Final Report

Alternative Systems Analysis

04.01.2010

Defense Media Activity Building

Fort George G. Meade

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Architectural Engineering

Mechanical Option

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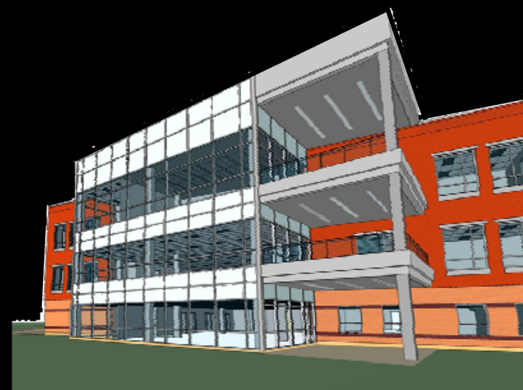
Defense Media Activity

Fort George G. Meade, MD

Project Information:

Size:	185,870 SF
Cost:	$56.2 million
Stories:	3
Delivery Method:	Design-Bid-Build
Construction:	Spring '09 to 09/2011



Project Team:

Owner:	Army Corps of Engineers
Architect:	HOK
Engineers:	HSMM|AECOM
General Contractor:	Hensel Phelps

Mechanical Systems:

- (3) 500 ton water-cooled chillers
- (3) 3,000 MBH gas fired condensing boilers
- The three story part of the building will use (6) AHU's using (2) AHU's per floor
- The remainder of the building will have (10) RTU's located on the roof
- APC Cooling racks are used in the Data Center and constant volume rooftop units are used for Tele-Video Studios

Architecture:

The DMA building is large facility for the US armed forces that was designed to mimic "Georgian" Architecture. It is on track for a LEED Silver rating. Some of the features of the building are; red brick and white trim, symmetrical design, portico with classical columns at the entrance, and "punched" windows.

Electrical/Lighting:

- 3,000 A, 480Y/277 V, 3 phase 4 wire three-sectioned switchboard feeds 480/277V distribution in the building
- Redundant power used from two separate 13.8 KV feeds
- (3) exterior 3,000 KVA 13.8KV-480/277V transformers
- Emergency power provided at two emergency power levels using UPS and an emergency generator
- Energy efficient T8 fluorescent lamps used in most spaces
- Occupancy sensors are implemented for lighting control

Structural:

- DMA uses a steel composite construction with 3" metal decking and 2.5" lightweight concrete
- Typical beam size of W14x22 with a typical girder of W18x35
- The three story part is laterally supported using moment frames while the rest is supported by combination of braced and lateral frames
- Soil Bearing Capacity ranges from 2000psf to 3000psf for walls and spread footings

CPEP SITE: http://www.engr.psu.edu/ae/thesis/portfolios/2010/pvl104

Pavel Likhonin — **Mechanical Option**

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1.0 Executive Summary

The Defense Media Activity (DMA) building is a three story, 186,000 square foot facility designed for the Army Corps of Engineers. This building has a data center, television studios, media centers, offices, and editing suites. The DMA building will operate 24 hours a day which distinguishes it from a typical office building. It is designed to operate with redundancy in mind, as well as efficiency for LEED Certification.

Overall, the mechanical system of the DMA building is well planned out and implemented. The energy usage is kept to a minimum by utilizing efficient equipment. VAV systems combined with high efficiency chillers and boilers are very effective if implemented correctly. The data center uses high efficiency and high density APC cooling racks to take care of the data center loads.

The object of this report is to minimize costs spent on energy consumption, making the building less expensive and more efficient to operate. In order to optimize the building's energy use, several options have been proposed as alternatives. These options are: combined heat and power (CHP), thermal energy storage, CHP with thermal energy storage, and system optimization.

Two different prime movers were analyzed for the implementation in a combined heat and power system. Internal combustion engines were selected as the more economical option. CHP system E showed the best savings as well as the fastest payback. Annual savings from system E were around $368,273 and a simple payback period for this system was calculated to be around 8.8 years. An acoustical analysis was done on CHP systems to see the impact of noise they had on adjacent spaces. An electrical analysis was also performed on the selected CHP system E.

A peak shaving strategy was used to analyze two types of thermal storage systems. Ice storage had a range of results that ranged from negative benefits to very minimal benefits when it came to cost savings. Chilled water storage produced an average yearly savings of around $10,643, which included demand savings and on-peak kWh savings. An initial investment of $173,667 would have to be made for this system. The payback period for the chilled water storage system was around 16.32 years.

The third analysis performed was the integration of a chilled water storage system with a combined heat and power system. When incorporating a chilled water storage system with a CHP system, calculations showed yearly energy cost savings around $11,644. The initial investment for adding a chilled water storage system in was around $123,409. This led to a 10.6 year payback period to justify the additional investment in thermal storage.

The fourth analysis was separated into two sections. Section one dealt with energy cost savings due to a DOAS system as compared to a VAV system. When using DOAS in the DMA building, yearly cost savings from energy usage were around $46,494. Section two introduced a separate chiller for the data center that would run at different temperatures to optimize energy cost savings. Running the chiller at 55˚ F as compared to the original 44˚ F produced a yearly savings of about $28,155. The initial investment of a couple valves, piping and pumps was paid off in less than a year for this option.

CHP system E was recommended by this report. This system showed the largest energy cost savings, the fastest payback period, and a big reduction of the carbon dioxide footprint for the DMA building.

2.0 Existing Conditions

2.1 Introduction

Defense Media Activity is a three story, 186,000 square foot, facility designed for the Army Corps of Engineers. This building has a data center, television studios, media centers, offices, and editing suites. The DMA building will operate 24 hours a day which separates it from a typical office building. It is designed to operate with redundancy in mind, as well as efficiency for LEED Certification.

2.2 Design Objectives

The main design objectives for the DMA building are as follows: meeting the ASHRAE Standards and earning LEED certification as government requirements. Based on these standards, the building must meet energy, ventilation, temperature, and humidity requirements. The design produces an energy efficient building using a conventional Variable Air Volume (VAV) system, high efficiency chillers, cooling towers and boilers to condition the building as well as high density APC cooling racks to take care of the data center loads. However, other design alternatives might provide even better energy performance, although at a greater initial cost.

2.2.1 Site and Budget

The site for the DMA building is located in Fort George G. Meade, Maryland. Fort Meade is one of the largest Army installations in the U.S. It is currently expanding to accommodate the Base Realignment And Closure (BRAC) plan. The current site of the DMA building is located on a golf course. Special storm water permits and wetland waterway permits had to be obtained for site work in order to prevent erosion and provide sediment control. The building was bid and awarded for $56,195,000 - a price that fit within its budget constraints. The building was designed to be energy efficient while keeping budget in mind. The current economic situation certainly aided in keeping the building within the original budget.

2.3 System Design and Equipment Summaries

The majority of the DMA building is conditioned by a VAV system. There are a total of 168 terminal units in the building. These terminal units are connected to six Air Handling Units (AHU's) with two units per floor. The rest of the ventilation is done with nine Roof Top Units. The sizes of AHU's range from about 12,000 CFM to almost 18,000 CFM. RTU's range from 3,200 CFM to almost 23,000 CFM. The AHU's and RTU's can be seen in Table 1.

Table 1: Airflow Rates

Airflow Rates		
Unit	Design Max CFM	Design Min OA
AHU-EG-1	12455	2380
AHU-EG-2	12070	1580
AHU-E1-2	15810	1800
AHU-E1-1	17660	2590
AHU-E2-1	12350	1460
AHU-E2-2	16710	2120
RTU-W1-1	3190	340
RTU-W1-2	9810	2580
RTU-W1-3	12895	3100
RTU-W1-4	14000	1400
RTU-W1-5	9200	480
RTU-W1-6	4700	450
RTU-W1-7	4910	470
RTU-W1-8	15890	4560
RTU-W1-9	22930	1200

The DMA building uses three 500 ton centrifugal chillers that have a COP of 6.1. These chillers can be seen in Table 2. The condenser water is then pumped to the three cooling towers. These cooling towers are double cell induced draft and have a maximum flow rate of 1500 GPM with 25Hp fans. Cooling towers are shown in Table 3. The building is heated by three 3000 MBH natural gas condensing boilers which are 98% efficient. Boiler statistics can be seen in Table 4. One chiller, one boiler, and one cooling tower are on standby in case of failure.

Table 2: Chillers

Chillers											
Chilled Water									Condenser Water		
Unit	Tons	GPM	IPLV kW/ton	75% Load kW/ton	50% Load kW/ton	25% Load kW/ton	L.W.T. (F)	E.W.T (F)	GPM	L.W.T. (F)	E.W.T. (F)
1	500	1000	0.356	0.418	0.304	0.39	45	85	1500	85	95
2	500	1000	0.356	0.418	0.304	0.39	45	85	1500	85	95
3	500	1000	0.356	0.418	0.304	0.39	45	85	1500	85	95

Table 3: Cooling Towers

Cooling Towers				
Unit	GPM	Fan HP	E.W.T.	L.W.T
1	1500	25	95	85
2	1500	25	95	85
3	1500	25	95	85

Table 4: Boilers

Boilers				
Unit	Type	Capacity (MBH)	GPM	Supply Temp (F)
1	Condensing	3000	150	180
2	Condensing	3000	150	180
3	Condensing	3000	150	180

The chilled water side of the mechanical system uses a primary/secondary flow system with two sets of pumps. One set is dedicated to pumping water through the chiller, and the second set distributes the chilled water throughout the building. Pumps are a major component of the mechanical system. Most of the pumps used in the DMA building are Variable Frequency Drive except for the primary side of the chilled water system.

Each set of pumps for the chilled water and hot water systems consists of three Variable Frequency Drive pumps. Two pumps are dedicated for the heat exchangers. Chilled water pumps are 1000 GPM each for the primary loop and 2000 GPM for the secondary. The condenser water pumps are 1500 GPM and the hot water pumps are 150 GPM for the primary and 300 GPM for secondary. The rest of the pumps can be seen in Table 5.

Table 5: Pumps

Pumps				
Description	**Capacity**	**Head (ft)**	**HP**	**RPM**
Primary Chilled Water	1000	40	15	1750
Primary Chilled Water	1000	40	15	1750
Primary Chilled Water	1000	40	15	1750
Secondary Chilled Water	2000	60	40	1750
Secondary Chilled Water	2000	60	40	1750
Secondary Chilled Water	1000	60	20	1750
Condenser Water	1500	50	30	1750
Condenser Water	1500	50	30	1750
Condenser Water	1500	50	30	1750
Primary Hot Water	150	40	3	1750
Primary Hot Water	150	40	3	1750
Primary Hot Water	150	40	3	1750
Secondary Hot Water	300	60	10	1750
Secondary Hot Water	300	60	10	1750
Secondary Hot Water	150	60	7.5	1750
Heat Exchanger	1000	25	10	1150
Heat Exchanger	1500	55	30	1770

A 2000 KW 480/277V emergency generator is used as a backup to provide 48-hour stand-by power to all life safety power loads as well as a backup for the data center. The system is also backed up by 20-minute UPS at a technical and critical level. [1]

[1] HSMM|AECOM. 2007. *DMA Final Design Analysis.* HSMM|AECOM, Washington, DC.

2.4 Design Air Conditions

Fort George Meade is located just outside of Baltimore, MD., so the design conditions for Baltimore were used in the building model. The design outdoor air conditions were obtained from the ASHRAE Fundamentals 2005. The coldest month was January, and the hottest month was July. These values are shown in Table 6.

Table 6: Design Conditions

ASHRAE Design Conditions for Baltimore, MD		
Summer		Winter
DB (˚F)	MCWB (˚F)	DB (˚F)
93.6	75	12.3

Design indoor air conditions for the DMA building were obtained from the designer. These values are seen in Table 7.

Table 7: Indoor Conditions

Indoor Conditions	
Cooling Set Point	75 ˚F
Heating Set Point	68 ˚F
Relative Humidity	50%

2.5 System Operation

2.5.1 Schematics

Figure 1 shows the cooling tower flow. Cooling Tower 1 (CT-1) is the only tower that is used for waterside free cooling. Water side free cooling was done specifically for the data center. This was done in order to help reduce the large cooling loads from the data center. The rest of the building was not considered for waterside free cooling.

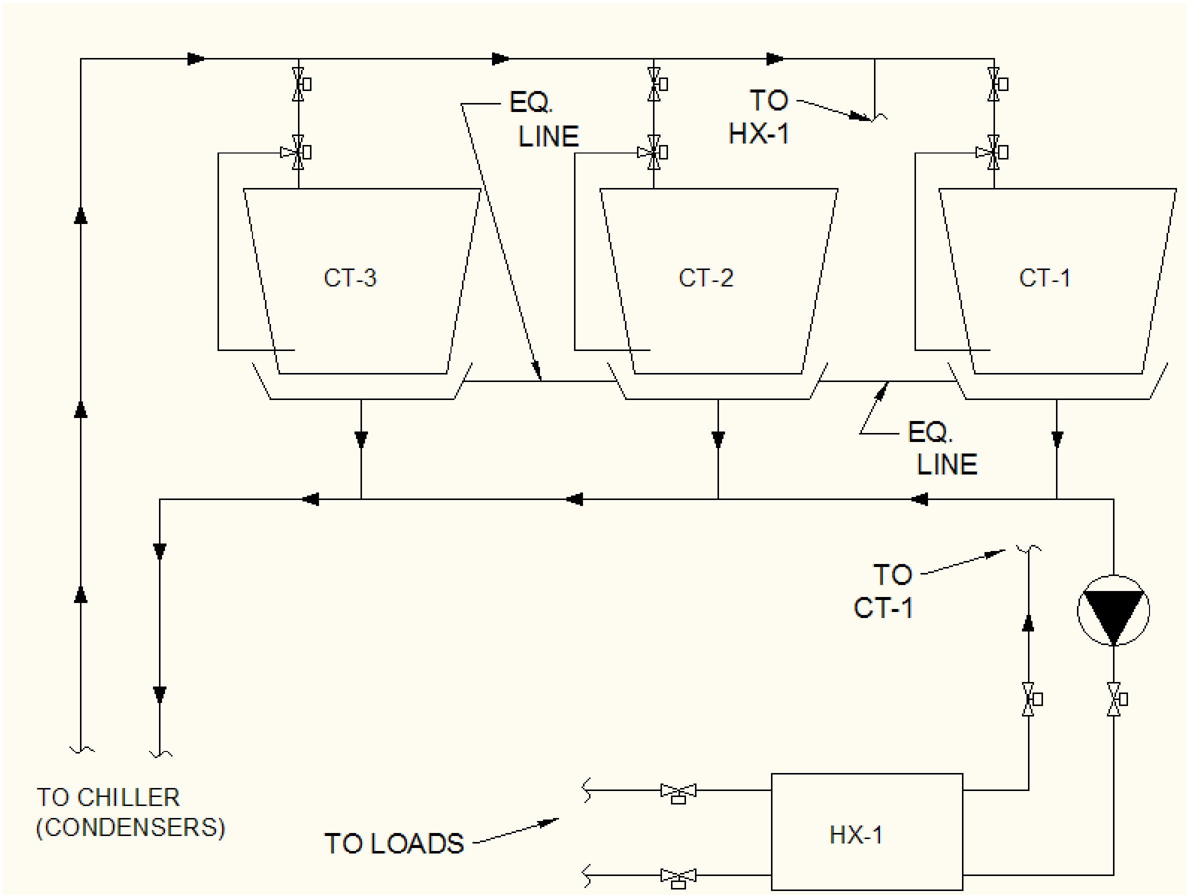


Figure 1: Cooling Tower Schematic

Figure 2 shows the condenser water going up to the cooling towers.

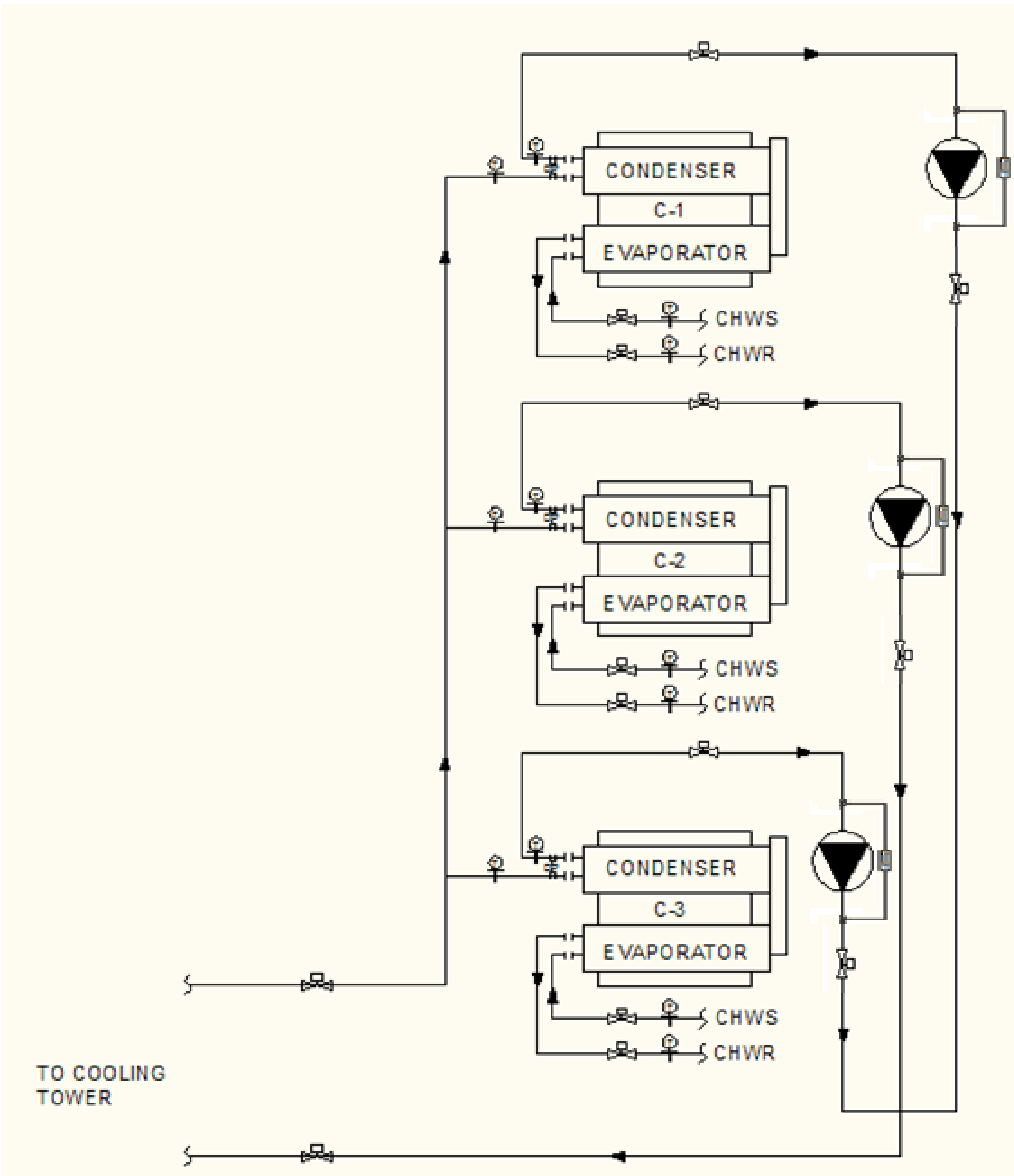


Figure 2: Condenser Schematic

Figure 3 shows the chilled water system and the primary/secondary flow pumping system.

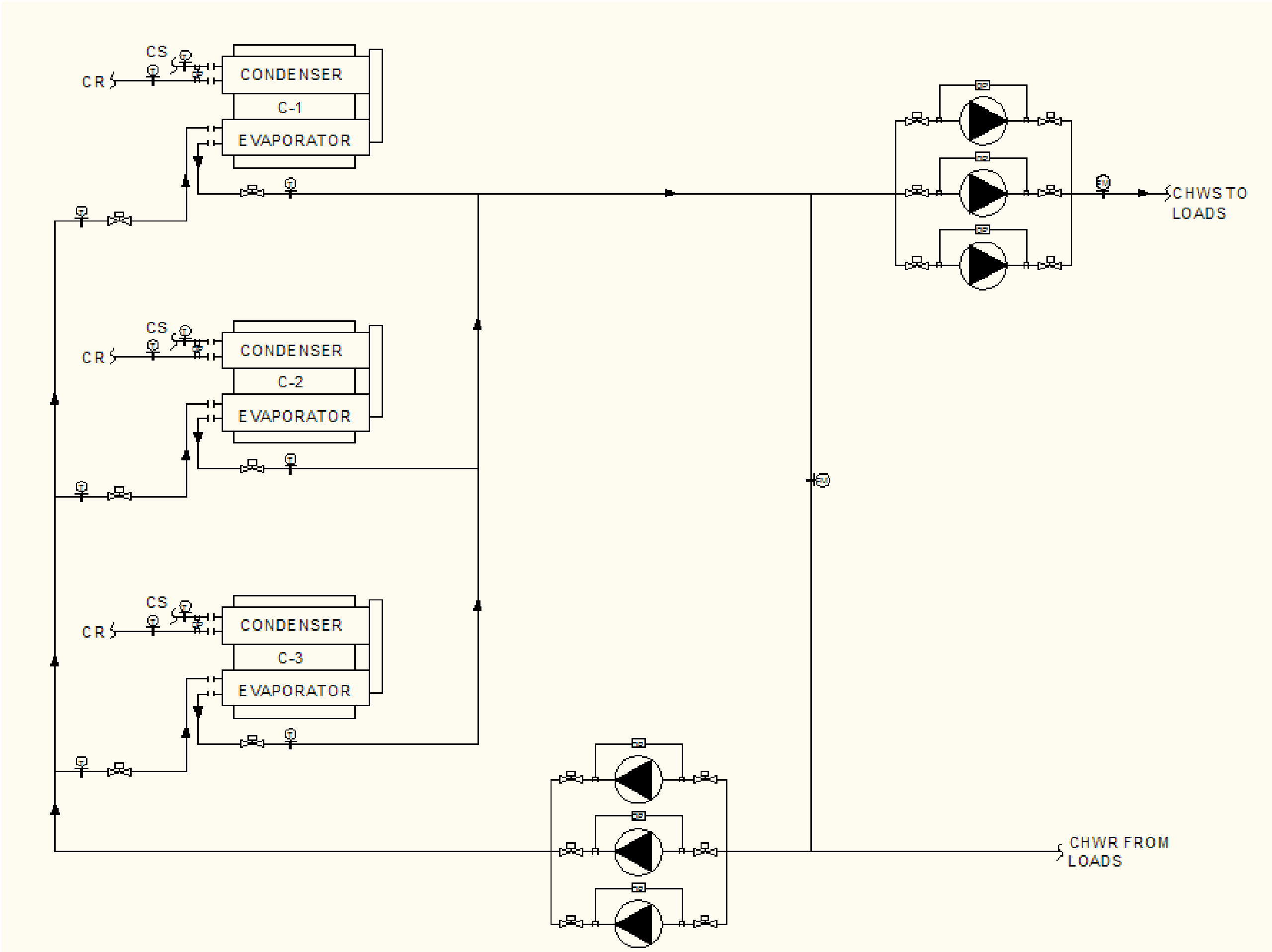


Figure 3: Evaporator Schematic

Figure 4 shows the hot water system.

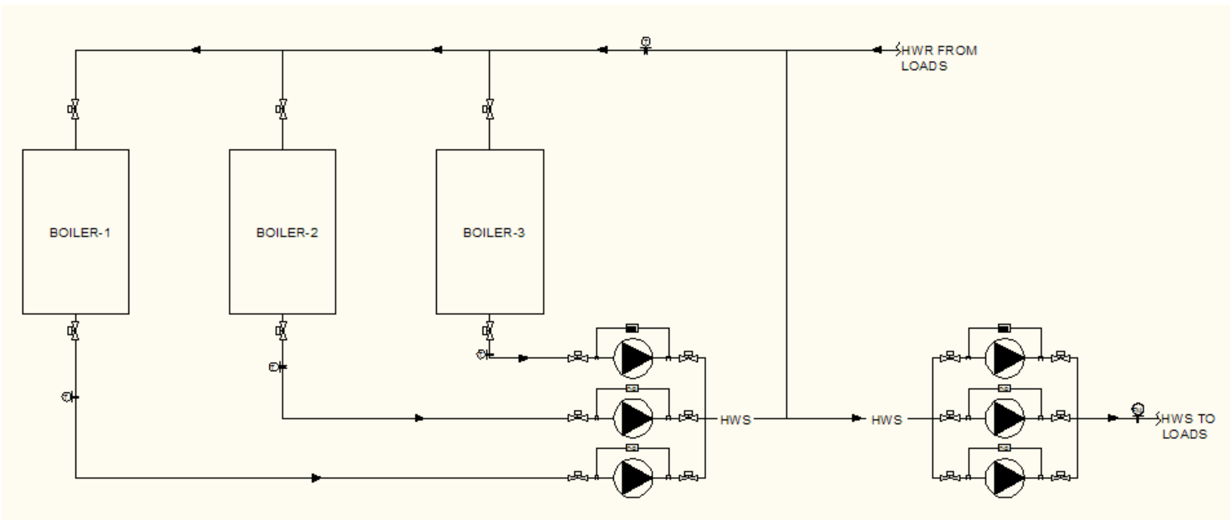


Figure 4: Boiler Schematic

2.5.2 Air-Side

The DMA building uses a VAV system. Each terminal unit is supplied with air from an AHU. Variable Speed Drive supply fans in the AHU's are set up to automatically start based on the optimum time for warming up or cooling down. A DDC control system is used in combination with temperatures and operation schedules to determine this optimum time. The DDC system controls the pressurization of the building by varying the supply and exhaust fans until an appropriate pressure is obtained. Minimum outside air will be maintained at all times. Humidity and temperature sensors will tell the DDC system to modulate supply air to meet the cooling or heating loads of the building. During cooling mode, the maximum supply air temperature will be kept at 56˚ F and a minimum of 48˚ F. During an Economizer mode, the outside air will be modulated up to 100 percent open to condition spaces.

2.5.3 Water-Side

2.5.3.1 Chilled Water

The DMA building uses a chilled water system utilizing water cooled centrifugal chillers. Chillers use a DDC system control. Using this system control, allows for remote monitoring. This system will also allow chillers to be remotely operated including shut downs and starts. As mentioned earlier in the report, the chilled water system uses a primary/secondary flow system. The primary chilled water pumps provide water to each evaporator, while the secondary chilled water pumps will distribute the chilled water throughout the system.

The master control panel sequences and controls each chiller to maintain a supply temperature of 45˚ F. Each pump is associated with its own chiller and staged at the same time the chillers are turned on. The lag chiller is turned on once the lead chiller reaches 85% of capacity. Capacity is measured by the temperature difference between the supply and return. This can be seen on the schematic with temperature sensors located on the supply and return. To measure capacity, a flow meter is used on the secondary side as well as the decoupling line. Chillers are rotated automatically from lead to lag. Time delays are also built in for sequencing chillers on or off. This is done to prevent cycling when loads vary slightly below and above the capacity at which chillers are staged.

For redundancy, the secondary pumps are sized for 50% of the load and the third pump is on standby. Upon failure of a pump, the standby pump is automatically turned on. Condenser pumps are also monitored with pressure sensors in case of failure. These pressure sensors can be seen in Figures 3 and 4.

Cooling towers are controlled to keep the condensing water temperature at 85˚ F. Cooling tower fans are Variable Speed Drive to control capacity more closely. Another feature built into the cooling towers is keeping the condensing water temperature at 65˚ F for partial free cooling as well as for full free cooling in cooling tower one. If the temperature drops below 40˚ F, waterside free cooling is enabled. Once waterside free cooling is enabled, the pumps for the heat exchanger are staged on and isolated with cooling tower 1. If needed, a sump heater will be utilized to keep the water from freezing.

2.5.3.2 Hot Water

When the outside temperature falls below 45˚ F the secondary heating pumps run continuously. The outside air temperature also determines the number of boilers running. Secondary pumps are variable frequency drive and are modulated by the DDC control system. Constant downstream differential pressure is maintained through the DDC system by monitoring the pressure with pressure sensors as seen in Figure 4.

2.5.4 System Initial Cost

The estimated cost for the HVAC system in the DMA building is about $13,466,024. That is about $75.37 per square foot of area. The estimated cost for plumbing is about $807,990, which is around $6.65 per square foot. When comparing the total estimated cost of the HVAC system, the construction cost for the mechanical system about 18% of the total cost.

2.5.5 Energy Sources

The site does not have district cooling or heating available. The energy sources that are available for the DMA building are two electrical feeds and a natural gas line. The utility providing these sources is Baltimore Gas and Electric. The rates used for analysis are provided in Table 8.

Table 8: BG&E Rates

Baltimore Gas and Electric Rates				
Electricity	Demand Charge ($/kW)	3.61		
	Summer June 1-Sept 30			
	Rate	On-Peak	Mid-Peak	Off-Peak
	(C/kWh)	11.551	9.265	8.82
	Non-Summer (Oct 1- May 31)			
	Rate	On-Peak	Mid-Peak	Off-Peak
	(C/kWh)	9.01	7.717	6.253
Gas	Up to first 10000 therms ($/therm)	1.03		
	Above 10000 therms ($/therm)	0.93		

3.0 Data from Previous Technical Reports

Three Technical reports have been written prior to the final report. These technical reports analyzed current components of the building systems as well as performances. The areas discussed in these reports includes ASHRAE 62.1-2007 analysis, ASHRAE 90.1-2007 analysis, heating and cooling load analysis, LLED NC analysis, and an Annual Energy Use Analysis.

3.1 Ventilation Requirements

To verify that the building air handling system is providing adequate ventilation for the different spaces, an ASHRAE 62.1 Analysis was performed. The calculations performed included all critical spaces in the building such as television studios, offices, media centers, and data centers. A total of seven zones were checked for compliance with minimum airflow rates to different zones. Analyzing critical zones of the building represents the rest of the building and its compliance or non-compliance of Section 6 of ASHRAE Standard 62.1.

When looking closer to Section 6 of ASHRAE Standard 62.1, one can see slight deviation from the requirements in the actual design. A possible reason for non-compliance is the use of higher default occupancy values in the calculations and differences in assumptions made in the spaces with open floor plans. The AHU's may need to be re-sized or adjusted for higher airflow rates if the occupancy values stay true. Table 9 shows the design airflow rates as compared to the ASHRAE calculation.

Table 9: Airflow Rates

Airflow Rates				
Unit	**Design Max CFM**	**Design Min OA**	**ASHRAE 62.1 Min OA**	**Compliance**
(A) AHU-EG-1	12455	2380	2924	No
(B) AHU-EG-2	12070	1580	1338	Yes
(E) AHU-E1-2	15810	1800	3159	No
(G)AHU-E2-2	16710	2120	3761	No
(H) AHU-E1-1	17660	2590	4022	No
(J) AHU-E2-1	12350	1460	2070	No
(K) RTU-W1-9	22930	1200	1198	Yes

Units B and K comply with the ASHRAE Standard 62.1 requirements for minimum outside air. The rest of the units (A, E, G, H and J) will need to be adjusted to meet the minimum outside air requirements to be compliant with Section 6. Once that is done, the DMA building is compliant with ASHRAE Standard 62.1.

3.2 Heating and Cooling Loads Comparison with Design

The entire building was modeled and simulated in Trane TRACE 700. For the purpose of this report, (6) main air handlers will be discussed to the original design because the rest of the building follows the same trend. Table 10 below summarizes the space cooling SF/ton, heating Btuh/SF, total supply air CFM/SF, and ventilation supply as a percentage for the designed vs. modeled zones. The rest of the zones share a similar pattern as seen from the total building energy consumption later in the report when compared to the design.

Table 10: Loads and Ventilation Indices

Comparison of Loads and Ventilation Indices									
AREA	Zone	Cooling SF/ton		Heating Btuh/SF		Supply CFM/SF		Ventilation %OA	
(SF)	(AHU)	Design	Modeled	Design	Modeled	Design	Modeled	Design	Modeled
12672	A	513.66	583.65	13.63	13.36	0.95	0.53	13.09	22
16000	B	623.30	554.54	8.08	13.84	0.78	0.57	19.10	21.2
19532	D	430.79	360.67	14.33	19.72	0.90	1.04	14.67	38.9
19748	E	428.28	352.84	15.16	19.12	0.85	1.2	12.69	11.6
16648	F	510.05	446.64	11.83	17.2	0.74	0.7	11.82	18.4
18363	G	516.98	385.09	12.84	19.12	0.86	0.74	11.38	21.6

When comparing the design versus modeled cooling loads, there is a slight deviation from space to space. There is no significant trend of the modeled loads having a large deviation from the design. Some of spaces, such as Zone A, have a higher modeled square foot per ton while others, like Zone B, have a lower square foot per ton value. This deviation may come from slightly different areas used for the model. Another difference for this deviation is the modeling technique and the use of different software. The final design analysis for the DMA building was done in eQuest with a room by room model. eQuest uses a different interface than TRACE and is a different modeling program so there is an expectation of differences in loads. The biggest contribution to this deviation of loads is possibly the use of block loads instead of a room by room building analysis which was done by the designer.

Heating loads for the model were generally higher than the designer’s loads. This is an interesting observation for the main AHU’s because the total heating use of the model was lower than the design. The other areas of the building such as the warehouses and mechanical rooms in the model had much lower heating values than the design, which lowered the heating energy use.

The total modeled CFM was lower than the design, which made the percentage of the outside air higher. This lower CFM is directly related to a slightly lower cooling load in the model. Total CFM is usually calculated from the cooling design and a smaller cooling load would yield a lower supply of air into the space.

In general, the modeled building was relatively close to the design. The biggest difference between the modeled building and the design is the modeling method used. The designed building calculated loads room by room, while the modeled building used block loads, where multiple rooms with same functions were combined.

3.3 Annual Energy Consumption

The designed and baseline energy figures were available from the LEED submission for EA Credit 1. Table 11 below shows the total energy consumption per year split up based on different types of loads in the building. The table shows a comparison between the modeled (block loads), designed building, and baseline building energy usage on a yearly basis. Data center energy consumption was added in after the model was created. This value was provided by the engineers based on the energy consumption of data center racks.

Table 11: Annual Energy Consumption

Annual Energy Consumption			
	Modeled	**Designed**	**Baseline**
Space Heating	1,937 (MBtu)	3,173 (MBtu)	4,433 (Mbtu)
Space Cooling	1,044,978 (kWh)	1,280,000 (kWh)	2,945,750 (kWh)
Lighting	705,581 (kWh)	834,000 (kWh)	932000 (kWh)
Pumps	154,484 (kWh)	366,000 (kWh)	388,000 (kWh)
Fans	834,583 (kWh)	291,000 (kWh)	701,500 (kWh)
Heat Rejection	8,760 (kWh)	7,000 (kWh)	4,000 (kWh)
Receptacle	1,832,882 (kWh)	826,000 (kWh)	826,000 (kWh)
Data Center	9,364,000 (kWh)	9,364,000 (kWh)	9,364,000 (kWh)
Water Heating	155 (Mbtu)	155 (Mbtu)	155 (Mbtu)

From this analysis, the biggest consumer of energy is the data center, followed by space cooling. Several large differences can be seen in the modeled versus designed buildings. Space heating is lower by 30% in the modeled as compared to the designed. Several attempts were made to raise the space heating value with very little success. 30% difference between the loads was the best scenario.

Space Cooling was lower than the Designed, but much closer to the design value than Space Heating. Lighting was also a little bit lower as well as the pumps. Fans on the other hand were a much higher energy consumer than the design as well as receptacles. The reason for high receptacle consumption is the type of function of this building. One must remember that the building contains rooms such as television studios, media centers, editing suites, control rooms, and offices. All of the DMA equipment was modeled as a receptacle load.

Figure 5 below shows the calculated/modeled percentage of energy use in the DMA building. The data center is consuming 42% of the building's total energy.

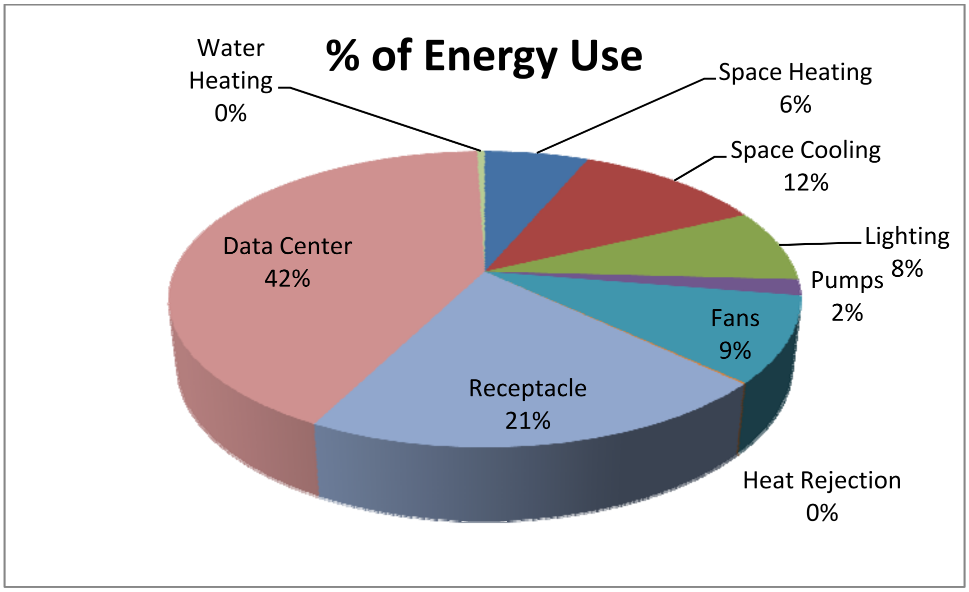


Figure 5: Energy Usage Breakdown

In addition to an annual consumption, monthly consumption was also computed with Trane TRACE 700. Table 12 shows the monthly consumption based on Peak, Mid-Peak, and Off-Peak hours for both natural gas and electricity.

Table 12: Monthly Energy Consumption

Monthly Energy Consumption												
Electric	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
On-Peak	173,817	156,484	184,873	178,873	196,423	200,688	204,045	209,045	188,896	188,099	179,185	174,730
Off-Peak	99,583	89,881	101,132	99,492	107,920	107,511	113,707	111,445	105,909	103,226	98,615	100,377
Mid-Peak	89,028	80,461	92,354	90,148	99,172	100,406	104,955	104,273	95,811	94,422	89,582	89,603
Data Center	780,333	780,333	780,333	780,333	780,333	780,333	780,333	780,333	780,333	780,333	780,333	780,333
Total	1,142,761	1,107,159	1,158,692	1,148,846	1,183,848	1,188,938	1,203,040	1,205,096	1,170,949	1,166,080	1,147,715	1,145,043
Gas												
On-Peak	383,200	350,100	225,000	140,500	71,100	43,700	34,700	46,000	66,800	151,200	180,100	289,400

The total consumption of electricity is highest in the summer while natural gas consumption is highest in the winter. Natural gas is used to heat the building and electricity is used to cool it. Figure 6 shows the modeled energy consumption by month.

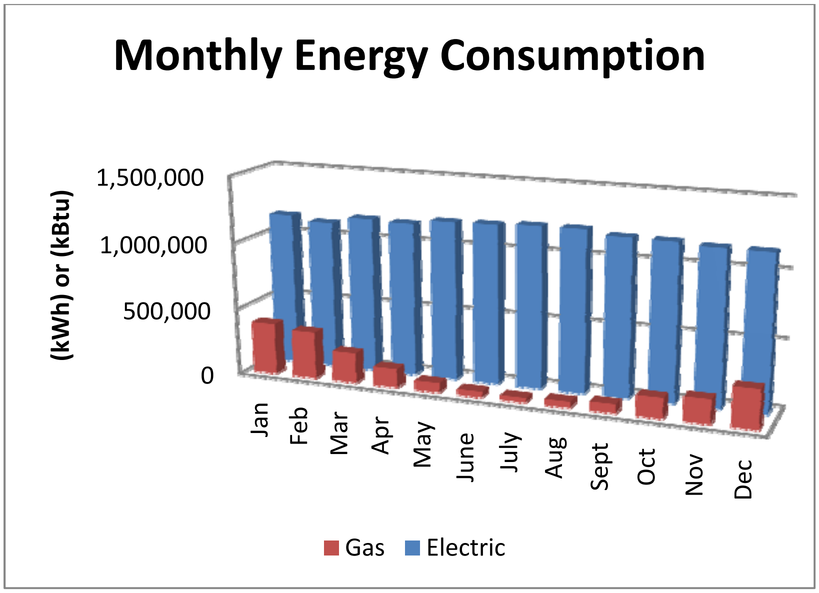


Figure 6: Monthly Energy Consumption

3.4 LEED NC Discussion

LEED assessment was done for the DMA building using LEED-NC 2.2 by the engineers. LEED-NC 3.0 follows the same procedure except it gives more points for energy efficiency. There are two main categories for assessing the building's mechanical systems. They are Energy and Atmosphere, and Indoor Environmental Quality. The new version has 3 prerequisites for Energy and Atmosphere and 6 categories to earn credits. Indoor Environmental Quality has 2 prerequisites and 5 mechanical systems categories to earn credits in.

