Final Report

Charles E. Smith Center Renovation

Washington, DC

Paul Hallowell

Adviser: Treado

Mechanical Option

7 April 2010

Charles E. Smith Center Renovation

Washington, DC

Project Team

Owner:
The George Washington University
Architect: Gensler
Structural:
Spiegel Zamecnick & Shah Inc
MEP:
Summer Consultants, Inc
Fire Protection:
The Protection Engineering Group
Civil:
Christopher Consultants

Building Information

Size: 104,280 SF

Stories:
3 Stories with a Basement

Total Cost: $43 M

Schedule: Fall 2008 to Fall 2010

Project Delivery:
Design, Bid, Build

Architectural

This newly renovated arena was designed to maximize efficiency as well as space for improved aesthetics and circulation. There is also a brand new façade being placed on the street facing portion of the building which will be covered in a glass paneling system so that they can project profiles of images to the passerby's of the street.

Mechanical

The facility is equipped with 2 cooling towers and 12 AHU's in order to satisfy the requirements of containing an arena, natatorium, fitness center, and offices. Hot water is used for the heating aspect of the arena. Some of the more intensive rooms such as the fitness rooms and arena have also incorporated desiccant wheel systems in order to dehumidify these spaces.

Structural

The arena is supported with a 5" thick reinforced concrete slab foundation and floors 1 through 3 mostly supported with 8" posttensioned concrete slabs and 3 1/2" concrete on metal decking supported by structural steel framing. The roof of the arena is supported by precast concrete tees that run into concrete girders and columns.

Lighting

Throughout the building in most of the spaces excluding the gymnasium and natatorium, they have incorporated the use of fluorescent lights and LEDs to keep energy costs down while maximizing efficiency. In the main spaces of the gymnasium and the natatorium they used metal halide lamps to illuminate the large spaces.

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Acknowledgements

I would like to thank everyone that has helped me through this experience. I could not have accomplished this if it were not for my friends, family, colleagues, and mentors supporting me throughout. Special thanks to the following:

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The George Washington University

Amy Argasinski

Executive Summary

The Charles E. Smith Center is a 4 story athletic facility located in Washington, DC. It plays host to the GWU basketball teams and water polo team as well as hosts other offices and locker rooms for various other GWU athletic teams. As the facility is over 30 years old, the main goal of this renovation project was to update the entire facility to both function better and become more aesthetically pleasing so it may become a landmark for GWU athletics.

The mechanical systems of the Smith Center have a variety specific design criteria because of the many types of occupancies. The first floor is almost completely supplied by 100% outside air because of the ventilation requirements while the upper floors use a both VAV and CAV AHUs to supply the spaces. All major heating is supplied by four natural gas powered condensing boilers. Cooling is provided by two air cooled cooling towers supplying two chillers.

In order to try to increase the efficiency of the facility, multiple alternative systems were considered. A combined heat and power plant and an energy recovery wheel were both considered to enhance the Smith Center's mechanical systems. Along with the mechanical alternatives, a look into the effects these systems would have on both the electrical system and the construction process were investigated.

When analyzed, the CHP system had a much lower life cycle cost compared to the current boilers even though the initial investment was greater. The energy recovery wheel resulted in both a lower life cycle cost as well as a lower initial cost.

CHP could be a valuable alternative to the boilers with a low payback period if the initial cost is able to be overcome. Implementing the energy recovery wheel would also be valuable to help reduce energy use and cost of the Smith Center

Introduction

The Charles E. Smith Center is a four story athletic facility for the George Washington University located in downtown Washington, DC. The facility is over 104,000SF and is home to most of the sports teams of the GWU. Included in the facility are locker rooms, athletic courts, basketball arena, natatorium, offices, conference rooms, and suites. It is currently under major construction which has been ongoing since fall of 2008 and is expected to be completed this year. At the completion of this project the Charles E. Smith Center aims to bring the over 30 year old building up to date in both function and design.

Existing Conditions

Design Objectives and Requirements

All HVAC systems are designed to provide proper ventilation and maintain occupant comfort levels for temperature, relative humidity, air quality, etc. However, each system is designed for a specific building with different objectives and requirements depending on building type and location that makes each system unique.

The Charles E. Smith Center had a main objective of being sustainable while still maintaining budget. To accomplish this in the design process a number of objectives were set. Energy efficient equipment was selected as well as building automation and commissioning in order to reduce operating costs and maintain that all systems continue to work as designed. Other requirements that were set forth were to comply with ASHRAE Std. 62.1 for ventilation and ASHRAE Std. 55 for comfort. Another option that was considered was to purchase “green power” as a way to further increase the sustainability.

Design Conditions

The Charles E. Smith Center was designed for the area of Washington, DC. Table 1 shows the indoor and outdoor conditions that were used as stated in the design documents.

Table 1 - Design Conditions

	Indoor Design (°F)		Outdoor Design (°F)
	Cond. Spaces	Uncond. Spaces	
Summer	78	85	95 DB, 78 WB
Winter	70	65	7

Current Systems

Design Loads and Ventilation Requirements

The designed heating, cooling and ventilation loads and requirements are summarized in Table 2 below and compared with the computed loads from the Trane TRACE model. The design cooling load is slightly larger than the computed load and the designed heating load is slightly less than the computed load. A possible explanation for this could be that the gym was modeled as empty which could lower the cooling load required for such a large area as well as raise the heating load when there is no additional load from people. The airflow for supply and ventilation was considerably less for the designed loads which could also be a result of modeling the gym as empty. This does correlate however since almost the entire first floor is 100% OA because of the types of rooms contained there. This would greatly increase the overall airflow without the gymnasium being considered.

Table 2 - Design vs Computed Block Loads

	Cooling (SF/ton)	Heating (BTUh/SF)	Supply Air (CFM/SF)	Ventilation (CFM/SF)
Design Load	378.8	49.0	0.56	0.63
Modeled Load	328.7	57.3	0.84	0.92

Annual Energy Use

The Charles E. Smith Center relies on electric for its main utility. The cooling towers, chillers, pumps, fans, lights, and miscellaneous space heating and receptacles are all powered using supplied electricity. The only aspect of the facility that does not rely entirely on electricity are the four boilers which use natural gas.

Table 3 below shows the breakdown of the total energy each system uses. As the table shows, approximately 80% of the buildings energy consumption is supplied by electricity. The auxiliary equipment including the supply fans and pumps account for 26% of the buildings total energy consumption. This may be a result of the high amounts of OA being supplied to the first floor because of the high latent loads and exhaust requirements.

The primary heating system with the combined consumption of the electric and gas accounts for the next largest load on the building. This could result from the gym being modeled as empty which would increase the heating load and energy consumption. The consumed cooling energy is seen as a rather low percentage of the buildings total energy consumption, which is typical for this type of building.

