2009

Amanda Cronauer

Thesis Technical Assignment 3

School District Of Haverford Township

Manoa Elementary School

[MECHANICAL SYSTEMS EXISTING CONDITIONS]

Table of Contents

Executive Summary

Technical Report III summarizes the objectives, design considerations, equipment, system design and performance and possible LEED Certification of Manoa Elementary School.

The design of the building systems were based off of various detailed design objectives that are described in this report. These design objectives in conjunction with standards such as ASHRAE Standards 55, 62.1 and 90.1 and the funding available dictated the level of complexity of the mechanical system designed. All requirements used in design were used to develop an energy model to aid in predicting the system performance.

Energy sources utilized by the mechanical systems are electricity and natural gas. The cost of the mechanical systems was documented as $3,486,000 which is approximately 21% of the total project budget. The operation cost of these systems was determined from Technical Report to be $1.23 per square foot which is slightly above the specified ASHRAE value.

When evaluating the compliance of Manoa Elementary School with the U.S. Green Building Council's LEED Certification, it is important to take into account that the building was not initially designed to meet these standards. All prerequisites for the mechanical systems detailed in LEED-NC are already met by the design of the building therefore it is possible to attain a certification.

Design Objectives

Architecture

The design of Manoa Elementary School had very specific architectural and system design objectives. The building site was 3.1 acres of a 10 acre community sports complex located in a Philadelphia streetcar suburb. The design of the school required four classrooms for each grade level, kindergarten through fifth grade. This requirement along with the objective to maximize the amount of usable athletic field space resulted in a three story classroom wing constructed at a height which did not exceed local zoning ordinances. The utilization of the cafeteria as both a stage area and a sub divisible large group instructional area created a spatially efficient building footprint. To further minimize the building's impact on the neighborhood the building envelope utilizes a mixture of reflective zinc colored metal panels which decrease the apparent mass of the building by allowing it to assume the color of the surrounding environment.

Structural

Structural design objectives utilized were to minimize cost and construction duration. A reinforced masonry bearing and pre-cast concrete plank structural system were utilized for the classroom wing which also limited the overall height of the building to meet the zoning requirement of 30 feet.

Sustainability

Cost effective and environmentally protective sustainability strategies were incorporated into the architectural and systems design. Sustainable materials and finishes such as bamboo wainscot and acid etched and sealed concrete floors in circulation spaces. To reduce the load on the mechanical systems, sustainable design features such as insulated glass windows and doors, DDC Building Automation System, energy recovery systems, lighting control system which includes occupancy sensors, high efficiency indirect/direct lighting and daylighting were utilized.

Mechanical

The mechanical design objectives for Manoa Elementary School were relatively straight forward. The primary design objective for the HVAC system was to provide adequate heating and cooling to conditioned spaces while complying with ASHRAE Standards 55, 62.1 and 90.1. Another design objective was to control the humidity of spaces in order to decrease mold and mildew growth and improve the indoor air quality of the space.

Design Factors

Site

The location of the building in the heart of a residential community and within the center of a community sports complex provided many issues for the design. One of the main design concerns was maximizing the amount of athletic field space available for the community. This was achieved by utilizing a subsurface storm water detention system, hard surface playground that doubles as event parking and the efficient building layout described in the architectural objectives above. Noise generated by the mechanical systems was another issue of concern. Great effort was made in the design process to minimize the impact of noise generated by the mechanical systems to the surrounding community.

Cost

Manoa Elementary School is one of five elementary schools in the Haverford Township School District. As a public school, all funds for the construction of the new building were obtained through tax dollars or donations. As such, the total cost of the building was limited to the amount allotted by the Pennsylvania Department of Education though taxes and donations.

Outdoor and Indoor Design Conditions

Outdoor air conditions are specified in the ASHRAE Handbook of Fundamentals and are based on location of the site. Weather information for Philadelphia as noted in Table 1 was utilized in the model. Indoor design temperatures were derived from the design engineer's specifications. All interior conditioned spaces were to have the same design temperatures and are also included in the table below.

Table 1: Design Indoor and Outdoor Air Conditions

Design Temperatures	
ASHRAE 0.4% Cooling Dry Bulb	92.7 ˚F
ASHRAE 0.4% Cooling Wet Bulb	75.6 ˚F
ASHRAE 99.6% Heating Dry Bulb	11.6 ˚F
Indoor Cooling Dry Bulb	75 ˚F
Indoor Heating Dry Bulb	70 ˚F

Design Ventilation Requirements

Design ventilation requirements were calculated using ASHRAE Standard 62.1. A detailed procedure of the calculation method can be found in Technical Report I and a summary of the results is included below and in Table 2. The majority of the air handling units meets the ventilation requirements; however AHU-1 and AHU-4 do not. AHU-1 serves the lobby and half of the classroom wing while AHU-4 serves the multipurpose room. The discrepancies between the required and designed ventilation rates for these systems are caused by a lack of information from the designer of the space occupancies. For spaces where specific information about the occupancy was not shown in the design documents, zone population values calculated from Standard 62.1 were used, despite being unrealistically high.

Table 2: Design vs. Calculated Ventilation Requirements

Compliance Summary				
	Calculated Outdoor Air	Design Supply Air Flow	Design Minimum Outdoor Air	ASHRAE 62.1 Compliance
AHU-1	**8051 cfm**	**20395 cfm**	**7000 cfm**	**No**
AHU-2	7250 cfm	20750 cfm	8000 cfm	Yes
AHU-3	2565 cfm	13600 cfm	5300 cfm	Yes
AHU-4	**5192 cfm**	**5800 cfm**	**3000 cfm**	**No**
AHU-5	3579 cfm	8090 cfm	4500 cfm	Yes

Summary of Major Equipment

Manoa Elementary School was designed to utilize several different mechanical system types. This was accomplished due to the fact that it houses several different types of spaces. These systems include four rooftop air handling units with energy recovery systems, one indoor air handling unit, a make-up air unit, 5 split system packaged rooftop air handling units and two duel fuel boilers. Two of the rooftop air handling units are variable volume outdoor air units and serve Wing A as shown in Figure 1. The other two rooftop air handling units in conjunction with the indoor air handling unit are constant volume systems that condition the classroom, office, gymnasium and kitchen spaces of Wing B which can be seen in Figure 2. The make-up air unit serves the kitchen and is a constant volume system that serves to replace the air exhausted from the space. The five air-cooled ductless split system units are two speed constant volume units that serve to condition the electrical and data distribution rooms in the Classroom Wing A.