3.4.1 Energy and Atmosphere (EA)

EA Prerequisite One requires the project to have a fundamental commissioning of the building energy systems. This prerequisite was satisfied. EA Prerequisite Two requires meeting the minimum energy performance. This was met and exceeded to attain additional points under EA Credit One. EA Prerequisite Three is refrigerant management where no CFC based refrigerants can be used in the building. The selected equipment will not use CFC based refrigerants.

EA Credit One is for evaluating energy performance. Based on the designer's submittal, the building will save around 15.5% of energy use over the baseline. This earns two credits under that category.

EA Credit Two requires on-site renewable energy which the DMA building doesn't have. Points range from one to seven based on percentage of renewable energy generated on-site.

EA Credit Three is worth two points and requires enhanced commissioning. Only basic commissioning will be done on this project.

EA Credit Four is enhanced refrigerant management. The total refrigerant impact per ton must be less than 100. Based on the calculation done for this credit, the total refrigerant impact is only 51.7. This is worth two points.

EA Credit Five is measurement and verification. Currently the building is just beginning construction, and if more points were needed, measurement and verification of the energy consumption can be done for an extra 3 points.

EA Credit Six is buying at least 35% of the buildings electricity from green power for two years. This option is worth two points. Currently, the DMA building is not planning to buy renewable energy.

3.4.2 Indoor Environmental Quality (EQ)

EQ Prerequisite One requires ASHRAE 62.1 to be met for indoor air quality. Based on the calculations done for the earlier version of LEED by the engineer, this prerequisite is met. The calculated values in Technical Report One were off and required more outside air because of different assumptions of occupancy were made in the selected spaces.

EQ Prerequisite Two is environmental tobacco smoke control. The DMA building is a non-smoking building.

The credits associated with the mechanical systems are EQ C1, EQ C2, EQ C6.2, EQ C7.1, and EQ 7.2. The rest of the credits are associated with construction practices, electrical, and day lighting.

EQ Credit One is outdoor air delivery monitoring. CO_2 monitoring must be done in every densely-occupied space. This is worth 1 credit. Not all densely occupied spaces have CO_2 sensors and therefore EQ Credit 1 was given.

EQ Credit Two requires increased ventilation. Increasing ventilation will increase energy consumption of the building. This was not done in the DMA building.

EQ Credit 6.2 requires individual comfort control for 50% of the building occupants including multi-occupant spaces. This credit is not achieved because more than two offices in an open space are served by the same VAV box.

EQ Credit 7.1 deals with design of thermal comfort. Based on the calculations done for EQ 7.1, Standard 55-2004 is satisfied and one point can be earned for this category.

EQ Credit 7.2 is the verification of thermal comfort. The owner of the building will conduct a thermal comfort survey one year after occupancy. Through the survey, verification of thermal comfort can be achieved for an additional point.

4.0 Mechanical System Evaluation

Overall, the mechanical system of the DMA building is well planned out and implemented. Very efficient equipment is used to keep the energy usage of the building to a minimum. VAV systems combined with high efficiency chillers and boilers are very effective if implemented correctly. VAV systems have been used in many office buildings and it is the most typical mechanical system used today.

The design of the building envelope for the DMA building was one of the first considerations made for building efficiency. The envelope plays one of the biggest roles on mechanical system's performance. The envelope for the DMA building was designed to exceed the ASHRAE Standard 90.1. This can be seen in Technical Report 1 which discussed the building envelope of the DMA building.

The estimated construction cost for the mechanical system about 18% of the total cost. This is a typical cost of mechanical systems in the office buildings. VAV systems are conventional and are not too complicated to install and operate. The biggest cost and added value for this VAV system are the high efficiency chillers and boilers controlled by a DDC system.

Operating cost of the building is quite high because of the type of loads in the building. The calculated operating cost is \$5.03/ft^2 a year, 67% of this cost is contributed by the data center. Cost of maintenance for this system should be relatively low. The system consists of only boilers, chillers, pumps AHU's and VAV boxes. It is a conventional system installed in many of today's buildings. Typical building engineers will know how to work on this type of system because there is no special maintenance or required.

Implementing a simple design, with a DDC control system and high efficiency boilers and chillers, was a good solution for this building. However, there are few improvements that could be made to minimize operational cost and further reduce energy consumption. Looking into more sophisticated designs and doing an in-depth analysis of new energy efficient systems can provide a more environmentally-friendly building with fewer emissions.

5.0 Proposed Alternative Systems

The current mechanical system is sufficient to meet LEED certification and save energy over the ASHRAE Standard 90.1. However, there are several alternatives that can further reduce energy consumption and reduce the costs of operation. The objective for alternative solutions is to increase efficiency as well as reducing operating cost and carbon footprint. These alternatives can be easily implemented into the design and their potential for the DMA building will be discussed below. The following alternatives will be included in this report: Combined Heat and Power, Thermal Storage, and System Optimization.

5.1 Combined Heat and Power

DMA has a high electrical demand as well as a high cooling load year round. The current utilities available to the DMA building include a natural gas line and two electrical feeds from Baltimore Gas & Electric. An onsite emergency generator is also implemented in the original design. The DMA building may be a good candidate for CHP, because the building will operate around the clock with a fairly constant electrical load.

Combined Heat and Power uses several types of prime movers to provide onsite generation of electricity. It also uses waste heat recovery for heating and cooling the building. Two prime movers will be discussed for CHP in the DMA building. The two prime movers that will be evaluated are: reciprocating internal combustion engines and natural gas turbines. An advantage of internal combustion engine is the higher efficiency at making electricity. An advantage of a turbine is the higher output of thermal energy for use in heating or cooling. The building will be evaluated for the optimum prime mover in terms of initial cost, payback, and efficiency.

The biggest advantage of CHP is the utilization of fuel, and the impact it has on carbon footprint of the building. Fuel utilization is much higher with a CHP system than a typical setup where the building uses grid power. CHP has this advantage because it utilizes waste heat, which is a byproduct of electrical generation, and uses it to run a process such as an absorption chiller. A typical power plant doesn't utilize waste heat, which is simply rejected to the environment, and just concentrates on producing electricity.

Several factors have to be considered while implementing CHP into the design. One of the biggest factors that would have to be considered when evaluating CHP is the Spark Gap. Spark Gap is the difference in cost between electricity and natural gas. The larger the difference, the more feasible it is to implement CHP into the design. Another factor that would have to be considered is the base load and peak loads. It would be much easier to use CHP in a building when the load profiles are relatively flat, since that would allow the fuel-fired generator to operate at its most efficient load condition.

5.2 Thermal Energy Storage

Thermal storage can be a great asset in reducing equipment size as well as reducing peak loads. It allows the building to level its load profile. Areas where on-peak electricity charges are much larger than off-peak can greatly benefit from cost savings. Running equipment during off-peak at full load and then using the stored energy during the on-peak hours is the basis of thermal storage. There are also energy savings because there are very little part load inefficiencies due to chillers running at full load to store chilled water or ice. Operating equipment at a fairly constant load and during the night when conditions are moderate, allows for better COP of equipment.

Adding thermal storage to the DMA building would reduce the on-peak cooling hours and as a counter effect, lower the operating cost by reducing the on-peak electricity use. It will also reduce the peak loads during the day and level the load profiles. CHP can greatly benefit from thermal storage because of load leveling.

Two types of available thermal storage are: ice storage and chilled water storage. Both of these options will be evaluated for the DMA building as both of these systems have advantages and disadvantages.

Several requirements would have to be evaluated for thermal storage such as space requirements for chilled water storage as well as ice storage, and the efficiency of producing ice vs. chilled water. Efficiency of storing chilled water and ice would also have to be considered when sizing and estimating total operation costs and benefits.

There are also several options for operating thermal storage. Full storage has the highest initial cost because the entire on-peak cooling load is shifted to off-peak hours. Using this option requires large tanks and large equipment. This option would work well in areas where the rates are a big driving force. Partial storage is shifting the peak load to off-peak hours and operating at base capacity at all times. This special case is called load leveling, and will have the best results when coupled with CHP. This option will be evaluated for the DMA building.

5.3 System Optimization

There are several ways that system optimization can benefit the DMA building. Modifications to the current system can further reduce the energy use of the building as well as operational costs. Several options can be looked at such as Dedicated Outdoor Air Systems (DOAS) and dedicating a chiller to the data center to reduce energy consumption.

5.3.1 DOAS

Dedicated Outdoor Air Systems use 100% outside air to ventilate the space. In a DOAS system, latent and sensible loads must be decoupled and treated separately. Several advantages are associated with using DOAS. Because only ventilation air is delivered to the spaces, your duct sizes are reduced dramatically over a conventional VAV system. The rest of the load is met with a parallel system such as fan-coil units, radiant panels (chilled ceiling), chilled beams, etc. The latent load must be met at the AHU while the sensible load can be picked up in the space.

A typical DOAS system consists of an enthalpy wheel, AHU's, and parallel terminal units. Total heat recovery is also a must in DOAS because 100% of the supplied air is outside air. In a typical VAV system, mixing is done between the outside air and the return air to precondition the air before the coils. In a DOAS system, there is no mixing and therefore preconditioning the air with a total energy recovery unit is required by ASHRAE 90.1. The energy from inside of the building is exchanged in this process with the fresh outside air based on the effectiveness of the heat recovery unit.

Incorporating this type of system into the DMA building may have significant energy savings according to an article in ASHRAE Transactions. [2] AHU fan energy is reduced, the cooling coil load is reduced, and the chiller energy consumption is reduced as well. There are a few areas where the DOAS system consumes more energy such as pumping. These will have to be taken into account when calculating the total energy usage of the system and then compared to the VAV system that is currently installed in the DMA building.

5.3.2 Dedicated Chiller for the Data Center

The data center in the DMA building uses a considerable amount of electricity to run. The connected load of the data center for the first five to ten years will be 1089 kW. This load is connected 24 hours a day, seven days a week. Reducing this large load will result in considerable savings.

The current data center uses state of the art APC liquid cooled cooling racks. These cooling racks are much more efficient than conventional CRAC units. However, because the data center uses a big part of the building's energy, possible reduction of the cooling load for the data center in the system optimization analysis will be considered.

[2] Jeong et al. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. 109. KC-03-7-1 (2003): 627-636. Print.

6.0 Combined Heat and Power

Combined Heat and Power provides heating cooling and electricity to the end user. CHP has great potential when implemented at the right conditions. In order for a CHP system to be feasible in a building, several variables have to be present at the correct values and levels. These variables include: price of the fuel, price of electricity, load profiles, and the thermal to electrical ratios.

In an ideal situation for implementing a CHP system, the price of electricity would be higher when compared to natural gas or any other fuel used for cogeneration. The loads have to be fairly constant and the building must have a compatible heat to power ratio. The DMA building will operate 24 hours a day, seven days a week. The building also has a data center which runs at fairly constant loads. When combining these two conditions, the DMA building makes a good candidate for CHP.

The heat to power ratio for the building ranges from 1.2 to 0.85 which also gives the DMA building an advantage when considering a CHP system. Since the heat to power ratio falls below one, the building uses more electricity when compared to thermal energy. A lower heat to power ratio means that higher electrical efficiency prime movers should be used when designing a CHP system.

6.1 Preliminary Analysis

The first step in the CHP analysis was calculating the Spark Gap. A Spark Gap is the difference in the cost of electricity and natural gas. Spark Gap was calculated based on Baltimore Gas and Electric rates. The difference between 1,000,000 BTU/hr of electricity and 1,000,000 BTU/hr of natural gas was about $18.99. This is a good Spark Gap which allows for further investigation of the CHP system.

The second step to running a CHP analysis was to build an energy model to obtain base and peak loads. The energy model was built in Trane TRACE 700. TRACE provided an 8760 hour load analysis for each component of the building. The loads included in the TRACE output are as follows: lighting loads, miscellaneous loads, chiller loads, boiler loads, ventilation loads, pump, fans, data center loads, etc.

The third step in the CHP analysis was to compile the information into a useful format. All of the electrical loads were separated from thermal loads and added for a total electrical load of the building. The peak electrical load for the DMA building is just below 2.2 MW. The base load for the DMA building is about 1.8 MW as seen from Figure 7. Figure 7 represents the total building electrical load excluding chiller loads. This was done to see what the total electrical load of the building is, without taking thermal loads into account. This analysis helped with the selection of the prime mover size. Thermal loads were also combined to perform a heat to power ratio analysis for the building. A heat to power ratio is an important step in selecting prime movers as mentioned earlier.

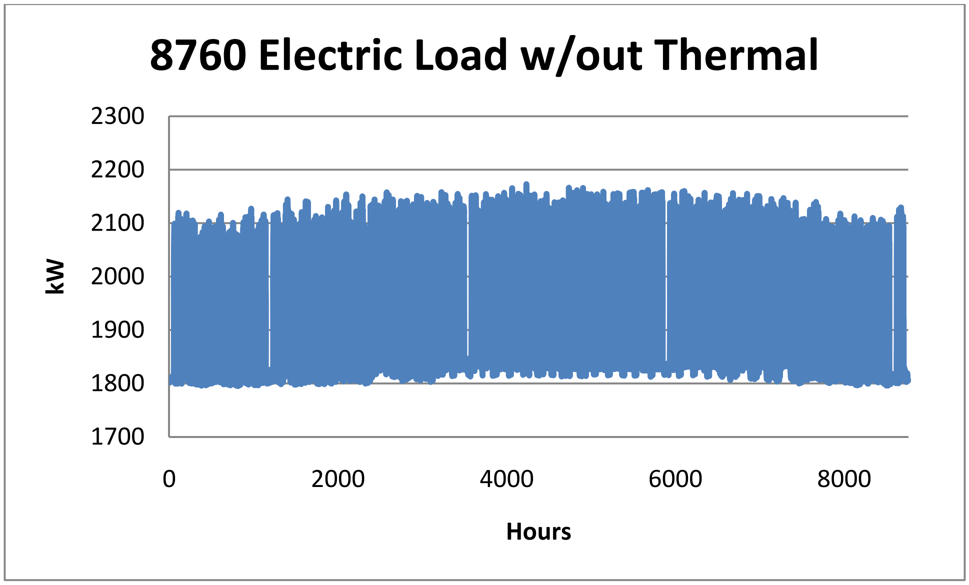


Figure 7: 8760 Hour Electric Load of the DMA Building

Figure 8 shows the total electrical demand on the design day not including thermal loads.

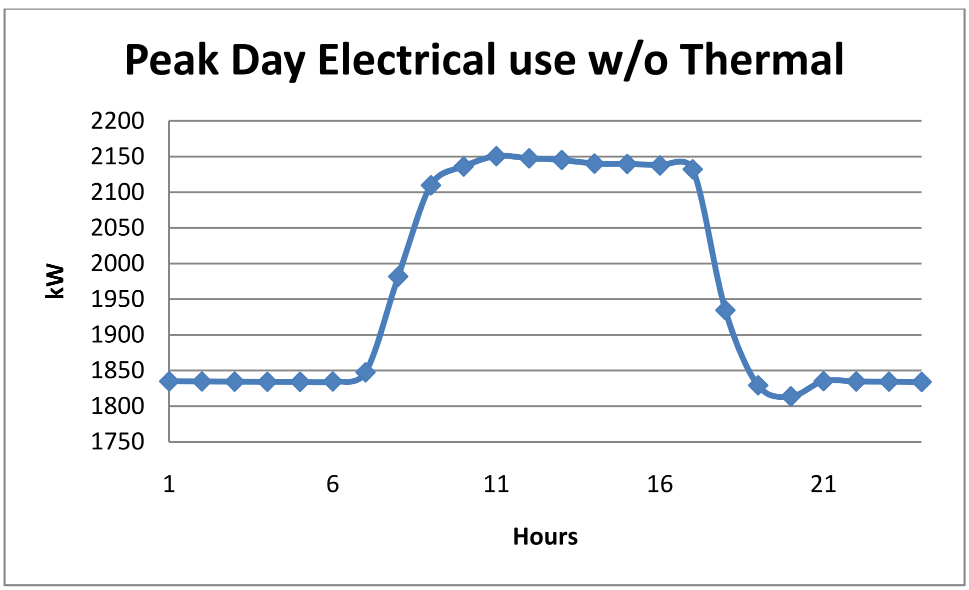


Figure 8: Peak Day Electrical Load

The current mechanical system implements an emergency generator that would kick in if both of the utility lines go down. The generator was sized at 2MW to take care of critical loads in case of a power outage. The cost of the generator can be subtracted from the CHP system because the CHP system will now be the primary source of power and the grid will be used as a backup.

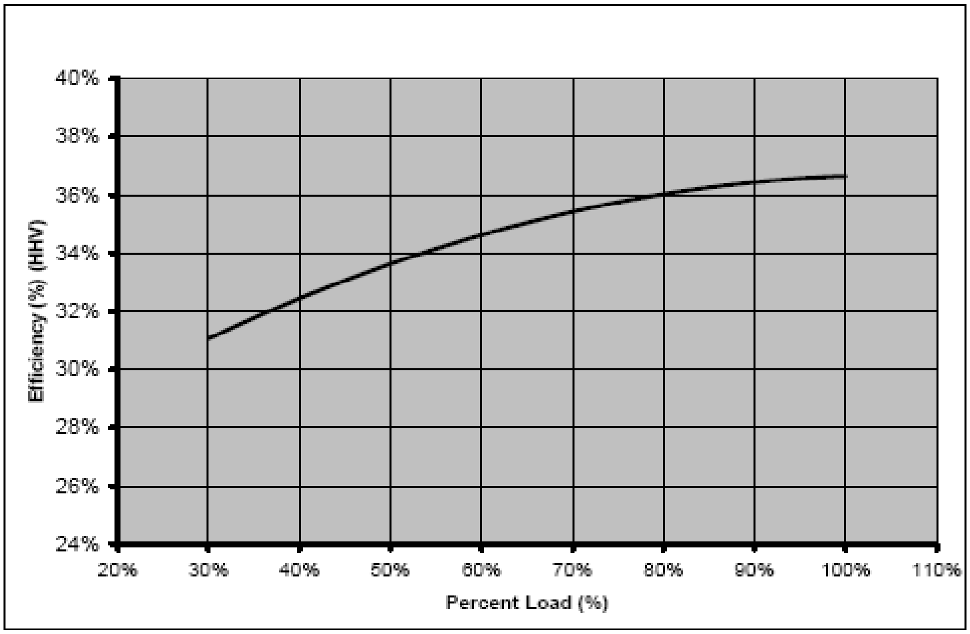
6.2 Prime Movers

There are several options to choose from when considering a prime mover for a CHP system. Internal combustion engines, gas turbines, and fuel cells can be used in a CHP application. The prime movers chosen to perform the analysis were an internal combustion engine and a gas turbine. Fuel cells are still under development and have high initial costs when compared to internal combustion engines and gas turbines. Saturn 20 a 'Solar' turbine, and a Jenbacher 'GE' internal combustion engine were used in the analysis.

6.2.1 Internal Combustion (IC) Engine

An internal combustion engine can be compared to a much larger version of your automobile engine. Several manufacturers produce stationary power stations that can be used for a CHP system. A Jenbacher engine was chosen because of its high electrical efficiency and low emissions required by law. The Jenbacher engine will run off natural gas provided to the building by Baltimore Gas & Electric.

Internal combustion engines can produce electricity at high efficiencies and can efficiently follow the electrical loads of the building. IC engines are much less sensitive to partial loads of the building. These generators are very efficient at part loads as can be seen from Figure 9. Figure 9 shows a generic IC engine. The engine used for CHP analysis has the same characteristics, but the efficiency is improved due to state of the art technology used in the CHP generator.



Source: Caterpillar, EEA/ICF [3]

Figure 9: Natural Gas Internal Combustion Engine Load Characteristic

Internal combustion engines have a much higher electrical efficiency than gas turbines. The downside to having a higher electrical efficiency is the lower grade thermal energy output. A lower grade output can be collected through heat exchangers and used in different applications. In a CHP application, heat can be collected and recovered from several parts of the engine. The primary source of thermal energy will come from the water jacket followed by the combustion exhaust. Heat can also be recovered from oil coolers. The recovered heat can be used for water heating or it can be used in a single stage absorption machine to create chilled water.

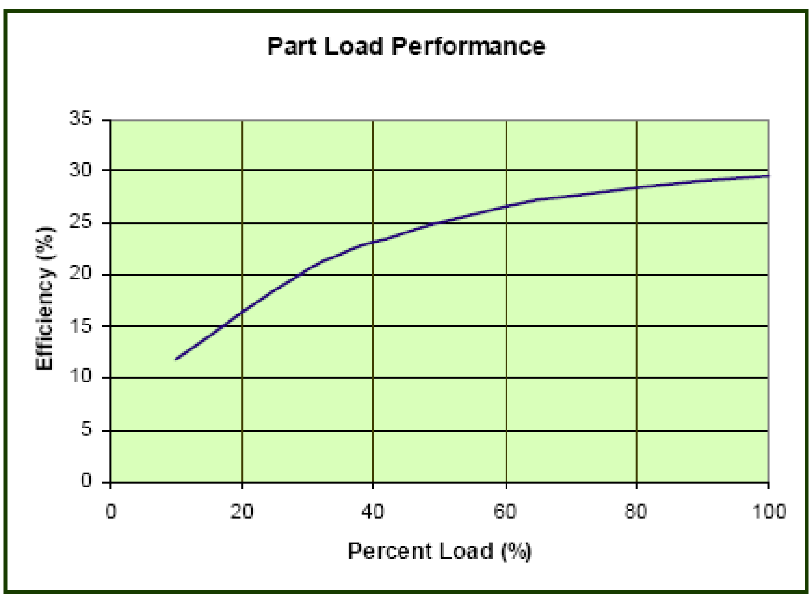
[3] "Combined Heat and Power Partnership." *U.S. Environmental Protection Agency*. 21 07 2009. U.S. Environmental Protection Agency, Web. 12 Dec 2009. < www.epa.gov/chp/basic/index.html>.

6.2.2 Gas Turbine

The second prime mover that will be discussed is a gas turbine. Gas turbines are similar to aircraft engines. Instead of pistons, turbines use blades to compress the air and then combust it to create mechanical energy.

The biggest advantage of gas turbines is the high grade thermal energy they produce. This high grade thermal energy of the exhaust can be easily converted to steam and used to run a steam turbine to produce more electricity. High pressure steam can also be used in a dual stage absorption cycle or a steam driven chiller.

A disadvantage of a gas turbine is the lower electrical efficiency. Higher electrical efficiencies can be achieved with larger turbines. Another disadvantage of a gas turbine is the part load efficiency. The part load efficiency of a generic gas turbine can be seen in Figure 10. The part load efficiency is much less for a turbine than it is for an internal combustion engine. When implementing a turbine, one has to make sure to run the turbine close to a full load in order to achieve good electrical efficiencies.



Source: EEA/ICF [4]

Figure 10: Natural Gas Turbine Load Characteristic

[4] "Combined Heat and Power Partnership." *U.S. Environmental Protection Agency*. 21 07 2009. U.S. Environmental Protection Agency, Web. 12 Dec 2009. < www.epa.gov/chp/basic/index.html>.

6.3 Redundancy

Redundancy is a very important factor when designing a CHP system. The DMA building has a lot of critical loads such as the data center, media centers, and editing suites. The original design of the building has three sets of 750 KVA 20 minute Uninterruptible Power Source (UPS) systems built in as well as a 2000 kW 480/277V generator. The building is also connected to two 13.2 kV utility sources for redundancy. If one of the utility feeds goes down, the system will switch over to the second feed. If the second feed is compromised, a generator will kick on while the UPS system will protect super critical loads such as the data center.

Installing a CHP system will basically replace the emergency generator with a larger system that will be able to produce enough electrical power to run the building. The CHP system will run constantly, 24 hours a day, seven days a week which makes these engines more reliable than the emergency generators that only kick on in emergencies. The whole building will be connected to the CHP system instead of just the emergency loads. This will create more redundancy than the original design.

In addition to increased reliability with the CHP system, the two separate grid services will serve as a backup in case of failure or maintenance. A UPS system will be used to protect the data center as well as other critical loads in case there is an interruption of power.

6.4 Energy Cost Comparison

Several different options were analyzed for two different prime movers. The different options analyzed are listed in Table 13 for IC engines and Table 14 for gas turbines. Six different options were analyzed for IC engines, and three options were analyzed for gas turbines.

Table 13: CHP Options for IC Engines

CHP Options for IC Engines	
System	Description
A	2390 kW Jenbacher IC Engine running at full load. Excess Electricity sold to the grid
	800 ton Single Stage Absorption Chiller used to cover all cooling loads of the building
	A boiler is used to make up needed thermal energy for the Absorption Chiller
	(2) 500 ton Electrical chillers used as a backup
	6000 MBH Backup boiler is used for redundancy
B	2390kW Jenbacher IC Engine running at full load. Excess Electricity sold to the grid
	(3) 500 ton Electrical Chillers used to cool the building
	Thermal energy is wasted
	Backup boiler is used for redundancy
C	2390 kW Jenbacher IC Engine running at full load. Excess Electricity sold to the grid
	700 ton Single Stage Absorption chiller used to meet cooling loads
	300 ton Electric Chiller used to meet loads not met with an Absorption Chiller
	500 Ton Electric Chiller used as a backup
	6000 MBH Backup boiler is used for redundancy
D	2390kW Jenbacher IC Engine running to meet electrical load
	800 ton Single Stage Absorption Chiller used to cover all cooling loads of the building
	A boiler is used to make up needed thermal energy for the Absorption Chiller
	(2) 500 ton Electrical chillers used as a backup
	6000 MBH Backup boiler is used for redundancy
E	2390kW Jenbacher IC Engine running to meet electrical load as well as peak electric chiller load
	650 ton Single Stage Absorption Chiller used to meet cooling loads
	300 Ton Electric Chiller meets loads not met by Absorption
	500 Ton Electric Chiller used as a backup
	6000 MBH Backup boiler is used for redundancy
F	1801kW Jenbacher IC Engine running to meet base electrical load
	Buy electricity from the grid to meet loads not met by CHP
	800 ton Single Stage Absorption Chiller used to cover loads of the building
	A 7000 MBH boiler is used to make up needed energy for the Absorption Chiller
	6000 MBH Backup boiler is used for redundancy
	(2) 500 ton Electric Chillers used as a backup

Table 14: CHP Options for Turbines

CHP Options for Turbines	
System	**Description**
G	1200 kW Saturn 20 Turbine used to meet base load
	Buy electricity from the grid to meet loads not met by CHP
	800 ton Double Stage Absorption Chiller used to cover all cooling loads of the building
	(2) 500 ton Electrical chillers used as a backup
	Backup boiler is used for redundancy
H	1200 kW Saturn 20 Turbine
	Back Pressure Steam Turbine runs off high pressure steam created by the turbine
	800 ton Single Stage Absorption Chiller used to cover all cooling loads of the building
	A boiler is used to make up needed thermal energy for the Absorption Chiller
	(2) 500 ton Electrical chillers used as a backup
I	1200 kW Saturn 20 Turbine
	Back Pressure Steam Turbine runs off high pressure steam created by the turbine
	400 ton Single Stage Absorption Chiller used to cover loads of the building
	500 ton Electric Chiller used to meet loads not met with an Absorption Chiller
	500 Ton Electric Chiller used as a backup

Table 15 includes the yearly savings by system. In order to calculate the base building, costs were broken down by electricity and by natural gas used. On-peak, mid-peak, and off-peak kWh were calculated and added for the whole year using Baltimore Gas & Electric rates. Peak demand was calculated on a monthly basis and added to the total electrical cost. Boiler costs were also calculated for the base building. All the energy costs were added to give baseline energy consumption for the DMA building.

To calculate the savings for each system type, the same steps were taken. For CHP systems, natural gas was used as the primary fuel to make electricity. Where applicable, electricity was bought or sold to the utility company. A conservative assumption of $0.03/kWh was made for buy back rates from the utility company. Savings in Table 15 only include savings obtained from the difference in energy costs. Operation and maintenance of these CHP systems is included in the payback analysis. Operation and maintenance for IC engines is about $0.005/kWh and about $0.015/kWh for gas turbines.[5]

[5] "Combined Heat and Power Partnership." *U.S. Environmental Protection Agency*. 21 07 2009. U.S. Environmental Protection Agency, Web. 12 Dec 2009. < www.epa.gov/chp/basic/index.html>.

Table 15: Yearly Cost Savings by CHP System

Yearly Energy Cost Savings	
System	Savings
A	$ 267,782.66
B	$ 237,719.65
C	$ 294,635.25
D	$ 295,660.92
E	$ 368,273.40
F	$ 188,960.22
G	$ (218,630.62)
H	$ 62,514.05
I	$ 147,354.61

When the energy cost analysis was completed, the largest savings came from CHP system E followed by system D. Systems E and D were both internal combustion engines. System G showed a negative savings. The cost of energy consumed by the DMA building went up by around $218,630 for system G. The reason for this cost increase is the nature of the gas turbines. Turbines are much more efficient in producing thermal energy than electrical power. The turbine chosen for system G was a 1.2 MW turbine that was only 24.4% efficient at producing electricity. An advantage of a gas turbine is the high grade thermal energy produced. This energy can be used to make high pressure steam that can be used in many processes. The DMA building doesn't have a high demand for this thermal energy and therefore the 1.2 MW turbine was producing too much thermal energy and not enough electrical energy. The next size up for gas turbines was a 3 MW turbine which is too big for the building. Because the heat to power ratio for the building drops as low as 0.85, choosing a prime mover that makes more thermal energy than electrical will be cause an inefficient design.

System H and I use a backpressure steam turbine in combination with a gas turbine. The backpressure steam turbine runs off thermal energy produced by the gas turbine. Adding a backpressure steam turbine to a building that has a higher electrical demand than thermal will produce better results as seen in Table 15. The team turbine uses the high pressure steam to produce electricity and sends the lower pressure to run other processes. Steam turbines range in efficiency from 15% to 35%. The steam turbine chosen for analysis has 25% electrical generation efficiency.

From this analysis, the gas turbines were eliminated from further evaluation because in their lower savings and higher installation cost. Gas turbines have a higher initial cost, and the cost of an additional backpressure steam turbine increases the initial investment well above the cost of internal combustion engines. Gas turbines are also more expensive to operate and maintain as mentioned earlier.

Jenbacher IC gas engines used for analysis have 42.9% electrical efficiency for the 1801 kW model and 42.6% electrical efficiency for the 2390 kW model. The thermal efficiencies for these engines are much lower than the gas turbines. The 1801 kW Jenbacher model has a thermal efficiency of 43.2%, and the 2390 kW model has a thermal efficiency of 43.4%.

Internal combustion engines are a better choice for the DMA building because of their higher electrical efficiency. The best option produced a very favorable outcome. System E has yearly savings around $368,273. System E used a 2390 kW Jenbacher IC engine running to meet electrical loads as well as electric chiller loads when needed. The waste heat was used to run a 650 ton absorption chiller which met most of the loads. A supplemental 300 ton electric chiller was used to meet the rest of the loads not met directly by absorption.

System D followed in second place with a $295,660 yearly savings. This system used the same Jenbacher engine but instead of implementing an electric chiller to meet loads not met by the thermal output, a boiler was used to provide additional thermal energy to a larger absorption chiller.

6.5 Initial Investment

System costs were obtained from RSMeans 2009 Costworks, as well as www.epa.gov. Each system was broken down by individual components which were priced out for material costs as well as installation costs. Table 16 shows system cost by system type.

Table 16: Initial Investment by System

Initial Investment by System	
System	**Cost**
A	$ 2,754,407.05
B	$ 2,483,717.55
C	$ 2,478,387.55
D	$ 2,800,156.55
E	$ 2,439,842.55
F	$ 2,381,676.53

The redundancy for each one of the options was considered and maintained or exceeded. The costs of the original equipment selected for the project were subtracted from the total for options where they weren't used, and additional costs such as absorption chillers, IC engines, and backup boilers were added to the initial investment. The acoustical treatment of the space was also included in the original cost of the systems. Acoustical analysis is discussed later in the report. An additional $28,085 was added for a double CMU wall to keep noise levels down produced by the Jenbacher IC engine.

6.6 Payback Period

A simple payback period for the different Jenbacher engines was performed to determine the feasibility of implementing these engines in a CHP system. The operation and maintenance (O&M) costs for an IC engine is about $0.005 per produced kWh.[6] This O&M cost was computed per each system and used in the payback period. An O&M cost for these options ranged from around $79,000 to around $105,000.

The second assumption made for this payback analysis was a conservative assumption. The assumption made stated no increase in electrical rates over the payback period calculated. This scenario will produce conservative results. Table 17 shows the payback periods of the different IC options presented earlier.

Table 17: CHP Payback Period

Payback Period	
System	**Years**
A	17.7
B	18.7
C	13.4
D	13.8
E	8.8
F	18.5

System E shows the best payback period followed by system C. System E has a payback period of about 8.8 years. This is a good payback period because it was based on an assumption that electrical costs will not increase. The current electrical rates for the DMA building are very low and will only go up as the demand for energy increases. System C shows a payback of 13.4 years which is also a decent payback period for a CHP plant.

6.7 Sensitivity Analysis

A sensitivity analysis was done on systems A through F to see how an increasing cost of electricity would affect the payback period. The sensitivity analysis performed increased electrical rates at increments of 10%. This analysis assumes an average increase of a certain percentage over the payback period.

[6] "Combined Heat and Power Partnership." *U.S. Environmental Protection Agency*. 21 07 2009. U.S. Environmental Protection Agency, Web. 12 Dec 2009. < www.epa.gov/chp/basic/index.html>.

Table 18 shows the sensitivity analysis done on System A.

Table 18: Sensitivity Analysis on System A

Electricity Sensitivity Analysis on System A		
Percent Increase	**Yearly Savings**	**Payback Period (years)**
0	$ 163,100.66	17.7
10	$ 323,512.27	8.9
20	$ 508,237.33	5.7
30	$ 680,805.66	4.2
40	$ 853,374.00	3.4
50	$ 1,025,942.33	2.8
60	$ 1,198,510.66	2.4
70	$ 1,371,078.99	2.1
80	$ 1,543,647.33	1.9
90	$ 1,716,215.66	1.7
100	$ 1,888,783.99	1.5

Table 19 shows the sensitivity analysis done on System B.

Table 19: Sensitivity Analysis on System B

Electricity Sensitivity Analysis on System B		
Percent Increase	**Yearly Savings**	**Payback Period (years)**
0	$ 133,037.65	18.7
10	$ 292,774.98	8.5
20	$ 477,099.29	5.2
30	$ 649,130.11	3.8
40	$ 821,160.93	3.0
50	$ 993,191.75	2.5
60	$ 1,165,222.57	2.1
70	$ 1,337,253.39	1.9
80	$ 1,509,284.21	1.6
90	$ 1,681,315.02	1.5
100	$ 1,853,345.84	1.3

Table 20 shows the sensitivity analysis done on System C.

Table 20: Sensitivity Analysis on System C

Electricity Sensitivity Analysis on System C		
Percent Increase	Yearly Savings	Payback Period (years)
0	$ 189,953.25	13.4
10	$ 350,364.85	7.3
20	$ 535,089.91	4.8
30	$ 707,658.25	3.6
40	$ 880,226.58	2.9
50	$ 1,052,794.91	2.4
60	$ 1,225,363.25	2.1
70	$ 1,397,931.58	1.8
80	$ 1,570,499.91	1.6
90	$ 1,743,068.24	1.5
100	$ 1,915,636.58	1.3

Table 21shows the sensitivity analysis done on System D.

Table 21: Sensitivity Analysis on System D

Electricity Sensitivity Analysis on System D		
Percent Increase	Yearly Savings	Payback Period (years)
0	$ 212,291.63	13.8
10	$ 372,703.23	8.4
20	$ 557,428.29	5.5
30	$ 729,996.62	4.1
40	$ 902,564.96	3.3
50	$ 1,075,133.29	2.8
60	$ 1,247,701.62	2.4
70	$ 1,420,269.95	2.1
80	$ 1,592,838.29	1.9
90	$ 1,765,406.62	1.7
100	$ 1,937,974.95	1.5

Table 22 shows the sensitivity analysis done on System E.

Table 22: Sensitivity Analysis on System E

Electricity Sensitivity Analysis on System E		
Percent Increase	Yearly Savings	Payback Period (years)
0	$ 284,904.11	8.8
10	$ 445,315.71	5.9
20	$ 630,040.77	4.1
30	$ 802,609.10	3.2
40	$ 975,177.44	2.6
50	$ 1,147,745.77	2.2
60	$ 1,320,314.10	1.9
70	$ 1,492,882.44	1.7
80	$ 1,665,450.77	1.5
90	$ 1,838,019.10	1.4
100	$ 2,010,587.43	1.2

Table 23 shows the sensitivity analysis done on System F.

Table 23: Sensitivity Analysis on System F

Electricity Sensitivity Analysis on System F		
Percent Increase	Yearly Savings	Payback Period (years)
0	$ 110,076.42	18.5
10	$ 272,548.06	7.5
20	$ 435,019.69	4.7
30	$ 580,290.72	3.5
40	$ 742,762.35	2.7
50	$ 905,233.98	2.3
60	$ 1,067,705.61	1.9
70	$ 1,230,177.24	1.7
80	$ 1,392,648.87	1.5
90	$ 1,555,120.50	1.3
100	$ 1,717,592.13	1.2

The sensitivity analysis performed accounted for operation and maintenance costs that affect the yearly savings and payback periods. When looking at the sensitivity analysis, every system shows a similar pattern of decreasing payback periods. The payback period decreases exponentially with a large drop off at the first 10% increase in electrical costs. This is a good trend because maximum drop in payback period is achieved with a slight increase in energy costs. Energy costs are always increasing, and in this economy, the cost of electricity has been constantly rising.

The most promising systems, with the shortest paybacks, in this analysis were System C, E, and F. System E had the smallest initial payback, and performed even better with an increase of electrical prices. System C was the second best performer followed by system F. System F had the biggest drop in payback period with a 10 % increase in electrical costs and then leveled out.

The two best options were further analyzed for their sensitivity to variation in natural gas costs. Systems C and E were further analyzed for increases in cost of natural gas. Table 24 shows a sensitivity analysis done to see what the payback period would be if both natural gas and electricity were increasing at the same rate for System C.

Table 24: CH_4 and Electric Sensitivity Analysis on System C

Natural Gas & Electricity Sensitivity Analysis on System C		
Percent Increase	**Yearly Savings**	**Payback Period (years)**
0	$ 189,953.25	13.4
10	$ 159,338.54	16.0
20	$ 172,162.66	14.8
30	$ 184,986.79	13.8
40	$ 197,810.91	12.9
50	$ 210,635.03	12.1
60	$ 208,979.54	12.2
70	$ 215,598.11	11.8
80	$ 222,216.69	11.5
90	$ 228,835.26	11.1
100	$ 235,453.84	10.8

Table 25 shows a sensitivity analysis done to see what the payback period would be if both natural gas and electricity were increased at the same rate for System E.