Table 3 - Annual System Energy Consumption

`	Electrical (kWh)	Natural Gas (kBtu)	Total Building Energy (kBtu/yr)	Building Pecentage (%)
Primary Heating	58,862	1,793,677	1,994,531	24.3
Primary Cooling	350,898	-	1,197,369	14.6
Auxiliary	624,453	-	2,130,820	26.0
Lighting	360,920	-	1,231,567	15.0
Receptacle	421,219	-	1,637,325	20.1
			8,191,612	**100**

Energy Sources and Rates

The Charles E. Smith Center has two main sources of energy that it uses, electricity and natural gas. To acquire a rate structure, the annual average of the District of Columbia was taken from the US Energy and Information Administration as of October 2010 and shown in Table 4 below.

Table 4 - Energy Prices

	Price	Units
Electric	0.101	$/kWh
Natural Gas	12.99	$/MBtu

Major Equipment

The facilities heating loads are serviced by four natural gas fired boilers and the cooling loads are serviced by two cooling towers which supply two water-cooled chillers.

These units provide the AHU's and the Air Conditioners with the necessary heating and cooling requirements. The Air Conditioners use an energy recovery system and provide the pool as well as all of the blower coils with their load requirements. Tables 5 through 9 below show in detail this equipment.

Table 5 - Boilers

	Type	Capacity (MBH)	GPM	Supply Temp. (°F)
B-1	Condensing	2000	172	180
B-2	Condensing	2000	172	180
B-3	Condensing	2000	172	180
B-4	Condensing	2000	172	180

Table 6 - Chillers

	Type	Capacity (Tons)	GPM	Condenser Supply Temp. (°F)
CH-1	Screw Compressor	275	375	85
CH-2	Screw Compressor	275	375	85

Table 7 - Air Conditioners

	Type	Capacity (CFM)	Cooling Load (BTU/Hr)	Heating Load (BTU/Hr)
AC-1	DOAS	8900	386260	248250
AC-2	DOAS	19000	671500	563864

Table 8 - Air Handling Units

	Capacity (CFM)	Cooling Coil		Heating Coil	
		EAT (°F)	Water Flow (GPM)	EAT (°F)	Water Flow (GPM)
AHU-3	8800	79	40.3	49	6.2
AHU-4	5800	87.6	48	30	20.2
AHU-5	2030	91.8	21.6	16	10.8
AHU-6	2900	88.8	21	25	9.7
AHU-7	1800	89	16.7	24	14.1
AHU-8	27000	86	220	36	62
AHU-9	27000	86	220	36	62
AHU-10	27000	86	220	36	62
AHU-11	14000	86	114	36	10
AHU-12	1200	77	26.5	60	2.6

Table 9 - Blower Coils

	Capacity (CFM)	Preheat (GPM)	Cooling (GPM)
BC-1	1780	4.3	7.4
BC-2	1300	3.5	5.5
BC-3	1000	2.6	5.7
BC-4	400	1.0	1.2
BC-5	1050	2.3	5.3
BC-6	800	2.1	2.8
BC-7	1240	2.6	5.0
BC-8	900	2.0	2.4
BC-9	415	2.8	4.1

Air Side Operation

The Smith Center facility is comprised of mostly VAV systems. All of the AHU's are single zone VAV and contain both heating and cooling coils which are interconnected with the chilled water and hot water systems. The AC's are 100% OA and provide the natatorium area and the blower coils which have their own chilled water and hot water connections just as the AHU's.

Water Side Operation

The hot water is supplied by four gas fired boilers with two variable frequency drive pumps, one being redundant. The hot water distributes itself to the facility and are on differential pressure controls to maintain the desired set points.

The chilled water is supplied by two water cooled chillers in series with two variable frequency drive pumps. The condensing water system configures the chillers in parallel to equalize the difference between the cooling towers.

Schematics

Figures 1, 2, and 3 below show the condensing water system, chilled water system, and hot water system respectively.

