Construction Documents. JBA Consulting Engineers, Costa Mesa, CA. 2006.

Leposky, George. “Oil Producer Installs Cogeneration System With Ultra-Low Nox Emissions.” *Distributed Energy: The Journal For Onsite Power Solutions* Aug. 2004. 4 Apr. 2008. http://www.gradingandexcavation.com/de_0407_oil.html.

National Electric Code (2005). National Fire Protection Agency, Quincy, MA. 2005.

RETScreen International, RETScreen: Photovoltaic Project Model v3.2. CANMET Energy Technology Center, Varennes (QC), Canada. 2007.

R.S. Means, CostWorks 2008 Program. Means, Incorporated, Kingston, MA. 2008.

Southern California Edison. “Large Business Rate Summary.” Effective 2008. Visited 27 Feb. 2008. http://www.sce.com.

Trane, Trane Acoustics Program v2.3. American Standard Inc., Tyler, TX. 1996.

Appendix A - HVAC System Diagrams

Figure A-1: Condenser Water Flow Schematic

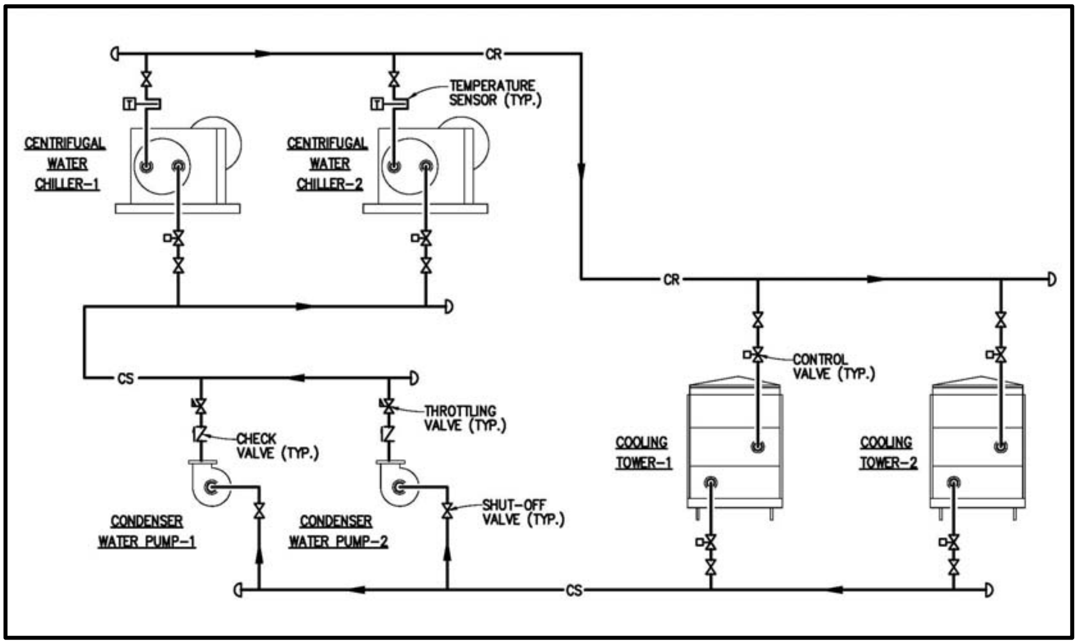


Figure A-1 shows the condenser water flow schematic from the chillers through the cooling towers and condenser water pumps. Note: Centrifugal Chiller 2 and Cooling Tower 2 are standby and only operate when equipment 1 is not.

Figure A-2: Chilled Water Flow Schematic

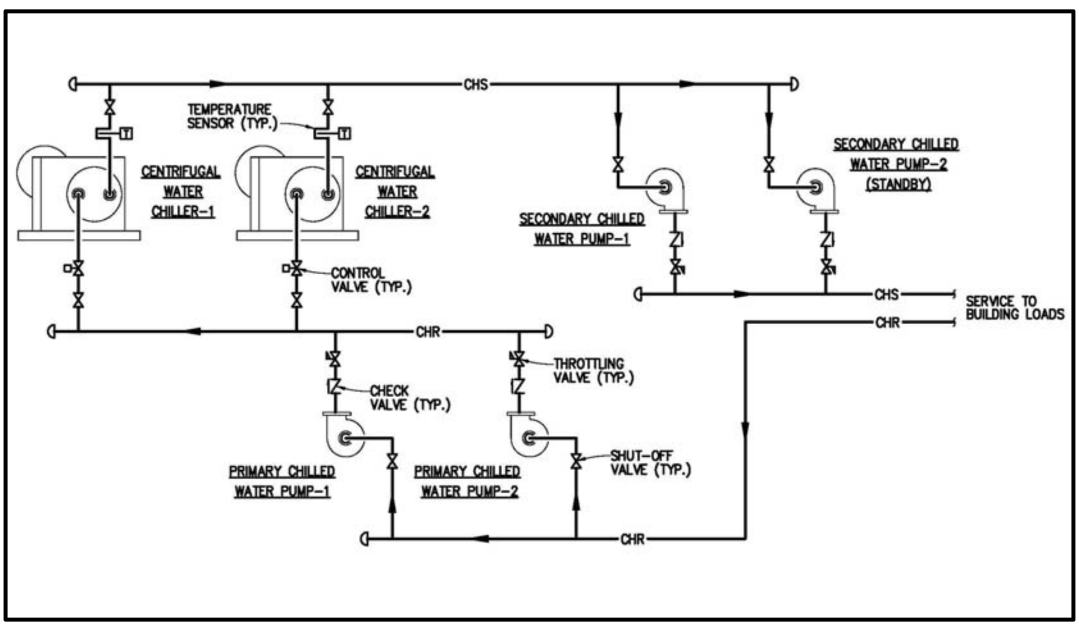


Figure A-2 shows the chilled water flow schematic from the primary chilled water pumps, through the chiller, secondary chilled water pumps and to service the building. Note: Centrifugal Chiller 2 as well as primary and secondary chilled water pumps 2 are standby and only operate when equipment 1 is not.

Figure A-3: Hot Water Flow Schematic

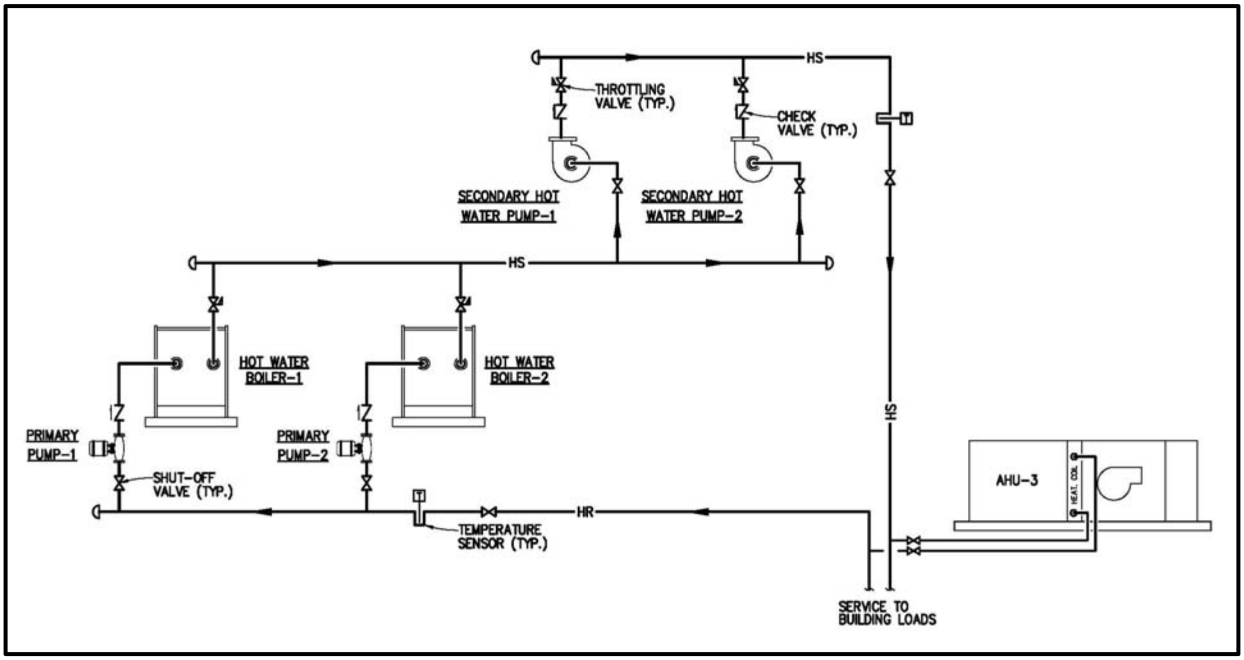


Figure A-3 shows the hot water flow schematic from the hot water boilers through the primary and secondary hot water pumps, service to AHU-3, and to the hot water loads of the building.