Table 25: CH_4 and Electric Sensitivity Analysis on System E

Natural Gas & Electricity Sensitivity Analysis on System E		
Percent Increase	**Yearly Savings**	**Payback Period (years)**
0	$ 284,904.11	8.7
10	$ 126,012.09	19.7
20	$ (23,416.04)	-

As seen from Table 25, an increase from 10% to 20% would make the CHP system E not feasible. If costs are increased at the same rate, System E can run at System C's operation settings to keep this option feasible. Another sensitivity analysis was performed on system E, assuming a 10% increase in electricity and a 4% increase in natural gas. Table 26 shows the associated yearly savings and payback periods.

Table 26: 4% CH_4 and 10% Electric Sensitivity Analysis on System E

Natural Gas & Electricity Sensitivity Analysis on System E		
Percent Increase	**Yearly Savings**	**Payback Period (years)**
0,0	$ 284,904.11	8.8
10,4	$ 305,732.94	8.2
20,8	$ 359,610.45	7.0
30,12	$ 408,995.63	6.1
40,16	$ 453,888.47	5.5
50,20	$ 494,288.96	5.1
60,24	$ 545,920.31	4.6
70,28	$ 593,059.31	4.2
80,32	$ 640,198.32	3.9
90,36	$ 687,337.33	3.6
100,40	$ 734,476.33	3.4

This analysis concludes that CHP would be a feasible option in the DMA building. If the electric rates keep rising in price, while natural gas rates remain constant, the CHP system will pay itself back at a much faster rate. If natural gas prices increase, then CHP systems can be optimized to produce maximum savings.

6.8 CO_{2e} Savings by System

Table 27 summarizes CO_{2e} savings by each system. To account for bought electricity for some of these systems, the grid emissions were added based on the amount of kWh bought from the grid. The biggest CO_{2e} savings are seen with system E, which is also the most cost effective system. As Table 27 shows, all of the systems save a great deal of CO_{2e} emissions due to a better utilization of primary fuel.

Table 27: CO_{2e} Emissions

CO2e Savings when compared to Grid							
		A	B	C	D	E	F
IC Engine	kWh	20,936,400.00	20,982,933.93	20,936,400.00	16,673,858.17	17,305,591.92	15,776,760.00
	BTU	74,893,389,355.47	71,635,736,437.02	71,476,869,600.00	70,082,301,286.29	59,081,290,819.32	53,861,858,640.00
	CO2e (lb)	10,260,394.34	9,814,095.89	9,792,331.14	9,601,275.28	8,094,136.84	9,011,793.30
Grid	kWh	18,602,443	18,602,443	18,602,443	18,602,443	18,602,443	18,602,443
	CO2e (lb)	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42
	Savings (lb)	**23,596,051.08**	**24,042,349.53**	**24,064,114.29**	**24,255,170.15**	**25,762,308.58**	**24,844,652.12**

6.9 Conclusions

Based on the completed analysis, CHP is a feasible option for the DMA building. Combined Heat and Power showed great potential in the DMA building because of fairly constant loads profiles. Two different prime movers were analyzed for the implementation if a CHP system. Gas turbines were eliminated from the analysis early on due to fractional savings when compared to internal combustion engines. System E included a Jenbacher 616 engine following the electric load. This system used a 650 ton absorption chiller and was supplemented with a 300 ton electric chiller. This system showed the best savings as well as the fastest payback. Annual savings from System E were around $368,273 and a simple payback period for this system was calculated to be around 8.8 years. A sensitivity analysis was also performed on the IC engines to see how the cost of electricity would impact the payback period. At only 10% average increase in electricity cost, the payback period for system E dropped to 5.9 years.

6.10 CHP Recommendations

From the completed analysis, the CHP system E would be recommended to the owner due to a quick payback period and large cost savings. Installing System E, which included a Jenbacher 616 engine following the electric load, showed the best cost savings and system payback. Annual energy cost savings from System E were around $368,273 and a simple payback period for this system was calculated to be around 8.8 years. When including O&M costs, yearly savings were around $284,904, which is a considerable amount of money.

7.0 Thermal Storage

Thermal storage shifts on-peak electrical demand for cooling systems to off-peak. This is done by storing either ice or chilled water during the night and then using it during the day to minimize on-peak use of electricity. There are several approaches to thermal storage but only one will be covered in this analysis.

The approach that will be covered in this analysis will be partial storage. Partial storage is shifting the peak load to off-peak hours and operating at base capacity at all times. This case is also known as load leveling, and has the smallest initial investment when compared to a full storage system.

7.1 Preliminary Analysis

The first step to running a thermal storage analysis was to build an energy model to get base and peak loads. The energy model was built in Trane TRACE 700. TRACE provided an 8760 hour load analysis for each component of the building. The loads included in the TRACE output are as follows: lighting loads, miscellaneous loads, chiller loads, boiler loads, ventilation loads, pump, fans, data center loads, etc. The electricity consumption for the chillers was split up into on-peak, mid-peak, and off-peak loads.

The second step in the analysis was to do a peak shaving analysis, which is the most cost efficient way of utilizing thermal storage. A peak cooling day was taken from the 8760 hour output from TRACE, and thermal loads were plotted to see base and peak loads of the building.

The design day load profile can be seen from Figure 11 and Figure 12. Figure 11 shows the total thermal design day load required by the DMA building in tons, while Figure 12 shows it in kW. From this analysis the thermal storage was sized for load leveling. Some of the costs were shifted from on-peak to off-peak. Demand charges were also recalculated due to leveling of loads.

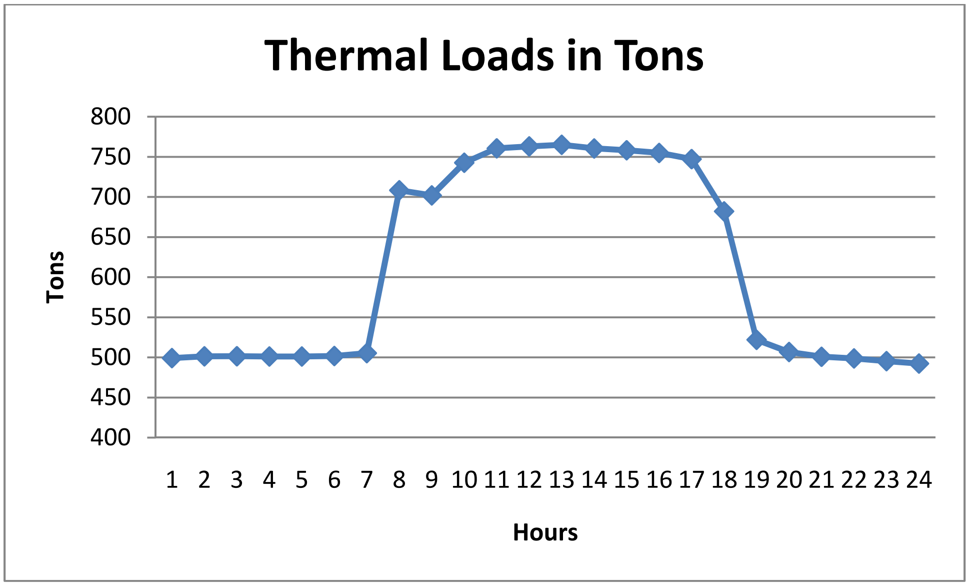


Figure 11: Thermal Loads on Peak Day [tons]

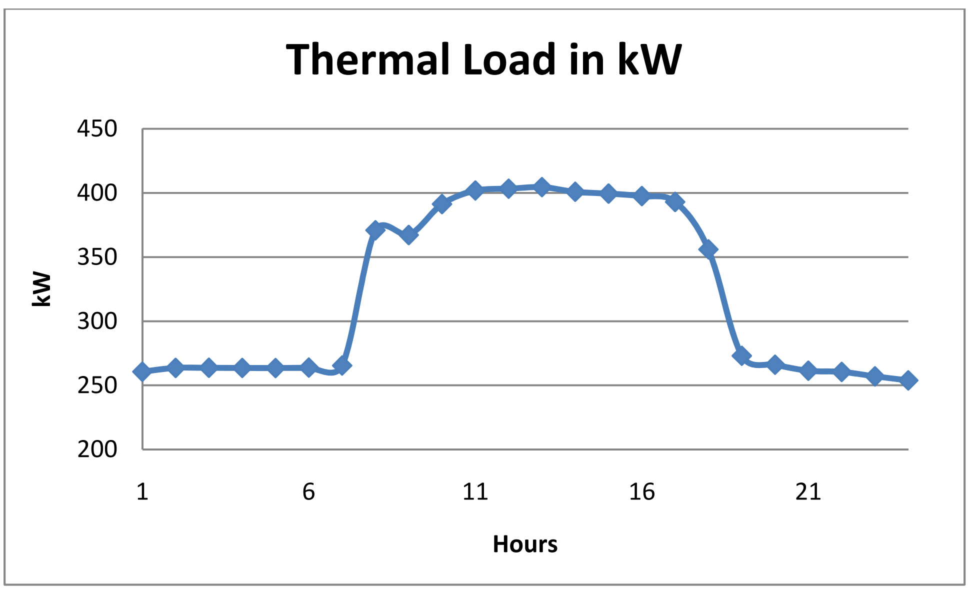


Figure 12: Thermal Loads on Peak Day [kW]

7.2 Chilled Water Storage vs. Ice Storage

The biggest difference between ice storage and chilled water storage is the difference of efficiency between making ice and chilled water. Ice storage requires less space but is less efficient compared to chilled water storage. Ice storage involves a much lower evaporator temperature. Efficiencies of a chiller were obtained from a manufacturer, which reflected about a 30% increase in kW per ton when running at suitable temperatures to make ice. There is also a second disadvantage in ice storage which is the capacity of the chiller. A 500 ton chiller is de-rated to about 375 tons for ice making. Chilled water storage has some disadvantages as well. A disadvantage for chilled water storage is the required space.

Chilled water storage has a clear advantage over ice storage because of the inefficiency of the chillers in making ice instead of chilled water. When consulting with CALMAC, an ice storage manufacturer, ice storage was not recommended for the DMA building since there would be very minimal if any cost savings because the building is operated 24 hours a day, 7 days a week. The current electricity rates in the Baltimore area do not allow for big savings either. The demand charges for a primary service is only $3.61 per kW, and the price difference between on-peak electricity and off-peak is only three cents.

Despite the negative feedback, an energy model was created for ice storage and compared to the base building. As it turns out, yearly savings from ice storage ranged from negative savings to only $1000 dollars a year. The reason for these results is the inefficiency of making ice as well as the low electricity costs in the area. Ice storage was dropped from any further evaluation.

Chilled water storage was modeled in TRACE 700 as well. Savings from TRACE showed a little more promise for chilled water storage when compared to ice storage. An hourly analysis was exported into excel for further analysis.

7.3 Redundancy

Redundancy is an important factor when considering the implementation of thermal storage. A redundancy study has been done on the DMA building to see if a chiller could be removed and replaced with thermal storage in order to minimize initial costs.

N+1 redundancy is required for the DMA building. Currently 2 chillers would meet the peak load. One chiller is redundant. When implementing thermal storage, this redundancy must remain. If storage fails, N chillers are needed to meet the load. In the case of the DMA building N chillers would be 2 Chillers. If a chiller fails, N-1 chillers must be able to level the design load.[7] In order to ensure that this is still the

[7] Bahnfleth, William. "Lecture 24 Central Cooling." *Penn State Architectural Engineering*. April (2009): 49-53.

case, the two chillers and their cooling towers need to be upsized by around 100 tons to make sure that the remaining chiller and thermal storage could take care of the design day loads.

If two chillers are upsized, the third chiller and its associated cooling tower can be used for investment into thermal storage. Upgrading two chillers and two cooling towers will add approximately $100,000 in order to keep the desired redundancy. The cost of one complete chiller and one cooling tower could be used towards the upgrade costs as well as reducing initial investment for the chilled water system.

7.4 Energy Cost Analysis

When implementing thermal storage, a peak shaving strategy was used. Figure 13 shows peak shaving on design day. During peak shaving, the selected chiller runs flat out at a selected setting. This can be seen as the green section of Figure 13. The actual loads during the night are lower than the day, which is when thermal storage comes into effect. During the night which is on an off-peak schedule, the chiller meets the smaller loads and charges the thermal storage. During the day, when the utility charges on-peak rates, the stored thermal energy is used to keep the on-peak costs down as well as cutting peak demand of the building. The chillers will run at 325kW for a 24 hour time period on design day to satisfy the thermal load during on-peak hours.

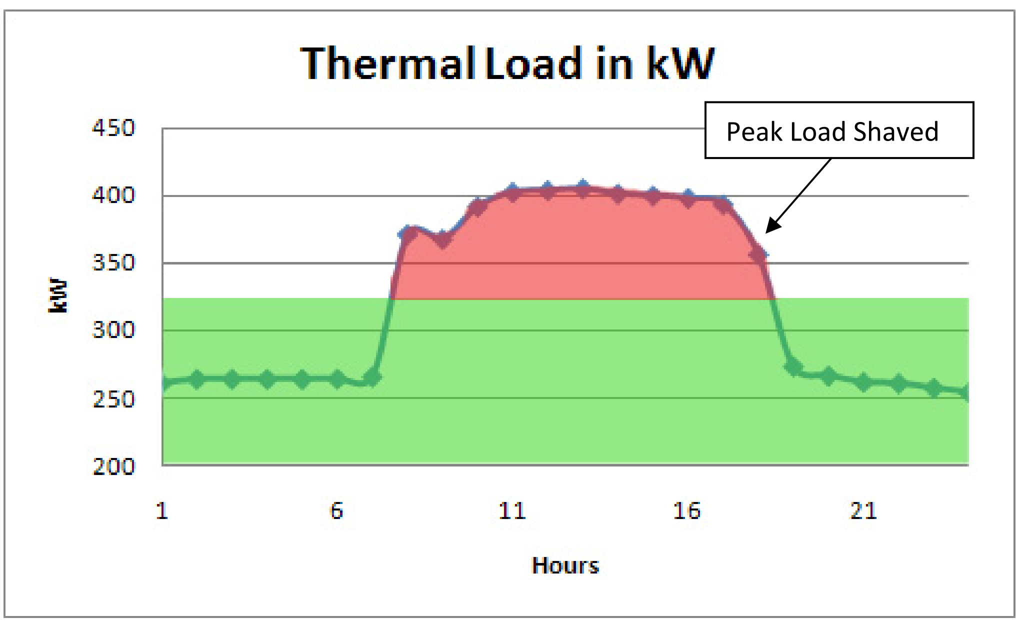


Figure 13: Peak Shaving Strategy

In order to calculate annual cost savings, several factors had to be considered. One of those factors is the demand savings due to thermal storage. Peak day of each month was selected and used to calculate the total demand savings. The second factor was calculating the shift between on-peak and off-peak operation. The difference between on-peak and off-peak costs was calculated and on a basis of a 3500 ton-hr thermal storage tank. Peak day shaving required a 3406 ton-hr storage tank, so a slightly larger tank was selected for future expansion and to account for thermal losses.

After adding up monthly demand savings as well as daily on-peak savings for the current rates, the yearly savings for thermal storage was calculated to be $10,643.43. This is a conservative estimate because the efficiency of the equipment will increase due to minimal part load operation. The savings due to charging at night instead of the day, when heat rejection costs more, were also not considered. In reality these savings could increase by a couple more percent.

7.5 Initial Investment

When calculating initial investment, several assumptions needed to be made. Assumptions were made on the length of pipe, insulation, and Figure of Merit (FoM). The volume for the storage tank also needed to be calculated in order to price it out in RSMeans 2009.

Tank size was calculated with the following formula: V[gal]= 1440*S[ton-hr]/(FoM*delta T]

- FoM was assumed to be 0.9, (0.9 is a typical figure used for a figure of merit in chilled water storage).
- The building was designed for a delta T of 14 F.
- Ton-hr for storage was 3,500.

The calculated volume of the Tank was 400,000 Gallons. The rest of the materials were assumed based on the location of the storage tower and pump size.

Table 28: Initial Investment for Thermal Storage

Initial Investment for Thermal Storage	
400,000 Gallon Tank	$ 382,800.00
300 Feet of 5" pipe	$ 10,500.00
300 Feet of 2" Insulation for 5" Pipe	$ 5,874.00
(2) 15 HP pumps	$ 10,220.00
One Less Chiller	$ (293,062.50)
One Less Cooling Tower	$ (50,472.80)
Increasing size of original Chillers	$ 94,648.00
Increasing size of original Towers	$ 13,160.00
Total	**$ 173,666.70**

The total investment for implementing chilled water storage was about $173,667. One of the redundant chillers as well as one cooling tower was subtracted out during this calculation. The two remaining chillers and cooling towers had to be upsized in order to keep original requirements of redundancy. Thermal storage would replace this redundant equipment, and the plant will still have a 1200 ton capacity plus the 3,500 ton-hr storage.

7.6 Payback and Sensitivity Analysis

Simple payback was calculated for the payback analysis. At the current electrical rate, assuming there would be no increase in electric costs, the calculated payback period was 16.3 years. This payback period is very conservative. As stated earlier in the report, yearly savings did not include increased efficiency in operation. The costs of electricity will more than likely increase, making this payback period even more conservative.

The biggest factor in payback periods is the cost of electricity. If the cost of electricity increases, the payback period will drop because yearly savings would increase. This is why the sensitivity analysis was performed. Table 29 shows the payback period in light of increasing energy costs.

Table 29: Sensitivity Analysis for Thermal Storage

Sensitivity Analysis		
Rates	Yearly Savings	Payback Period (years)
Current Electrical Rate	$ 10,643.43	16.3
An average of 10% cost increase during payback	$ 13,981.31	12.4
An average of 20% cost increase during payback	$ 17,319.19	10.0
An average of 30% cost increase during payback	$ 20,657.06	8.4
An average of 40% cost increase during payback	$ 23,994.94	7.2
An average of 50% cost increase during payback	$ 27,332.82	6.4
An average of 60% cost increase during payback	$ 30,670.69	5.7
An average of 70% cost increase during payback	$ 34,008.57	5.1
An average of 80% cost increase during payback	$ 37,346.45	4.7
An average of 90% cost increase during payback	$ 40,684.33	4.3
An average of 100% cost increase during payback	$ 44,022.20	3.9

When looking through Table 29, the payback period decreases to 10 years at an average of 20% increase of electricity costs over the ten year period. Increasing electricity costs and demand charges could make chilled water storage a good investment. When “real time” pricing for electricity is implemented by the utility companies, thermal storage can bring in much more savings. The thermal storage system can be configured to store up to the maximum amount of storage and use it to cut on-peak cooling hours. Charging the tank can be much cheaper as well during the off-peak hours which will further justify using thermal storage in the DMA building.

7.7 Conclusions

A peak shaving strategy was used to analyze two types of thermal storage systems. Ice storage had a range of results that ranged from negative benefits to very minimal benefits when it came to cost savings. Chilled water storage performed somewhat better because of increased efficiency when compared to ice storage. Chilled water storage produced an average yearly savings of around $10,643, which included demand savings and on-peak kWh savings. The payback period for the chilled water storage system was around 16.32 years. The payback would have been shorter if N+1 redundancy wasn't required. Due to N+1 redundancy, one chiller and cooling tower could be replaced by the chilled water storage system, but the two remaining chillers and cooling towers had to be upsized by 100 tons. A sensitivity analysis was also performed for thermal storage. At an average increase of 10% on-peak electricity prices as well as demand charges, the payback period dropped to 12.4 years.

7.8 Recommendations

Thermal storage showed very minimal savings when compared to the CHP system. The payback period was also more than 16 years. Thermal storage would be recommended if the electrical rates increase to make the thermal storage system more cost effective as shown in the sensibility analysis. If the rates do not show signs of increasing in price, then thermal storage would not be recommended due to little energy cost savings.

8.0 CHP Integrated with Chilled Water Storage

An integrated CHP system with a thermal storage system can lead to big savings. When running a CHP system at constant load, not all of the thermal energy produced by the CHP plant is utilized during the off-peak hours. Systems A and C run at a constant load and show excess thermal energy that could potentially be saved if stored and used during on-peak hours when the CHP system doesn't produce enough thermal energy.

For this part of the analysis, System A will be analyzed because it is the only system that shows a considerable amount of excess thermal energy not being utilized. System E, which shows the biggest savings, doesn't show any excess thermal energy left after heating and cooling the building. It has to be supplemented with further thermal energy.

8.1 Initial Analysis

Upon completion of the CHP and thermal storage analysis, combining the two together involved some work. An hour by hour sorting of storage had to be done over the summer months. As seen from sample calculations in Appendix D, additional thermal energy still had to be supplied to meet thermal loads. The analysis was to be done by hand on a daily basis, starting from May and ending with September, to see how much additional thermal energy was needed to satisfy loads.

First, the thermal energy that could be stored was calculated on a daily basis, including a 10% loss. Then this stored energy could be used during hours that required more thermal energy. Once all of the stored energy was used, additional energy had to be added to meet the required thermal loads.

8.2 Energy Cost Analysis

While performing cost analysis, it became clear that a good amount of thermal energy was wasted during the cooler months, while during the summer months, almost all of the thermal energy was used. The analysis was performed to see how much savings could be obtained from chilled water storage.

Comparing System A alone to System A with thermal storage, an annual savings between the two options was about $11,644. This savings came from using less natural gas in the boiler to make up the difference in thermal energy needed. Instead of spending an additional $31,774, thermal storage helped to decrease that cost down to $20,130.

8.3 Initial Investment for Chilled Water Storage

For the initial investment, the tank size for thermal storage could be decreased to 350,000 gallons instead of 400,000 gallons that was needed in the thermal storage study. Because the CHP system uses an absorption chiller and two backup electrical chillers, one electrical chiller could be removed as mentioned is Section 7 of this report. The second chiller would have to be upsized to 650 tons to meet N+1 redundancy requirements. Table 30 shows additional costs for a chilled water storage system.

Table 30: Thermal Storage Investment with CHP

Initial Investment for Thermal Storage with CHP	
400,000 Gallon Tank	$ 354,200.00
300 Feet of 5" Pipe	$ 10,500.00
300 Feet of 2" Insulation for 5" Pipe	$ 5,874.00
(2) 15 HP Pumps	$ 10,220.00
One Less Chiller	$ (293,062.50)
One Less Cooling Tower	$ (50,472.80)
Increasing Size of Original Chiller	$ 71,200.00
Increasing Size of Original Towers	$ 14,950.00
Total	**$ 123,408.70**

When integrating chilled water storage with a CHP system, the calculated additional investment is around $123,409. The initial investment is slightly smaller when compared to a standalone thermal storage system mentioned in Section 7 of this report.

8.4 Payback Period for Thermal Storage

The calculated simple payback period for the investment of this thermal storage system is 10.6 years. Considering the fact that this is a government building built to be used for more than 50 years, this payback period is probably reasonable.

8.5 Conclusions

The CHP system chosen for this analysis was the most favorable system for this study. This system showed excess thermal energy, which otherwise would be wasted. That excess thermal energy could be stored and used during peak hours. When incorporating a chilled water storage system with a CHP system, calculations showed annual savings around $11,644. The initial investment for adding a chilled water storage system was around $123,409. This leads to a 10.6 year payback period to justify this additional investment.

Internal combustion engines produce much less thermal energy than turbines, which made thermal storage not as effective. Almost all of the thermal energy is utilized during the summer, which leads to little savings when storing a relatively small amount of thermal energy during the night. When considering a peak week during July, the CHP plant wasn’t producing enough thermal energy even during the night. During that week, an additional boiler had to be run in order to supplement the DMA building with thermal energy. Most of the weeks during May, June, August, and September used thermal storage. In addition, thermal storage was utilized during the winter months and the shoulder seasons.

The maximum cost of buying additional natural gas for a boiler in System A was $31,774. The cost of buying additional natural gas for a supplemental boiler for System A, integrated with a chilled water storage system was around $20,130. The percentage of savings and reduction of additional energy was very favorable, but the actual dollar savings were very small. The maximum possible savings would be the additional natural gas bought for System A, which is only an additional $31,774.

8.6 Recommendations

When strictly looking at energy savings of the DMA building, implementing thermal storage with the selected system would be a good idea. The payback period is about 10.6 years, and the initial investment is not large, when comparing to the initial investment of a CHP system. However, when looking at cost savings, an additional $11,644 a year isn't that much. The CHP system chosen for this evaluation was the best candidate out of all the systems presented in this study for thermal storage and the cost savings from it are considerably small.

9.0 System Optimization

This part of the analysis will include a concise study of energy savings coming from DOAS as well as dedicating a chiller to the data center. This part of the analysis will only include the energy and cost savings of the proposed systems. This study will not include initial investment or payback periods due to the depth of study in other parts of the report.

9.1 DOAS

Variable Air Volume (VAV) systems are widely used in office buildings. These types of systems are conventional and are great for many uses. DOAS has several advantages over a VAV system. In order to meet ASHRAE Standard 62.1-20 ventilation requirements, a multiple space method must be used to increase outside air into the AHU's serving required spaces. Increasing outside air can significantly increase energy consumption as well as operating costs. [8]A properly designed DOAS with parallel

[8] Jeong, Jae-Weon, Stanley Mumma, and William Bahnfleth. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. 109.KC-03-7-1 (2003): 627-636. Print.

sensible system can save a considerable amount of energy when compared to a conventional system such as VAV.[8] The parallel sensible system chosen for analysis is an active chilled beam system.

Active chilled beams use ventilation air provided by the AHU, and re-circulate ambient air in the room. The chilled beam takes care of any sensible heat gain while the AHU is responsible for dehumidifying the incoming air (latent loads). Dehumidification is a very important step in implementing DOAS. Properly implemented chilled beams should not remove any latent loads, and if they do, problems with condensation may occur.

When implementing a DOAS system, energy recovery is a must. An enthalpy wheel is usually used to exchange latent and sensible energy from the exhaust with the incoming ventilation air. Unlike VAV systems, where most of the exhaust air is re-circulated, DOAS exhausts all of its air. Energy recovery must be used in DOAS in order be economically feasible. Figure 14 shows a typical schematic for a DOAS system.

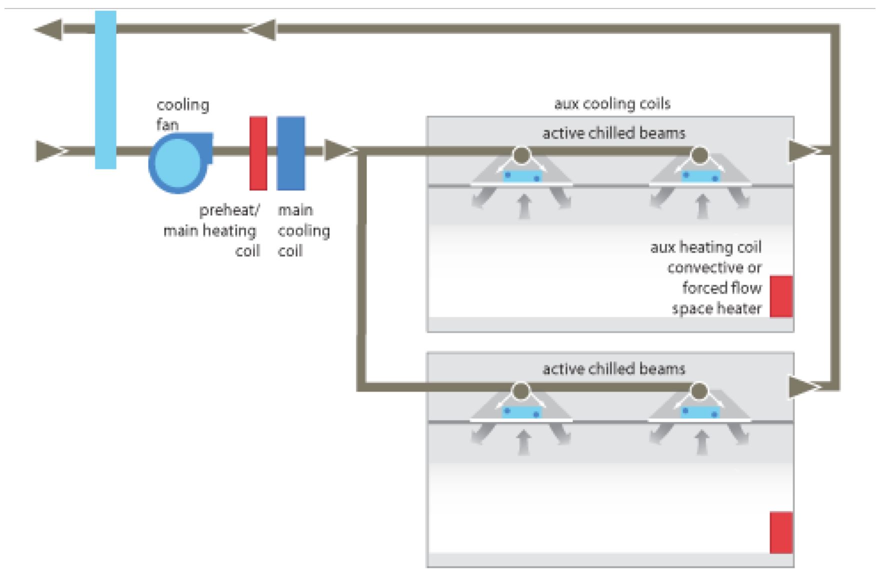


Figure 14: DOAS and Chilled Beam Schematic

To begin this analysis, an energy model was built in Trane TRACE 700. This energy model compared the current design with a DOAS design paralleled with chilled beams in lower energy density spaces like offices. VAV systems were still used in high energy density areas such as the television studios.

After completing the energy model, the results were obtained from TRACE. Annual savings in energy consumption were around 1,913E6 BTU/yr, and annual cost savings were around $46,494. The savings came from smaller AHU's, fans, as well as the efficiency of separating latent and sensible loads. Even with an enthalpy wheel, which adds an additional inch of pressure drop, there are considerable fan savings due to a much smaller requirement for airflow.

Cost savings can come from reductions in ducts that can be resized due to lower flows. AHU's will be downsized and there are savings even with an additional enthalpy wheel used for recovery. The only additional cost that has to be accounted for is the cost of chilled beams. Chilled beams are fairly new to the U.S., which will make them a considerable cost. However as more and more projects begin using chilled beams the cost of their installation will be reduced. Another option that could be used is implementing radiant panels. Radiant panels take care of the sensible loads just as chilled beams, but they have a few implications with them. These implications include higher integration with lighting design, and the risk of radiant panels leaking in a media center or a television studio and damaging expensive electrical equipment.

9.2 Dedicated Chiller to the Data Center

The current setup for the chillers in the DMA building can be seen earlier in Figure 3. The three chillers are set up in parallel in a primary/secondary pumping system. Evaporator temperature for the chillers is set at 44˚ F, and all the loads are served with a 44˚ F entering water temperature. As the temperature of the evaporator increases, the COP of the chiller increases. An increase in the COP results in a reduction of kW/ton used to run the chiller. Data centers usually require a higher entering temperature, but the current design uses APC cooling racks. APC cooling racks are liquid cooled racks that are used to cool the data center loads.

When looking further into the cooling racks, an important piece of information was obtained. The APC cooling racks that are used for the DMA building range in entering water temperature. The same cooling racks that were chosen to cool at 44˚ F are compatible at 55˚ F. However, at 60˚ F or above, the racks would have to be upgraded in order to meet the cooling capacity.

A manufacturer of magnetic frictionless chillers was contacted to obtain efficiency values at desired evaporator temperatures. Table 31 shows the manufacturer's kW/ton at three different temperature settings. These new values show a big drop off in energy consumption as the temperature increases.

Table 31: Data Center Chiller Temperatures

Data Center Analysis			
Evaporator Temperature (˚F)	44	55	60
Condensing Water Temperature (˚F)	85	85	85
kW/ton	0.535	0.418	0.314
NPLV	0.314	0.256	0.2334

The new kW/ton values would have to be modified to account for higher pumping energy due to a smaller temperature difference. Trane TRACE 700 was used to calculate the energy consumption of the data center with a dedicated chiller for the different temperature settings.

As predicted, the energy consumption of the data center decreased as the evaporator temperature increased. The pumping energy increased, but the savings from running the chiller at a higher temperature outweighed the increased pumping costs. Table 32 shows the yearly savings due to increasing temperature to 55˚ F and 60˚ F.

Table 32: Cooling Cost Comparison of the Data Center

Cooling Cost of the Data Center			
Temperature	**MMBTU/year**	**$/yr**	**Savings $/yr**
44˚ F	15137.0	$395,715.00	-
55˚ F	14065.4	$367,560.00	$28,155.00
60˚ F	13046.8	$340,769.00	$54,946.00

In order to dedicate a chiller to the data center, some modifications would have to take place. Keeping redundancy is a must, and therefore the standby chiller would have to be linked to both the building loads and the data center loads. Figure 15 shows the needed modifications to isolate a chiller to make higher temperature water. Some extra piping will be needed to go from the chiller room to the data center, as well as two VFD pumps for redundancy. A connection coming off the main chillers will also be added for redundancy in case the dedicated chiller for the data center fails.

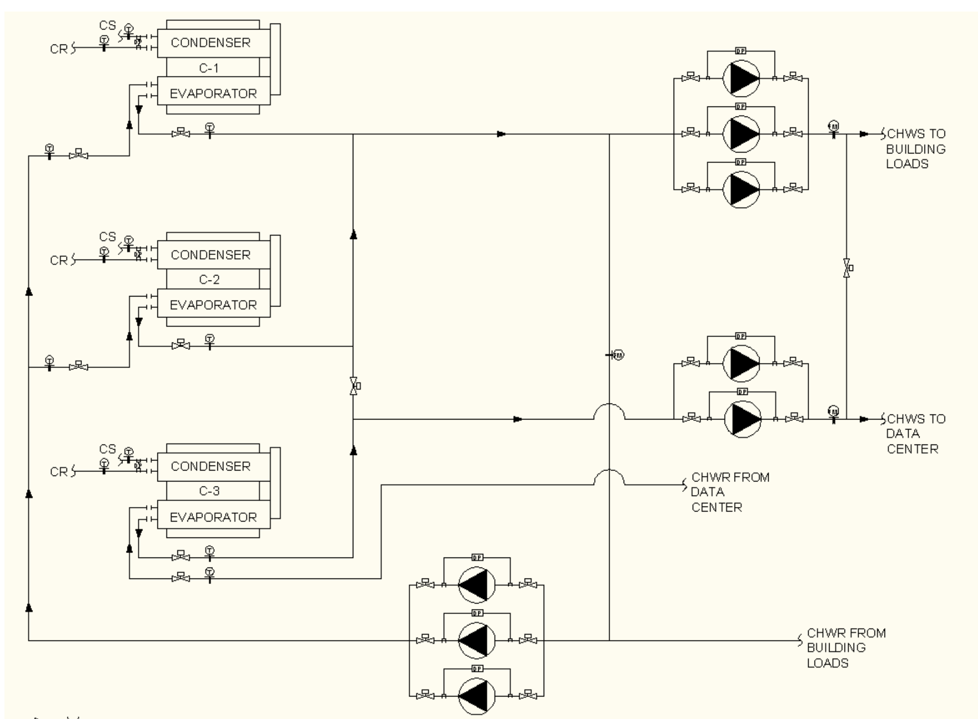


Figure 15: Dedicated Data Center Chiller Schematic

Dedicating a chiller to the data center will only involve a couple hundred feet of pipe and a couple of pumps. Installing two pumps and extra piping, as well as a couple valves, will cost around $19,600. If the 55˚ F water will be used the data center, the payback period would be around seven to eight months. This is definitely a good option to implement for additional savings with a very minimal initial investment.

10.0 Electrical Breadth

When installing a CHP plant an important factor that has to be considered is tying in the CHP system into the original electrical system while keeping the same redundancy level or improving it. Implementing a CHP system will also have electrical implications because the building would be generating its own electricity. Enough power must be supplied to the equipment as well as the data center in the DMA building. Emergency power must also be accounted for to ensure non-stop operation of the building.

An electrical analysis has been done on the DMA building. The CHP system tied in to the existing electrical system by connecting in after each one of the transformers on the load side of the service. An upgraded switchboard for the 2390 kW Jenbacher natural gas generator was designed. The CHP generator comes in three options. These options are: 480/277 V, 4160 V, and 13.2 kV. The option chosen for the design was the 480/277 V because of the close proximity of the machine to the transformers as well as for redundancy and economical reasons.

If a 13.2 kV generator was chosen, three more transformers would have to be added in order to keep the same redundancy level as provided in the original design. The original design used a 480/277 V, two megawatt generator that tied into the system right after the transformers. The current system does exactly the same thing, except all of the loads are covered by the generator instead of just the emergency loads.

Figure 16 shows the schematic of a CHP system being tied into the electrical system of the DMA building. The automatic transfer switches were sized based on the current protection devices put in place by the engineer. The maximum load was calculated for the building and the generator switchboard was sized based on that load. Each one of the breakers coming off the generator switchboard is oversized due to redundancy and future growth. The breakers designed by the engineer were oversized when checking the total connected load, so they were kept at the same sizes. Because the total load will not exceed a total of 3500 amps, the main breaker was selected at 3500 amps.

Extra automatic transfer switches were supplied to the critical loads and the fire pump. Because these ATS's are coming off the same switchboard, the total load of the switchboard doesn't increase. The reason a secondary automatic transfer switch was supplied to the critical loads as well as the fire pump was to keep redundancy. If one of the ATS's fails, the second ATS would come on to serve the critical loads as well as the fire pump.

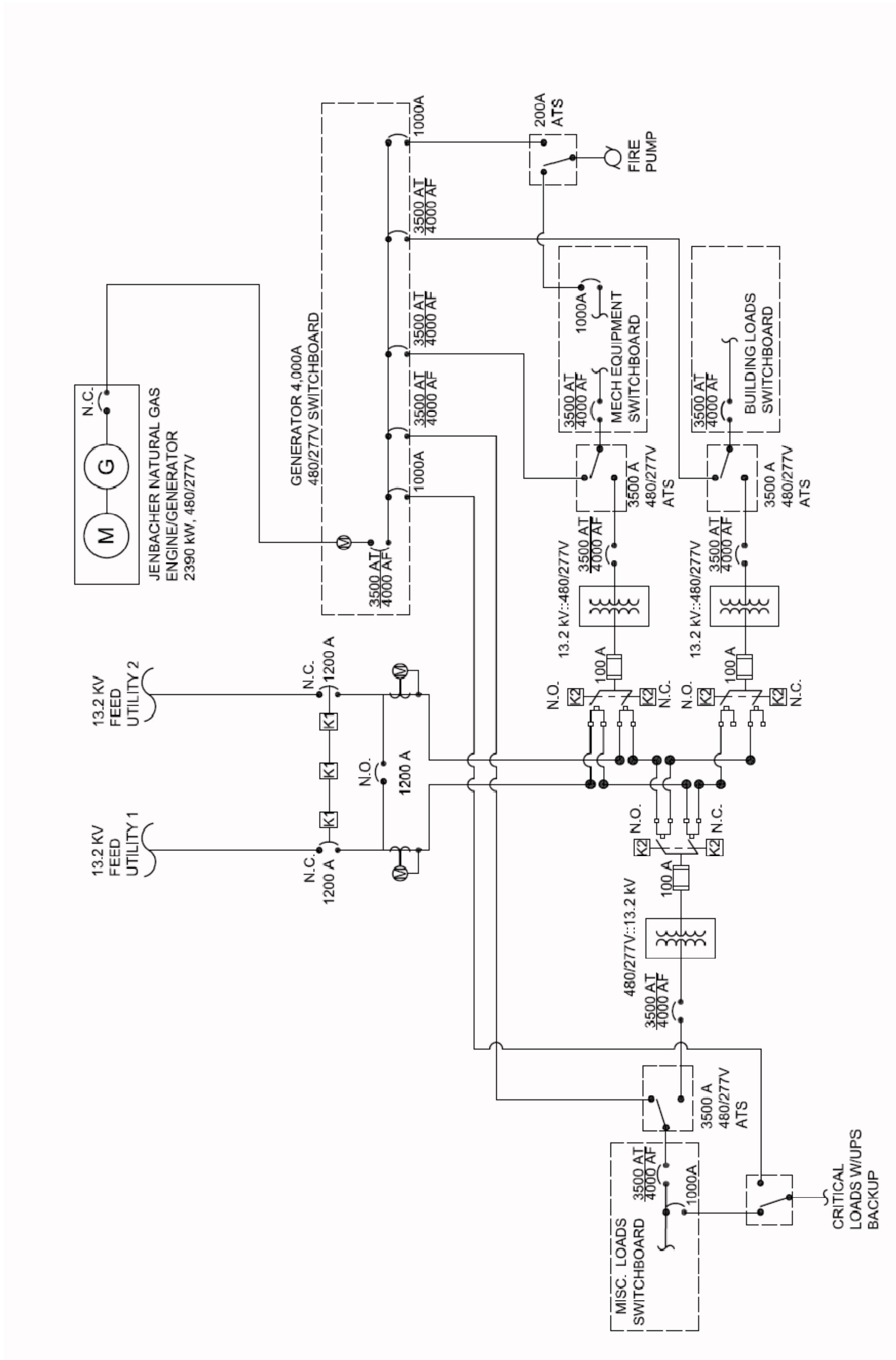


Figure 16: Electrical Service Schematic

Automatic transfer switches were sized based on the end loads of the building. Breakers and fuses were also sized based on the original design. If the loads exceed the capacity of the generator, certain ATS's would switch over to the utility feed. Paralleling gear could also be added in later if a second generator would be required or is determined feasible to use in the DMA building. Paralleling gear basically syncs the output of two generators and produces a constant output. This increases the reliability as well as adds in more redundancy. The data center racks still have room to grow, so with a larger data center an additional prime mover may be required down the road.

11.0 Acoustical Breadth

Acoustics can play an important part in building design when CHP is being considered. CHP prime movers such as turbines and internal combustion engines are very noisy. Acoustical considerations must be accounted for when designing this type of system. Spaces adjacent to the plant as well as above and below must be designed to reasonable operating levels. Noise levels from equipment must be isolated from the conference rooms and television studios. An acoustical study on the mechanical rooms with CHP equipment has been done on the DMA building to make sure acceptable noise levels are achieved.

