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Division of Capital Asset Management (DCAM)

Energy Upgrades – McCormack, Hurley, Lindemann and State House Buildings

Existing Conditions Assessment Final Submittal

Revised May 10, 2012

DCAM Project # DPC1021 ES1

KS Project # 36.7407.00

One Broadway
Cambridge, Massachusetts
02142

P 617.491.6450
F 617.491.7104

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Existing Conditions Assessment - Final Submittal

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Charles F. Hurley Building
Existing Conditions Assessment

1 Executive Summary

1.1 Study Objectives

The Division of Capital Asset Management (DCAM) retained KlingStubbins to recommend energy-conserving measures (ECM's) as a multi-task project. This report relates to Task 1, which is to assess existing conditions in order to understand the operations and provide a platform for future ECM's.

2 Building Overview

The seven-story Charles F. Hurley Building houses state offices and support spaces. Construction was completed in 1971. The gross area is 347,000 ft^2; the facility also includes a two-level below-grade parking garage. The building has a population of 975 people.

3 HVAC System Overview

A combination of induction units (perimeter zones) and air handling units (interior zones) maintain room environmental conditions and provide outside air. The Hurley Building generates chilled water and heating hot water used by the perimeter-zone induction units and interior-zone air handling units.

3.1 Supply Air Systems

Most perimeter zones use four-pipe induction units located under windows. The

induction units are supplied with 55°F high pressure air from air handling units. Nozzles inside the induction unit use the high pressure supply (primary) air to create a low pressure zone, which induces room air into the unit. This room (secondary) air passes over a coil, which heats or cools room air to maintain room temperature.

The induction unit coils are supplied with either chilled water or heating hot water.

Primary air is also the source for ventilation air for perimeter zones. Air distribution to the induction units is constant-volume, manually-balanced.

3.1.1 Mode of Operation – Perimeter Induction Units

Integral thermostats within the induction units modulate the coil control valve to maintain room temperature.

The perimeter induction units operate continuously.

3.1.2 Description – Air Handling Units

Air handling units supply air to induction units and interior zones of the Hurley Building: the units mix outside air and return air, then filter, heat and cool the air before it is supplied to the interior zones. Chilled water generated in the Hurley Building is the thermal medium for the cooling coils. Heating hot water generated in the Hurley Building is the thermal medium for the preheat coils.

The air handling units S-1 through 9 were field-assembled and installed in 1971. The equipment is located in Basement Mechanical Rooms MER-1, 2 and 3. The supply and return fans use standard-efficiency motors and are belt-driven with trapezoidal-cross section belts.

Return fan R-6 and supply fans S-7 and 8 are controlled through variable-frequency drives; other supply and return fans are constant-speed.

Air handling units originally had spray humidifiers; when these humidifiers were abandoned and the cooling/heating coils replaced, a path was provided for air to bypass the coil.

Supply air is distributed to interior zones through constant volume boxes.

The air handling units have airside economizer capability, in which outside air is uses outside air to produce 55°F supply air directly (i.e., without mechanical refrigeration) during shoulder seasons. However, some air handling units do not have operational economizer cycles because the dampers are frozen in place, or because of control system deficiencies.

3.1.3 Mode of Operation –Air Handling Units

Coil control valves are the 3-way type: chilled water or heating hot water either runs through the coil or bypasses the coil.

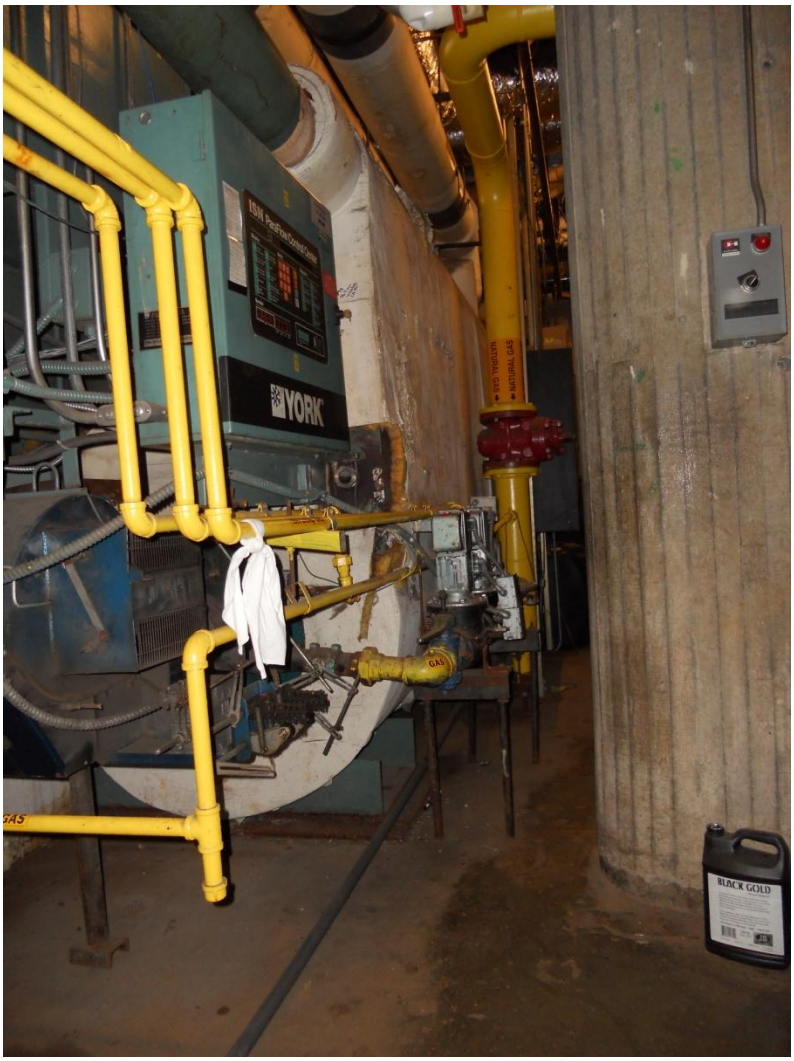
Supply air temperatures are reset as a function of outside air temperature and solar heat gain.

Air handling units S-3, 4 and 8 (supplying perimeter zones) operate continuously. The remaining air handling units generally operate from 6am to 6pm.

No demand-controlled ventilation is used to reduce airflow during unoccupied modes.

3.2 Heating Hot Water System Description

Chilled and hot water are centrally produced by two York, direct fired absorption, 600-ton chiller/heaters that burn natural gas to produce hot water when needed in the winter and produce chilled water (through the absorption refrigeration cycle) in the summer. The chiller/heaters are located in Basement Mechanical Room MER-1.



A 75 hp dual-temperature water pump circulates water (chilled water in the summer and heating hot water in the winter) to coils. Smaller zone pumps circulate heating hot water to finned tube radiation and cabinet unit heaters.

3.2.1 Heating Hot Water Mode of Operation

Heating hot water supply temperature is maintained in the range of 100°F to 130°F, based on a reset schedule with outside air temperature: as outside air temperature increases, the heating hot water supply temperature is reduced. Heating hot water pumps are deenergized when outside air temperature increases above 55°F.

3.3 Chilled Water System Description

Two natural gas-fired 600-ton absorption chiller/heaters in Basement Mechanical Room MER-1 provide chilled water to induction units and air handling units. The machines were manufactured by York and installed in 1992. The chillers are located in Basement Mechanical Room MER-1.

Chilled water can be exported to the Lindemann Building by changing position of manual isolation valves. However, chilled water cannot be imported from the Lindemann Building.

A 75 hp dual-temperature water pump circulates water (chilled water in the summer and heating hot water in the winter) to air handling unit coils

Condenser water is generated by (2) four-cell induced-draft cooling towers mounted on the roof. The cooling towers were manufactured by Baltimore Aircoil (BAC) and installed in 1994. Cooling tower fans are controlled by variable frequency drives to maintain the 85°F condenser water supply temperature setpoint.

Three 125 hp constant-speed pumps (P-15, 16 and 17) in Basement Mechanical Room MER-1 circulate condenser water between the condensers and the cooling towers. The pumps were manufactured by Paco and installed in 1971.

3.3.1 Chilled Water System Mode

When the outside air temperature is above 55°F, absorption chillers are staged on to

of Operation — meet the cooling load.

3.4 Special Areas

3.4.1 Kitchen — The kitchen is exhausted by two fans (7.5 and 5 hp); the fans are constant-speed with standard-efficiency motors, installed in 1971.

3.4.2 Data Center — Two 60-ton air-cooled roof-mounted chillers (CH-3 and4) supply chilled water to several room Liebert units. This separate chilled water loop can be interconnected with the absorption chillers as a backup source of cooling. Two 7-1/2 hp pumps circulate chilled water from the chillers to cooling coils.

4 Domestic Cold and Hot Water

4.1.1 Plumbing Fixtures — Most toilets were rated at 1.6 gallons per flush (gpf), urinals were rated to 1.0 gpf and lavatory faucets were rated at 0.5 gallons per minute (gpm). Low-flow fixtures are installed as fixtures are replaced.

4.1.2 Domestic Hot Water Generation — A centralized natural gas-fired domestic hot water (1,100,000 Btu/hr) serves part of the domestic hot water requirements for the building.

5 Building Automation System (BAS) Description

Johnson Controls Inc. (JCI) is the BAS supplier for this building; the building has multiple hardware and software platforms that have been implemented over the years.

The building originally used pneumatic controllers. Over the years, various parts of the building were upgraded to newer JCI controllers and devices. Electric-to-pneumatic (E-P) transducers have been used to provide direct digital control (DDC) of pneumatic actuators. Not every HVAC unit is under DDC control.

The Master Operator Workstation (OWS) head end personal computer (PC) is located in the Command Center of the McCormack Building. Other OWS are located in the Hurley and State House buildings. The master OWS, however, contains the primary programming database and corresponding backup and system restore functions.

6 Utility Consumption Analysis

6.1 Energy Use Intensity and Benchmarking

The energy use intensity (EUI) is defined as the energy consumption (in units of million Btu) divided by the gross building area (ft^2). This provides a metric to compare one building versus peer facilities, since databases sorted geographically and by building type exist.

The EUI for the Hurley Building is 176,467 Btu/ft^2-year. The US Energy Information Agency has developed a database (the Commercial Building Energy Consumption Survey) of EUI's for thousands of office buildings. Although the database was last updated in 2003, the database is still a good resource because it is so largely populated. As a comparison to other CBECS data points:

- The mean EUI for commercial buildings in the New England census region was 127,600 Btu/ft^2-year.
- The mean EUI for commercial buildings between 200,000 and 500,000 gross square feet (gsf) was 129,000 Btu/ft^2-year.
- The mean EUI for office buildings in the New England census region was 94,000 Btu/ft^2-year.

6.2 Electricity Consumption Analysis

Thirty months (July 2008 through December 2010) of electricity demand and consumption billing information was analyzed.

The facility purchases electricity from Direct Energy with NStar serving as the power delivery service. The tariff is Rate B7-NEMA LG, General Time of Use (TOU).

Electricity consumption information was provided from billing information. The billing-cycle consumption (kWh/billing cycle) was divided by the number of days in the billing cycle to create an average daily electricity consumption (kWh/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 1. This average daily electricity consumption was plotted against month on a radar-type chart (Appendix 2). The radar plot showed consumption peaks in the summer months (July 2008, August 2009 and July 2010), suggesting that loads related to air-conditioning drive electricity consumption.

This hypothesis was tested by correlating cooling degree days against electricity consumption. Cooling degree days are a single-measure, simplified means of characterizing outside air temperature data. Cooling degree days are a measure of how much (in degrees F) and for how long (in days), outside air temperature was higher

than a base temperature (65°F).

Actual cooling degree day information was obtained for the same timeframe as the electricity consumption data. The cooling degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Electricity consumption data was plotted against the cooling degree day data (Appendix 3). The electricity consumption and cooling degree day values peak in the same summer months.

The correlation coefficient, which measures the linear relationship between two variables: the correlation coefficient ranges between 1 and -1. A value of 1 means that if one variable increases, the other variable increases linearly. A value of -1 means that if one variable increases, the other variable decreases linearly. A value of 0 means there is no linear correlation between the two variables.

Electricity consumption and cooling degree days have a correlation coefficient of 0.76, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 4) confirms the strong relationship.

Power demand (kW) for each month was plotted against time (Appendix 5): this confirms that electricity demand is driven by air-conditioning equipment.

This relationship is anomalous, because chilled water is generated by natural gas-fired absorption chillers. Auxiliary chilled water equipment (cooling towers and pumps) use electricity, which may be enough to cause this positive correlation.

The electricity load factor (ELF) is defined as the ratio between the average daily use and the maximum possible use if the peak demand operated for a 24 hour period. This factor was calculated as 0.69.

The seasonally-adjusted electricity load factor (SELF) is the electricity load factor calculated over the cooling season.

This factor was calculated as 1.14 (2009) and 0.77 (2010).

The occupancy factor is defined as the percentage of time that the building is occupied. This building is occupied 6am to 6pm for five days per week, the occupancy factor is 0.36.

If the ELF is much greater than the OF, that implies that equipment or lighting operates when the building is unoccupied.

The conclusions of this billing-information analysis are:

- Although air-conditioning drives electricity consumption, baseload consumption (receptacles and lighting) still represent a target for energy-conservation measures.
- Operation of HVAC equipment, lights and receptacles during unoccupied hours represents an energy-reduction target.

6.3 Natural Gas Consumption Analysis

Thirty-three months (February 2008 through October 2010) of natural gas consumption billing information was analyzed.

The facility purchases natural gas from Hess Energy with National Grid serving as the natural gas delivery service. The tariff is Rate G-53T, Commercial Non-Heating.

Natural gas consumption information was provided from billing information. The billing-cycle consumption (10^6 Btu/billing cycle) was divided by the number of days in the billing cycle to create an average daily natural gas consumption (10^6 Btu/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 6. This average daily consumption was plotted against month on a radar-type chart (Appendix 7). The radar plot showed consumption peaks in both the winter and summer months, which is consistent with peak heating use and peak cooling use being satisfied by natural gas-fired absorption chiller-heaters.

This hypothesis was tested by correlating heating degree days against natural gas consumption. Heating degree days are a single-measure, simplified means of characterizing outside air temperature data. Heating degree days are defined as the difference between a base temperature (65°F) and the average temperature (maximum

temperature – minimum temperature) for each day; degree days are accumulated over a heating season.

Actual heating degree day information was obtained for the same timeframe as the natural gas consumption data. The heating degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Natural gas consumption data was plotted against the heating degree day data (Appendix 8). The natural gas consumption and heating degree day values peak in the same winter months, although natural gas consumption also spikes in summer months.

Natural gas consumption and heating degree days have a correlation coefficient of 0.04, which means that the two variables are unrelated. A scatter diagram of the two variables (Appendix 9) confirms the relationship.

The conclusion of this billing-information analysis is that, although natural gas consumption does not correlate to heating use, heating system reductions are critical to reducing natural gas consumption.

6.4 Water Consumption Analysis

Twenty-eight months (July 2008 through October 2010) of water consumption billing information was analyzed.

The facility purchases water from the Boston Water and Sewer Commission.

Water consumption information was provided from billing information. The billing-cycle consumption (thousand gallons/billing cycle) was divided by the number of days in the billing cycle to create an average daily water consumption (1000 gallons/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 10. This average daily water consumption was plotted against month on a radar-type chart (Appendix 11). The radar plot showed consumption peaks in the summer months, suggesting that cooling tower-related loads drive water consumption.

This hypothesis was tested by correlating cooling degree days against water consumption.

Water consumption data was plotted against the cooling degree day data (Appendix 12). The water consumption and cooling degree day values peak in the same summer months.

Water consumption and cooling degree days have a correlation coefficient of 0.92, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 13) confirms the strong relationship.

Absorption chillers use more cooling tower water than conventional (vapor-compression cycle) chillers; perhaps this causes the higher correlation coefficient relative to other buildings.

The conclusion of this billing-information analysis is:

- Although cooling tower use drives water consumption, baseload consumption (toilets and lavatories) still represent a target for reduction measures.

7 Existing Equipment Matrix

An Existing Equipment Matrix is included as Appendix 14. Central plant equipment (chillers, cooling towers and boilers) have been recently replaced, but areas of concern are support equipment (pumps) and air handling units.

For each piece of equipment, the matrix identifies the year of installation and the median life. Median life data was taken from two sources:

- Chapter 37 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) "HVAC Applications" Handbook, 2011 edition, lists median service lives for mechanical equipment.
- ASHRAE "Owning and Operating Cost Database" (available at ashrae.org) has compiled a database of 345 buildings, including life of mechanical equipment at the time of replacement.

The cost of maintenance of HVAC equipment is reported as part of the ASHRAE "Owning and Operating Cost Database". This information is reported by building type and geographic location, but not for specific pieces of equipment. The database reports a mean HVAC equipment maintenance cost of $0.494/ft^2, or $171,500 for this type of facility. However, this information has a standard deviation of $0.217/ft^2 ($75,300), which implies there is a large variation in these values.

Charles F. Hurley Building

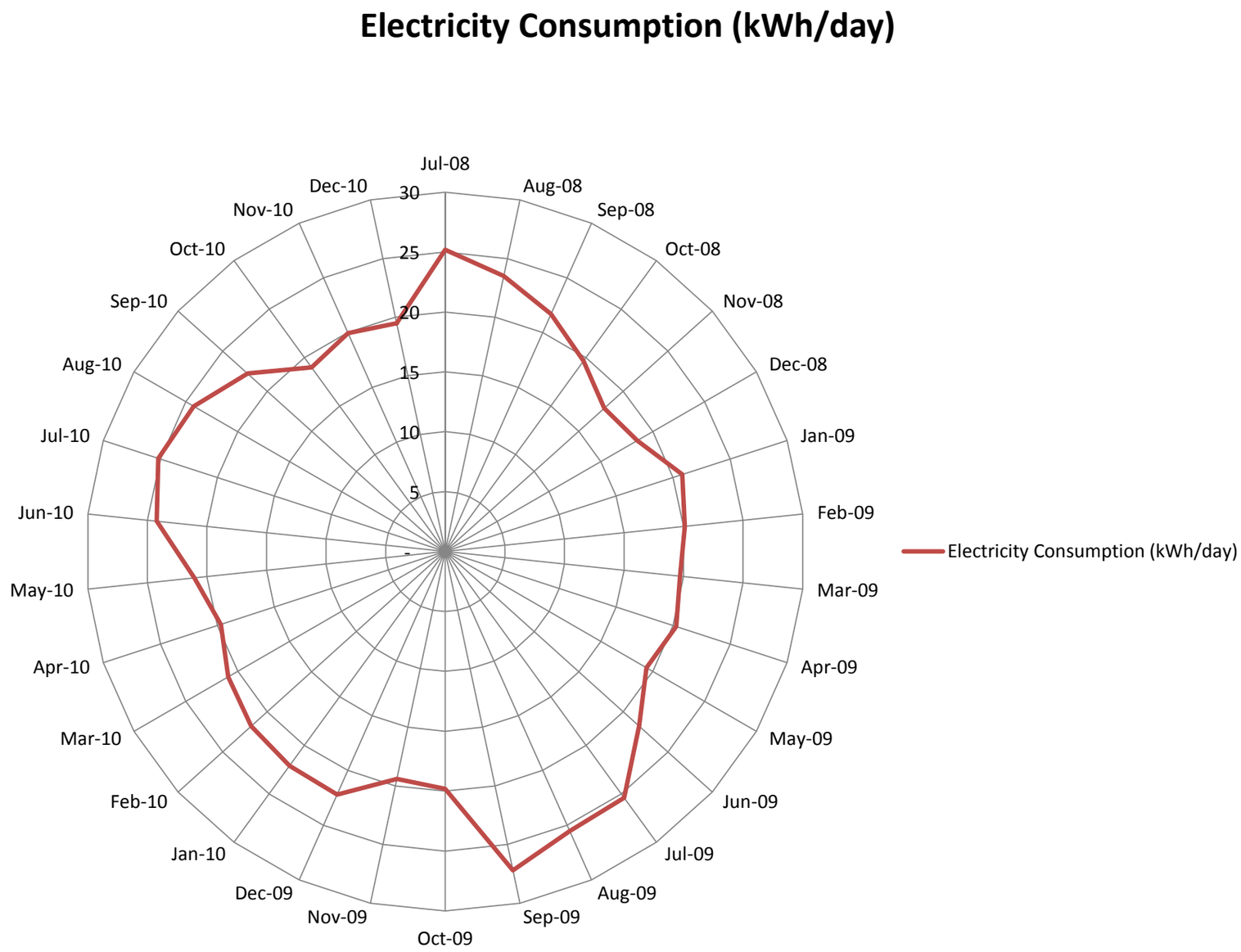
Appendix 1 - Electricity Consumption Data

	Consumption (kWh) - Offpeak	Consumption (kWh) - Onpeak	Consumption (kWh) - Total	Cooling Degree Days	Days/Month	Average elec Consumption per day (kWh/day)	Demand (kW)
Jul-08	505,217	250,683	755,900	320	30	25,197	1,433
Aug-08	445,770	235,930	681,700	179	29	23,507	1,317
Sep-08	455,690	238,910	694,600	105	32	21,706	1,332
Oct-08	304,494	285,306	589,800	10	30	19,660	1,288
Nov-08	306,277	265,623	571,900	2	32	17,872	1,139
Dec-08	279,742	275,758	555,500	-	30	18,517	1,153
Jan-09	335,574	288,426	624,000	-	30	20,800	1,121
Feb-09	352,535	290,565	643,100	-	32	20,097	1,138
Mar-09	293,007	278,393	571,400	-	29	19,703	1,141
Apr-09	311,363	297,037	608,400	30	30	20,280	1,242
May-09	337,970	282,330	620,300	57	32	19,384	1,307
Jun-09	408,268	222,832	631,100	55	29	21,762	1,369
Jul-09	506,708	255,592	762,300	204	30	25,410	1,406
Aug-09	538,577	253,123	791,700	289	31	25,539	1,403
Sep-09	562,419	253,781	816,200	64	30	27,207	1,369
Oct-09	311,711	282,489	594,200	7	30	19,807	1,251
Nov-09	336,108	284,592	620,700	2	32	19,397	1,147
Dec-09	363,370	302,530	665,900	1	30	22,197	1,166
Jan-10	403,482	303,818	707,300	-	32	22,103	1,179
Feb-10	354,646	298,954	653,600	-	30	21,787	1,166
Mar-10	328,094	278,506	606,600	2	29	20,917	1,135
Apr-10	353,206	296,594	649,800	23	33	19,691	1,275
May-10	315,912	295,088	611,000	104	29	21,069	1,400
Jun-10	460,878	241,422	702,300	205	29	24,217	1,401
Jul-10	550,389	255,411	805,800	389	32	25,181	1,420
Aug-10	470,514	232,786	703,300	285	29	24,252	1,413
Sep-10	429,535	236,465	666,000	170	30	22,200	1,379
Oct-10	330,913	276,787	607,700	22	32	18,991	1,332
Nov-10	325,318	293,582	618,900	-	31	19,965	1,103
Dec-10	315,263	269,037	584,300	-	30	19,477	1,087

Charles F. Hurley Building

Appendix 2 - Radar Plot of Electricity Consumption by Month

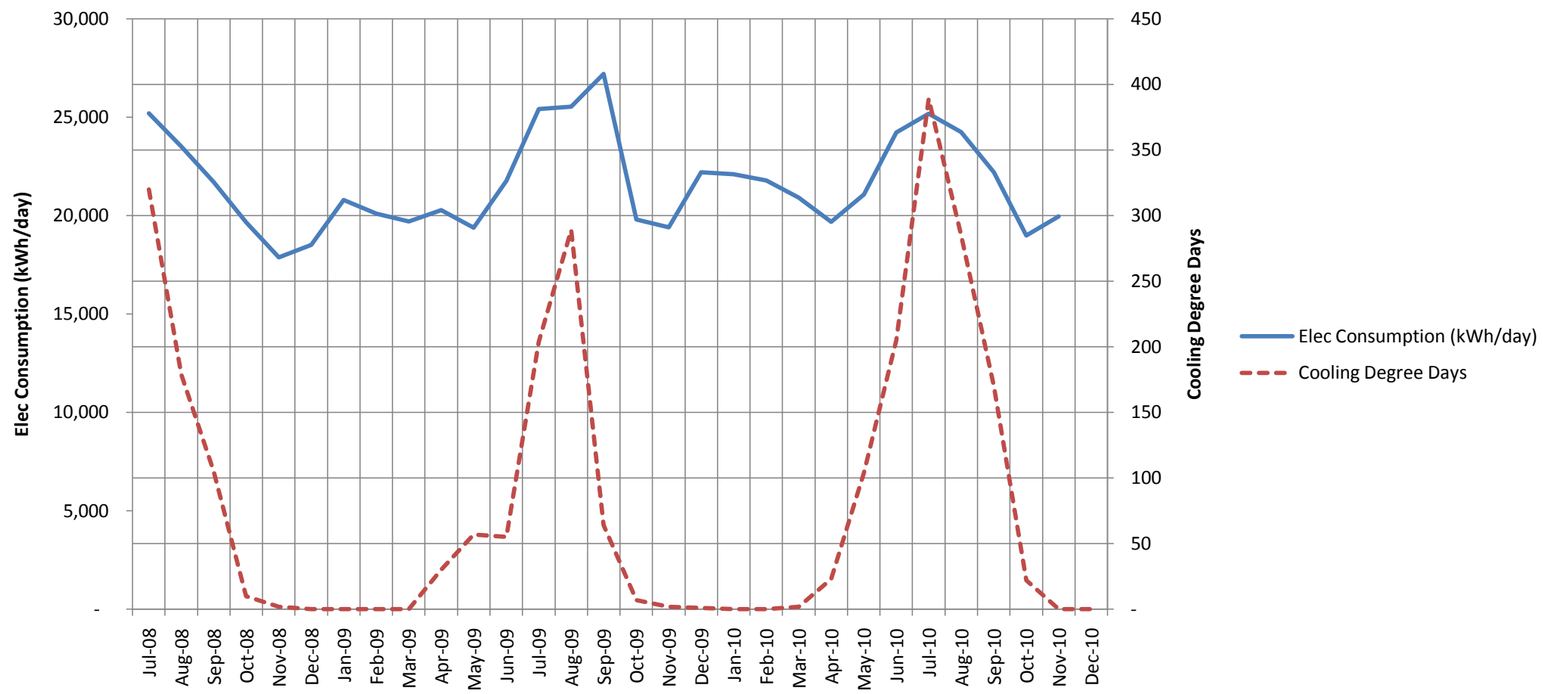
	Average elec Consumption per day (kWh/day)
Jul-08	25,197
Aug-08	23,507
Sep-08	21,706
Oct-08	19,660
Nov-08	17,872
Dec-08	18,517
Jan-09	20,800
Feb-09	20,097
Mar-09	19,703
Apr-09	20,280
May-09	19,384
Jun-09	21,762
Jul-09	25,410
Aug-09	25,539
Sep-09	27,207
Oct-09	19,807
Nov-09	19,397
Dec-09	22,197
Jan-10	22,103
Feb-10	21,787
Mar-10	20,917
Apr-10	19,691
May-10	21,069
Jun-10	24,217
Jul-10	25,181
Aug-10	24,252
Sep-10	22,200
Oct-10	18,991
Nov-10	19,965
Dec-10	19,477



Charles F. Hurley Building

Appendix 3 - Electricity v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	25,197
Aug-08	179	23,507
Sep-08	105	21,706
Oct-08	10	19,660
Nov-08	2	17,872
Dec-08	-	18,517
Jan-09	-	20,800
Feb-09	-	20,097
Mar-09	-	19,703
Apr-09	30	20,280
May-09	57	19,384
Jun-09	55	21,762
Jul-09	204	25,410
Aug-09	289	25,539
Sep-09	64	27,207
Oct-09	7	19,807
Nov-09	2	19,397
Dec-09	1	22,197
Jan-10	-	22,103
Feb-10	-	21,787
Mar-10	2	20,917
Apr-10	23	19,691
May-10	104	21,069
Jun-10	205	24,217
Jul-10	389	25,181
Aug-10	285	24,252
Sep-10	170	22,200
Oct-10	22	18,991
Nov-10	-	19,965
Dec-10	-	19,477