Appendix B – Electrical System Diagrams

Figure B-1 – As-Designed Electrical System Single Line Diagram

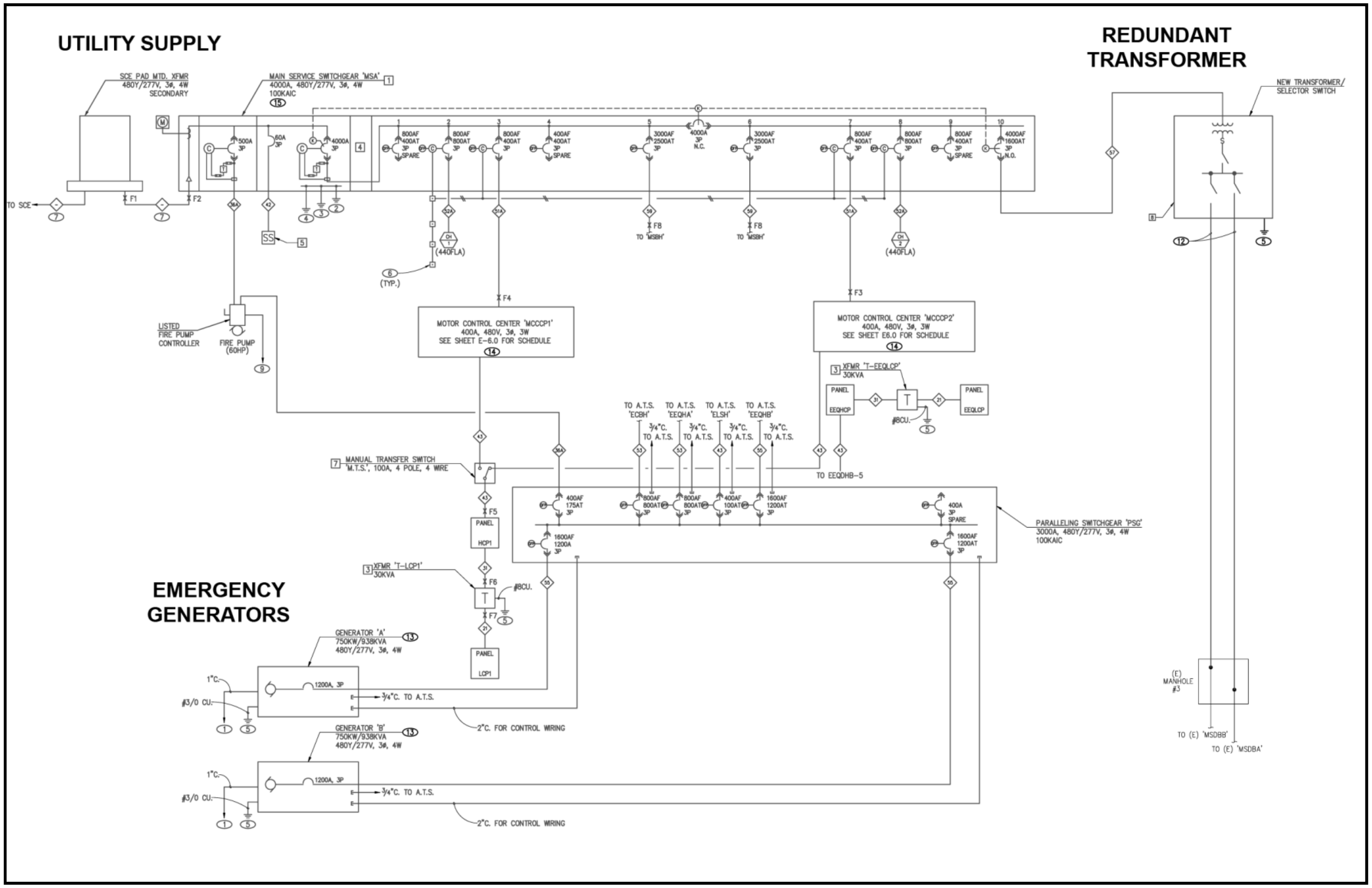


Figure B-1 shows the as-designed electrical system single line diagram for the Pediatric Inpatient Addition. The redundant transformer is tied into the existing Miller Children's Hospital and serves no loads. The emergency generators active through an automatic transfer switch when utility power supply has been interrupted.

Figure B-2 – Proposed CHP Electrical System Single Line Diagram

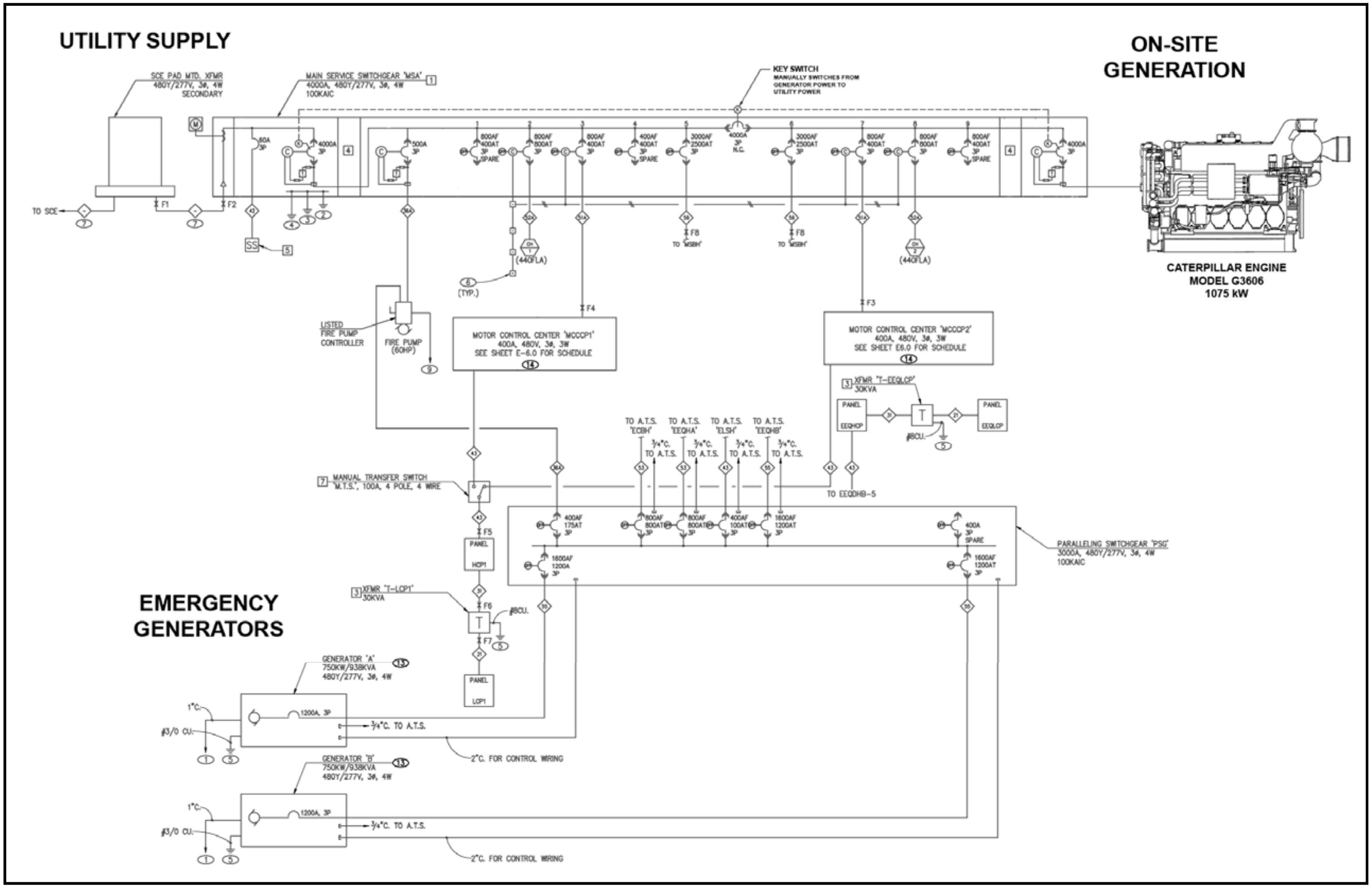


Figure B-2 shows the proposed CHP electrical system single line diagram for the Pediatric Inpatient Addition. The key switch allows for two breakers to be open at once, allowing the building owner to manually switch from on-site power to utility power. The fire pump was also moved in order to be powered by both power generator and utility.