The location of the internal combustion engine chosen for the DMA building will be located in the utility plant. The utility plant already has eight inch solid filled CMU block with reinforcing rebar for its 30 foot high walls. Unfortunately, having one wall won't bring the noise levels down to acceptable NC levels in the adjacent spaces. Figure 18 shows the location of the utility plant with respect to the surrounding rooms. The warehouse is located to the west of the plant. A hallway is directly south of the utility plant. A chiller room and an electrical room are located to the east of the plant. The chiller room as well as the electrical room is sufficiently isolated from the IC engine with the eight inch CMU block. The spaces that will require an acoustical analysis are the west wall to the warehouse where suggested NC levels are 40-50, as well as the south wall which has a hallway on the other side. Recommended NC levels for hallways are 40-45.[9]

[9] Mehta, Johnson and Rocafort. *Architectural Acoustics Principles and Design.* 1999 by Prentice-Hall, New Jersey. pg 164 and pg 168

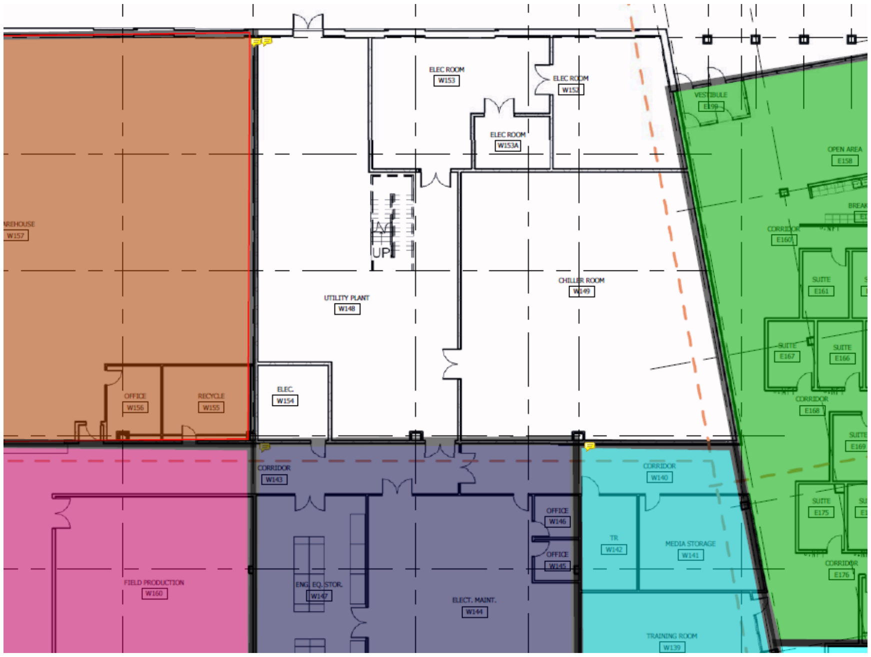


Figure 17: Utility Plant Location

Several options were looked at for this analysis. There are several requirements for all the options analyzed. The first requirement is to have mandatory ear protection inside the utility plant. The second requirement is to move the double doors that open from the utility into the chiller room.

STC Ratings were obtained from Architectural Acoustics by Marshall Long for the calculation of the different of wall types.[10] Because the facility was designed with an 8" filled CMU, additional walls are needed to reduce the noise levels to the recommended levels in adjacent spaces. The walls tested included an additional eight inch filled CMU, eight inch concrete wall, as well as two options of 3-5/8" metal stud walls with two sheets of drywall. One option didn't have insulation inside the wall while the other option included a two inch, R-11 insulation. Tables 33 and 34, show Jenbacher 612 and 616 IC engines, as well as their reduction of noise based on different wall types.

[10] Long, Marshall. *Architectural Acoustics.* Boston: Amsterdam; Elsevier/Academic Press, 2005.

Table 33: Acoustical Study on Jenbacher 612

Jenbacher 612 (1801 kW)											
Engine Data		A-weighting	Adjusted to dB	8" filled CMU wall	8" concrete wall	3 5/8" metal stud with R-11 insulation	3 5/8" metal stud no insulation	Two 8" CMU walls	8" CMU and 8" concrete wall	8" CMU with metal stud & insulation	8" CMU with metal stud no insulation
Hz	dBA	dB	dB	TL	TL	TL	TL	dB	dB	dB	dB
63	88	-26.2	114.2	33	44	20	18	48.2	37.2	61.2	63.2
125	100	-16.1	116.1	34	45	29	20	48.1	37.1	53.1	62.1
250	95	-8.6	103.6	36	55	42	31	31.6	12.6	25.6	36.6
500	94	-3.2	97.2	41	56	52	40	15.2	0.2	4.2	16.2
1000	93	0	93	44	58	57	45	5	0	0	4
2000	91	1.2	89.8	52	63	45	39	0	0	0	0
4000	91	1	90	55	67	40	46	0	0	0	0
8000	94	-1.1	95.1	56	68	42	45	0	0	0	0

Table 34: Acoustical Study on Jenbacher 616

Jenbacher 616 (2390 kW)											
Engine Data		A-weighting	Adjusted to dB	8" filled CMU wall	8" concrete wall	3 5/8" metal stud with R-11 insulation	3 5/8" metal stud no insulation	Two 8" CMU walls	8" CMU and 8" concrete wall	8" CMU with metal stud & insulation	8" CMU with metal stud no insulation
Hz	dBA	dB	dB	TL	TL	TL	TL	dB	dB	dB	dB
63	90	-26.2	116.2	33	44	20	18	50.2	39.2	63.2	65.2
125	96	-16.1	112.1	34	45	29	20	44.1	33.1	49.1	58.1
250	98	-8.6	106.6	36	55	42	31	34.6	15.6	28.6	39.6
500	97	-3.2	100.2	41	56	52	40	18.2	3.2	7.2	19.2
1000	95	0	95	44	58	57	45	7	0	0	6
2000	94	1.2	92.8	52	63	45	39	0	0	0	0
4000	94	1	93	55	67	40	46	0	0	0	0
8000	92	-1.1	93.1	56	68	42	45	0	0	0	0

Figures 18 and 19 show the NC ratings of different wall types as well as their corresponding engine. The eight inch poured concrete wall was ruled out because of the metal construction used for the structural system of the DMA building. When pricing out these walls in RSMeans, the metal stud wall that included insulation was the most expensive wall type, and it did less noise reduction than an additional block wall. The metal stud wall without insulation did not meet the recommended noise criteria in adjacent spaces.

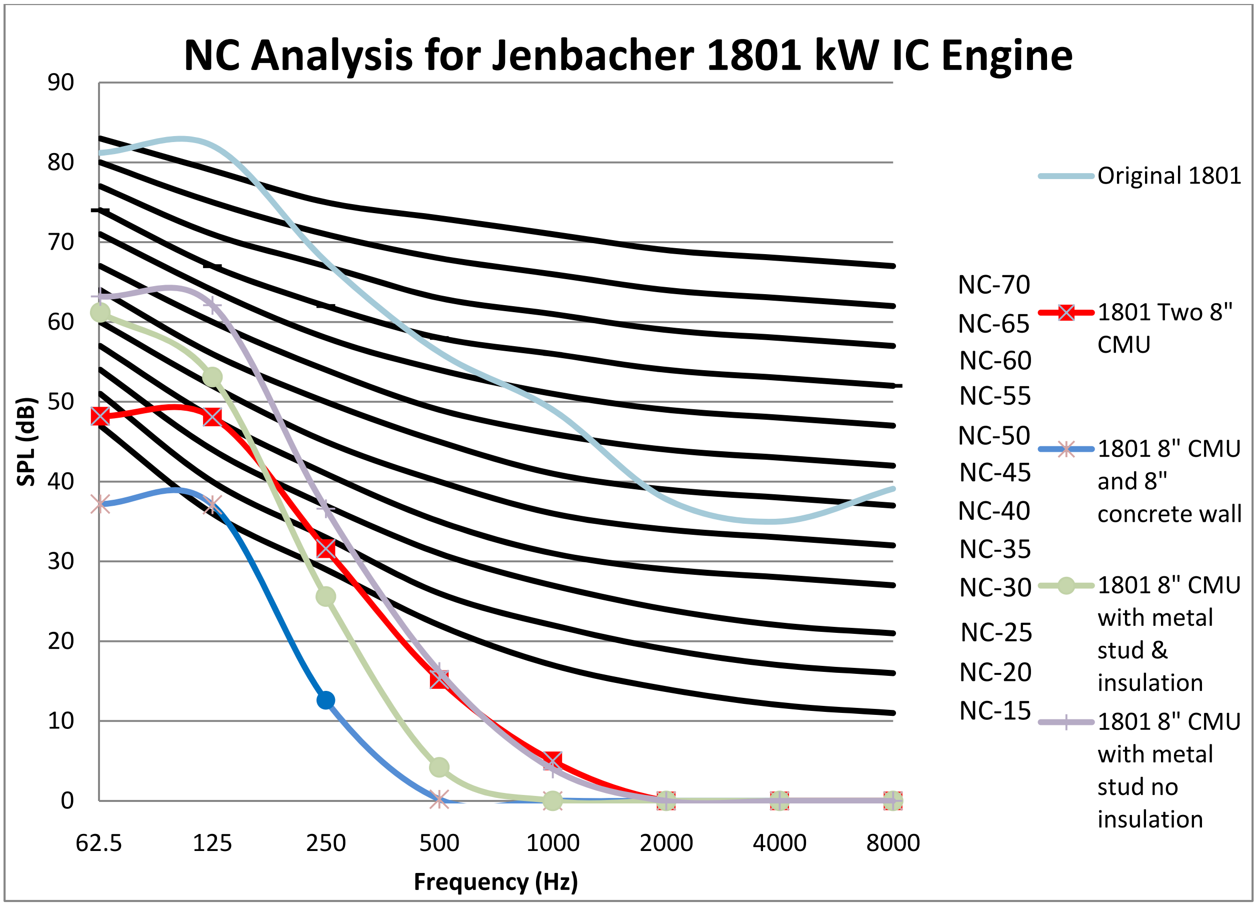


Figure 18: NC Curves for Jenbacher 612

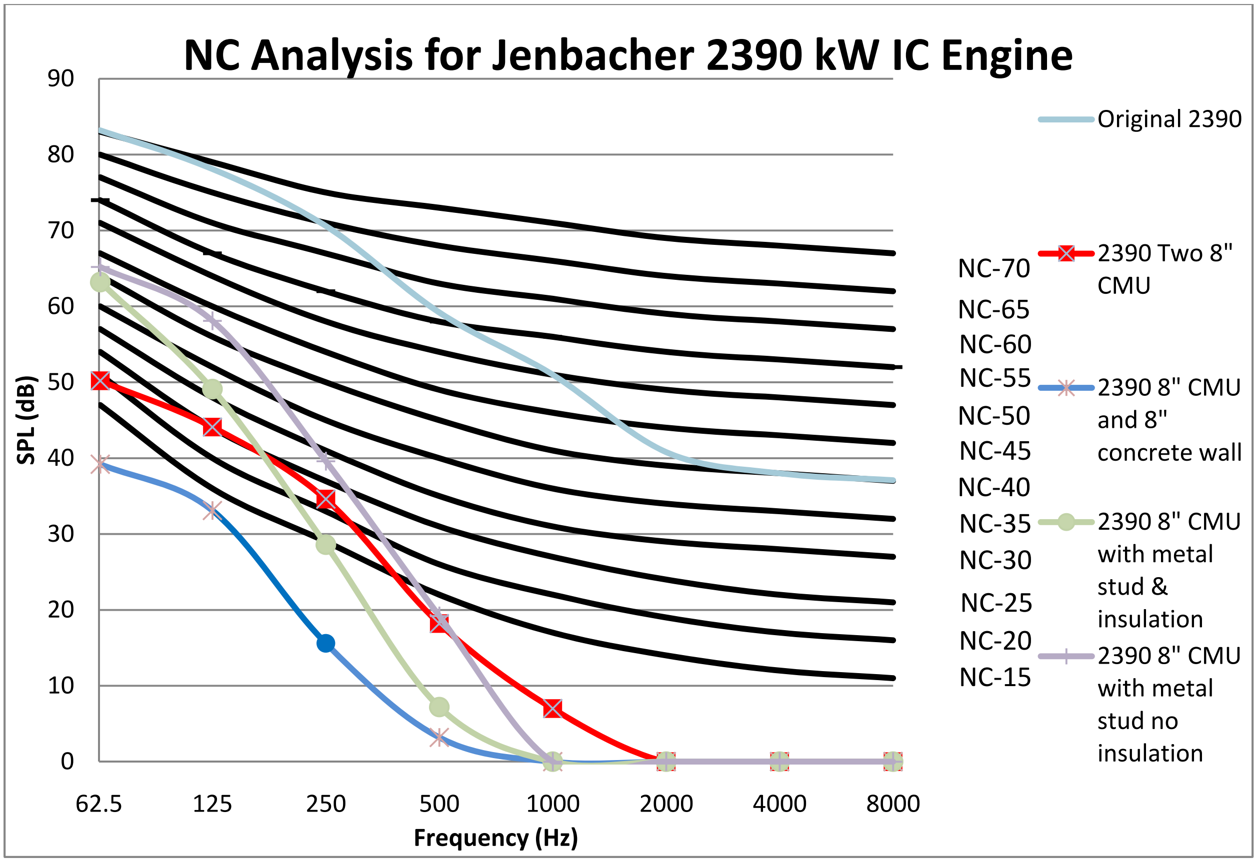


Figure 19: NC Curves for Jenbacher 616

Figures 18 and 19 show that the NC levels of the spaces are currently above NC-70 with the selected IC engines. These noise levels are outside the suggested comfort levels mentioned earlier. These figures show the quality of noise control by the double eight inch filled CMU wall to isolate the CHP plant from the rest of the building. Without this wall, it would be unbearable to be in the warehouse, hallways and offices on the other side of the hallway. The NC charts give a clear indication of this analysis.

Table 35 shows a sample method used to calculate the cost for the different wall types analyzed for the Acoustical analysis.

Table 35: RSMeans Acoustical Cost Estimate

RSMeans 2009 Acoustical Cost Estimate												
Item	Area	Volume	Volume	Material	Installation	Material	Equipment	Installation	Forming material	Forming labor	Caulking Labor cost	Total Cost
	ft^2	*ft^3*	*C.Y.*	*$/SF*	*$/SF*	*C.Y.*	*C.Y.*	*C.Y.*	*$/(Sq Ft of Cont Area)*	*$/(Sq Ft of Cont Area)*	*$/LF*	*$*
8" (3000 psi) concrete wall with Pilasters	-	2690	99.63	-	-	101	7.9	21.5	0.97	6.35	-	$13,720.99
3 5/8" metal stud, 5/8 drywall with R-11 insulation (2")	3585	-	-	3.37	4.29	-	-	-	-	-	-	$27,461.10
3 5/8" metal stud, 5/8 drywall with no insulation	3585	-	-	1.35	2.34	-	-	-	-	-	-	$13,228.65
	LF			*$/SF*							*$/LF*	
Acoustical Caulk (3/4" by 3/4")	665	-	-	0.88	-	-	-	-	-	-	1.03	$1,270.15
8" Block solid and reinforced alt courses	3585	-	-	3.29	4.19	-	-	-	-	-	-	$26,815.80
Totals												
Total: Additional 8" Concrete	-	-	-	-	-	-	-	-	-	-	-	$14,991.14
Total: Additional metal stud wall with insulation	-	-	-	-	-	-	-	-	-	-	-	$28,731.25
Total: Additional metal stud wall, no insulation	-	-	-	-	-	-	-	-	-	-	-	$14,498.80
Total: Additional block wall	-	-	-	-	-	-	-	-	-	-	-	$28,085.95

The recommended wall type for this project is to add an additional eight inch filled CMU wall on the warehouse side and the hallway side. The total cost of this addition will be around $28,086 when using RSMeans 2009. This is the most economical and practical solution when adding a CHP system to the DMA building.

12.0 Final Conclusion and Discussion of Results

The DMA building operates around the clock with a fairly constant load throughout the year. Large internal loads are contributed to this building by television studios, editing suites, media centers, as well as a 1.1 megawatt data center. Several systems were analyzed for their feasibility in the DMA building. Combined Heat and Power, Thermal Storage, and System Optimization were discussed in this report.

Combined Heat and Power showed great potential in the DMA building because of the fairly constant load profiles. Two different prime movers were analyzed for the implementation if a CHP system. Gas turbines were eliminated from the analysis early on due to fractional savings when compared to internal combustion engines. System E included a Jenbacher 616 engine following the electric load, utilizing a 650 ton absorption chiller and supplemented with a 300 ton electric chiller. This system showed the best savings as well as the fastest payback. Annual savings from System E were around $368,273 and a simple payback period for this system was calculated to be around 8.8 years. A sensitivity analysis was also performed on the IC engines to see how the cost of electricity would impact the payback period. At only a 10% average increase in electricity costs, the payback period for system E dropped to 5.9 years. An acoustical analysis was done on CHP systems to see the impact of noise it had on adjacent spaces. An electrical analysis was done on the CHP systems to see how the system will be tied in with the current electrical distribution.

Thermal storage was the second study performed for the DMA building. A peak shaving strategy was used to analyze two types of thermal storage systems. Ice storage was not recommended by the manufacturer of ice storage systems. Despite the negative recommendation, an ice storage analysis was performed. As it turns out, ice storage had a range of results that ranged from negative benefits to very minimal benefits when it came to cost savings. Chilled water storage performed somewhat better because of increase efficiency when compared to ice storage. Chilled water storage produced an average yearly savings of around $10,643, which included demand savings and on-peak kWh savings. The payback period for the chilled water storage system was around 16.32 years. The payback would have been shorter if N+1 redundancy wasn't required. Due to N+1 redundancy one chiller and cooling tower could be replaced by the chilled water storage system, but the two remaining chillers and cooling towers had to be upsized by 100 tons. A sensitivity analysis was also performed for thermal storage. At an average 10% increase of on peak electricity prices as well as demand charges, the payback period dropped to 12.4 years.

The third analysis performed was the integration of a chilled water storage system with a combined heat and power system. The most favorable CHP system for thermal storage was chosen for this analysis. When incorporating a chilled water storage system with a CHP system, calculations showed energy cost savings around $11,644. The initial investment for adding a chilled water storage system in was around $123,409. This led to a 10.6 year payback period to justify the additional investment in thermal storage.

The fourth analysis was separated into two sections. Section one dealt with energy cost savings due to a DOAS system as compared to a VAV system. Section two introduced a separate chiller for the data center that would run at different temperatures to optimize energy cost savings. When using DOAS in the DMA building, yearly cost savings from energy usage were around $46,494. DOAS was not used in all of the spaces and the higher load spaces used a conventional VAV system. Dedicating one of the chillers to the data center produced good results as well. Running the chiller at 55˚ F as compared to the original 44 F produced a yearly savings of about $28,155. Running the chillers at 55˚ F did not require switching out to bigger cooling racks so the initial investment of a couple valves, piping and pumps was paid off in less than a year.

12.0 Final Recommendations

After completing multiple analyses, the best system choice for the DMA building was Combined Heat and Power. Installing System E, which included a Jenbacher 616 engine following the electric load, showed the best cost savings and system payback. Annual energy cost savings from System E were around $368,273 and a simple payback period for this system was calculated to be around 8.8 years. When including O&M costs, yearly savings were around $284,904, which is a considerable amount of money. From the completed analysis, this system would be recommended to the owner due to a quick payback period and large energy cost savings.

Thermal storage showed very minimal savings when compared to the CHP system. The payback period was also more than 16 years. Thermal storage would be recommended if the electrical rates increase to make the thermal storage system more cost effective as shown in the sensibility analysis.

Adding in a thermal storage system to a CHP plant had good results when used with System A from the CHP options. System A by itself only saved around $163,100, which is much less than System E. System E followed the loads, so thermal storage was not necessary. Adding in a thermal storage system would add more complexity to the CHP plant, and from my analysis, would produce smaller saving if implemented in the DMA building.

Switching the VAV system to a DOAS system in office areas of the building would reduce energy usage of the building and have cost savings of around $46,494. Further analysis would have to be done to see initial costs of the system and the payback period. Based on Dr. Mumma’s research, implementing a DOAS system with radiant panels may cost less upfront than a VAV system.

Adding a dedicated chiller to the data center will save around $28,155 a year with a minimal additional cost. Dedicating a chiller to the data center while using a CHP plant would yield smaller savings. Currently, System E covers all of the base loads of the building, which include the data center. During on peak hours, when there isn't enough waste thermal energy from the engine, an electric chiller would kick on to cover the rest of the load. The waste thermal energy is "free" and running an electric chiller for the data center wouldn't make sense financially. Adding a dedicated chiller if CHP isn't used in the building would produce favorable results. My recommendation for adding a dedicated chiller would be to add it if CHP is not used in the building.

Appendix A: Literature Review

Introduction:

Global warming and energy optimization have been a hot topic for several years. New energy efficient vehicles and transportation have been implemented, starting with hybrid cars, but the building industry hasn't been touched. Buildings in the United States use more than a third of the total energy produced. Different options must be looked into and revisited to gain energy independence and minimize or even completely get rid of carbon dioxide emissions.

The concept of Combined Heat and Power (CHP) systems has been around for years, but the economics and technology weren't suitable for their application. Combined Heat and Power is a way of producing electricity. Normally, the power company creates all the electricity and discards all the waste heat which is the byproduct of electricity production. CHP uses a prime mover such as a turbine, an internal combustion engine, or a fuel cell to make electricity. The waste heat is then collected and used to directly heat buildings or used in industrial processes. This waste heat can also be used in an absorption cycle or steam chiller to create chilled water to cool buildings.

Many states including Pennsylvania and Maryland will de-regulate the sale of electricity by the power companies, placing a cap on the price the power company could demand for electricity. Once that cap is removed, prices will jump and some believe they would almost double. The purpose of this review is to re-examine the current state of CHP in light of deregulation of electricity.

In the processes of examining the current state of CHP, several issues must be addressed. 1) The difference between CHP systems and the current Separate Heat and Power system used for power generation; 2) Size of the power plant, and how size affects efficiency of energy utilization; and 3) Types of fuels used for CHP systems, and the difference between these fuels.

The scope of this review is to focus on the three issues listed above to determine if it is worth-while to look further into CHP. The review is constrained by these three issues due to available space, creating the necessity for a concise review of the topic at hand.

Combined Heat and Power (CHP) vs. Separate Heat and Power (SHP):

Separate heat and power is defined as producing electricity with a power plant, while throwing out waste heat. That electricity is then distributed to the building sector and used in buildings to run processes such as lighting, computers, data centers, printers, kitchens, basic electric requirements, etc. The electricity can also be used to cool the building by running electric chillers, as well as heat the building by using resistance heating or electric boilers. Where natural gas is available, buildings use it in gas-fired boilers to heat the building and make domestic hot water. Most of the United States uses SHP to power their buildings.

Fuel Energy Utilization is defined as the useful energy out over the total energy of the fuel in. Typical SHP plants have energy utilization of about 30-45%. Energy utilization for CHP plants range from 70% to more than 90% [1]. These energy utilization numbers for a CHP system are verified in a recent article from the department of building science in Tsinghua University in Beijing written by X.L. Zhao et al. "The electric efficiency is about 24%–27%, and the thermal recovery efficiency of the flue gas is about 14%–15%, and the thermal recovery efficiency of jacket water is about 39%–44%" [2]. Zhao works in the Department of Building Science at the Tsinghua University. The department tests Internal Combustion Engines for electrical and thermal efficiencies for different scenarios and different engine sizes.

Emissions from energy production are another factor examine when analyzing the difference between CHP and SHP. Several sources agree that CHP reduces emissions when compared to SHP power plants. Zhao et al, states that the second benefit of distributed CCHP systems is emission reduction [2]. D.W Wu et al, also mention the differences in emissions from prime mover to prime mover, and state the fact that CHP systems utilize energy at a much greater efficiency which decreases emissions [1]. Rodney Evans, a researcher from Harwell Laboratory, also mentions that CHP "can reduce SO_2 emissions significantly because of the low sulfur content of natural gas" [3]. He also states that emissions from CHP systems are very technologically and fuel dependent. Depending on the fuel type, new emissions from CHP plant will be produced, but these new emissions will be counter-balanced by the reduction in old emissions from the conventional SHP system.

Plant size and how it affects efficiency of energy utilization:

The size of the prime mover is a very important factor when using CHP. The prime mover, such as an IC engine or a gas turbine, must meet the electrical or thermal load of the building. Once the main load is met, the byproduct is used by the building. The most successful systems meet both loads without any waste. Meeting both loads at the same time is a very difficult task, because thermal loads usually don't correspond with electrical loads. The load type determines the size of the plant. Larger loads, like campus loads, are fairly constant. A campus load would require a large CHP system. The larger the CHP system and the more constant the load is, the more efficient the system will be.

When CHP systems get smaller, the efficiency starts to decrease. Wu mentions, "The average efficiency of the micro-turbine is 26.9%, when operating at full output capacity and an average air inlet temperature of 71˚ C. However, the partial-load efficiency drops to a low of 11% at 9 kW output power." [1]. The reason for this lower efficiency is the operation of these plants. Smaller plants usually operate at part load, which decreases efficiency. A lot of development is being done right now to increase efficiency of smaller plants. In fact, the author concluded that the efficiency of the smaller plants is low also said, "Small scale CHP would be an extremely efficient means of using natural gas both for electricity production and CO_2 abatement" [1].

The Institute of Sustainable Energy Technology reports, "All CHP installations can save the primary energy and reduce CO_2 emission when operated on heat demand. However, installing a micro-scale CHP in a residential house is not financially favorable at the present time because of high investment cost and long payback period." [4]. While the micro-scale CHP systems save primary energy and reduce CO_2 emissions, they are still much less efficient than larger systems. Larger systems start from 1megawatt and go up. The smaller systems require much smaller engines that are currently not developed to be as efficient.

The common trend for all the articles is that the larger systems have a much better fuel utilization efficiency when compared to smaller or micro-CHP systems. These micro-systems are under development to improve efficiency of utilization of the prime fuel.

Types of fuels used for CHP systems:

Several different fuels can be potentially used for CHP systems. Typically natural gas is the most common fuel type. Natural gas has many advantages. It is energy dense and can be used in most of the CHP systems. Natural gas is available in many locations and is environmentally friendly [3] as mentioned by Evans in his report for the Energy Policy. Biomass fuels are currently being developed to be used in CHP systems. Other fuels used include diesel, alcohol, butane, gasoline, and methanol [1].

Biomass fuels are increasing in popularity. Leilei Dong and Hao Liu mention, "Of all the renewable energy resources, biomass is plentiful and prominent." [4]. Biomass is one of the largest energy sources on earth, which when burned can be considered carbon neutral, given that you grow as much biomass as you burn. Biomass does have some complications such as being delivered and storage. Tuula Savola and Carl-Johan Fogelholm who are mechanical engineers in Helsinki University of Technology mention that biomass fuels have about 55% moisture content by volume [5]. A fuel dryer must be used when implementing a biomass fuel. When burning biomass fuels, a boiler is usually used. Biomass fuel is a solid fuel that would ruin an IC engine or a turbine due to the design of these engines. This can be seen from the article written by Dong, "Biomass gasification product gases can cause extreme engine wear due to tar contamination and unstable operation" [4].

Conclusion:

The energy industry is seeing more and more development in CHP systems. CHP systems have many benefits including lower total emissions, and a higher fuel utilization efficiency when compared to conventional SHP systems. The efficiency is heavily dependent on the size of the plant, the prime mover choice, and the type of fuel used.

It is my belief that CHP will become a much more predominant way of producing electricity for buildings as the price electricity increases. With the improvements in technology and current economic conditions, CHP can be a solution. Although there are a few examples of working CHP systems, the bigger campus systems such as Bucknell's Cogeneration plant, are very efficient and economical because they match thermal as well as electrical loads very well.

At this point, there are still many questions to be addressed. The articles discussed all seem to agree on one thing; CHP systems reduce emissions as well as improve total utilization of the fuel. Further research and analysis should be done to determine if CHP would produce a feasible outcome.

Sources

[1] Wu, D.W., Wang, R.Z., *Combined cooling, heating and power: A review.* Progress in Energy and Combustion Science. 21 August 2006.

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Appendix C: Masters Coursework

As a portion of the analysis for this report, materials covered in Masters Classes must be incorporated. The Masters Courses which have been included in this report are as follows:

AE 557 Central Cooling – The materials covered in this course was directly used for the thermal storage analysis. The dedicated chiller study was also done with the help of this course.

AE 558 Central Heating – The materials covered in this course were used for CHP analysis.

AE 551 Combined Heat and Power – CHP was one of the major studies in this report. Knowledge from this course was directly applied to this report when selecting equipment and doing load calculations.

AE 467 Advanced Electrical Design – Electrical design was used for tying in the CHP system into the current electrical distribution system.

Appendix D: Sample Calculations

Base Building Sample Calculations

			Alt 1					Alt 1			Not Including Chiller			Includes Chiller			
			Total kW	**Total kW including Chiller**	Electric kW in BTU's	**Total Electric converted to MBH**	Cooling Load TONS converted to Mbh	Total Boiler Mbh	**Total Thermal Load**	Thermal Ratio	On Peak	Mid-Peak	Off Peak	Current Electric Cost On Peak	Current Electric Cost Mid Peak	Current Electric Cost Off Peak	Current Boiler Cost
Month	Day	Hour	**kW**		BTU/hr	**Mbh**	Mbh	Mbh	**Mbh**		kWh	kWh	kWh				
Jan	1	1	**1802.8**	**1994.9**	6155664	**6155.7**	4950.552	274.86	**5225.4**	0.848879			1802.84	0	0	149.6856	2.831058
Jan	1	2	**1802.5**	**1994**	6154639	**6154.6**	4932.54	280.27	**5212.8**	0.846972			1802.54	0	0	149.624	2.886781
Jan	1	3	**1802.4**	**1993.5**	6154161	**6154.2**	4918.611	287.15	**5205.8**	0.845893			1802.4	0	0	149.5835	2.957645
Jan	1	4	**1801.9**	**1991.5**	6152420	**6152.4**	4868.777	287.84	**5156.6**	0.838145			1801.89	0	0	149.4364	2.964752
Jan	1	5	**1801.7**	**1990.2**	6151771	**6151.8**	4827.59	294.3	**5121.9**	0.832588			1801.7	0	0	149.3329	3.03129
Jan	1	6	**1801.7**	**1989.7**	6151771	**6151.8**	4811.019	310.39	**5121.4**	0.83251			1801.7	0	0	149.2969	3.197017
Jan	1	7	**1801.8**	**1989.5**	6151942	**6151.9**	4801.412	339.28	**5140.7**	0.835621		1801.75		0	184.231	0	3.494584
Jan	1	8	**1802.2**	**1990.3**	6153376	**6153.4**	4816.182	292.31	**5108.5**	0.830193		1802.17		0	184.3088	0	3.010793
Jan	1	9	**1802.9**	**1991.3**	6155766	**6155.8**	4827.35	277.59	**5104.9**	0.829294		1802.87		0	184.4042	0	2.859177
Jan	1	10	**1804.5**	**1994**	6161229	**6161.2**	4863.254	256.06	**5119.3**	0.830892	1804.47			215.585874	0	0	2.637418
Jan	1	11	**1805.7**	**1996**	6165292	**6165.3**	4891.472	257.31	**5148.8**	0.835124	1805.66			215.8031952	0	0	2.650293
Jan	1	12	**1806.4**	**1997.3**	6167921	**6167.9**	4911.046	215.96	**5127**	0.831237	1806.43			215.948076	0	0	2.224388
Jan	1	13	**1806.7**	**1998.1**	6168980	**6169**	4926.536	196.98	**5123.5**	0.830529	1806.74			216.0302472	0	0	2.028894
Jan	1	14	**1806.9**	**1998.1**	6169595	**6169.6**	4921.252	361.29	**5282.5**	0.856222	1806.92			216.0324096	0	0	3.721287
Jan	1	15	**1806.1**	**1997.1**	6166897	**6166.9**	4915.609	277.39	**5193**	0.842076	1806.13			215.9296956	0	0	2.857117
Jan	1	16	**1805.7**	**1996.2**	6165429	**6165.4**	4899.278	395.03	**5294.3**	0.858709	1805.7			215.8313064	0	0	4.068809
Jan	1	17	**1805.2**	**1995.4**	6163722	**6163.7**	4888.47	436.89	**5325.4**	0.863985	1805.2			215.7437292	0	0	4.499967
Jan	1	18	**1804.8**	**1995**	6162458	**6162.5**	4888.11	377.81	**5265.9**	0.854516	1804.83			215.7026436	0	0	3.891443
Jan	1	19	**1804.6**	**1994.7**	6161776	**6161.8**	4883.667	429.9	**5313.6**	0.862344	1804.63			215.666964	0	0	4.42797
Jan	1	20	**1804.5**	**1994.4**	6161195	**6161.2**	4879.705	413.43	**5293.1**	0.859108	1804.46			215.6366904	0	0	4.258329
Jan	1	21	**1805**	**1994.6**	6162902	**6162.9**	4868.537	528.61	**5397.1**	0.875748		1804.96		0	184.7079	0	5.444683
Jan	1	22	**1804.3**	**1993.9**	6160785	**6160.8**	4866.136	434.89	**5301**	0.860446		1804.34		0	184.6431	0	4.479367
Jan	1	23	**1804.7**	**1994.2**	6162117	**6162.1**	4864.334	429.58	**5293.9**	0.859106		1804.73		0	184.6746	0	4.424674
Jan	1	24	**1805**	**1994.5**	6162971	**6163**	4862.893	501.68	**5364.6**	0.870453			1804.98	0	0	149.6556	5.167304
Jan	2	1	**1805.4**	**1995.3**	6164439	**6164.4**	4878.144	487.87	**5366**	0.870479			1805.41	0	0	149.7208	5.025061
Jan	2	2	**1805.1**	**1994.8**	6163414	**6163.4**	4871.659	480.23	**5351.9**	0.868332			1805.11	0	0	149.6848	4.946369
Jan	2	3	**1804.7**	**1993.8**	6161878	**6161.9**	4852.086	476.52	**5328.6**	0.86477			1804.66	0	0	149.6083	4.908156
Jan	2	4	**1804.8**	**1993.8**	6162254	**6162.3**	4846.803	549.09	**5395.9**	0.875636			1804.77	0	0	149.6053	5.655627
Jan	2	5	**1805.1**	**1993.6**	6163380	**6163.4**	4828.911	677.7	**5506.6**	0.89344			1805.1	0	0	149.591	6.98031
Jan	2	6	**1804.1**	**1992.3**	6159898	**6159.9**	4819.905	469.09	**5289**	0.858617			1804.08	0	0	149.495	4.831627
Jan	2	7	**1804.3**	**1992**	6160649	**6160.6**	4802.373	662.37	**5464.7**	0.88704		1804.3		0	184.469	0	6.822411
Jan	2	8	**1805.1**	**1992.9**	6163278	**6163.3**	4806.095	655.58	**5461.7**	0.886164		1805.07		0	184.5505	0	6.752474
Jan	2	9	**1804.7**	**1992.9**	6161980	**6162**	4820.145	465.75	**5285.9**	0.857824		1804.69		0	184.5533	0	4.797225
Jan	2	10	**1806.4**	**1995.2**	6167819	**6167.8**	4840.318	470.63	**5310.9**	0.861074	1806.4			215.7231864	0	0	4.847489
Jan	2	11	**1808.5**	**1998**	6174853	**6174.9**	4864.695	464.36	**5329.1**	0.863025	1808.46			216.0215976	0	0	4.782908
Jan	2	12	**1810.7**	**2000.9**	6182433	**6182.4**	4889.071	438.01	**5327.1**	0.861648	1810.68			216.3383892	0	0	4.511503
Jan	2	13	**1811.6**	**2002.1**	6185540	**6185.5**	4898.677	383.06	**5281.7**	0.853885	1811.59			216.467052	0	0	3.945518
Jan	2	14	**1811.5**	**2001.9**	6185096	**6185.1**	4897.356	397.38	**5294.7**	0.856048	1811.46			216.4486716	0	0	4.093014
Jan	2	15	**1812.8**	**2003.7**	6189671	**6189.7**	4911.886	358.66	**5270.5**	0.851507	1812.8			216.6389628	0	0	3.694198
Jan	2	16	**1812.9**	**2003.8**	6190115	**6190.1**	4909.845	414.7	**5324.5**	0.860169	1812.93			216.6465312	0	0	4.27141
Jan	2	17	**1813.5**	**2004.3**	6192198	**6192.2**	4906.002	401.64	**5307.6**	0.85715	1813.54			216.7005912	0	0	4.136892
Jan	2	18	**1812.8**	**2003.1**	6189501	**6189.5**	4893.154	426.92	**5320.1**	0.859532	1812.75			216.575172	0	0	4.397276
Jan	2	19	**1814.1**	**2004.5**	6194110	**6194.1**	4893.274	447.56	**5340.8**	0.862244	1814.1			216.721134	0	0	4.609868
Jan	2	20	**1812.4**	**2002.2**	6188306	**6188.3**	4875.742	512.52	**5388.3**	0.870717	1812.4			216.4821888	0	0	5.278956
Jan	2	21	**1812.6**	**2002**	6188886	**6188.9**	4862.773	541.15	**5403.9**	0.873166		1812.57		0	185.3969	0	5.573845