Charles F. Hurley Building

Appendix 4 Scatter Diagram: Electric Consumption v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	25,197
Aug-08	179	23,507
Sep-08	105	21,706
Oct-08	10	19,660
Nov-08	2	17,872
Dec-08	-	18,517
Jan-09	-	20,800
Feb-09	-	20,097
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Jan-10	-	22,103
Feb-10	-	21,787
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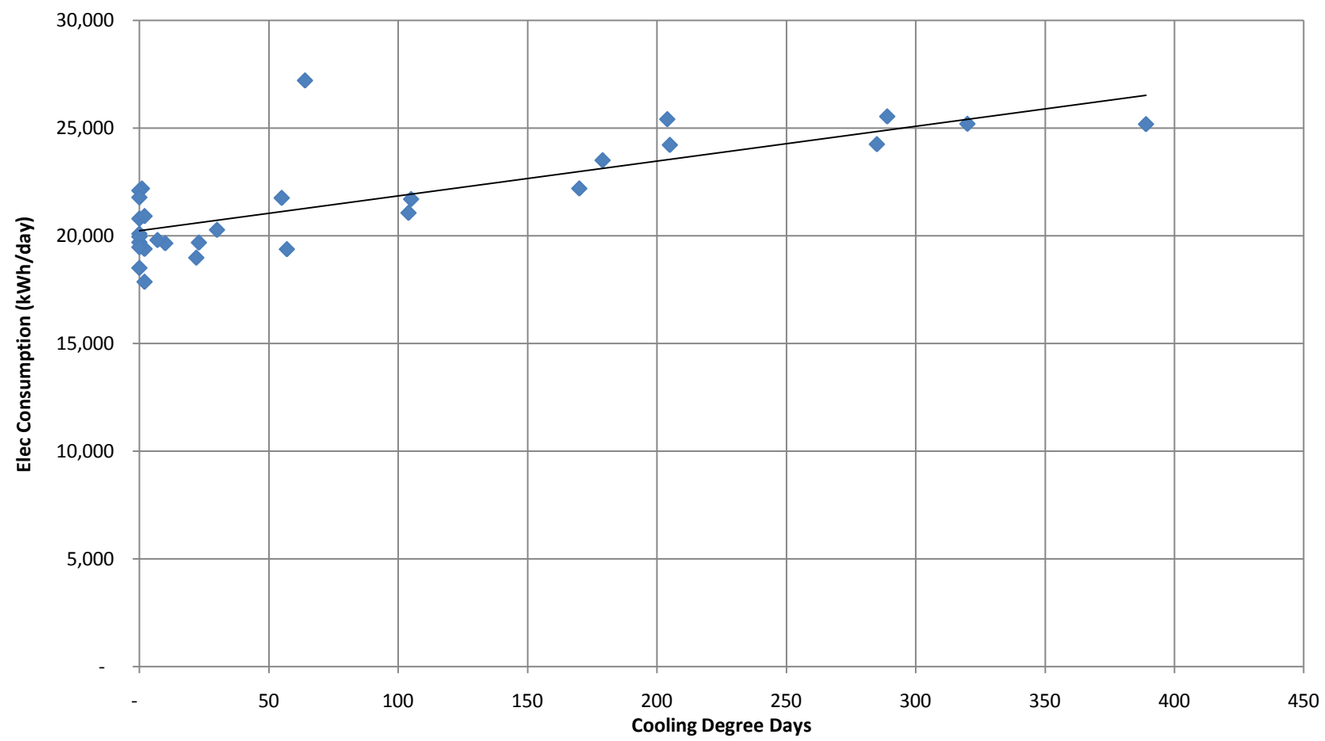
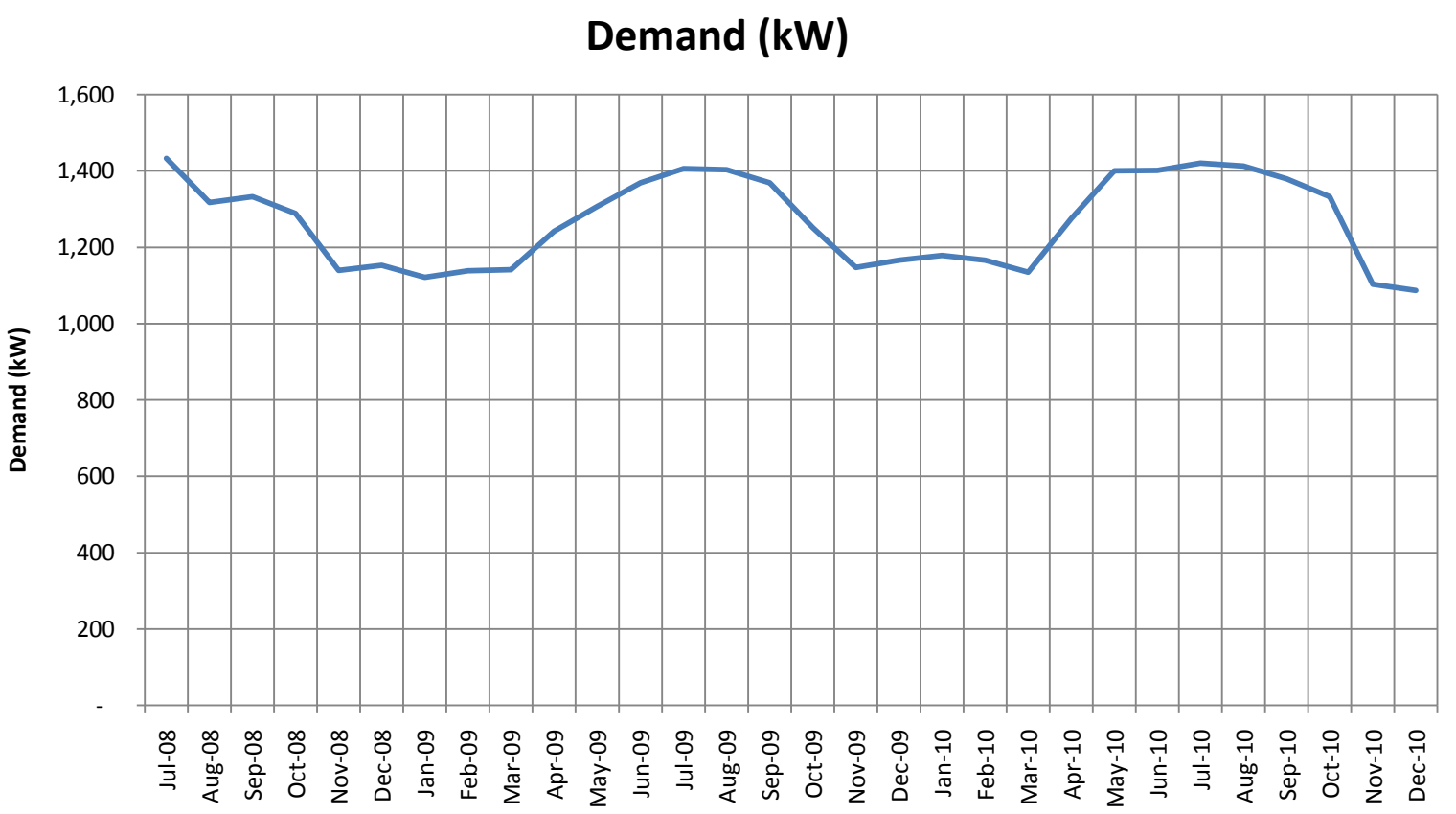


Charles F. Hurley Building

Appendix 5 - Power Demand

	Demand (kW)
Jul-08	1,433
Aug-08	1,317
Sep-08	1,332
Oct-08	1,288
Nov-08	1,139
Dec-08	1,153
Jan-09	1,121
Feb-09	1,138
Mar-09	1,141
Apr-09	1,242
May-09	1,307
Jun-09	1,369
Jul-09	1,406
Aug-09	1,403
Sep-09	1,369
Oct-09	1,251
Nov-09	1,147
Dec-09	1,166
Jan-10	1,179
Feb-10	1,166
Mar-10	1,135
Apr-10	1,275
May-10	1,400
Jun-10	1,401
Jul-10	1,420
Aug-10	1,413
Sep-10	1,379
Oct-10	1,332
Nov-10	1,103
Dec-10	1,087



Charles F. Hurley Building

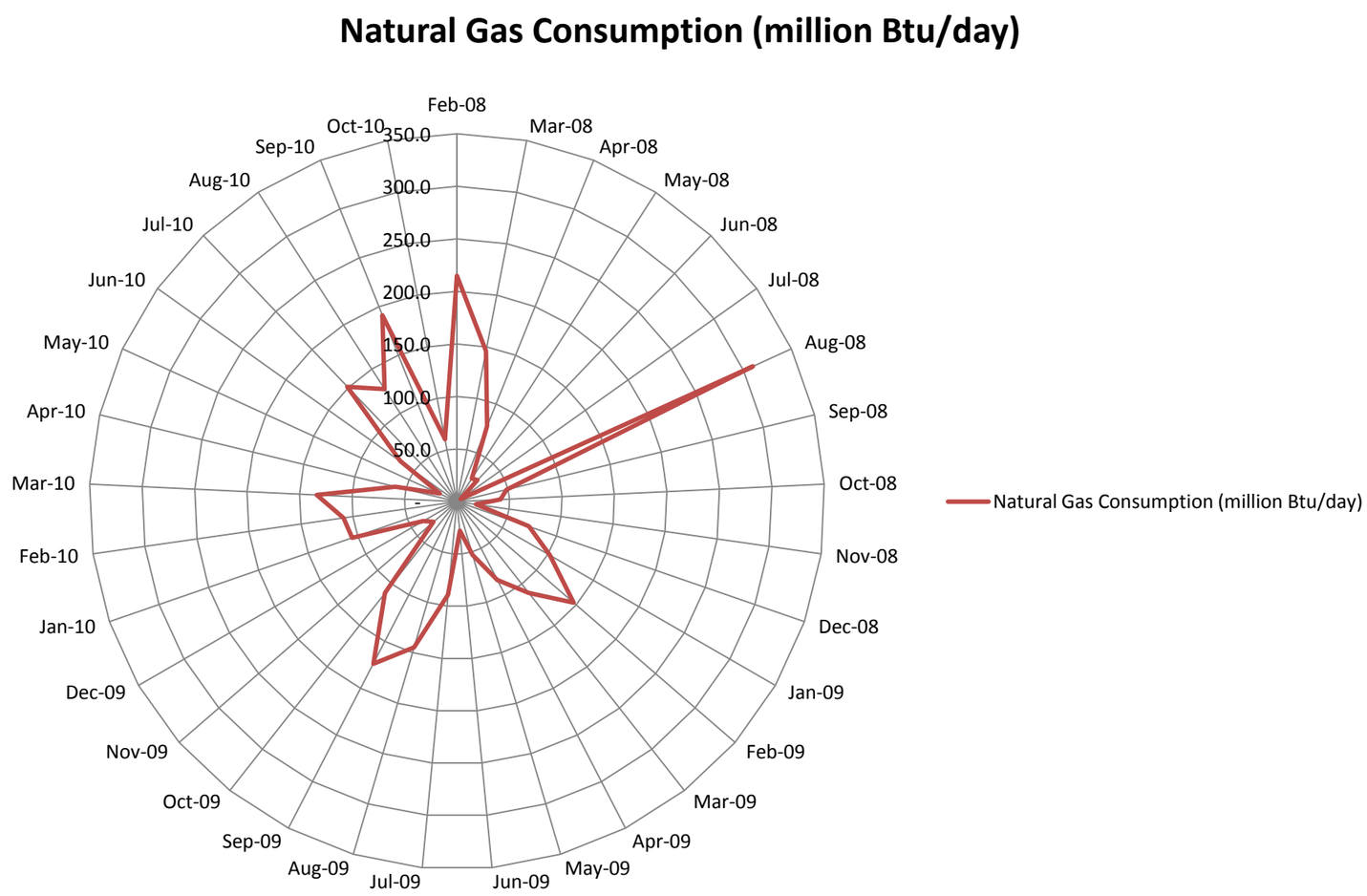
Appendix 6 - Natural Gas Consumption

	Usage Begin Date	Consumption (therms)	Consumption (10^6 Btu)	Heating Degree Days	Days/Month	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	2/8/2008	68,761	6,876	934	32	214.9
Mar-08	3/11/2008	39,392	3,939	822	27	145.9
Apr-08	4/7/2008	24,035	2,404	462	31	77.5
May-08	5/8/2008	7,604	760	232	29	26.2
Jun-08	6/6/2008	6,785	679	27	24	28.3
Jul-08	6/30/2008	2,076	208	-	50	4.2
Aug-08	8/19/2008	61,969	6,197	-	20	309.8
Sep-08	9/8/2008	14,018	1,402	78	29	48.3
Oct-08	10/7/2008	11,625	1,163	356	28	41.5
Nov-08	11/4/2008	6,208	621	641	34	18.3
Dec-08	12/8/2008	21,715	2,172	902	30	72.4
Jan-09	1/7/2009	30,587	3,059	1,238	30	102.0
Feb-09	2/6/2009	41,145	4,115	894	28	146.9
Mar-09	3/6/2009	34,385	3,439	844	31	110.9
Apr-09	4/6/2009	25,143	2,514	447	30	83.8
May-09	5/6/2009	15,923	1,592	191	30	53.1
Jun-09	6/5/2009	9,503	950	78	34	28.0
Jul-09	7/9/2009	25,823	2,582	13	29	89.0
Aug-09	8/7/2009	47,721	4,772	5	33	144.6
Sep-09	9/9/2009	50,387	5,039	87	29	173.7
Oct-09	10/8/2009	30,991	3,099	398	28	110.7
Nov-09	11/5/2009	9,484	948	479	32	29.6
Dec-09	12/7/2009	11,479	1,148	961	31	37.0
Jan-10	1/7/2010	35,863	3,586	1,091	34	105.5
Feb-10	2/10/2010	29,466	2,947	864	27	109.1
Mar-10	3/9/2010	37,416	3,742	649	28	133.6
Apr-10	4/6/2010	18,655	1,866	355	31	60.2
May-10	5/7/2010	5,638	564	130	31	18.2
Jun-10	6/7/2010	20,581	2,058	18	31	66.4
Jul-10	7/8/2010	40,811	4,081	-	27	151.2
Aug-10	8/4/2010	44,625	4,463	6	35	127.5
Sep-10	9/8/2010	43,976	4,398	28	23	191.2
Oct-10	10/1/2010	18,740	1,874	298	31	60.5

Charles F. Hurley Building

Appendix 7 - Natural Gas Radar Plot

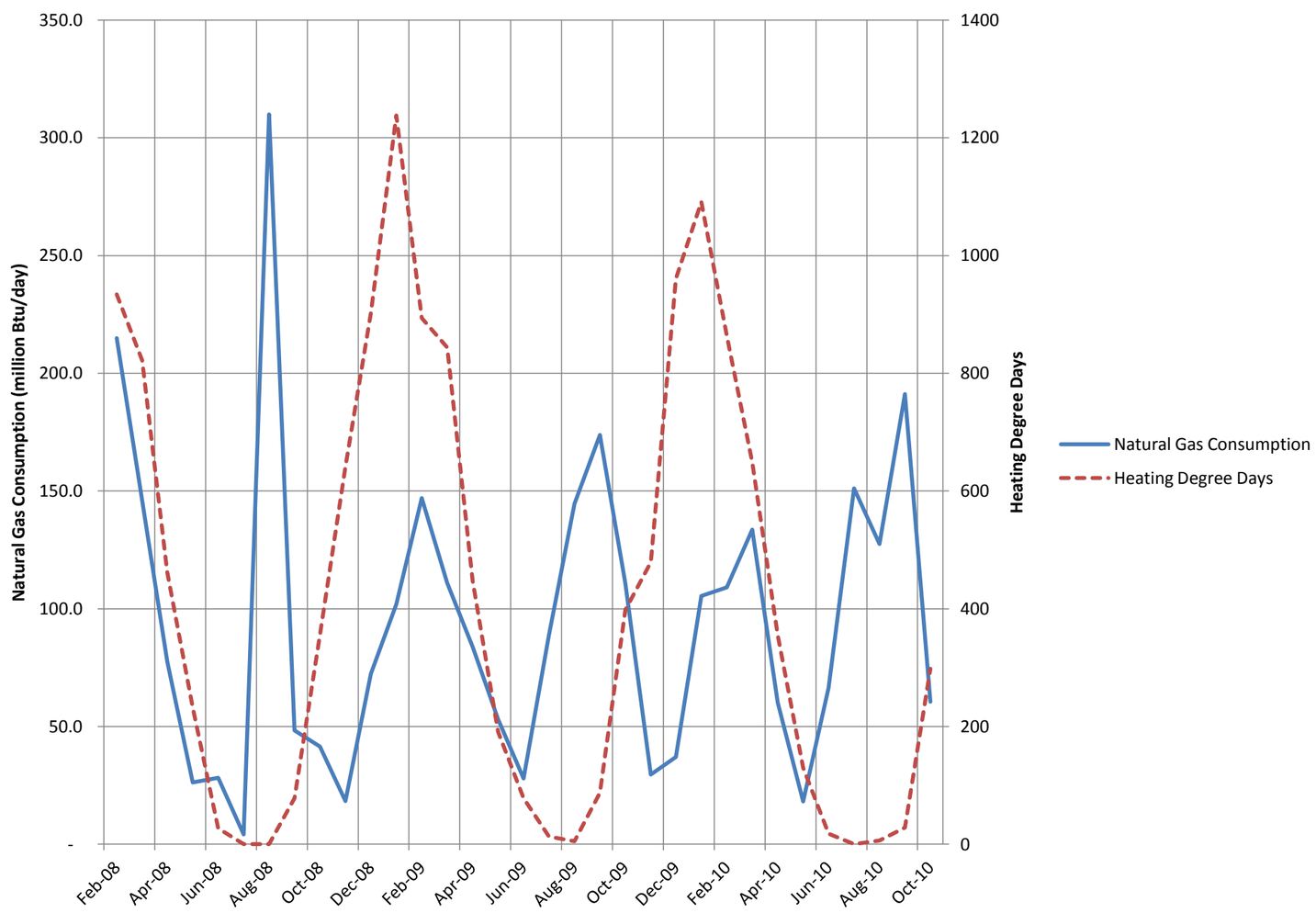
	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	214.9
Mar-08	145.9
Apr-08	77.5
May-08	26.2
Jun-08	28.3
Jul-08	4.2
Aug-08	309.8
Sep-08	48.3
Oct-08	41.5
Nov-08	18.3
Dec-08	72.4
Jan-09	102.0
Feb-09	146.9
Mar-09	110.9
Apr-09	83.8
May-09	53.1
Jun-09	28.0
Jul-09	89.0
Aug-09	144.6
Sep-09	173.7
Oct-09	110.7
Nov-09	29.6
Dec-09	37.0
Jan-10	105.5
Feb-10	109.1
Mar-10	133.6
Apr-10	60.2
May-10	18.2
Jun-10	66.4
Jul-10	151.2
Aug-10	127.5
Sep-10	191.2
Oct-10	60.5



Charles F. Hurley Building

Appendix 8 - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	214.9
Mar-08	822	145.9
Apr-08	462	77.5
May-08	232	26.2
Jun-08	27	28.3
Jul-08	-	4.2
Aug-08	-	309.8
Sep-08	78	48.3
Oct-08	356	41.5
Nov-08	641	18.3
Dec-08	902	72.4
Jan-09	1,238	102.0
Feb-09	894	146.9
Mar-09	844	110.9
Apr-09	447	83.8
May-09	191	53.1
Jun-09	78	28.0
Jul-09	13	89.0
Aug-09	5	144.6
Sep-09	87	173.7
Oct-09	398	110.7
Nov-09	479	29.6
Dec-09	961	37.0
Jan-10	1,091	105.5
Feb-10	864	109.1
Mar-10	649	133.6
Apr-10	355	60.2
May-10	130	18.2
Jun-10	18	66.4
Jul-10	-	151.2
Aug-10	6	127.5
Sep-10	28	191.2
Oct-10	298	60.5



Charles F. Hurley Building

Appendix 9 - Scatter Diagram - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	214.9
Mar-08	822	145.9
Apr-08	462	77.5
May-08	232	26.2
Jun-08	27	28.3
Jul-08	-	4.2
Aug-08	-	309.8
Sep-08	78	48.3
Oct-08	356	41.5
Nov-08	641	18.3
Dec-08	902	72.4
Jan-09	1,238	102.0
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Mar-09	844	110.9
Apr-09	447	83.8
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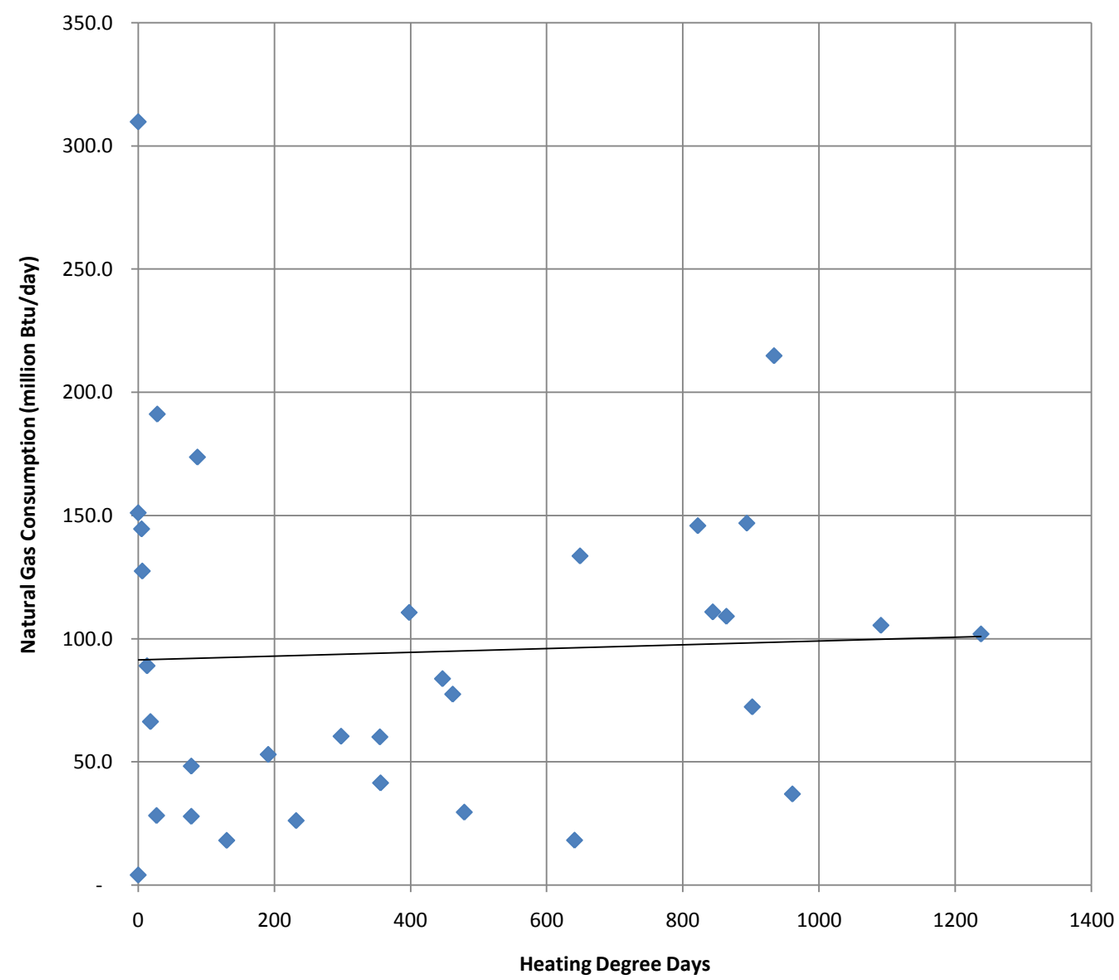
Jul-09	13	89.0
Aug-09	5	144.6
Sep-09	87	173.7
Oct-09	398	110.7
Nov-09	479	29.6
Dec-09	961	37.0
Jan-10	1,091	105.5
Feb-10	864	109.1
Mar-10	649	133.6
Apr-10	355	60.2
May-10	130	18.2
Jun-10	18	66.4
Jul-10	-	151.2
Aug-10	6	127.5
Sep-10	28	191.2
Oct-10	298	60.5



Charles F. Hurley Building

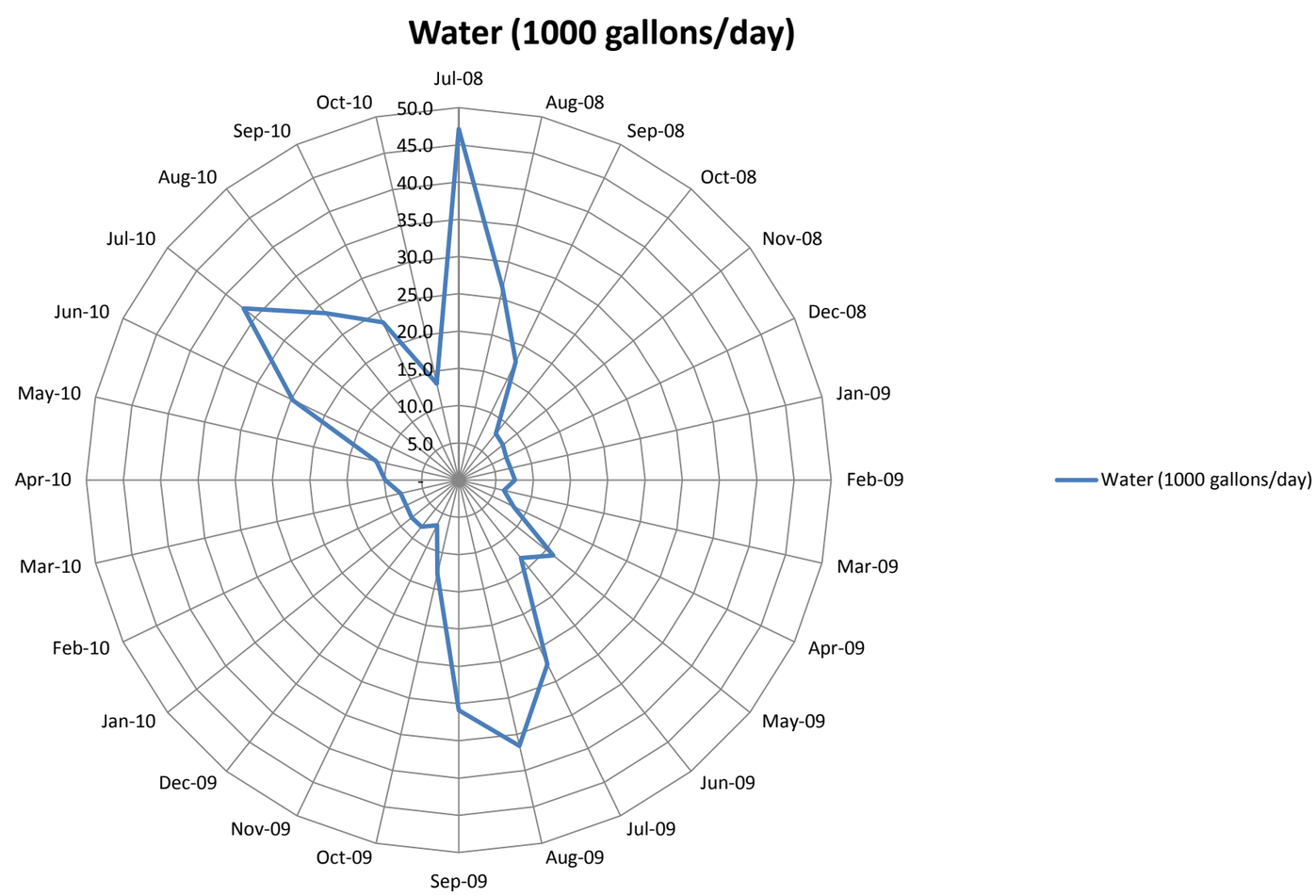
Appendix 10 - Water Consumption

Month	End Date	Number of Days in Cycle	Water Consumption (1000 gallons)	Water Consumption (1000 gallons/day)
Jul-08	7/24/2008	31	1,461	47.1
Aug-08	8/24/2008	30	794	26.5
Sep-08	9/23/2008	30	529	17.6
Oct-08	10/23/2008	41	327	8.0
Nov-08	12/3/2008	34	257	7.6
Dec-08	1/6/2009	29	205	7.1
Jan-09	2/4/2009	28	200	7.1
Feb-09	3/4/2009	30	226	7.5
Mar-09	4/3/2009	32	199	6.2
Apr-09	5/5/2009	29	236	8.1
May-09	6/3/2009	33	535	16.2
Jun-09	7/6/2009	30	402	13.4
Jul-09	8/5/2009	29	795	27.4
Aug-09	9/3/2009	32	1,171	36.6
Sep-09	10/5/2009	30	926	30.9
Oct-09	11/4/2009	29	376	13.0
Nov-09	12/3/2009	34	229	6.7
Dec-09	1/6/2010	28	224	8.0
Jan-10	2/3/2010	28	226	8.1
Feb-10	3/3/2010	33	258	7.8
Mar-10	4/5/2010	30	240	8.0
Apr-10	5/5/2010	29	286	9.9
May-10	6/3/2010	33	375	11.4
Jun-10	7/6/2010	29	716	24.7
Jul-10	8/4/2010	30	1,108	36.9
Aug-10	9/3/2010	32	917	28.7
Sep-10	10/5/2010	29	681	23.5
Oct-10	11/3/2010	31	413	13.3

Charles F. Hurley Building

Appendix 11 - Radar Plot of Water Consumption by Month

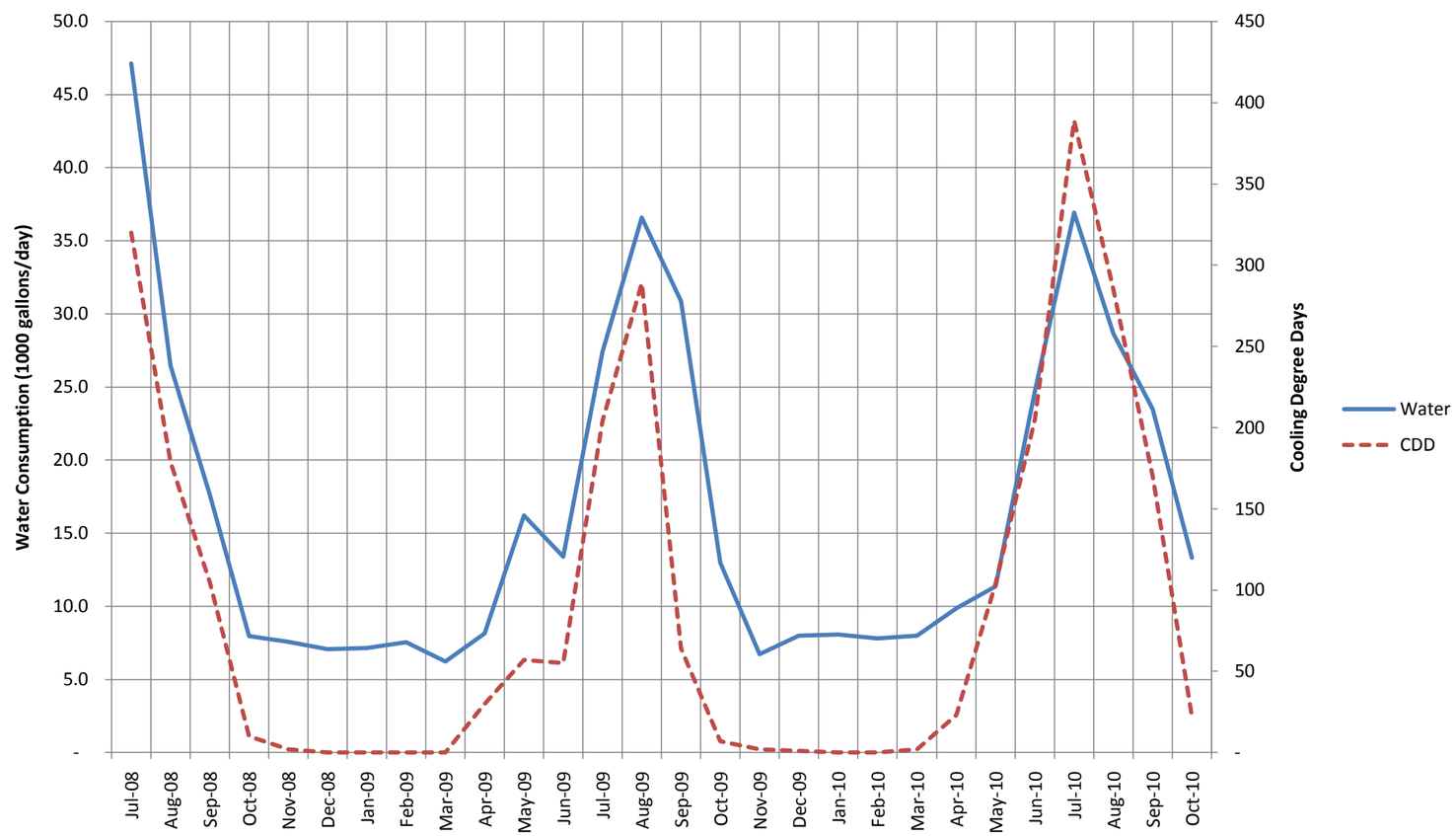
Month	Water Consumption (1000 gallons/day)
Jul-08	47.1
Aug-08	26.5
Sep-08	17.6
Oct-08	8.0
Nov-08	7.6
Dec-08	7.1
Jan-09	7.1
Feb-09	7.5
Mar-09	6.2
Apr-09	8.1
May-09	16.2
Jun-09	13.4
Jul-09	27.4
Aug-09	36.6
Sep-09	30.9
Oct-09	13.0
Nov-09	6.7
Dec-09	8.0
Jan-10	8.1
Feb-10	7.8
Mar-10	8.0
Apr-10	9.9
May-10	11.4
Jun-10	24.7
Jul-10	36.9
Aug-10	28.7
Sep-10	23.5
Oct-10	13.3



Charles F. Hurley Building

Appendix 12 - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	47.1	320
Aug-08	26.5	179
Sep-08	17.6	105
Oct-08	8.0	10
Nov-08	7.6	2
Dec-08	7.1	-
Jan-09	7.1	-
Feb-09	7.5	-
Mar-09	6.2	-
Apr-09	8.1	30
May-09	16.2	57
Jun-09	13.4	55
Jul-09	27.4	204
Aug-09	36.6	289
Sep-09	30.9	64
Oct-09	13.0	7
Nov-09	6.7	2
Dec-09	8.0	1
Jan-10	8.1	-
Feb-10	7.8	-
Mar-10	8.0	2
Apr-10	9.9	23
May-10	11.4	104
Jun-10	24.7	205
Jul-10	36.9	389
Aug-10	28.7	285
Sep-10	23.5	170
Oct-10	13.3	22