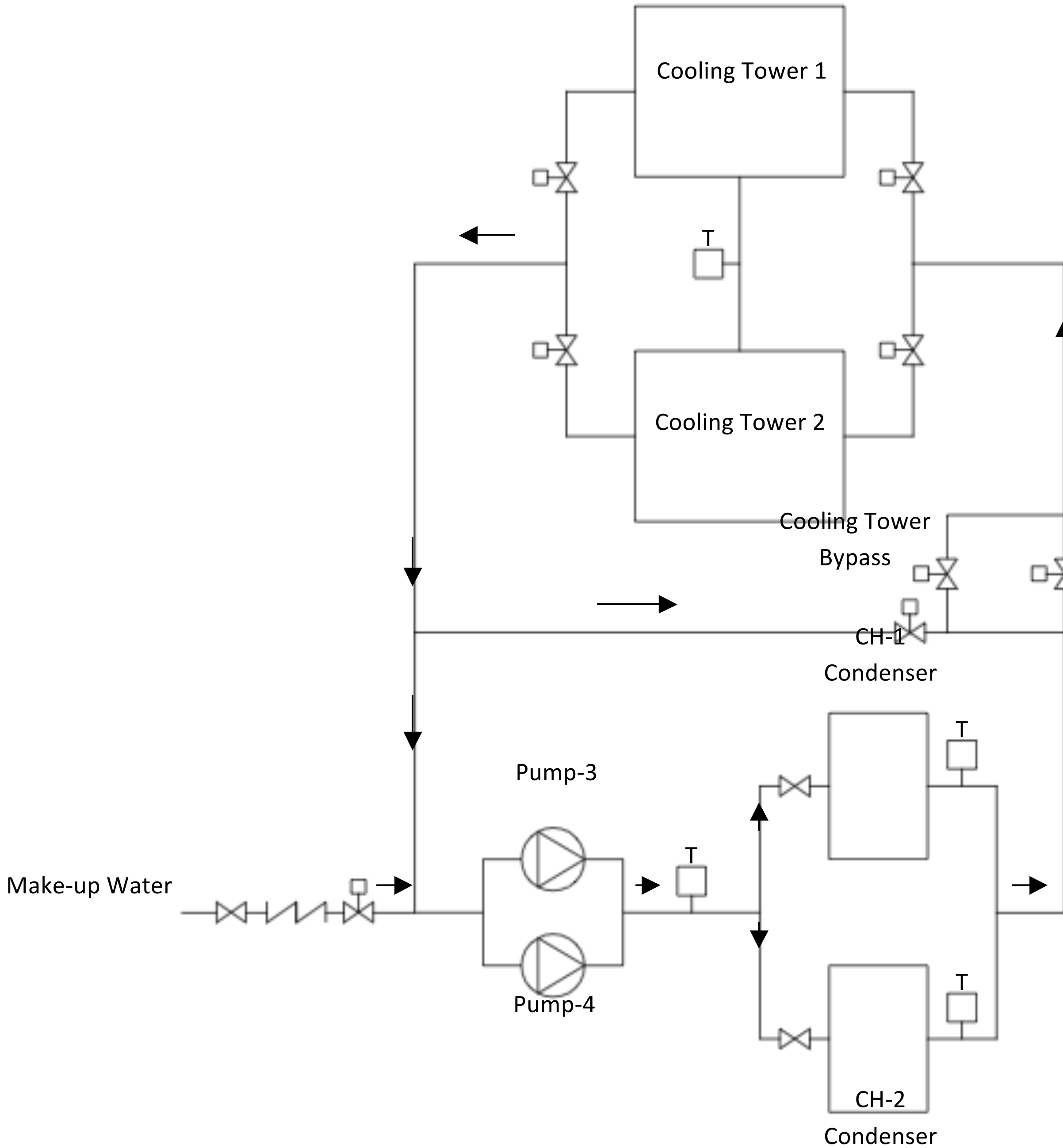

Figure 1 - Condensing Water

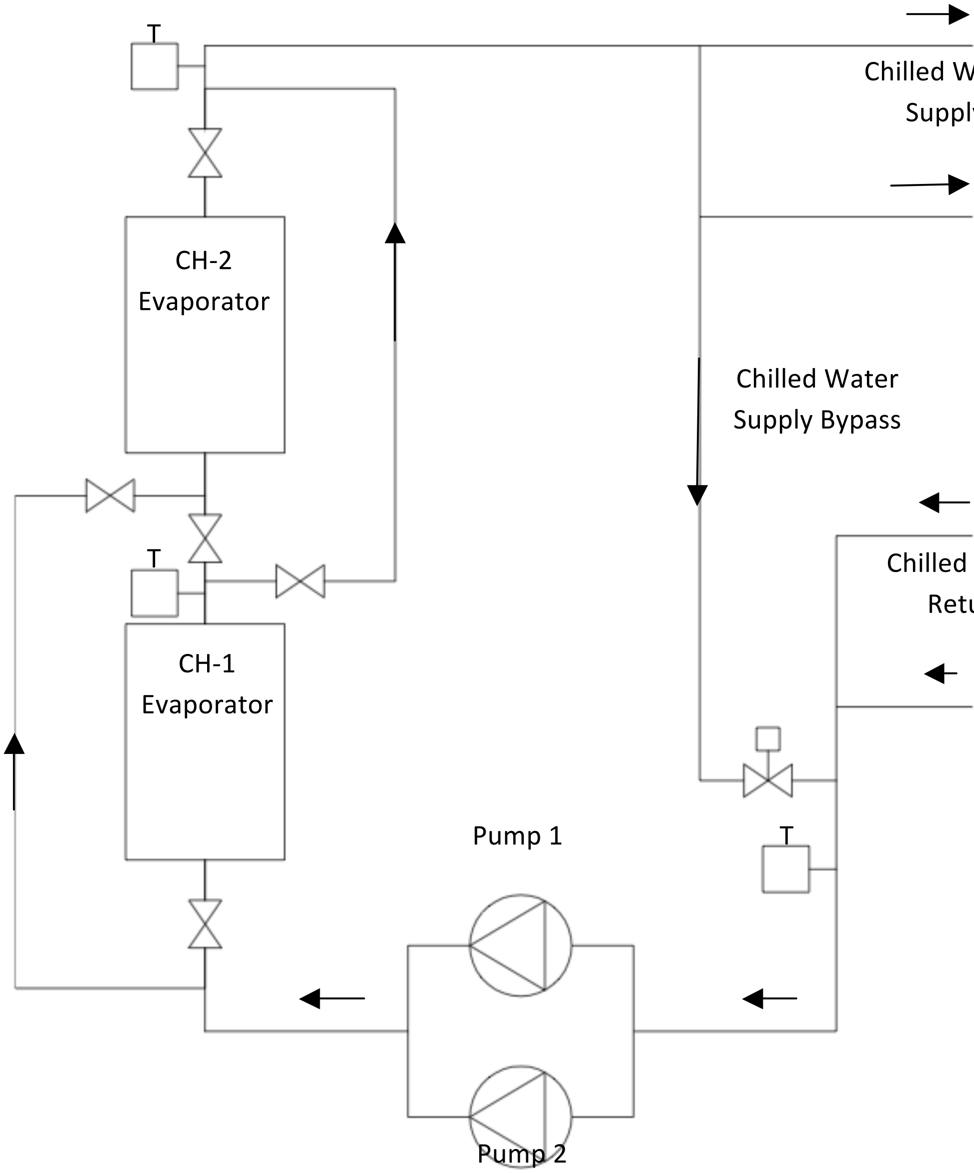

Figure 2 - Chilled Water

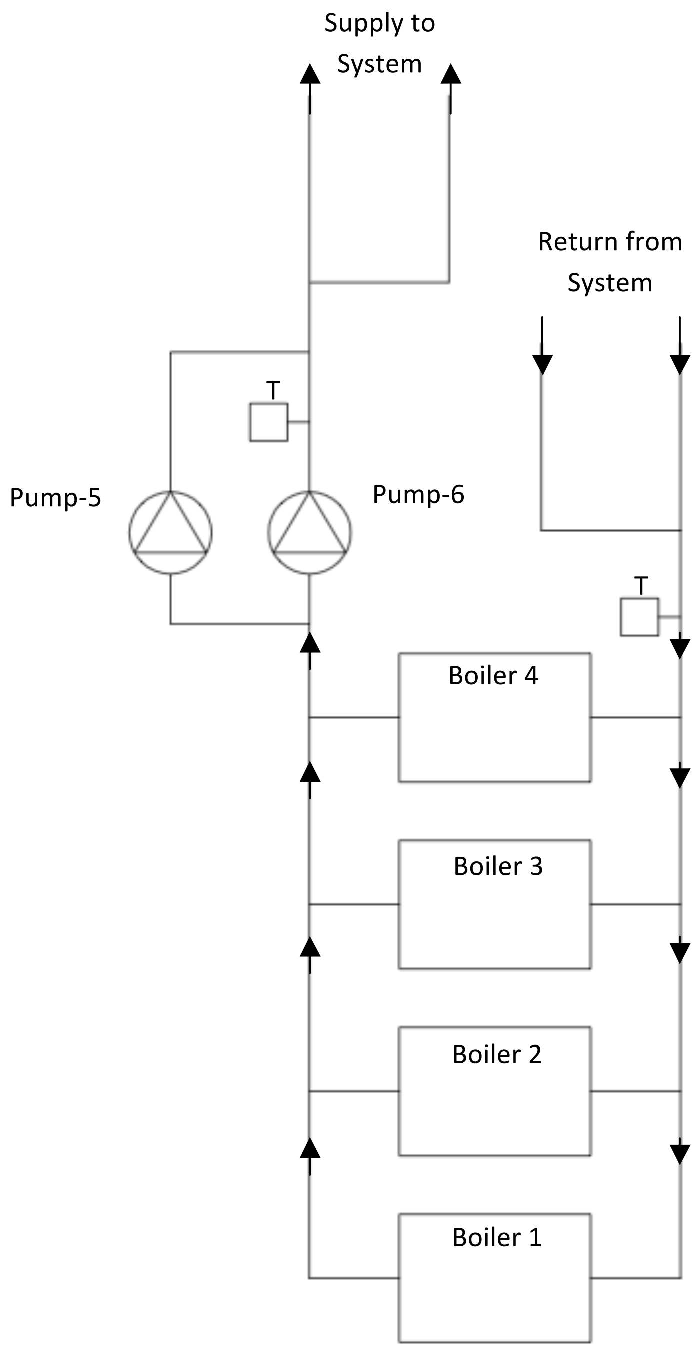

Figure 3 - Hot Water

Mechanical System First Cost

The information on the first cost of the system was unavailable. Since this was a renovation, some of the equipment that was replaced recently(within the past few years) such as the cooling towers and chillers were not replaced under this project and should help keep the first cost down.