			Alt 1				Alt 1				Not Including Chiller			Includes Chiller			
Month	Day	Hour	Total kW kW	Total kW including Chiller	Electric kW in BTU's BTU/hr	Total Electric converted to MBH Mbh	Cooling Load TONS converted to Mbh Mbh	Total Boiler Mbh Mbh	Total Thermal Load Mbh	Thermal Ratio	On Peak kWh	Mid-Peak kWh	Off Peak kWh	Current Electric Cost On Peak	Current Electric Cost Mid Peak	Current Electric Cost Off Peak	Current Boiler Cost
May	31	6	1830.7	2028.4	6250619	6250.6	5071.833	130.04	5201.9	0.832217			1830.65	0	0	152.2023	1.339412
May	31	7	1842	2039.6	6289441	6289.4	5067.991	125.07	5193.1	0.825679		1842.02		0	188.8788	0	1.288221
May	31	8	1936.6	2141.8	6612275	6612.3	5301.667	754.21	6055.9	0.915854		1936.57		0	198.343	0	7.768363
May	31	9	2104.3	2322.7	7185113	7185.1	5702.015	64.27	5766.3	0.802532		2104.34		0	215.0904	0	0.661981
May	31	10	2119.1	2349.8	7235510	7235.5	6088.553	45.35	6133.9	0.84775	2119.1			254.0625384	0	0	0.467105
May	31	11	2129.9	2367.2	7272318	7272.3	6291.729	32.9	6324.6	0.869686	2129.88			255.9459888	0	0	0.33887
May	31	12	2131	2370.6	7276005	7276	6359.935	22.71	6382.6	0.877218	2130.96			256.3060284	0	0	0.233913
May	31	13	2130.5	2370.8	7274332	7274.3	6382.27	15.47	6397.7	0.879495	2130.47			256.3330584	0	0	0.159341
May	31	14	2109.3	2352.4	7202117	7202.1	6440.629	0	6440.6	0.894269	2109.32			254.3425692	0	0	0
May	31	15	2112.1	2358.5	7211677	7211.7	6538.855	0	6538.9	0.906704	2112.12			255.0021012	0	0	0
May	31	16	2113.4	2362.3	7215911	7215.9	6613.304	0	6613.3	0.916489	2113.36			255.4086324	0	0	0
May	31	17	2111.7	2358.3	7210209	7210.2	6568.274	0	6568.3	0.910969	2111.69			254.9750712	0	0	0
May	31	18	1923.5	2150.3	6567580	6567.6	5967.392	0	5967.4	0.908614	1923.48			232.4882736	0	0	0
May	31	19	1824	2027.1	6228015	6228	5230.579	4.46	5235	0.840563	1824.03			219.1711332	0	0	0.045938
May	31	20	1832	2031.2	6255194	6255.2	5135.236	64.38	5199.6	0.831248	1831.99			219.6122628	0	0	0.663114
May	31	21	1830.5	2027.6	6249970	6250	5081.199	109.24	5190.4	0.830474		1830.46		0	187.7648	0	1.125172
May	31	22	1829.9	2026.2	6247990	6248	5053.221	129.86	5183.1	0.82956		1829.88		0	187.6333	0	1.337558
May	31	23	1829.7	2025.7	6247239	6247.2	5044.335	135.65	5180	0.829164		1829.66		0	187.5879	0	1.397195
May	31	24	1830.3	2027	6249356	6249.4	5054.422	136.92	5191.3	0.8307			1830.28	0	0	152.101	1.410276
Jun	1	1	1831.2	2031.6	6252360	6252.4	5124.548	115.54	5240.1	0.838098			1831.16	0	0	215.1168	1.190062
Jun	1	2	1830.9	2032.3	6251609	6251.6	5135.356	119.61	5255	0.840578			1830.94	0	0	215.1919	1.231983
Jun	1	3	1830.9	2033.3	6251472	6251.5	5149.645	122.74	5272.4	0.843383			1830.9	0	0	215.3021	1.264222
Jun	1	4	1830.9	2035.8	6251575	6251.6	5181.467	122.38	5303.8	0.848402			1830.93	0	0	215.5615	1.260514
Jun	1	5	1831	2037.5	6251814	6251.8	5210.406	120.81	5331.2	0.852747			1831	0	0	215.7479	1.244343
Jun	1	6	1832	2040.7	6255194	6255.2	5253.515	112.11	5365.6	0.857787			1831.99	0	0	216.0846	1.154733
Jun	1	7	1846.8	2061.1	6305591	6305.6	5372.754	84.99	5457.7	0.86554		1846.75		0	229.1542	0	0.875397
Jun	1	8	1948	2188.9	6651131	6651.1	6072.823	529.35	6602.2	0.992639		1947.95		0	243.363	0	5.452305
Jun	1	9	2130.4	2398.3	7274127	7274.1	6834.612	32.29	6866.9	0.944017		2130.41		0	266.6441	0	0.332587
Jun	1	10	2152.3	2432.2	7348835	7348.8	7197.255	20.18	7217.4	0.98212	2152.29			337.1348786	0	0	0.207854
Jun	1	11	2139	2428.4	7303286	7303.3	7408.837	8.92	7417.8	1.015674	2138.95			336.608153	0	0	0.091876
Jun	1	12	2133.3	2422.8	7283824	7283.8	7411.118	8.92	7420	1.018701	2133.25			335.8305397	0	0	0.091876
Jun	1	13	2128.6	2414.6	7267913	7267.9	7357.682	8.92	7366.6	1.013579	2128.59			334.6939213	0	0	0.091876
Jun	1	14	2126.8	2412.8	7261801	7261.8	7357.682	8.92	7366.6	1.014432	2126.8			334.4458058	0	0	0.091876
Jun	1	15	2126.3	2415.5	7259923	7259.9	7402.833	8.92	7411.8	1.020913	2126.25			334.8158999	0	0	0.091876
Jun	1	16	2120.8	2406.9	7241212	7241.2	7321.298	8.92	7330.2	1.012292	2120.77			333.6210644	0	0	0.091876
Jun	1	17	2113.8	2394.4	7217482	7217.5	7177.202	8.92	7186.1	0.995655	2113.82			331.8981173	0	0	0.091876
Jun	1	18	1945.7	2201.4	6643517	6643.5	6494.305	22.94	6517.2	0.980993	1945.72			305.1362984	0	0	0.236282
Jun	1	19	1847	2067.9	6306411	6306.4	5509.886	37.52	5547.4	0.879646	1846.99			286.6329826	0	0	0.386456
Jun	1	20	1833.2	2050.4	6259292	6259.3	5430.753	66.81	5497.6	0.878304	1833.19			284.2142032	0	0	0.688143
Jun	1	21	1832.6	2049.1	6257414	6257.4	5406.137	81.41	5487.5	0.876967		1832.64		0	227.8167	0	0.838523
Jun	1	22	1832.4	2045.1	6256423	6256.4	5351.74	89.71	5441.5	0.869738		1832.35		0	227.372	0	0.924013
Jun	1	23	1832.2	2043	6255809	6255.8	5318.838	95.32	5414.2	0.865461		1832.17		0	227.1352	0	0.981796
Jun	1	24	1831.9	2042.3	6254887	6254.9	5305.63	99.61	5405.2	0.864163			1831.9	0	0	216.2508	1.025983
Jun	2	1	1831.9	2042	6254716	6254.7	5299.505	100.99	5400.5	0.863428			1831.85	0	0	216.2244	1.040197
Jun	2	2	1831.8	2041.9	6254477	6254.5	5297.584	102.29	5399.9	0.863361			1831.78	0	0	216.2116	1.053587
Jun	2	3	1831.8	2041.8	6254375	6254.4	5296.263	103.5	5399.8	0.863358			1831.75	0	0	216.2032	1.06605
Jun	2	4	1831.7	2043.1	6254306	6254.3	5310.553	105.47	5416	0.865967			1831.73	0	0	216.344	1.086341

			Alt 1					Alt 1			Not Including Chiller			Includes Chiller			
			Total kW	**Total kW including Chiller**	Electric kW in BTU's	**Total Electric converted to MBH**	Cooling Load TONS converted to Mbh	Total Boiler Mbh	**Total Thermal Load**	Thermal Ratio	On Peak	Mid-Peak	Off Peak	Current Electric Cost On Peak	Current Electric Cost Mid Peak	Current Electric Cost Off Peak	Current Boiler Cost
Month	Day	Hour	**kW**		BTU/hr	**Mbh**	Mbh	Mbh	**Mbh**		kWh	kWh	kWh				
Dec	31	10	**1812.7**	**2004.3**	6189466	**6189.5**	4936.022	265.36	**5201.4**	0.84036	1812.74			216.7081596	0	0	2.733208
Dec	31	11	**1816.1**	**2009**	6200802	**6200.8**	4982.974	287.18	**5270.2**	0.849915	1816.06			217.2141612	0	0	2.957954
Dec	31	12	**1816**	**2009.5**	6200734	**6200.7**	5001.826	166.08	**5167.9**	0.833435	1816.04			217.2714648	0	0	1.710624
Dec	31	13	**1819.1**	**2013.8**	6211285	**6211.3**	5042.894	91.68	**5134.6**	0.826652	1819.13			217.7342184	0	0	0.944304
Dec	31	14	**1818.5**	**2013.5**	6209065	**6209.1**	5052.74	62.39	**5115.1**	0.823816	1818.48			217.6952952	0	0	0.642617
Dec	31	15	**1817.2**	**2011.8**	6204729	**6204.7**	5039.772	63.88	**5103.7**	0.822542	1817.21			217.5168972	0	0	0.657964
Dec	31	16	**1812.9**	**2005.8**	6189910	**6189.9**	4982.253	136.68	**5118.9**	0.82698	1812.87			216.867096	0	0	1.407804
Dec	31	17	**1810.2**	**2001.9**	6180760	**6180.8**	4939.865	198.26	**5138.1**	0.83131	1810.19			216.4443468	0	0	2.042078
Dec	31	18	**1808.5**	**1998.8**	6174853	**6174.9**	4892.193	390.39	**5282.6**	0.855499	1808.46			216.1080936	0	0	4.021017
Dec	31	19	**1808**	**1997.8**	6173316	**6173.3**	4874.181	475.67	**5349.9**	0.866609	1808.01			216.0032172	0	0	4.899401
Dec	31	20	**1806.7**	**1996**	6168980	**6169**	4856.169	440.3	**5296.5**	0.858565	1806.74			215.8096824	0	0	4.53509
Dec	31	21	**1806.8**	**1995.7**	6169253	**6169.3**	4841.759	521.96	**5363.7**	0.869428		1806.82		0	184.808	0	5.376188
Dec	31	22	**1806.7**	**1995.5**	6168980	**6169**	4837.797	497.43	**5335.2**	0.864847		1806.74		0	184.7904	0	5.123529
Dec	31	23	**1806**	**1994.3**	6166556	**6166.6**	4822.066	570.99	**5393.1**	0.874565		1806.03		0	184.682	0	5.881197
Dec	31	24	**1805.2**	**1993.3**	6163653	**6163.7**	4814.861	607.56	**5422.4**	0.879741			1805.18	0	0	149.5663	6.257868
														1054061.956	**432037**	**457280**	**17558**
													Total	**$2,088,377.65**			

	Max Monthly Demand	Cost of Demand
Month	kW	$
Jan	2354.25	10198.611
Feb	2390.31	10354.82292
Mar	2411.02	10444.53864
Apr	2427.4	10515.4968
May	2441.64	10577.18448
Jun	2519.75	10915.557
Jul	2552.44	11057.17008
Aug	2536.58	10988.46456
Sep	2502.39	10840.35348
Oct	2441.77	10577.74764
Nov	2472.59	10711.25988
Dec	2368.52	10260.42864
total		**$127,441.64**

System A Sample Calculations

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
Jan	1	1	2390	587.16	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8025.609363	953.3921995	0
Jan	1	2	2390	587.46	17.62	5610.329	191.4323349	197.175305	2431	8300.469363	8020.199363	973.7137001	0
Jan	1	3	2390	587.6	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8013.319363	986.7327272	0
Jan	1	4	2390	588.11	17.64	5610.329	191.4323349	197.175305	2431	8300.469363	8012.629363	1057.233212	0
Jan	1	5	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	8006.169363	1109.612577	0
Jan	1	6	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7990.079363	1117.195557	0
Jan	1	7	2390	588.25	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7961.189363	1102.029024	0
Jan	1	8	2390	587.83	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8008.159363	1127.899194	0
Jan	1	9	2390	587.13	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8022.879363	1126.665664	0
Jan	1	10	2390	585.53	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	8044.409363	1096.904206	0
Jan	1	11	2390	584.34	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	8043.159363	1055.341521	0
Jan	1	12	2390	583.57	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	8084.509363	1068.729957	0
Jan	1	13	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	8103.489363	1065.580867	0
Jan	1	14	2390	583.08	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7939.179363	908.8187738	0
Jan	1	15	2390	583.87	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	8023.079363	1000.781311	0
Jan	1	16	2390	584.3	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	7905.439363	906.4712045	0
Jan	1	17	2390	584.8	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7863.579363	880.0501049	0
Jan	1	18	2390	585.17	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7922.659363	939.6447349	0
Jan	1	19	2390	585.37	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.569363	893.9018384	0
Jan	1	20	2390	585.54	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7887.039363	916.0327685	0
Jan	1	21	2390	585.04	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7771.859363	816.8062988	0
Jan	1	22	2390	585.66	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7865.579363	913.9571656	0
Jan	1	23	2390	585.27	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.889363	921.8403156	0
Jan	1	24	2390	585.02	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7798.789363	851.7988357	0
Jan	2	1	2390	584.59	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7812.599363	843.8228319	0
Jan	2	2	2390	584.89	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7820.239363	860.7261721	0
Jan	2	3	2390	585.34	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7823.949363	892.397736	0
Jan	2	4	2390	585.23	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7751.379363	827.3756429	0
Jan	2	5	2390	584.9	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7622.769363	724.3256001	0
Jan	2	6	2390	585.92	17.58	5610.329	191.4323349	197.175305	2431	8300.469363	7831.379363	945.8013504	0
Jan	2	7	2390	585.7	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7638.099363	777.5666776	0
Jan	2	8	2390	584.93	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7644.889363	779.0388342	0
Jan	2	9	2390	585.31	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7834.719363	948.7982637	0
Jan	2	10	2390	583.6	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	7829.839363	915.0989831	0
Jan	2	11	2390	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7836.109363	886.5456856	0
Jan	2	12	2390	579.32	17.38	5610.329	191.4323349	197.175305	2431	8300.469363	7862.459363	878.0723882	0
Jan	2	13	2390	578.41	17.35	5610.329	191.4323349	197.175305	2431	8300.469363	7917.409363	919.2989212	0
Jan	2	14	2390	578.54	17.36	5610.329	191.4323349	197.175305	2431	8300.469363	7903.089363	906.8658979	0
Jan	2	15	2390	577.2	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7941.809363	924.8291541	0
Jan	2	16	2390	577.07	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	7885.769363	871.7053908	0
Jan	2	17	2390	576.46	17.29	5610.329	191.4323349	197.175305	2431	8300.469363	7898.829363	890.2547776	0
Jan	2	18	2390	577.25	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7873.549363	883.3299147	0
Jan	2	19	2390	575.9	17.28	5610.329	191.4323349	197.175305	2431	8300.469363	7852.909363	862.5183714	0
Jan	2	20	2390	577.6	17.33	5610.329	191.4323349	197.175305	2431	8300.469363	7787.949363	822.6036986	0
Jan	2	21	2390	577.43	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7759.319363	812.500379	0

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
May	31	6	2390	559.35	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8170.429363	924.9534289	0
May	31	7	2390	547.98	16.44	5610.329	191.4323349	197.175305	2431	8300.469363	8175.399363	935.4128157	0
May	31	8	2390	453.43	13.60	5610.329	191.4323349	197.175305	2431	8300.469363	7546.259363	-27.55051849	27.55051849
May	31	9	2390	285.66	8.57	5610.329	191.4323349	197.175305	2431	8300.469363	8236.199363	90.46399523	0
May	31	10	2390	270.9	8.13	5610.329	191.4323349	197.175305	2431	8300.469363	8255.119363	-442.8140073	442.8140073
May	31	11	2390	260.12	7.80	5610.329	191.4323349	197.175305	2431	8300.469363	8267.569363	-720.6153338	720.6153338
May	31	12	2390	259.04	7.77	5610.329	191.4323349	197.175305	2431	8300.469363	8277.759363	-807.8619494	807.8619494
May	31	13	2390	259.53	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8284.999363	-832.5290101	832.5290101
May	31	14	2390	280.68	8.42	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-900.429072	900.429072
May	31	15	2390	277.88	8.34	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1040.751522	1040.751522
May	31	16	2390	276.64	8.30	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1147.108391	1147.108391
May	31	17	2390	278.31	8.35	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1082.779639	1082.779639
May	31	18	2390	466.52	14.00	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-224.37678	224.37678
May	31	19	2390	565.97	16.98	5610.329	191.4323349	197.175305	2431	8300.469363	8296.009363	823.7531371	0
May	31	20	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8236.089363	900.0385469	0
May	31	21	2390	559.54	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8191.229363	932.3730486	0
May	31	22	2390	560.12	16.80	5610.329	191.4323349	197.175305	2431	8300.469363	8170.609363	951.7226462	0
May	31	23	2390	560.34	16.81	5610.329	191.4323349	197.175305	2431	8300.469363	8164.819363	958.6268532	0
May	31	24	2390	559.72	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8163.549363	942.9472128	0
Jun	1	1	2390	558.84	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8184.929363	864.1459039	0
Jun	1	2	2390	559.06	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8180.859363	844.6370036	0
Jun	1	3	2390	559.1	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8177.729363	821.0933464	0
Jun	1	4	2390	559.07	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8178.089363	775.9943621	0
Jun	1	5	2390	559	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8179.659363	736.2224178	0
Jun	1	6	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8188.359363	683.3383597	0
Jun	1	7	2390	543.25	16.30	5610.329	191.4323349	197.175305	2431	8300.469363	8215.479363	540.1158259	0
Jun	1	8	2390	442.05	13.26	5610.329	191.4323349	197.175305	2431	8300.469363	7771.119363	-904.3418301	904.3418301
Jun	1	9	2390	259.59	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8268.179363	-1495.552761	1495.552761
Jun	1	10	2390	237.71	7.13	5610.329	191.4323349	197.175305	2431	8300.469363	8280.289363	-2001.50364	2001.50364
Jun	1	11	2390	251.05	7.53	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2292.503	2292.503
Jun	1	12	2390	256.75	7.70	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2295.762323	2295.762323
Jun	1	13	2390	261.41	7.84	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538
Jun	1	14	2390	263.2	7.90	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538
Jun	1	15	2390	263.75	7.91	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2283.925833	2283.925833
Jun	1	16	2390	269.23	8.08	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2167.447907	2167.447907
Jun	1	17	2390	276.18	8.29	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-1961.595902	1961.595902
Jun	1	18	2390	444.28	13.33	5610.329	191.4323349	197.175305	2431	8300.469363	8277.529363	-1000.048944	1000.048944
Jun	1	19	2390	543.01	16.29	5610.329	191.4323349	197.175305	2431	8300.469363	8262.949363	391.6833348	0
Jun	1	20	2390	556.81	16.70	5610.329	191.4323349	197.175305	2431	8300.469363	8233.659363	475.440394	0
Jun	1	21	2390	557.36	16.72	5610.329	191.4323349	197.175305	2431	8300.469363	8219.059363	496.0067781	0
Jun	1	22	2390	557.65	16.73	5610.329	191.4323349	197.175305	2431	8300.469363	8210.759363	565.4159099	0
Jun	1	23	2390	557.83	16.73	5610.329	191.4323349	197.175305	2431	8300.469363	8205.149363	606.8087843	0
Jun	1	24	2390	558.1	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8200.859363	621.3885514	0
Jun	2	1	2390	558.15	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8199.479363	628.7572616	0
Jun	2	2	2390	558.22	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8198.179363	630.201955	0
Jun	2	3	2390	558.25	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8196.969363	630.8789317	0
Jun	2	4	2390	558.27	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8194.999363	608.4952746	0

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
Dec	30	21	2390	583.77	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	7799.189363	883.5912664	0
Dec	30	22	2390	584.46	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	7753.109363	859.4688136	0
Dec	30	23	2390	584.79	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7768.439363	879.4304837	0
Dec	30	24	2390	585.78	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7611.929363	757.4006945	0
Dec	31	1	2390	586.61	17.60	5610.329	191.4323349	197.175305	2431	8300.469363	7772.809363	924.4562546	0
Dec	31	2	2390	587.1	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	7695.259363	873.8385585	0
Dec	31	3	2390	586.36	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7654.199363	826.0883684	0
Dec	31	4	2390	586.79	17.60	5610.329	191.4323349	197.175305	2431	8300.469363	7667.049363	850.2602286	0
Dec	31	5	2390	586.43	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7720.209363	886.6089816	0
Dec	31	6	2390	586.04	17.58	5610.329	191.4323349	197.175305	2431	8300.469363	7551.099363	723.5029984	0
Dec	31	7	2390	586.46	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7771.789363	922.4069946	0
Dec	31	8	2390	586.25	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7843.179363	987.4498911	0
Dec	31	9	2390	582.98	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7857.059363	943.0051564	0
Dec	31	10	2390	577.26	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	8035.109363	983.6489433	0
Dec	31	11	2390	573.94	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8013.289363	894.7554985	0
Dec	31	12	2390	573.96	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8134.389363	988.9231945	0
Dec	31	13	2390	570.87	17.13	5610.329	191.4323349	197.175305	2431	8300.469363	8208.789363	1004.655373	0
Dec	31	14	2390	571.52	17.15	5610.329	191.4323349	197.175305	2431	8300.469363	8238.079363	1019.87882	0
Dec	31	15	2390	572.79	17.18	5610.329	191.4323349	197.175305	2431	8300.469363	8236.589363	1036.9155	0
Dec	31	16	2390	577.13	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	8163.789363	1046.284758	0
Dec	31	17	2390	579.81	17.39	5610.329	191.4323349	197.175305	2431	8300.469363	8102.209363	1045.259557	0
Dec	31	18	2390	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7910.079363	921.2322614	0
Dec	31	19	2390	581.99	17.46	5610.329	191.4323349	197.175305	2431	8300.469363	7824.799363	861.683762	0
Dec	31	20	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7860.169363	922.7852626	0
Dec	31	21	2390	583.18	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7778.509363	861.710463	0
Dec	31	22	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7803.039363	891.9013932	0
Dec	31	23	2390	583.97	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	7729.479363	840.8135703	0
Dec	31	24	2390	584.82	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7692.909363	814.5361706	0
					######		1676947.254	1727255.67					
					Adjusted for 10Cent sa		120000				8300.469363	MBH added by t	3416519.755
							1556947.254	1571560.9		chiller tons	691.7057802	Therms addition	34165.19755
			20936400									Cost additional	31773.63373
			o&m costs	$0.005/kilowatt-hour (kWh)									
			104682	0.005			Costs with ABS		$1,475,458.33				
							Savings over original		$612,919.33				
												4827.399148	
							Additional Cost	Payback (years)					
							2,890,905	4.71661589	$612,919.33				

System A Sample Calculations with Thermal Storage

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh	Thermal Storage Using System A: Thermal energy that could be stored Mbh	How much can be utilized	Thermal Still needed to be bought
Jan	1	1	2390	587.16	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8025.609363	953.3921995	0	953.3921995	953.3921995	
Jan	1	2	2390	587.46	17.62	5610.329	191.4323349	197.175305	2431	8300.469363	8020.199363	973.7137001	0	973.7137001	1927.1059	
Jan	1	3	2390	587.6	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8013.319363	986.7327272	0	986.7327272	2913.838627	
Jan	1	4	2390	588.11	17.64	5610.329	191.4323349	197.175305	2431	8300.469363	8012.629363	1057.233212	0	1057.233212	3971.071839	
Jan	1	5	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	8006.169363	1109.612577	0	1109.612577	5080.684416	
Jan	1	6	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7990.079363	1117.195557	0	1117.195557	6197.879973	
Jan	1	7	2390	588.25	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7961.189363	1102.029024	0	1102.029024	7299.908998	
Jan	1	8	2390	587.83	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8008.159363	1127.899194	0	1127.899194	8427.808191	
Jan	1	9	2390	587.13	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8022.879363	1126.665664	0	1126.665664	9554.473855	
Jan	1	10	2390	585.53	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	8044.409363	1096.904206	0	1096.904206	10651.37806	
Jan	1	11	2390	584.34	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	8043.159363	1055.341521	0	1055.341521	11706.71958	
Jan	1	12	2390	583.57	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	8084.509363	1068.729957	0	1068.729957	12775.44954	
Jan	1	13	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	8103.489363	1065.580867	0	1065.580867	13841.03041	
Jan	1	14	2390	583.08	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7939.179363	908.8187738	0	908.8187738	14749.84918	
Jan	1	15	2390	583.87	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	8023.079363	1000.781311	0	1000.781311	15750.63049	
Jan	1	16	2390	584.3	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	7905.439363	906.4712045	0	906.4712045	16657.1017	
Jan	1	17	2390	584.8	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7863.579363	880.0501049	0	880.0501049	17537.1518	
Jan	1	18	2390	585.17	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7922.659363	939.6447349	0	939.6447349	18476.79654	
Jan	1	19	2390	585.37	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.569363	893.9018384	0	893.9018384	19370.69837	
Jan	1	20	2390	585.54	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7887.039363	916.0327685	0	916.0327685	20286.73114	
Jan	1	21	2390	585.04	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7771.859363	816.8062988	0	816.8062988	21103.53744	
Jan	1	22	2390	585.66	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7865.579363	913.9571656	0	913.9571656	22017.49461	
Jan	1	23	2390	585.27	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.889363	921.8403156	0	921.8403156	22939.33492	
Jan	1	24	2390	585.02	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7798.789363	851.7988357	0	851.7988357	23791.13376	
Jan	2	1	2390	584.59	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7812.599363	843.8228319	0	843.8228319	24634.95659	
Jan	2	2	2390	584.89	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7820.239363	860.7261721	0	860.7261721	25495.68276	
Jan	2	3	2390	585.34	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7823.949363	892.397736	0	892.397736	26388.0805	
Jan	2	4	2390	585.23	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7751.379363	827.3756429	0	827.3756429	27215.45614	
Jan	2	5	2390	584.9	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7622.769363	724.3256001	0	724.3256001	27939.78174	
Jan	2	6	2390	585.92	17.58	5610.329	191.4323349	197.175305	2431	8300.469363	7831.379363	945.8013504	0	945.8013504	28885.58309	
Jan	2	7	2390	585.7	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7638.099363	777.5666776	0	777.5666776	29663.14977	
Jan	2	8	2390	584.93	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7644.889363	779.0388342	0	779.0388342	30442.1886	
Jan	2	9	2390	585.31	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7834.719363	948.7982637	0	948.7982637	31390.98687	
Jan	2	10	2390	583.6	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	7829.839363	915.0989831	0	915.0989831	32306.08585	
Jan	2	11	2390	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7836.109363	886.5456856	0	886.5456856	33192.63154	
Jan	2	12	2390	579.32	17.38	5610.329	191.4323349	197.175305	2431	8300.469363	7862.459363	878.0723882	0	878.0723882	34070.70392	
Jan	2	13	2390	578.41	17.35	5610.329	191.4323349	197.175305	2431	8300.469363	7917.409363	919.2989212	0	919.2989212	34990.00284	
Jan	2	14	2390	578.54	17.36	5610.329	191.4323349	197.175305	2431	8300.469363	7903.089363	906.8658979	0	906.8658979	35896.86874	
Jan	2	15	2390	577.2	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7941.809363	924.8291541	0	924.8291541	36821.6979	
Jan	2	16	2390	577.07	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	7885.769363	871.7053908	0	871.7053908	37693.40329	
Jan	2	17	2390	576.46	17.29	5610.329	191.4323349	197.175305	2431	8300.469363	7898.829363	890.2547776	0	890.2547776	38583.65807	
Jan	2	18	2390	577.25	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7873.549363	883.3299147	0	883.3299147	39466.98798	

														Thermal Storage Using System A		
Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh		Thermal energy that could be stored Mbh	How much can be utilized	Thermal Still needed to be bought
May	31	10	2390	270.9	8.13	5610.329	191.4323349	197.175305	2431	8300.469363	8255.119363	-442.8140073	442.8140073		0		
May	31	11	2390	260.12	7.80	5610.329	191.4323349	197.175305	2431	8300.469363	8267.569363	-720.6153338	720.6153338		0		
May	31	12	2390	259.04	7.77	5610.329	191.4323349	197.175305	2431	8300.469363	8277.759363	-807.8619494	807.8619494		0		
May	31	13	2390	259.53	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8284.999363	-832.5290101	832.5290101		0		
May	31	14	2390	280.68	8.42	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-900.429072	900.429072		0		
May	31	15	2390	277.88	8.34	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1040.751522	1040.751522		0		
May	31	16	2390	276.64	8.30	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1147.108391	1147.108391		0		
May	31	17	2390	278.31	8.35	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1082.779639	1082.779639		0		
May	31	18	2390	466.52	14.00	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-224.37678	224.37678		0		
May	31	19	2390	565.97	16.98	5610.329	191.4323349	197.175305	2431	8300.469363	8296.009363	823.7531371	0		823.7531371		
May	31	20	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8236.089363	900.0385469	0		900.0385469		
May	31	21	2390	559.54	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8191.229363	932.3730486	0		932.3730486		
May	31	22	2390	560.12	16.80	5610.329	191.4323349	197.175305	2431	8300.469363	8170.609363	951.7226462	0		951.7226462		
May	31	23	2390	560.34	16.81	5610.329	191.4323349	197.175305	2431	8300.469363	8164.819363	958.6268532	0		958.6268532		
May	31	24	2390	559.72	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8163.549363	942.9472128	0		942.9472128		
Jun	1	1	2390	558.84	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8184.929363	864.1459039	0		864.1459039		
Jun	1	2	2390	559.06	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8180.859363	844.6370036	0		844.6370036		
Jun	1	3	2390	559.1	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8177.729363	821.0933464	0		821.0933464		
Jun	1	4	2390	559.07	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8178.089363	775.9943621	0		775.9943621		
Jun	1	5	2390	559	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8179.659363	736.2224178	0		736.2224178		
Jun	1	6	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8188.359363	683.3383597	0		683.3383597		
Jun	1	7	2390	543.25	16.30	5610.329	191.4323349	197.175305	2431	8300.469363	8215.479363	540.1158259	0		540.1158259	9697.507798	
Jun	1	8	2390	442.05	13.26	5610.329	191.4323349	197.175305	2431	8300.469363	7771.119363	-904.3418301	904.3418301		0	8793.165968	
Jun	1	9	2390	259.59	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8268.179363	-1495.552761	1495.552761		0	7297.613206	
Jun	1	10	2390	237.71	7.13	5610.329	191.4323349	197.175305	2431	8300.469363	8280.289363	-2001.50364	2001.50364		0	5296.109567	
Jun	1	11	2390	251.05	7.53	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2292.503	2292.503		0	3003.606567	
Jun	1	12	2390	256.75	7.70	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2295.762323	2295.762323		0	707.8442432	
Jun	1	13	2390	261.41	7.84	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538		0	-1511.5813	1512
Jun	1	14	2390	263.2	7.90	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538		0		2219.425538
Jun	1	15	2390	263.75	7.91	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2283.925833	2283.925833		0		2283.925833
Jun	1	16	2390	269.23	8.08	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2167.447907	2167.447907		0		2167.447907
Jun	1	17	2390	276.18	8.29	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-1961.595902	1961.595902		0		1961.595902
Jun	1	18	2390	444.28	13.33	5610.329	191.4323349	197.175305	2431	8300.469363	8277.529363	-1000.048944	1000.048944		0		1000.048944
Jun	1	19	2390	543.01	16.29	5610.329	191.4323349	197.175305	2431	8300.469363	8262.949363	391.6833348	0		391.6833348		
Jun	1	20	2390	556.81	16.70	5610.329	191.4323349	197.175305	2431	8300.469363	8233.659363	475.440394	0		475.440394		
Jun	1	21	2390	557.36	16.72	5610.329	191.4323349	197.175305	2431	8300.469363	8219.059363	496.0067781	0		496.0067781		
Jun	1	22	2390	557.65	16.73	5610.329	191.4323349	197.175305	2431	8300.469363	8210.759363	565.4159099	0		565.4159099		
Jun	1	23	2390	557.83	16.73	5610.329	191.4323349	197.175305	2431	8300.469363	8205.149363	606.8087843	0		606.8087843		
Jun	1	24	2390	558.1	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8200.859363	621.3885514	0		621.3885514		
Jun	2	1	2390	558.15	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8199.479363	628.7572616	0		628.7572616		
Jun	2	2	2390	558.22	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8198.179363	630.201955	0		630.201955		
Jun	2	3	2390	558.25	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8196.969363	630.8789317	0		630.8789317		
Jun	2	4	2390	558.27	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8194.999363	608.4952746	0		608.4952746		
Jun	2	5	2390	558.36	16.75	5610.329	191.4323349	197.175305	2431	8300.469363	8194.549363	637.2076419	0		637.2076419		

															Thermal Storage Using System A		
Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh		Thermal energy that could be stored Mbh	How much can be utilized	Thermal Still needed to be bought
Dec	31	8	2390	586.25	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7843.179363	987.4498911	0		987.4498911		
Dec	31	9	2390	582.98	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7857.059363	943.0051564	0		943.0051564		
Dec	31	10	2390	577.26	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	8035.109363	983.6489433	0		983.6489433		
Dec	31	11	2390	573.94	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8013.289363	894.7554985	0		894.7554985		
Dec	31	12	2390	573.96	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8134.389363	988.9231945	0		988.9231945		
Dec	31	13	2390	570.87	17.13	5610.329	191.4323349	197.175305	2431	8300.469363	8208.789363	1004.655373	0		1004.655373		
Dec	31	14	2390	571.52	17.15	5610.329	191.4323349	197.175305	2431	8300.469363	8238.079363	1019.87882	0		1019.87882		
Dec	31	15	2390	572.79	17.18	5610.329	191.4323349	197.175305	2431	8300.469363	8236.589363	1036.9155	0		1036.9155		
Dec	31	16	2390	577.13	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	8163.789363	1046.284758	0		1046.284758		
Dec	31	17	2390	579.81	17.39	5610.329	191.4323349	197.175305	2431	8300.469363	8102.209363	1045.259557	0		1045.259557		
Dec	31	18	2390	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7910.079363	921.2322614	0		921.2322614		
Dec	31	19	2390	581.99	17.46	5610.329	191.4323349	197.175305	2431	8300.469363	7824.799363	861.683762	0		861.683762		
Dec	31	20	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7860.169363	922.7852626	0		922.7852626		
Dec	31	21	2390	583.18	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7778.509363	861.710463	0		861.710463		
Dec	31	22	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7803.039363	891.9013932	0		891.9013932		
Dec	31	23	2390	583.97	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	7729.479363	840.8135703	0		840.8135703		
Dec	31	24	2390	584.82	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7692.909363	814.5361706	0		814.5361706		
					127876.25		1676947.254	1727255.67									
					Adjusted for 10Cent savings		120000				8300.469363	MBH added by t	3416519.755			MBH added by	2164514.748
							1556947.254	1571560.9		chiller tons	691.7057802	Therms addition	34165.19755			Therms additio	21645.14748
			20936400									Cost additional	31773.63373			Cost additiona	20129.98715
			o&m costs	$0.005/kilowatt-hour (kWh)													
			104682	0.005			Costs with ABS		$1,475,458.33						Costs with Thermal		$1,463,814.68
							Savings over original		$612,919.33						Cost Savings		$ 11,643.65
															Max Thermal Stored (MBH)		39466.98798
												4827.399148				Ton-hr	3288.915665
							Additional Cost	Payback (years)									3000 ton hr
							2,890,905	4.71661589	$612,919.33								
					Original Rate		Additional Cost	Payback (years)	savings	adjusted payback including O&M					Additional Cost (Chilled water storage	Payback (years)	Savings
						1	2,890,905	10.79571398	267782.6642	17.72466755					123,409	10.59880161	11643.64657

System B Sample Calculations

														Electric Chiller Option instead of Absorption		
Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh	kW left over after running Electric Chiller kW	Additional Electricity Needed kW	Selling back extra $
Jan	1	1	2390	587.16	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8025.609363	953.3921995	0	395.15	0	11.8545
Jan	1	2	2390	587.46	17.62	5610.329	191.4323349	197.175305	2431	8300.469363	8020.199363	973.7137001	0	395.97	0	11.8791
Jan	1	3	2390	587.6	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8013.319363	986.7327272	0	396.51	0	11.8953
Jan	1	4	2390	588.11	17.64	5610.329	191.4323349	197.175305	2431	8300.469363	8012.629363	1057.233212	0	398.47	0	11.9541
Jan	1	5	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	8006.169363	1109.612577	0	399.85	0	11.9955
Jan	1	6	2390	588.3	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7990.079363	1117.195557	0	400.33	0	12.0099
Jan	1	7	2390	588.25	17.65	5610.329	191.4323349	197.175305	2431	8300.469363	7961.189363	1102.029024	0	400.55	0	12.0165
Jan	1	8	2390	587.83	17.63	5610.329	191.4323349	197.175305	2431	8300.469363	8008.159363	1127.899194	0	399.71	0	11.9913
Jan	1	9	2390	587.13	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	8022.879363	1126.665664	0	398.68	0	11.9604
Jan	1	10	2390	585.53	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	8044.409363	1096.904206	0	396.05	0	11.8815
Jan	1	11	2390	584.34	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	8043.159363	1055.341521	0	394.04	0	11.8212
Jan	1	12	2390	583.57	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	8084.509363	1068.729957	0	392.7	0	11.781
Jan	1	13	2390	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	8103.489363	1065.580867	0	391.94	0	11.7582
Jan	1	14	2390	583.08	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7939.179363	908.8187738	0	391.92	0	11.7576
Jan	1	15	2390	583.87	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	8023.079363	1000.781311	0	392.87	0	11.7861
Jan	1	16	2390	584.3	17.53	5610.329	191.4323349	197.175305	2431	8300.469363	7905.439363	906.4712045	0	393.78	0	11.8134
Jan	1	17	2390	584.8	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7863.579363	880.0501049	0	394.59	0	11.8377
Jan	1	18	2390	585.17	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7922.659363	939.6447349	0	394.97	0	11.8491
Jan	1	19	2390	585.37	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.569363	893.9018384	0	395.3	0	11.859
Jan	1	20	2390	585.54	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7887.039363	916.0327685	0	395.58	0	11.8674
Jan	1	21	2390	585.04	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7771.859363	816.8062988	0	395.4	0	11.862
Jan	1	22	2390	585.66	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7865.579363	913.9571656	0	396.1	0	11.883
Jan	1	23	2390	585.27	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7870.889363	921.8403156	0	395.76	0	11.8728
Jan	1	24	2390	585.02	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7798.789363	851.7988357	0	395.55	0	11.8665
Jan	2	1	2390	584.59	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7812.599363	843.8228319	0	394.68	0	11.8404
Jan	2	2	2390	584.89	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7820.239363	860.7261721	0	395.16	0	11.8548
Jan	2	3	2390	585.34	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7823.949363	892.397736	0	396.18	0	11.8854
Jan	2	4	2390	585.23	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7751.379363	827.3756429	0	396.22	0	11.8866
Jan	2	5	2390	584.9	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7622.769363	724.3256001	0	396.41	0	11.8923
Jan	2	6	2390	585.92	17.58	5610.329	191.4323349	197.175305	2431	8300.469363	7831.379363	945.8013504	0	397.69	0	11.9307
Jan	2	7	2390	585.7	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7638.099363	777.5666776	0	397.98	0	11.9394
Jan	2	8	2390	584.93	17.55	5610.329	191.4323349	197.175305	2431	8300.469363	7644.889363	779.0388342	0	397.1	0	11.913
Jan	2	9	2390	585.31	17.56	5610.329	191.4323349	197.175305	2431	8300.469363	7834.719363	948.7982637	0	397.07	0	11.9121
Jan	2	10	2390	583.6	17.51	5610.329	191.4323349	197.175305	2431	8300.469363	7829.839363	915.0989831	0	394.78	0	11.8434
Jan	2	11	2390	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7836.109363	886.5456856	0	392.02	0	11.7606
Jan	2	12	2390	579.32	17.38	5610.329	191.4323349	197.175305	2431	8300.469363	7862.459363	878.0723882	0	389.09	0	11.6727
Jan	2	13	2390	578.41	17.35	5610.329	191.4323349	197.175305	2431	8300.469363	7917.409363	919.2989212	0	387.9	0	11.637
Jan	2	14	2390	578.54	17.36	5610.329	191.4323349	197.175305	2431	8300.469363	7903.089363	906.8658979	0	388.07	0	11.6421
Jan	2	15	2390	577.2	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7941.809363	924.8291541	0	386.31	0	11.5893
Jan	2	16	2390	577.07	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	7885.769363	871.7053908	0	386.24	0	11.5872
Jan	2	17	2390	576.46	17.29	5610.329	191.4323349	197.175305	2431	8300.469363	7898.829363	890.2547776	0	385.74	0	11.5722
Jan	2	18	2390	577.25	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	7873.549363	883.3299147	0	386.9	0	11.607