Charles F. Hurley Building

Appendix 13 - Scatter Diagram - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	47.1	320
Aug-08	26.5	179
Sep-08	17.6	105
Oct-08	8.0	10
Nov-08	7.6	2
Dec-08	7.1	-
Jan-09	7.1	-
Feb-09	7.5	-
Mar-09	6.2	-
Apr-09	8.1	30
May-09	16.2	57
Jun-09	13.4	55
Jul-09	27.4	204
Aug-09	36.6	289
Sep-09	30.9	64
Oct-09	13.0	7
Nov-09	6.7	2
Dec-09	8.0	1
Jan-10	8.1	-
Feb-10	7.8	-
Mar-10	8.0	2
Apr-10	9.9	23
May-10	11.4	104
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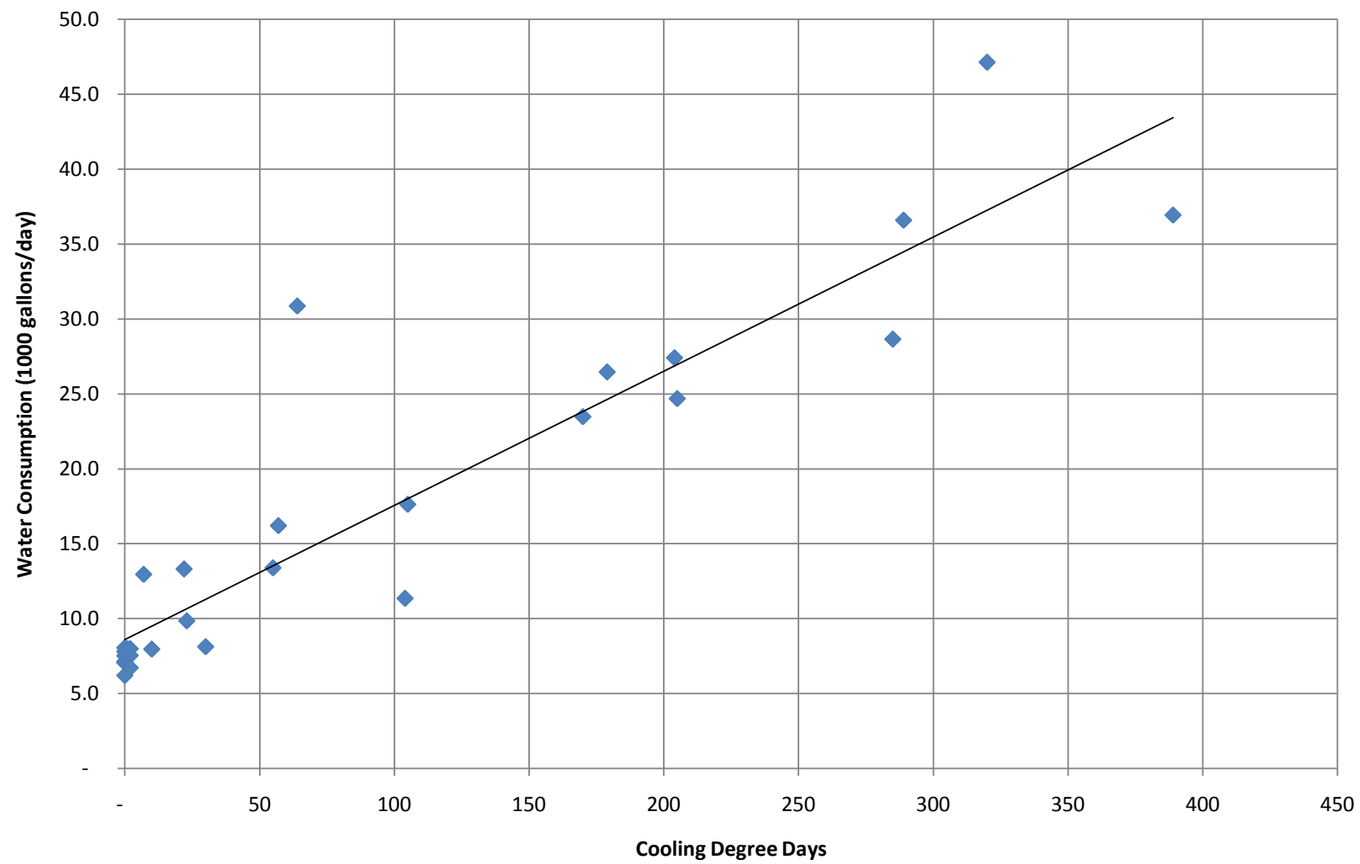
Aug-10	28.7	285
Sep-10	23.5	170
Oct-10	13.3	22



Charles F. Hurley Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition		Remarks
Chiller	CH-1	Mechanical Room MER-1	York	YPC FD-18G-46-H-A	Absorption	600 tons	1992	23	2015		-	Good-Fair	Paint peeling in a few areas	-
Chiller	CH-2	Mechanical Room MER-1	York	YPC FD-18G-46-H-A	Absorption	600 tons	1992	23	2015		-	Good-Fair	Paint peeling in a few areas	-
Chiller	CH-3	Roof	York	YCAL0065EC46XD	Reciprocating	60 tons	2006	20	2026		Data center	Good	-	-
Chiller	CH-4	Roof	York	YCAL0065EC46XD	Reciprocating	60 tons	2006	20	2026		Data center	Good	-	-
Chilled Water Pump	CHW-P1	Data Center	Bell and Gossett	L39	Centrifugal	300 gpm at 70 feet (7-1/2 hp)	2006	20	2026	-	-	Good-Fair	-	-
Chilled Water Pump	CHW-P2	Data Center	Bell and Gossett	2.5BB	Centrifugal	300 gpm at 70 feet (7-1/2 hp)	2006	20	2026	-	-	Good-Fair	-	-
Hot Water Pump	P1 zone	Mechanical Room MER-2	Worthington	4LR12	Centrifugal	20 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P2 zone	Mechanical Room MER-2	Worthington	3LR12	Centrifugal	25 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P3 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	5 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P4 zone	Mechanical Room MER-2	Worthington	3LR9	Centrifugal	7-1/2 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P5 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	5 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P6 zone	Mechanical Room MER-2	Worthington	3LR9	Centrifugal	10 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P7 zone	Mechanical Room MER-2	Worthington	3LR12	Centrifugal	25 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P8 zone	Mechanical Room MER-2	Worthington	3LR9	Centrifugal	10 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P9 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	5 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P10 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	5 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P11 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	1 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Hot Water Pump	P12 zone	Mechanical Room MER-2	Worthington	-	Centrifugal	1 hp	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Dual Temperature Water Pump	P13 DT	Mechanical Room MER-2	Bell and Gossett	HSC	Centrifugal	3000 gpm at 80 feet (75 hp)	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Dual Temperature Water Pump	P14 DT	Mechanical Room MER-2	Paco	-	Centrifugal	150 gpm at 40 feet (25 hp)	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Condenser Water Pump	P15 CW	Mechanical Room MER-1	Paco	29-60151	Centrifugal	2450 gpm at 160 feet (125 hp)	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Condenser Water Pump	P16 CW	Mechanical Room MER-1	Paco	29-60151	Centrifugal	2450 gpm at 160 feet (125 hp)	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Condenser Water Pump	P17 CW	Mechanical Room MER-1	Paco	29-60151	Centrifugal	2450 gpm at 160 feet (125 hp)	1971	20	Expected life has been exceeded	-	-	Good-Fair	-	-
Cooling Tower	CT-1	Roof	Baltimore Aircoil (BAC)	-	Induced draft, 2 cell	75 hp	1994	22	2016	-	-	Fair	Sump leaking - Scaling on louvers	-
Cooling Tower	CT-2	Roof	Baltimore Aircoil (BAC)	-	Induced draft, 2 cell	75 hp	1994	22	2016	-	-	Fair	Sump leaking - Scaling on louvers	-
Air Handling Unit	S-1	Mechanical Room MER-1	Westinghouse	-	-	75 hp	1971	25	Expected life has been exceeded	-	Interior	Fair	-	-
AHU S-1 return fan	R-1	Mechanical Room MER-1	Westinghouse	-		15 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	S-2	Mechanical Room MER-1	Westinghouse	-	-	50 hp	1971	25	Expected life has been exceeded	-	North interior	Fair	Rust on fan access door	-
AHU S-2 return fan	R-2	Mechanical Room MER-1	Westinghouse	-	-	15 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	S-3	Mechanical Room MER-2	Westinghouse	-	-	-	1971	25	Expected life has been exceeded	-	Perimeter	Fair	-	-
AHU S-3 return fan	R-3	Mechanical Room MER-2	Westinghouse	-	-	-	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	S-4	Mechanical Room MER-2	Westinghouse	-	-	25 hp	1971	25	Expected life has been exceeded	-	Elevator lobby, 1st and 2nd floors	Fair-Poor	Air leaking from cassing	-

Charles F. Hurley Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition		Remarks
AHU S-4 return fan	R-4	Mechanical Room MER-2	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	S-5	Mechanical Room MER-2	Westinghouse	-	-	60 hp	1971	25	Expected life has been exceeded	-	C. Interior	Fair	-	-
AHU S-5 return fan	R-5	Mechanical Room MER-2	Westinghouse	-	-	20 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	S-6	Mechanical Room MER-2	Westinghouse	-	-	-	1971	25	Expected life has been exceeded	-	Basement	Fair-Poor	Air leaking from cassing	-
AHU S-6 return fan	R-6	Mechanical Room MER-2	Westinghouse	-	-	-	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	Variable-speed
Air Handling Unit	S-7	Mechanical Room MER-3	Westinghouse	-	-	75 hp	1971	25	Expected life has been exceeded	-	Interior	Fair-Poor	-	Variable-speed
Air Handling Unit	S-8	Mechanical Room MER-3	Westinghouse	-	-	100 hp	1971	25	Expected life has been exceeded	-	Perimeter	Fair-Poor	-	Variable-speed
Air Handling Unit	S-9	Mechanical Room MER-3	Westinghouse	-	-	40 hp	1971	25	Expected life has been exceeded	-	Basement exterior wall	Fair-Poor	Abandoned unit	-
Exhaust Fan	E-1	Mechanical Room MER-1	-	-	-	5600 cfm (1-1/2 hp)	1971	20	Expected life has been exceeded	-	Mechanical Room MER-1	Good-Fair	-	-
Exhaust Fan	E-2	Mechanical Room MER-2	-	-	-	5000 cfm (2 hp)	1971	20	Expected life has been exceeded	-	Mechanical Room MER-2	Good-Fair	-	-
Exhaust Fan	E-3	Mechanical Room MER-2	-	-	-	18,245 cfm (7-1/2 hp)	1971	20	Expected life has been exceeded	-	Mechanical Room MER-2	Good-Fair	-	-
Exhaust Fan	E-4	Mechanical Room MER-3	-	-	-	11,330 cfm (7-1/2 hp)	1971	20	Expected life has been exceeded	-	Basement	Good-Fair	-	-
Exhaust Fan	E-5	Mechanical Room MER-3	-	-	-	5750 cfm (2 hp)	1971	20	Expected life has been exceeded	-	Mechanical Room MER-3	Good-Fair	-	-
Exhaust Fan	E-6	Kitchen	-	-	-	8135 cfm (7-1/2 hp)	1971	20	Expected life has been exceeded	-	Kitchen	-	-	-
Exhaust Fan	E-7	Kitchen	-	-	-	7970 cfm (5 hp)	1971	20	Expected life has been exceeded	-	Kitchen	-	-	-
Exhaust Fan	E-8	Basement	-	-	-	4700 cfm (2 hp)	1971	20	Expected life has been exceeded	-	Basement	Good-Fair	-	-

KLING STUBBINS

ARCHITECTURE
ENGINEERING
INTERIORS
PLANNING

Division of Capital Asset Management (DCAM)

Energy Upgrades – McCormack, Hurley, Lindemann and State House Buildings

Existing Conditions Assessment Erich Lindemann Building Final Submittal

Revised May 10, 2012

DCAM Project # DPC1021 ES1

KS Project # 36.7407.00

One Broadway
Cambridge, Massachusetts
02142

P 617.491.6450
F 617.491.7104

Erich Lindemann Building

Existing Conditions Assessment

1 Executive Summary

1.1 Study Objectives

The Division of Capital Asset Management (DCAM) retained KlingStubbins to recommend energy-conserving measures (ECM's) as a multi-task project. This report relates to Task 1, which is to assess existing conditions in order to understand the operations and provide a platform for future ECM's.

2 Building Overview

The 7-story Erich Lindemann Mental Health Center houses occupational therapy, outpatient mental health and homeless support programs. Construction was completed in 1971. The gross area is 225,000 ft^2; there are two below-grade parking floors. The building has a population of 650 people.

3 HVAC System Overview

A combination of perimeter fan coil units and air handling units maintain room environmental conditions and provide outside air. The Lindemann Center generates chilled water and heating hot water used by the perimeter fan coil units and air handling units. Equipment is housed in eight mechanical rooms distributed through the center.

3.1 Supply Air Systems

3.1.1 Description – Perimeter Fan Coil Units

Most perimeter zones use four-pipe fan coil units located under windows for heating and cooling.

3.1.2 Mode of Operation – Perimeter Induction Units

Wall-mounted temperature sensors modulate the coil control valve to maintain room temperature setpoint.

No demand-controlled ventilation is used to reduce airflow during unoccupied modes.

The perimeter fan coil units operate continuously.

3.1.3 Description – Interior Air Handling Units

Air handling units mix outside air and return air, then filter, heat and cool the air before it is supplied to interior zones. Chilled water generated in the Lindemann Center is the thermal medium for the cooling coils. Heating hot water generated in the Lindemann Center is the thermal medium for the preheat coils.

Air handling units are located in mechanical rooms distributed throughout the building.

Five air handling units use 100% outside air. No heat recovery is used.

- AHU-1 (Kitchen);
- AHU-3 (Perimeter Classrooms);
- AHU-9 (4th Floor East Exterior);
- AHU-14 (4th Floor Center Interior);
- AHU-16 (Mezzanine West).

All air handling units were manufactured by Westinghouse and installed in 1971. The supply and return fans use standard-efficiency motors and are belt-driven with trapezoidal-cross section belts.

Supply air is distributed to interior zones through a manually-balanced constant volume distribution system.

3.1.4 Mode of Operation – Interior Air Handling Units

Cooling coil control valves are the 3-way type: chilled water either runs through the coil or bypasses the coil.

Preheat coil control valves are the 3-way type: heating hot water either runs through the coil or bypasses the coil.

All air handling units operate continuously.

No demand-controlled ventilation is used to reduce airflow during unoccupied modes.

AHU-1, 7, 9, 14, 15, and 16 are equipped with heating coils and the leaving air temperature setpoint is manually reset. All air handlers are manually controlled locally and run 24 hours a day, 7 days a week. Fan coil temperature setpoints are reset based on outdoor air temperature.

3.2 Heating Hot Water System Description

Heating hot water is generated by five natural gas-fired boilers located in a mechanical room near the loading dock. The boilers are the condensing type manufactured by Aerco and each has a capacity of 2,000,000 Btu/hr; they were installed in 2007.

Condensing type boilers cool flue gas with return heating hot water to below the dewpoint, which increases efficiency by recovering the latent enthalpy of vaporization.

Two 50 hp pumps circulate heating hot water. The pumps are constant-speed, have standard-efficiency motors, were manufactured by Weinman and installed in 1971.

3.2.1 Heating Hot Water Mode of Operation

Heating hot water supply temperature is maintained in the range of 130°F to 150°F, based on a reset schedule with outside air temperature: as outside air temperature increases, the heating hot water supply temperature is reduced. Heating hot water pumps are deenergized when the outside air temperature increases above 55°F.

3.3 Chilled Water System Description

One water-cooled chiller in Mechanical Room 8 provides chilled water to fan coil units and air handling units. The machine is a 370-ton variable-speed electric centrifugal chiller, manufactured by Carrier and installed in 2002.

Chilled water can be imported from the Hurley Building by changing positions of manual isolation valves. However, chilled water cannot be exported to the Hurley Building.

Three 40 hp constant-volume pumps circulate chilled water to cooling coils. The pumps are constant-speed, with standard-efficiency motors, manufactured by Weinman and installed in 1971.

Condenser water is generated by one forced-draft cooling tower mounted on the roof. The cooling tower was manufactured by Baltimore Aircoil (BAC) and installed in 2002. Cooling tower fans are controlled by variable frequency drives to maintain the 85°F condenser water supply temperature setpoint.

Two 20 hp constant-speed pumps (CWP-1 and 2) in Mechanical Room 8 circulate condenser water between the condensers and the cooling towers. The pumps have standard-efficiency motors, were manufactured by Weinman and installed in 1971. One pump is active; one is standby.

3.3.1 Chilled Water System Mode of Operation

The chiller is started when the outside air temperature exeeds 60°F; the variable-speed drive controls compressor speed to maintain chilled water supply temperature setpoint.

3.4 Special Areas

3.4.1 Kitchen Air System Description

AHU-1 supplies air to the kitchen. This unit is constant-volume, 100% outside air. The kitchen is exhausted by two fans (7.5 hp and 2 hp); the fans are constant-speed with standard-efficiency motors, installed in 1971.

3.4.2 Kitchen Exhaust Air Mode of Operation

The kitchen supply and exhaust air systems operate continuously.

4 Domestic Cold and Hot Water

4.1.1 Plumbing Fixtures

Most toilets were rated at 1.6 gallons per flush (gpf), urinals were rated to 1.0 gpf and

lavatory faucets were rated at 0.5 gallons per minute (gpm). Low-flow fixtures are installed as fixtures are replaced.

4.1.2 Domestic Hot Water Generation

Domestic hot water is generated in a heating hot water-to-domestic water heat exchanger.

5 Building Automation System (BAS) Description

Johnson Controls Inc. (JCI) is the BAS supplier for this building; the building has multiple hardware and software platforms that have been implemented over the years.

The building originally used pneumatic controllers. Over the years, various parts of the building were upgraded to newer JCI controllers and devices. Electric-to-pneumatic (E-P) transducers have been used to provide direct digital control (DDC) of pneumatic actuators. Not every HVAC unit is under DDC control.

The Master Operator Workstation (OWS) head end personal computer (PC) is located in the Command Center of the McCormack Building. Other OWS are located in the Hurley and State House buildings. The master OWS, however, contains the primary programming database and corresponding backup and system restore functions.

6 Utility Consumption Analysis

6.1 Energy Use Intensity and Benchmarking

The energy use intensity (EUI) is defined as the energy consumption (in units of million Btu) divided by the gross building area (ft^2). This provides a metric to compare one building versus peer facilities, since databases sorted geographically and by building type exist.

The EUI for the Lindemann Center is 129,525 Btu/ft^2-year. It is difficult to benchmark this EUI, since the Lindemann Center has a unique program.

6.2 Electricity Consumption Analysis

Thirty months (July 2008 through December 2010) of electricity demand and consumption billing information was analyzed.

The facility purchases electricity from Direct Energy with NStar serving as the power delivery service. The tariff is Rate B7-NEMA LG, General Time of Use (TOU).

Electricity consumption information was provided from billing information. The billing-cycle consumption (kWh/billing cycle) was divided by the number of days in the billing cycle to create an average daily electricity consumption (kWh/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 1. This average daily electricity consumption was plotted against month on a radar-type chart (Appendix 2). The radar plot showed consumption peaks in the summer months of 2008 and

2010, suggesting that loads related to air-conditioning drive electricity consumption. The peaks did not coincide in the summer of 2009.

This hypothesis was tested by correlating cooling degree days against electricity consumption. Cooling degree days are a single-measure, simplified means of characterizing outside air temperature data. Cooling degree days are a measure of how much (in degrees F) and for how long (in days), outside air temperature was higher than a base temperature (65°F).

Actual cooling degree day information was obtained for the same timeframe as the electricity consumption data. The cooling degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Electricity consumption data was plotted against the cooling degree day data (Appendix 3). The electricity consumption and cooling degree day values peak in the same summer months in 2008 and 2010, but not 2009.

The correlation coefficient, which measures the linear relationship between two variables: the correlation coefficient ranges between 1 and -1. A value of 1 means that if one variable increases, the other variable increases linearly. A value of -1 means that if one variable increases, the other variable decreases linearly. A value of 0 means there is no linear correlation between the two variables.

Electricity consumption and cooling degree days have a correlation coefficient of 0.70, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 4) confirms the strong relationship.

Power demand (kW) for each month was plotted against time (Appendix 5): this confirms that electricity demand is driven by air-conditioning equipment.

The electricity load factor (ELF) is defined as the ratio between the average daily use and the maximum possible use if the peak demand operated for a 24 hour period. This factor was calculated as 0.73.

The seasonally-adjusted electricity load factor (SELF) is the electricity load factor calculated over the cooling season.

This factor was calculated as 0.25 (2009) and 0.90 (2010).

The occupancy factor is defined as the percentage of time that the building is occupied. This building has an occupancy factor is 0.6.

If the ELF is much greater than the OF, that implies that equipment or lighting operates when the building is unoccupied.

The conclusions of this billing-information analysis are:

- Although air-conditioning drives electricity consumption, baseload consumption (receptacles and lighting) still represent a target for energy-conservation measures.
- Operation of HVAC equipment, lights and receptacles during unoccupied hours represents an energy-reduction target.

6.3 Natural Gas Consumption Analysis

Thirty-three months (February 2008 through October 2010) of natural gas consumption billing information was analyzed.

The facility purchases natural gas from Hess Energy with National Grid serving as the natural gas delivery service. The tariff is Rate G-44T, Demand Heating.

Natural gas consumption information was provided from billing information. The billing-cycle consumption (10^6 Btu/billing cycle) was divided by the number of days in the billing cycle to create an average daily natural gas consumption (10^6 Btu/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 6. This average daily natural gas consumption was plotted by month on a radar-type chart (Appendix 7). The radar plot showed consumption peaks in the winter months, suggesting that heating-related loads drive natural gas consumption.

This hypothesis was tested by correlating heating degree days against natural gas consumption. Heating degree days are a single-measure, simplified means of

characterizing outside air temperature data. Heating degree days are defined as the difference between a base temperature (65°F) and the average temperature (maximum temperature – minimum temperature) for each day; degree days are accumulated over a heating season.

Actual heating degree day information was obtained for the same timeframe as the natural gas consumption data. The heating degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Natural gas consumption data was plotted against the heating degree day data (Appendix 8). The natural gas consumption and heating degree day values peak in the same winter months.

Natural gas consumption and heating degree days have a correlation coefficient of 0.83, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 9) confirms the strong relationship.

The conclusion of this billing-information analysis is that heating use reduction is critical to reducing natural gas consumption.

6.4 Water Consumption Analysis

Twenty-eight months (July 2008 through October 2010) of water consumption billing information was analyzed.

The facility purchases water from the Boston Water and Sewer Commission.

Water consumption information was provided from billing information. The billing-cycle consumption (thousand gallons/billing cycle) was divided by the number of days in the billing cycle to create an average daily water consumption (1000 gallons/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 10. This average daily water consumption was plotted against month on a radar-type chart (Appendix 11). The radar plot showed consumption peaks in the summer months, suggesting that cooling tower-related loads drive water consumption.

This hypothesis was tested by correlating cooling degree days against water

consumption.

Water consumption data was plotted against the cooling degree day data (Appendix 12). The water consumption and cooling degree day values peak in the same summer months.

Water consumption and cooling degree days have a correlation coefficient of 0.40, which means that the two variables are weakly related. A scatter diagram of the two variables (Appendix 13) confirms the weak relationship.

The conclusion of this billing-information analysis is:

- Although cooling tower use drives water consumption, baseload consumption (toilets and lavatories) still represent a target for reduction measures.

7 Existing Equipment Matrix

An Existing Equipment Matrix is included as Appendix 14. Central plant equipment (chillers, cooling towers and boilers) have been recently replaced, but areas of concern are support equipment (pumps) and air handling units.

For each piece of equipment, the matrix identifies the year of installation and the median life. Median life data was taken from two sources:

- Chapter 37 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) "HVAC Applications" Handbook, 2011 edition, lists median service lives for mechanical equipment.
- ASHRAE "Owning and Operating Cost Database" (available at ashrae.org) has compiled a database of 345 buildings, including life of mechanical equipment at the time of replacement.

The cost of maintenance of HVAC equipment is reported as part of the ASHRAE "Owning and Operating Cost Database". This information is reported by building type and geographic location, but not for specific pieces of equipment. The database reports a mean HVAC equipment maintenance cost of $0.494/ft^2, or $111,200 for this type of facility. However, this information has a standard deviation of $0.217/ft^2 ($48,900), which implies there is a large variation in these values.

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Appendix 1 - Electricity Consumption Data

	Consumption (kWh) - Offpeak	Consumption (kWh) - Onpeak	Consumption (kWh) - Total	Cooling Degree Days	Days/Month	Average elec Consumption per day (kWh/day)	Demand (kW)
Jul-08	282,205	120,995	403,200	320	30	13,440	711
Aug-08	252,641	109,059	361,700	179	29	12,472	699
Sep-08	241,504	99,196	340,700	105	32	10,647	684
Oct-08	143,888	109,712	253,600	10	30	8,453	703
Nov-08	164,644	114,856	279,500	2	32	8,734	494
Dec-08	152,280	115,620	267,900	-	30	8,930	515
Jan-09	151,979	116,121	268,100	-	30	8,937	500
Feb-09	168,333	113,667	282,000	-	32	8,813	508
Mar-09	143,028	107,172	250,200	-	29	8,628	489
Apr-09	138,071	107,329	245,400	30	30	8,180	632
May-09	161,836	106,664	268,500	57	32	8,391	659
Jun-09	185,364	76,936	262,300	55	29	9,045	652
Jul-09	168,466	74,034	242,500	204	30	8,083	658
Aug-09	191,189	77,111	268,300	289	31	8,655	667
Sep-09	167,150	72,850	240,000	64	30	8,000	433
Oct-09	130,228	98,872	229,100	7	30	7,637	469
Nov-09	148,338	101,462	249,800	2	32	7,806	446
Dec-09	149,375	112,825	262,200	1	30	8,740	491
Jan-10	166,409	112,391	278,800	-	32	8,713	483
Feb-10	148,027	112,373	260,400	-	30	8,680	481
Mar-10	137,948	100,952	238,900	2	29	8,238	466
Apr-10	149,505	103,095	252,600	23	33	7,655	477
May-10	129,441	94,359	223,800	104	29	7,717	443
Jun-10	163,295	70,405	233,700	205	29	8,059	467
Jul-10	291,659	112,141	403,800	389	32	12,619	673
Aug-10	239,800	100,800	340,600	285	29	11,745	658
Sep-10	212,895	98,605	311,500	170	30	10,383	672
Oct-10	157,846	106,954	264,800	22	32	8,275	616
Nov-10	150,776	112,824	263,600	-	31	8,503	480
Dec-10	149,533	110,167	259,700	-	30	8,657	505

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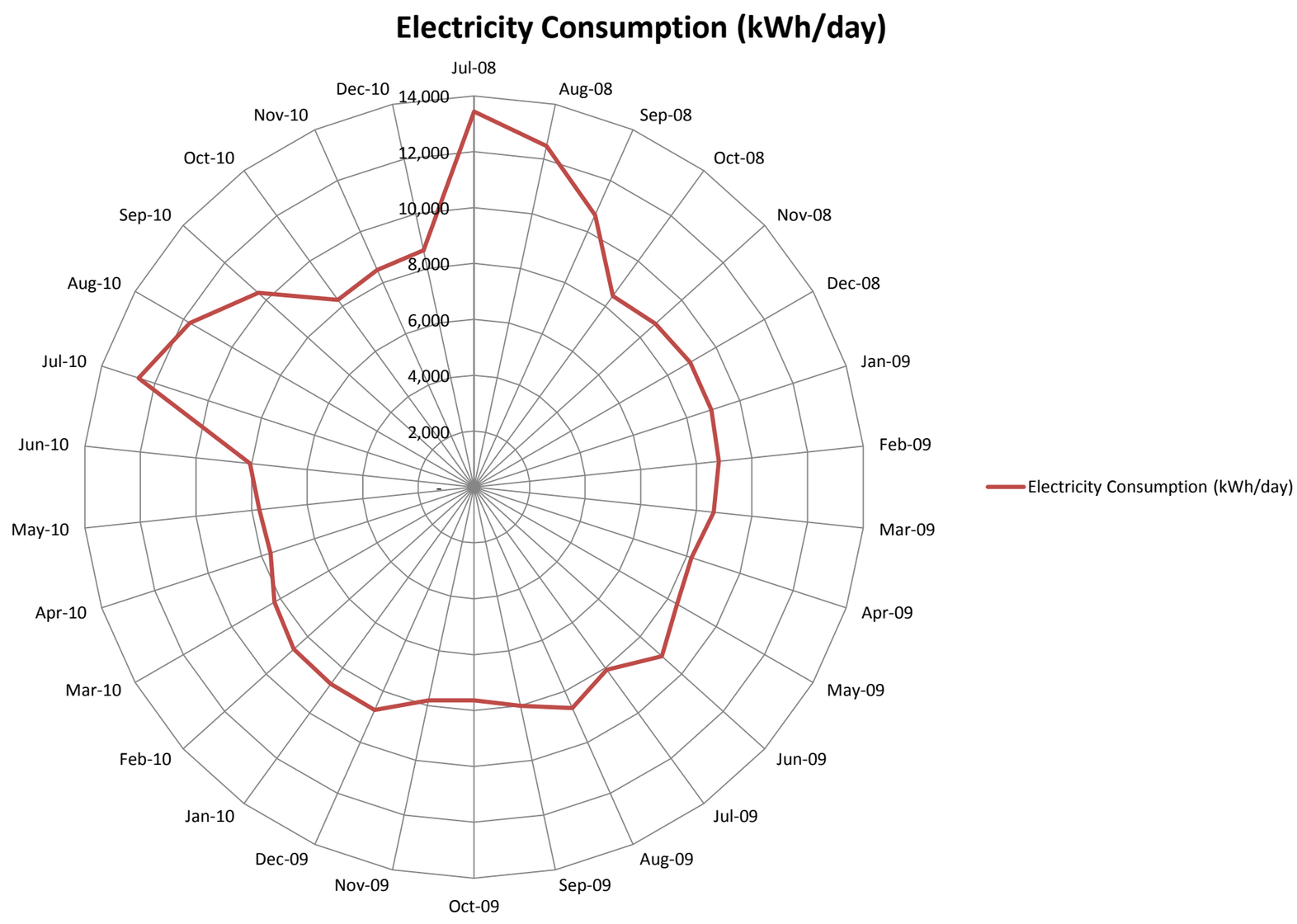
Appendix 2 - Radar Plot of Electricity Consumption by Month

	Average elec Consumption per day (kWh/day)
Jul-08	13,440
Aug-08	12,472
Sep-08	10,647
Oct-08	8,453
Nov-08	8,734
Dec-08	8,930
Jan-09	8,937
Feb-09	8,813
Mar-09	8,628
Apr-09	8,180
May-09	8,391
Jun-09	9,045
Jul-09	8,083
Aug-09	8,655
Sep-09	8,000
Oct-09	7,637
Nov-09	7,806
Dec-09	8,740
Jan-10	8,713
Feb-10	8,680
Mar-10	8,238
Apr-10	7,655
May-10	7,717
Jun-10	8,059
Jul-10	12,619
Aug-10	11,745
Sep-10	10,383
Oct-10	8,275
Nov-10	8,503
Dec-10	8,657