Figure 1: Wing A AHU Distribution Schematic

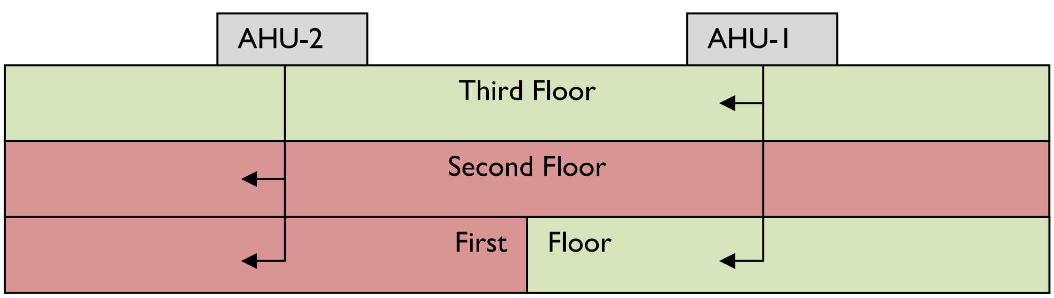
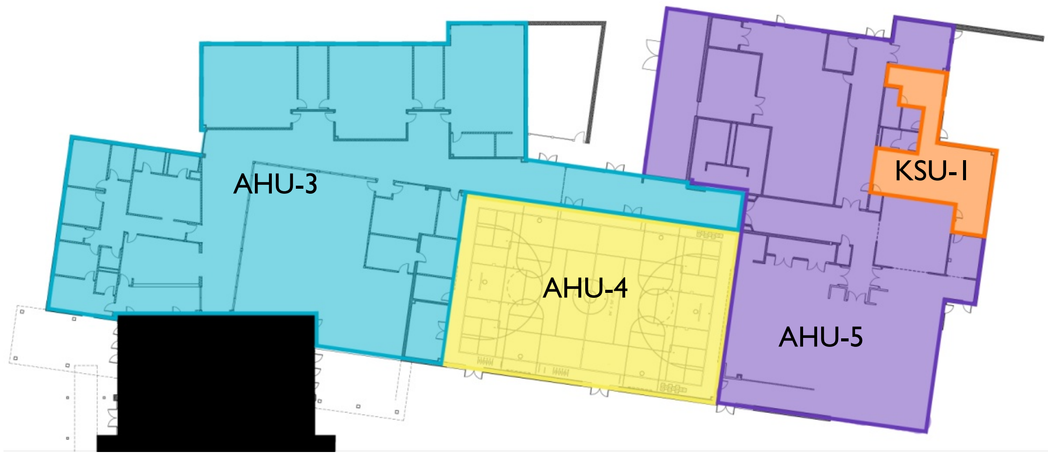


Figure 2: Wing B AHU Distribution



Equipment Schedules

Equipment schedules summarizing major HVAC equipment can be found in Appendix A.