LEED Evaluation

The Charles E. Smith Center has been designed to be LEED certified using the LEED NC v2.2 rating system. This report will analyze the Smith Center using the LEED v3 for New Buildings and Major Renovations.

Proposed Systems

The current systems set in place were designed to work well for this facility and the owner. There are always alternatives that could be implemented to help achieve different goals. A few possible system alterations or replacements will be looked into with the associated changes.

Combined Heat and Power (CHP)

Currently the heating system uses boilers and electrical resistance. Combined heat and power is another type of system that integrates the production of energy and heat on location. CHP is similar to a typical power plant except that instead of discarding the heat that is produced, the heat is captured and used to heat the facility. This produces both electric energy as well as heat.

With CHP, the electric dependency should be reduced along with the production of heat which can be used for the hot water. A CHP system does occupy more space so there will have to be other changes that will be looked into to accommodate such a system. The system also has a greater first cost but should be offset by the added usage savings.

Energy Recovery Wheel

The first floor of the building currently uses an energy recovery system because of the high percentage of OA required. Floors two and three do not require 100% OA but they do require between 50% and 70% OA. This gives a lot of wasted heat that could be recovered. A similar system to that of the first floor with one air conditioner and subsequent blower coils would enable an energy recovery wheel. The energy recovery wheel would be placed between the supply and exhaust and recover the leftover energy from the exhaust air.

The installation of an energy recovery wheel for the additional floors would reduce the amount of heat required. This system would be able to occupy the same amount of space as the current air handling units.

Electrical

With the addition of a combined heat and power plant, there will be an additional electrical supply to the facility. The exploration of this additional supply will be used as an electrical breadth. Ideally, this could drastically reduce the outside energy use required by the Smith Center. The amount of electrical energy generated by the new CHP system could have a large effect on building cost and therefore could offset an increase in space by the CHP system.

Construction Management

To analyze the time and cost of construction of implementing the proposed alternatives, a construction management breadth will be explored. Time is a large factor when it comes to construction which in turn relates to the cost. With a shorter construction period, there will be less labor charges as well as a sooner move in time both of which will reduce overall cost. Because this is used for athletic events and is an existing building, the schedule should take into account the seasons of the respected sports.

Combined Heat and Power (CHP)

One of the proposed alternatives that could potentially be useful to the Charles E. Smith Center is CHP. This alternative generates heat and power that can be distributed throughout the facility. There are variables that make CHP more or less effective as well as if it is even possible in certain situations.

In order for the CHP system to be effective and the most efficient, you need to have a relatively flat load profile so that the system can run at its most efficient load. If this is not the case, there are a number of ways this can be altered. Depending on if there is excess heat or electricity produced, you will need some sort of thermal storage or be able to feed electricity back onto the grid. Another aspect that will be analyzed will be if it is feasible to have an additional boiler running in order to reduce the size of the CHP system so to be able to run it at a higher efficiency more often.

Spark Gap

The spark gap is what is used to determine if it is even feasible to investigate a CHP system. It is calculated by taking the difference between the cost of 1 MBTU/hr of electricity and 1 MBTU/hr of natural gas. The greater the difference the more feasible and worth while CHP could be. Table 10 shows the spark gap.

Table 10 - Spark Gap

	Price $/MBtu	Spark Gap
Electric	29.59	$16.6
Natural Gas	12.99	

From Table 10, the spark gap can be seen to be approximately $16.60. This indicates that a CHP system could be a feasible option since the baseline for considering CHP should be above $12. Figure 4 below shows how the prices of the electric and natural gas vary on a month to month basis throughout the year.

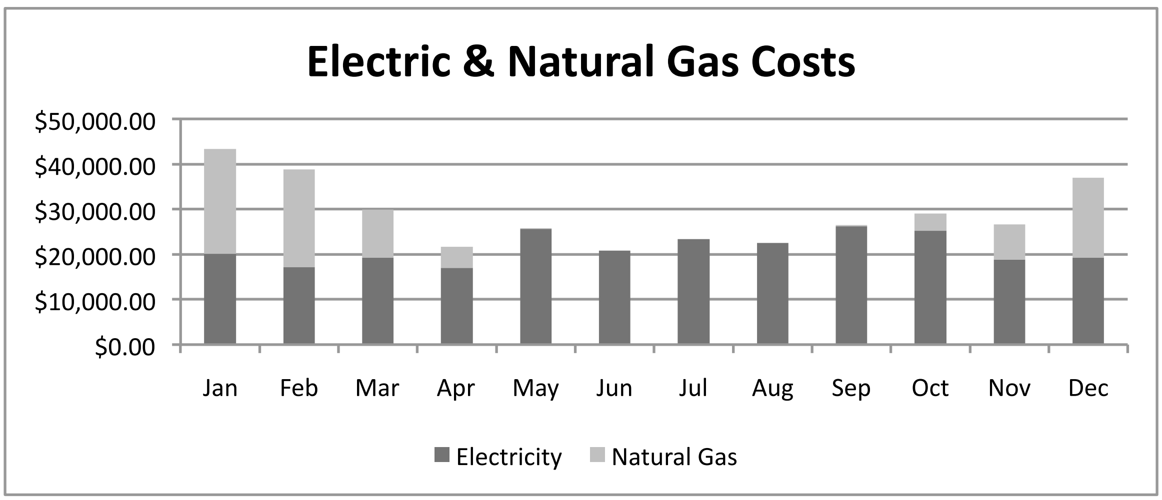

Figure 4 - Monthly Electric and Natural Gas Costs

Current System

In order to properly design a CHP system, the utilities consumption has to be known. This needs to be known in order to properly select and size the prime mover that will be used. Figure 5 below illustrates the yearly consumption of electric and natural gas on a month to month basis of the Smith Center.