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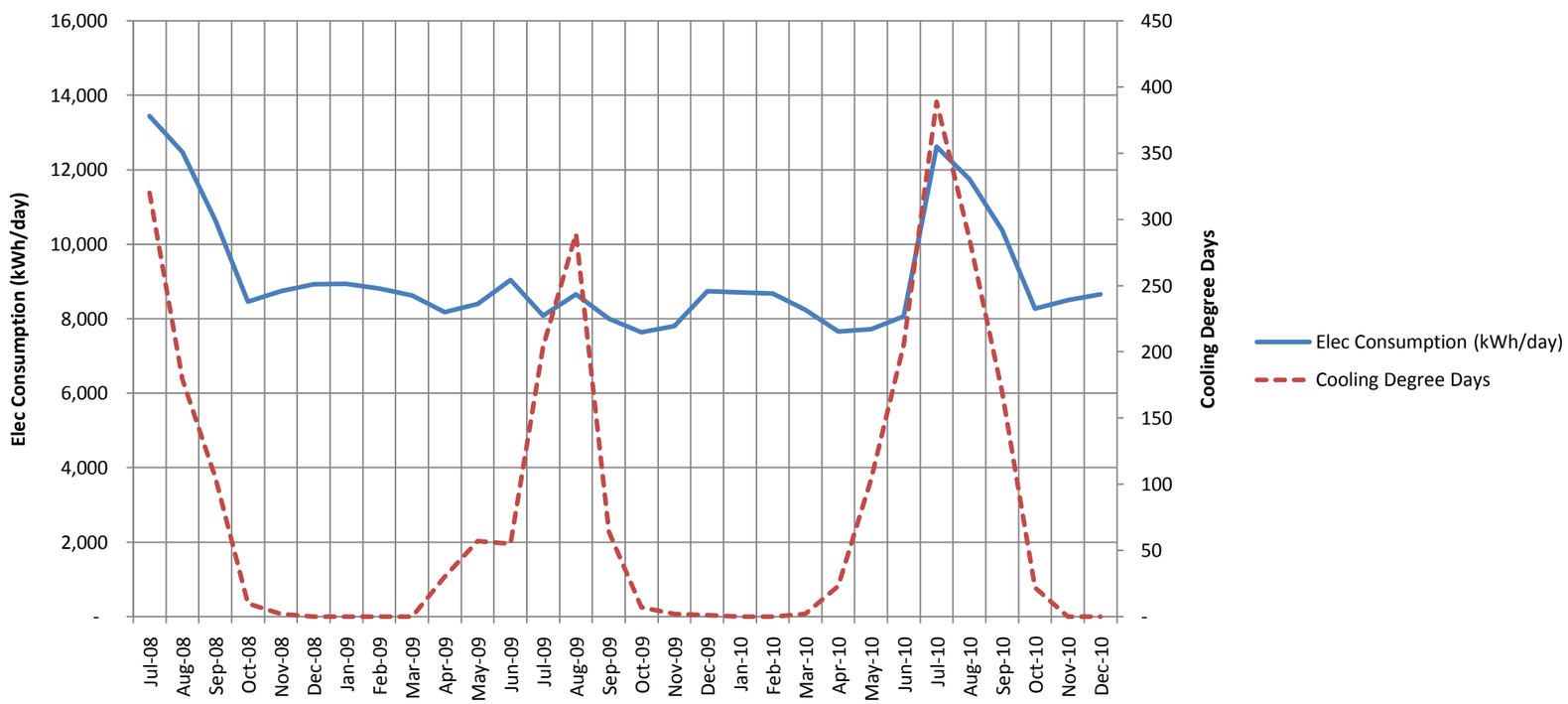
Appendix 3 - Electricity v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	13,440
Aug-08	179	12,472
Sep-08	105	10,647
Oct-08	10	8,453
Nov-08	2	8,734
Dec-08	-	8,930
Jan-09	-	8,937
Feb-09	-	8,813
Mar-09	-	8,628
Apr-09	30	8,180
May-09	57	8,391
Jun-09	55	9,045
Jul-09	204	8,083
Aug-09	289	8,655
Sep-09	64	8,000
Oct-09	7	7,637
Nov-09	2	7,806
Dec-09	1	8,740
Jan-10	-	8,713
Feb-10	-	8,680
Mar-10	2	8,238
Apr-10	23	7,655
May-10	104	7,717
Jun-10	205	8,059
Jul-10	389	12,619
Aug-10	285	11,745
Sep-10	170	10,383
Oct-10	22	8,275
Nov-10	-	8,503
Dec-10	-	8,657



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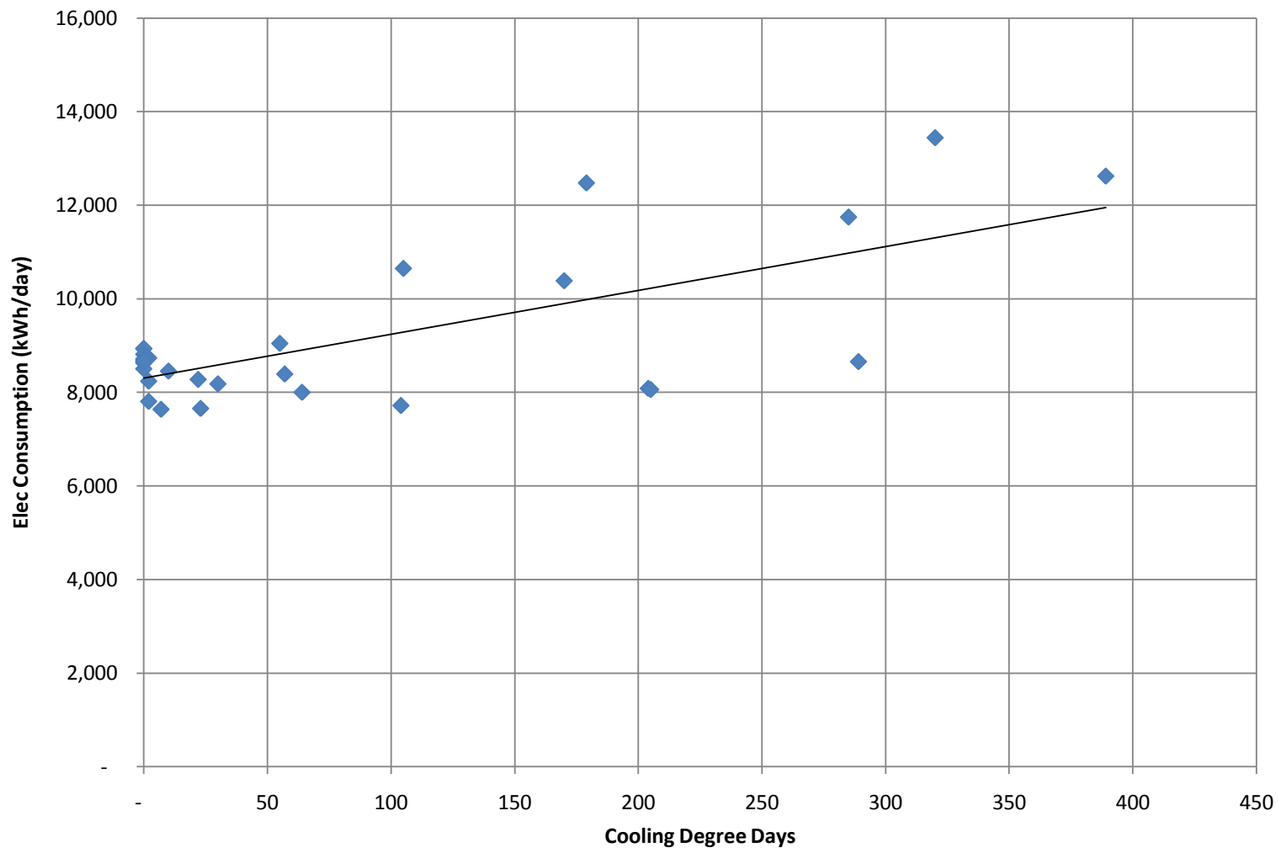
Appendix 4 Scatter Diagram: Electric Consumption v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	13,440
Aug-08	179	12,472
Sep-08	105	10,647
Oct-08	10	8,453
Nov-08	2	8,734
Dec-08	-	8,930
Jan-09	-	8,937
Feb-09	-	8,813
Mar-09	-	8,628
Apr-09	30	8,180
May-09	57	8,391
Jun-09	55	9,045
Jul-09	204	8,083
Aug-09	289	8,655
Sep-09	64	8,000
Oct-09	7	7,637
Nov-09	2	7,806
Dec-09	1	8,740
Jan-10	-	8,713
Feb-10	-	8,680
Mar-10	2	8,238
Apr-10	23	7,655
May-10	104	7,717
Jun-10	205	8,059
Jul-10	389	12,619
Aug-10	285	11,745
Sep-10	170	10,383
Oct-10	22	8,275
Nov-10	-	8,503
Dec-10	-	8,657



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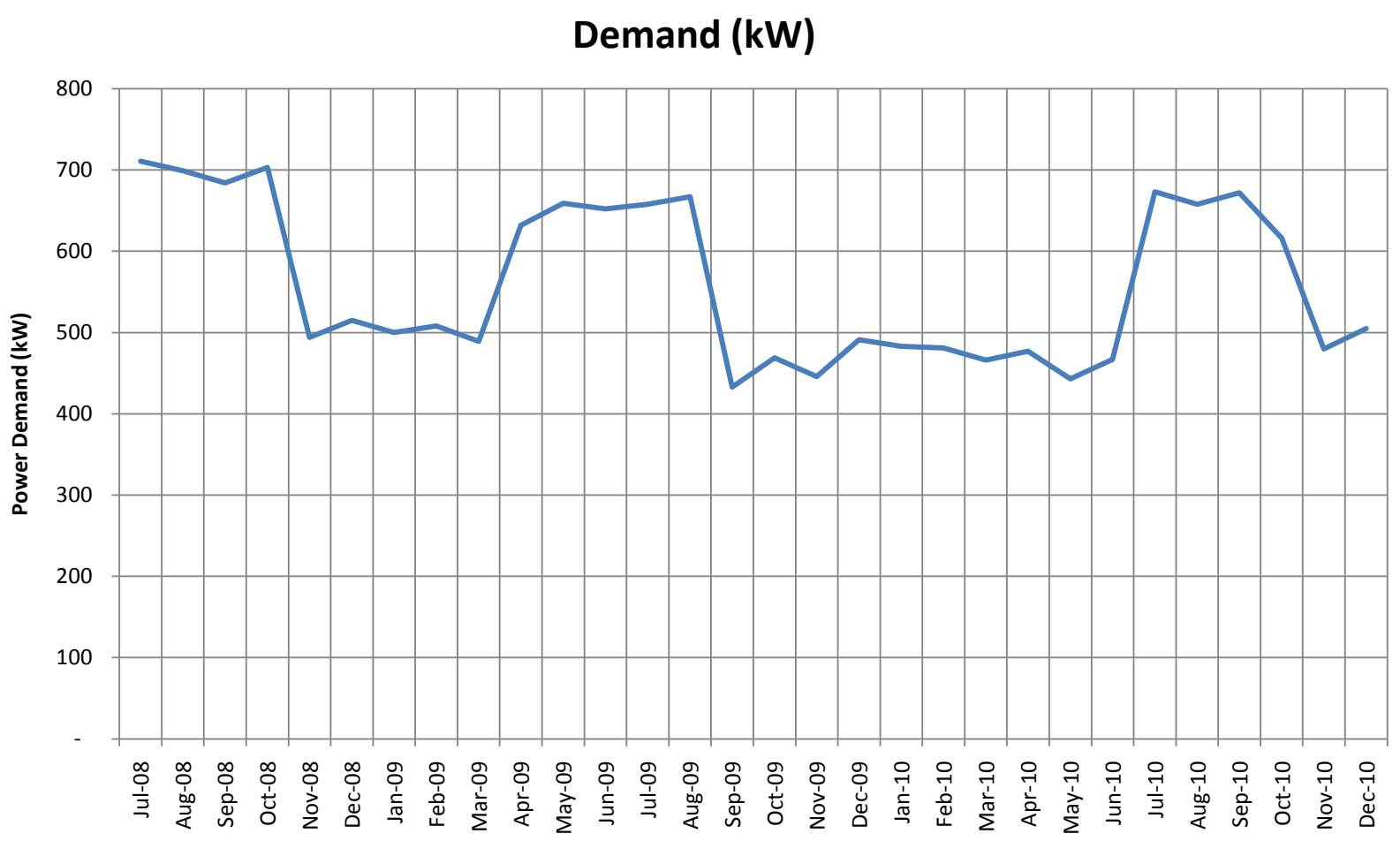
Appendix 5 - Power Demand

	Demand (kW)
Jul-08	711
Aug-08	699
Sep-08	684
Oct-08	703
Nov-08	494
Dec-08	515
Jan-09	500
Feb-09	508
Mar-09	489
Apr-09	632
May-09	659
Jun-09	652
Jul-09	658
Aug-09	667
Sep-09	433
Oct-09	469
Nov-09	446
Dec-09	491
Jan-10	483
Feb-10	481
Mar-10	466
Apr-10	477
May-10	443
Jun-10	467
Jul-10	673
Aug-10	658
Sep-10	672
Oct-10	616
Nov-10	480
Dec-10	505



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Appendix 6 - Natural Gas Consumption

	Usage Begin Date	Consumption (therms)	Consumption (10^6 Btu)	Heating Degree Days	Days/Month	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	2/7/2008	23,779	2,378	934	33	72.1
Mar-08	3/11/2008	29,106	2,911	822	27	107.8
Apr-08	4/7/2008	19,960	1,996	462	31	64.4
May-08	5/8/2008	11,515	1,152	232	29	39.7
Jun-08	6/6/2008	5,541	554	27	34	16.3
Jul-08	7/10/2008	2,191	219	-	29	7.6
Aug-08	8/8/2008	2,007	201	-	31	6.5
Sep-08	9/8/2008	2,281	228	78	30	7.6
Oct-08	10/8/2008	5,486	549	356	27	20.3
Nov-08	11/4/2008	5,691	569	641	34	16.7
Dec-08	12/8/2008	21,321	2,132	902	30	71.1
Jan-09	1/7/2009	28,269	2,827	1,238	30	94.2
Feb-09	2/6/2009	31,053	3,105	894	28	110.9
Mar-09	3/6/2009	25,712	2,571	844	31	82.9
Apr-09	4/6/2009	20,177	2,018	447	30	67.3
May-09	5/6/2009	10,146	1,015	191	30	33.8
Jun-09	6/5/2009	4,258	426	78	34	12.5
Jul-09	7/9/2009	2,594	259	13	29	8.9
Aug-09	8/7/2009	1,559	156	5	33	4.7
Sep-09	9/9/2009	1,458	146	87	29	5.0
Oct-09	10/8/2009	2,795	280	398	28	10.0
Nov-09	11/5/2009	7,998	800	479	32	25.0
Dec-09	12/7/2009	10,153	1,015	961	31	32.8
Jan-10	1/7/2010	26,905	2,691	1,091	34	79.1
Feb-10	2/10/2010	30,270	3,027	864	27	112.1
Mar-10	3/9/2010	28,325	2,833	649	28	101.2
Apr-10	4/6/2010	14,302	1,430	355	31	46.1
May-10	5/7/2010	5,690	569	130	31	18.4
Jun-10	6/7/2010	2,711	271	18	54	5.0
Jul-10	7/31/2010		-	-	39	-
Aug-10			-	6	30	-
Sep-10	9/8/2010	4,926	493	28	23	21.4
Oct-10	10/1/2010	2,178	218	298	31	7.0

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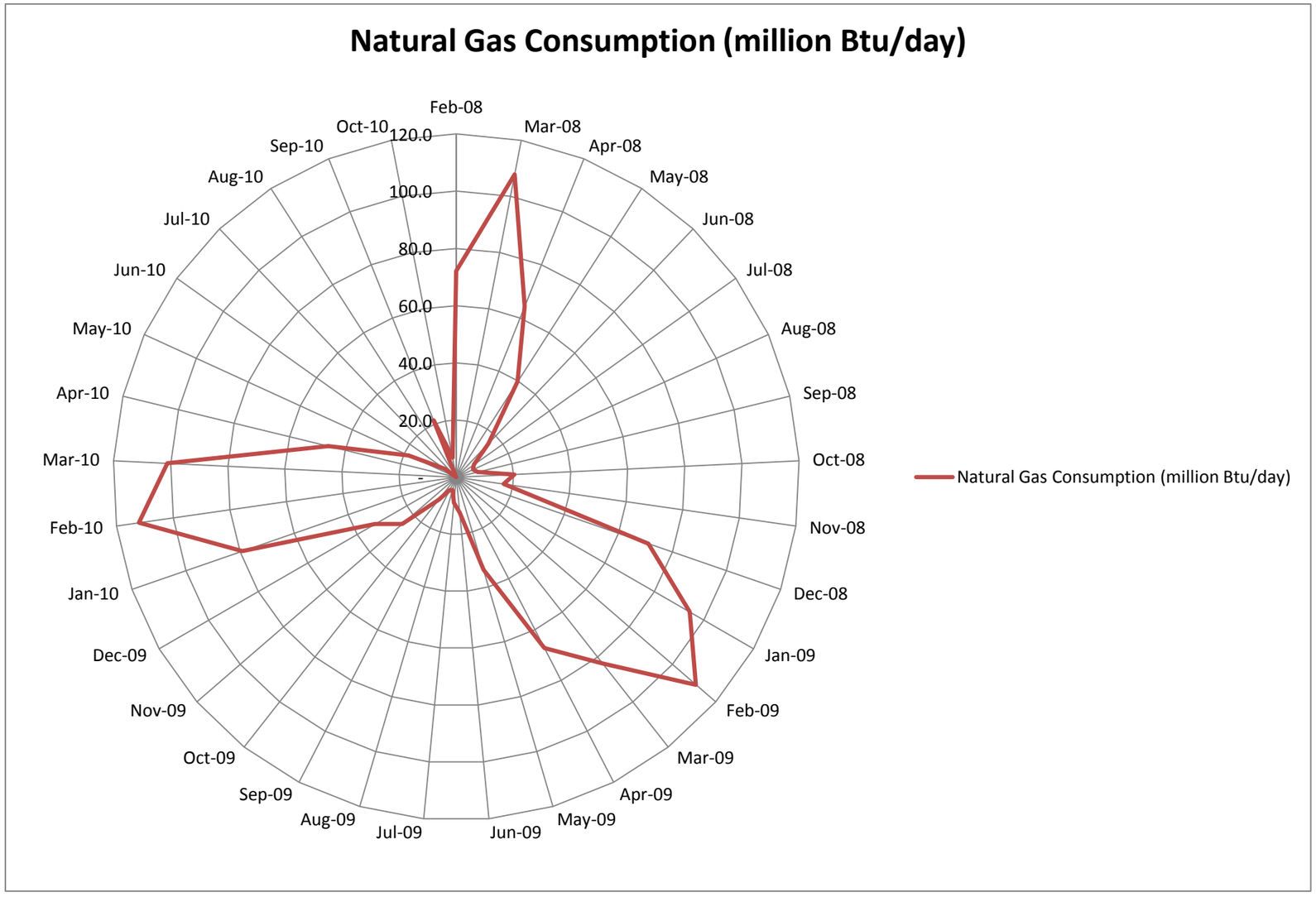
Appendix 7 - Natural Gas Radar Plot

	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	72.1
Mar-08	107.8
Apr-08	64.4
May-08	39.7
Jun-08	16.3
Jul-08	7.6
Aug-08	6.5
Sep-08	7.6
Oct-08	20.3
Nov-08	16.7
Dec-08	71.1
Jan-09	94.2
Feb-09	110.9
Mar-09	82.9
Apr-09	67.3
May-09	33.8
Jun-09	12.5
Jul-09	8.9
Aug-09	4.7
Sep-09	5.0
Oct-09	10.0
Nov-09	25.0
Dec-09	32.8
Jan-10	79.1
Feb-10	112.1
Mar-10	101.2
Apr-10	46.1
May-10	18.4
Jun-10	5.0
Jul-10	-
Aug-10	-
Sep-10	21.4
Oct-10	7.0



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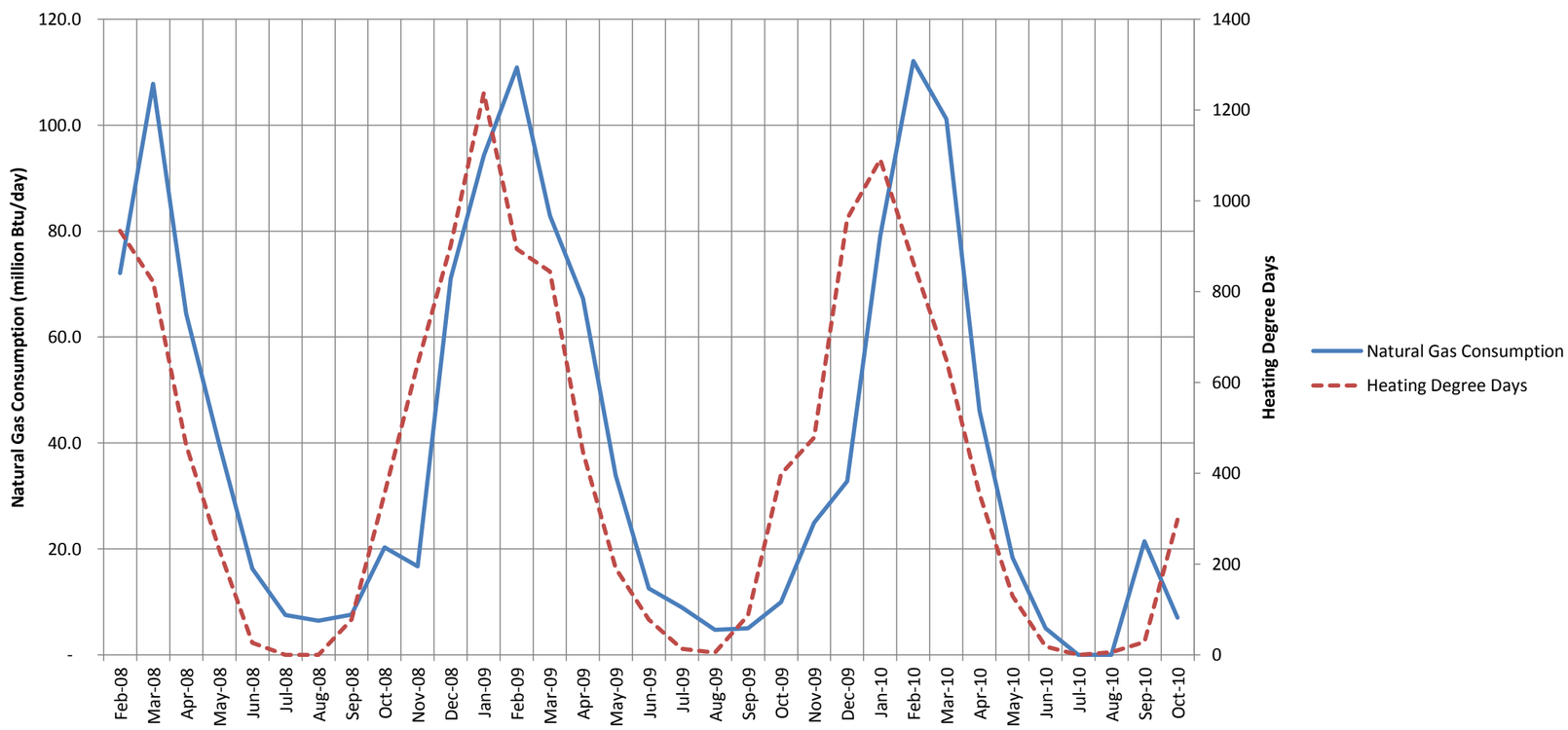
Appendix 8 - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	72.1
Mar-08	822	107.8
Apr-08	462	64.4
May-08	232	39.7
Jun-08	27	16.3
Jul-08	-	7.6
Aug-08	-	6.5
Sep-08	78	7.6
Oct-08	356	20.3
Nov-08	641	16.7
Dec-08	902	71.1
Jan-09	1,238	94.2
Feb-09	894	110.9
Mar-09	844	82.9
Apr-09	447	67.3
May-09	191	33.8
Jun-09	78	12.5
Jul-09	13	8.9
Aug-09	5	4.7
Sep-09	87	5.0
Oct-09	398	10.0
Nov-09	479	25.0
Dec-09	961	32.8
Jan-10	1,091	79.1
Feb-10	864	112.1
Mar-10	649	101.2
Apr-10	355	46.1
May-10	130	18.4
Jun-10	18	5.0
Jul-10	-	-
Aug-10	6	-
Sep-10	28	21.4
Oct-10	298	7.0



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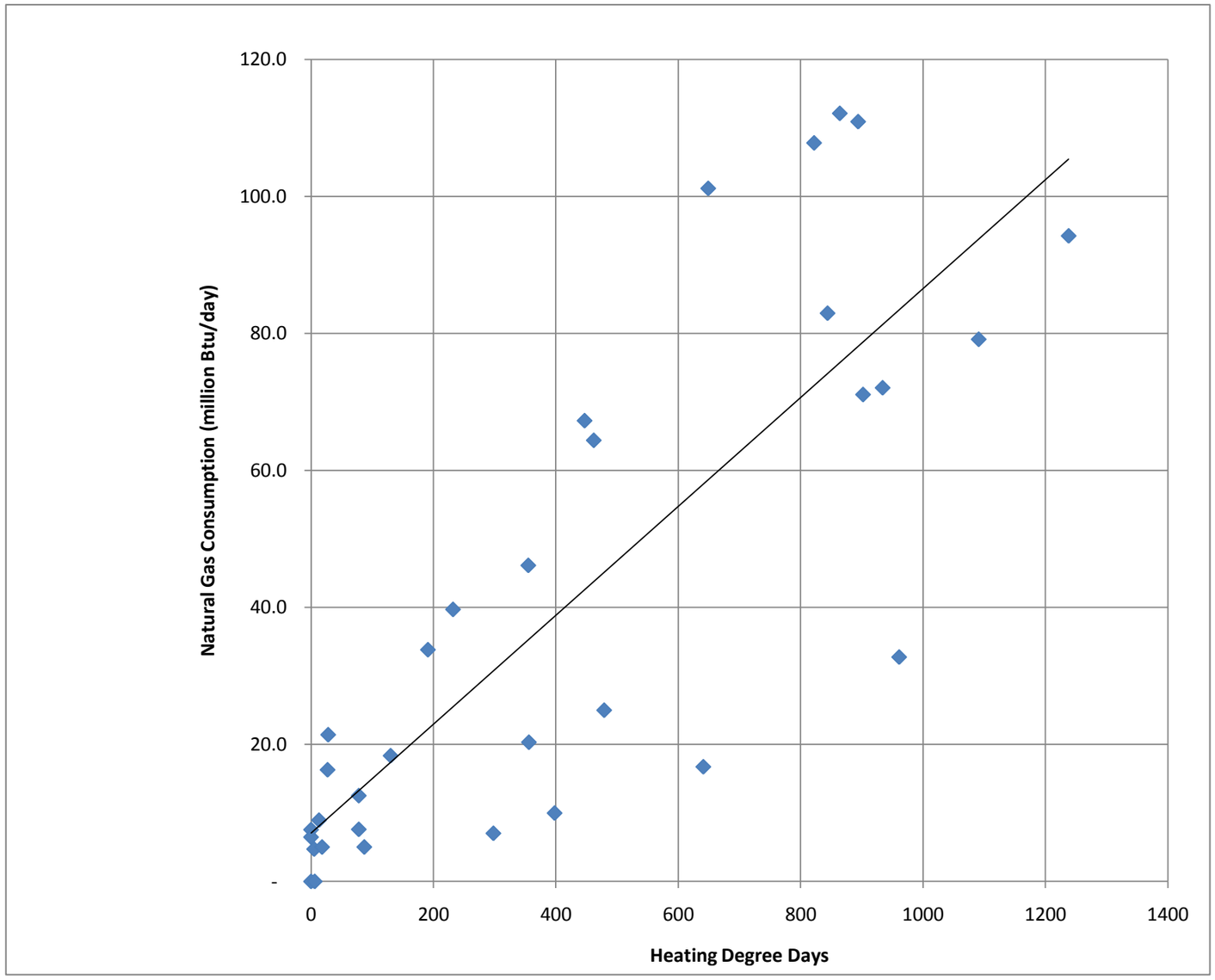
Appendix 9 - Scatter Diagram - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	72.1
Mar-08	822	107.8
Apr-08	462	64.4
May-08	232	39.7
Jun-08	27	16.3
Jul-08	-	7.6
Aug-08	-	6.5
Sep-08	78	7.6
Oct-08	356	20.3
Nov-08	641	16.7
Dec-08	902	71.1
Jan-09	1,238	94.2
Feb-09	894	110.9
Mar-09	844	82.9
Apr-09	447	67.3
May-09	191	33.8
Jun-09	78	12.5
Jul-09	13	8.9
Aug-09	5	4.7
Sep-09	87	5.0
Oct-09	398	10.0
Nov-09	479	25.0
Dec-09	961	32.8
Jan-10	1,091	79.1
Feb-10	864	112.1
Mar-10	649	101.2
Apr-10	355	46.1
May-10	130	18.4
Jun-10	18	5.0
Jul-10	-	-
Aug-10	6	-
Sep-10	28	21.4
Oct-10	298	7.0



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Appendix 10 - Water Consumption

Month	End Date	Number of Days in Cycle	Water Consumption (1000 gallons)	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	7/24/2008	31	739	23.8	320
Aug-08	8/24/2008	30	732	24.4	179
Sep-08	9/23/2008	30	616	20.5	105
Oct-08	10/23/2008	41	504	12.3	10
Nov-08	12/3/2008	34	654	19.2	2
Dec-08	1/6/2009	29	491	16.9	-
Jan-09	2/4/2009	28	280	10.0	-
Feb-09	3/4/2009	30	300	10.0	-
Mar-09	4/3/2009	32	261	8.2	-
Apr-09	5/5/2009	29	291	10.0	30
May-09	6/3/2009	33	356	10.8	57
Jun-09	7/6/2009	30	382	12.7	55
Jul-09	8/5/2009	29	336	11.6	204
Aug-09	9/3/2009	32	355	11.1	289
Sep-09	10/5/2009	30	493	16.4	64
Oct-09	11/4/2009	29	345	11.9	7
Nov-09	12/3/2009	34	275	8.1	2
Dec-09	1/6/2010	28	276	9.9	1
Jan-10	2/3/2010	28	372	13.3	-
Feb-10	3/3/2010	33	349	10.6	-
Mar-10	4/5/2010	30	273	9.1	2
Apr-10	5/5/2010	29	279	9.6	23
May-10	6/3/2010	33	279	8.5	104
Jun-10	7/6/2010	29	257	8.9	205
Jul-10	8/4/2010	30	483	16.1	389
Aug-10	9/3/2010	32	591	18.5	285
Sep-10	10/5/2010	29	582	20.1	170
Oct-10	11/3/2010	31	453	14.6	22