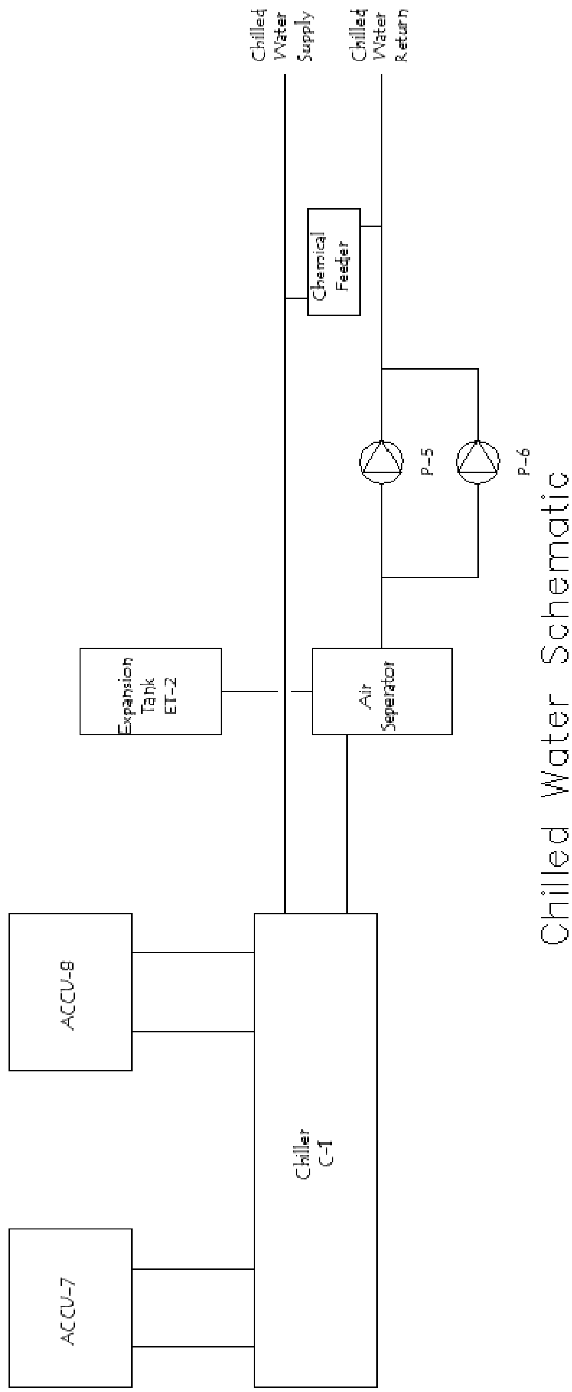
Mechanical System First Cost

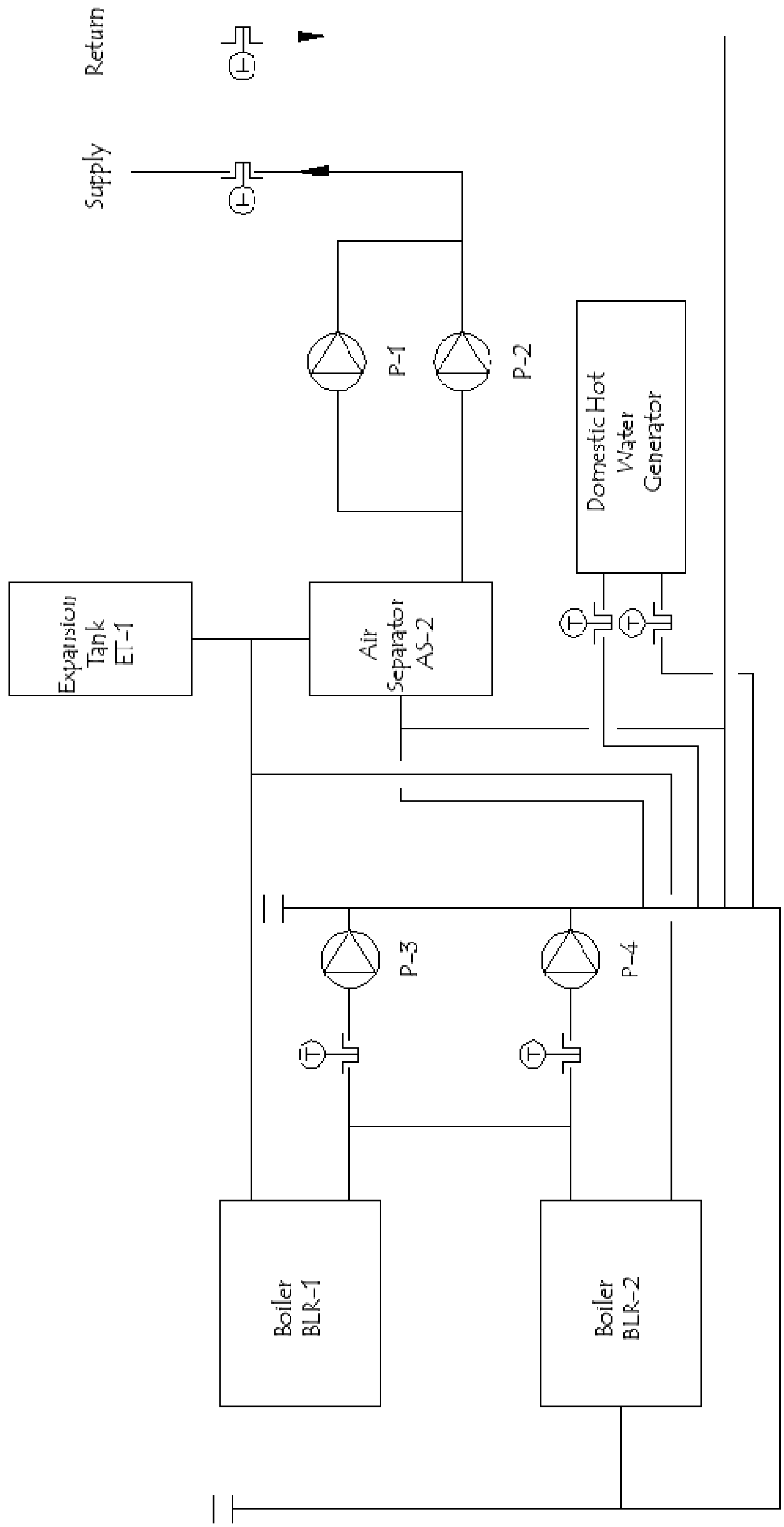
A breakdown of the mechanical system first cost from the design documents is included below in Table 3.

Table 3: Mechanical System First Cost

Mechanical System First Cost			
	HVAC	Plumbing	Total
Cost	$ 2,724,000	$ 762,000	$ 3,486,000
Cost per Square Foot	$ 31.91	$ 8.93	$ 40.84
% of Budget	16.40%	4.59%	20.99%

Schematic Drawings of Mechanical Systems





Hot Water System Schematic

System Operation Description

AHU-1, AHU-2 and AHU-3 all follow the same sequence of operation. These air handling units operate in the following control modes based on time of year and time of day: Summer Occupied, Summer Unoccupied, School Year Occupied, School Year Unoccupied, and Stand-by. In order for the spaces to reach their occupied setpoints the air handling units are programmed to begin operating before the occupants arrive. The units serve variable air volume boxes and are therefore equipped with variable frequency drives to modulate the supply fan speed in order to maintain the static pressure above the minimum 1.3" of water. The system return fans operate in unison with the supply fans and are also equipped with variable frequency drives that operate simultaneously with the supply fan variable frequency drive. A fixed supply air temperature of 55˚F for cooling and 75˚F for heating maintains the temperature of the spaces served at 72˚F for cooling and 70˚F for heating. An air side economizer is used to maintain a setpoint of 2˚F less than the supply air temperature and is enabled when the outside air temperature falls below 70˚F, the outside air enthalpy is less than 25 BTU/lb, the outside air temperature is less than the return air temperature, the outside air enthalpy is less than the return air enthalpy and the supply fan status is on. The economizer is programmed to close when the freezestat is on or when the supply fan is no longer operating. These air handling units are also equipped with energy recovery ventilators. These ventilators as well as their supply and exhaust fans are enabled when the air handling units are in occupied mode. The speed of the when is controlled to maintain a supply air temperature based off of outdoor air temperature.