															Electric Chiller Option instead of Absorption		
Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh		kW left over after running Electric Chiller kW	Additional Electricity Needed kW	Selling back extra $
May	31	2	2390	559.46	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8167.809363	892.3133449	0		360.59	0	10.8177
May	31	3	2390	559.4	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8170.569363	901.2489051	0		360.66	0	10.8198
May	31	4	2390	559.34	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8172.239363	900.1742117	0		361.04	0	10.8312
May	31	5	2390	559.42	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8170.479363	915.2254587	0		361.47	0	10.8441
May	31	6	2390	559.35	16.78	5610.329	191.4323349	197.175305	2431	8300.469363	8170.429363	924.9534289	0		361.61	0	10.8483
May	31	7	2390	547.98	16.44	5610.329	191.4323349	197.175305	2431	8300.469363	8175.399363	935.4128157	0		350.36	0	10.5108
May	31	8	2390	453.43	13.60	5610.329	191.4323349	197.175305	2431	8300.469363	7546.259363	-27.55051849	27.55051849		248.16	0	7.4448
May	31	9	2390	285.66	8.57	5610.329	191.4323349	197.175305	2431	8300.469363	8236.199363	90.46399523	0		67.31	0	2.0193
May	31	10	2390	270.9	8.13	5610.329	191.4323349	197.175305	2431	8300.469363	8255.119363	-442.8140073	442.8140073		40.18	0	1.2054
May	31	11	2390	260.12	7.80	5610.329	191.4323349	197.175305	2431	8300.469363	8267.569363	-720.6153338	720.6153338		22.76	0	0.6828
May	31	12	2390	259.04	7.77	5610.329	191.4323349	197.175305	2431	8300.469363	8277.759363	-807.8619494	807.8619494		19.43	0	0.5829
May	31	13	2390	259.53	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8284.999363	-832.5290101	832.5290101		19.18	0	0.5754
May	31	14	2390	280.68	8.42	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-900.429072	900.429072		37.59	0	1.1277
May	31	15	2390	277.88	8.34	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1040.751522	1040.751522		31.49	0	0.9447
May	31	16	2390	276.64	8.30	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1147.108391	1147.108391		27.73	0	0.8319
May	31	17	2390	278.31	8.35	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-1082.779639	1082.779639		31.74	0	0.9522
May	31	18	2390	466.52	14.00	5610.329	191.4323349	197.175305	2431	8300.469363	8300.469363	-224.37678	224.37678		239.72	0	7.1916
May	31	19	2390	565.97	16.98	5610.329	191.4323349	197.175305	2431	8300.469363	8296.009363	823.7531371	0		362.89	0	10.8867
May	31	20	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8236.089363	900.0385469	0		358.81	0	10.7643
May	31	21	2390	559.54	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8191.229363	932.3730486	0		362.39	0	10.8717
May	31	22	2390	560.12	16.80	5610.329	191.4323349	197.175305	2431	8300.469363	8170.609363	951.7226462	0		363.81	0	10.9143
May	31	23	2390	560.34	16.81	5610.329	191.4323349	197.175305	2431	8300.469363	8164.819363	958.6268532	0		364.3	0	10.929
May	31	24	2390	559.72	16.79	5610.329	191.4323349	197.175305	2431	8300.469363	8163.549363	942.9472128	0		362.96	0	10.8888
Jun	1	1	2390	558.84	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8184.929363	864.1459039	0		358.45	0	10.7535
Jun	1	2	2390	559.06	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8180.859363	844.6370036	0		357.74	0	10.7322
Jun	1	3	2390	559.1	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8177.729363	821.0933464	0		356.7	0	10.701
Jun	1	4	2390	559.07	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8178.089363	775.9943621	0		354.25	0	10.6275
Jun	1	5	2390	559	16.77	5610.329	191.4323349	197.175305	2431	8300.469363	8179.659363	736.2224178	0		352.49	0	10.5747
Jun	1	6	2390	558.01	16.74	5610.329	191.4323349	197.175305	2431	8300.469363	8188.359363	683.3383597	0		349.31	0	10.4793
Jun	1	7	2390	543.25	16.30	5610.329	191.4323349	197.175305	2431	8300.469363	8215.479363	540.1158259	0		328.89	0	9.8667
Jun	1	8	2390	442.05	13.26	5610.329	191.4323349	197.175305	2431	8300.469363	7771.119363	-904.3418301	904.3418301		201.09	0	6.0327
Jun	1	9	2390	259.59	7.79	5610.329	191.4323349	197.175305	2431	8300.469363	8268.179363	-1495.552761	1495.552761		-8.31	8.31	0
Jun	1	10	2390	237.71	7.13	5610.329	191.4323349	197.175305	2431	8300.469363	8280.289363	-2001.50364	2001.50364		-42.22	42.22	0
Jun	1	11	2390	251.05	7.53	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2292.503	2292.503		-38.42	38.42	0
Jun	1	12	2390	256.75	7.70	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2295.762323	2295.762323		-32.81	32.81	0
Jun	1	13	2390	261.41	7.84	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538		-24.61	24.61	0
Jun	1	14	2390	263.2	7.90	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538		-22.82	22.82	0
Jun	1	15	2390	263.75	7.91	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2283.925833	2283.925833		-25.49	25.49	0
Jun	1	16	2390	269.23	8.08	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-2167.447907	2167.447907		-16.87	16.87	0
Jun	1	17	2390	276.18	8.29	5610.329	191.4323349	197.175305	2431	8300.469363	8291.549363	-1961.595902	1961.595902		-4.44	4.44	0
Jun	1	18	2390	444.28	13.33	5610.329	191.4323349	197.175305	2431	8300.469363	8277.529363	-1000.048944	1000.048944		188.63	0	5.6589
Jun	1	19	2390	543.01	16.29	5610.329	191.4323349	197.175305	2431	8300.469363	8262.949363	391.6833348	0		322.12	0	9.6636
Jun	1	20	2390	556.81	16.70	5610.329	191.4323349	197.175305	2431	8300.469363	8233.659363	475.440394	0		339.57	0	10.1871
Jun	1	21	2390	557.36	16.72	5610.329	191.4323349	197.175305	2431	8300.469363	8219.059363	496.0067781	0		340.92	0	10.2276

														Electric Chiller Option instead of Absorption		
Month	Day	Hour	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh		kW left over after running Electric Chiller kW	Additional Electricity Needed kW	Selling back extra $
Dec	30	24	585.78	17.57	5610.329	191.4323349	197.175305	2431	8300.469363	7611.929363	757.4006945	0		398.18	0	11.9454
Dec	31	1	586.61	17.60	5610.329	191.4323349	197.175305	2431	8300.469363	7772.809363	924.4562546	0		399.13	0	11.9739
Dec	31	2	587.1	17.61	5610.329	191.4323349	197.175305	2431	8300.469363	7695.259363	873.8385585	0		400.17	0	12.0051
Dec	31	3	586.36	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7654.199363	826.0883684	0		399.29	0	11.9787
Dec	31	4	586.79	17.60	5610.329	191.4323349	197.175305	2431	8300.469363	7667.049363	850.2602286	0		399.95	0	11.9985
Dec	31	5	586.43	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7720.209363	886.6089816	0		399.25	0	11.9775
Dec	31	6	586.04	17.58	5610.329	191.4323349	197.175305	2431	8300.469363	7551.099363	723.5029984	0		398.98	0	11.9694
Dec	31	7	586.46	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7771.789363	922.4069946	0		398.96	0	11.9688
Dec	31	8	586.25	17.59	5610.329	191.4323349	197.175305	2431	8300.469363	7843.179363	987.4498911	0		398.62	0	11.9586
Dec	31	9	582.98	17.49	5610.329	191.4323349	197.175305	2431	8300.469363	7857.059363	943.0051564	0		394.17	0	11.8251
Dec	31	10	577.26	17.32	5610.329	191.4323349	197.175305	2431	8300.469363	8035.109363	983.6489433	0		385.67	0	11.5701
Dec	31	11	573.94	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8013.289363	894.7554985	0		380.99	0	11.4297
Dec	31	12	573.96	17.22	5610.329	191.4323349	197.175305	2431	8300.469363	8134.389363	988.9231945	0		380.46	0	11.4138
Dec	31	13	570.87	17.13	5610.329	191.4323349	197.175305	2431	8300.469363	8208.789363	1004.655373	0		376.18	0	11.2854
Dec	31	14	571.52	17.15	5610.329	191.4323349	197.175305	2431	8300.469363	8238.079363	1019.87882	0		376.54	0	11.2962
Dec	31	15	572.79	17.18	5610.329	191.4323349	197.175305	2431	8300.469363	8236.589363	1036.9155	0		378.19	0	11.3457
Dec	31	16	577.13	17.31	5610.329	191.4323349	197.175305	2431	8300.469363	8163.789363	1046.284758	0		384.2	0	11.526
Dec	31	17	579.81	17.39	5610.329	191.4323349	197.175305	2431	8300.469363	8102.209363	1045.259557	0		388.11	0	11.6433
Dec	31	18	581.54	17.45	5610.329	191.4323349	197.175305	2431	8300.469363	7910.079363	921.2322614	0		391.22	0	11.7366
Dec	31	19	581.99	17.46	5610.329	191.4323349	197.175305	2431	8300.469363	7824.799363	861.683762	0		392.19	0	11.7657
Dec	31	20	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7860.169363	922.7852626	0		393.98	0	11.8194
Dec	31	21	583.18	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7778.509363	861.710463	0		394.32	0	11.8296
Dec	31	22	583.26	17.50	5610.329	191.4323349	197.175305	2431	8300.469363	7803.039363	891.9013932	0		394.51	0	11.8353
Dec	31	23	583.97	17.52	5610.329	191.4323349	197.175305	2431	8300.469363	7729.479363	840.8135703	0		395.68	0	11.8704
Dec	31	24	584.82	17.54	5610.329	191.4323349	197.175305	2431	8300.469363	7692.909363	814.5361706	0		396.74	0	11.9022
				127876.25		1676947.254	1727255.67								46533.93	
				Adjusted for 10Cent savings		120000				8300.469363	MBH added by t	3416519.755			$6,450.16	$71,414.74
						1556947.254	1571560.9		chiller tons	691.7057802	Therms addition	34165.19755				
											Cost additional	31773.63373				
			$0.005/kilowatt-hour (kWh)													
			0.005			Costs with ABS		$1,475,458.33						Costs with electric Chiller		$1,506,596.37
						Savings over original		$612,919.33						Savings over original		$581,781.29
											4827.399148					
						Additional Cost	Payback (years)							Additional Cost	Payback (years)	
						2,890,905	4.71661589	$612,919.33						2483717.55	4.27	$581,781.29

System C Sample Calculations

Cover Base with ABS rest with Elect. Chiller

Month	Day	Hour	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still Needed Mbh	Thermal Needed Converted to kW	Electricity left over from production to be used on electric chiller kW	Electricity left over after electric chiller (COP 6.1) kW
Jan	1	1	587.16	17.61	191.4323349	197.175305	2431	8300.469363	8025.609363	953.3921995	0	953.3921995	0	0	587.16	587.16
Jan	1	2	587.46	17.62	191.4323349	197.175305	2431	8300.469363	8020.199363	973.7137001	0	973.7137001	0	0	587.46	587.46
Jan	1	3	587.6	17.63	191.4323349	197.175305	2431	8300.469363	8013.319363	986.7327272	0	986.7327272	0	0	587.6	587.6
Jan	1	4	588.11	17.64	191.4323349	197.175305	2431	8300.469363	8012.629363	1057.233212	0	1057.233212	0	0	588.11	588.11
Jan	1	5	588.3	17.65	191.4323349	197.175305	2431	8300.469363	8006.169363	1109.612577	0	1109.612577	0	0	588.3	588.3
Jan	1	6	588.3	17.65	191.4323349	197.175305	2431	8300.469363	7990.079363	1117.195557	0	1117.195557	0	0	588.3	588.3
Jan	1	7	588.25	17.65	191.4323349	197.175305	2431	8300.469363	7961.189363	1102.029024	0	1102.029024	0	0	588.25	588.25
Jan	1	8	587.83	17.63	191.4323349	197.175305	2431	8300.469363	8008.159363	1127.899194	0	1127.899194	0	0	587.83	587.83
Jan	1	9	587.13	17.61	191.4323349	197.175305	2431	8300.469363	8022.879363	1126.665664	0	1126.665664	0	0	587.13	587.13
Jan	1	10	585.53	17.57	191.4323349	197.175305	2431	8300.469363	8044.409363	1096.904206	0	1096.904206	0	0	585.53	585.53
Jan	1	11	584.34	17.53	191.4323349	197.175305	2431	8300.469363	8043.159363	1055.341521	0	1055.341521	0	0	584.34	584.34
Jan	1	12	583.57	17.51	191.4323349	197.175305	2431	8300.469363	8084.509363	1068.729957	0	1068.729957	0	0	583.57	583.57
Jan	1	13	583.26	17.50	191.4323349	197.175305	2431	8300.469363	8103.489363	1065.580867	0	1065.580867	0	0	583.26	583.26
Jan	1	14	583.08	17.49	191.4323349	197.175305	2431	8300.469363	7939.179363	908.8187738	0	908.8187738	0	0	583.08	583.08
Jan	1	15	583.87	17.52	191.4323349	197.175305	2431	8300.469363	8023.079363	1000.781311	0	1000.781311	0	0	583.87	583.87
Jan	1	16	584.3	17.53	191.4323349	197.175305	2431	8300.469363	7905.439363	906.4712045	0	906.4712045	0	0	584.3	584.3
Jan	1	17	584.8	17.54	191.4323349	197.175305	2431	8300.469363	7863.579363	880.0501049	0	880.0501049	0	0	584.8	584.8
Jan	1	18	585.17	17.56	191.4323349	197.175305	2431	8300.469363	7922.659363	939.6447349	0	939.6447349	0	0	585.17	585.17
Jan	1	19	585.37	17.56	191.4323349	197.175305	2431	8300.469363	7870.569363	893.9018384	0	893.9018384	0	0	585.37	585.37
Jan	1	20	585.54	17.57	191.4323349	197.175305	2431	8300.469363	7887.039363	916.0327685	0	916.0327685	0	0	585.54	585.54
Jan	1	21	585.04	17.55	191.4323349	197.175305	2431	8300.469363	7771.859363	816.8062988	0	816.8062988	0	0	585.04	585.04
Jan	1	22	585.66	17.57	191.4323349	197.175305	2431	8300.469363	7865.579363	913.9571656	0	913.9571656	0	0	585.66	585.66
Jan	1	23	585.27	17.56	191.4323349	197.175305	2431	8300.469363	7870.889363	921.8403156	0	921.8403156	0	0	585.27	585.27
Jan	1	24	585.02	17.55	191.4323349	197.175305	2431	8300.469363	7798.789363	851.7988357	0	851.7988357	0	0	585.02	585.02
Jan	2	1	584.59	17.54	191.4323349	197.175305	2431	8300.469363	7812.599363	843.8228319	0	843.8228319	0	0	584.59	584.59
Jan	2	2	584.89	17.55	191.4323349	197.175305	2431	8300.469363	7820.239363	860.7261721	0	860.7261721	0	0	584.89	584.89
Jan	2	3	585.34	17.56	191.4323349	197.175305	2431	8300.469363	7823.949363	892.397736	0	892.397736	0	0	585.34	585.34
Jan	2	4	585.23	17.56	191.4323349	197.175305	2431	8300.469363	7751.379363	827.3756429	0	827.3756429	0	0	585.23	585.23
Jan	2	5	584.9	17.55	191.4323349	197.175305	2431	8300.469363	7622.769363	724.3256001	0	724.3256001	0	0	584.9	584.9
Jan	2	6	585.92	17.58	191.4323349	197.175305	2431	8300.469363	7831.379363	945.8013504	0	945.8013504	0	0	585.92	585.92
Jan	2	7	585.7	17.57	191.4323349	197.175305	2431	8300.469363	7638.099363	777.5666776	0	777.5666776	0	0	585.7	585.7
Jan	2	8	584.93	17.55	191.4323349	197.175305	2431	8300.469363	7644.889363	779.0388342	0	779.0388342	0	0	584.93	584.93
Jan	2	9	585.31	17.56	191.4323349	197.175305	2431	8300.469363	7834.719363	948.7982637	0	948.7982637	0	0	585.31	585.31
Jan	2	10	583.6	17.51	191.4323349	197.175305	2431	8300.469363	7829.839363	915.0989831	0	915.0989831	0	0	583.6	583.6
Jan	2	11	581.54	17.45	191.4323349	197.175305	2431	8300.469363	7836.109363	886.5456856	0	886.5456856	0	0	581.54	581.54
Jan	2	12	579.32	17.38	191.4323349	197.175305	2431	8300.469363	7862.459363	878.0723882	0	878.0723882	0	0	579.32	579.32
Jan	2	13	578.41	17.35	191.4323349	197.175305	2431	8300.469363	7917.409363	919.2989212	0	919.2989212	0	0	578.41	578.41
Jan	2	14	578.54	17.36	191.4323349	197.175305	2431	8300.469363	7903.089363	906.8658979	0	906.8658979	0	0	578.54	578.54
Jan	2	15	577.2	17.32	191.4323349	197.175305	2431	8300.469363	7941.809363	924.8291541	0	924.8291541	0	0	577.2	577.2
Jan	2	16	577.07	17.31	191.4323349	197.175305	2431	8300.469363	7885.769363	871.7053908	0	871.7053908	0	0	577.07	577.07
Jan	2	17	576.46	17.29	191.4323349	197.175305	2431	8300.469363	7898.829363	890.2547776	0	890.2547776	0	0	576.46	576.46
Jan	2	18	577.25	17.32	191.4323349	197.175305	2431	8300.469363	7873.549363	883.3299147	0	883.3299147	0	0	577.25	577.25

												Cover Base with ABS rest with Elect. Chiller				
Month	Day	Hour	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still Needed Mbh	Thermal Needed Converted to kW	Electricity left over from over production to be used on electric chiller kW	Electricity left over after electric chiller (COP 6.1) kW
May	31	10	270.9	8.13	191.4323349	197.175305	2431	8300.469363	8255.119363	-442.8140073	442.8140073	-442.8140073	442.8140073	129.6891524	270.9	249.6394832
May	31	11	260.12	7.80	191.4323349	197.175305	2431	8300.469363	8267.569363	-720.6153338	720.6153338	-720.6153338	720.6153338	211.0502159	260.12	225.521604
May	31	12	259.04	7.77	191.4323349	197.175305	2431	8300.469363	8277.759363	-807.8619494	807.8619494	-807.8619494	807.8619494	236.6025684	259.04	220.2526937
May	31	13	259.53	7.79	191.4323349	197.175305	2431	8300.469363	8284.999363	-832.5290101	832.5290101	-832.5290101	832.5290101	243.8269338	259.53	219.5583715
May	31	14	280.68	8.42	191.4323349	197.175305	2431	8300.469363	8300.469363	-900.429072	900.429072	-900.429072	900.429072	263.7131645	280.68	237.4483337
May	31	15	277.88	8.34	191.4323349	197.175305	2431	8300.469363	8300.469363	-1040.751522	1040.751522	-1040.751522	1040.751522	304.810102	277.88	227.9111308
May	31	16	276.64	8.30	191.4323349	197.175305	2431	8300.469363	8300.469363	-1147.108391	1147.108391	-1147.108391	1147.108391	335.95937	276.64	221.5646934
May	31	17	278.31	8.35	191.4323349	197.175305	2431	8300.469363	8300.469363	-1082.779639	1082.779639	-1082.779639	1082.779639	317.1190869	278.31	226.3232644
May	31	18	466.52	14.00	191.4323349	197.175305	2431	8300.469363	8300.469363	-224.37678	224.37678	-224.37678	224.37678	65.71434945	466.52	455.7471558
May	31	19	565.97	16.98	191.4323349	197.175305	2431	8300.469363	8296.009363	823.7531371	0	823.7531371	0	0	565.97	565.97
May	31	20	558.01	16.74	191.4323349	197.175305	2431	8300.469363	8236.089363	900.0385469	0	900.0385469	0	0	558.01	558.01
May	31	21	559.54	16.79	191.4323349	197.175305	2431	8300.469363	8191.229363	932.3730486	0	932.3730486	0	0	559.54	559.54
May	31	22	560.12	16.80	191.4323349	197.175305	2431	8300.469363	8170.609363	951.7226462	0	951.7226462	0	0	560.12	560.12
May	31	23	560.34	16.81	191.4323349	197.175305	2431	8300.469363	8164.819363	958.6268532	0	958.6268532	0	0	560.34	560.34
May	31	24	559.72	16.79	191.4323349	197.175305	2431	8300.469363	8163.549363	942.9472128	0	942.9472128	0	0	559.72	559.72
Jun	1	1	558.84	16.77	191.4323349	197.175305	2431	8300.469363	8184.929363	864.1459039	0	864.1459039	0	0	558.84	558.84
Jun	1	2	559.06	16.77	191.4323349	197.175305	2431	8300.469363	8180.859363	844.6370036	0	844.6370036	0	0	559.06	559.06
Jun	1	3	559.1	16.77	191.4323349	197.175305	2431	8300.469363	8177.729363	821.0933464	0	821.0933464	0	0	559.1	559.1
Jun	1	4	559.07	16.77	191.4323349	197.175305	2431	8300.469363	8178.089363	775.9943621	0	775.9943621	0	0	559.07	559.07
Jun	1	5	559	16.77	191.4323349	197.175305	2431	8300.469363	8179.659363	736.2224178	0	736.2224178	0	0	559	559
Jun	1	6	558.01	16.74	191.4323349	197.175305	2431	8300.469363	8188.359363	683.3383597	0	683.3383597	0	0	558.01	558.01
Jun	1	7	543.25	16.30	191.4323349	197.175305	2431	8300.469363	8215.479363	540.1158259	0	540.1158259	0	0	543.25	543.25
Jun	1	8	442.05	13.26	191.4323349	197.175305	2431	8300.469363	7771.119363	-904.3418301	904.3418301	-904.3418301	904.3418301	264.8591135	442.05	398.6304732
Jun	1	9	259.59	7.79	191.4323349	197.175305	2431	8300.469363	8268.179363	-1495.552761	1495.552761	-1495.552761	1495.552761	438.010015	259.59	187.7850795
Jun	1	10	237.71	7.13	191.4323349	197.175305	2431	8300.469363	8280.289363	-2001.50364	2001.50364	-2001.50364	2001.50364	586.1903785	237.71	141.6132166
Jun	1	11	251.05	7.53	191.4323349	197.175305	2431	8300.469363	8291.549363	-2292.503	2292.503	-2292.503	2292.503	671.4168161	251.05	140.9816695
Jun	1	12	256.75	7.70	191.4323349	197.175305	2431	8300.469363	8291.549363	-2295.762323	2295.762323	-2295.762323	2295.762323	672.3713905	256.75	146.5251819
Jun	1	13	261.41	7.84	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538	-2219.425538	2219.425538	650.0142545	261.41	154.8502861
Jun	1	14	263.2	7.90	191.4323349	197.175305	2431	8300.469363	8291.549363	-2219.425538	2219.425538	-2219.425538	2219.425538	650.0142545	263.2	156.6402861
Jun	1	15	263.75	7.91	191.4323349	197.175305	2431	8300.469363	8291.549363	-2283.925833	2283.925833	-2283.925833	2283.925833	668.9047784	263.75	154.093479
Jun	1	16	269.23	8.08	191.4323349	197.175305	2431	8300.469363	8291.549363	-2167.447907	2167.447907	-2167.447907	2167.447907	634.7913058	269.23	165.1658515
Jun	1	17	276.18	8.29	191.4323349	197.175305	2431	8300.469363	8291.549363	-1961.595902	1961.595902	-1961.595902	1961.595902	574.5023999	276.18	181.9992787
Jun	1	18	444.28	13.33	191.4323349	197.175305	2431	8300.469363	8277.529363	-1000.048944	1000.048944	-1000.048944	1000.048944	292.8893344	444.28	396.265355
Jun	1	19	543.01	16.29	191.4323349	197.175305	2431	8300.469363	8262.949363	391.6833348	0	391.6833348	0	0	543.01	543.01
Jun	1	20	556.81	16.70	191.4323349	197.175305	2431	8300.469363	8233.659363	475.440394	0	475.440394	0	0	556.81	556.81
Jun	1	21	557.36	16.72	191.4323349	197.175305	2431	8300.469363	8219.059363	496.0067781	0	496.0067781	0	0	557.36	557.36
Jun	1	22	557.65	16.73	191.4323349	197.175305	2431	8300.469363	8210.759363	565.4159099	0	565.4159099	0	0	557.65	557.65
Jun	1	23	557.83	16.73	191.4323349	197.175305	2431	8300.469363	8205.149363	606.8087843	0	606.8087843	0	0	557.83	557.83
Jun	1	24	558.1	16.74	191.4323349	197.175305	2431	8300.469363	8200.859363	621.3885514	0	621.3885514	0	0	558.1	558.1
Jun	2	1	558.15	16.74	191.4323349	197.175305	2431	8300.469363	8199.479363	628.7572616	0	628.7572616	0	0	558.15	558.15
Jun	2	2	558.22	16.75	191.4323349	197.175305	2431	8300.469363	8198.179363	630.201955	0	630.201955	0	0	558.22	558.22
Jun	2	3	558.25	16.75	191.4323349	197.175305	2431	8300.469363	8196.969363	630.8789317	0	630.8789317	0	0	558.25	558.25

Month	Day	Hour	Amount of Elect. To sell kW	Grid Pays $	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh		Cover Base with ABS rest with Elect. Chiller Thermal left over after 0.7 COP ABS Chiller Mbh	Thermal still Needed Mbh	Thermal Needed Converted to kW kW	Electricity left over from over production to be used on electric chiller kW	Electricity left over after electric chiller (COP 6.1) kW
Dec	30	24	585.78	17.57	191.4323349	197.175305	2431	8300.469363	7611.929363	757.4006945	0		757.4006945	0	0	585.78	585.78
Dec	31	1	586.61	17.60	191.4323349	197.175305	2431	8300.469363	7772.809363	924.4562546	0		924.4562546	0	0	586.61	586.61
Dec	31	2	587.1	17.61	191.4323349	197.175305	2431	8300.469363	7695.259363	873.8385585	0		873.8385585	0	0	587.1	587.1
Dec	31	3	586.36	17.59	191.4323349	197.175305	2431	8300.469363	7654.199363	826.0883684	0		826.0883684	0	0	586.36	586.36
Dec	31	4	586.79	17.60	191.4323349	197.175305	2431	8300.469363	7667.049363	850.2602286	0		850.2602286	0	0	586.79	586.79
Dec	31	5	586.43	17.59	191.4323349	197.175305	2431	8300.469363	7720.209363	886.6089816	0		886.6089816	0	0	586.43	586.43
Dec	31	6	586.04	17.58	191.4323349	197.175305	2431	8300.469363	7551.099363	723.5029984	0		723.5029984	0	0	586.04	586.04
Dec	31	7	586.46	17.59	191.4323349	197.175305	2431	8300.469363	7771.789363	922.4069946	0		922.4069946	0	0	586.46	586.46
Dec	31	8	586.25	17.59	191.4323349	197.175305	2431	8300.469363	7843.179363	987.4498911	0		987.4498911	0	0	586.25	586.25
Dec	31	9	582.98	17.49	191.4323349	197.175305	2431	8300.469363	7857.059363	943.0051564	0		943.0051564	0	0	582.98	582.98
Dec	31	10	577.26	17.32	191.4323349	197.175305	2431	8300.469363	8035.109363	983.6489433	0		983.6489433	0	0	577.26	577.26
Dec	31	11	573.94	17.22	191.4323349	197.175305	2431	8300.469363	8013.289363	894.7554985	0		894.7554985	0	0	573.94	573.94
Dec	31	12	573.96	17.22	191.4323349	197.175305	2431	8300.469363	8134.389363	988.9231945	0		988.9231945	0	0	573.96	573.96
Dec	31	13	570.87	17.13	191.4323349	197.175305	2431	8300.469363	8208.789363	1004.655373	0		1004.655373	0	0	570.87	570.87
Dec	31	14	571.52	17.15	191.4323349	197.175305	2431	8300.469363	8238.079363	1019.87882	0		1019.87882	0	0	571.52	571.52
Dec	31	15	572.79	17.18	191.4323349	197.175305	2431	8300.469363	8236.589363	1036.9155	0		1036.9155	0	0	572.79	572.79
Dec	31	16	577.13	17.31	191.4323349	197.175305	2431	8300.469363	8163.789363	1046.284758	0		1046.284758	0	0	577.13	577.13
Dec	31	17	579.81	17.39	191.4323349	197.175305	2431	8300.469363	8102.209363	1045.259557	0		1045.259557	0	0	579.81	579.81
Dec	31	18	581.54	17.45	191.4323349	197.175305	2431	8300.469363	7910.079363	921.2322614	0		921.2322614	0	0	581.54	581.54
Dec	31	19	581.99	17.46	191.4323349	197.175305	2431	8300.469363	7824.799363	861.683762	0		861.683762	0	0	581.99	581.99
Dec	31	20	583.26	17.50	191.4323349	197.175305	2431	8300.469363	7860.169363	922.7852626	0		922.7852626	0	0	583.26	583.26
Dec	31	21	583.18	17.50	191.4323349	197.175305	2431	8300.469363	7778.509363	861.710463	0		861.710463	0	0	583.18	583.18
Dec	31	22	583.26	17.50	191.4323349	197.175305	2431	8300.469363	7803.039363	891.9013932	0		891.9013932	0	0	583.26	583.26
Dec	31	23	583.97	17.52	191.4323349	197.175305	2431	8300.469363	7729.479363	840.8135703	0		840.8135703	0	0	583.97	583.97
Dec	31	24	584.82	17.54	191.4323349	197.175305	2431	8300.469363	7692.909363	814.5361706	0		814.5361706	0	0	584.82	584.82
				127876.25	1676947.254	1727255.67									1000613.223	4262541.83	4098506.875
				Adjusted for 10C	120000				8300.469363	MBH added by t	3416519.755						$122,955.21
					1556947.254	1571560.9		chiller tons	691.7057802	Therms addition	34165.19755						
										Cost additional	31773.63373						
			$0.005/kilowatt-hour (kWh)														
			0.005		Costs with ABS		$1,475,458.33							Costs with electric Chiller		$1,448,605.74	
					Savings over original		$612,919.33							Savings over original		$639,771.91	
										4827.399148							
					Additional Cost	Payback (years)								Additional Cost	Payback (years)		
					2,890,905	4.71661589	$612,919.33							2546177.55	3.98	$639,771.91	

System D Sample Calculations

Month	Day	Hour	T	2390 kW Jenbacher IC Engine Elec Output kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left after cooling with 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
Jan	1	1		1802.84	4344.192771	148.2299913	152.6768911	1846.281928	6303.992833	6029.132833	-1043.08433	1043.084331
Jan	1	2		1802.54	4343.46988	148.2053253	152.651485	1845.974699	6302.943822	6022.673822	-1023.81184	1023.81184
Jan	1	3		1802.4	4343.13253	148.1938144	152.6396289	1845.831325	6302.454284	6015.304284	-1011.28235	1011.282352
Jan	1	4		1801.89	4341.903614	148.1518821	152.5964386	1845.309036	6300.670967	6012.830967	-942.565184	942.5651842
Jan	1	5		1801.7	4341.445783	148.1362602	152.580348	1845.114458	6300.006593	6005.706593	-890.850193	890.8501928
Jan	1	6		1801.7	4341.445783	148.1362602	152.580348	1845.114458	6300.006593	5989.616593	-883.267212	883.2672122
Jan	1	7		1801.75	4341.566265	148.1403713	152.5845824	1845.165663	6300.181428	5960.901428	-898.25891	898.2589102
Jan	1	8		1802.17	4342.578313	148.1749038	152.6201509	1845.595783	6301.650043	6009.340043	-870.920126	870.9201262
Jan	1	9		1802.87	4344.26506	148.232458	152.6794317	1846.312651	6304.097734	6026.507734	-869.705966	869.7059657
Jan	1	10		1804.47	4348.120482	148.3640104	152.8149307	1847.951205	6309.692456	6053.632456	-893.872702	893.8727015
Jan	1	11		1805.66	4350.987952	148.4618525	152.9157081	1849.16988	6313.85353	6056.54353	-931.274311	931.2743113
Jan	1	12		1806.43	4352.843373	148.5251621	152.980917	1849.958434	6316.54599	6100.58599	-915.193415	915.1934154
Jan	1	13		1806.74	4353.590361	148.5506504	153.0071699	1850.275904	6317.629967	6120.649967	-917.258528	917.2585285
Jan	1	14		1806.92	4354.024096	148.5654501	153.0224136	1850.460241	6318.259374	5956.969374	-1073.39122	1073.391215
Jan	1	15		1806.13	4352.120482	148.500496	152.9555109	1849.651205	6315.49698	6038.10698	-984.191073	984.1910725
Jan	1	16		1805.7	4351.084337	148.4651413	152.9190956	1849.210843	6313.993398	5918.963398	-1080.00476	1080.00476
Jan	1	17		1805.2	4349.879518	148.4240312	152.8767521	1848.698795	6312.245048	5875.355048	-1108.17421	1108.17421
Jan	1	18		1804.83	4348.987952	148.3936097	152.845418	1848.31988	6310.951268	5933.141268	-1049.87336	1049.87336
Jan	1	19		1804.63	4348.506024	148.3771656	152.8284806	1848.11506	6310.251928	5880.351928	-1096.3156	1096.315597
Jan	1	20		1804.46	4348.096386	148.3631882	152.8140838	1847.940964	6309.657489	5896.227489	-1074.77911	1074.779106
Jan	1	21		1804.96	4349.301205	148.4042983	152.8564273	1848.453012	6311.405839	5782.795839	-1172.25722	1172.257225
Jan	1	22		1804.34	4347.807229	148.3533218	152.8039214	1847.818072	6309.237885	5874.347885	-1077.27431	1077.274313
Jan	1	23		1804.73	4348.746988	148.3853877	152.8369493	1848.21747	6310.601598	5881.021598	-1068.02745	1068.027449
Jan	1	24		1804.98	4349.349398	148.4059427	152.858121	1848.473494	6311.475773	5809.795773	-1137.19475	1137.194754
Jan	2	1		1805.41	4350.385542	148.4412974	152.8945364	1848.913855	6312.979355	5825.109355	-1143.66718	1143.667176
Jan	2	2		1805.11	4349.662651	148.4166314	152.8691303	1848.606627	6311.930344	5831.700344	-1127.81285	1127.812846
Jan	2	3		1804.66	4348.578313	148.3796322	152.8310212	1848.145783	6310.356829	5833.836829	-1097.7148	1097.714798
Jan	2	4		1804.77	4348.843373	148.3886765	152.8403368	1848.258434	6310.741466	5761.651466	-1162.35225	1162.352254
Jan	2	5		1805.1	4349.638554	148.4158092	152.8682834	1848.596386	6311.895377	5634.195377	-1264.24839	1264.248385
Jan	2	6		1804.08	4347.180723	148.3319445	152.7819028	1847.551807	6308.328742	5839.238742	-1046.33927	1046.33927
Jan	2	7		1804.3	4347.710843	148.3500329	152.8005339	1847.777108	6309.098016	5646.728016	-1213.80467	1213.804669
Jan	2	8		1805.07	4349.566265	148.4133426	152.8657428	1848.565663	6311.790476	5656.210476	-1209.64005	1209.640052
Jan	2	9		1804.69	4348.650602	148.3820988	152.8335618	1848.176506	6310.46173	5844.71173	-1041.20937	1041.209369
Jan	2	10		1806.4	4352.771084	148.5226955	152.9783764	1849.927711	6316.441089	5845.811089	-1068.92929	1068.929291
Jan	2	11		1808.46	4357.73494	148.6920693	153.1528313	1852.037349	6323.644294	5859.284294	-1090.27938	1090.279384
Jan	2	12		1810.68	4363.084337	148.8745983	153.3408362	1854.310843	6331.40697	5893.39697	-1090.99	1090.990004
Jan	2	13		1811.59	4365.277108	148.9494187	153.4179013	1855.242771	6334.588968	5951.528968	-1046.58147	1046.581473
Jan	2	14		1811.46	4364.963855	148.9387301	153.406892	1855.109639	6334.134397	5936.754397	-1059.46907	1059.469068
Jan	2	15		1812.8	4368.192771	149.0489052	153.5203724	1856.481928	6338.819977	5980.159977	-1036.82023	1036.820232
Jan	2	16		1812.93	4368.506024	149.0595939	153.5313817	1856.61506	6339.274548	5924.574548	-1089.48942	1089.489424
Jan	2	17		1813.54	4369.975904	149.1097482	153.5830407	1857.239759	6341.407536	5939.767536	-1068.80705	1068.80705
Jan	2	18		1812.75	4368.072289	149.0447942	153.5161381	1856.430723	6338.645142	5911.725142	-1078.49431	1078.494306

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left after cooling with 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
May	31	4	1830.66	4411.228916	150.5173593	155.03288	1874.772289	6401.271061	6273.041061	-999.024091	999.0240905
May	31	5	1830.58	4411.036145	150.5107816	155.0261051	1874.690361	6400.991325	6271.001325	-984.25258	984.2525796
May	31	6	1830.65	4411.204819	150.5165371	155.0320332	1874.762048	6401.236094	6271.196094	-974.27984	974.2798403
May	31	7	1842.02	4438.60241	151.4513815	155.994923	1886.406024	6440.993587	6315.923587	-924.062961	924.0629606
May	31	8	1936.57	4666.433735	159.225308	164.0020673	1983.234337	6771.606687	6017.396687	-1556.41319	1556.413194
May	31	9	2104.34	5070.698795	173.0194027	178.2099848	2155.046988	7358.248251	7293.978251	-851.757116	851.7571163
May	31	10	2119.1	5106.26506	174.2329739	179.4599631	2170.162651	7409.859561	7364.509561	-1333.42381	1333.423809
May	31	11	2129.88	5132.240964	175.1193084	180.3728877	2181.20241	7447.554001	7414.654001	-1573.5307	1573.530696
May	31	12	2130.96	5134.843373	175.2081063	180.4643495	2182.308434	7451.330438	7428.620438	-1657.00087	1657.000874
May	31	13	2130.47	5133.662651	175.1678184	180.4228529	2181.806627	7449.617054	7434.147054	-1683.38132	1683.381319
May	31	14	2109.32	5082.698795	173.4288597	178.6317255	2160.146988	7375.661823	7375.661823	-1825.23661	1825.236611
May	31	15	2112.12	5089.445783	173.6590764	178.8688487	2163.014458	7385.452587	7385.452587	-1955.7683	1955.768298
May	31	16	2113.36	5092.433735	173.7610296	178.9738604	2164.284337	7389.788496	7389.788496	-2057.78926	2057.789257
May	31	17	2111.69	5088.409639	173.6237217	178.8324334	2162.574096	7383.949005	7383.949005	-1999.3	1999.299997
May	31	18	1923.48	4634.891566	158.1490447	162.893516	1969.828916	6725.834868	6725.834868	-1799.01127	1799.011275
May	31	19	1824.03	4395.253012	149.9722389	154.471406	1867.98253	6378.087932	6373.627932	-1098.62829	1098.628294
May	31	20	1831.99	4414.433735	150.6267122	155.1455136	1876.134337	6405.921673	6341.541673	-994.509143	994.5091427
May	31	21	1830.46	4410.746988	150.5009152	155.0159427	1874.56747	6400.57172	6291.33172	-967.524594	967.5245938
May	31	22	1829.88	4409.349398	150.4532274	154.9668243	1873.973494	6398.543634	6268.683634	-950.203083	950.2030829
May	31	23	1829.66	4408.819277	150.435139	154.9481932	1873.748193	6397.774359	6262.124359	-944.06815	944.0681503
May	31	24	1830.28	4410.313253	150.4861156	155.000699	1874.383133	6399.942314	6263.022314	-957.579836	957.5798358
Jun	1	1	1831.16	4412.433735	150.5584694	155.0752235	1875.284337	6403.019411	6287.479411	-1033.30405	1033.304048
Jun	1	2	1830.94	4411.903614	150.5403809	155.0565924	1875.059036	6402.250137	6282.640137	-1053.58222	1053.582222
Jun	1	3	1830.9	4411.807229	150.5370921	155.0532049	1875.018072	6402.110269	6279.370269	-1077.26575	1077.265747
Jun	1	4	1830.93	4411.879518	150.5395587	155.0557455	1875.048795	6402.21517	6279.83517	-1122.25983	1122.259831
Jun	1	5	1831	4412.048193	150.5453141	155.0616736	1875.120482	6402.459939	6281.649939	-1161.78701	1161.787006
Jun	1	6	1831.99	4414.433735	150.6267122	155.1455136	1876.134337	6405.921673	6293.811673	-1211.20933	1211.20933
Jun	1	7	1846.75	4450	151.8402834	156.3954919	1891.25	6457.532983	6372.542983	-1302.82055	1302.820554
Jun	1	8	1947.95	4693.855422	160.1609747	164.965804	1994.888554	6811.399147	6282.049147	-2393.41205	2393.412046
Jun	1	9	2130.41	5133.518072	175.1628852	180.4177717	2181.745181	7449.407252	7417.117252	-2346.61487	2346.614872
Jun	1	10	2152.29	5186.240964	176.9618647	182.2707206	2204.15241	7525.915075	7505.735075	-2776.05793	2776.057928
Jun	1	11	2138.95	5154.096386	175.8650463	181.1409976	2190.490964	7479.269081	7470.349081	-3113.70328	3113.703282
Jun	1	12	2133.25	5140.361446	175.3963907	180.6582824	2184.653614	7459.337884	7450.417884	-3136.8938	3136.893803
Jun	1	13	2128.59	5129.13253	175.0132443	180.2636416	2179.881325	7443.043256	7434.123256	-3076.85165	3076.851645
Jun	1	14	2126.8	5124.819277	174.86607	180.1120521	2178.048193	7436.784161	7427.864161	-3083.11074	3083.11074
Jun	1	15	2126.25	5123.493976	174.8208488	180.0654743	2177.48494	7434.860975	7425.940975	-3149.53422	3149.534221
Jun	1	16	2120.77	5110.289157	174.3702818	179.6013902	2171.872892	7415.699052	7406.779052	-3052.21822	3052.218218
Jun	1	17	2113.82	5093.542169	173.7988509	179.0128164	2164.755422	7391.396979	7382.476979	-2870.66829	2870.668286
Jun	1	18	1945.72	4688.481928	159.9776235	164.7769522	1992.604819	6803.601503	6780.661503	-2496.9168	2496.916803
Jun	1	19	1846.99	4450.578313	151.8600163	156.4158168	1891.495783	6458.372192	6420.852192	-1450.41384	1450.413836
Jun	1	20	1833.19	4417.325301	150.7253765	155.2471378	1877.363253	6410.117715	6343.307715	-1414.91125	1414.911254
Jun	1	21	1832.64	4416	150.6801554	155.2005601	1876.8	6408.194529	6326.784529	-1396.26806	1396.268056
Jun	1	22	1832.35	4415.301205	150.6563115	155.1760009	1876.503012	6407.180486	6317.470486	-1327.87297	1327.872967
Jun	1	23	1832.17	4414.86747	150.6415119	155.1607572	1876.318675	6406.55108	6311.23108	-1287.1095	1287.109499