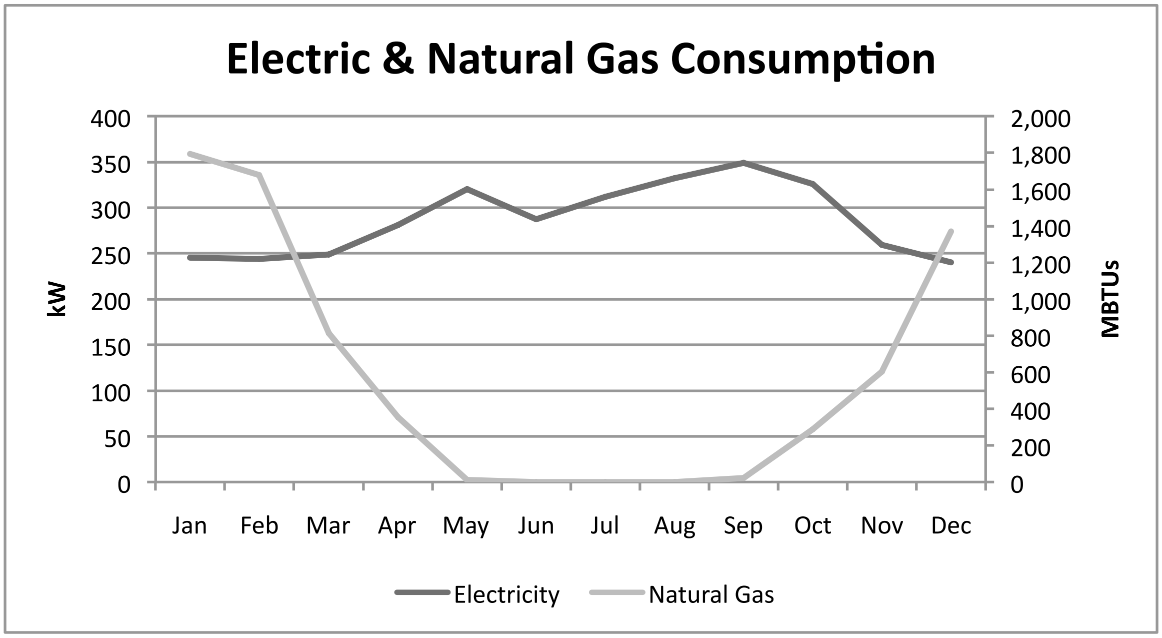

Figure 5 - Monthly Electric and Natural Gas Consumption

From Figure 5 above, it can be seen that the electrical demand is fairly constant with a baseline use of approximately 250 kW and a peak use of 350 kW. This is what will be used to select the prime mover. Also, it shows that the natural gas use is basically non existent during the summer months since its sole use is for heating. This will also be taken into consideration.

Prime Movers

For this analysis there will be multiple prime movers that are examined. When looking for which types of prime movers to select there are multiple factors to consider. Some of these include type of technology, costs (both first cost and operations and maintenance), start up time, emissions, etc. Another consideration should be the Thermal to Electric (T/P) ratio. This is done by taking the ratio of the annual BTUs of natural gas used and the annual BTUs of electric used. Table 11 below illustrates this difference. A general rule of thumb for the T/P ratio is for anything under 1, Internal Combustion engines the preferred choice.

Table 11 - T/P Ratio

	Annual BTUs	T/P Ratio
Electric	2,533,812,400	0.8
Natural Gas	2,033,364,596	

Figures 6 and 7 illustrate the different technologies available with some advantages and disadvantages of each as well as some simple operating characteristics. From Figures 6 and 7, it can be seen that the best options to consider would be an IC engine, microturbine, or fuel cell. Because of the added complexity, very high initial cost, and overall availability of fuel cells, they will not be considered for this analysis.

For the purpose of this analysis, an internal combustion, spark ignited engine was chosen. IC engines are cheaper and easier to maintain than microturbines because of their similarity to a typical car engine. IC engines also can be sized to handle a larger load than microturbines. Another very good aspect of an IC CHP system is that it has an extremely fast start up time of approximately 10 seconds. This would be very good for situations when it might be needed very fast such as in a power outage.

<table>
<tr><th>CHP system</th><th>Advantages</th><th>Disadvantages</th><th>Available sizes</th></tr>
<tr><td>Gas turbine</td><td>High reliability.
Low emissions.
High grade heat available.
No cooling required.</td><td>Require high pressure gas or in-house gas compressor.
Poor efficiency at low loading.
Output falls as ambient temperature rises.</td><td>500 kW to 250 MW</td></tr>
<tr><td>Microturbine</td><td>Small number of moving parts.
Compact size and light weight.
Low emissions.
No cooling required.</td><td>High costs.
Relatively low mechanical efficiency.
Limited to lower temperature cogeneration applications.</td><td>30 kW to 250 kW</td></tr>
<tr><td>Spark ignition (SI) reciprocating engine</td><td rowspan="3">High power efficiency with part-load operational flexibility.
Fast start-up.
Relatively low investment cost.
Can be used in island mode and have good load following capability.
Can be overhauled on site with normal operators.
Operate on low-pressure gas.</td><td rowspan="3">High maintenance costs.
Limited to lower temperature cogeneration applications.
Relatively high air emissions.
Must be cooled even if recovered heat is not used.
High levels of low frequency noise.</td><td>< 5 MW in DG applications</td></tr>
<tr><td rowspan="2">Compression ignition (CI) reciprocating engine (dual fuel pilot ignition)</td><td>High speed (1,200 RPM) ≤4MW</td></tr>
<tr><td>Low speed (102-514 RPM) 4-75 MW</td></tr>
<tr><td>Steam turbine</td><td>High overall efficiency.
Any type of fuel may be used.
Ability to meet more than one site heat grade requirement.
Long working life and high reliability.
Power to heat ratio can be varied.</td><td>Slow start up.
Low power to heat ratio.</td><td>50 kW to 250 MW</td></tr>
<tr><td>Fuel Cells</td><td>Low emissions and low noise.
High efficiency over load range.
Modular design.</td><td>High costs.
Low durability and power density.
Fuels requiring processing unless pure hydrogen is used.</td><td>5 kW to 2 MW</td></tr>
</table>

Source: U.S. Environmental Protection Agency Combined Heat and Power Partnership

Figure 6 - Advantages & Disadvantages of CHP by Technology

Technology	Steam Turbine[1]	Recip. Engine	Gas Turbine	Microturbine	Fuel Cell
Power efficiency (HHV)	15-38%	22-40%	22-36%	18-27%	30-63%
Overall efficiency (HHV)	80%	70-80%	70-75%	65-75%	55-80%
Effective electrical efficiency	75%	70-80%	50-70%	50-70%	55-80%
Typical capacity (MW_e)	0.5-250	0..01-5	0.5-250	0.03-0.25	0.005-2
Typical power to heat ratio	0.1-0.3	0.5-1	0.5-2	0.4-0.7	1-2
Part-load	ok	ok	poor	ok	good
CHP Installed costs ($/kW$_e$)	430-1,100	1,100-2,200	970-1,300 (5-40 MW)	2,400-3,000	5,000-6,500
O&M costs ($/kWh$_e$)	<0.005	0.009-0.022	0.004-0.011	0.012-0.025	0.032-0.038
Availability	near 100%	92-97%	90-98%	90-98%	>95%
Hours to overhauls	>50,000	25,000-50,000	25,000-50,000	20,000-40,000	32,000-64,000
Start-up time	1 hr - 1 day	10 sec	10 min - 1 hr	60 sec	3 hrs - 2 days
Fuel pressure (psig)	n/a	1-45	100-500 (compressor)	50-80 (compressor)	0.5-45
Fuels	all	natural gas, biogas, propane, landfill gas	natural gas, biogas, propane, oil	natural gas, biogas, propane, oil	hydrogen, natural gas, propane, methanol
Noise	high	high	moderate	moderate	low
Uses for thermal output	LP-HP steam	hot water, LP steam	heat, hot water, LP-HP steam	heat, hot water, LP steam	hot water, LP-HP steam
Power Density (kW/m^2)	>100	35-50	20-500	5-70	5-20
NO_x (lb/MMBtu) (not including SCR)	Gas 0.1-.2 Wood 0.2-.5 Coal 0.3-1.2	0.013 rich burn 3-way cat. 0.17 lean burn	0.036-0.05	0.015-0.036	0.0025-.0040
$lb/MWh_{TotalOutput}$ (not including SCR)	Gas 0.4-0.8 Wood 0.9-1.4 Coal 1.2-5.0.	0.06 rich burn 3-way cat. 0.8 lean burn	0.17-0.25	0.08-0.20	0.011-0.016

Source: U.S. Environmental Protection Agency Combined Heat and Power Partnership

Figure 7 - Basic Performance Characteristics of CHP by Technology

Results

While the electrical load of the building peaks at 350 kW, the CHP system was sized at an average load of 300 kW. This was done to maximize the efficiency of the system year round for increased savings. Refer to Figure 8 to see the efficiency as a result of load.