AHU-4 which serves the multipurpose room is designed to maintain an occupied temperature of 74˚F during occupied mode and 85˚F during unoccupied mode whenever cooling and 70˚F and 55˚F whenever heating. This system is designed to optimize the starting of the unit by minimizing the unoccupied warm-up or cool-down periods while maintaining comfortable thermal conditions for occupants. The constant volume supply fan is programmed to operate whenever the unit is running. An air side economizer is designed to operate whenever the outside air temperature is less than 65˚F, the outside air enthalpy is less than 22 BTU/lb, the outside air temperature is less than the return air temperature, the outside air enthalpy is less than the return air enthalpy and the supply fan status is on. The economizer will shut down when the freezestat is on or the supply fan is no longer running.

AHU-5 is designed to maintain a temperature of 74˚F during occupied mode and 85˚F during unoccupied mode whenever cooling and 70˚F and 55˚F whenever heating. This system is designed to optimize the starting of the unit by minimizing the unoccupied warm-up or cool-down periods while maintaining comfortable thermal conditions for occupants. The supply and return air fans are programmed to run whenever the unit is in operation. The return fan variable frequency drive will decrease the return airflow when exhaust fans are in use. An air-side economizer is used to maintain a setpoint of 2˚F less than the zone cooling temperature. The economizer is designed to operate when the outside air temperature is less than 65˚F, the outside air enthalpy is less than 22 BTU/lb, the outside air enthalpy is less than the return air enthalpy, and the supply air fan is operating. The economizer shall be disabled when the freezestat is on or the supply air fan is not operating.

Design Heating and Cooling Loads

Technical Report II details the procedure used to estimate the cooling and heating loads for Manoa Elementary School. Table 4 shows the results of this analysis along with the designer's calculations.

Table 4: Modeled Results versus Designed System

Modeled vs Designed						
		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5
Cooling sf/ton	Modeled	373.70	426.83	330.40	63.43	129.80
	Designed	336.31	272.86	228.49	171.62	170.73
Cooling Load tons	Modeled	64.40	51.10	38.20	85.20	51.50
	Designed	71.58	81.50	55.17	31.50	39.17
Supply Air cfm/sf	Modeled	0.67	0.61	0.44	2.33	1.39
	Designed	0.73	0.92	1.07	1.48	2.18
Ventilation Air cfm/sf	Modeled	0.33	0.33	0.23	2.33	0.93
	Designed	0.29	0.36	0.42	0.55	0.75

Great effort was put into modeling as accurately as possible, however several discrepancies exist between the design system and the model. The major discrepancies seen in the table above occur in AHU-4 and AHU-5. Further analysis of the model inputs revealed that the space occupancies calculated using ASHRAE Standard 62.1 were drastically larger than the amount that would ever be in the space at any given time. For instance, Standard 62.1 calculated 629 people to be the zone population of the multipurpose room which is almost the total school population. In the event of a school assembly, the partition between the multipurpose room and the cafeteria is retracted meaning the air handling equipment will never service the entire population. Also, this occupant load is modeled using the schedule outlined in Technical Report II which is unreasonable for such a large population. An additional analysis was run using more reasonable zone populations to determine the magnitude of error caused by population alone. The results are summarized in Table 5 below:

Table 5: Alternate Analysis

Zone Population Adjustments			
		62.1	Adjustment
AHU-4	Multipurpose Room	629	150
AHU-5	Serving	57	10
	Kitchen	82	20
	Dishwash	15	2

Modeled vs Designed			
		AHU-4	AHU-5
Cooling sf/ton	Modeled	194.86	172.75
	Designed	171.62	170.73
Cooling Load tons	Modeled	27.70	38.70
	Designed	31.50	39.17
Supply Air cfm/sf	Modeled	0.95	0.79
	Designed	1.48	2.18
Ventilation Air cfm/sf	Modeled	0.55	0.56
	Designed	0.55	0.75

It can be seen that these population values result in less error between the designed and modeled systems; therefore this result has been used for the remaining analysis detailed for this report. Additional sources for error in the systems can be caused by the generic schedules used instead of the actual room schedules. For example, it is very unlikely that both music classrooms will be used at once or for the entire day as dictated by the schedule detailed in Table 6 which would cause the modeled cooling load to be higher than the design. Other sources of discrepancy are the use of ASHRAE 62.1 values for zone population to be used instead of actual information about the number of people in each space, which as seen above can cause a large margin of error in system design as well as the assumption of values for the miscellaneous loads which could be significantly larger than what was modeled.

Site Energy Sources

The current mechanical systems of Manoa Elementary School utilize electricity as the primary fuel for cooling systems and a combination of natural gas and diesel fuel oil for the heating systems. The boiler functions primarily on natural gas. However, the District takes full advantage of a significant cost savings by agreeing to curtail usage during peak natural gas demand. Therefore, by transferring to duel oil during peak demand periods, the District purchases their natural gas at a significantly lower rate. Due to limitations in the modeling software, the energy analysis performed for Technical Report II used only natural gas boilers. A detailed breakdown of electricity and natural gas rates from Technical Report II along with #2 Fuel Oil rates is included below in Table 6. Other possible energy sources for the site could be district heating or cooling if such services were offered in the area.

Table 6: Site Utility Rates

Utility Rates				
	Supplier	Price		Units
Electricity	PECO Electric Company	$	0.07	per kWh per month for the first 300 kWh
		$	0.06	per kWh per month for 301 to 1200 kWh
		$	0.05	per kWh per month for remaining kWh
		$	6.21	per kW per month
Natural Gas	PECO	$	25.00	per month fixed distribution charge
		$	3.78	per Mcf per month for the first 200 Mcf
		$	2.64	per Mcf per month for the remaining Mcf
#2 Fuel Oil	Pennsylvania	$	2.64	per gallon