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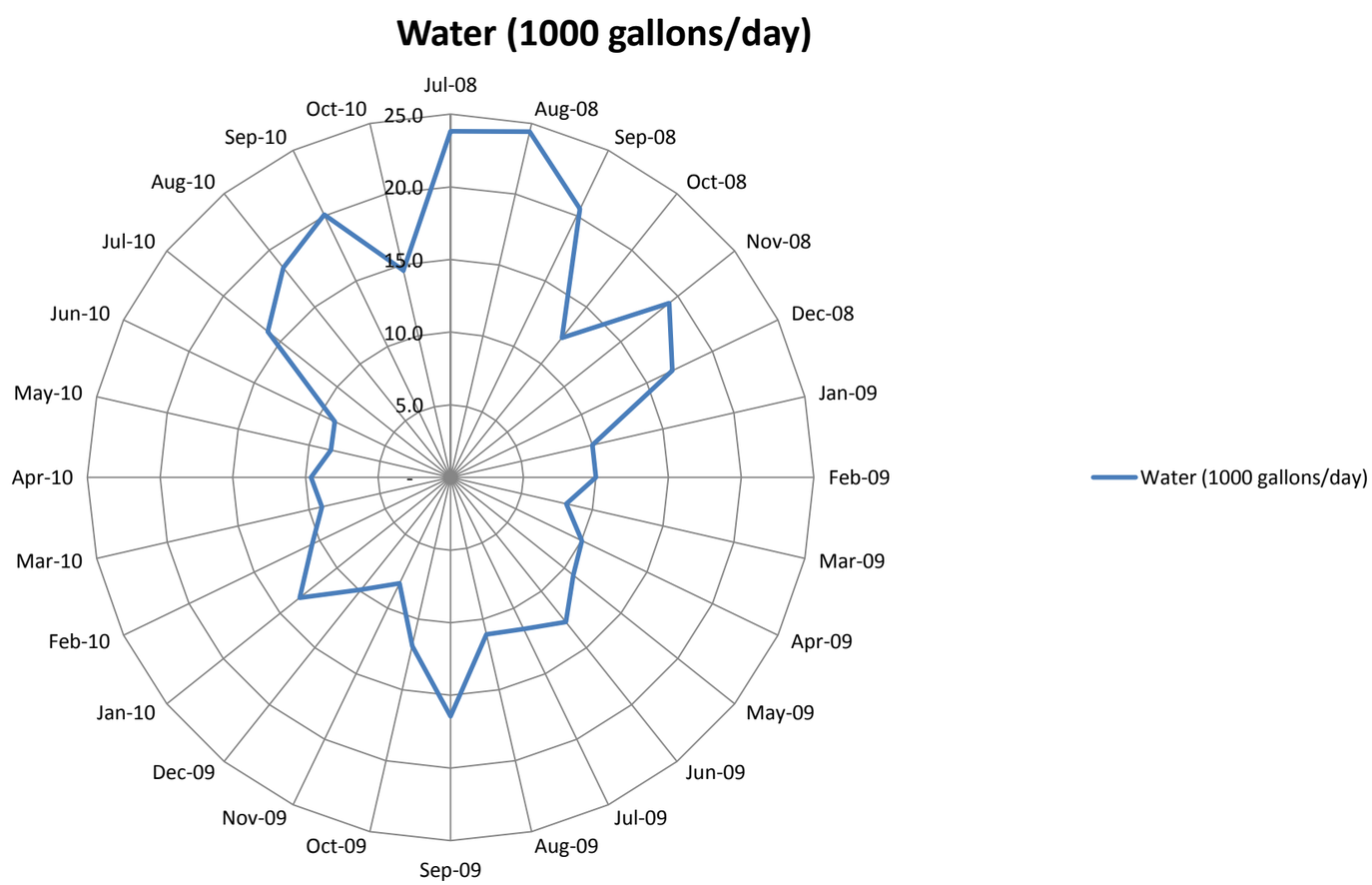
Appendix 11 - Radar Plot of Water Consumption by Month

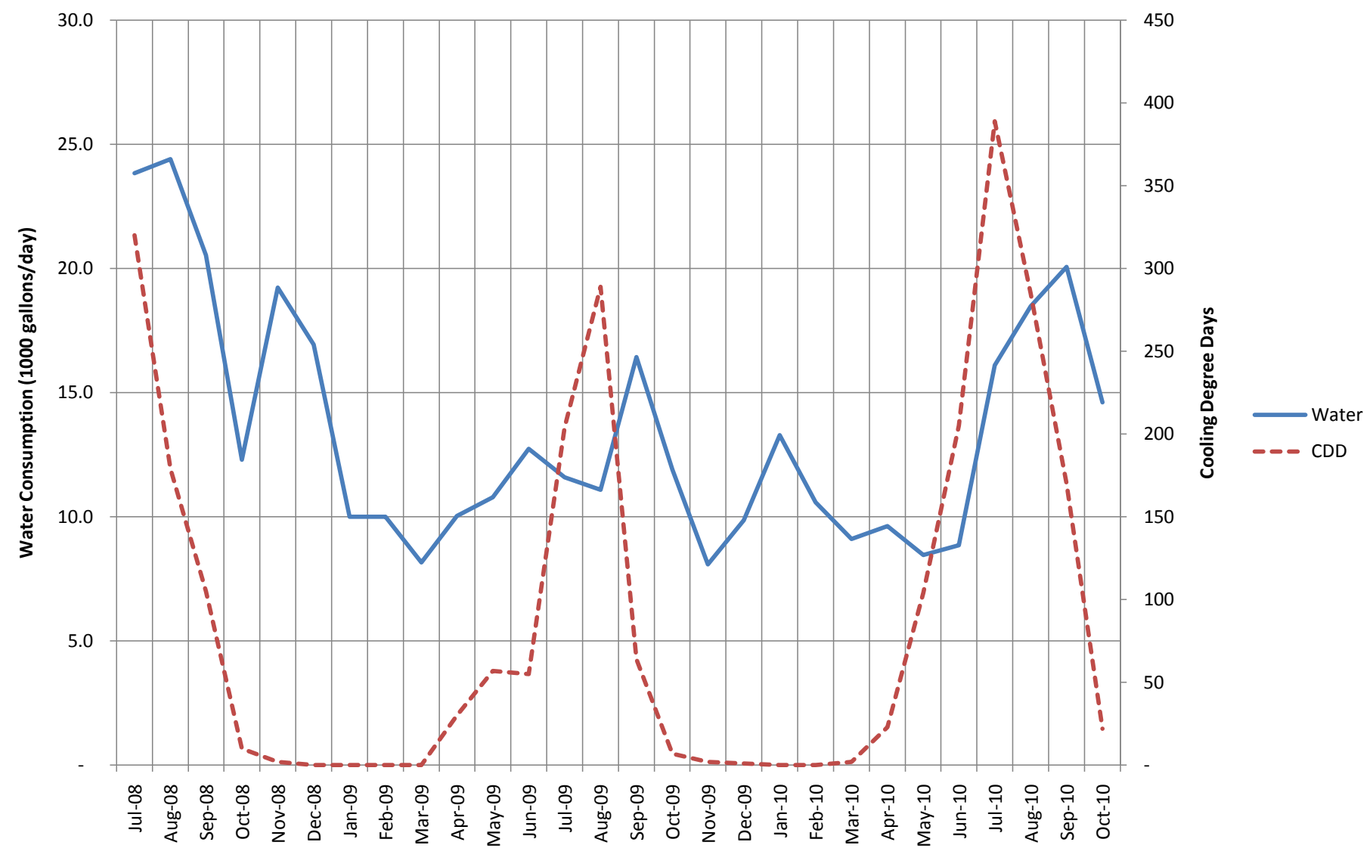
Month	Water Consumption (1000 gallons/day)
Jul-08	23.8
Aug-08	24.4
Sep-08	20.5
Oct-08	12.3
Nov-08	19.2
Dec-08	16.9
Jan-09	10.0
Feb-09	10.0
Mar-09	8.2
Apr-09	10.0
May-09	10.8
Jun-09	12.7
Jul-09	11.6
Aug-09	11.1
Sep-09	16.4
Oct-09	11.9
Nov-09	8.1
Dec-09	9.9
Jan-10	13.3
Feb-10	10.6
Mar-10	9.1
Apr-10	9.6
May-10	8.5
Jun-10	8.9
Jul-10	16.1
Aug-10	18.5
Sep-10	20.1
Oct-10	14.6



Erich Lindemann Building

Appendix 12 - Water Consumption v. Cooling Degree Days

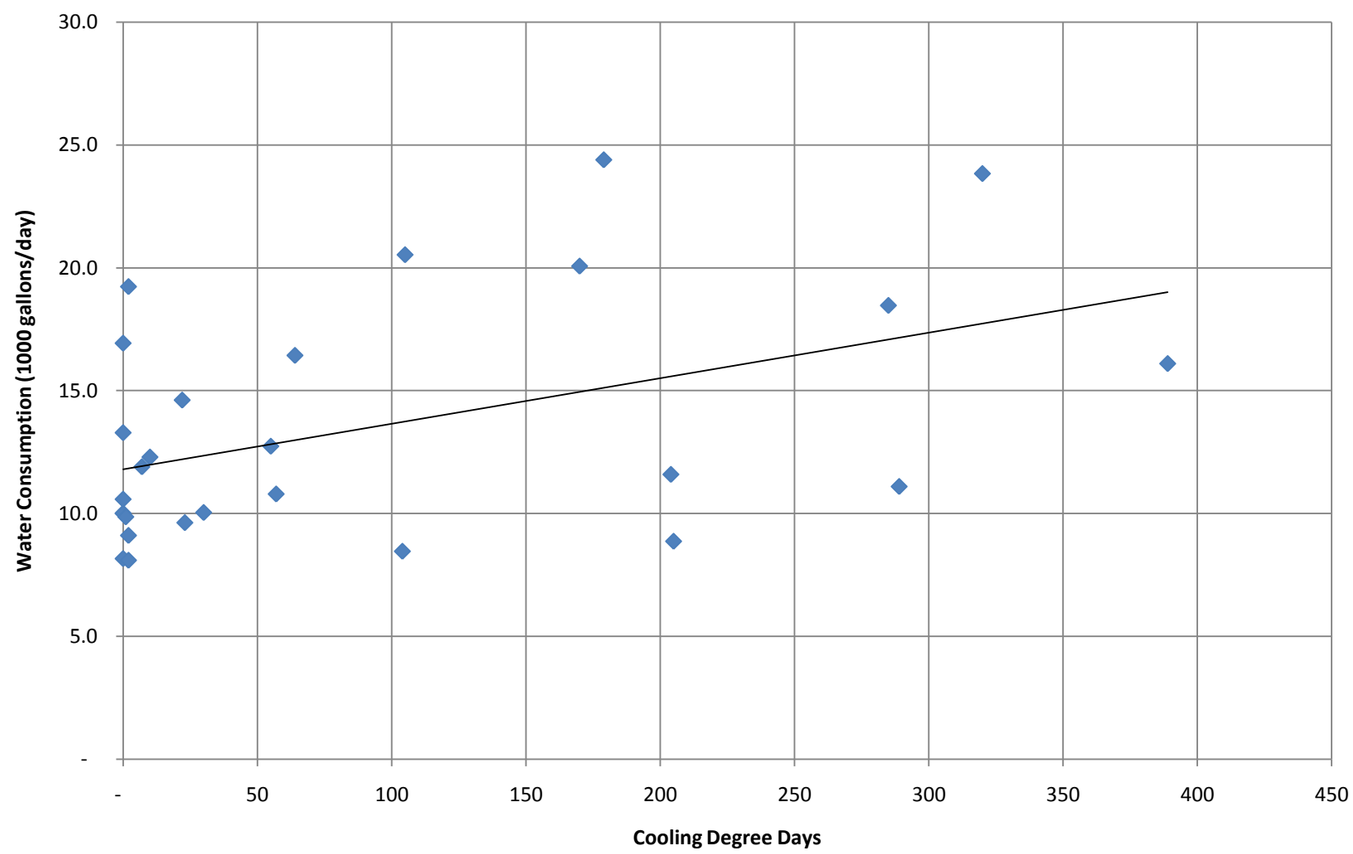
Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	23.8	320
Aug-08	24.4	179
Sep-08	20.5	105
Oct-08	12.3	10
Nov-08	19.2	2
Dec-08	16.9	-
Jan-09	10.0	-
Feb-09	10.0	-
Mar-09	8.2	-
Apr-09	10.0	30
May-09	10.8	57
Jun-09	12.7	55
Jul-09	11.6	204
Aug-09	11.1	289
Sep-09	16.4	64
Oct-09	11.9	7
Nov-09	8.1	2
Dec-09	9.9	1
Jan-10	13.3	-
Feb-10	10.6	-
Mar-10	9.1	2
Apr-10	9.6	23
May-10	8.5	104
Jun-10	8.9	205
Jul-10	16.1	389
Aug-10	18.5	285
Sep-10	20.1	170
Oct-10	14.6	22



Erich Lindemann Building

Appendix 13 - Scatter Diagram - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	23.8	320
Aug-08	24.4	179
Sep-08	20.5	105
Oct-08	12.3	10
Nov-08	19.2	2
Dec-08	16.9	-
Jan-09	10.0	-
Feb-09	10.0	-
Mar-09	8.2	-
Apr-09	10.0	30
May-09	10.8	57
Jun-09	12.7	55
Jul-09	11.6	204
Aug-09	11.1	289
Sep-09	16.4	64
Oct-09	11.9	7
Nov-09	8.1	2
Dec-09	9.9	1
Jan-10	13.3	-
Feb-10	10.6	-
Mar-10	9.1	2
Apr-10	9.6	23
May-10	8.5	104
Jun-10	8.9	205
Jul-10	16.1	389
Aug-10	18.5	285
Sep-10	20.1	170
Oct-10	14.6	22



Erich Lindemann Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition	Remarks
Chiller	CH-1	MER-8	Carrier	19XRV3636332CEH64	Centrifugal	370 tons	2002	23	2025	0.65 kW/ton	-	Good -	Variable-speed
Pump	CHW-P1	MER-8	Weinman	4KB-4A	Centrifugal	950 gpm at 110 feet (40 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	CHW-P2	MER-8	Weinman	4KB-4A	Centrifugal	950 gpm at 110 feet (40 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	CHW-P3	MER-8	Weinman	4KB-4A	Centrifugal	950 gpm at 110 feet (40 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	PCHW-P1	MER-8	Weinman	-	Centrifugal	787 gpm (15 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	PCHW-P2	MER-8	Weinman	-	Centrifugal	787 gpm (15 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	CW-P1	MER-8	Weinman	-	Centrifugal	1180 gpm at 80 feet (20 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	CW-P2	MER-8	Weinman	-	Centrifugal	1180 gpm at 80 feet (20 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P5	MER-2	Taco	-	Centrifugal	10 hp	1990	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P6	MER-2	Taco	-	Centrifugal	10 hp	1990	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P	MER-2	Taco	-	Centrifugal	10 hp	1990	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P	MER-2	Bell and Gossett	-	Centrifugal	50 gpm, 1 hp	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P	MER-2	Bell and Gossett	-	Centrifugal	50 gpm, 1 hp	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P1	MER-2	Weinman	-	Centrifugal	1600 gpm at 100 feet (50 hp)	1971	20	Expected life has been exceeded	-	-	Fair -	-
Pump	HWP-P2	MER-2	Weinman	-	Centrifugal	50 hp	1971	20	Expected life has been exceeded	-	-	Fair -	-
Cooling Tower	CT-1	Roof	Baltimore Aircoil (BAC)	VT1-N370-OR	Forced draft, 1 cell	-	2002	22	2024	-	-	Good -	-
Boiler	B-1 thru B-5	Boiler Room near Loading Dock	Aerco	Benchmark 2.0	Natural gas-fired hot water	2,000,000 Btu/hr output each	2007	22	2029	90%	-	Good -	-
Air Handling Unit	AHU-1	MER-1	Westinghouse	-	-	10 hp	1971	25	Expected life has been exceeded	-	Kitchen	Fair -	-
Air Handling Unit	AHU-2	MER-1	Westinghouse	-	-	30 hp	1971	25	Expected life has been exceeded	-	Mezzanine center and west interior	Fair -	-
AHU-2 return fan	REF-1	MER-1	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair -	-
Air Handling Unit	AHU-3	MER-1	Westinghouse	-	-	1/2 hp	1971	25	Expected life has been exceeded	-	Perimeter classroom	Fair -	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-4	MER-3	Westinghouse	-	-	7-1/2 hp	1971	25	Expected life has been exceeded	-	Mezzanine and gym	Fair - Poor Internal insulation breaking off	-
AHU-4 return fan	REF-2	MER-3	Westinghouse	-	-	3 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair -	-
Air Handling Unit	AHU-5	MER-3	Westinghouse	-	-	3/4 hp	1971	25	Expected life has been exceeded	-	and ground floor interior	Fair - Poor Internal insulation breaking off	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-6	MER-4	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	2nd & 3rd floor plaza west	Fair -	3-way control valves at cooling and preheat coils
AHU-6 return fan	REF-3	MER-4	Westinghouse	-	-	1 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair -	-

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition		Remarks
Air Handling Unit	AHU-7	MER-4	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	2nd & 3rd east perimeter	Fair - Poor	Internal insulation breaking off	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-8	MER-4	Westinghouse	-	-	15 hp	1971	25	Expected life has been exceeded	-	2nd floor east interior	Fair - Poor	-	-
AHU-8 return fan	REF-5	MER-4	Westinghouse	-	-	3 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	AHU-9	MER-6	Westinghouse	-	-	1-1/2 hp	1971	25	Expected life has been exceeded	-	4th floor east perimeter	Fair - Poor	-	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-10	MER-6	Westinghouse	-	-	7-1/2 hp	1971	25	Expected life has been exceeded	-	3rd floor east interior	Fair - Poor	-	3-way control valves at cooling and preheat coils
AHU-10 return fan	REF-6	MER-6	Westinghouse	-	-	3 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	AHU-11	MER-6	Westinghouse	-	-	1-1/2 hp	1971	25	Expected life has been exceeded	-	floor center/east interior	Fair - Poor	-	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-12	MER-6	Westinghouse	-	-	10 hp	1971	25	Expected life has been exceeded	-	All elevator lobbies	Fair - Poor	Tube ends not insulated Air leakage at access door	3-way control valves at cooling and preheat coils
AHU-12 return fan	REF-7	MER-6	Westinghouse	-	-	2 hp	1971	25	Expected life has been exceeded	-	-	Fair	Fan vibration can be felt on the Mech Rm floor	-
Air Handling Unit	AHU-13	MER-7	Westinghouse	-	-	20 hp	1971	25	Expected life has been exceeded	-	4th floor center interior	Fair	Unoccupied AHU zone - Unit not running	3-way control valves at cooling and preheat coils
AHU-13 return fan	REF-8	MER-7	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	Unoccupied AHU zone - Unit not running	-
Air Handling Unit	AHU-14	MER-7	Westinghouse	-	-	30 hp	1971	25	Expected life has been exceeded	-	4th floor center perimeter	Fair	Unoccupied AHU zone - Unit not running	3-way control valves at cooling and preheat coils
AHU-14 return fan	REF-9	MER-7	Westinghouse	-	-	5 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	Unoccupied AHU zone - Unit not running	-
Air Handling Unit	AHU-15	MER-8	McQuay	-	-	5 hp	1990	25	2015	-	4th & 5th floor west interior	Fair	-	3-way control valves at cooling and preheat coils
AHU-15 return fan	REF-11	MER-8	Westinghouse	-	-	3 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	AHU-16	MER-8	Westinghouse	-	-	1 hp	1971	25	Expected life has been exceeded	-	Mezzanine west	Fair	-	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-17	MER-8	Westinghouse	-	-	15 hp	1971	25	Expected life has been exceeded	-	Therapy pool area	Fair	-	-
AHU-17 return fan	REF-12	MER-8	Westinghouse	-	-	3/4 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Air Handling Unit	AHU-18	MER-2A	Westinghouse	-	-	3/4 hp	1971	25	Expected life has been exceeded	-	Switchgear room	Fair	-	Coil connection cut
Air Handling Unit	AHU-19	MER-3	Westinghouse	-	-	1-1/2 hp	1971	25	Expected life has been exceeded	-	PRV Station	Fair	-	-
Air Handling Unit	AHU-20	Room 64	Westinghouse	-	-	2 hp	1971	25	Expected life has been exceeded	-	Room 64	Fair	-	-
Air Handling Unit	AHU-21	MER-2	Westinghouse	-	-	2 hp	1971	25	Expected life has been exceeded	-	MER-2	Fair	-	-
Exhaust Fan	EF-4	MER-3	-	-	-	2 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Exhaust Fan	EF-10	MER-7	-	-	-	1-1/2 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Exhaust Fan	EF-13	MER-8	-	-	-	1 hp	1971	25	Expected life has been exceeded	-	Cage Wash Room	Good-Fair	Fan not running	-
Exhaust Fan	EF-14	Shaft @ 46 & F	-	-	-	5 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-
Exhaust Fan	EF-15	Transformer Vault	-	-	-	3 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair	-	-

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition	Remarks
Exhaust Fan	EF-16	MER-3	-	-	-	1/2 hp	1971	25	Expected life has been exceeded	-	-	Good-Fair -	-
Exhaust Fan	EF-17	5th Floor East Toilet Core	-	-	-	2 hp	1971	25	Expected life has been exceeded	-	-	- -	-

KLING STUBBINS

ARCHITECTURE
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PLANNING

Division of Capital Asset Management (DCAM)

Energy Upgrades – McCormack, Hurley, Lindemann and State House Buildings

Existing Conditions Assessment John W. McCormack Building Final Submittal

Revised May 10, 2012

DCAM Project # DPC1021 ES1

KS Project # 36.7407.00

One Broadway
Cambridge, Massachusetts
02142

P 617.491.6450
F 617.491.7104

John W. McCormack Building
Existing Conditions Assessment

1 Executive Summary

1.1 Study Objectives

The Division of Capital Asset Management (DCAM) retained KlingStubbins to recommend energy-conserving measures (ECM's) as a multi-task project. This report relates to Task 1, which is to assess existing conditions in order to understand the operations and provide a platform for future ECM's.

2 Building Overview

The 23-story John W. McCormack Building houses state offices and support spaces (such as a Plaza-level cafeteria). Construction was completed in 1975. The gross area is 660,000 ft^2; there are four below-grade parking floors. The building has a population of 3,400 people.

The 7th Floor and the 22nd Floor Penthouse are dedicated to mechanical systems. Most of the 8th Floor houses a data center.

Except for the 8th floor, the windows are single-pane.

3 HVAC System Overview

A combination of perimeter induction units and air handling units maintain room environmental conditions and provide outside air. The McCormack Building generates chilled water and heating hot water used by the perimeter induction units and air handling units.

3.1 Supply Air Systems

3.1.1 Description – Perimeter Induction Units

Most perimeter zones use four-pipe induction units located under windows. The induction units are supplied with 55°F high pressure air from air handling units AHU-1 through 4. Nozzles inside the induction unit use the high pressure supply (primary) air to create a low pressure zone, which induces room air into the unit. This room (secondary) air passes over a coil, which heats or cools room air to maintain room temperature.

The induction unit coils are supplied with either chilled water or heating hot water.

Primary air is also the source for ventilation air for perimeter zones. Air distribution to the induction units is constant-volume, manually-balanced.

Air handling units AHU-1 through 4 supplying the induction units were manufactured by Buffalo and installed in 1975. The supply fans use standard-efficiency motors, are belt-driven with trapezoidal-cross section belts.

The supply fans are constant-speed and were originally controlled through variable inlet vanes. However, many of these devices are no longer functional.

3.1.2 Mode of Operation – Perimeter Induction Units

Local thermostats modulate the coil control valve to maintain room temperature.

Supply air temperatures from AHU-1 through 4 are adjusted as a function of outside air temperature and solar heat gain.

Cooling coil control valves at AHU-1 through 4 are the 3-way type: chilled water either runs through the coil or bypasses the coil.

Preheat coil control valves at AHU-1 through 4 are the 3-way type: heating hot water either runs through the coil or bypasses the coil.

No demand-controlled ventilation is used to reduce airflow during unoccupied modes.

Air handling units AHU-1 through 4 and the perimeter induction units operate continuously.

3.1.3 Description – Interior Air Handling Units

Air handling units AHU-5 through 16 supply interior zones of the McCormack Building: the units mix outside air and return air, then filter and cool the air before it is supplied to the interior zones. Chilled water generated in the McCormack Building is the thermal medium for the cooling coils.

Only air handling units AHU-14 and 15 use preheat coils to heat mixed air to meet the supply air temperature setpoint. Heating hot water generated in the McCormack Building is the thermal medium for the preheat coils. The mixed air temperature in the other air handling units is greater than the supply air temperature, so preheat is not required.

The air handling units supplying interior zones were manufactured by Buffalo and installed in 1975. The supply and return fans use standard-efficiency motors and are belt-driven with trapezoidal-cross section belts.

The supply and return fans are constant-speed and were originally controlled through variable inlet vanes. However, many of these devices are no longer functional.

About 80% of air is distributed to interior zones through variable air volume (VAV)

boxes: as the room temperature sensor rises above setpoint, a damper in the VAV opens to maintain room temperature setpoint.

The remaining 20% of air is distributed to interior zones through constant volume boxes.

The air handling units have airside economizer capability, in which outside air is uses outside air to produce 55°F supply air directly (i.e., without mechanical refrigeration) during shoulder seasons. However, some air handling units do not have operational economizer cycles because the dampers are frozen in place, or because of control system deficiencies.

3.1.4 Mode of Operation – Interior Air Handling Units

Cooling coil control valves for AHU-5 through 16 are the 3-way type: chilled water either runs through the coil or bypasses the coil.

Preheat coil control valves for AHU-5 through 16 are the 3-way type: heating hot water either runs through the coil or bypasses the coil.

Supply air temperatures are adjusted as a function of outside air temperature and solar heat gain.

Air handling units AHU-15 and 16 operate continuously. The remaining air handling

units generally operate from 6am to 6pm.

As part of renovation projects, conference rooms have been retrofitted with carbon dioxide-based demand-controlled ventilation to reduce airflow during unoccupied modes.

3.2 Heating Hot Water System Description

Heating hot water is generated by 13 natural gas-fired boilers located in the 22nd Floor Penthouse. The boilers are the condensing type manufactured by Aerco and each has a capacity of 2,000,000 Btu/hr; they were installed in 2009.

Condensing type boilers cool flue gas with return heating hot water to below the dewpoint, which increases efficiency by recovering the latent enthalpy of vaporization.

Three 40 hp pumps (HWP-9, 32 and 33) circulate water between the boilers and the terminal devices. Two pumps are variable-speed, have high-efficiency motors and were manufactured by Taco and installed in 2006. One pump is constant-speed, has a standard-efficiency motor and was manufactured by Allis Chalmers and installed in 1975.

One 40 hp pump (HWP-21) circulates heating hot water to low-rise induction units. The

pump is constant-speed, was manufactured by Allis Chalmers and installed in 1975.

3.2.1 Heating Hot Water Mode of Operation

Heating hot water supply temperature is maintained in the range of 110°F to 180°F, based on a reset schedule with outside air temperature: as outside air temperature increases, the heating hot water supply temperature is reduced.

3.3 Chilled Water System Description

Five water-cooled chillers in the 22nd Floor Penthouse provide chilled water to induction units and air handling units:

- CH-1: 650-ton constant-speed electric centrifugal machine, manufactured by Carrier and installed in 1996.
- CH-2: 550-ton constant-speed electric centrifugal machine, manufactured by Carrier and installed in 1996.
- CH-3: 450-ton variable-speed electric centrifugal machine, manufactured by Carrier and installed in 1999.
- CH-4 and 5: 400-ton natural gas-fired absorption chillers, manufactured by York and installed in 2004.

The two absorption chillers are base-loaded; the electric machines are dispatched to meet cooling load after the absorption chillers can no longer satisfy the demand.

Two 125 hp Taco double-suction pumps (CHWP-1 and 3) circulate chilled water from the chillers to the air handling units in the 22nd Floor Penthouse and the 7th Floor Mechanical Room. These pumps are controlled through variable frequency drives and were installed in 2006. The pumps have high-efficiency motors.

Chilled water is supplied to the low-rise induction units by three (two active, one standby) 40 hp pumps (CHWP-19, 20 and 21). The pumps have standard-efficiency motors, were manufactured by Allis-Chalmers and installed in 1975. Two pumps are active; one is standby.

Chilled water to the 8th Floor induction units are supplied by three 3 hp pumps (CHWP-16, 17 and 18). The pumps have standard-efficiency motors, were manufactured by

Allis-Chalmers and installed in 1975.

Condenser water is generated by three induced-draft cooling towers mounted on the roof. Two towers are 3-cell; one tower is a single cell. The cooling towers were manufactured by Baltimore Aircoil (BAC) and installed in 2006. Cooling tower fans are controlled by variable frequency drives to maintain the 85°F condenser water supply temperature setpoint.

Three 150 hp variable-speed pumps (CWP-4, 5 and 6) in the 22nd Floor Penthouse circulate condenser water between the condensers and the cooling towers. The pumps have high-efficiency motors and were manufactured by Aurora and installed in 2006. Two pumps are active; one is standby.

A plate-and-frame heat exchanger uses condenser water to produce chilled water in the winter, allowing mechanical refrigeration systems to be deenergized.

3.3.1 Chilled Water System Mode of Operation

When the outside air temperature is between 30°F and 50°F, one absorption chiller provides chilled water to the data center and to interior zones, where air handling units do not have operational economizer cycles.

When outside air temperature is below 30°F, the chillers are deenergized and the plate-and-frame heat exchanger is used to generate chilled water by heat exchange with cooling tower water.

3.4 Special Areas

3.4.1 Kitchen

AHU-14 supplies air to the kitchen and cafeteria. This unit is constant-volume, 100% outside air. The kitchen is exhausted by a 30 hp fan; the fan is constant-speed with a standard-efficiency motor, installed in 1975.

3.4.2 Toilet Exhaust System

Three fans exhaust the toilet cores: (2) 71/2 hp and (1) 15 hp. There is no exhaust air heat recovery. The fans are constant-speed with standard-efficiency motors, installed

in 1975. The fans are belt-driven with trapezoidal-cross section belts.

3.4.3 Parking Garage Exhaust System Description

Seven fans, ranging from 3 to 15 hp, exhaust the underground parking garages. The fans are constant-speed with standard-efficiency motors, installed in 1975. The fans are staged on, based on carbon monoxide concentration.

3.4.4 Data Center

A sixth chiller (CH-6), a Carrier machine located on the 7th Floor was originally dedicated to the 8th Floor data center. Replacement of this unit is currently in process; meanwhile the data center load is being satisfied using the main (house) chiller arrangement or free-cooling heat exchangers through piping cross-connects.

Chilled water is distributed to the data center by two 25 hp Taco pumps installed in 2006.

4 Domestic Cold and Hot Water

4.1.1 Plumbing Fixtures

Most toilets were rated at 1.6 gallons per flush (gpf), urinals were rated to 1.0 gpf and lavatory faucets were rated at 0.5 gallons per minute (gpm). Low-flow fixtures are installed as fixtures are replaced.

4.1.2 Domestic Hot Water Generation

Domestic hot water is generated in a heating hot water-to-domestic water heat exchanger.

5 Building Automation System (BAS) Description

Johnson Controls Inc. (JCI) is the BAS supplier for this building; the building has multiple hardware and software platforms that have been implemented over the years.

The building originally used pneumatic controllers. Over the years, various parts of the building were upgraded to newer JCI controllers and devices. Electric-to-pneumatic (E-P) transducers have been used to provide direct digital control (DDC) of pneumatic actuators. Not every HVAC unit is under DDC control.

The Master Operator Workstation (OWS) head end personal computer (PC) is located in the Command Center of the McCormack Building. Other OWS are located in the Hurley and State House buildings. The master OWS, however, contains the primary programming database and corresponding backup and system restore functions.

Most end devices (dampers and valves) use pneumatic actuation.

The chiller upgrade for the 8th Floor data center has been specified to use BACnet open protocol.

6 Utility Consumption Analysis

6.1 Energy Use Intensity and Benchmarking

The energy use intensity (EUI) is defined as the energy consumption (in units of million Btu) divided by the gross building area (ft^2). This provides a metric to compare one building versus peer facilities, since databases sorted geographically and by building type exist.

The EUI for the McCormack Building is 139,076 Btu/ft^2-year. The US Energy Information Agency has developed a database (the Commercial Building Energy Consumption Survey) of EUI's for thousands of office buildings. Although the database was last updated in 2003, the database is still a good resource because it is so largely populated. As a comparison to other CBECS data points:

- The mean EUI for commercial buildings in the New England census region was 127,600 Btu/ft^2-year.
- The mean EUI for commercial buildings larger than 500,000 gross square feet (gsf) was 141,200 Btu/ft^2-year.
- The mean EUI for office buildings in the New England census region was 94,000 Btu/ft^2-year.