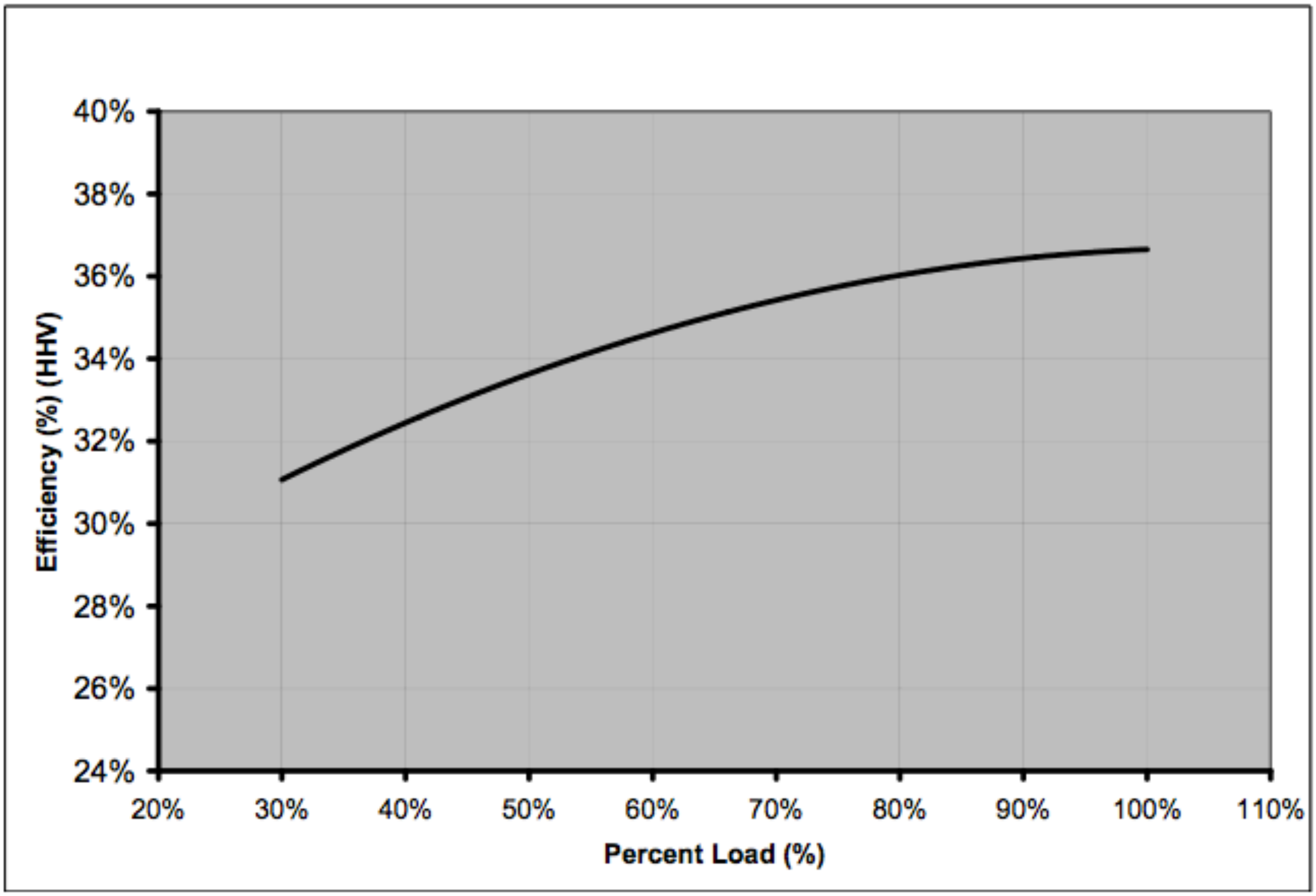

Figure 8 - Reciprocating Engine Part Load Efficiency

This system was not designed to make the Smith Center completely self sufficient but rather to increase the efficiency of the facility and reduce overall costs. At this size, the system should cover the full electrical load approximately 60% of the time. When it provides more than needed useful electricity to the facility it will be fed back into the grid.

After calculating the needed electric supply it was discovered that the CHP system alone did not meet all of the heating needs in the winter months. Since the total heating load was not met with the CHP alone at its current size, it is still necessary to include one of the original condensing boilers to make up this difference. The initial cost of the existing boilers and the proposed CHP system with boiler is shown in Table 12.

Table 12 - System Initial Costs

	Initial Cost	Price Difference
Existing	$230,000	$390,000
w/ CHP	$620,000	

Using the initial costs provided in Table 12 with the utility consumption of both systems, a lifecycle analysis was performed to determine a payback period for the system. This analysis included both electrical and natural gas consumption assuming a flat 3% increase in utility costs each year. The CHP system includes the electric sold back to the utility company as well. From Figure 9 it can be seen that the payback period would be about 5 to 7 years depending on utility rate fluxuations.