Annual Energy Use

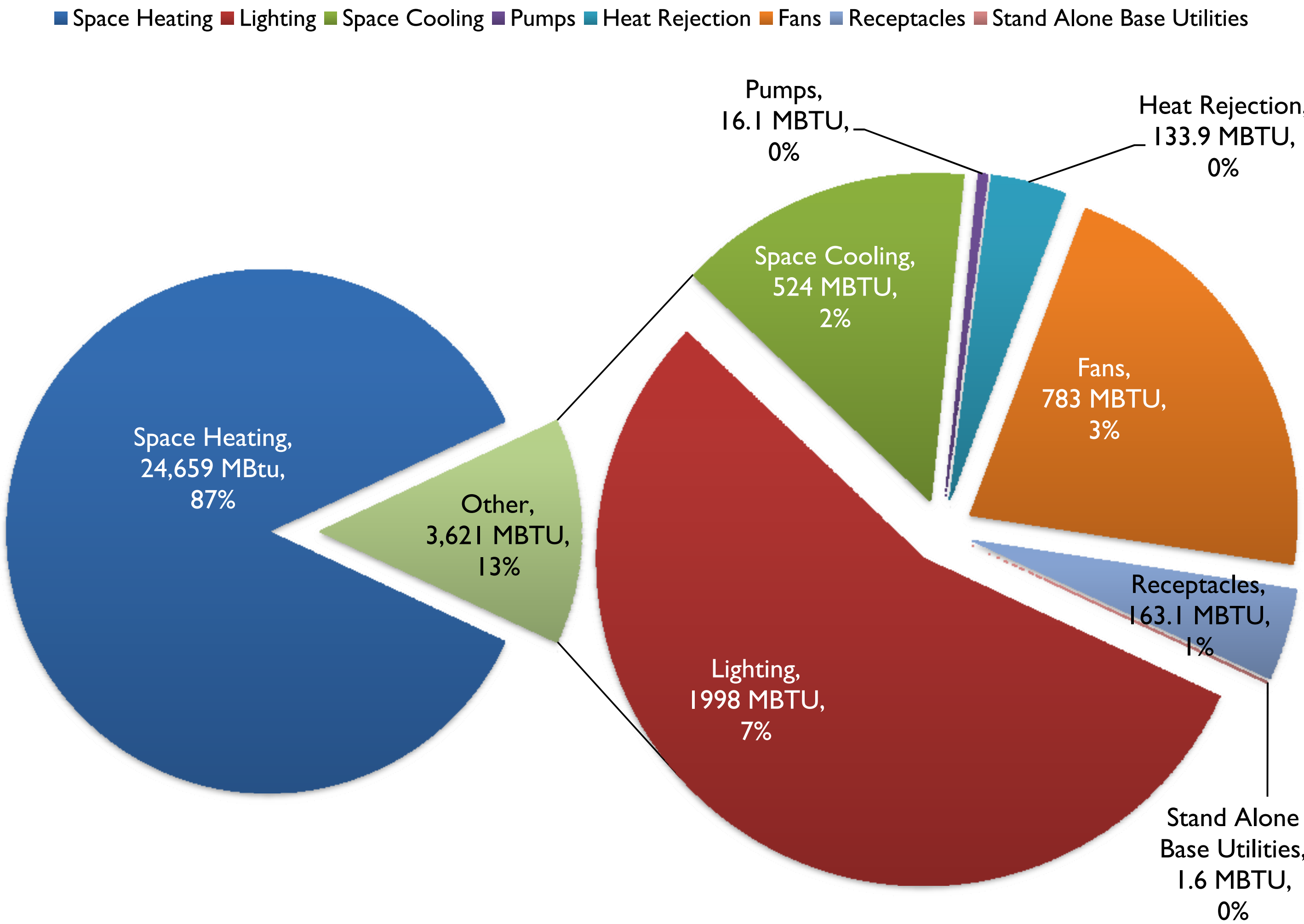
Design Engineer Energy Analysis

Manoa Elementary School was not designed to be a LEED Certified project, therefore an energy analysis was not necessary or in the project budget.

Modeled Energy Analysis

Total Energy Consumption: As modeled, Manoa Elementary School consumes a total of 1,055,152 kWh and 446 kW from the power company and 224,819 therms of natural gas per year. A breakdown of energy use per category is shown below in Figure 3.

Figure 3: Annual Energy Consumption by Category



Total Energy Cost: The total annual energy cost of Manoa Elementary School is $87,337 or approximately $1.23 per square foot which is comparable to the value listed is ASHRAE Handbook of Applications. Table 4 in Chapter 35 of this handbook gives a reference value of $1.09 for the 50th percentile. The data used by the authors of the handbook are from 2003 and are obviously outdated.

Monthly Energy Consumption and Cost: A month by month analysis is also useful when looking for areas of energy savings. Figure 4 shows the monthly combined usage of natural gas and electricity. From this figure it is obvious that during the summer months electric consumption increases because air conditioning is utilized and consumption of natural gas consumption increases during the winter months when heating is required. Figure 5 shows each utilities contribution to the monthly utility bills. The same relationship for heating and cooling described above is also indicated here. The figures clearly show that space heating controls both energy consumption and monthly utility costs and therefore energy saving measures should be focused here. A more efficient heating system design and further analysis of the model is necessary to determine what energy saving measures would be most effective.