Figure B-3 – Proposed PV Electrical System Single Line Diagram

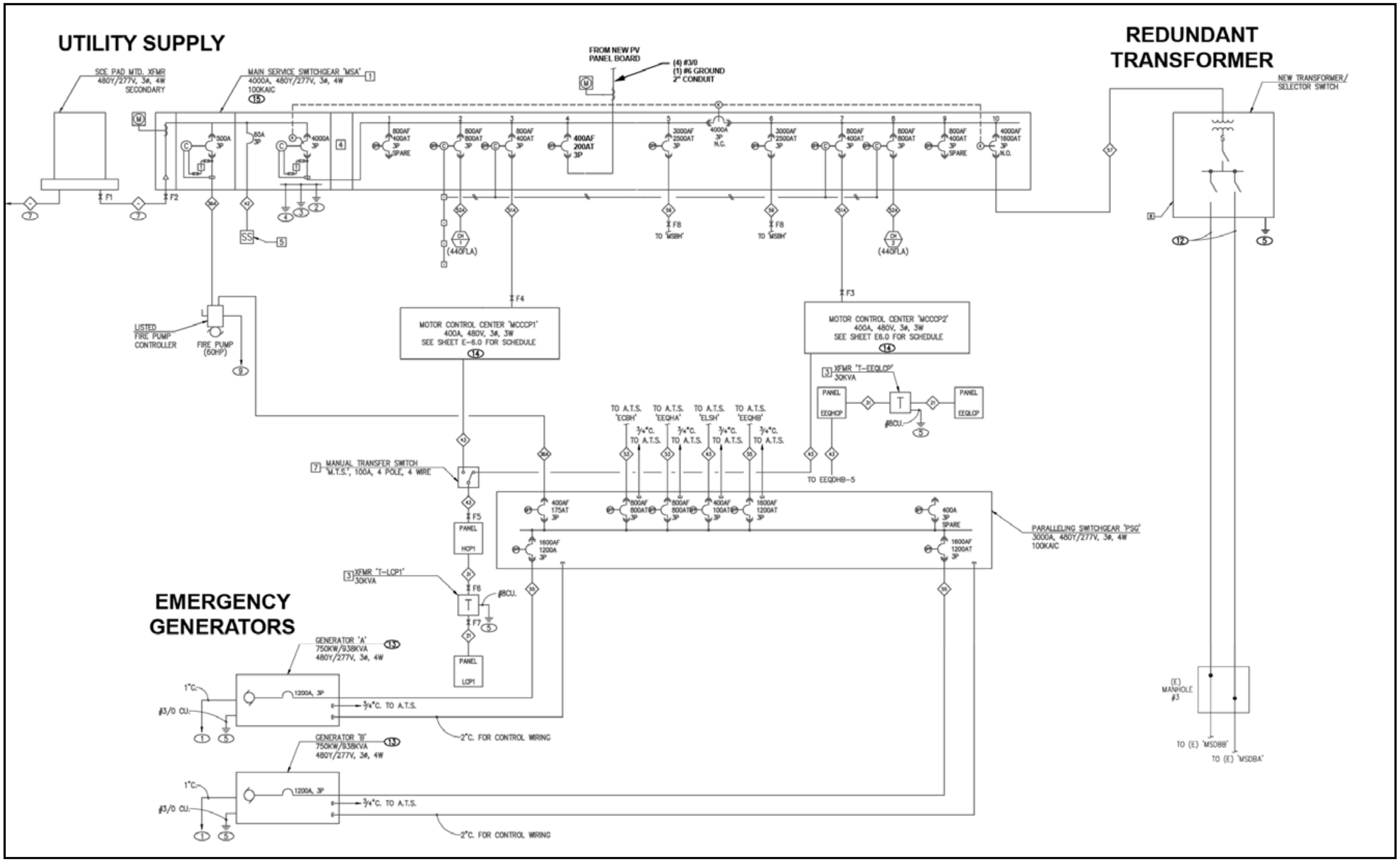
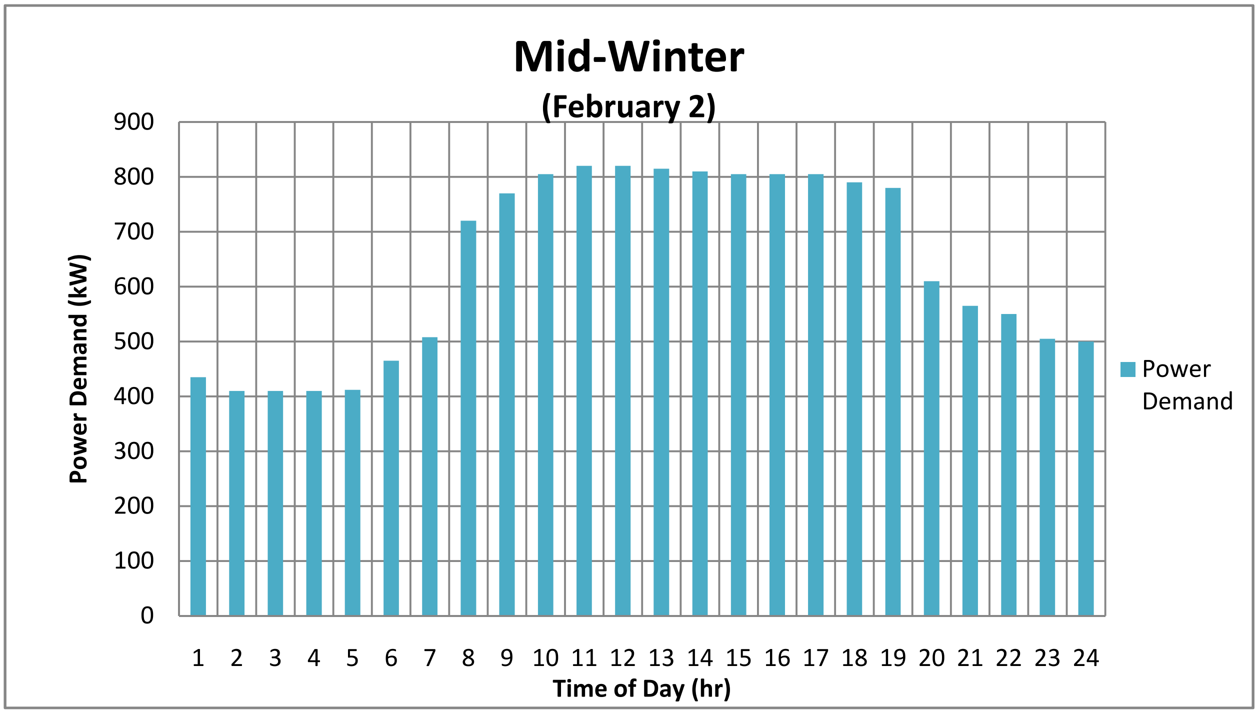
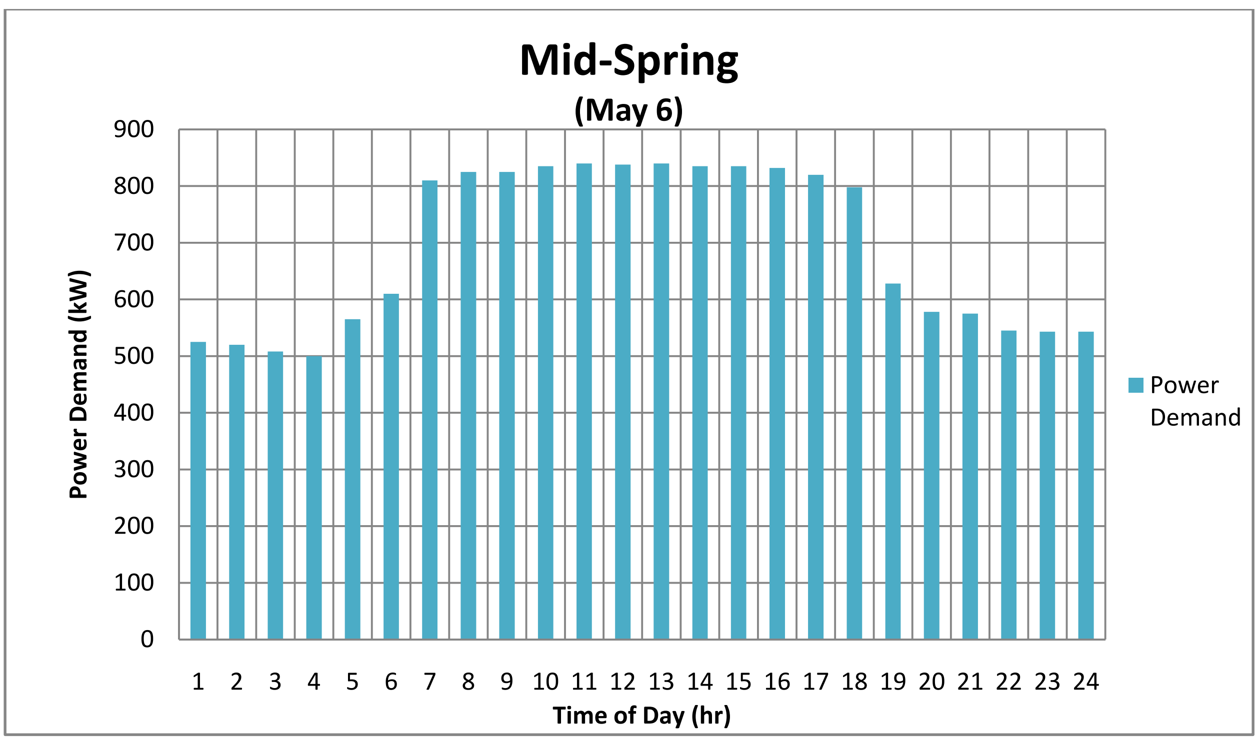