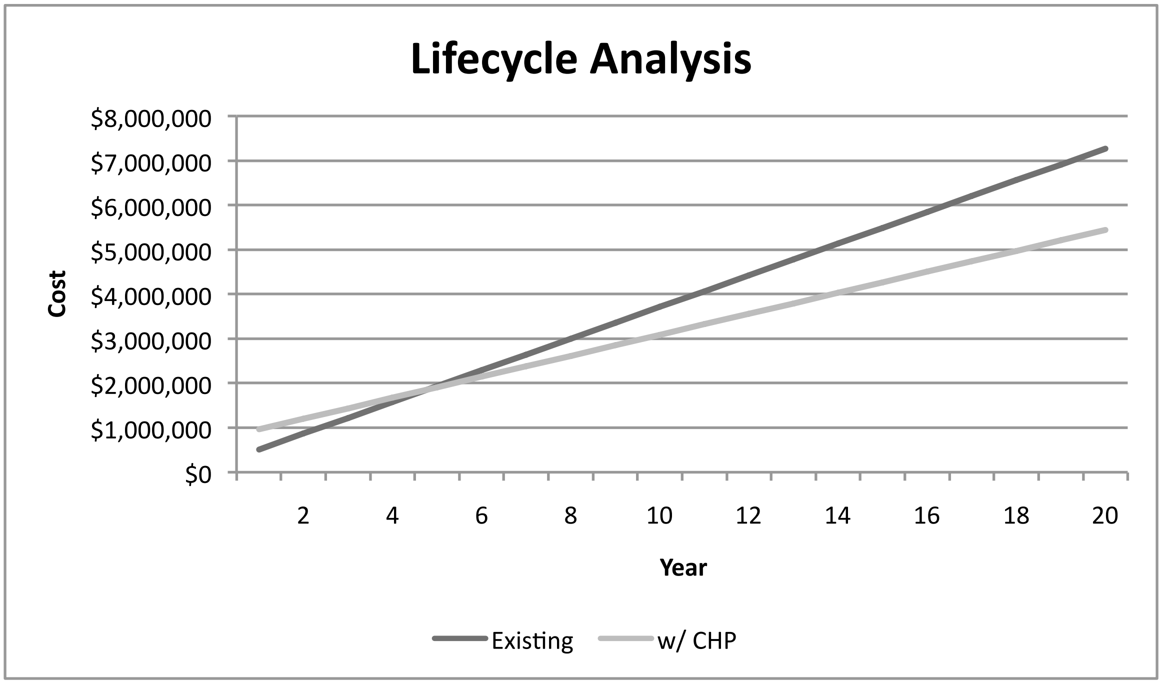

Figure 9 - Lifecycle Analysis

Energy Recovery Wheel

An energy recovery wheel was examined to replace the AHUs in the second floor mechanical room of the Charles E. Smith Center. This was chosen to be a potential alternative because of the higher amounts of OA required for the spaces in which these units serve (about 50% to 70%). By applying this alternative, it would enable the facility to capture some of the energy that would otherwise be discarded to the air.

There are currently four AHUs that would be replaced by a single air conditioning unit with enthalpy wheel and then supplied to the space with smaller blower coils. The single air conditioning unit should be smaller than the four AHUs currently in the mechanical room and the blower coils are able to be mounted in the ceiling to save space. This would enable more workable area in the mechanical room for maintenance or storage.

Equipment Selection

In order to select the proper air conditioning unit it must be known how much air is needed. The individual calculations for these spaces has been calculated in previous reports and the capacity requirements for each AHU is shown below in Table 13.

Table 13 - Air Conditioning Unit Capacity

	Capacity (CFM)
AHU-4	5800
AHU-5	2030
AHU-6	2900
AHU-7	1800
Total	**12530**

Results

In order to stay consistent with the other systems currently in place, a face velocity of 500 FPM was used to calculate a pressure drop of approximately 0.8 FT WG. This information was put into the existing TRACE model and used to determine the possible energy savings that this alternative could have on the facility. This resulted in an average energy savings of about 4%. This is illustrated as the resulting cost savings in Figure 10. Table 14 shows a first cost estimate for the existing AHUs and the proposed Air Conditioning Unit with energy recovery wheel.

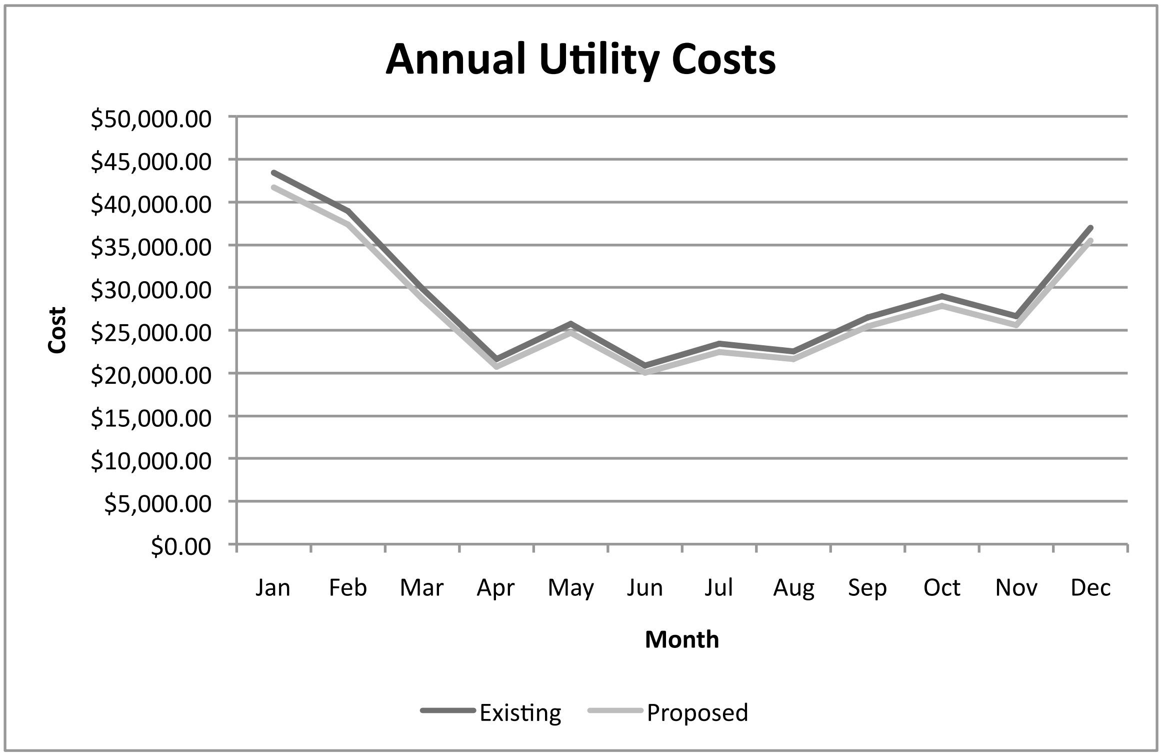

Figure 10 - Annual Utility Costs of Systems

Table 14 - System Initial Costs

	Initial Cost	Price Difference
Existing AHUs	$390,000	-$8,000
ACU	$382,000	

These initial costs include all associated ductwork, piping, and calibration. It should be noted that the proposed system is actually cheaper than the existing AHUs. While the proposed ACU is more expensive than any one of the existing AHUs, the combination of the AHU's together is more than the combination of the ACU and associated blower coils. Figure 11 shows a life cycle cost comparison between the two systems.