Figure 4: Monthly Combined Natural Gas and Electric Consumption

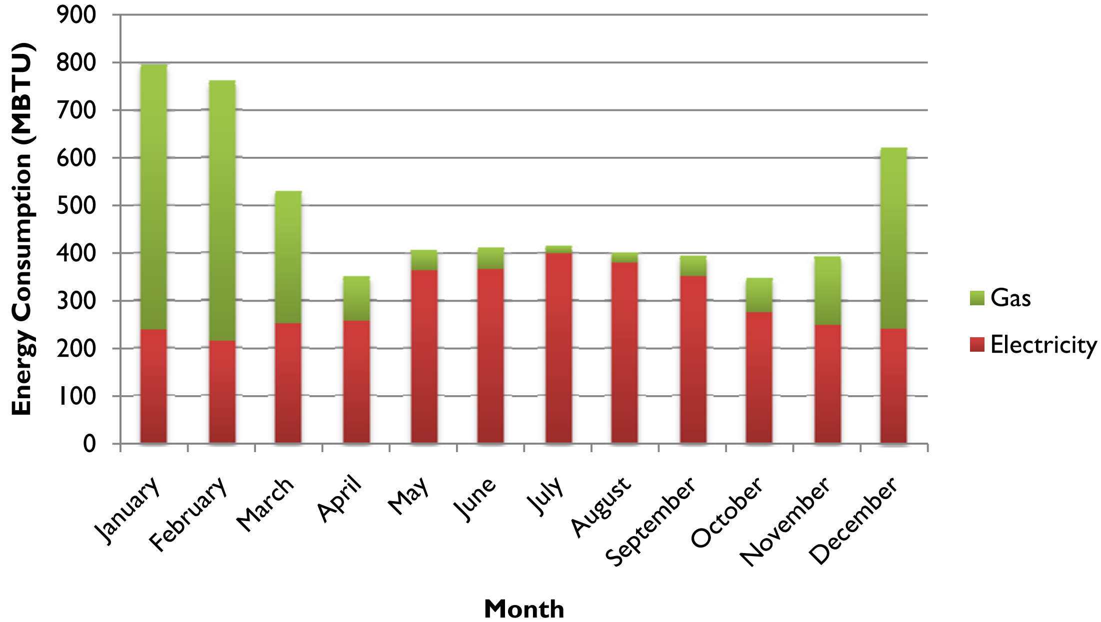
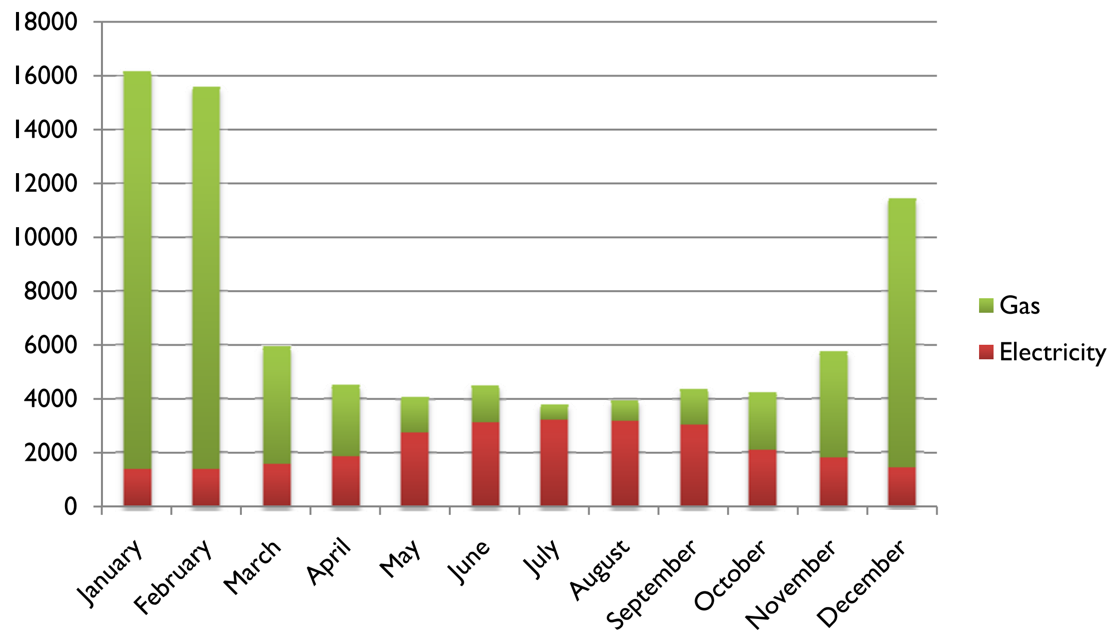


Figure 5: Monthly Combined Natural Gas and Electric Cost



Metered Values

Accurate monthly metered values for utilities are not currently available due to the fact that the systems are still undergoing final adjustments and due to the recent occupancy of the building.

LEED NC Rating

LEED is a rating system launched by the U.S. Green Building Council that defines and measures how "green" a building is. This rating system is broken down into different requirements based off of different types of Construction. For the purpose of this analysis, LEED for New Construction was used to analyze the performance of Manoa Elementary School. This rating method is subdivided into seven categories, two of which are pertinent to the mechanical systems and a preliminary analysis is described below.

Energy and Atmosphere

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems

In order to achieve certification by the U.S. Green Building Council, all requirements of this prerequisite must be met. Manoa Elementary School will hire a commissioning authority with the appropriate experience to lead, review and oversee the completion of the commissioning process. The commissioning process includes reviewing the design documents verifying clarity and completeness and developing and incorporating commissioning requirements into these documents, developing and implementing a commissioning plan, verifying the installation and performance of commissioned systems and completing a summary commissioning report.

EA Prerequisite 2: Minimum Energy Performance

To determine the compliance with this prerequisite Option 1: Whole Building Energy Simulation was used and a base system meeting the requirements of ASHRAE 90.1 2007 Appendix G must be compared to the designed system. In order to meet the prerequisite, a 10% energy savings must be documented for the design scenario as compared to the base case. The energy model described in Technical Report II was compared to the base case. A preliminary analysis of compliance showed a 26.68% designed energy savings. This value far surpasses the requirement for this prerequisite and the model should be further analyzed to determine its accuracy.

EA Prerequisite 3: Fundamental Refrigerant Management

All requirements of this prerequisite must be met in order to obtain certification. The air handling units at Manoa Elementary School were designed to utilize either R-22 or R-134a as a refrigerant. Both of these refrigerants are halocarbons, not chlorofluorocarbons therefore the requirements of this prerequisite are met.

EA Credit 1: Optimize Energy Performance

Credits for this section are awarded based on further improving the energy savings described in EA Prerequisite 2. Currently, with the energy savings described above Manoa Elementary School would be awarded 8 points towards LEED certification for their mechanical system design.