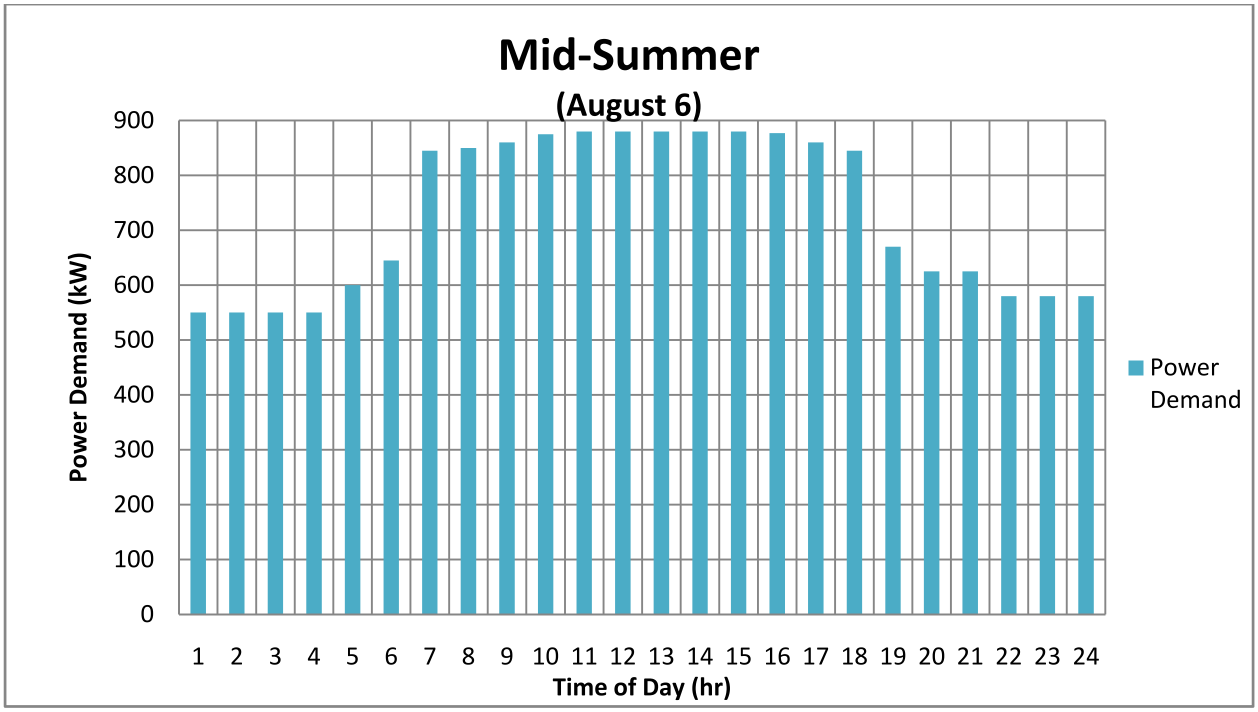
Figure B-3 shows the proposed PV electrical system single line diagram for the Pediatric Inpatient Addition. The PV array will feed into the main distribution panel and a meter will be put into place to monitor the amount of power supplied by the PV array. The PV system will take precedence over the building demands and after which the difference determined by the meters will be drawn from the utility.

Appendix C – Building Energy Consumption

Figure C-1 – Electric Load Profiles







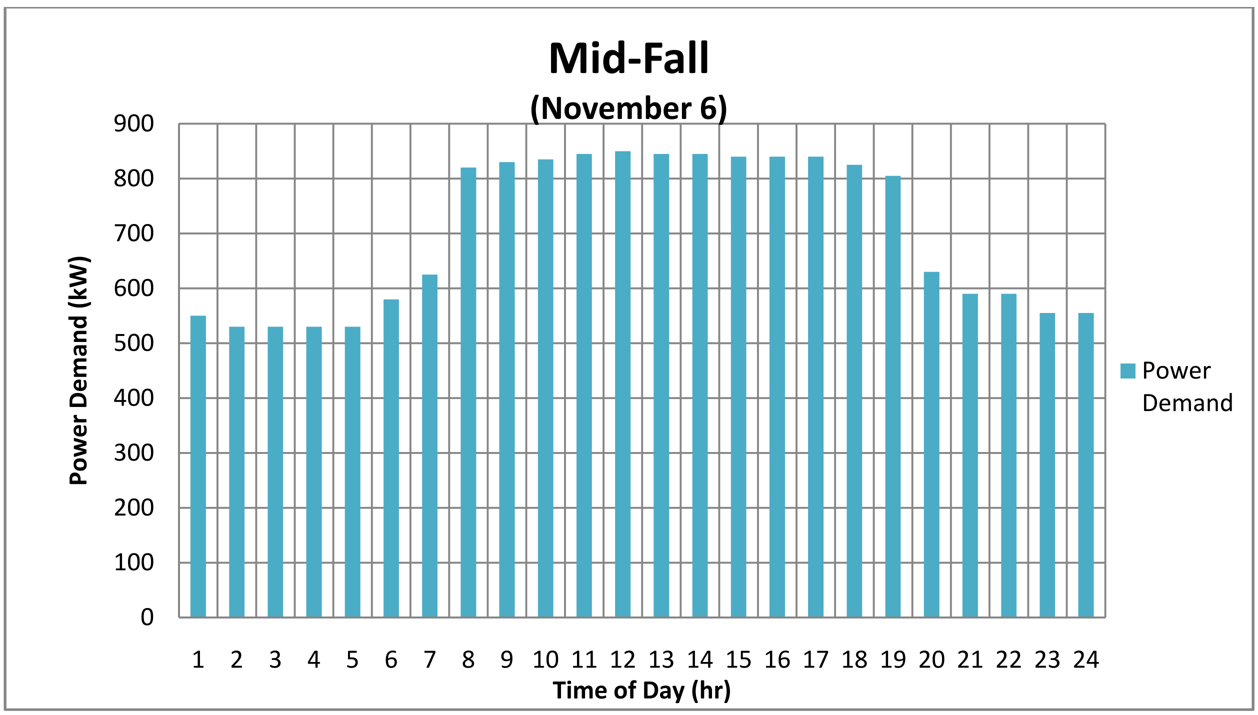


Figure C-1 - The following figures are the electric load profiles for the Pediatric Inpatient Addition for four typical days throughout a given year. The generator for CHP will operate under these conditions year round.

Appendix D – Building Cost Data

Table D-1 – Annual Operation Costs

Basecase Scenario (without Cogen)

Rate Schedule TOU-8 (Electric Demand; Electric Use) | Schedule 3 - Commercial and Industrial (Natural Gas Consumption)

		Electric Demand: Peak (kW)	Adjusted Peak (kW)	Charges: Delivery ($/kW)	Charges: Demand ($/kW)	Charges: Total ($)	Electric Use: Monthly Use (kWh)	On-peak (kWh)	Mid-peak (kWh)	Off-peak (kWh)	Monthly Charges ($)	Natural Gas: Gas Use (therm)	Transmission Charge ($/therm)	Cost of gas ($/therm)	Monthly Cost ($)	
Winter	January	847	-	$9.20	$0.00	$8,038.49	466,684	0	182,007	284,677	$73,396.65	4,901	$0.09	$0.78	$4,275.40	
Winter	February	843	-	$9.20	$0.00	$8,006.29	426,311	0	166,261	260,050	$67,047.12	3,706	$0.09	$0.77	$3,179.72	
Winter	March	862	-	$9.20	$0.00	$8,182.01	488,234	0	190,411	297,823	$76,785.90	3,068	$0.09	$0.86	$2,918.70	
Winter	April	878	-	$9.20	$0.00	$8,325.53	487,212	0	190,013	297,199	$76,625.16	2,688	$0.09	$0.61	$1,894.78	
Winter	May	890	-	$9.20	$0.00	$8,436.85	512,880	0	200,023	312,857	$80,662.11	2,623	$0.09	$0.71	$2,100.44	
Summer	June	894	-	$9.20	$15.62	$22,431.40	502,284	135,617	90,411	276,256	$83,464.55	2,493	$0.09	$0.73	$2,057.81	
Summer	July	894	-	$9.20	$15.62	$22,441.33	526,648	142,195	94,797	289,657	$87,513.27	2,580	$0.09	$0.80	$2,300.34	
Summer	August	900	-	$9.20	$15.62	$22,587.77	532,625	143,809	95,872	292,944	$88,506.35	2,574	$0.09	$0.57	$1,689.45	
Summer	September	908	-	$9.20	$15.62	$22,793.78	511,946	138,225	92,150	281,570	$85,070.10	2,489	$0.09	$0.58	$1,666.86	
Winter	October	881	-	$9.20	$0.00	$8,358.65	516,122	0	201,288	314,834	$81,171.95	2,839	$0.09	$0.57	$1,864.81	
Winter	November	862	-	$9.20	$0.00	$8,182.01	472,595	0	184,312	288,283	$74,326.37	3,161	$0.09	$0.71	$2,530.62	
Winter	December	851	-	$9.20	$0.00	$8,077.13	471,198	0	183,767	287,431	$74,106.66	4,985	$0.09	$0.69	$3,881.40	**Yearly Total**
					Total =	$155,861.24	5,914,738			Total =	$948,676.20			Total =	$30,540.35	**$1,135,077.80**