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $	2390 kW Jenbacher IC Engine Thermal Output kW	2390 kW Jenbacher IC Engine Thermal Output Mbh	Thermal left over after Heating Mbh	Thermal left after cooling with 0.7 COP ABS Chiller Mbh	Thermal still needed Mbh
Dec	30	24	1804.22	4347.518072	148.3434553	152.793759	1847.695181	6308.81828	5620.27828	-1234.25039	1234.250388
Dec	31	1	1803.39	4345.518072	148.2752125	152.7234689	1846.845181	6305.916018	5778.256018	-1070.09709	1070.09709
Dec	31	2	1802.9	4344.337349	148.2349246	152.6819723	1846.343373	6304.202635	5698.992635	-1122.42817	1122.42817
Dec	31	3	1803.64	4346.120482	148.2957676	152.7446406	1847.101205	6306.790194	5660.520194	-1167.5908	1167.590801
Dec	31	4	1803.21	4345.084337	148.2604128	152.7082252	1846.660843	6305.286612	5671.866612	-1144.92252	1144.922522
Dec	31	5	1803.57	4345.951807	148.2900121	152.7387125	1847.029518	6306.545425	5726.285425	-1107.31496	1107.314957
Dec	31	6	1803.96	4346.891566	148.3220781	152.7717404	1847.428916	6307.909138	5558.539138	-1269.05723	1269.057226
Dec	31	7	1803.54	4345.879518	148.2875455	152.7361719	1846.998795	6306.440524	5777.760524	-1071.62184	1071.621845
Dec	31	8	1803.75	4346.385542	148.3048118	152.7539561	1847.213855	6307.174831	5849.884831	-1005.84464	1005.844641
Dec	31	9	1807.02	4354.26506	148.5736721	153.0308822	1850.562651	6318.609044	5875.199044	-1038.85516	1038.855163
Dec	31	10	1812.74	4368.048193	149.043972	153.5152912	1856.420482	6338.610175	6073.250175	-978.210245	978.2102448
Dec	31	11	1816.06	4376.048193	149.3169433	153.7964516	1859.820482	6350.219223	6063.039223	-1055.49464	1055.494642
Dec	31	12	1816.04	4376	149.3152989	153.7947579	1859.8	6350.149289	6184.069289	-961.39688	961.3968795
Dec	31	13	1819.13	4383.445783	149.5693595	154.0564403	1862.964458	6360.954096	6269.274096	-934.859894	934.8598941
Dec	31	14	1818.48	4381.879518	149.5159164	154.0013939	1862.298795	6358.68124	6296.29124	-921.909304	921.9093035
Dec	31	15	1817.21	4378.819277	149.4114966	153.8938415	1860.998193	6354.240429	6290.360429	-909.313434	909.3134337
Dec	31	16	1812.87	4368.361446	149.0546607	153.5263005	1856.553614	6339.064746	6202.384746	-915.119858	915.1198585
Dec	31	17	1810.19	4361.903614	148.8343103	153.2993396	1853.809036	6329.693587	6131.433587	-925.51622	925.5162197
Dec	31	18	1808.46	4357.73494	148.6920693	153.1528313	1852.037349	6323.644294	5933.254294	-1055.59281	1055.592808
Dec	31	19	1808.01	4356.650602	148.6550701	153.1147222	1851.576506	6322.070778	5846.400778	-1116.71482	1116.714823
Dec	31	20	1806.74	4353.590361	148.5506504	153.0071699	1850.275904	6317.629967	5877.329967	-1060.05413	1060.054133
Dec	31	21	1806.82	4353.783133	148.557228	153.0139449	1850.357831	6317.909704	5795.949704	-1120.8492	1120.849196
Dec	31	22	1806.74	4353.590361	148.5506504	153.0071699	1850.275904	6317.629967	5820.199967	-1090.938	1090.938002
Dec	31	23	1806.03	4351.879518	148.492274	152.9470422	1849.548795	6315.14731	5744.15731	-1144.50848	1144.508483
Dec	31	24	1805.18	4349.831325	148.4223868	152.8750584	1848.678313	6312.175114	5704.615114	-1173.75808	1173.758079
					1370929.119	**1412056.992**					
			Adjusted for 10Cent savings		120000					MBH added b	13157749.49
					1292056.992	**$1,325,213.00**				Therms additic	131577.4949
									7587.456329	Cost additiona	$122,367.07
								ton	632.2880274		
			16673858.17						700 ton absorption chiller		5626.884915
							Costs with ABS		**$1,447,580.07**		
			83369.29085				Savings over original		**$640,797.58**		
							Additional Cost	Payback (years)			
							2936654.55	4.58	$640,797.58		

System E Sample Calculations

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Thermal still needed Mbh	Thermal needed converted to electrical chiller COP 6.1 kW	New Load Follow kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $
Jan	1	1	1802.84	1043.084331	50.08087268	1852.920873	4464.869573	152.3476542	156.9180838
Jan	1	2	1802.54	1023.81184	49.15555619	1851.695556	4461.917003	152.2469084	156.8143156
Jan	1	3	1802.4	1011.282352	48.55398667	1850.953987	4460.130088	152.1859363	156.7515144
Jan	1	4	1801.89	942.5651842	45.25471776	1847.144718	4450.951127	151.8727372	156.4289193
Jan	1	5	1801.7	890.8501928	42.77176233	1844.471762	4444.510271	151.6529661	156.2025551
Jan	1	6	1801.7	883.2672122	42.40768603	1844.107686	4443.632978	151.6230316	156.1717226
Jan	1	7	1801.75	898.2589102	43.12747186	1844.877472	4445.487884	151.6863236	156.2369133
Jan	1	8	1802.17	870.9201262	41.81487409	1843.984874	4443.337046	151.612934	156.161322
Jan	1	9	1802.87	869.7059657	41.75657946	1844.626579	4444.883324	151.6656952	156.215666
Jan	1	10	1804.47	893.8727015	42.91687991	1847.38688	4451.53465	151.8926478	156.4494273
Jan	1	11	1805.66	931.2743113	44.71261704	1850.372617	4458.729198	152.138136	156.70228
Jan	1	12	1806.43	915.1934154	43.94053631	1850.370536	4458.724184	152.1379649	156.7021038
Jan	1	13	1806.74	917.2585285	44.03968714	1850.779687	4459.710089	152.1716054	156.7367535
Jan	1	14	1806.92	1073.391215	51.53597577	1858.455976	4478.207171	152.8027519	157.3868344
Jan	1	15	1806.13	984.1910725	47.25327219	1853.383272	4465.983788	152.3856728	156.957243
Jan	1	16	1805.7	1080.00476	51.85350724	1857.553507	4476.032548	152.7285507	157.3104072
Jan	1	17	1805.2	1108.17421	53.20598719	1858.405987	4478.086716	152.7986418	157.3826011
Jan	1	18	1804.83	1049.87336	50.40682955	1855.23683	4470.450192	152.5380728	157.114215
Jan	1	19	1804.63	1096.315597	52.63662793	1857.266628	4475.341272	152.7049634	157.2861123
Jan	1	20	1804.46	1074.779106	51.60261157	1856.062612	4472.440028	152.6059688	157.1841479
Jan	1	21	1804.96	1172.257225	56.28275979	1861.24276	4484.922313	153.031882	157.6228385
Jan	1	22	1804.34	1077.274313	51.72241219	1856.062412	4472.439547	152.6059524	157.184131
Jan	1	23	1804.73	1068.027449	51.27844905	1856.008449	4472.309516	152.6015156	157.179561
Jan	1	24	1804.98	1137.194754	54.59933009	1859.57933	4480.914048	152.8951144	157.4819678
Jan	2	1	1805.41	1143.667176	54.91008594	1860.320086	4482.699002	152.9560195	157.5447001
Jan	2	2	1805.11	1127.812846	54.14888318	1859.258883	4480.141887	152.8687672	157.4548302
Jan	2	3	1804.66	1097.714798	52.70380679	1857.363807	4475.575438	152.7129535	157.2943421
Jan	2	4	1804.77	1162.352254	55.80719941	1860.577199	4483.318553	152.9771595	157.5664743
Jan	2	5	1805.1	1264.248385	60.69946653	1865.799467	4495.902329	153.4065357	158.0087317
Jan	2	6	1804.08	1046.33927	50.2371498	1854.31715	4468.234096	152.4624565	157.0363302
Jan	2	7	1804.3	1213.804669	58.27754793	1862.577548	4488.13867	153.1416287	157.7358775
Jan	2	8	1805.07	1209.640052	58.07759513	1863.147595	4489.512277	153.1884981	157.784153
Jan	2	9	1804.69	1041.209369	49.99085148	1854.680851	4469.110485	152.4923601	157.067131
Jan	2	10	1806.4	1068.929291	51.32174853	1857.721749	4476.437948	152.7423835	157.324655
Jan	2	11	1808.46	1090.279384	52.34681549	1860.806815	4483.871845	152.9960386	157.5859197
Jan	2	12	1810.68	1090.990004	52.38093402	1863.060934	4489.303455	153.1813728	157.776814
Jan	2	13	1811.59	1046.581473	50.24877852	1861.838779	4486.358502	153.0808868	157.6733134
Jan	2	14	1811.46	1059.469068	50.86754151	1862.327542	4487.536245	153.1210731	157.7147053
Jan	2	15	1812.8	1036.820232	49.78011892	1862.580119	4488.144865	153.14184	157.7360953
Jan	2	16	1812.93	1089.489424	52.30888771	1865.238888	4494.551537	153.3604447	157.9612581
Jan	2	17	1813.54	1068.80705	51.31587945	1864.855879	4493.628625	153.3289537	157.9288223
Jan	2	18	1812.75	1078.494306	51.78098688	1864.530987	4492.845752	153.3022409	157.9013082

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Thermal still needed Mbh	Thermal needed converted to electrical chiller COP 6.1 kW	New Load Follow kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $
May	31	2	1830.54	1007.304561	48.36300384	1878.903004	4527.477118	154.4839121	159.1184294
May	31	3	1830.6	998.1591992	47.92391401	1878.523914	4526.563648	154.4527432	159.0863255
May	31	4	1830.66	999.0240905	47.96543943	1878.625439	4526.808288	154.4610906	159.0949234
May	31	5	1830.58	984.2525796	47.25622528	1877.836225	4524.906567	154.3962012	159.0280873
May	31	6	1830.65	974.2798403	46.7774118	1877.427411	4523.921473	154.3625884	158.9934661
May	31	7	1842.02	924.0629606	44.36638354	1886.386384	4545.509358	155.0991976	159.7521735
May	31	8	1936.57	1556.413194	74.72696955	2011.29697	4846.498722	165.3693796	170.330461
May	31	9	2104.34	851.7571163	40.894814	2145.234814	5169.240516	176.3817854	181.6732389
May	31	10	2119.1	1333.423809	64.02073737	2183.120737	5260.531897	179.4967762	184.8816795
May	31	11	2129.88	1573.530696	75.5488201	2205.42882	5314.286313	181.3309528	186.7708814
May	31	12	2130.96	1657.000874	79.55641493	2210.516415	5326.545578	181.7492562	187.2017339
May	31	13	2130.47	1683.381319	80.8230006	2211.293001	5328.416869	181.8131073	187.2675005
May	31	14	2109.32	1825.236611	87.63379878	2196.953799	5293.864575	180.6341342	186.0531583
May	31	15	2112.12	1955.768298	93.90092463	2206.020925	5315.713071	181.3796358	186.8210249
May	31	16	2113.36	2057.789257	98.79918504	2212.159185	5330.50406	181.8843252	187.340855
May	31	17	2111.69	1999.299997	95.99098141	2207.680981	5319.713208	181.5161261	186.9616099
May	31	18	1923.48	1799.011275	86.37466017	2009.85466	4843.023278	165.2507926	170.2083164
May	31	19	1824.03	1098.628294	52.74766584	1876.777666	4522.355821	154.3091662	158.9384412
May	31	20	1831.99	994.5091427	47.74866642	1879.738666	4529.490762	154.5526205	159.1891991
May	31	21	1830.46	967.5245938	46.4530763	1876.913076	4522.682112	154.3202997	158.9499087
May	31	22	1829.88	950.2030829	45.62143081	1875.501431	4519.280556	154.2042338	158.8303608
May	31	23	1829.66	944.0681503	45.32687861	1874.986879	4518.040671	154.1619272	158.786785
May	31	24	1830.28	957.5798358	45.97560564	1876.255606	4521.097845	154.2662423	158.8942295
Jun	1	1	1831.16	1033.304048	49.61129885	1880.771299	4531.979033	154.6375238	159.2766495
Jun	1	2	1830.94	1053.582222	50.58490055	1881.524901	4533.794941	154.6994851	159.3404697
Jun	1	3	1830.9	1077.265747	51.72200095	1882.622001	4536.438557	154.789689	159.4333797
Jun	1	4	1830.93	1122.259831	53.88227015	1884.81227	4541.716314	154.9697735	159.6188667
Jun	1	5	1831	1161.787006	55.78006055	1886.780061	4546.457977	155.1315658	159.7855128
Jun	1	6	1831.99	1211.20933	58.15293975	1890.14294	4554.561301	155.4080626	160.0703045
Jun	1	7	1846.75	1302.820554	62.55140486	1909.301405	4600.726277	156.9832768	161.6927751
Jun	1	8	1947.95	2393.412046	114.9132054	2062.863205	4970.754712	169.6091695	174.6974446
Jun	1	9	2130.41	2346.614872	112.6663657	2243.076366	5405.003291	184.4263441	189.9591345
Jun	1	10	2152.29	2776.057928	133.2849124	2285.574912	5507.409427	187.9205861	193.5582037
Jun	1	11	2138.95	3113.703282	149.4960408	2288.446041	5514.327809	188.1566511	193.8013506
Jun	1	12	2133.25	3136.893803	150.6094709	2283.859471	5503.275833	187.7795421	193.4129283
Jun	1	13	2128.59	3076.851645	147.7267091	2276.316709	5485.100504	187.1593742	192.7741554
Jun	1	14	2126.8	3083.11074	148.0272226	2274.827223	5481.51138	187.0369082	192.6480154
Jun	1	15	2126.25	3149.534221	151.2163664	2277.466366	5487.870762	187.2538993	192.8715163
Jun	1	16	2120.77	3052.218218	146.5440017	2267.314002	5463.407233	186.4191691	192.0117442
Jun	1	17	2113.82	2870.668286	137.8273728	2251.647373	5425.65632	185.1310547	190.6849863
Jun	1	18	1945.72	2496.916803	119.8827063	2065.602706	4977.355919	169.834412	174.9294443
Jun	1	19	1846.99	1450.413836	69.63769711	1916.627697	4618.379993	157.5856465	162.3132159
Jun	1	20	1833.19	1414.911254	67.93313665	1901.123137	4581.019606	156.3108574	161.0001831
Jun	1	21	1832.64	1396.268056	67.0380339	1899.678034	4577.537431	156.1920406	160.8778019

Month	Day	Hour	2390 kW Jenbacher IC Engine Elec Output kW	Thermal still needed Mbh	Thermal needed converted to electrical chiller COP 6.1 kW	New Load Follow kW	Natural Gas Bought kW	Natural Gas bought Therms	Cost of Natural Gas $
Dec	30	24	1804.22	1234.250388	59.25919384	1863.479194	4490.31131	153.2157622	157.8122351
Dec	31	1	1803.39	1070.09709	51.37781725	1854.767817	4469.320042	152.4995105	157.0744958
Dec	31	2	1802.9	1122.42817	53.89035249	1856.790352	4474.19362	152.6658039	157.245778
Dec	31	3	1803.64	1167.590801	56.05871406	1859.698714	4481.201721	152.9049302	157.4920781
Dec	31	4	1803.21	1144.922522	54.97035798	1858.180358	4477.543031	152.7800905	157.3634932
Dec	31	5	1803.57	1107.314957	53.16473245	1856.734732	4474.059596	152.6612308	157.2410677
Dec	31	6	1803.96	1269.057226	60.93035003	1864.89035	4493.711687	153.3317879	157.9317415
Dec	31	7	1803.54	1071.621845	51.45102423	1854.991024	4469.85789	152.5178626	157.0933985
Dec	31	8	1803.75	1005.844641	48.29290971	1852.04291	4462.753999	152.2754679	156.8437319
Dec	31	9	1807.02	1038.855163	49.87782062	1856.897821	4474.45258	152.6746399	157.2548791
Dec	31	10	1812.74	978.2102448	46.96611892	1859.706119	4481.219564	152.905539	157.4927052
Dec	31	11	1816.06	1055.494642	50.67672019	1866.73672	4498.160772	153.4835969	158.0881048
Dec	31	12	1816.04	961.3968795	46.15887067	1862.198871	4487.226194	153.1104937	157.7038085
Dec	31	13	1819.13	934.8598941	44.88476909	1864.014769	4491.601853	153.2597974	157.8575913
Dec	31	14	1818.48	921.9093035	44.26298152	1862.742982	4488.537305	153.1552307	157.7498876
Dec	31	15	1817.21	909.3134337	43.6582249	1860.868225	4484.019819	153.0010877	157.5911203
Dec	31	16	1812.87	915.1198585	43.93700468	1856.807005	4474.233746	152.667173	157.2471882
Dec	31	17	1810.19	925.5162197	44.43615784	1854.626158	4468.978694	152.4878632	157.0624991
Dec	31	18	1808.46	1055.592808	50.68143338	1859.141433	4479.858876	152.8591104	157.4448837
Dec	31	19	1808.01	1116.714823	53.6160416	1861.626042	4485.845883	153.0633956	157.6552974
Dec	31	20	1806.74	1060.054133	50.89563183	1857.635632	4476.230438	152.735303	157.3173621
Dec	31	21	1806.82	1120.849196	53.81454235	1860.634542	4483.456729	152.9818742	157.5713304
Dec	31	22	1806.74	1090.938002	52.37843728	1859.118437	4479.803463	152.8572197	157.4429362
Dec	31	23	1806.03	1144.508483	54.95047901	1860.980479	4484.290311	153.0103172	157.6006267
Dec	31	24	1805.18	1173.758079	56.35481923	1861.534819	4485.62607	153.0558952	157.6475721
								1422870.438	**1465556.551**
					631733.7513			120000	
								1345556.551	**$1,374,967.59**
					270.16	kW			
					100 ton chiller				
						Costs with ABS		**$1,374,967.59**	
						Savings over original		**$713,410.06**	
					total O&M	86527.95961			
						Additional Co:	Payback (years)		
						2483595.55	3.48	$713,410.06	

System F Sample Calculations

Month	Day	Hour	1801 kW Jenbacher IC Engine Elec. Output kW	Amount of Elect. To buy kW	REAL Amount of Elect. To buy On peak $	REAL Amount of Elect. To buy Mid peak $	Amount of Elect. To buy Off peak $	Sell Extra	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	1801 kW Jenbacher IC Engine Thermal Output kW	MBH	Left for Cooling MBH	Needed MBH for 0.7 COP Absorber	Additional CH4 to Buy
Jan	1	1	1801	1.84	**0.00**	**0.00**	**0.14**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5918.908673	7072.217163	-1153.3085
Jan	1	2	1801	1.54	**0.00**	**0.00**	**0.12**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5913.498673	7046.485663	-1132.987
Jan	1	3	1801	1.4	**0.00**	**0.00**	**0.11**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5906.618673	7026.586636	-1119.968
Jan	1	4	1801	0.89	**0.00**	**0.00**	**0.07**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5905.928673	6955.396151	-1049.4675
Jan	1	5	1801	0.7	**0.00**	**0.00**	**0.05**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5899.468673	6896.556786	-997.08811
Jan	1	6	1801	0.7	**0.00**	**0.00**	**0.05**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5883.378673	6872.883806	-989.50513
Jan	1	7	1801	0.75	**0.00**	**0.07**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5854.488673	6859.160339	-1004.6717
Jan	1	8	1801	1.17	**0.00**	**0.11**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5901.458673	6880.260169	-978.8015
Jan	1	9	1801	1.87	**0.00**	**0.17**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5916.178673	6896.213699	-980.03503
Jan	1	10	1801	3.47	**0.38**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5937.708673	6947.505157	-1009.7965
Jan	1	11	1801	4.66	**0.50**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5936.458673	6987.817841	-1051.3592
Jan	1	12	1801	5.43	**0.59**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5977.808673	7015.779405	-1037.9707
Jan	1	13	1801	5.74	**0.62**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5996.788673	7037.908496	-1041.1198
Jan	1	14	1801	5.92	**0.64**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5832.478673	7030.360589	-1197.8819
Jan	1	15	1801	5.13	**0.55**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5916.378673	7022.298052	-1105.9194
Jan	1	16	1801	4.7	**0.51**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5798.738673	6998.968158	-1200.2295
Jan	1	17	1801	4.2	**0.45**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5756.878673	6983.529258	-1226.6506
Jan	1	18	1801	3.83	**0.41**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5815.958673	6983.014628	-1167.056
Jan	1	19	1801	3.63	**0.39**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5763.868673	6976.667525	-1212.7989
Jan	1	20	1801	3.46	**0.37**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5780.338673	6971.006594	-1190.6679
Jan	1	21	1801	3.96	**0.00**	**0.37**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5665.158673	6955.053064	-1289.8944
Jan	1	22	1801	3.34	**0.00**	**0.31**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5758.878673	6951.622197	-1192.7435
Jan	1	23	1801	3.73	**0.00**	**0.35**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5764.188673	6949.049047	-1184.8604
Jan	1	24	1801	3.98	**0.00**	**0.00**	**0.30**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5692.088673	6946.990527	-1254.9019
Jan	2	1	1801	4.41	**0.00**	**0.00**	**0.33**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5705.898673	6968.776531	-1262.8779
Jan	2	2	1801	4.11	**0.00**	**0.00**	**0.31**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5713.538673	6959.513191	-1245.9745
Jan	2	3	1801	3.66	**0.00**	**0.00**	**0.27**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5717.248673	6931.551627	-1214.303
Jan	2	4	1801	3.77	**0.00**	**0.00**	**0.28**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5644.678673	6924.00372	-1279.325
Jan	2	5	1801	4.1	**0.00**	**0.00**	**0.31**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5516.068673	6898.443763	-1382.3751
Jan	2	6	1801	3.08	**0.00**	**0.00**	**0.23**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5724.678673	6885.578012	-1160.8993
Jan	2	7	1801	3.3	**0.00**	**0.31**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5531.398673	6860.532685	-1329.134
Jan	2	8	1801	4.07	**0.00**	**0.38**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5538.188673	6865.850529	-1327.6619
Jan	2	9	1801	3.69	**0.00**	**0.34**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5728.018673	6885.921099	-1157.9024
Jan	2	10	1801	5.4	**0.58**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5723.138673	6914.74038	-1191.6017
Jan	2	11	1801	7.46	**0.81**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5729.408673	6949.563677	-1220.155
Jan	2	12	1801	9.68	**1.05**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5755.758673	6984.386975	-1228.6283
Jan	2	13	1801	10.59	**1.14**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5810.708673	6998.110442	-1187.4018
Jan	2	14	1801	10.46	**1.13**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5796.388673	6996.223465	-1199.8348
Jan	2	15	1801	11.8	**1.28**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5835.108673	7016.980209	-1181.8715
Jan	2	16	1801	11.93	**1.29**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5779.068673	7014.063972	-1234.9953
Jan	2	17	1801	12.54	**1.36**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5792.128673	7008.574585	-1216.4459
Jan	2	18	1801	11.75	**1.27**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5766.848673	6990.219448	-1223.3708

Month	Day	Hour	1801 kW Jenbacher IC Engine Elec. Output kW	Amount of Elect. To buy kW	REAL Amount of Elect. To buy On peak $	REAL Amount of Elect. To buy Mid peak $	Amount of Elect. To buy Off peak $	Sell Extra	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	1801 kW Jenbacher IC Engine Thermal Output kW	MBH	Left for Cooling MBH	Needed MBH for 0.7 COP Absorber	Additional CH4 to Buy
May	31	2	1801	29.54	**0.00**	**0.00**	**2.22**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6061.108673	7275.496018	-1214.3873
May	31	3	1801	29.6	**0.00**	**0.00**	**2.22**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6063.868673	7269.320458	-1205.4518
May	31	4	1801	29.66	**0.00**	**0.00**	**2.23**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6065.538673	7272.065151	-1206.5265
May	31	5	1801	29.58	**0.00**	**0.00**	**2.22**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6063.778673	7255.253904	-1191.4752
May	31	6	1801	29.65	**0.00**	**0.00**	**2.22**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6063.728673	7245.475934	-1181.7473
May	31	7	1801	41.02	**0.00**	**3.80**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6068.698673	7239.986547	-1171.2879
May	31	8	1801	135.57	**0.00**	**12.55**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5439.558673	7573.809881	-2134.2512
May	31	9	1801	303.34	**0.00**	**28.09**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6129.498673	8145.735368	-2016.2367
May	31	10	1801	318.1	**34.39**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6148.418673	8697.93337	-2549.5147
May	31	11	1801	328.88	**35.56**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6160.868673	8988.184697	-2827.316
May	31	12	1801	329.96	**35.68**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6171.058673	9085.621312	-2914.5626
May	31	13	1801	329.47	**35.62**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6178.298673	9117.528373	-2939.2297
May	31	14	1801	308.32	**33.34**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6193.768673	9200.898435	-3007.1298
May	31	15	1801	311.12	**33.64**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6193.768673	9341.220885	-3147.4522
May	31	16	1801	312.36	**33.77**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6193.768673	9447.577754	-3253.8091
May	31	17	1801	310.69	**33.59**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6193.768673	9383.249002	-3189.4803
May	31	18	1801	122.48	**13.24**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6193.768673	8524.846143	-2331.0775
May	31	19	1801	23.03	**2.49**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6189.308673	7472.256226	-1282.9476
May	31	20	1801	30.99	**3.35**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6129.388673	7336.050816	-1206.6621
May	31	21	1801	29.46	**0.00**	**2.73**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6084.528673	7258.856314	-1174.3276
May	31	22	1801	28.88	**0.00**	**2.67**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6063.908673	7218.886717	-1154.978
May	31	23	1801	28.66	**0.00**	**2.65**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6058.118673	7206.19251	-1148.0738
May	31	24	1801	29.28	**0.00**	**0.00**	**2.20**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6056.848673	7220.60215	-1163.7535
Jun	1	1	1801	30.16	**0.00**	**0.00**	**3.19**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6078.228673	7320.783459	-1242.5548
Jun	1	2	1801	29.94	**0.00**	**0.00**	**3.17**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6074.158673	7336.222359	-1262.0637
Jun	1	3	1801	29.9	**0.00**	**0.00**	**3.17**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6071.028673	7356.636016	-1285.6073
Jun	1	4	1801	29.93	**0.00**	**0.00**	**3.17**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6071.388673	7402.095001	-1330.7063
Jun	1	5	1801	30	**0.00**	**0.00**	**3.18**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6072.958673	7443.436945	-1370.4783
Jun	1	6	1801	30.99	**0.00**	**0.00**	**3.28**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6081.658673	7505.021003	-1423.3623
Jun	1	7	1801	45.75	**0.00**	**5.09**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6108.778673	7675.363537	-1566.5849
Jun	1	8	1801	146.95	**0.00**	**16.34**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5664.418673	8675.461193	-3011.0425
Jun	1	9	1801	329.41	**0.00**	**36.62**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6161.478673	9763.732124	-3602.2535
Jun	1	10	1801	351.29	**48.69**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6173.588673	10281.793	-4108.2043
Jun	1	11	1801	337.95	**46.84**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10584.05236	-4399.2037
Jun	1	12	1801	332.25	**46.05**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10587.31169	-4402.463
Jun	1	13	1801	327.59	**45.41**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10510.9749	-4326.1262
Jun	1	14	1801	325.8	**45.16**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10510.9749	-4326.1262
Jun	1	15	1801	325.25	**45.08**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10575.4752	-4390.6265
Jun	1	16	1801	319.77	**44.32**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10458.99727	-4274.1486
Jun	1	17	1801	312.82	**43.36**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6184.848673	10253.14527	-4068.2966
Jun	1	18	1801	144.72	**20.06**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6170.828673	9277.578307	-3106.7496
Jun	1	19	1801	45.99	**6.37**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6156.248673	7871.266028	-1715.0174
Jun	1	20	1801	32.19	**4.46**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6126.958673	7758.218969	-1631.2603
Jun	1	21	1801	31.64	**0.00**	**3.52**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6112.358673	7723.052585	-1610.6939

Month	Day	Hour	1801 kW Jenbacher IC Engine Elec. Output kW	Amount of Elect. To buy kW	**REAL Amount of Elect. To buy On peak $**	**REAL Amount of Elect. To buy Mid peak $**	**Amount of Elect. To buy Off peak $**	Sell Extra	Natural Gas bought kW	Natural Gas bought Therms	Cost of Natural Gas $	1801 kW Jenbacher IC Engine Thermal Output kW	MBH	Left for Cooling MBH	Needed MBH for 0.7 COP Absorber	Additional CH4 to Buy
Dec	31	16	1801	11.87	**1.28**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	6057.088673	7117.504604	-1060.4159
Dec	31	17	1801	9.19	**0.99**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5995.508673	7056.949806	-1061.4411
Dec	31	18	1801	7.46	**0.81**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5803.378673	6988.847101	-1185.4684
Dec	31	19	1801	7.01	**0.76**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5718.098673	6963.115601	-1245.0169
Dec	31	20	1801	5.74	**0.62**	**0.00**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5753.468673	6937.3841	-1183.9154
Dec	31	21	1801	5.82	**0.00**	**0.54**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5671.808673	6916.7989	-1244.9902
Dec	31	22	1801	5.74	**0.00**	**0.53**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5696.338673	6911.13797	-1214.7993
Dec	31	23	1801	5.03	**0.00**	**0.47**	**0.00**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5622.778673	6888.665793	-1265.8871
Dec	31	24	1801	4.18	**0.00**	**0.00**	**0.31**	0.00	4198.135198	143.3422176	147.6424841	1814	6193.769	5586.208673	6878.373192	-1292.1645
					84108.31	**14343.33**	**4481.15**	**27.25**	**36775664.34**	**1255677.83**	**1293348.16**					-172006.01
								Adjusted for 10Cent savings		120000			tons	516.1473894		$159,965.59
			15776760	897098.2						1135677.83	**$1,179,780.38**					-6934.0998
													costs for absorber		**$1,574,474.17**	
													savings over original		**$513,903.49**	
			total O&M													
			78883.8										Additional	Payback (years)		
													2037933	3.97	$513,903.49	
									Max Monthly Demand	Cost of Demand			Original Rate			
									kW	$			Additional Cost	Payback (years)	savings	adjusted payback including O&M
								Month				1	2037933	11.8650268	188960.22	18.5137973
								Jan	318.56	1380.00192		1.1	2037933	6.378908394	351431.86	7.47733273
								Feb	343.65	1488.6918		1.2	2037933	4.10292066	513903.4862	4.68469036
								Mar	352.8	1528.3296		1.3	2037933	3.09164338	659174.5165	3.51191648
								Apr	356.31	1543.53492		1.4	2037933	2.480304369	821646.1477	2.74372084
								May	357.01	1546.56732		1.5	2037933	2.070821779	984117.7789	2.2512771
								Jun	372.13	1612.06716		1.6	2037933	1.777386493	1146589.41	1.90870265
								Jul	365.43	1583.04276		1.7	2037933	1.556789535	1309061.041	1.656617
								Aug	360.57	1561.98924		1.8	2037933	1.384904711	1471532.672	1.46334986
								Sep	359	1555.188		1.9	2037933	1.247201446	1634004.304	1.31046599
								Oct	355.14	1538.46648		2	2037933	1.134405694	1796475.935	1.18650551
								Nov	338.52	1466.46864						
								Dec	328.55	1423.2786						
								total		**$18,227.63**						

System G Sample Calculations

Using a Saturn 20 turbine flat out to make steam for 1.2 COP absorption chiller or steam driven chiller

Using a Saturn 20 turbine flat out to make steam for 1.2 COP absorption chiller or steam driven chiller
Month | Day | Hour | Saturn 20 kW | Amount of Elect. To buy kW | REAL Amount of Elect. To buy On peak $ | REAL Amount of Elect. To buy Mid peak $ | REAL Amount of Elect. To buy Off peak $ | Natural Gas to buy Therms | Cost of Natural Gas, not adjusted $ | Thermal Produced Mbh | Left Over After Steam Chiller COP 1.2 and Heating MBH | Extra Needed MBH

Month	Day	Hour	Saturn 20 kW	Amount of Elect. To buy kW	**REAL Amount of Elect. To buy On peak** **$**	**REAL Amount of Elect. To buy Mid peak** **$**	**REAL Amount of Elect. To buy Off peak** **$**	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted **$**	Thermal Produced Mbh	Left Over After Steam Chiller COP 1.2 and Heating **MBH**	Extra Needed **MBH**
Jan	1	1	1200	602.84	**0.00**	**0.00**	**37.70**	167.9225877	172.9602653	9617	5216.679988	0
Jan	1	2	1200	602.54	**0.00**	**0.00**	**37.68**	167.9225877	172.9602653	9617	5226.28003	0
Jan	1	3	1200	602.4	**0.00**	**0.00**	**37.67**	167.9225877	172.9602653	9617	5231.007796	0
Jan	1	4	1200	601.89	**0.00**	**0.00**	**37.64**	167.9225877	172.9602653	9617	5271.845579	0
Jan	1	5	1200	601.7	**0.00**	**0.00**	**37.62**	167.9225877	172.9602653	9617	5299.708541	0
Jan	1	6	1200	601.7	**0.00**	**0.00**	**37.62**	167.9225877	172.9602653	9617	5297.42778	0
Jan	1	7	1200	601.75	**0.00**	**46.44**	**0.00**	167.9225877	172.9602653	9617	5276.543136	0
Jan	1	8	1200	602.17	**0.00**	**46.47**	**0.00**	167.9225877	172.9602653	9617	5311.204901	0
Jan	1	9	1200	602.87	**0.00**	**46.52**	**0.00**	167.9225877	172.9602653	9617	5316.618675	0
Jan	1	10	1200	604.47	**54.46**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5308.228658	0
Jan	1	11	1200	605.66	**54.57**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5283.462926	0
Jan	1	12	1200	606.43	**54.64**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5308.502013	0
Jan	1	13	1200	606.74	**54.67**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5314.573377	0
Jan	1	14	1200	606.92	**54.68**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5154.666323	0
Jan	1	15	1200	606.13	**54.61**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5243.26947	0
Jan	1	16	1200	605.7	**54.57**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5139.238574	0
Jan	1	17	1200	605.2	**54.53**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5106.384599	0
Jan	1	18	1200	604.83	**54.50**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5165.7648	0
Jan	1	19	1200	604.63	**54.48**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5117.377277	0
Jan	1	20	1200	604.46	**54.46**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5137.149487	0
Jan	1	21	1200	604.96	**0.00**	**46.68**	**0.00**	167.9225877	172.9602653	9617	5031.275713	0
Jan	1	22	1200	604.34	**0.00**	**46.64**	**0.00**	167.9225877	172.9602653	9617	5126.997052	0
Jan	1	23	1200	604.73	**0.00**	**46.67**	**0.00**	167.9225877	172.9602653	9617	5133.808056	0
Jan	1	24	1200	604.98	**0.00**	**0.00**	**37.83**	167.9225877	172.9602653	9617	5062.908859	0
Jan	2	1	1200	605.41	**0.00**	**0.00**	**37.86**	167.9225877	172.9602653	9617	5064.010357	0
Jan	2	2	1200	605.11	**0.00**	**0.00**	**37.84**	167.9225877	172.9602653	9617	5077.053972	0
Jan	2	3	1200	604.66	**0.00**	**0.00**	**37.81**	167.9225877	172.9602653	9617	5097.074884	0
Jan	2	4	1200	604.77	**0.00**	**0.00**	**37.82**	167.9225877	172.9602653	9617	5028.90783	0
Jan	2	5	1200	605.1	**0.00**	**0.00**	**37.84**	167.9225877	172.9602653	9617	4915.207805	0
Jan	2	6	1200	604.08	**0.00**	**0.00**	**37.77**	167.9225877	172.9602653	9617	5131.322826	0
Jan	2	7	1200	604.3	**0.00**	**46.63**	**0.00**	167.9225877	172.9602653	9617	4952.6526	0
Jan	2	8	1200	605.07	**0.00**	**46.69**	**0.00**	167.9225877	172.9602653	9617	4956.340525	0
Jan	2	9	1200	604.69	**0.00**	**46.66**	**0.00**	167.9225877	172.9602653	9617	5134.462692	0
Jan	2	10	1200	606.4	**54.64**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5112.771445	0
Jan	2	11	1200	608.46	**54.82**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5098.727855	0
Jan	2	12	1200	610.68	**55.02**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5104.764265	0
Jan	2	13	1200	611.59	**55.10**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5151.708909	0
Jan	2	14	1200	611.46	**55.09**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5138.489645	0

Using a Saturn 20 turbine flat out to make steam for 1.2 COP absorption chiller or steam driven chiller

Month	Day	Hour	Saturn 20 kW	Amount of Elect. To buy kW	**REAL Amount of Elect. To buy On peak $**	**REAL Amount of Elect. To buy Mid peak $**	**REAL Amount of Elect. To buy Off peak $**	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted $	Thermal Produced Mbh	Left Over After Steam Chiller COP 1.2 and Heating **MBH**	Extra Needed **MBH**
May	31	6	1200	630.65	**0.00**	**0.00**	**39.43**	167.9225877	172.9602653	9617	5260.432372	0
May	31	7	1200	642.02	**0.00**	**49.54**	**0.00**	167.9225877	172.9602653	9617	5268.604514	0
May	31	8	1200	736.57	**0.00**	**56.84**	**0.00**	167.9225877	172.9602653	9617	4444.734236	0
May	31	9	1200	904.34	**0.00**	**69.79**	**0.00**	167.9225877	172.9602653	9617	4801.051036	0
May	31	10	1200	919.1	**82.81**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4497.855534	0
May	31	11	1200	929.88	**83.78**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4340.99226	0
May	31	12	1200	930.96	**83.88**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4294.344235	0
May	31	13	1200	930.47	**83.84**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4282.971782	0
May	31	14	1200	909.32	**81.93**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4249.809246	0
May	31	15	1200	912.12	**82.18**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4167.954484	0
May	31	16	1200	913.36	**82.29**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4105.912977	0
May	31	17	1200	911.69	**82.14**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4143.438082	0
May	31	18	1200	723.48	**65.19**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4644.173083	0
May	31	19	1200	624.03	**56.23**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5253.723868	0
May	31	20	1200	631.99	**56.94**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5273.257024	0
May	31	21	1200	630.46	**0.00**	**48.65**	**0.00**	167.9225877	172.9602653	9617	5273.42715	0
May	31	22	1200	629.88	**0.00**	**48.61**	**0.00**	167.9225877	172.9602653	9617	5276.122749	0
May	31	23	1200	629.66	**0.00**	**48.59**	**0.00**	167.9225877	172.9602653	9617	5277.737703	0
May	31	24	1200	630.28	**0.00**	**0.00**	**39.41**	167.9225877	172.9602653	9617	5268.062079	0
Jun	1	1	1200	631.16	**0.00**	**0.00**	**55.69**	167.9225877	172.9602653	9617	5231.002982	0
Jun	1	2	1200	630.94	**0.00**	**0.00**	**55.67**	167.9225877	172.9602653	9617	5217.926957	0
Jun	1	3	1200	630.9	**0.00**	**0.00**	**55.67**	167.9225877	172.9602653	9617	5202.88899	0
Jun	1	4	1200	630.93	**0.00**	**0.00**	**55.67**	167.9225877	172.9602653	9617	5176.73125	0
Jun	1	5	1200	631	**0.00**	**0.00**	**55.68**	167.9225877	172.9602653	9617	5154.185115	0
Jun	1	6	1200	631.99	**0.00**	**0.00**	**55.77**	167.9225877	172.9602653	9617	5126.961081	0
Jun	1	7	1200	646.75	**0.00**	**59.92**	**0.00**	167.9225877	172.9602653	9617	5054.714603	0
Jun	1	8	1200	747.95	**0.00**	**69.30**	**0.00**	167.9225877	172.9602653	9617	4026.964304	0
Jun	1	9	1200	930.41	**0.00**	**86.20**	**0.00**	167.9225877	172.9602653	9617	3889.199594	0
Jun	1	10	1200	952.29	**110.00**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3599.107415	0
Jun	1	11	1200	938.95	**108.46**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3434.049455	0
Jun	1	12	1200	933.25	**107.80**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3432.148183	0
Jun	1	13	1200	928.59	**107.26**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3476.677974	0
Jun	1	14	1200	926.8	**107.05**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3476.677974	0
Jun	1	15	1200	926.25	**106.99**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3439.052802	0
Jun	1	16	1200	920.77	**106.36**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3506.998259	0
Jun	1	17	1200	913.82	**105.56**	**0.00**	**0.00**	167.9225877	172.9602653	9617	3627.078595	0
Jun	1	18	1200	745.72	**86.14**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4182.139321	0
Jun	1	19	1200	646.99	**74.73**	**0.00**	**0.00**	167.9225877	172.9602653	9617	4987.90815	0
Jun	1	20	1200	633.19	**73.14**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5024.562268	0
Jun	1	21	1200	632.64	**0.00**	**58.61**	**0.00**	167.9225877	172.9602653	9617	5030.475992	0
Jun	1	22	1200	632.35	**0.00**	**58.59**	**0.00**	167.9225877	172.9602653	9617	5067.506319	0
Jun	1	23	1200	632.17	**0.00**	**58.57**	**0.00**	167.9225877	172.9602653	9617	5089.314662	0
Jun	1	24	1200	631.9	**0.00**	**0.00**	**55.76**	167.9225877	172.9602653	9617	5096.032027	0
Jun	2	1	1200	631.85	**0.00**	**0.00**	**55.75**	167.9225877	172.9602653	9617	5099.755441	0
Jun	2	2	1200	631.78	**0.00**	**0.00**	**55.75**	167.9225877	172.9602653	9617	5100.056512	0

Using a Saturn 20 turbine flat out to make steam for 1.2 COP absorption chiller or steam driven chiller

Month	Day	Hour	Saturn 20 kW	Amount of Elect. To buy kW	**REAL Amount of Elect. To buy On peak** **$**	**REAL Amount of Elect. To buy Mid peak** **$**	**REAL Amount of Elect. To buy Off peak** **$**	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted **$**	Thermal Produced Mbh	Left Over After Steam Chiller COP 1.2 and Heating **MBH**	Extra Needed **MBH**
Dec	31	1[illegible]	1200	617.21	**55.61**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5353.310247	0
Dec	31	1[illegible]	1200	612.87	**55.22**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5328.442314	0
Dec	31	1[illegible]	1200	610.19	**54.98**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5302.185946	0
Dec	31	1[illegible]	1200	608.46	**54.82**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5149.782524	0
Dec	31	1[illegible]	1200	608.01	**54.78**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5079.512566	0
Dec	31	2[illegible]	1200	606.74	**54.67**	**0.00**	**0.00**	167.9225877	172.9602653	9617	5129.892608	0
Dec	31	2[illegible]	1200	606.82	**0.00**	**46.83**	**0.00**	167.9225877	172.9602653	9617	5060.240642	0
Dec	31	2[illegible]	1200	606.74	**0.00**	**46.82**	**0.00**	167.9225877	172.9602653	9617	5088.072851	0
Dec	31	2[illegible]	1200	606.03	**0.00**	**46.77**	**0.00**	167.9225877	172.9602653	9617	5027.621621	0
Dec	31	2[illegible]	1200	605.18	**0.00**	**0.00**	**37.84**	167.9225877	172.9602653	9617	4997.055638	0
			10512000	6161858.17	**$307,989.46**	**$115,852.48**	**$116,772.93**	**1,471,001.87**	**1,515,131.92**	**84,244,920.00**	**41,850,816.85**	**0.00**
								120000				
								1,351,001.87				
							Adjusted Price		**$1,380,031.74**			
							costs for steam driven chiller			**$1,961,871.61**		
							savings over original			**-$218,630.62**	NEGATIVE SAVINGS	

Month	Max Monthly Demand kW	Cost of Demand $
Jan	919.56	3319.6116
Feb	944.65	3410.1865
Mar	953.8	3443.218
Apr	957.31	3455.8891
May	958.01	3458.4161
Jun	973.13	3512.9993
Jul	966.43	3488.8123
Aug	961.57	3471.2677
Sep	960	3465.6
Oct	956.14	3451.6654
Nov	939.52	3391.6672
Dec	929.55	3355.6755
total		**$41,225.01**

System H Sample Calculations

Using a Saturn 20 Turbine with a combination of a steam turbine to make more electricity.