EA Credit 2: On-site Renewable Energy

As designed, Manoa Elementary School does not utilize any on-site renewable energy sources such as solar, wind or geothermal and therefore does not earn any points for certification.

EA Credit 3: Enhanced Commissioning

This credit awards points for additional commissioning services beyond what is required for EA Prerequisite 1. Manoa Elementary School was not designed with the intent of achieving LEED Certification therefore no additional commissioning services were incorporated into the design and receives no points for this credit.

EA Credit 4: Enhanced Refrigerant Management

The intent of this credit is to reward buildings that reduce their emissions and in turn reduce the depletion of the ozone layer and also to promote early compliance with the Montreal Protocol. This credit defines a calculation method which determines a maximum threshold for the combined contributions to ozone depletion and global warming potential. Compliance with this credit is determined by analyzing the impact per ton of the systems using the before mentioned calculation method.

EA Credit 5: Measurement and Verification

No plan for measurement and verification was implemented because Manoa Elementary School was not designed to achieve LEED Certification and therefore does not meet the requirements of this credit.

EA Credit 6: Green Power

The requirements of this standard dictate that the school board enters into a two year renewable energy contract where 35% of the electricity purchased is generated by renewable resources. No such contract has been established with PECO Energy Company therefore no credit can be awarded for compliance.

Indoor Environmental Quality

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance

This prerequisite requires that the building ventilation systems and other indoor air quality factors comply with Sections 4 through 7 of ASHRAE Standard 62.1 2007. Technical Report I details the compliance of the mechanical systems with this standard. Manoa Elementary School meets the requirements of this prerequisite and therefore can be considered for LEED Certification.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Smoking in the school and on all school grounds is prohibited by law. Because of this, Manoa Elementary School meets the requirements of this prerequisite.

IEQ Credit 1: Outdoor Air Delivery Monitoring

All air handling units are configured so that which in occupied mode, a controller measures the return air and outdoor air CO_2 levels and modulates the outdoor air damper in order to maintain a return CO_2 setpoint of 500 PPM greater than the outdoor air CO_2 setpoint. Also, alarms have been provided to engage the Building Automation System when the return air CO_2 concentration is greater than 1200 PPM. This operating sequence meets the requirements of this credit.

IEQ Credit 2: Increased Ventilation

Compliance with this credit requires a 30% increase in the supplied ventilation air as compared to the minimum described in ASHRAE Standard 62.1 2007. These minimum values were defined in Technical Report I and although some systems were slightly overdesigned, they were not designed with the intention of supplying the excess air required to comply with this credit.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan- During Construction

Detailed information of the compliance with the requirements of this credit was not available from the general contractor, but it is reasonable to assume that there was no detailed indoor air quality management plan for the construction and pre-occupancy phases of building construction with the exception that all volatile and hazardous materials were stored complying with codes. Without more information, credit cannot be awarded for compliance.

IEQ Credit 3.2: Construction Indoor Air Quality Management Plan- Before Occupancy

Completion of construction occurred during the summer when the building was unoccupied. Mechanical systems were run to remove contaminants from the air but with no specific documentation of the method used therefore credit for compliance cannot be awarded.

IEQ Credit 6.2: Controllability of Systems- Thermal Comfort

This credit requires comfort controls to be provided for a minimum of 50% of occupants. As designed, a majority of the variable air volume boxes serve individual classrooms. As such it is possible for Manoa Elementary School to be awarded points for compliance with this credit.

IEQ Credit 7.1: Thermal Comfort- Design

The design engineer utilized ASHRAE Standard 55 when determining the indoor design conditions required for occupant thermal comfort. This meets the requirements of the credit therefore Manoa Elementary School can be awarded points for compliance.

IEQ Credit 7.2: Thermal Comfort- Verification

Although Manoa Elementary School meets Credit 7.1, there is not currently a plan to survey building occupants within 6 to 18 months of occupancy to determine the overall thermal comfort of the occupants therefore credit for compliance cannot be awarded.

Lost Usable Space

Lost usable space was determined to be the available occupied space which is instead used to house mechanical equipment. All air handling units are placed on the roof and ducted downwards to reduce the mechanical floor space and required shaft area. Table 7 below summarizes the lost usable space of the building.

Table 7: Lost Usable Space Summary

Lost Usable Space				
Wing	Level	Lost Space (sf)	Total (sf)	% Lost
Wing A	First	82	16880	0.49%
	Second	112	16880	0.66%
	Third	112	16880	0.66%
Wing B	First	1582	30033	5.27%

Overall System Evaluation

Construction Cost

The construction cost of the mechanical system is 16.4% of the overall project budget. However, the utilization of energy recovery ventilators raises the complexity of the mechanical system. The increase in complexity to save energy does not substantially increase the cost of the mechanical system.

Operating Cost

The operating cost of the system determined from Technical Report II was determined to be $1.23 per square foot. This value is comparable to the value listed is ASHRAE Handbook of Applications. Table 4 in Chapter 35 of this handbook gives a reference value of $1.09 for the 50th percentile. The data used by the authors of the handbook are from 2003 and are obviously outdated.

Space Requirements

Because of the design objective to minimize the building footprint, interior spaces needed to be used for educational purposes, not mechanical spaces. To minimize the impact of the mechanical equipment on the building rooftop air handling units and a mechanical penthouse were utilized. Implementation of other mechanical systems would take up far more floor space than the designed system.

Maintainability

The system requires a relatively knowledgeable maintenance staff in order to keep the system running. The system includes pumps, chillers, boilers and energy recovery units which all need supervision by a qualified staff. Since the air handling units are either on the roof or in the mechanical penthouse, components such as the coils, filters and fans requiring maintenance are easily accessible by the maintenance staff.

Indoor Air Quality Issues

A variable air volume system can create indoor air quality problems. Air delivered to the conditioned spaces is a mixture of the ventilation air and return air. The mixing with the return air can produce issues with the quality of the air distributed to the space. Ironically, another source for a reduction in the quality of air supplied to spaces can occur by the air filtration system. Leakage around the filters due to the inherent nature of filter construction or incorrect installation of the filters significantly reduces the performance of the filter and also reduces the air quality.