Cogen Scenario - 1075 kW Reciprocating Engine operating along demand curve

Rate Schedule TOU-8 (Electric Demand; Electric Use) | Schedule 7 - Electric Generation (Natural Gas Consumption)

		Electric Demand: Peak (kW)	Adjusted Peak (kW)	Charges: Delivery ($/kW)	Charges: Demand ($/kW)	Charges: Total ($)	Electric Use: Monthly Use (kWh)	On-peak (kWh)	Mid-peak (kWh)	Off-peak (kWh)	Monthly Charges ($)	Natural Gas: Gas Use (therm)	Transmission Charge ($/therm)	Cost of gas ($/therm)	Monthly Cost ($)	
Winter	January	847	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	63,099	$0.08	$0.86	$59,615.75	
Winter	February	843	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	57,524	$0.08	$0.85	$53,785.22	
Winter	March	862	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	65,507	$0.08	$0.93	$66,404.55	
Winter	April	878	878	$9.20	$0.00	$8,327.37	113,683	0	19,508	15,256	$13,744.31	64,976	$0.08	$0.71	$51,688.57	
Winter	May	890	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	68,146	$0.08	$0.79	$59,430.30	
Summer	June	894	0	$9.20	$15.62	$249.77	0	0	0	0	$0.00	66,568	$0.08	$0.81	$59,338.45	
Summer	July	894	0	$9.20	$15.62	$249.77	0	0	0	0	$0.00	69,525	$0.08	$0.87	$66,465.42	
Summer	August	900	0	$9.20	$15.62	$249.77	0	0	0	0	$0.00	70,125	$0.08	$0.62	$49,606.14	
Summer	September	908	0	$9.20	$15.62	$249.77	0	0	0	0	$0.00	67,534	$0.08	$0.67	$50,947.65	
Winter	October	881	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	68,474	$0.08	$0.62	$47,931.52	
Winter	November	862	862	$9.20	$0.00	$8,180.17	110,272	0	19,783	14,799	$13,397.92	63,392	$0.08	$0.88	$61,096.82	
Winter	December	851	0	$9.20	$0.00	$249.77	0	0	0	0	$0.00	63,621	$0.08	$0.76	$53,664.31	**Yearly Total**
					Total =	$19,005.24				Total =	$27,142.23			Total =	$680,573.30	**$726,720.78**

Savings = $408,357.02

Table D-1 shows the annual operation costs for the Pediatric Inpatient Addition both for the as-designed (basecase) and cogen system. Note: The cogen scenario takes into account two weeks per year (one in spring and one in fall) when the generator will be offline for maintenance purposes and electricity will need to be purchased from Southern California Edison to meet the building demands.

Figure D-1 – Long Beach Gas Utility Rate

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GAS RATE SCHEDULE
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Long Beach Municipal Code
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Effective Date: **November 1, 2007**

SCHEDULE 3

COMMERCIAL AND INDUSTRIAL

Applicable to commercial and industrial service of natural gas to customers with annual consumption in excess of 12,000 therms or less than 250,000 therms based on the customer's prior calendar year consumption, or estimated annual consumption for new customers, as set forth in Section 15.36.040 of the Municipal Code.

RATES:

- **Daily Service Charge per Meter** — $0.4932

- **Transmission Charge (per therm)**

Tier I:	All usage not to exceed 100 therms per summer month (April – November) or 250 therms per winter month (December – March) (prorated on a daily basis)	$0.4517
Tier II:	All usage exceeding Tier I volumes but not exceeding 4,167 therms monthly (prorated on a daily basis)	$0.2423
Tier III:	All usage exceeding 4,167 therms monthly (prorated on a daily basis)	$0.0907

- **Cost of Gas (per therm)**
  Applicable to all usage — Core Commodity Charge

USE PRIORITY:

Customers receiving service under this schedule shall have priority in the use of gas over customers served under other rate schedules, except Schedules 1 and 2 when there is curtailment or insufficient gas to supply the demands of all customers, and such customers shall be subject to discontinuance of service without notice in case of curtailment or threatened or actual shortage of gas in favor of customers under Schedules 1 and 2. The City shall not be liable for damages, which may be occasioned by the curtailment, discontinuance or shut off of such gas supply or service.

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SCHEDULE 7

ELECTRIC GENERATION

Applicable to service of customer's gas used for the production of electrical energy.

RATES:

- **Daily Service Charge per Customer**

For Customers using less than 3 million therms per year	$1.6438
For Customers using 3 million therms or more per year	No Charge

- **Transmission Charge (per therm)**

For Customers using less than 3 million therms per year	$0.0838
For Customers using 3 million therms or more per year	$0.0395

- **Cost of Gas (per therm)** Non-Core Commodity Charge Plus a Surcharge of $0.0500

Upon recommendation by the Director of LBGO, the City Manager, subject to approval of City Council, may adjust on a case-by-case basis the amount of the surcharge in the Cost of Gas per therm a maximum of $0.03 above or below the stated surcharge rate to reflect current changes in market conditions. Notice of the upcoming monthly surcharge amount will be posted at LBGO at least 15 days before the beginning of each month and will also be available from LBGO by telephone or facsimile upon request. The Non-Core Commodity Charge will be posted at LBGO within 10 days after the end of each month and will also be available from the LBGO website www.lbgo.org as well as by telephone or facsimile upon request.

USE PRIORITY:

Customers receiving service under this schedule shall have priority in the use of gas equal to customers served under Rate Schedule 9 and lower than Rate Schedules 1, 2, 3, 4, and 5, when there is curtailment or insufficient gas to supply the demands of all customers, and such customers shall be subject to discontinuance of service without notice in case of curtailment or threatened or actual shortage of gas in favor of customers under Schedules 1, 2, 3, 4, and 5. The City shall not be liable for damages which may be occasioned by the curtailment, discontinuance or shut off of such gas supply or service.

Figure D-2 – Southern California Electric Utility Rate

Rate Schedule	Rate Structure	Customer Charge	Demand (kW) Charge	Energy Charge (per kWh)	Some Other Conditions/Charges
TOU-8 (Below 2 kV)	• Time-of-Use rates • Facilities- and Time-related demand charges • Seasonal structure • Voltage discount	Delivery: $414.98 per month per meter	Facilities-related demand charge per monthly maximum kW per meter Delivery: $9.71 Generation: $0.00 Time-related demand charge per monthly maximum kW per meter in the summer season only Delivery: $0.00/on-peak $0.00/mid-peak Generation: $15.37/on-peak $5.19/mid-peak	Delivery: $.01378 DWR Generation: $.08875 SCE Generation: Summer Season – $.09985/on-peak $.07238/mid-peak $.03637/off-peak Winter Season – $.07515/mid-peak $.04014/off-peak	• Schedule TOU-8 is only applicable for customers whose demands exceed 500 kW. This may be initially determined by SCE or when 500 kW is exceeded in any three months out of the previous 12 months. Customers with maximum demands of 500 kW or less are not eligible for this rate unless they are concurrently served under Schedule I-6. • Power factor adjustment charge. • Summer season is the first Sunday in June to the first Sunday in October. All other periods comprise the winter season. (See time-of-use charts for more information.)
TOU-8 (From 2 kV to 50 kV)	• Time-of-Use rates • Facilities- and Time-related demand charges • Seasonal structure • Voltage discount	Delivery: $249.77 per month per meter	Facilities-related demand charge per monthly maximum kW per meter Delivery: $9.20 Generation: $0.00 Time-related demand charge per monthly maximum kW per meter in the summer season only Delivery: $0.00/on-peak $0.00/mid-peak Generation: $15.62/on-peak $5.29/mid-peak	Delivery: $.01346 DWR Generation: $.08875 SCE Generation: Summer Season – $.10175/on-peak $.07391/mid-peak $.03737/off-peak Winter Season – $.07674/mid-peak $.04122/off-peak	
TOU-8 (Above 50 kV)	• Time-of-Use rates • Facilities- and Time-related demand charges • Seasonal structure • Voltage discount	Delivery: $2199.04 per month per meter	Facilities-related demand charge per monthly maximum kW per meter Delivery: $2.48 Generation: $0.00 Time-related demand charge per monthly maximum kW per meter in the summer season only Delivery: $0.00/on-peak $0.00/mid-peak Generation: $12.33/on-peak $4.25/mid-peak	Delivery: $.01270 DWR Generation: $.08875 SCE Generation: Summer Season – $.07164/on-peak $.04998/mid-peak $.02146/off-peak Winter Season – $.05240/mid-peak $.02462/off-peak	

Figure D-2 shows the Southern California Edison electric rate structure for large-sized commercial and industrial customers. The rate used for the cost analysis was TOU-8 (From 2kV to 50kV). These rates were obtained from Southern California Edison's website.