6.2 Electricity Consumption Analysis

Thirty months (July 2008 through December 2010) of electricity demand and consumption billing information was analyzed.

The facility purchases electricity from Direct Energy with NStar serving as the power delivery service. The tariff is Rate B7-NEMA LG, General Time of Use (TOU).

Electricity consumption information was provided from billing information. The billing-cycle consumption (kWh/billing cycle) was divided by the number of days in the billing cycle to create an average daily electricity consumption (kWh/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 1. This average daily electricity consumption was plotted against month on a radar-type chart (Appendix 2). The radar plot showed consumption peaks in the summer months (July 2008, August 2009 and July 2010), suggesting that loads related to air-conditioning drive

electricity consumption.

This hypothesis was tested by correlating cooling degree days against electricity consumption. Cooling degree days are a single-measure, simplified means of characterizing outside air temperature data. Cooling degree days are a measure of how much (in degrees F) and for how long (in days), outside air temperature was higher than a base temperature (65°F).

Actual cooling degree day information was obtained for the same timeframe as the electricity consumption data. The cooling degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Electricity consumption data was plotted against the cooling degree day data (Appendix 3). The electricity consumption and cooling degree day values peak in the same summer months.

The correlation coefficient, which measures the linear relationship between two variables: the correlation coefficient ranges between 1 and -1. A value of 1 means that if one variable increases, the other variable increases linearly. A value of -1 means that if one variable increases, the other variable decreases linearly. A value of 0 means there is no linear correlation between the two variables.

Electricity consumption and cooling degree days have a correlation coefficient of 0.85, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 4) confirms the strong relationship.

Power demand (kW) for each month was plotted against time (Appendix 5): this confirms that electricity demand is driven by air-conditioning equipment.

The electricity load factor (ELF) is defined as the ratio between the average daily use and the maximum possible use if the peak demand operated for a 24 hour period. This factor was calculated as 0.56.

The seasonally-adjusted electricity load factor (SELF) is the electricity load factor

calculated over the cooling season.

This factor was calculated as 0.88 (2009) and 0.77 (2010).

The occupancy factor is defined as the percentage of time that the building is occupied. This office building is occupied 6am to 6pm for five days per week, the occupancy factor is 0.36.

If the ELF is much greater than the OF, that implies that equipment or lighting operates when the building is unoccupied.

The conclusions of this billing-information analysis are:

- Although air-conditioning drives electricity consumption, baseload consumption (receptacles and lighting) still represent a target for energy-conservation measures.
- Operation of HVAC equipment, lights and receptacles during unoccupied hours represents an energy-reduction target.

6.3 Natural Gas Consumption Analysis

Thirty-three months (February 2008 through October 2010) of natural gas consumption billing information was analyzed.

The facility purchases natural gas from Hess Energy with National Grid serving as the natural gas delivery service. The tariff is Rate G-42T, Commercial Heating.

Natural gas consumption information was provided from billing information. The billing-cycle consumption (10^6 Btu/billing cycle) was divided by the number of days in the billing cycle to create an average daily natural gas consumption (10^6 Btu/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 6. This average daily consumption was plotted against month on a radar-type chart (Appendix 7). The radar plot showed consumption peaks in the winter months, suggesting that heating-related loads drive natural gas consumption.

This hypothesis was tested by correlating heating degree days against natural gas consumption. Heating degree days are a single-measure, simplified means of

characterizing outside air temperature data. Heating degree days are defined as the difference between a base temperature (65°F) and the average temperature (maximum temperature – minimum temperature) for each day; degree days are accumulated over a heating season.

Actual heating degree day information was obtained for the same timeframe as the natural gas consumption data. The heating degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Natural gas consumption data was plotted against the heating degree day data (Appendix 8). The natural gas consumption and heating degree day values peak in the same winter months.

Natural gas consumption and heating degree days have a correlation coefficient of 0.79, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 9) confirms the strong relationship.

The conclusion of this billing-information analysis is that heating use reduction is critical to reducing natural gas consumption.

6.4 Water Consumption Analysis

Twenty-eight months (July 2008 through October 2010) of water consumption billing information was analyzed.

The facility purchases water from the Boston Water and Sewer Commission.

Water consumption information was provided from billing information. The billing-cycle consumption (thousand gallons/billing cycle) was divided by the number of days in the billing cycle to create an average daily water consumption (1000 gallons/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 10. This average daily water consumption was plotted against month on a radar-type chart (Appendix 11). The radar plot showed consumption peaks in the summer months, suggesting that cooling tower-related loads drive water consumption.

This hypothesis was tested by correlating cooling degree days against water

consumption.

Water consumption data was plotted against the cooling degree day data (Appendix 12). The water consumption and cooling degree day values peak in the same summer months.

Water consumption and cooling degree days have a correlation coefficient of 0.88, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 13) confirms the strong relationship.

The conclusion of this billing-information analysis is:

- Although cooling tower use drives water consumption, baseload consumption (toilets and lavatories) still represent a target for reduction measures.

7 Existing Equipment Matrix

An Existing Equipment Matrix is included as Appendix 14. Central plant equipment (chillers, cooling towers and boilers) have been recently replaced, but areas of concern are support equipment (pumps) and air handling units.

For each piece of equipment, the matrix identifies the year of installation and the median life. Median life data was taken from two sources:

- Chapter 37 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) "HVAC Applications" Handbook, 2011 edition, lists median service lives for mechanical equipment.
- ASHRAE "Owning and Operating Cost Database" (available at ashrae.org) has compiled a database of 345 buildings, including life of mechanical equipment at the time of replacement.

The cost of maintenance of HVAC equipment is reported as part of the ASHRAE "Owning and Operating Cost Database". This information is reported by building type and geographic location, but not for specific pieces of equipment. The database reports a mean HVAC equipment maintenance cost of $0.494/ft^2, or $326,100 for this type of facility. However, this information has a standard deviation of $0.217/ft^2 ($143,200), which implies there is a large variation in these values.

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Appendix 1 - Electricity Consumption Data

	Consumption (kWh) - Offpeak	Consumption (kWh) - Onpeak	Consumption (kWh) - Total	Cooling Degree Days	Days/Month	Average elec Consumption per day (kWh/day)	Demand (kW)
Jul-08	1,191,987	660,013	1,852,000	320	30	61,733	3,741
Aug-08	1,151,773	601,987	1,753,760	179	29	60,474	3,678
Sep-08	1,085,183	594,257	1,679,440	105	32	52,483	3,621
Oct-08	576,523	685,397	1,261,920	10	30	42,064	3,279
Nov-08	610,611	648,909	1,259,520	2	32	39,360	2,913
Dec-08	572,839	670,361	1,243,200	-	30	41,440	2,921
Jan-09	704,717	695,443	1,400,160	-	30	46,672	2,923
Feb-09	639,083	694,357	1,333,440	-	32	41,670	2,967
Mar-09	536,973	682,707	1,219,680	-	29	42,058	2,983
Apr-09	542,712	686,408	1,229,120	30	30	40,971	3,519
May-09	631,356	695,604	1,326,960	57	32	41,468	3,376
Jun-09	749,352	579,208	1,328,560	55	29	45,812	3,589
Jul-09	858,194	639,806	1,498,000	204	30	49,933	3,629
Aug-09	1,033,789	636,851	1,670,640	289	31	53,892	3,649
Sep-09	972,484	582,476	1,554,960	64	30	51,832	3,490
Oct-09	583,786	659,174	1,242,960	7	30	41,432	2,966
Nov-09	548,519	638,521	1,187,040	2	32	37,095	2,990
Dec-09	609,436	673,364	1,282,800	1	30	42,760	2,855
Jan-10	783,200	680,640	1,463,840	-	32	45,745	2,855
Feb-10	716,738	695,902	1,412,640	-	30	47,088	2,868
Mar-10	624,978	658,382	1,283,360	2	29	44,254	2,925
Apr-10	640,564	699,836	1,340,400	23	33	40,618	3,559
May-10	665,477	719,643	1,385,120	104	29	47,763	3,659
Jun-10	918,984	579,016	1,498,000	205	29	51,655	3,584
Jul-10	1,186,828	629,972	1,816,800	389	32	56,775	3,583
Aug-10	1,031,392	598,688	1,630,080	285	29	56,210	3,556
Sep-10	953,196	604,164	1,557,360	170	30	51,912	3,563
Oct-10	778,556	721,674	1,500,230	22	32	46,882	3,466
Nov-10	621,884	692,596	1,314,480	-	31	42,403	2,992
Dec-10	630,674	637,406	1,268,080	-	30	42,269	2,780

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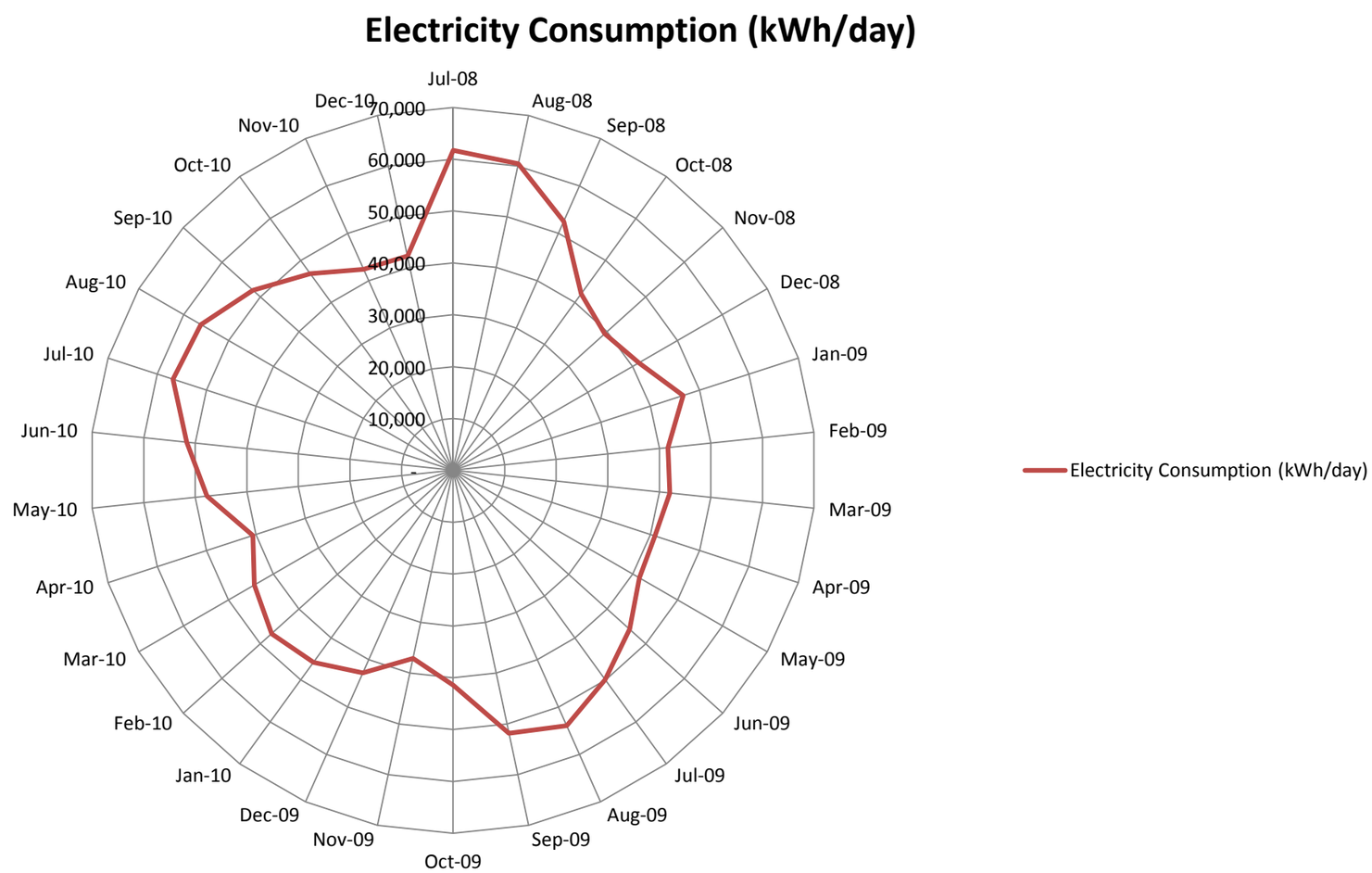
Appendix 2 - Radar Plot of Electricity Consumption by Month

	Average elec Consumption per day (kWh/day)
Jul-08	61,733
Aug-08	60,474
Sep-08	52,483
Oct-08	42,064
Nov-08	39,360
Dec-08	41,440
Jan-09	46,672
Feb-09	41,670
Mar-09	42,058
Apr-09	40,971
May-09	41,468
Jun-09	45,812
Jul-09	49,933
Aug-09	53,892
Sep-09	51,832
Oct-09	41,432
Nov-09	37,095
Dec-09	42,760
Jan-10	45,745
Feb-10	47,088
Mar-10	44,254
Apr-10	40,618
May-10	47,763
Jun-10	51,655
Jul-10	56,775
Aug-10	56,210
Sep-10	51,912
Oct-10	46,882
Nov-10	42,403
Dec-10	42,269



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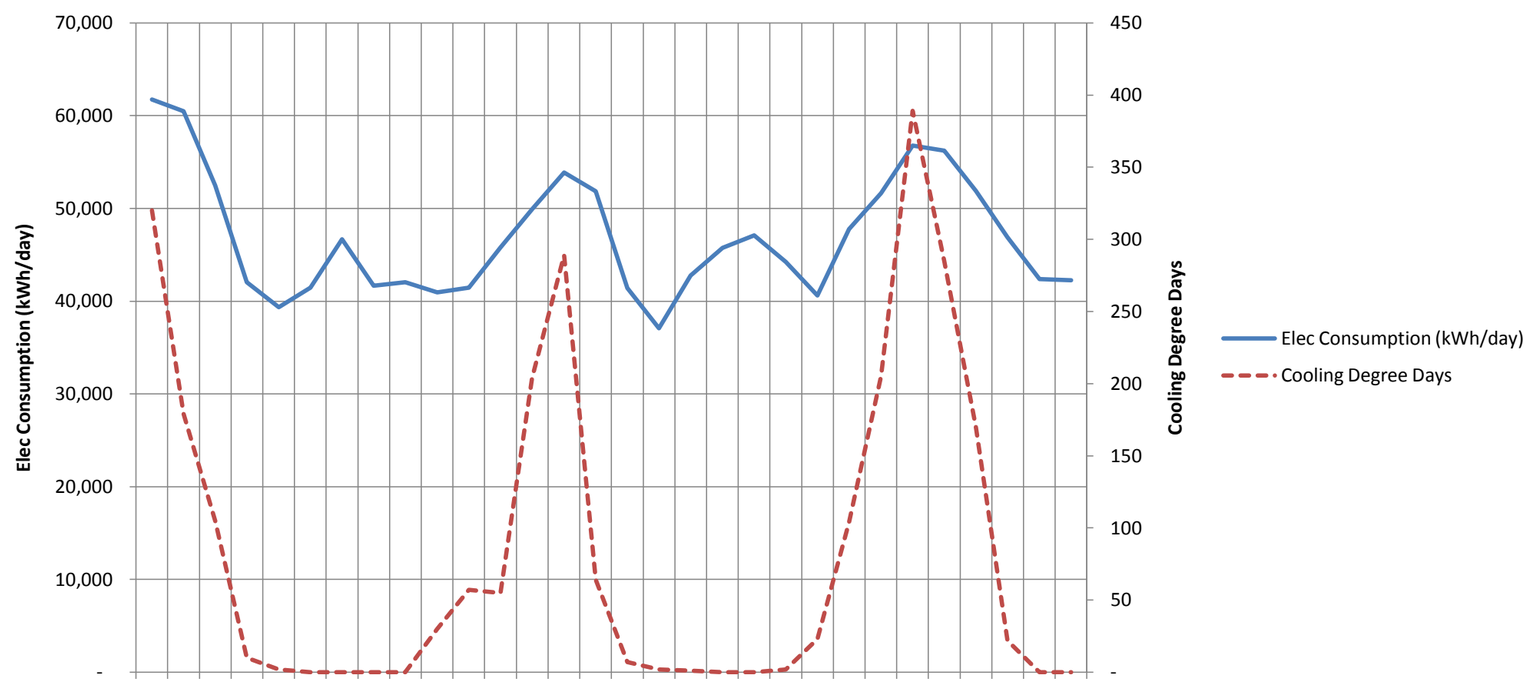
Appendix 3 - Electricity v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	61,733
Aug-08	179	60,474
Sep-08	105	52,483
Oct-08	10	42,064
Nov-08	2	39,360
Dec-08	-	41,440
Jan-09	-	46,672
Feb-09	-	41,670
Mar-09	-	42,058
Apr-09	30	40,971
May-09	57	41,468
Jun-09	55	45,812
Jul-09	204	49,933
Aug-09	289	53,892
Sep-09	64	51,832
Oct-09	7	41,432
Nov-09	2	37,095
Dec-09	1	42,760
Jan-10	-	45,745
Feb-10	-	47,088
Mar-10	2	44,254
Apr-10	23	40,618
May-10	104	47,763
Jun-10	205	51,655
Jul-10	389	56,775
Aug-10	285	56,210
Sep-10	170	51,912
Oct-10	22	46,882
Nov-10	-	42,403
Dec-10	-	42,269



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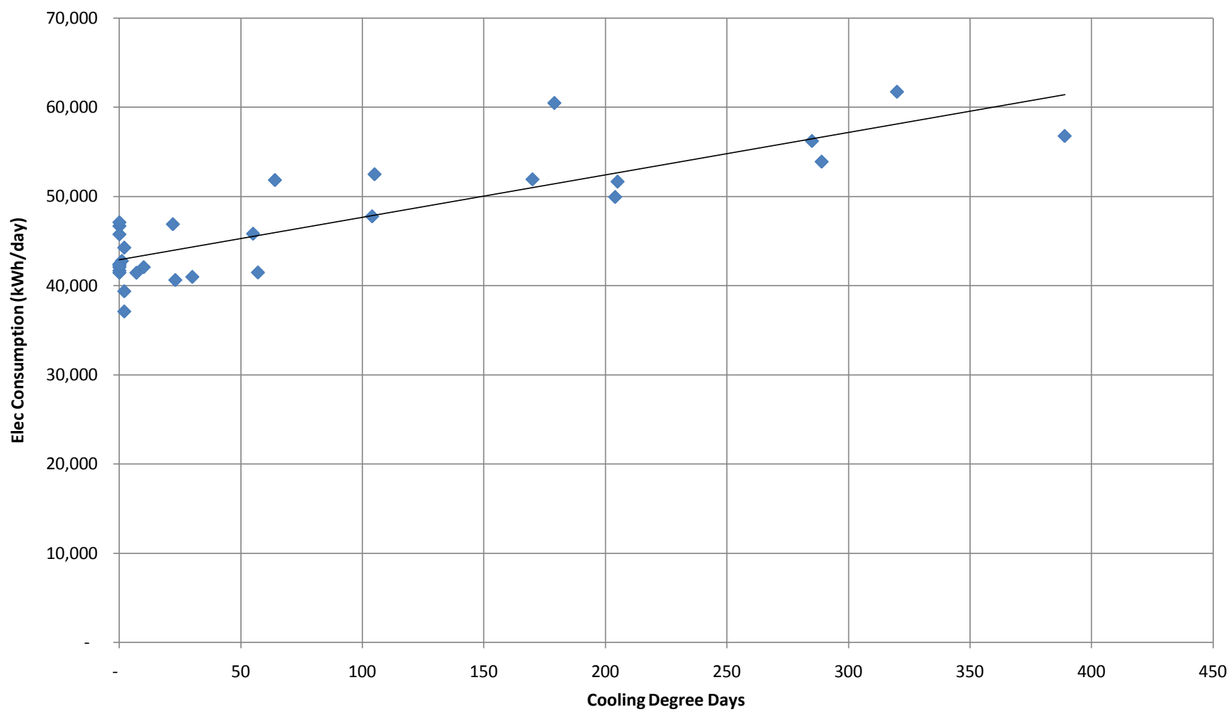
Appendix 4 Scatter Diagram: Electric Consumption v. Cooling Degree Days

	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	61,733
Aug-08	179	60,474
Sep-08	105	52,483
Oct-08	10	42,064
Nov-08	2	39,360
Dec-08	-	41,440
Jan-09	-	46,672
Feb-09	-	41,670
Mar-09	-	42,058
Apr-09	30	40,971
May-09	57	41,468
Jun-09	55	45,812
Jul-09	204	49,933
Aug-09	289	53,892
Sep-09	64	51,832
Oct-09	7	41,432
Nov-09	2	37,095
Dec-09	1	42,760
Jan-10	-	45,745
Feb-10	-	47,088
Mar-10	2	44,254
Apr-10	23	40,618
May-10	104	47,763
Jun-10	205	51,655
Jul-10	389	56,775
Aug-10	285	56,210
Sep-10	170	51,912
Oct-10	22	46,882
Nov-10	-	42,403
Dec-10	-	42,269



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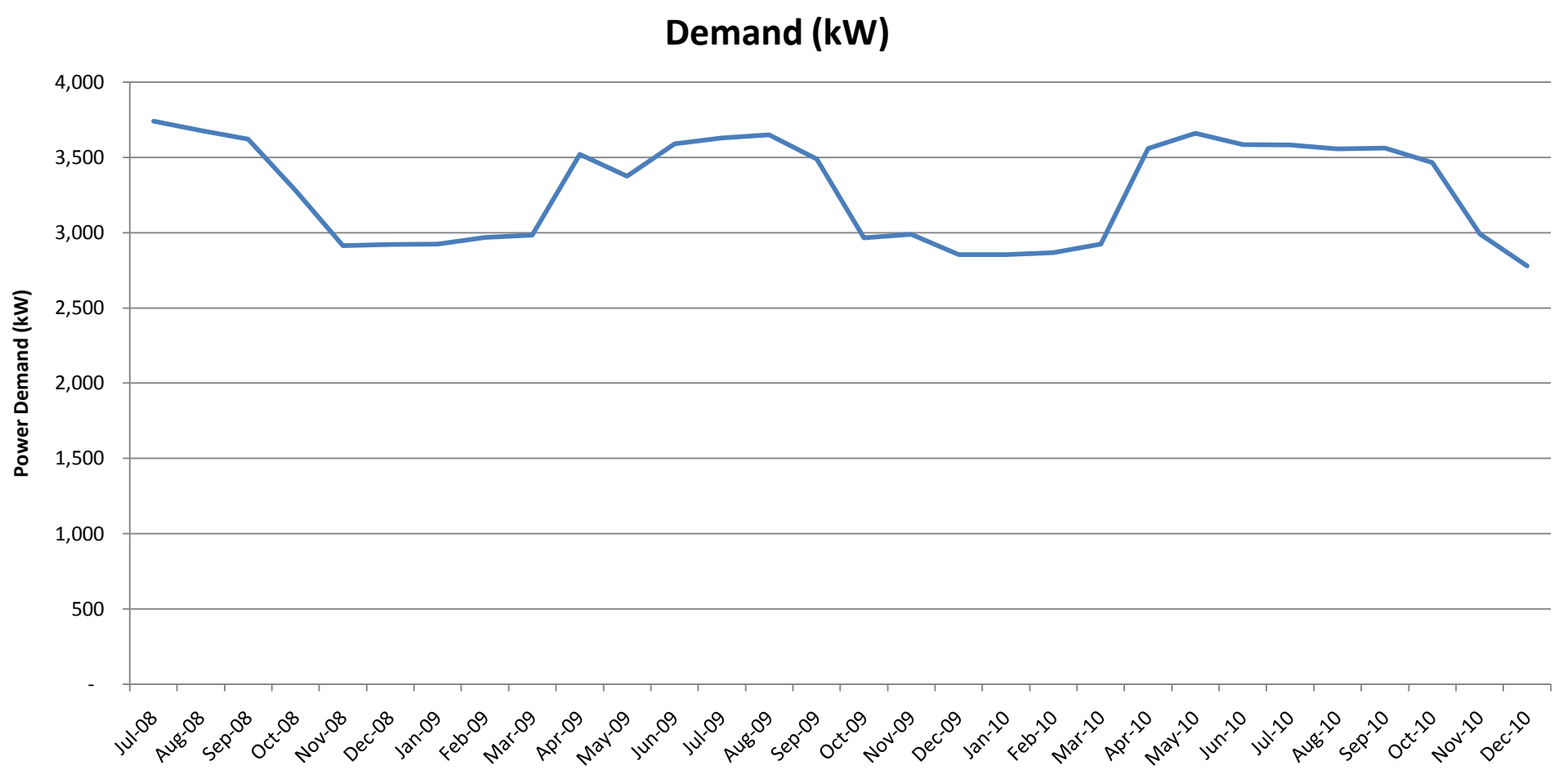
Appendix 5: Power Demand

	Demand (kW)
Jul-08	3,741
Aug-08	3,678
Sep-08	3,621
Oct-08	3,279
Nov-08	2,913
Dec-08	2,921
Jan-09	2,923
Feb-09	2,967
Mar-09	2,983
Apr-09	3,519
May-09	3,376
Jun-09	3,589
Jul-09	3,629
Aug-09	3,649
Sep-09	3,490
Oct-09	2,966
Nov-09	2,990
Dec-09	2,855
Jan-10	2,855
Feb-10	2,868
Mar-10	2,925
Apr-10	3,559
May-10	3,659
Jun-10	3,584
Jul-10	3,583
Aug-10	3,556
Sep-10	3,563
Oct-10	3,466
Nov-10	2,992
Dec-10	2,780



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Appendix 6 - Natural Gas Consumption

	Usage Begin Date	Consumption (therms)	Consumption (10^6 Btu)	Heating Degree Days	Days/Month	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	2/7/2008	43,724	4,372	934	32	136.6
Mar-08	3/10/2008	56,431	5,643	822	28	201.5
Apr-08	4/7/2008	32,011	3,201	462	30	106.7
May-08	5/7/2008	30,056	3,006	232	54	55.7
Jun-08	6/30/2008	4,741	474	27	38	12.5
Jul-08			-	-	30	-
Aug-08	8/7/2008	3,295	330	-	32	10.3
Sep-08	9/8/2008		-	78	30	-
Oct-08	10/8/2008	9,823	982	356	27	36.4
Nov-08	11/4/2008	4,988	499	641	34	14.7
Dec-08	12/8/2008	24,592	2,459	902	30	82.0
Jan-09	1/7/2009	40,055	4,006	1,238	30	133.5
Feb-09	2/6/2009	54,260	5,426	894	28	193.8
Mar-09	3/6/2009	47,128	4,713	844	31	152.0
Apr-09	4/6/2009	28,154	2,815	447	30	93.8
May-09	5/6/2009	16,202	1,620	191	30	54.0
Jun-09	6/5/2009	10,334	1,033	78	63	16.4
Jul-09			-	13	30	-
Aug-09	8/7/2009	862	86	5	33	2.6
Sep-09	9/9/2009	425	43	87	30	1.4
Oct-09	10/9/2009	4,753	475	398	27	17.6
Nov-09	11/5/2009	29,597	2,960	479	32	92.5
Dec-09	12/7/2009	30,417	3,042	961	32	95.1
Jan-10	1/8/2010	74,951	7,495	1,091	32	234.2
Feb-10	2/9/2010	58,647	5,865	864	28	209.5
Mar-10	3/9/2010	70,300	7,030	649	28	251.1
Apr-10	4/6/2010	39,052	3,905	355	31	126.0
May-10	5/7/2010	15,021	1,502	130	31	48.5
Jun-10	6/7/2010	7,892	789	18	31	25.5
Jul-10	7/8/2010	14,861	1,486	-	27	55.0
Aug-10	8/4/2010	2,495	250	6	35	7.1
Sep-10	9/8/2010	3,298	330	28	28	11.8
Oct-10	10/6/2010	11,561	1,156	298	31	37.3

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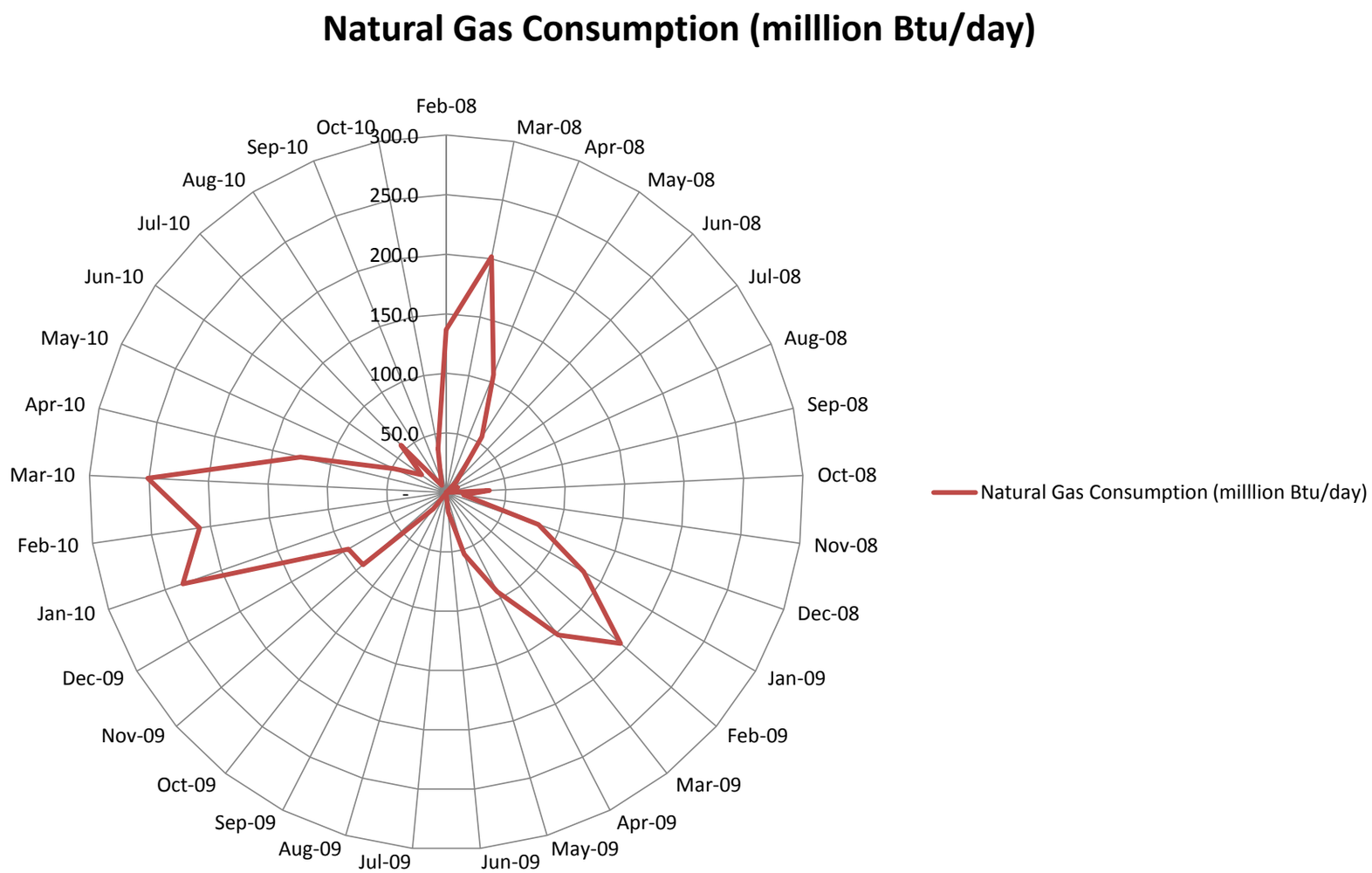
Appendix 7 - Natural Gas Radar Plot