Month	Day	Hour	Saturn 20	Thermal Produced (High Pressure 125psi steam)	Electricity Produced by Backpressure steam turbine	Total kW produced	Natural Gas to buy	Cost of Natural Gas, not adjusted	Total Electrical efficiency	Electricity to sell	REAL Amount of Elect. To buy On peak	REAL Amount of Elect. To buy Mid peak	REAL Amount of Elect. To buy Off peak	Thermal Left	Thermal left Over After Heating	Needed for 0.7 COP Absorption Chiller	Additional supplement from boiler
			kW	Mbh	kW	kW	Therms	$	0.387176093	kW	$	$	$	MBH	MBH	MBH	MBH
Jan	1	1	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		101.3047	0.00	0.00	0.00	4808.50	4533.64	7072.22	-2538.58
Jan	1	2	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		101.6047	0.00	0.00	0.00	4808.50	4528.23	7046.49	-2518.26
Jan	1	3	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		101.7447	0.00	0.00	0.00	4808.50	4521.35	7026.59	-2505.24
Jan	1	4	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		102.2547	0.00	0.00	0.00	4808.50	4520.66	6955.40	-2434.74
Jan	1	5	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		102.4447	0.00	0.00	0.00	4808.50	4514.20	6896.56	-2382.36
Jan	1	6	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		102.4447	0.00	0.00	0.00	4808.50	4498.11	6872.88	-2374.77
Jan	1	7	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		102.3947	0.00	0.00	0.00	4808.50	4469.22	6859.16	-2389.94
Jan	1	8	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		101.9747	0.00	0.00	0.00	4808.50	4516.19	6880.26	-2364.07
Jan	1	9	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		101.2747	0.00	0.00	0.00	4808.50	4530.91	6896.21	-2365.30
Jan	1	10	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.67472	0.00	0.00	0.00	4808.50	4552.44	6947.51	-2395.07
Jan	1	11	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.48472	0.00	0.00	0.00	4808.50	4551.19	6987.82	-2436.63
Jan	1	12	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.71472	0.00	0.00	0.00	4808.50	4592.54	7015.78	-2423.24
Jan	1	13	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.40472	0.00	0.00	0.00	4808.50	4611.52	7037.91	-2426.39
Jan	1	14	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.22472	0.00	0.00	0.00	4808.50	4447.21	7030.36	-2583.15
Jan	1	15	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.01472	0.00	0.00	0.00	4808.50	4531.11	7022.30	-2491.19
Jan	1	16	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.44472	0.00	0.00	0.00	4808.50	4413.47	6998.97	-2585.50
Jan	1	17	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.94472	0.00	0.00	0.00	4808.50	4371.61	6983.53	-2611.92
Jan	1	18	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.31472	0.00	0.00	0.00	4808.50	4430.69	6983.01	-2552.32
Jan	1	19	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.51472	0.00	0.00	0.00	4808.50	4378.60	6976.67	-2598.07
Jan	1	20	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.68472	0.00	0.00	0.00	4808.50	4395.07	6971.01	-2575.94
Jan	1	21	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.18472	0.00	0.00	0.00	4808.50	4279.89	6955.05	-2675.16
Jan	1	22	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.80472	0.00	0.00	0.00	4808.50	4373.61	6951.62	-2578.01
Jan	1	23	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.41472	0.00	0.00	0.00	4808.50	4378.92	6949.05	-2570.13
Jan	1	24	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.16472	0.00	0.00	0.00	4808.50	4306.82	6946.99	-2640.17
Jan	2	1	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.73472	0.00	0.00	0.00	4808.50	4320.63	6968.78	-2648.15
Jan	2	2	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.03472	0.00	0.00	0.00	4808.50	4328.27	6959.51	-2631.24
Jan	2	3	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.48472	0.00	0.00	0.00	4808.50	4331.98	6931.55	-2599.57
Jan	2	4	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.37472	0.00	0.00	0.00	4808.50	4259.41	6924.00	-2664.59
Jan	2	5	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.04472	0.00	0.00	0.00	4808.50	4130.80	6898.44	-2767.64
Jan	2	6	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		100.0647	0.00	0.00	0.00	4808.50	4339.41	6885.58	-2546.17
Jan	2	7	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.84472	0.00	0.00	0.00	4808.50	4146.13	6860.53	-2714.40
Jan	2	8	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.07472	0.00	0.00	0.00	4808.50	4152.92	6865.85	-2712.93
Jan	2	9	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		99.45472	0.00	0.00	0.00	4808.50	4342.75	6885.92	-2543.17
Jan	2	10	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.74472	0.00	0.00	0.00	4808.50	4337.87	6914.74	-2576.87
Jan	2	11	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		95.68472	0.00	0.00	0.00	4808.50	4344.14	6949.56	-2605.42
Jan	2	12	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		93.46472	0.00	0.00	0.00	4808.50	4370.49	6984.39	-2613.90
Jan	2	13	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		92.55472	0.00	0.00	0.00	4808.50	4425.44	6998.11	-2572.67
Jan	2	14	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		92.68472	0.00	0.00	0.00	4808.50	4411.12	6996.22	-2585.10
Jan	2	15	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.34472	0.00	0.00	0.00	4808.50	4449.84	7016.98	-2567.14
Jan	2	16	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.21472	0.00	0.00	0.00	4808.50	4393.80	7014.06	-2620.26
Jan	2	17	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		90.60472	0.00	0.00	0.00	4808.50	4406.86	7008.57	-2601.71
Jan	2	18	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.39472	0.00	0.00	0.00	4808.50	4381.58	6990.22	-2608.64
Jan	2	19	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		90.04472	0.00	0.00	0.00	4808.50	4360.94	6990.39	-2629.45
Jan	2	20	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.74472	0.00	0.00	0.00	4808.50	4295.98	6965.35	-2669.37
Jan	2	21	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.57472	0.00	0.00	0.00	4808.50	4267.35	6946.82	-2679.47

Using a Saturn 20 Turbine with a combination of a steam turbine to make more electricity.

Month	Day	Hour	Saturn 20 kW	Thermal Produced (High Pressure 125psi steam) Mbh	Electricity Produced by Backpressure steam turbine kW	Total kW produced kW	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted $	Total Electrical efficiency 0.387176093	Electricity to sell kW	REAL Amount of Elect. To buy On peak $	REAL Amount of Elect. To buy Mid peak $	REAL Amount of Elect. To buy Off peak $	Thermal Left MBH	Thermal left Over After Heating MBH	Needed for 0.7 COP Absorption Chiller MBH	Additional supplement from boiler MBH
May	31	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	0.00	15.45	0.00	4808.50	4744.23	8145.74	-3401.5
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	19.37	0.00	0.00	4808.50	4763.15	8697.93	-3934.7
May	31	1	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	20.34	0.00	0.00	4808.50	4775.60	8988.18	-4212.5
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	20.44	0.00	0.00	4808.50	4785.79	9085.62	-4299.8
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	20.39	0.00	0.00	4808.50	4793.03	9117.53	-4324.5
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	18.49	0.00	0.00	4808.50	4808.50	9200.90	-4392.4
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	18.74	0.00	0.00	4808.50	4808.50	9341.22	-4532.7
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	18.85	0.00	0.00	4808.50	4808.50	9447.58	-4639.0
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	18.70	0.00	0.00	4808.50	4808.50	9383.25	-4574.7
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	1.74	0.00	0.00	4808.50	4808.50	8524.85	-3716.3
May	31	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		80.11472	0.00	0.00	0.00	4808.50	4804.04	7472.26	-2668.2
May	31	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.15472	0.00	0.00	0.00	4808.50	4744.12	7336.05	-2591.9
May	31	2	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.68472	0.00	0.00	0.00	4808.50	4699.26	7258.86	-2559.6
May	31	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		74.26472	0.00	0.00	0.00	4808.50	4678.64	7218.89	-2540.2
May	31	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		74.48472	0.00	0.00	0.00	4808.50	4672.85	7206.19	-2533.3
May	31	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.86472	0.00	0.00	0.00	4808.50	4671.58	7220.60	-2549.0
Jun	1		1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.98472	0.00	0.00	0.00	4808.50	4692.96	7320.78	-2627.8
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.20472	0.00	0.00	0.00	4808.50	4688.89	7336.22	-2647.3
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.24472	0.00	0.00	0.00	4808.50	4685.76	7356.64	-2670.8
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.21472	0.00	0.00	0.00	4808.50	4686.12	7402.10	-2715.9
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		73.14472	0.00	0.00	0.00	4808.50	4687.69	7443.44	-2755.7
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.15472	0.00	0.00	0.00	4808.50	4696.39	7505.02	-2808.6
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		57.39472	0.00	0.00	0.00	4808.50	4723.51	7675.36	-2951.8
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	0.00	4.06	0.00	4808.50	4279.15	8675.46	-4396.3
Jun	1	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	0.00	20.96	0.00	4808.50	4776.21	9763.73	-4987.5
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	28.66	0.00	0.00	4808.50	4788.32	10281.79	-5493.4
Jun	1	1	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	27.12	0.00	0.00	4808.50	4799.58	10584.05	-5784.4
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	26.46	0.00	0.00	4808.50	4799.58	10587.31	-5787.7
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	25.93	0.00	0.00	4808.50	4799.58	10510.97	-5711.3
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	25.72	0.00	0.00	4808.50	4799.58	10510.97	-5711.3
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	25.66	0.00	0.00	4808.50	4799.58	10575.48	-5775.9
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	25.02	0.00	0.00	4808.50	4799.58	10459.00	-5659.4
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	24.22	0.00	0.00	4808.50	4799.58	10253.15	-5453.5
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		0	4.80	0.00	0.00	4808.50	4785.56	9277.58	-4492.0
Jun	1	1[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		57.15472	0.00	0.00	0.00	4808.50	4770.98	7871.27	-3100.2
Jun	1	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		70.95472	0.00	0.00	0.00	4808.50	4741.69	7758.22	-3016.5
Jun	1	2	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		71.50472	0.00	0.00	0.00	4808.50	4727.09	7723.05	-2995.9
Jun	1	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		71.79472	0.00	0.00	0.00	4808.50	4718.79	7645.34	-2926.5
Jun	1	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		71.97472	0.00	0.00	0.00	4808.50	4713.18	7598.34	-2885.1
Jun	1	2[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.24472	0.00	0.00	0.00	4808.50	4708.89	7579.47	-2870.5
Jun	2		1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.29472	0.00	0.00	0.00	4808.50	4707.51	7570.72	-2863.2
Jun	2	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.36472	0.00	0.00	0.00	4808.50	4706.21	7567.98	-2861.7
Jun	2	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.39472	0.00	0.00	0.00	4808.50	4705.00	7566.09	-2861.0
Jun	2	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.41472	0.00	0.00	0.00	4808.50	4703.03	7586.50	-2883.4
Jun	2	[illegible]	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		72.50472	0.00	0.00	0.00	4808.50	4702.58	7557.34	-2854.7

Using a Saturn 20 Turbine with a combination of a steam turbine to make more electricity.

Month	Day	Hour	Saturn 20 kW	Thermal Produced (High Pressure 125psi steam) Mbh	Electricity Produced by Backpressure steam turbine kW	Total kW produced kW	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted $	Total Electrical efficiency 0.387176093	Electricity to sell kW	REAL Amount of Elect. To buy On peak $	REAL Amount of Elect. To buy Mid peak $	REAL Amount of Elect. To buy Off peak $	Thermal Left MBH	Thermal left Over After Heating MBH	Needed for 0.7 COP Absorption Chiller MBH	Additional supplement from boiler MBH
Dec	31	1!	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		86.93472	0.00	0.00	0.00	4808.50	4744.62	7199.67	-2455.05
Dec	31	1(	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		91.27472	0.00	0.00	0.00	4808.50	4671.82	7117.50	-2445.68
Dec	31	1'	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		93.95472	0.00	0.00	0.00	4808.50	4610.24	7056.95	-2446.71
Dec	31	1:	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		95.68472	0.00	0.00	0.00	4808.50	4418.11	6988.85	-2570.74
Dec	31	1:	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		96.13472	0.00	0.00	0.00	4808.50	4332.83	6963.12	-2630.29
Dec	31	2(	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.40472	0.00	0.00	0.00	4808.50	4368.20	6937.38	-2569.18
Dec	31	2	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.32472	0.00	0.00	0.00	4808.50	4286.54	6916.80	-2630.26
Dec	31	2:	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		97.40472	0.00	0.00	0.00	4808.50	4311.07	6911.14	-2600.07
Dec	31	2:	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.11472	0.00	0.00	0.00	4808.50	4237.51	6888.67	-2651.16
Dec	31	2·	1200	9617	704.1447187	1904.144719	167.9225877	172.9602653		98.96472	0.00	0.00	0.00	4808.50	4200.94	6878.37	-2677.43
			1.1E+07	84,244,920.00	6,168,307.74	16,680,307.74	1,471,001.87	1,515,131.92		495,891.99	$42,974.97	$4,735.25	$0.00				#########
							120000										
							1,351,001.87			elect to sell					Cost for Boiler CH4		$272,820.66
						Adjusted Price		$1,380,031.74		$19,835.68							
															tons	400.71	
						costs for steam driven chiller w/boiler for supplement			$1,680,726.94								
						savings over original			$62,514.05								

	Max Monthly Demand	Cost of Demand
	kW	$
Month		
Jan	215.4152813	777.6491654
Feb	240.5052813	868.2240654
Mar	249.6552813	901.2555654
Apr	253.1652813	913.9266654
May	253.8652813	916.4536654
Jun	268.9852813	971.0368654
Jul	262.2852813	946.8498654
Aug	257.4252813	929.3052654
Sep	255.8552813	923.6375654
Oct	251.9952813	909.7029654
Nov	235.3752813	849.7047654
Dec	225.4052813	813.7130654
total		$10,721.46

System I Sample Calculations

			f a steam turbine to make more electricity.						Using Electric Chiller for additional cooling					
Month	Day	Hour	Total kW produced	Natural Gas to buy	Cost of Natural Gas, not adjusted	Electricity to sell	Needed for 0.7 COP Absorption Chiller	Additional supplement from boiler	Convert additional thermal to kW	Electricity Needed for 6.1 COP Chiller	Extra Electricity Needed	REAL Amount of Elect. To buy On peak	REAL Amount of Elect. To buy Mid peak	REAL Amount of Elect. To buy Off peak
			kW	Therms	$	kW	MBH	MBH	kW	kW	kW	$	$	$
Jan	1	1	1904.144719	167.9225877	172.9602653	101.3047	7072.22	-2538.58	743.49	121.88	20.58	0.00	0.00	1.29
Jan	1	2	1904.144719	167.9225877	172.9602653	101.6047	7046.49	-2518.26	737.53	120.91	19.30	0.00	0.00	1.21
Jan	1	3	1904.144719	167.9225877	172.9602653	101.7447	7026.59	-2505.24	733.72	120.28	18.54	0.00	0.00	1.16
Jan	1	4	1904.144719	167.9225877	172.9602653	102.2547	6955.40	-2434.74	713.07	116.90	14.64	0.00	0.00	0.92
Jan	1	5	1904.144719	167.9225877	172.9602653	102.4447	6896.56	-2382.36	697.73	114.38	11.94	0.00	0.00	0.75
Jan	1	6	1904.144719	167.9225877	172.9602653	102.4447	6872.88	-2374.77	695.51	114.02	11.57	0.00	0.00	0.72
Jan	1	7	1904.144719	167.9225877	172.9602653	102.3947	6859.16	-2389.94	699.95	114.75	12.35	0.00	0.95	0.00
Jan	1	8	1904.144719	167.9225877	172.9602653	101.9747	6880.26	-2364.07	692.38	113.50	11.53	0.00	0.89	0.00
Jan	1	9	1904.144719	167.9225877	172.9602653	101.2747	6896.21	-2365.30	692.74	113.56	12.29	0.00	0.95	0.00
Jan	1	10	1904.144719	167.9225877	172.9602653	99.67472	6947.51	-2395.07	701.45	114.99	15.32	1.38	0.00	0.00
Jan	1	11	1904.144719	167.9225877	172.9602653	98.48472	6987.82	-2436.63	713.63	116.99	18.50	1.67	0.00	0.00
Jan	1	12	1904.144719	167.9225877	172.9602653	97.71472	7015.78	-2423.24	709.71	116.35	18.63	1.68	0.00	0.00
Jan	1	13	1904.144719	167.9225877	172.9602653	97.40472	7037.91	-2426.39	710.63	116.50	19.09	1.72	0.00	0.00
Jan	1	14	1904.144719	167.9225877	172.9602653	97.22472	7030.36	-2583.15	756.54	124.02	26.80	2.41	0.00	0.00
Jan	1	15	1904.144719	167.9225877	172.9602653	98.01472	7022.30	-2491.19	729.61	119.61	21.59	1.95	0.00	0.00
Jan	1	16	1904.144719	167.9225877	172.9602653	98.44472	6998.97	-2585.50	757.23	124.14	25.69	2.31	0.00	0.00
Jan	1	17	1904.144719	167.9225877	172.9602653	98.94472	6983.53	-2611.92	764.97	125.40	26.46	2.38	0.00	0.00
Jan	1	18	1904.144719	167.9225877	172.9602653	99.31472	6983.01	-2552.32	747.51	122.54	23.23	2.09	0.00	0.00
Jan	1	19	1904.144719	167.9225877	172.9602653	99.51472	6976.67	-2598.07	760.91	124.74	25.22	2.27	0.00	0.00
Jan	1	20	1904.144719	167.9225877	172.9602653	99.68472	6971.01	-2575.94	754.43	123.68	23.99	2.16	0.00	0.00
Jan	1	21	1904.144719	167.9225877	172.9602653	99.18472	6955.05	-2675.16	783.49	128.44	29.26	0.00	2.26	0.00
Jan	1	22	1904.144719	167.9225877	172.9602653	99.80472	6951.62	-2578.01	755.04	123.78	23.97	0.00	1.85	0.00
Jan	1	23	1904.144719	167.9225877	172.9602653	99.41472	6949.05	-2570.13	752.73	123.40	23.98	0.00	1.85	0.00
Jan	1	24	1904.144719	167.9225877	172.9602653	99.16472	6946.99	-2640.17	773.24	126.76	27.60	0.00	0.00	1.73
Jan	2	1	1904.144719	167.9225877	172.9602653	98.73472	6968.78	-2648.15	775.58	127.14	28.41	0.00	0.00	1.78
Jan	2	2	1904.144719	167.9225877	172.9602653	99.03472	6959.51	-2631.24	770.63	126.33	27.30	0.00	0.00	1.71
Jan	2	3	1904.144719	167.9225877	172.9602653	99.48472	6931.55	-2599.57	761.35	124.81	25.33	0.00	0.00	1.58
Jan	2	4	1904.144719	167.9225877	172.9602653	99.37472	6924.00	-2664.59	780.39	127.93	28.56	0.00	0.00	1.79
Jan	2	5	1904.144719	167.9225877	172.9602653	99.04472	6898.44	-2767.64	810.57	132.88	33.84	0.00	0.00	2.12
Jan	2	6	1904.144719	167.9225877	172.9602653	100.0647	6885.58	-2546.17	745.71	122.25	22.18	0.00	0.00	1.39
Jan	2	7	1904.144719	167.9225877	172.9602653	99.84472	6860.53	-2714.40	794.98	130.32	30.48	0.00	2.35	0.00
Jan	2	8	1904.144719	167.9225877	172.9602653	99.07472	6865.85	-2712.93	794.55	130.25	31.18	0.00	2.41	0.00
Jan	2	9	1904.144719	167.9225877	172.9602653	99.45472	6885.92	-2543.17	744.83	122.10	22.65	0.00	1.75	0.00
Jan	2	10	1904.144719	167.9225877	172.9602653	97.74472	6914.74	-2576.87	754.70	123.72	25.98	2.34	0.00	0.00
Jan	2	11	1904.144719	167.9225877	172.9602653	95.68472	6949.56	-2605.42	763.06	125.09	29.41	2.65	0.00	0.00
Jan	2	12	1904.144719	167.9225877	172.9602653	93.46472	6984.39	-2613.90	765.55	125.50	32.03	2.89	0.00	0.00
Jan	2	13	1904.144719	167.9225877	172.9602653	92.55472	6998.11	-2572.67	753.47	123.52	30.97	2.79	0.00	0.00
Jan	2	14	1904.144719	167.9225877	172.9602653	92.68472	6996.22	-2585.10	757.11	124.12	31.43	2.83	0.00	0.00
Jan	2	15	1904.144719	167.9225877	172.9602653	91.34472	7016.98	-2567.14	751.85	123.25	31.91	2.88	0.00	0.00
Jan	2	16	1904.144719	167.9225877	172.9602653	91.21472	7014.06	-2620.26	767.41	125.80	34.59	3.12	0.00	0.00
Jan	2	17	1904.144719	167.9225877	172.9602653	90.60472	7008.57	-2601.71	761.98	124.91	34.31	3.09	0.00	0.00
Jan	2	18	1904.144719	167.9225877	172.9602653	91.39472	6990.22	-2608.64	764.01	125.25	33.85	3.05	0.00	0.00
Jan	2	19	1904.144719	167.9225877	172.9602653	90.04472	6990.39	-2629.45	770.10	126.25	36.20	3.26	0.00	0.00
Jan	2	20	1904.144719	167.9225877	172.9602653	91.74472	6965.35	-2669.37	781.79	128.16	36.42	3.28	0.00	0.00
Jan	2	21	1904.144719	167.9225877	172.9602653	91.57472	6946.82	-2679.47	784.75	128.65	37.07	0.00	2.86	0.00

			f a steam turbine to make more electricity.						Using Electric Chiller for additional cooling					
Month	Day	Hour	Total kW produced kW	Natural Gas to buy Therms	Cost of Natural Gas, not adjusted $	Electricity to sell kW	Needed for 0.7 COP Absorption Chiller MBH	Additional supplement from boiler MBH	Convert additional thermal to kW kW	Electricity Needed for 6.1 COP Chiller kW	Extra Electricity Needed kW	REAL Amount of Elect. To buy On peak $	REAL Amount of Elect. To buy Mid peak $	REAL Amount of Elect. To buy Off peak $
May	31		1904.144719	167.9225877	172.9602653	62.12472	7239.99	-2556.56	748.75	122.75	60.62	0.00	4.68	0.00
May	31		1904.144719	167.9225877	172.9602653	0	7573.81	-3519.52	1030.78	168.98	201.41	0.00	15.54	0.00
May	31		1904.144719	167.9225877	172.9602653	0	8145.74	-3401.51	996.22	163.31	363.51	0.00	28.05	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	8697.93	-3934.78	1152.40	188.92	403.87	36.39	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	8988.18	-4212.58	1233.76	202.26	427.99	38.56	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9085.62	-4299.83	1259.31	206.44	433.26	39.04	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9117.53	-4324.50	1266.54	207.63	433.95	39.10	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9200.90	-4392.40	1286.42	210.89	416.06	37.49	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9341.22	-4532.72	1327.52	217.63	425.60	38.35	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9447.58	-4639.08	1358.67	222.73	431.95	38.92	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	9383.25	-4574.75	1339.83	219.64	427.19	38.49	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	0	8524.85	-3716.35	1088.42	178.43	197.77	17.82	0.00	0.00
May	31	1	1904.144719	167.9225877	172.9602653	80.11472	7472.26	-2668.22	781.45	128.11	47.99	4.32	0.00	0.00
May	31	2	1904.144719	167.9225877	172.9602653	72.15472	7336.05	-2591.93	759.11	124.44	52.29	4.71	0.00	0.00
May	31	2	1904.144719	167.9225877	172.9602653	73.68472	7258.86	-2559.60	749.64	122.89	49.21	0.00	3.80	0.00
May	31	2	1904.144719	167.9225877	172.9602653	74.26472	7218.89	-2540.25	743.97	121.96	47.70	0.00	3.68	0.00
May	31	2	1904.144719	167.9225877	172.9602653	74.48472	7206.19	-2533.34	741.95	121.63	47.15	0.00	3.64	0.00
May	31	2	1904.144719	167.9225877	172.9602653	73.86472	7220.60	-2549.02	746.54	122.38	48.52	0.00	0.00	3.03
Jun	1		1904.144719	167.9225877	172.9602653	72.98472	7320.78	-2627.82	769.62	126.17	53.18	0.00	0.00	4.69
Jun	1		1904.144719	167.9225877	172.9602653	73.20472	7336.22	-2647.33	775.34	127.10	53.90	0.00	0.00	4.76
Jun	1		1904.144719	167.9225877	172.9602653	73.24472	7356.64	-2670.88	782.23	128.23	54.99	0.00	0.00	4.85
Jun	1		1904.144719	167.9225877	172.9602653	73.21472	7402.10	-2715.98	795.44	130.40	57.19	0.00	0.00	5.05
Jun	1		1904.144719	167.9225877	172.9602653	73.14472	7443.44	-2755.75	807.09	132.31	59.17	0.00	0.00	5.22
Jun	1		1904.144719	167.9225877	172.9602653	72.15472	7505.02	-2808.63	822.58	134.85	62.69	0.00	0.00	5.53
Jun	1		1904.144719	167.9225877	172.9602653	57.39472	7675.36	-2951.85	864.52	141.73	84.33	0.00	7.81	0.00
Jun	1		1904.144719	167.9225877	172.9602653	0	8675.46	-4396.31	1287.57	211.08	254.88	0.00	23.61	0.00
Jun	1		1904.144719	167.9225877	172.9602653	0	9763.73	-4987.52	1460.72	239.46	465.73	0.00	43.15	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10281.79	-5493.47	1608.90	263.75	511.90	59.13	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10584.05	-5784.47	1694.13	277.73	512.53	59.20	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10587.31	-5787.73	1695.08	277.88	506.99	58.56	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10510.97	-5711.39	1672.72	274.22	498.66	57.60	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10510.97	-5711.39	1672.72	274.22	496.87	57.39	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10575.48	-5775.90	1691.62	277.31	499.42	57.69	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10459.00	-5659.42	1657.50	271.72	488.35	56.41	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	10253.15	-5453.57	1597.21	261.84	471.51	54.46	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	0	9277.58	-4492.02	1315.60	215.67	257.25	29.71	0.00	0.00
Jun	1	1	1904.144719	167.9225877	172.9602653	57.15472	7871.27	-3100.29	908.00	148.85	91.70	10.59	0.00	0.00
Jun	1	2	1904.144719	167.9225877	172.9602653	70.95472	7758.22	-3016.53	883.47	144.83	73.88	8.53	0.00	0.00
Jun	1	2	1904.144719	167.9225877	172.9602653	71.50472	7723.05	-2995.96	877.44	143.84	72.34	0.00	6.70	0.00
Jun	1	2	1904.144719	167.9225877	172.9602653	71.79472	7645.34	-2926.55	857.11	140.51	68.72	0.00	6.37	0.00
Jun	1	2	1904.144719	167.9225877	172.9602653	71.97472	7598.34	-2885.16	844.99	138.52	66.55	0.00	6.17	0.00
Jun	1	2	1904.144719	167.9225877	172.9602653	72.24472	7579.47	-2870.58	840.72	137.82	65.58	0.00	0.00	5.79
Jun	2		1904.144719	167.9225877	172.9602653	72.29472	7570.72	-2863.21	838.56	137.47	65.17	0.00	0.00	5.75
Jun	2		1904.144719	167.9225877	172.9602653	72.36472	7567.98	-2861.77	838.14	137.40	65.04	0.00	0.00	5.74
Jun	2		1904.144719	167.9225877	172.9602653	72.39472	7566.09	-2861.09	837.94	137.37	64.97	0.00	0.00	5.73

			f a steam turbine to make more electricity.						Using Electric Chiller for additional cooling					
			Total kW produced	Natural Gas to buy	Cost of Natural Gas, not adjusted	Electricity to sell	Needed for 0.7 COP Absorption Chiller	Additional supplement from boiler	Convert additional thermal to kW	Electricity Needed for 6.1 COP Chiller	Extra Electricity Needed	REAL Amount of Elect. To buy On peak	REAL Amount of Elect. To buy Mid peak	REAL Amount of Elect. To buy Off peak
Month	Day	Hour	kW	Therms	$	kW	MBH	MBH	kW	kW	kW	$	$	$
Dec	31	1[illegible]	1904.144719	167.9225877	172.9602653	86.93472	7199.67	-2455.05	719.02	117.87	30.94	2.79	0.00	0.00
Dec	31	1[illegible]	1904.144719	167.9225877	172.9602653	91.27472	7117.50	-2445.68	716.28	117.42	26.15	2.36	0.00	0.00
Dec	31	1[illegible]	1904.144719	167.9225877	172.9602653	93.95472	7056.95	-2446.71	716.58	117.47	23.52	2.12	0.00	0.00
Dec	31	1[illegible]	1904.144719	167.9225877	172.9602653	95.68472	6988.85	-2570.74	752.90	123.43	27.74	2.50	0.00	0.00
Dec	31	1[illegible]	1904.144719	167.9225877	172.9602653	96.13472	6963.12	-2630.29	770.34	126.29	30.15	2.72	0.00	0.00
Dec	31	2[illegible]	1904.144719	167.9225877	172.9602653	97.40472	6937.38	-2569.18	752.45	123.35	25.95	2.34	0.00	0.00
Dec	31	2	1904.144719	167.9225877	172.9602653	97.32472	6916.80	-2630.26	770.34	126.28	28.96	0.00	2.23	0.00
Dec	31	2[illegible]	1904.144719	167.9225877	172.9602653	97.40472	6911.14	-2600.07	761.49	124.84	27.43	0.00	2.12	0.00
Dec	31	2[illegible]	1904.144719	167.9225877	172.9602653	98.11472	6888.67	-2651.16	776.46	127.29	29.17	0.00	2.25	0.00
Dec	31	2[illegible]	1904.144719	167.9225877	172.9602653	98.96472	6878.37	-2677.43	784.15	128.55	29.58	0.00	0.00	1.85
			16,680,307.74	1,471,001.87	1,515,131.92	495,891.99		29,335,554.47				$105,370.36	$20,038.67	$9,295.84
				120000										
				1,351,001.87		elect to sell		$272,820.66						
			Adjusted Price		$1,380,031.74	$19,835.68								
							400.71							
										costs for steam driven chiller w/boiler for supple			$1,595,886.38	
										savings over original			$147,354.61	

	Max Monthly Demand	Cost of Demand
	kW	$
Month		
Jan	215.4152813	777.6491654
Feb	240.5052813	868.2240654
Mar	249.6552813	901.2555654
Apr	253.1652813	913.9266654
May	253.8652813	916.4536654
Jun	268.9852813	971.0368654
Jul	262.2852813	946.8498654
Aug	257.4252813	929.3052654
Sep	255.8552813	923.6375654
Oct	251.9952813	909.7029654
Nov	235.3752813	849.7047654
Dec	225.4052813	813.7130654
total		$10,721.46

Max Monthly Demand
kW
623.82
696.79
733.81
767.19
705.48
878.66
904.47
883.05
847.77
775.57
795.48
650.92

Assumptions

1801 kW Jenbacher IC Engine Elec Efficiency	1801 kW Jenbacher IC Engine Thermal Efficiency	2390 kW Jenbacher IC Engine Elec Efficiency	2390 kW Jenbacher IC Engine Thermal Efficiency	2390 kW Jenbacher IC Engine Elec Efficiency When Load following	2390 kW Jenbacher IC Engine Thermal Efficiency when Load following	Selling back elect $/kW	Cost per Therm up to 10,000 therms($)	Cost per Therm up to 10,000 therms($)
0.429	0.432	0.426	0.434	0.415	0.425	0.03	1.03	0.93

	Original Nat Gas Cost	
	Cost per Therm	Cost per Therm
1	1.03	0.93
1.04	1.0712	0.996216
1.08	1.1124	1.034532
1.12	1.1536	1.072848
1.16	1.1948	1.111164
1.2	1.236	1.14948
1.24	1.2772	1.187796
1.28	1.3184	1.226112

	Original Nat Gas Cost	
	Cost per	Cost per
1	1.03	0.93
1.1	1.133	1.05369
1.2	1.236	1.14948
1.3	1.339	1.24527
1.4	1.442	1.34106
1.5	1.545	1.43685
1.6	1.648	1.53264
1.7	1.751	1.62843

Original Energy Charge							
	Summer June 1-Sept 30			Non-Summer (Oct 1- May 31)			
	On-Peak	Mid-Peak	Off-Peak	On-Peak	Mid-Peak	Off-Peak	
C/kWh	11.551	9.265	$8.82	9.01	7.717	6.253	Demand
$/kWh	0.11551	0.09265	$0.09	0.0901	0.07717	0.06253	3.61
1.1	0.127061	0.101915	0.097064	0.09911	0.084887	0.068783	3.971
1.2	0.138612	0.11118	0.105888	0.10812	0.092604	0.075036	4.332
1.3	0.150163	0.120445	0.114712	0.11713	0.100321	0.081289	4.693
1.4	0.161714	0.12971	0.123536	0.12614	0.108038	0.087542	5.054
1.5	0.173265	0.138975	0.13236	0.13515	0.115755	0.093795	5.415
1.6	0.184816	0.14824	0.141184	0.14416	0.123472	0.100048	5.776
1.7	0.196367	0.157505	0.150008	0.15317	0.131189	0.106301	6.137
1.8	0.207918	0.16677	0.158832	0.16218	0.138906	0.112554	6.498
1.9	0.219469	0.176035	0.167656	0.17119	0.146623	0.118807	6.859
2	0.23102	0.1853	0.17648	0.1802	0.15434	0.12506	7.22

Selling back elect $/kW	Cost per Therm below 10,000 therms ($)	cost per therm above 10,000 therms	Electrical Efficiency for Saturn 20	**Steam Turbine Electrical Efficiency**	**Steam Turbine Thermal Efficiency**
0.03	1.03	0.93	0.244	**0.25**	**0.5**

Energy Charge							
	Summer June 1-Sept 30			Non-Summer (Oct 1- May 31)			Demand Charge
	On-Peak	Mid-Peak	Off-Peak	On-Peak	Mid-Peak	Off-Peak	3.61
C/kWh	11.551	9.265	$8.82	9.01	7.717	6.253	
$/kWh	0.11551	0.09265	$0.09	0.0901	0.07717	0.06253	

“The greater danger for most of us lies not in setting our aim too high and falling short; but in setting our aim too low, and achieving our mark.”

Michelangelo