Figure D-3 – CHP Cost Estimate Figures

Table 3. Estimated Capital Cost for Typical Gas Engine Generators in Grid Interconnected, Combined Heat and Power Application ($/kW)

Cost Component	System 1	System 2	System 3	System 4	System 5
Nominal Capacity (kW)	100	300	800	3,000	5,000
Costs ($/kW)					
Equipment					
Gen Set Package	$260	$230	$269	$400	$450
Heat Recovery	$205	$179	$89	$65	$40
Interconnect/Electrical	$260	$90	$40	$22	$12
Total Equipment	$725	$499	$398	$487	$502
Labor/Materials	$359	$400	$379	$216	$200
Total Process Capital	$1,084	$899	$777	$703	$702
Project and Construction Management	$235	$158	$121	$95	$95
Engineering and Fees	$129	$81	$45	$41	$41
Project Contingency	$43	$34	$28	$25	$25
Project Financing (interest during construction)	$24	$25	$31	$55	$55
Total Plant Cost ($/kW)	$1,515	$1,197	$1,002	$919	$919

Source: Energy Nexus Group

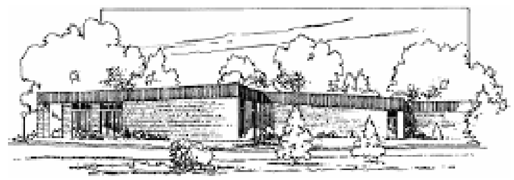
Figure D-3 shows the estimated costs for a typical gas engine generator CHP system, obtained from the EPA Combined Heat and Power Partnership's *Catalogue of CHP Technologies*. The source is the Energy Nexus Group. The values used were interpolated between System 3 and System 4 for the 1,075 kW generator proposed.

Figure D-4 – Central Plant Expansion Cost Estimate

Square Foot Cost Estimate Report

Estimate Name: **Pediatric Inpatient Addition**

Building Type:	Factory, 1 Story with Concrete Block / Steel Frame
Location:	LONG BEACH, CA
Stores Count (L.F.):	1.00
Stores Height	15.00
Floor Area (S.F.):	1,180.00
LaborType	Open Shop
Basement Included:	No
Data Release:	Year 2008
Cost Per Square Foot	$441.55
Total Building Cost	$521,500



Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.
Parameters are not within the ranges recommended

		% of Total	Cost Per SF	Cost
A Substructure		25.5%	84.32	$99,500
A1010	**Standard Foundations**		27.12	$32,000
	Strip footing, concrete, reinforced, load 5.1 KLF, soil bearing capacity 3 KSF, 12" deep x 24" wide			
	spread footings, 3000 PSI concrete, load 50K, soil bearing capacity 6 KSF, 3' - 0" square x 12" deep			
	Spread footings, 3000 PSI concrete, load 75K, soil bearing capacity 6 KSF, 4' - 0" square x 12" deep			
	Spread footings, 3000 PSI concrete, load 100K, soil bearing capacity 6 KSF, 4' - 6" square x 15" deep			
A1030	**Slab on Grade**		6.36	$7,500
	Slab on grade, 5" thick, light industrial, reinforced			
A2010	**Basement Excavation**		0.00	$0
	Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, on site storage			
A2020	**Basement Walls**		50.85	$60,000
	Foundation wall, CIP, 4' wall height, direct chute, .140 CY/LF, 7.2 PLF, 12" thick			
B Shell		41.3%	136.44	$161,000
B1020	**Roof Construction**		8.47	$10,000
	Roof, steel joists, joist girder, 1.5" 22 ga metal deck, on columns, 40'x40' bay, 40 PSF superimposed load, 40.5" dee			
	Roof, steel joists, joist girder, 1.5" 22 ga metal deck, on columns, 40'x40' bay, 40 PSF superimposed load, 40.5" dee			
B2010	**Exterior Walls**		45.76	$54,000
	Concrete block (CMU) wall, lightweight, hollow, 4 x 8 x 16, 85 PCF			
B2020	**Exterior Windows**		54.24	$64,000
	Windows, aluminum, sliding, insulated glass, 8' x 4'			
B2030	**Exterior Doors**		0.85	$1,000
	Door, aluminum & glass, with transom, narrow stile, double door, hardware, 6'-0" x 10'-0" opening			
	Door, steel 18 gauge, hollow metal, 1 door with frame, no label, 3'-0" x 7'-0" opening			
	Door, steel 24 gauge, overhead, sectional, electric operator, 10'-0" x 10'-0" opening			
B3010	**Roof Coverings**		25.00	$29,500
	Roofing, asphalt flood coat, gravel, base sheet, 3 plies 15# asphalt felt, mopped			
	Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite			
	Roof edges, aluminum, duranodic, .050" thick, 6" face			

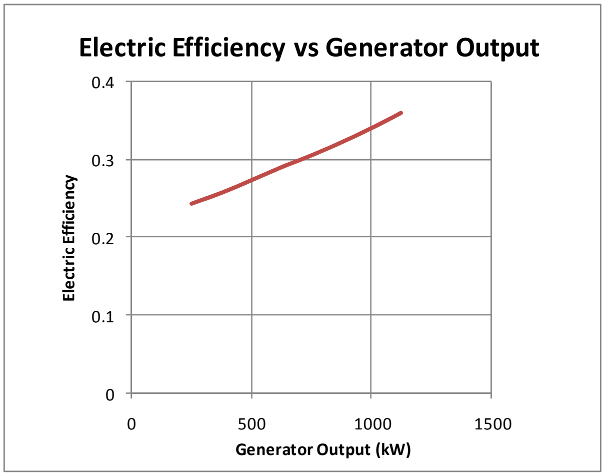
		% of Total	Cost Per SF	Cost
	Flashing, aluminum, no backing sides, .019"			
	Gravel stop, aluminum, extruded, 4", mill finish, .050" thick			
B302(	**Roof Openings**		2.12	$2,500
	Roof hatch, with curb, 1" fiberglass insulation, 2'-6" x 3'-0", galvanized steel, 165 lbs			
	Smoke hatch, unlabeled, galvanized, 2'-6" x 3', not incl hand winch operator			
C Interiors		7.1%	23.31	$27,500
C101(	**Partitions**		1.27	$1,500
	Partition, concrete block, 6" thick			
C102(	**Interior Doors**		1.27	$1,500
	Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8"			
C103(	**Fittings**		0.85	$1,000
	Toilet partitions, cubicles, ceiling hung, stainless steel			
C301(	**Wall Finishes**		19.07	$22,500
	2 coats paint on masonry with block filler			
	Painting, masonry or concrete, latex, brushwork, primer & 2 coats			
C302(	**Floor Finishes**		0.42	$500
	Vinyl, composition tile, maximum			
C303(	**Ceiling Finishes**		0.42	$500
	Accustic ceilings, 3/4"mineral fiber, 12" x 12" tile, concealed 2" bar & channel grid, suspended support			
D Services		26.2%	86.44	$102,000
D201(	**Plumbing Fixtures**		2.54	$3,000
	Water closet, vitreous china, bowl only with flush valve, wall hung			
	Urinal, vitreous china, stall type			
	Lavatory w/trim, vanity top, PE on CI, 19" x 16" oval			
	Kitchen sink w/trim, countertop, stainless steel, 33" x 22" double bowl			
	Service sink w/trim, PE on CI, corner floor, wall hung w/rim guard, 22" x 18"			
	Shower, stall, baked enamel, terrazzo receptor, 36" square			
	Shower, stall, fiberglass 1 piece, three walls, 32' square			
	Water cooler, electric, floor mounted, dual height, 14.3 GPH			
D202(	**Domestic Water Distribution**		10.17	$12,000
	Gas fired water heater, commercial, 100< F rise, 115 MBH input, 110 GPH			
D204(	**Rain Water Drainage**		13.56	$16,000
	Roof drain, CI, soil,single hub, 5" diam, 10' high			
	Roof drain, CI, soil,single hub, 5" diam, for each additional foot add			
D301(	**Energy Supply**		7.20	$8,500
	Commercial building heating systems, terminal unit heaters, forced hot water, 10,000 SF bldg,100,000 CF, total, 2 fk			
D303(	**Cooling Generating Systems**		8.90	$10,500
	Packaged chiller, air cooled, with fan coil unit, factories, 40,000 SF, 133.33 ton			
D401(	**Sprinklers**		2.97	$3,500
	Wet pipe sprinkler systems, steel, ordinary hazard, 1 floor, 50,000 SF			
D501(	**Electrical Service/Distribution**		32.63	$38,500
	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 600 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 600 A			
	Switchgear installation, incl switchboard, panels & circuit breaker, 600 A			
D502(	**Lighting and Branch Wiring**		8.05	$9,500
	Receptacles incl plate, box, conduit, wire, 2.5 per 1000 SF, .3 watts per SF			
	Miscellaneous power, 1 watt			
	Central air conditioning power, 4 watts			
	HID fixture, 0'-10' above work plane, 100 FC, type C, 0 fixtures per 1000 SF			
D503(	**Communications and Security**		0.42	$500