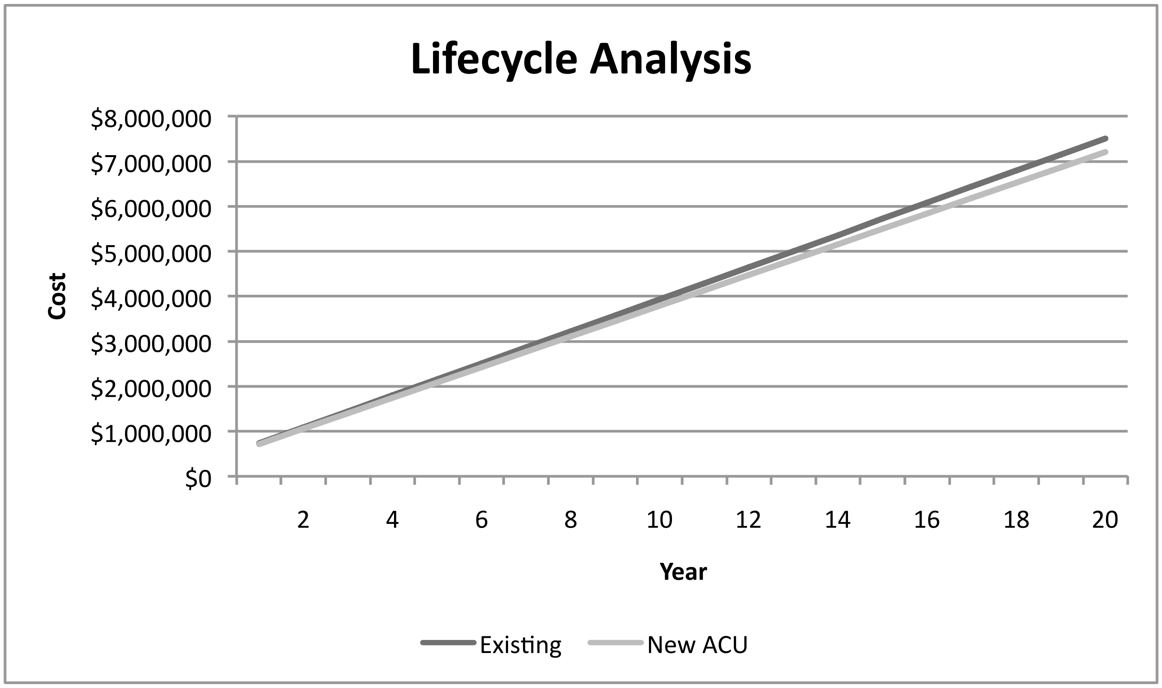

Figure 11 - Lifecycle Analysis

Electrical Breadth

With the installation of a CHP system, the electrical system of the facility must be considered. Because CHP is providing the facility with its own electricity, certain things must be taken into consideration. With connection of the CHP plant to the utility, there must be precautions taken. An additional transformer must be sized to connect the unused electricity produced by the facilities CHP system back into the grid.

Currently the Smith Center has a 150kW backup generator to run the critical systems if there should be a power outage. With the addition of the CHP system, this would no longer be necessary since the new plant would act as a generator if the electric would happen to go out.

Construction Management Breadth

Since time is a very valuable asset, the new schedules of implementing the proposed alternative systems must be analyzed. Currently the construction schedule was designed around the main use of the Smith Center, basketball and water polo. The idea was to have the construction of each phase take place in the off season.

From Figure 12 it can be seen that the CHP system would be implemented in Phase II with the majority of the first floor and main mechanical room. The energy recovery wheel would be constructed during Phase III with the second and third floors and the upper mechanical room.

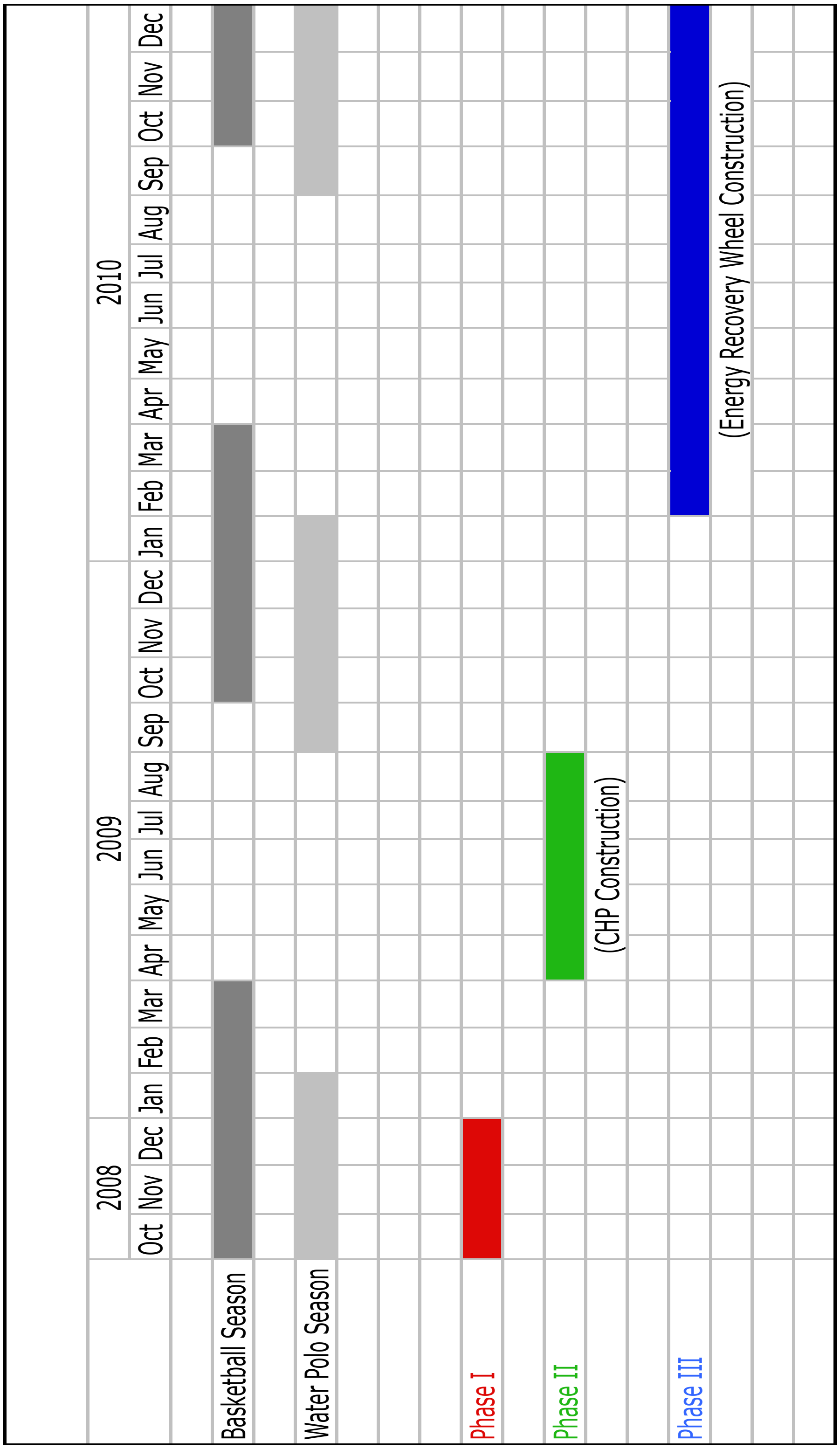

Figure 12 - Construction Schedule

Conclusion/Recomendations

After analyzing the current systems as well as the proposed alternatives, it has been determined that certain systems could work as viable alternatives.

According to this analysis, CHP would be the best alternative with the highest amount of energy and money saved over the course of its lifecycle. There would have to be a desire and ability for a higher initial cost with this system which may or may not be a possibility depending on funding. The payback for this system, 5-7 years is relatively short and should be incentive for applying this option.

Applying the energy recovery wheel in the form of an ACU with blower coils to replace the current AHUs supplying the upper floors is also recommended according to this report. It had a lower initial cost and a lower life cycle cost as well along with the ability to reduce the loads required by the facility.

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