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Appendix A: Mechanical Equipment Schedules

Roof Top Air Handling Units

Symbol	Connected System CFM	OA CFM	CFM	Supply Fan Data				Return Fan Data				Exhaust Fan Data						Chilled Water Coil	Pre-Heat Hot Water Coil	Heat Hot Water Coil	Pre-Filter Data		Cartridge Filter Data	
				Drive	RPM	HP	VFD	Drive	RPM	HP	VFD	Symbol	CFM	Drive	RPM	HP	VFD	Total MBH	Total MBH	Total MBH	Efficiency %	MERV	Efficiency %	MERV
AHU-1	17,030	7,000	17,500	Belt	1,215	25	Yes	Belt	883	10	Yes	EF-6	1,500	Belt	1,339	0.5	No	859	633	N/A	30	8	85	13
AHU-2	21,175	8,000	20,500	Belt	1,033	30	Yes	Belt	590	10	Yes	EF-7 EF-13	2,200 1,000	Belt Belt	1,294 1,689	1 0.5	No No	978	725	N/A	30	8	85	13
AHU-3	13,020	5,300	13,500	Belt	1,280	25	Yes	Belt	881	7.5	Yes	EF-10 EF-11	1,850 310	Belt Belt	1,540 1,370	0.8 0.2	No No	662	525	N/A	30	8	85	13
AHU-4	8,000	3,000	8,000	Belt	1,860	20	No	N/a	N/A	N/A	N/A	EF-12	150	Belt	1,623	0.3	No	378	417	N/A	30	8	85	13
AHU-5	8,200	4,500	8,500	Belt	1,966	20	No	Belt	1,397	7.5	Yes	EF-8 EF-9	1,750 815	Belt Belt	1,510 2,350	1 0.5	No No	470	622	266	30	8	85	13

Air-Cooled Ductless Split Systm Units

ACCU Symbol	SSAHU Symbol	Supply @ High CFM	OA CFM	Net Cooling BTUh	ACCU Condenser Fan CFM		ACCU Compressor		System SEER	System EER
					High	Low	Type	LRA		
ACCU-1	SSAHU-1	726	0	18,600	1,000	830	Recip	48	10	9.6
ACCU-2	SSAHU-2	726	0	18,600	1,000	830	Recip	48	10	9.6
ACCU-3	SSAHU-3	726	0	18,600	1,000	830	Recip	48	10	9.6
ACCU-4	SSAHU-4	726	0	18,600	1,000	830	Recip	48	10	9.6
ACCU-5	SSAHU-5	726	0	18,600	1,000	830	Recip	48	10	9.6

Kitchen Make-up Air Unit

Symbol	% Outdoor Air	Supply Fan Data					Gas Furnace Data	Filter Type
		CFM	Drive	RPM	HP	VFD	Output MBH	
KSU-1	100	3880	Belt	1160	3	No	295.8	2" Aluminum Mesh

Chiller

Symbol	GPM	EWT ˚F	LWT ˚F	Compressors				Tons Cooling
				Quantity	Steps Capacity	Type	kW	
C-1	545	54	44	3	11	Screw	255	227

Air-Cooled Condensing Units

Symbol	Condenser Fans			Serves
	HP	RPM	Total CFM	
ACCU-6	1.5	1,140	155,000	C-1 Circuit A
ACCU-7	1.5	1,140	124,000	C-1 Circuit B

Boilers

Symbol	Input MBH	Gross Output MBH	EWT ˚F	LWT ˚F	Boiler HP
BLR-1	2,668	2,103	150	180	62.8
BLR-2	2,668	2,103	150	180	62.8

Pumps											
Pump No	Type	System	Operation	Max BHP	Motor HP	RPM	VFD	Operating Conditions		Impeller Diameter
P-1	Floor Mounted	HWS/R	Duty	13.6	15	1750	Yes	GPM	320	10.0"
								Feet Head	90	
								Efficiency	75	
P-2	Floor Mounted	HWS/R	Standby	13.6	15	1750	Yes	GPM	320	10.0"
								Feet Head	90	
								Efficiency	75	
P-3	In-Line	BLR-1	Duty	2.46	3	1750	No	GPM	210	6.5"
								Feet Head	30	
								Efficiency	71	
P-4	In-Line	BLR-2	Duty	2.46	3	1750	No	GPM	210	6.5"
								Feet Head	30	
								Efficiency	71	
P-5	Floor Mounted	CHS/R	Duty	18.2	20	1750	No	GPM	545	10.375"
								Feet Head	90	
								Efficiency	80	
P-6	Floor Mounted	CHS/R	Standby	18.2	20	1750	No	GPM	545	10.375"
								Feet Head	90	
								Efficiency	80	
P-7	In-Line	Domestic Hot Water Heater	Duty	0.98	1	1750	No	GPM	100	5.375"
								Feet Head	20	
								Efficiency	57	
P-8	In-Line	Domestic Hot Water Heater	Standby	0.98	1	1750	No	GPM	100	5.375"
								Feet Head	20	
								Efficiency	57	
P-9	In-Line	AHU-1 HWS/R	Duty	0.24	0.25	1725	No	GPM	35	4"
								Feet Head	12	
								Efficiency	51	
P-10	In-Line	AHU-2 HWS/R	Duty	0.2	0.25	1725	No	GPM	29	4.625"
								Feet Head	12	
								Efficiency	45	
P-11	In-Line	AHU-3 HWS/R	Duty	0.3	0.33	1725	No	GPM	35	4.375"
								Feet Head	15	
								Efficiency	52	
P-12	In-Line	AHU-4 HWS/R	Duty	0.19	0.25	1725	No	GPM	28	4.5"
								Feet Head	12	
								Efficiency	45	
P-13	In-Line	AHU-5 HWS/R	Duty	0.33	0.33	1725	No	GPM	42	5.25"
								Feet Head	15	
								Efficiency	54	