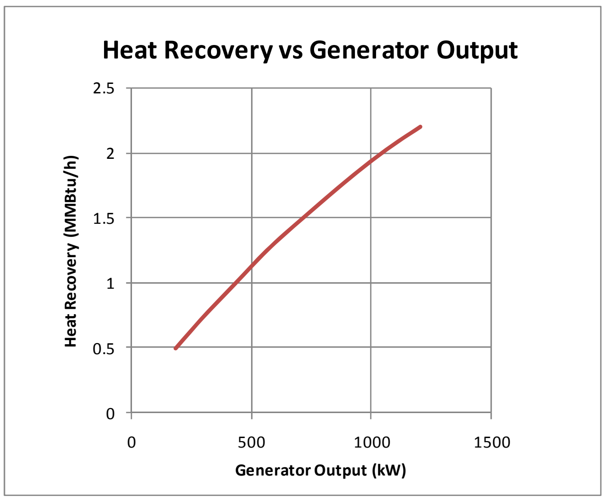
		% of Total	Cost Per SF	Cost
	Communication and alarm systems, includes outlets, boxes, conduit and wire, fire detection systems, 25 detectors			
E Equipment & Furnishings		0.0%	0.00	$0
E1090	Other Equipment		0.00	$0
F Special Construction		0.0%	0.00	$0
G Building Sitework		0.0%	0.00	$0
Sub Total		100%	$330.51	$390,000
Contractor's Overhead & Profit		25.0%	$82.63	$97,500
Architectural Fees		7.0%	$28.81	$34,000
User Fees		0.0%	$0.00	$0
Total Building Cost			$441.95	$521,500

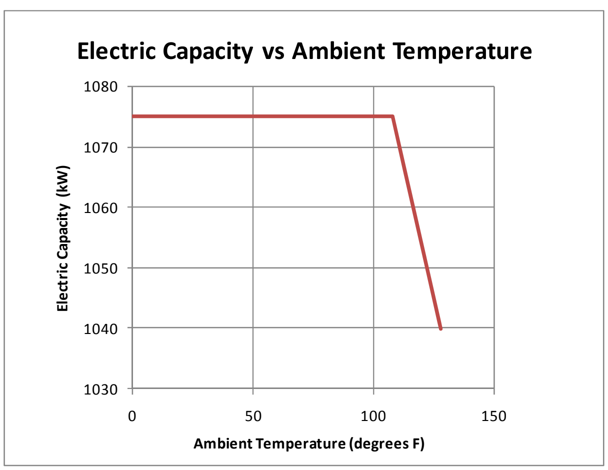
Figure D-4 is the cost estimate on a square foot basis for the central plant expansion. The additional 1,180 sq. ft. for the cogen equipment will cost $521,500. The model generalizes the central plant as a 1-story factory-type facility with concrete block and steel frame.

Appendix E – Equipment Data

Figure E-1 – Generator Operation Data







Appendix F – Acoustical Data

Figure F-1 – Transmission Loss Path1

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1: Transmission Losses from Generator Room

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
	Octave Band Data							
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**4**	**4**	**6**	**5**	**5**	**4**	**4**	Generator Room
SubSum	113	115	116	116	116	113	109	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Generator Room to Chiller Room
Rec Rm Corr	**-12**	**-11**	**-10**	**-9**	**-9**	**-10**	**-11**	Chiller Room
SubSum	70	69	71	70	68	63	58	
Cooling Tower	**108**	**108**	**105**	**102**	**99**	**96**	**92**	25 hp Induced Draft Cooling Tower
CVHE Chiller	**74**	**77**	**74**	**74**	**75**	**75**	**74**	500 ton Chiller
SubSum	108	108	105	102	99	96	92	
Wall or Floor	**2**	**3**	**5**	**3**	**3**	**2**	**2**	Chiller Room
SubSum	110	111	110	105	102	98	94	
Trans Loss Val	**-31**	**-35**	**-38**	**-39**	**-40**	**-40**	**-40**	Loss from Chiller Room to Pump Room
Rec Rm Corr	**-12**	**-10**	**-9**	**-8**	**-8**	**-9**	**-10**	Pump Room
SubSum	67	66	63	58	54	49	44	
Pump	**96**	**97**	**99**	**99**	**102**	**99**	**95**	Condenser Water Pump
Pump	**93**	**94**	**96**	**96**	**99**	**96**	**92**	Chilled Water Pump 1
Pump	**93**	**94**	**96**	**96**	**99**	**96**	**92**	Chilled Water Pump 2
SubSum	99	100	102	102	105	102	98	
Wall or Floor	**-3**	**-3**	**-1**	**-2**	**-2**	**-3**	**-3**	Pump Room
Trans Loss Val	**-24**	**-28**	**-33**	**-36**	**-39**	**-40**	**-40**	Loss from Pump Room to Storage Room Wall 1
Trans Loss Val	**-31**	**-35**	**-38**	**-39**	**-40**	**-40**	**-40**	Loss from Pump Room to Storage Room Wall 2
Rec Rm Corr	**-1**	**-1**	**0**	**-1**	**-1**	**0**	**0**	Storage Receiver

Program User: Stephen Haines
File Name: P:\SRTHES~1\THESIS~1\ACOUST~1\CP.PDT
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Page Number: 1

THE TRANE ACOUSTICS PROGRAM
Project Name: Pediatric Inpatient Addition
Project Number:

Path Table View -- Path1: Transmission Losses from Generator Room

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
	Octave Band Data							
SUM	40	33	30	24	23	19	15	
RATING	NC 21			RC 22(N)		28 dBA		

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Figure F-2 – Transmission Loss Path 2

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1 Branch2 : Generator Room to Office

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
			Octave Band Data					
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**4**	**4**	**6**	**5**	**5**	**4**	**4**	Generator Room
SubSum	113	115	116	116	116	113	109	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Generator Room to Chiller Room
Rec Rm Corr	**-12**	**-11**	**-10**	**-9**	**-9**	**-10**	**-11**	Chiller Room
SubSum	70	69	71	70	68	63	58	
Cooling Tower	**108**	**108**	**105**	**102**	**99**	**96**	**92**	25 hp Induced Draft Cooling Tower
CVHE Chiller	**74**	**77**	**74**	**74**	**75**	**75**	**74**	500 ton Chiller
SubSum	108	108	105	102	99	96	92	
Wall or Floor	**2**	**3**	**5**	**3**	**3**	**2**	**2**	Chiller Room
SubSum	110	111	110	105	102	98	94	
Trans Loss Val	**-31**	**-35**	**-38**	**-39**	**-40**	**-40**	**-40**	Loss from Chiller Room to Pump Room
Rec Rm Corr	**-12**	**-10**	**-9**	**-8**	**-8**	**-9**	**-10**	Pump Room
SubSum	67	66	63	58	54	49	44	
Pump	**96**	**97**	**99**	**99**	**102**	**99**	**95**	Condenser Water Pump
Pump	**93**	**94**	**96**	**96**	**99**	**96**	**92**	Chilled Water Pump 1
Pump	**93**	**94**	**96**	**96**	**99**	**96**	**92**	Chilled Water Pump 2
SubSum	99	100	102	102	105	102	98	
Wall or Floor	**-1**	**-1**	**1**	**0**	**0**	**-1**	**-1**	Pump Room
Trans Loss Val	**-24**	**-28**	**-33**	**-36**	**-39**	**-40**	**-40**	Loss from Pump Room to Office Wall 1
Trans Loss Val	**-31**	**-35**	**-38**	**-39**	**-40**	**-40**	**-40**	Loss from Pump Room to Office Wall 2
Rec Rm Corr	**-4**	**-4**	**-4**	**-4**	**-5**	**-5**	**-5**	Office Receiver

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THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Project Number:

Path Table View -- Path1 Branch2 : Generator Room to Office

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
			Octave Band Data					
SUM	39	32	28	23	21	16	12	
RATING	NC 19			RC 20(N)		26 dBA		

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Figure F-3 – Transmission Loss Path 3