	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	136.6
Mar-08	201.5
Apr-08	106.7
May-08	55.7
Jun-08	12.5
Jul-08	-
Aug-08	10.3
Sep-08	-
Oct-08	36.4
Nov-08	14.7
Dec-08	82.0
Jan-09	133.5
Feb-09	193.8
Mar-09	152.0
Apr-09	93.8
May-09	54.0
Jun-09	16.4
Jul-09	-
Aug-09	2.6
Sep-09	1.4
Oct-09	17.6
Nov-09	92.5
Dec-09	95.1
Jan-10	234.2
Feb-10	209.5
Mar-10	251.1
Apr-10	126.0
May-10	48.5
Jun-10	25.5
Jul-10	55.0
Aug-10	7.1
Sep-10	11.8
Oct-10	37.3



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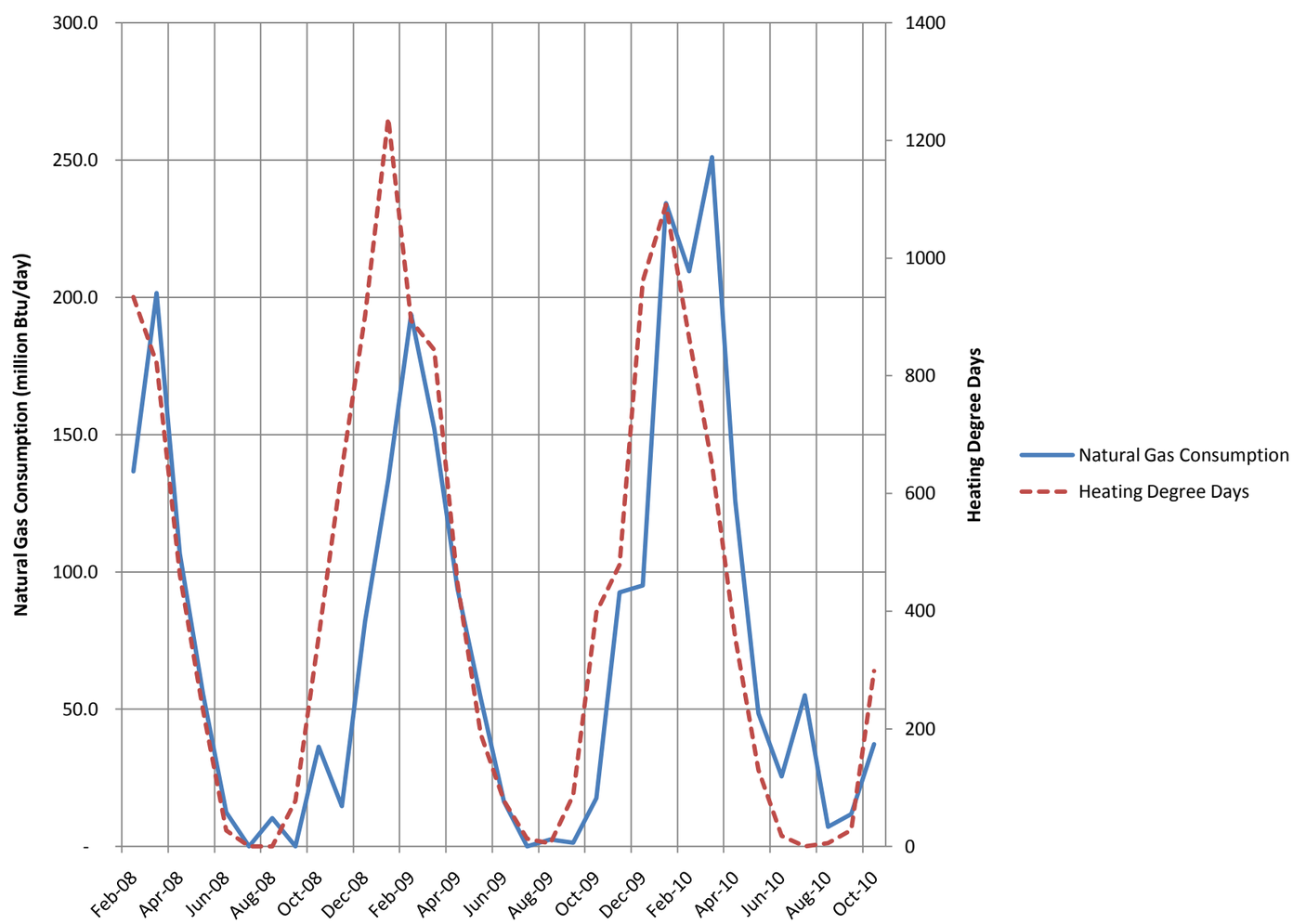
Appendix 8 - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	136.6
Mar-08	822	201.5
Apr-08	462	106.7
May-08	232	55.7
Jun-08	27	12.5
Jul-08	-	-
Aug-08	-	10.3
Sep-08	78	-
Oct-08	356	36.4
Nov-08	641	14.7
Dec-08	902	82.0
Jan-09	1,238	133.5
Feb-09	894	193.8
Mar-09	844	152.0
Apr-09	447	93.8
May-09	191	54.0
Jun-09	78	16.4
Jul-09	13	-
Aug-09	5	2.6
Sep-09	87	1.4
Oct-09	398	17.6
Nov-09	479	92.5
Dec-09	961	95.1
Jan-10	1,091	234.2
Feb-10	864	209.5
Mar-10	649	251.1
Apr-10	355	126.0
May-10	130	48.5
Jun-10	18	25.5
Jul-10	-	55.0
Aug-10	6	7.1
Sep-10	28	11.8
Oct-10	298	37.3



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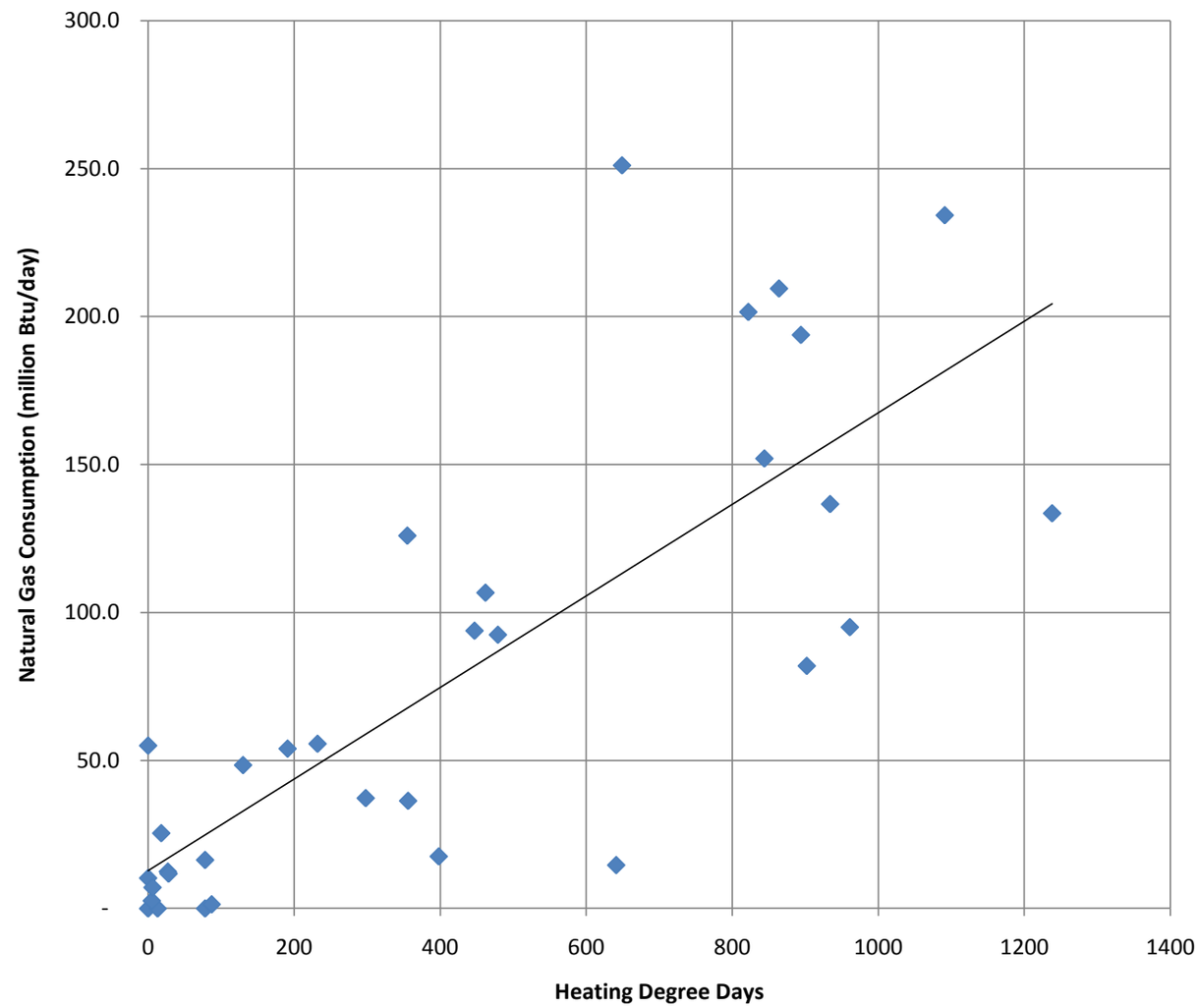
Appendix 9 - Scatter Diagram - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	136.6
Mar-08	822	201.5
Apr-08	462	106.7
May-08	232	55.7
Jun-08	27	12.5
Jul-08	-	-
Aug-08	-	10.3
Sep-08	78	-
Oct-08	356	36.4
Nov-08	641	14.7
Dec-08	902	82.0
Jan-09	1,238	133.5
Feb-09	894	193.8
Mar-09	844	152.0
Apr-09	447	93.8
May-09	191	54.0
Jun-09	78	16.4
Jul-09	13	-
Aug-09	5	2.6
Sep-09	87	1.4
Oct-09	398	17.6
Nov-09	479	92.5
Dec-09	961	95.1
Jan-10	1,091	234.2
Feb-10	864	209.5
Mar-10	649	251.1
Apr-10	355	126.0
May-10	130	48.5
Jun-10	18	25.5
Jul-10	-	55.0
Aug-10	6	7.1
Sep-10	28	11.8
Oct-10	298	37.3



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Appendix 10 - Water Consumption

Month	End Date	Number of Days in Cycle	Water Consumption (1000 gallons)	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	7/24/2008	31	1,705	55.0	320
Aug-08	8/24/2008	30	1,577	52.6	179
Sep-08	9/23/2008	30	1,421	47.4	105
Oct-08	10/23/2008	41	1,214	29.6	10
Nov-08	12/3/2008	34	778	22.9	2
Dec-08	1/6/2009	29	653	22.5	-
Jan-09	2/4/2009	28	731	26.1	-
Feb-09	3/4/2009	30	744	24.8	-
Mar-09	4/3/2009	32	726	22.7	-
Apr-09	5/5/2009	29	818	28.2	30
May-09	6/3/2009	33	1,299	39.4	57
Jun-09	7/6/2009	30	1,321	44.0	55
Jul-09	8/5/2009	29	1,241	42.8	204
Aug-09	9/3/2009	32	1,642	51.3	289
Sep-09	10/5/2009	30	1,301	43.4	64
Oct-09	11/4/2009	29	1,121	38.7	7
Nov-09	12/3/2009	34	928	27.3	2
Dec-09	1/6/2010	28	851	30.4	1
Jan-10	2/3/2010	28	805	28.8	-
Feb-10	3/3/2010	33	863	26.2	-
Mar-10	4/5/2010	30	824	27.5	2
Apr-10	5/5/2010	29	956	33.0	23
May-10	6/3/2010	33	1,137	34.5	104
Jun-10	7/6/2010	29	1,440	49.7	205
Jul-10	8/4/2010	30	2,118	70.6	389
Aug-10	9/3/2010	32	1,710	53.4	285
Sep-10	10/5/2010	29	1,419	48.9	170
Oct-10	11/3/2010	31	1,446	46.6	22

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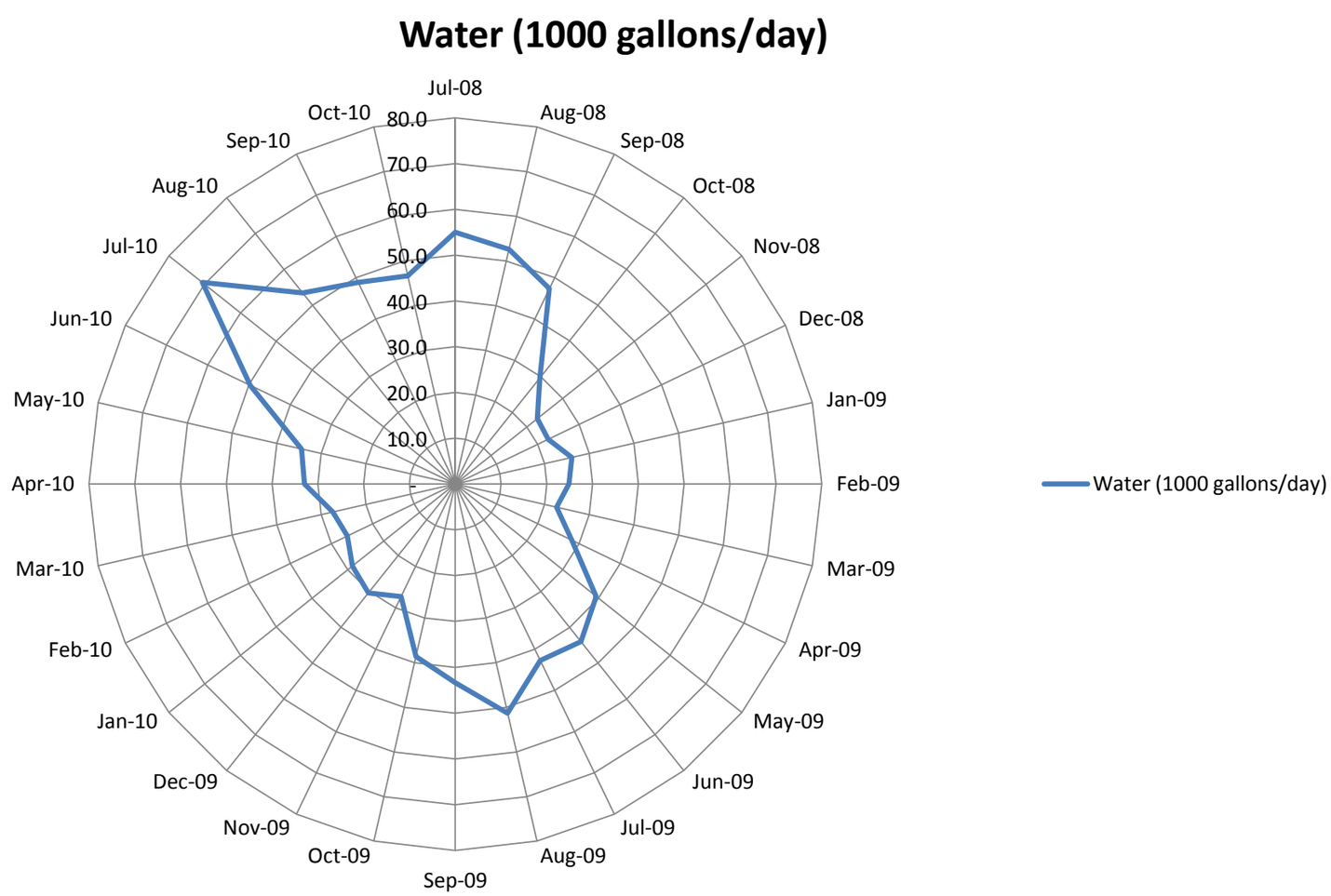
Appendix 11 - Radar Plot of Water Consumption by Month

Month	Water Consumption (1000 gallons/day)
Jul-08	55.0
Aug-08	52.6
Sep-08	47.4
Oct-08	29.6
Nov-08	22.9
Dec-08	22.5
Jan-09	26.1
Feb-09	24.8
Mar-09	22.7
Apr-09	28.2
May-09	39.4
Jun-09	44.0
Jul-09	42.8
Aug-09	51.3
Sep-09	43.4
Oct-09	38.7
Nov-09	27.3
Dec-09	30.4
Jan-10	28.8
Feb-10	26.2
Mar-10	27.5
Apr-10	33.0
May-10	34.5
Jun-10	49.7
Jul-10	70.6
Aug-10	53.4
Sep-10	48.9
Oct-10	46.6



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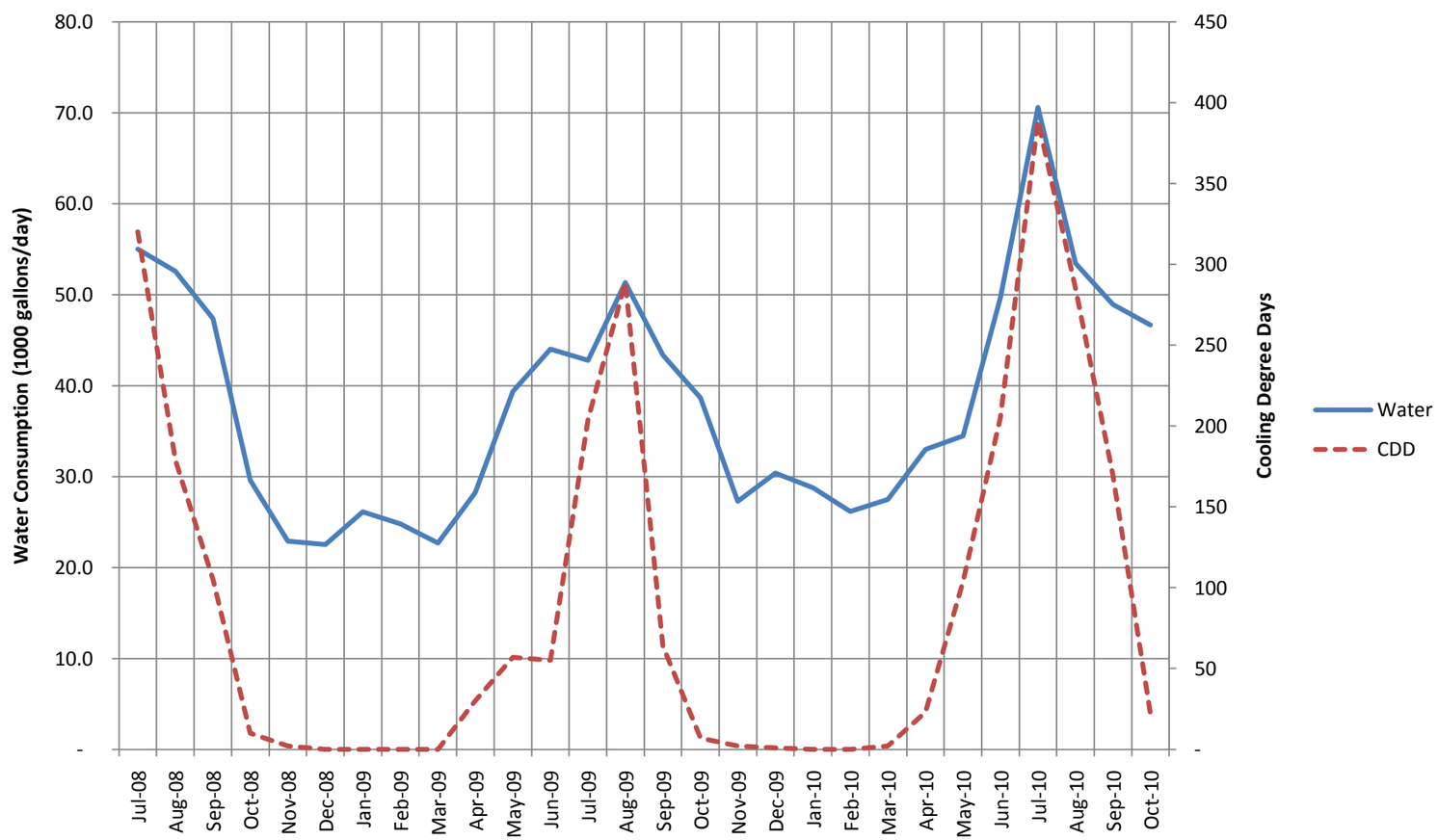
Appendix 12 - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	55.0	320
Aug-08	52.6	179
Sep-08	47.4	105
Oct-08	29.6	10
Nov-08	22.9	2
Dec-08	22.5	-
Jan-09	26.1	-
Feb-09	24.8	-
Mar-09	22.7	-
Apr-09	28.2	30
May-09	39.4	57
Jun-09	44.0	55
Jul-09	42.8	204
Aug-09	51.3	289
Sep-09	43.4	64
Oct-09	38.7	7
Nov-09	27.3	2
Dec-09	30.4	1
Jan-10	28.8	-
Feb-10	26.2	-
Mar-10	27.5	2
Apr-10	33.0	23
May-10	34.5	104
Jun-10	49.7	205
Jul-10	70.6	389
Aug-10	53.4	285
Sep-10	48.9	170
Oct-10	46.6	22



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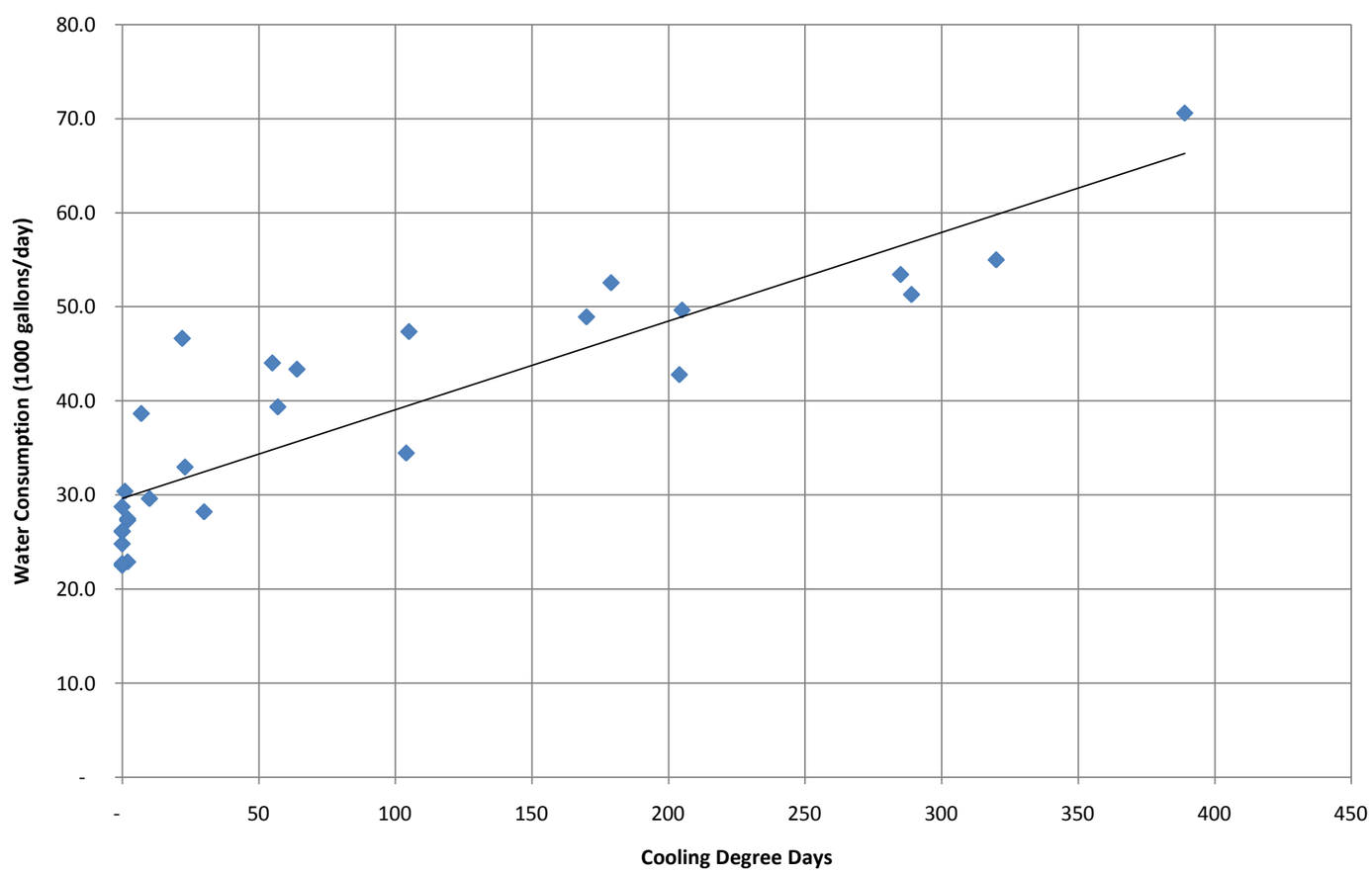
Appendix 13 - Scatter Diagram - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	55.0	320
Aug-08	52.6	179
Sep-08	47.4	105
Oct-08	29.6	10
Nov-08	22.9	2
Dec-08	22.5	-
Jan-09	26.1	-
Feb-09	24.8	-
Mar-09	22.7	-
Apr-09	28.2	30
May-09	39.4	57
Jun-09	44.0	55
Jul-09	42.8	204
Aug-09	51.3	289
Sep-09	43.4	64
Oct-09	38.7	7
Nov-09	27.3	2
Dec-09	30.4	1
Jan-10	28.8	-
Feb-10	26.2	-
Mar-10	27.5	2
Apr-10	33.0	23
May-10	34.5	104
Jun-10	49.7	205
Jul-10	70.6	389
Aug-10	53.4	285
Sep-10	48.9	170
Oct-10	46.6	22



John W. McCormack Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition	Remarks
Chiller	CH-1	22nd Floor Penthouse	Carrier	19XR6767445DDS	Centrifugal	650 tons	1996	25	2021	0.59 kW/ton	-		-
Chiller	CH-2	22nd Floor Penthouse	Carrier	19XL5353493CQ	Centrifugal	550 tons	1996	25	2021	0.61 kW/ton	-		-
Chiller	CH-3	22nd Floor Penthouse	Carrier	19XRV3737354CNH 64	Centrifugal	450 tons	1999	25	2024	0.65 kW/ton	-		-
Chiller	CH-4	22nd Floor Penthouse	York	YCP-FN-16S-46-HSC	Absorption	400 tons	2004	23	2027		-		-
Chiller	CH-5	22nd Floor Penthouse	York	YCP-FN-16S-46-HSC	Absorption	400 tons	2004	23	2027		-		-
Chiller	CH-6	7th Floor Mechanical Room	Pending				2011				-		-
Pump	CHW-P1	22nd Floor Penthouse	Taco	-	Centrifugal	2880 gpm at 125 feet (125 hp)	2006	20	2026	95.4	Primary chilled water		Variable-speed
Pump	CHW-P3	22nd Floor Penthouse	Taco	-	Centrifugal	2880 gpm at 125 feet (125 hp)	2006	20	2026	95.4	Primary chilled water		Variable-speed
Pump	CW-P4	22nd Floor Penthouse	Aurora	-	Centrifugal	4300 gpm at 100 feet (150 hp)	2006	20	2026	94.5	Condenser water		Variable-speed
Pump	CW-P5	22nd Floor Penthouse	Aurora	-	Centrifugal	4300 gpm at 100 feet (150 hp)	2006	20	2026	94.5	Condenser water		Variable-speed
Pump	CW-P6	22nd Floor Penthouse	Aurora	-	Centrifugal	4300 gpm at 100 feet (150 hp)	2006	20	2026	94.5	Condenser water		Variable-speed
Pump	CH/HW-P7	22nd Floor Penthouse	Allis Chalmers	-	Centrifugal	1125 gpm at 103 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Condenser water 11-21		
Pump	CH/HW-P8	22nd Floor Penthouse	Allis Chalmers	-	Centrifugal	1125 gpm at 103 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Condenser water 11-21		
Pump	CH/HW-P9	22nd Floor Penthouse	Allis Chalmers	-	Centrifugal	1125 gpm at 103 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Condenser water 11-21		
Pump	HWP-32	22nd Floor Penthouse	Taco	FI-5013	End suction	750 gpm at 110 feet (40 hp)	2006	20	2026	94.6	Primary chiller / heater hot water loop		Variable-speed
Pump	HWP-33	22nd Floor Penthouse	Taco	FI-5013	End suction	750 gpm at 110 feet (40 hp)	2006	20	2026	94.6	Primary chiller / heater hot water loop		Variable-speed
Pump	HWP-34	22nd Floor Penthouse	Taco	KV-3007	Vertical in-line	262 gpm at 25 feet (3 hp)	2006	20	2026		Primary chiller / heater hot water loop		Variable-speed
Pump	HWP-35	22nd Floor Penthouse	Taco	KV-3007	Vertical in-line	262 gpm at 25 feet (3 hp)	2006	20	2026		Primary chiller / heater hot water loop		Variable-speed
Pump	CW-P1	7th Floor Mechanical Room	Taco	-	Centrifugal	900 gpm at 105 feet (50 hp)	2006	20	2026	94.5	Data center	Good -	-
Pump	CW-P2	7th Floor Mechanical Room	Taco	-	Centrifugal	900 gpm at 105 feet (40 hp)	2006	20	2026	94.5	Data center	Good -	-
Pump	CHW-P4	7th Floor Mechanical Room	Taco	-	Centrifugal	720 gpm at 80 feet (25 hp)	2006	20	2026	94.1	Air handling units 13, 15 and 16	Good -	-
Pump	CHW-P5	7th Floor Mechanical Room	Taco	-	Centrifugal	720 gpm at 80 feet (25 hp)	2006	20	2026	94.1	Air handling units 13, 15 and 16	Good -	-
Pump	CH/HW-P16	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	102 gpm at 60 feet (3 hp)	1971	20	Expected life has been exceeded	87.5	8th Flr induction units	Good -	-
Pump	CH/HW-P17	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	102 gpm at 60 feet (3 hp)	1971	20	Expected life has been exceeded	87.5	8th Flr induction units	Good -	-
Pump	CH/HW-P18	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	102 gpm at 60 feet (3 hp)	1971	20	Expected life has been exceeded	88.5	8th Flr induction units	Good -	-
Pump	CH/HW-P19	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	780 gpm at 125 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Low-rise induction units	Good -	-
Pump	CH/HW-P20	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	780 gpm at 125 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Low-rise induction units	Good -	-