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1 Branch1 : Generator Room to Exam Room

	Octave Band Data							
LINE ELEMENT	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**COMMENTS**
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**4**	**4**	**6**	**5**	**5**	**4**	**4**	Generator Room
SubSum	113	115	116	116	116	113	109	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Generator Room to Chiller Room
Rec Rm Corr	**-12**	**-11**	**-10**	**-9**	**-9**	**-10**	**-11**	Chiller Room
SubSum	70	69	71	70	68	63	58	
Cooling Tower	**108**	**108**	**105**	**102**	**99**	**96**	**92**	25 hp Induced Draft Cooling Tower
CVHE Chiller	**74**	**77**	**74**	**74**	**75**	**75**	**74**	500 ton Chiller
SubSum	108	108	105	102	99	96	92	
Wall or Floor	**-3**	**-2**	**0**	**-2**	**-2**	**-3**	**-3**	Chiller Room
Trans Loss Val	**-24**	**-28**	**-33**	**-36**	**-39**	**-40**	**-40**	Loss from Chiller Room to Exam Room Wall 1
Trans Loss Val	**-31**	**-35**	**-38**	**-39**	**-40**	**-40**	**-40**	Loss from Chiller Room to Exam Room Wall 2
Rec Rm Corr	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	Exam Room Receiver
SUM	46	39	30	21	14	9	5	
RATING	NC 19			RC 15(R)		27 dBA		

Program User: Stephen Haines
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Figure F-4 – Transmission Loss Path 4

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1 Branch3 : Generator Room to Outdoors

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
				Octave Band Data				
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**4**	**4**	**7**	**5**	**5**	**4**	**4**	Generator Room
SubSum	113	115	117	116	116	113	109	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Generator Room to Switchgear
Rec Rm Corr	**-12**	**-12**	**-11**	**-11**	**-11**	**-11**	**-12**	Switchgear Receiver
SubSum	70	68	71	68	66	62	57	
Wall or Floor	**1**	**1**	**3**	**2**	**1**	**1**	**1**	Switchgear
SubSum	71	69	74	70	67	63	58	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Switchgear to Outdoors
Outdoor	**-18**	**-18**	**-18**	**-18**	**-18**	**-18**	**-18**	Outdoor Receiver
SUM	22	16	21	15	10	5	5	
RATING	NC < 15			RC 10(H)		17 dBA		

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Figure F-5 – Transmission Loss Path 5

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1 Branch4 : Generator Room to Outdoors

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
				Octave Band Data				
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**4**	**4**	**7**	**5**	**5**	**4**	**4**	Generator Room
SubSum	113	115	117	116	116	113	109	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Generator Room to Emergency Generator Room
Rec Rm Corr	**-10**	**-9**	**-8**	**-8**	**-8**	**-8**	**-9**	Emergency Generator Room Receiver
SubSum	72	71	74	71	69	65	60	
Wall or Floor	**4**	**4**	**7**	**5**	**5**	**4**	**4**	Emergency Generator Room
SubSum	76	75	81	76	74	69	64	
Trans Loss Val	**-31**	**-35**	**-35**	**-37**	**-39**	**-40**	**-40**	Loss from Emergency Generator Room to Outdoors
Outdoor	**-27**	**-27**	**-27**	**-27**	**-27**	**-27**	**-27**	Outdoor Receiver
SUM	18	13	19	12	8	5	5	
RATING	NC < 15			RC 8(H)		15 dBA		

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Figure F-6 – Transmission Loss Path 6

THE TRANE ACOUSTICS PROGRAM

Project Name: Pediatric Inpatient Addition
Location: Long Beach, CA
Building Owner: Long Beach Memorial Medical Center
Project Number:
Comments:

Path Table View -- Path1 Branch5 : Generator Room to Outdoors

LINE ELEMENT	Octave Band Data 63	125	250	500	1k	2k	4k	COMMENTS
Recip Engine	**109**	**111**	**110**	**111**	**111**	**109**	**105**	1075kW Reciprocating Engine Generator
Wall or Floor	**3**	**3**	**5**	**4**	**4**	**3**	**3**	Generator Room
SubSum	112	114	115	115	115	112	108	
Trans Loss Val	**-24**	**-28**	**-33**	**-36**	**-39**	**-40**	**-40**	Loss from Generator Room to Transformer Yard
SubSum	88	86	82	79	76	72	68	
Electric Transform	**89**	**91**	**86**	**86**	**80**	**75**	**70**	Utility Provided Electric Transformer
SubSum	92	92	87	87	81	77	72	
Outdoor	**-31**	**-31**	**-31**	**-31**	**-31**	**-31**	**-31**	Outdoor Receiver
Barrier	**-7**	**-8**	**-10**	**-12**	**-14**	**-17**	**-19**	Barrier insertion loss
SUM	54	53	46	44	36	29	22	
RATING	NC 39			RC 36(N)		45 dBA		

Program User: Stephen Haines
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Appendix G – Reference Information

Figure G-1 – Satellite Image of Pediatric Inpatient Addition

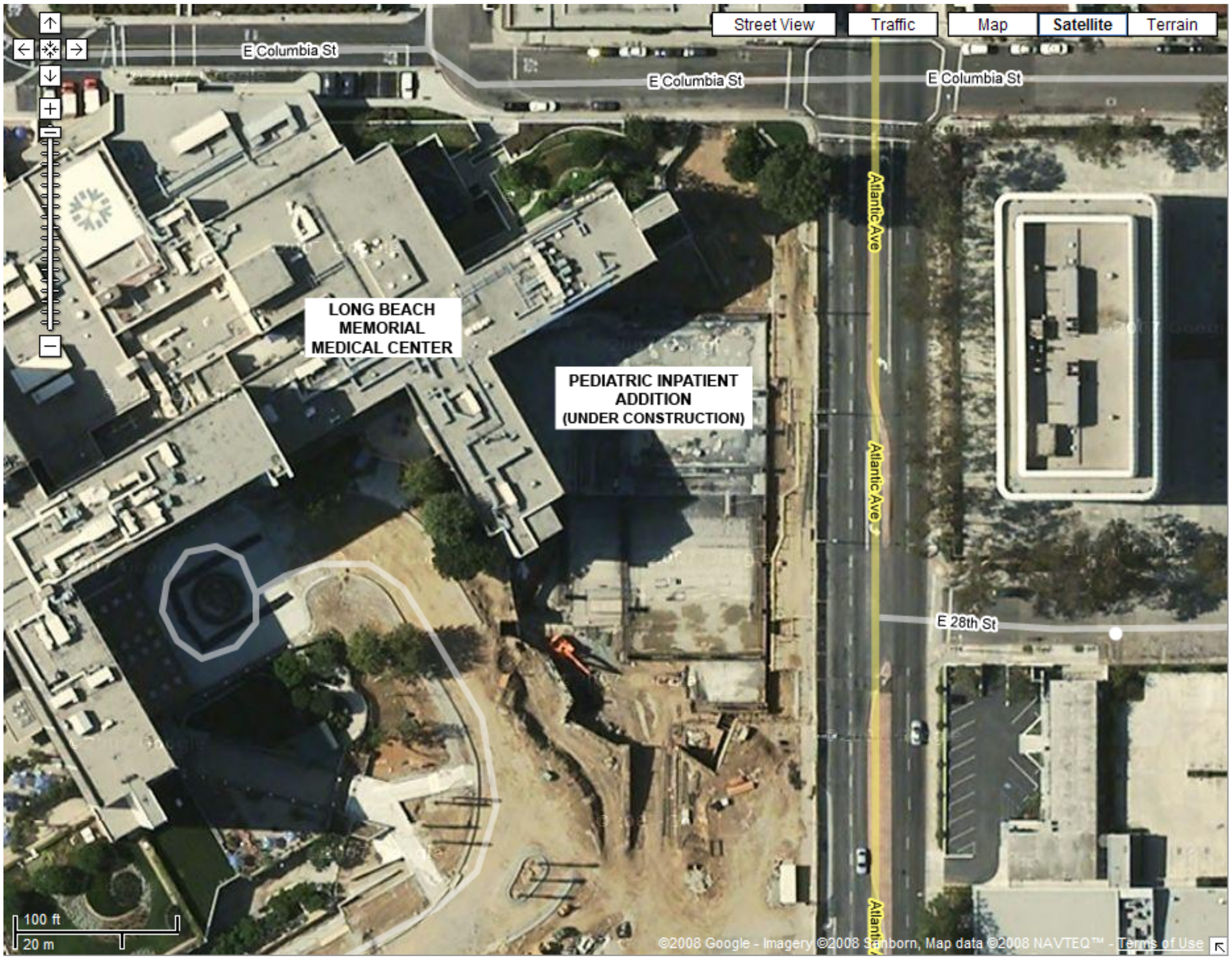

Figure G-1 is a satellite image of the Pediatric Inpatient Addition under construction. The image was obtained using *Google Maps* and is included for reference purposes.