John W. McCormack Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition		Remarks
Pump	HW-P21	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	780 gpm at 125 feet (40 hp)	1971	20	Expected life has been exceeded	94.5	Low-rise induction units	Good	-	-
Pump	HW-P22	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	112 gpm at 60 feet (5 hp)	1971	20	Expected life has been exceeded	---	Secondary hot water	Good	-	-
Pump	HW-P23	7th Floor Mechanical Room	Allis Chalmers	-	Centrifugal	112 gpm at 60 feet (5 hp)	1971	20	Expected life has been exceeded	---	Secondary hot water	Good	-	-
Cooling Tower	CT-1	Roof	Baltimore Aircoil (BAC)	JE – Model 133485-3	Induced draft, 3 cell	40 hp	2006	22	2028	-	-	Fair	Sump leaking - Scaling on louvers	Variable-speed
Cooling Tower	CT-2	Roof	Baltimore Aircoil (BAC)	JE – Model 133485-3	Induced draft, 3 cell	40 hp	2006	22	2028	-	-	Fair	Sump leaking - Scaling on louvers	Variable-speed
Cooling Tower	CT-3	Roof	Baltimore Aircoil (BAC)	JE – Model 133485-1	Induced draft, 1 cell	15 hp	2006	22	2028	-	-			Variable-speed
Side-Stream Sand Filter	SSF-1	Roof	PEP	SMF/FG-24	Side-Stream	2 hp	2006	25	2031	-	Condenser water			-
Boilers	B-1 thru B-13	22nd Floor Penthouse	Aerco	Benchmark BMK 2.0	Natural gas fired hot water boiler	2 million Btu/hr output	2009	22	2031	90%	-			-
Air Handling Unit	AHU-1	7th Floor Mechanical Room	Buffalo	J-320PCH	-	100 hp	1974	25	Expected life has been exceeded	-	Low-rise south primary air	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valves at cooling and preheat coils
AHU-1 return fan	R-1	7th Floor Mechanical Room	-	-	-	10 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-2	7th Floor Mechanical Room	Buffalo	J-250PCH	-	100 hp	1974	25	Expected life has been exceeded	-	Low-rise north primary air	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-2 return fan	R-2	7th Floor Mechanical Room	-	-	-	10 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-3	22nd Floor Penthouse	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	High-rise north primary air	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-3 return fan	R-3	22nd Floor Penthouse	-	-	-	15 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-4	22nd Floor Penthouse	Buffalo	J-390PCH	-	150 hp	1974	25	Expected life has been exceeded	-	High-rise south primary air	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-4 return fan	R-4	22nd Floor Penthouse	-	-	-	20 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-5	22nd Floor Penthouse	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	High-rise SW interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-5 return fan	R-5	22nd Floor Penthouse	-	-	-	30 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-6	22nd Floor Penthouse	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	High-rise SE interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-6 return fan	R-6	22nd Floor Penthouse	-	-	-	40 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-7	22nd Floor Penthouse	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	High-rise NE interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-7 return fan	R-7	22nd Floor Penthouse	-	-	-	30 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-8	22nd Floor Penthouse	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	High-rise NW interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil

John W. McCormack Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition		Remarks
AHU-8 return fan	R-8	22nd Floor Penthouse	-	-	-	30 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-9	7th Floor Mechanical Room	Buffalo	J-320PCH	-	75 hp	1974	25	Expected life has been exceeded	-	Low-rise SW interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-9 return fan	R-9	7th Floor Mechanical Room	-	-	-	20 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-10	7th Floor Mechanical Room	Buffalo	J-390PCH	-	100 hp	1974	25	Expected life has been exceeded	-	Low-rise SE interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-10 return fan	R-10	7th Floor Mechanical Room	-	-	-	30 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-11	7th Floor Mechanical Room	Buffalo	J-320PCH	-	60 hp	1974	25	Expected life has been exceeded	-	Low-rise NW interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-11 return fan	R-11	7th Floor Mechanical Room	-	-	-	25 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-12	7th Floor Mechanical Room	Buffalo	J-320PCH	-	60 hp	1974	25	Expected life has been exceeded	-	Low-rise NE interior	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valve at cooling; no preheat coil
AHU-12 return fan	R-12	7th Floor Mechanical Room	-	-	-	20 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-13	7th Floor Mechanical Room	Buffalo	J-320PCH	-	60 hp	1974	25	Expected life has been exceeded	-	8th floor open space	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valves at cooling and preheat coils
AHU-13 return fan	R-13	7th Floor Mechanical Room	-	-	-	20 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-14	7th Floor Mechanical Room	Buffalo	J-210PCH	-	60 hp	1974	25	Expected life has been exceeded	-	Ashburton Café	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valves at cooling and preheat coils
Air Handling Unit	AHU-15	7th Floor Mechanical Room	Buffalo	J-170PCH	-	50 hp	1974	25	Expected life has been exceeded	-	Lobby	Fair-Poor	Repair drain pan & flex connection - Casing air leak - Insulate CHW air vents	3-way control valves at cooling and preheat coils
AHU-15 return fan	R-15	7th Floor Mechanical Room	-	-	-	7-1/2 hp	1974	25	Expected life has been exceeded	-	-			-
Air Handling Unit	AHU-16	7th Floor Mechanical Room	Cambridgeport	50V-4260	-	-	1974	25	Expected life has been exceeded	-	8th floor data center	Good		3-way control valve at cooling; no preheat coil
Heating & Ventilating Unit	HV-2	Garage Mechanical Room	Buffalo Forge	272A	-	10 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed
Heating & Ventilating Unit	HV-3	Garage Mechanical Room	Buffalo Forge	272A	-	10 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed
Heating & Ventilating Unit	HV-4	Garage Mechanical Room	Buffalo Forge	272A	-	10 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed
Heating & Ventilating Unit	HV-5	Garage Mechanical Room	Buffalo Forge	320	-	15 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed
Heating & Ventilating Unit	HV-6	Garage Mechanical Room	Buffalo Forge	250	-	15 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed
Heating & Ventilating Unit	HV-9	Garage Mechanical Room	Buffalo Forge	122	-	3/4 hp	1974	25	Expected life has been exceeded	-	Garage			Coil connection removed

John W. McCormack Building

Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Condition	Remarks
Exhaust Fan	WCV-1	7th Floor Mechanical Room	-	-	-	7-1/2 hp	1974	20	Expected life has been exceeded	-	Toilet rooms		-
Exhaust Fan	WCV-2	7th Floor Mechanical Room	-	-	-	7-1/2 hp	1974	20	Expected life has been exceeded	-	Toilet rooms		-
Exhaust Fan	WCV-3	22nd Floor Penthouse	-	-	-	15 hp	1974	20	Expected life has been exceeded	-	Toilet rooms		-
Exhaust Fan	KE-1	7th Floor Mechanical Room	-	-	-	30 hp	1974	20	Expected life has been exceeded	-	Kitchen		-
Exhaust Fan	E-2	7th Floor Mechanical Room	-	-	-	2 hp	1974	20	Expected life has been exceeded	-	Mechanical room		-
Exhaust Fan	E-3	7th Floor Mechanical Room	-	-	-	2 hp	1974	20	Expected life has been exceeded	-	Mechanical room		-
Exhaust Fan	E-4	22nd Floor Penthouse	-	-	-	2 hp	1974	20	Expected life has been exceeded	-	Mechanical room		-
Exhaust Fan	E-5	22nd Floor Penthouse	-	-	-	2 hp	1974	20	Expected life has been exceeded	-	Mechanical room		-
Exhaust Fan	EF-1	Garage		--	--	27, 600 cfm (10 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-
Exhaust Fan	EF-2	Garage		--	--	41,500 cfm (15 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-
Exhaust Fan	EF-3	Garage		--	--	13,800 cfm (3 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-
Exhaust Fan	EF-5	Garage		--	--	18,500 cfm (5 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-
Exhaust Fan	EF-6	Garage		--	--	10,000 cfm (2 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-
Exhaust Fan	EF-7	Garage		--	--	8,450 cfm (2 hp)	1974	20	Expected life has been exceeded	-	Loading dock		-
Exhaust Fan	EF-8	Garage		--	--	18,400 cfm (5 hp)	1974	20	Expected life has been exceeded	-	Mechanical room		-
Exhaust Fan	EF-9	Garage		--	--	2,200 cfm (1/2 hp)	1974	20	Expected life has been exceeded	-	General exhaust		-
Exhaust Fan	EF-10	Garage		--	--	240 cfm (9W)	1974	20	Expected life has been exceeded	-	Toilet		-
Exhaust Fan	EF-11	Garage		--	--	10,000 cfm (2 hp)	1974	20	Expected life has been exceeded	-	Parking garage		-

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Division of Capital Asset Management (DCAM)

Energy Upgrades – McCormack, Hurley, Lindemann and State House Buildings

Existing Conditions Assessment
State House
Final Submittal

Revised May 10, 2012

DCAM Project # DPC1021 ES1

KS Project # 36.7407.00

One Broadway
Cambridge, Massachusetts
02142

P 617.491.6450
F 617.491.7104

Massachusetts State House

Existing Conditions Assessment

1 Executive Summary

1.1 Study Objectives

The Division of Capital Asset Management (DCAM) retained KlingStubbins to recommend energy-conserving measures (ECM's) as a multi-task project. This report relates to Task 1, which is to assess existing conditions in order to understand the operations and provide a platform for future ECM's.

2 Building Overview

The Massachusetts State House consists of the original 1798 red-brick building designed by Charles Bulfinch and two expansions. The building is the State Capitol and seat of government of the Commonwealth of Massachusetts. The gross building area is 650,000 ft^2, distributed over five above-grade floors and two below-grade floors. The building has a population of 2,500 people.

The building is listed on the National Register of Historic Places (NRHP) and is a registered National Historic Landmark (NHL).

The original building houses the governor's office, support staff office space and the Massachusetts Senate legislative space.

The 1898 Brighton Annex houses the Massachusetts House of Representatives.

The East and West Wings were completed in 1917. This portion of the complex mostly houses legislative offices.

3 HVAC System Overview

A combination of fan coil units and air handling units maintain room environmental conditions and to provide outside air. The State House generates chilled water and heating hot water used by fan coil units and air handling units.

3.1 Supply Air Systems

The State House is cooled and heated by a combination of fan coil units and central air handling units.

Many perimeter zones use two-pipe fan coil units located under windows. Most of these areas receive outside air via operable windows, with no outside air provided by the HVAC system.

Some interior zones use two-pipe fan coil units.

Other areas use air handling units to provide cooling, heating and outside air.

Air distribution is constant volume except AHU-1 (serving the Great Hall hearing rooms?), which has variable-volume air distribution.

Air handling units (except those described below) mix outside air and return air, then filter, heat or cool the air before it is supplied to the zones. Chilled water and heating

hot water (described below) are used by cooling and heating coils in these air handling units.

Five air handling units supply preconditioned ventilation air to areas that use fan coil units. Chilled water and heating hot water (described above) are used by cooling and heating coils in these air handling units. These units and the areas they serve are:

- AHU-1 - Great Hall;
- AHU-2 - East side of the Brighton Annex;
- AHU-3 - West side of the Brighton Annex;
- AHU-11 - West Wing A and F;
- AHU-14 – East Wing.

Most air handling units have airside economizer capability; however, many of these units do not use this mode because of controls or damper limitations.

3.1.1 Air Systems Mode of Operation

The supply and return fans use standard-efficiency motors and are belt-driven with trapezoidal-cross section belts.

No demand-controlled ventilation is used to reduce airflow during unoccupied modes.

Fan coil units are controlled by local temperature sensors, which modulate the coil to maintain room temperature setpoint.

3.2 Heating Hot Water System Description

Heating hot water is generated by five natural gas-fired boilers located in the Brighton Annex sub-basement. The boilers are the condensing type manufactured by DeDietrich and each have a capacity of 3,935,000 Btu/hr; they were installed in 2008.

Condensing type boilers cool flue gas with return heating hot water to below the dewpoint, which increases efficiency by recovering the latent enthalpy of vaporization.

3.2.1 Heating Hot Water System Mode of Operation

Heating hot water distribution uses a primary/secondary arrangement. Three 20 hp constant-speed primary pumps circulate heating hot water through the boilers; three 25 hp variable-speed secondary pumps take heating hot water from the primary loop and distribute it to heating coils. These pumps were manufactured by Bell and Gossett,

installed in 2008 and use high-efficiency motors.

3.3 Chilled Water System Description

Two electric centrifugal water-cooled chillers in the Brighton Annex provide chilled water to fan coil units and air handling units. The 750-ton lead chiller was manufactured by Carrier, installed in 2008 and has a variable-speed compressor. The 800-ton lag chiller was manufactured by Trane, installed in 1988 and turns down by variable compressor inlet vanes.

Chilled water distribution uses a primary/secondary arrangement. Two 20 hp constant-speed primary pumps circulate chilled water through the chillers; two 40 hp variable-speed secondary pumps take chilled water from the primary loop and distribute it to cooling coils. These pumps were manufactured by Bell and Gossett, installed in 1988 and use standard-efficiency motors.

Condenser water is generated by a two-cell induced draft cooling tower mounted on the roof. The cooling tower was manufactured by Baltimore Aircoil (BAC) and installed in 2008. The condenser water is treated through a side-stream sand filter located adjacent to the cooling tower.

Two 100 hp constant-speed pumps (CDWP-1 and 2) in the Brighton Annex sub-basement circulate water between the condensers and the cooling towers. These pumps were manufactured by Bell and Gossett and installed in 1988.

3.3.1 Chilled Water System Mode of Operation

The two electric chillers are brought on in a lead/lag arrangement to maintain chilled water supply temperature setpoint.

3.4 Special Systems

3.4.1 Archives

A 15-ton semi-hermetic chiller supplies chilled water to an air handling unit dedicated to the archives area.

4 Domestic Cold and Hot Water

4.1.1 Plumbing Fixtures

Most toilets were rated at 1.6 gallons per flush (gpf), urinals were rated to 1.0 gpf and lavatory faucets were rated at 0.5 gallons per minute (gpm). Low-flow fixtures are installed as fixtures are replaced.

Domestic hot water is generated in a heating hot water-to-domestic water heat exchanger.

5 Building Automation System (BAS) Description

Johnson Controls Inc. (JCI) is the BAS supplier for this building; the building has multiple hardware and software platforms that have been implemented over the years.

The building originally used pneumatic controllers. Over the years, various parts of the building were upgraded to newer JCI controllers and devices. Electric-to-pneumatic (E-P) transducers have been used to provide direct digital control (DDC) of pneumatic actuators. Not every HVAC unit is under DDC control.

The Master Operator Workstation (OWS) head end personal computer (PC) is located in the Command Center of the McCormack Building. Other OWS are located in the Hurley and State House buildings. The master OWS, however, contains the primary programming database and corresponding backup and system restore functions.

DDC systems are used to control and monitor large equipment (chillers and boilers).

6 Utility Consumption Analysis

6.1 Energy Use Intensity and Benchmarking

The energy use intensity (EUI) is defined as the energy consumption (in units of million Btu) divided by the gross building area (ft^2). This provides a metric to compare one building versus peer facilities, since databases sorted geographically and by building type exist.

The EUI for the State House is 53,657 Btu/ft^2-year. It is difficult to benchmark this EUI, since the State House has a unique program.

6.2 Electricity Consumption Analysis

Thirty months (July 2008 through December 2010) of electricity demand and consumption billing information was analyzed.

The facility purchases electricity from Direct Energy with NStar serving as the power delivery service. The tariff is Rate B7-NEMA LG, General Time of Use (TOU).

Electricity consumption information was provided from billing information. The billing-cycle consumption (kWh/billing cycle) was divided by the number of days in the billing cycle to create an average daily electricity consumption (kWh/day). This neutralizes the

effect of billing cycle length; this information is presented in Appendix 1. This average daily electricity consumption was plotted against month on a radar-type chart (Appendix 2). The radar plot showed consumption peaks in the summer months (July 2008, August 2009 and July 2010), suggesting that loads related to air-conditioning drive electricity consumption.

This hypothesis was tested by correlating cooling degree days against electricity consumption. Cooling degree days are a single-measure, simplified means of characterizing outside air temperature data. Cooling degree days are a measure of how much (in degrees F) and for how long (in days), outside air temperature was higher than a base temperature (65°F).

Actual cooling degree day information was obtained for the same timeframe as the electricity consumption data. The cooling degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Electricity consumption data was plotted against the cooling degree day data (Appendix 3). The electricity consumption and cooling degree day values peak in the same summer months.

The correlation coefficient, which measures the linear relationship between two variables: the correlation coefficient ranges between 1 and -1. A value of 1 means that if one variable increases, the other variable increases linearly. A value of -1 means that if one variable increases, the other variable decreases linearly. A value of 0 means there is no linear correlation between the two variables.

Electricity consumption and cooling degree days have a correlation coefficient of 0.76, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 4) confirms the strong relationship.

Electricity consumption attributable to air-conditioning usage was isolated by subtracting baseline consumption from the total consumption. Baseline electricity consumption is defined as the amount of electricity consumed in a month when no electricity is used to generate air-conditioning: the majority of electricity is used by

receptacles and lighting. For the State House, the baseline electricity consumption is 11 MWh/day.

The isolated air-conditioning electricity consumption had a correlation coefficient of 0.90 with cooling degree days. This indicates a very strong correlation between electricity consumption and air-conditioning use.

Power demand (kW) for each month was plotted against time (Appendix 5): this confirms that electricity demand is driven by air-conditioning equipment.

The electricity load factor (ELF) is defined as the ratio between the average daily use and the maximum possible use if the peak demand operated for a 24 hour period. This factor was calculated as 0.51.

The seasonally-adjusted electricity load factor (SELF) is the electricity load factor calculated over the cooling season.

This factor was calculated as 0.63 (2009) and 0.46 (2010).

The occupancy factor is defined as the percentage of time that the building is occupied. This building is occupied 6am to 6pm for five days per week, the occupancy factor is 0.36.

If the ELF is much greater than the OF, that implies that equipment or lighting operates when the building is unoccupied.

The conclusions of this billing-information analysis are:

- Although air-conditioning drives electricity consumption, baseload consumption (receptacles and lighting) still represent a target for energy-conservation measures.
- Operation of HVAC equipment, lights and receptacles during unoccupied hours represents an energy-reduction target.

6.3 Natural Gas Consumption

Thirty-four months (February 2008 through November 2010) of natural gas

Analysis

consumption billing information was analyzed.

The facility purchases natural gas from Hess Energy with National Grid serving as the natural gas delivery service. The tariff is Rate G-44T, Demand Heating.

Natural gas consumption information was provided from billing information. The billing-cycle consumption (10^6 Btu/billing cycle) was divided by the number of days in the billing cycle to create an average daily natural gas consumption (10^6 Btu/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 6. This average daily consumption was plotted against month on a radar-type chart (Appendix 7). The radar plot showed consumption peaks in the winter months, suggesting that heating-related loads drive natural gas consumption.

This hypothesis was tested by correlating heating degree days against natural gas consumption. Heating degree days are a single-measure, simplified means of characterizing outside air temperature data. Heating degree days are defined as the difference between a base temperature (65°F) and the average temperature (maximum temperature – minimum temperature) for each day; degree days are accumulated over a heating season.

Actual heating degree day information was obtained for the same timeframe as the natural gas consumption data. The heating degree day information is traceable to the National Climatic Data Center for the Logan Airport weather station.

Natural gas consumption data was plotted against the heating degree day data (Appendix 8). The natural gas consumption and heating degree day values peak in the same winter months.

Natural gas consumption and heating degree days have a correlation coefficient of 0.85, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 9) confirms the strong relationship.

The conclusion of this billing-information analysis is that heating use reduction is critical to reducing natural gas consumption.

6.4 Water Consumption Analysis

Twenty-eight months (July 2008 through October 2010) of water consumption billing information was analyzed.

The facility purchases water from the Boston Water and Sewer Commission.

Water consumption information was provided from billing information. The billing-cycle consumption (thousand gallons/billing cycle) was divided by the number of days in the billing cycle to create an average daily water consumption (1000 gallons/day). This neutralizes the effect of billing cycle length; this information is presented in Appendix 10. This average daily water consumption was plotted against month on a radar-type chart (Appendix 11). The radar plot showed consumption peaks in the summer months, suggesting that cooling tower-related loads drive water consumption.

This hypothesis was tested by correlating cooling degree days against water consumption.

Water consumption data was plotted against the cooling degree day data (Appendix 12). The water consumption and cooling degree day values peak in the same summer months.

Water consumption and cooling degree days have a correlation coefficient of 0.78, which means that the two variables are strongly related. A scatter diagram of the two variables (Appendix 13) confirms the strong relationship.

The conclusion of this billing-information analysis is:

- Although cooling tower use drives water consumption, baseload consumption (toilets and lavatories) still represent a target for reduction measures.

7 Existing Equipment Matrix

An Existing Equipment Matrix is included as Appendix 14. Central plant equipment (chillers, cooling towers and boilers) have been recently replaced, but areas of concern are support equipment (pumps) and air handling units.

For each piece of equipment, the matrix identifies the year of installation and the median life. Median life data was taken from two sources:

- Chapter 37 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) "HVAC Applications" Handbook, 2011 edition, lists median service lives for mechanical equipment.
- ASHRAE "Owning and Operating Cost Database" (available at ashrae.org) has compiled a database of 345 buildings, including life of mechanical equipment at the time of replacement.

The cost of maintenance of HVAC equipment is reported as part of the ASHRAE "Owning and Operating Cost Database". This information is reported by building type and geographic location, but not for specific pieces of equipment. The database reports a mean HVAC equipment maintenance cost of $0.494/ft^2, or $321,100 for this type of facility. However, this information has a standard deviation of $0.217/ft^2 ($141,100), which implies there is a large variation in these values.

State House

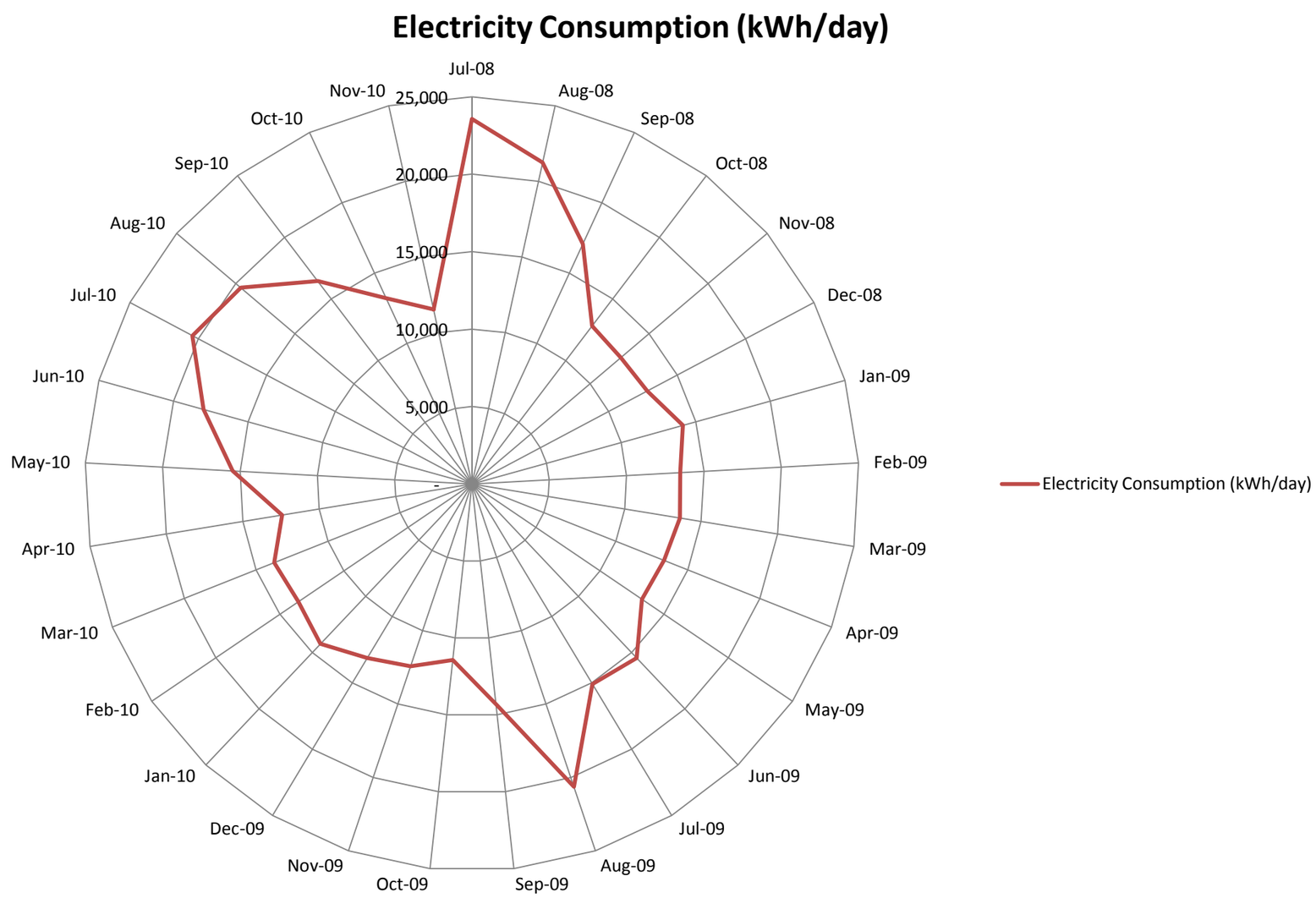
Appendix 1 - Electricity Consumption Data

	Usage Begin Date	Consumption (kWh) - Offpeak	Consumption (kWh) - Onpeak	Consumption (kWh) - Total	Cooling Degree Days	Days/Month	Average elec Consumption per day (kWh/day)	Demand (kW)
Jul-08	6/30/2008	422,629	284,531	707,160	320	30	23,572	1,706
Aug-08	7/30/2008	389,207	227,153	616,360	179	29	21,254	1,593
Sep-08	8/28/2008	335,126	211,354	546,480	105	32	17,078	1,570
Oct-08	9/29/2008	164,943	219,337	384,280	10	30	12,809	1,464
Nov-08	10/29/2008	191,705	211,895	403,600	2	32	12,613	1,017
Dec-08	11/30/2008	170,042	214,038	384,080	-	30	12,803	1,022
Jan-09	12/30/2008	192,258	232,022	424,280	-	30	14,143	1,075
Feb-09	1/29/2009	198,636	232,604	431,240	-	32	13,476	1,053
Mar-09	3/2/2009	169,467	225,053	394,520	-	29	13,604	1,054
Apr-09	3/31/2009	172,231	228,609	400,840	30	30	13,361	1,519
May-09	4/30/2009	193,409	230,911	424,320	57	32	13,260	1,592
Jun-09	6/1/2009	238,325	210,595	448,920	55	29	15,480	1,634
Jul-09	6/30/2009	239,613	212,787	452,400	204	30	15,080	1,566
Aug-09	7/30/2009	375,702	264,298	640,000	289	31	20,645	1,567
Sep-09	8/30/2009	243,339	186,101	429,440	64	30	14,315	1,623
Oct-09	9/29/2009	164,361	178,999	343,360	7	30	11,445	1,081
Nov-09	10/29/2009	189,666	208,094	397,760	2	32	12,430	1,028
Dec-09	11/30/2009	177,285	216,235	393,520	1	30	13,117	1,035
Jan-10	12/30/2009	224,000	231,680	455,680	-	32	14,240	1,065
Feb-10	1/31/2010	187,393	218,847	406,240	-	30	13,541	1,050
Mar-10	3/2/2010	179,723	218,957	398,680	2	29	13,748	1,057
Apr-10	3/31/2010	194,198	216,122	410,320	23	33	12,434	1,180
May-10	5/3/2010	195,580	253,420	449,000	104	29	15,483	1,627
Jun-10	6/1/2010	291,254	230,586	521,840	205	29	17,994	1,598
Jul-10	6/30/2010	394,272	259,728	654,000	389	32	20,438	1,668
Aug-10	8/1/2010	335,865	232,175	568,040	285	29	19,588	1,712
Sep-10	8/30/2010	270,223	223,217	493,440	170	30	16,448	1,741
Oct-10	9/29/2010	205,330	217,470	422,800	22	32	13,213	1,400
Nov-10	10/31/2010	171,448	186,032	357,480	-	31	11,532	927
Dec-10	12/1/2010	-	-	-	-	30	-	

State House

Appendix 2 - Radar Plot of Electricity Consumption by Month

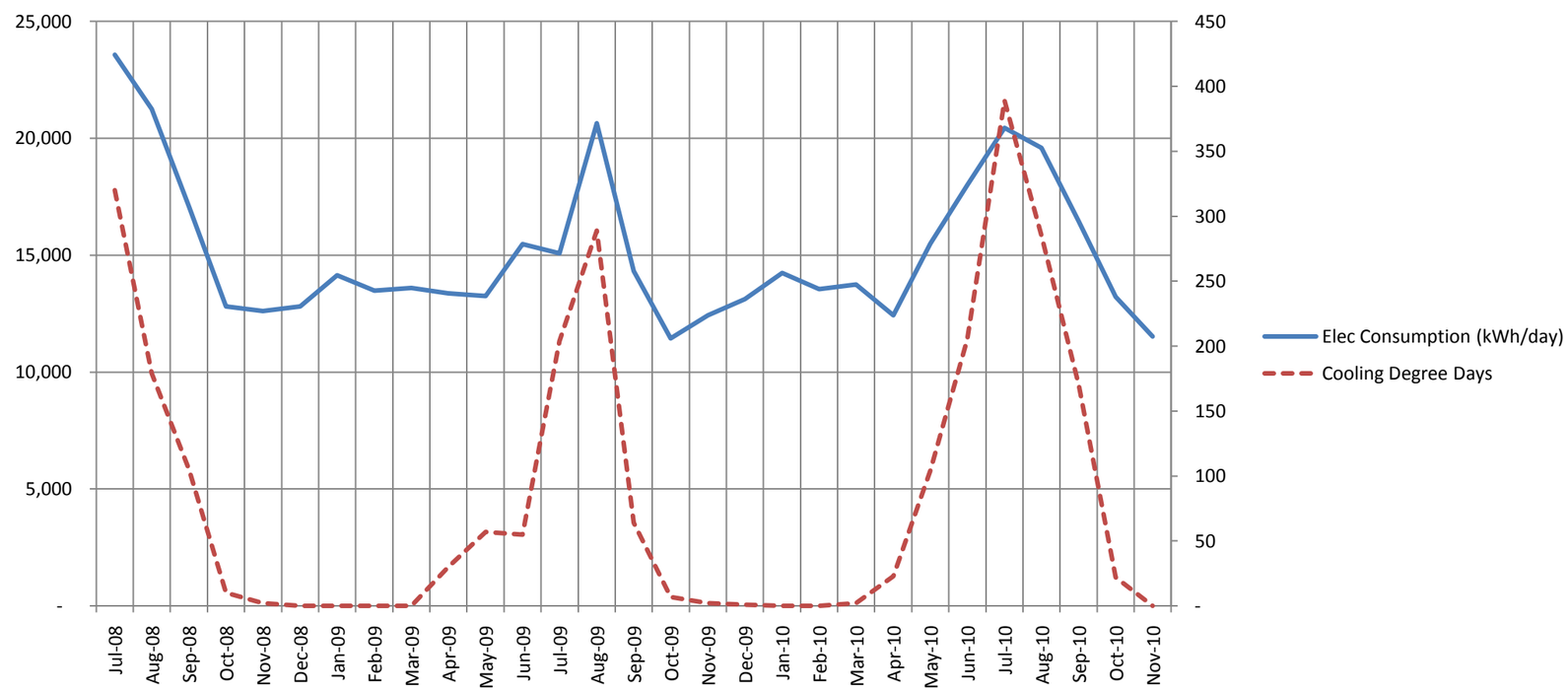
	Average elec Consumption per day (kWh/day)
Jul-08	23,572
Aug-08	21,254
Sep-08	17,078
Oct-08	12,809
Nov-08	12,613
Dec-08	12,803
Jan-09	14,143
Feb-09	13,476
Mar-09	13,604
Apr-09	13,361
May-09	13,260
Jun-09	15,480
Jul-09	15,080
Aug-09	20,645
Sep-09	14,315
Oct-09	11,445
Nov-09	12,430
Dec-09	13,117
Jan-10	14,240
Feb-10	13,541
Mar-10	13,748
Apr-10	12,434
May-10	15,483
Jun-10	17,994
Jul-10	20,438
Aug-10	19,588
Sep-10	16,448
Oct-10	13,213
Nov-10	11,532
Dec-10	-



State House

Appendix 3 - Electricity v. Cooling Degree Days

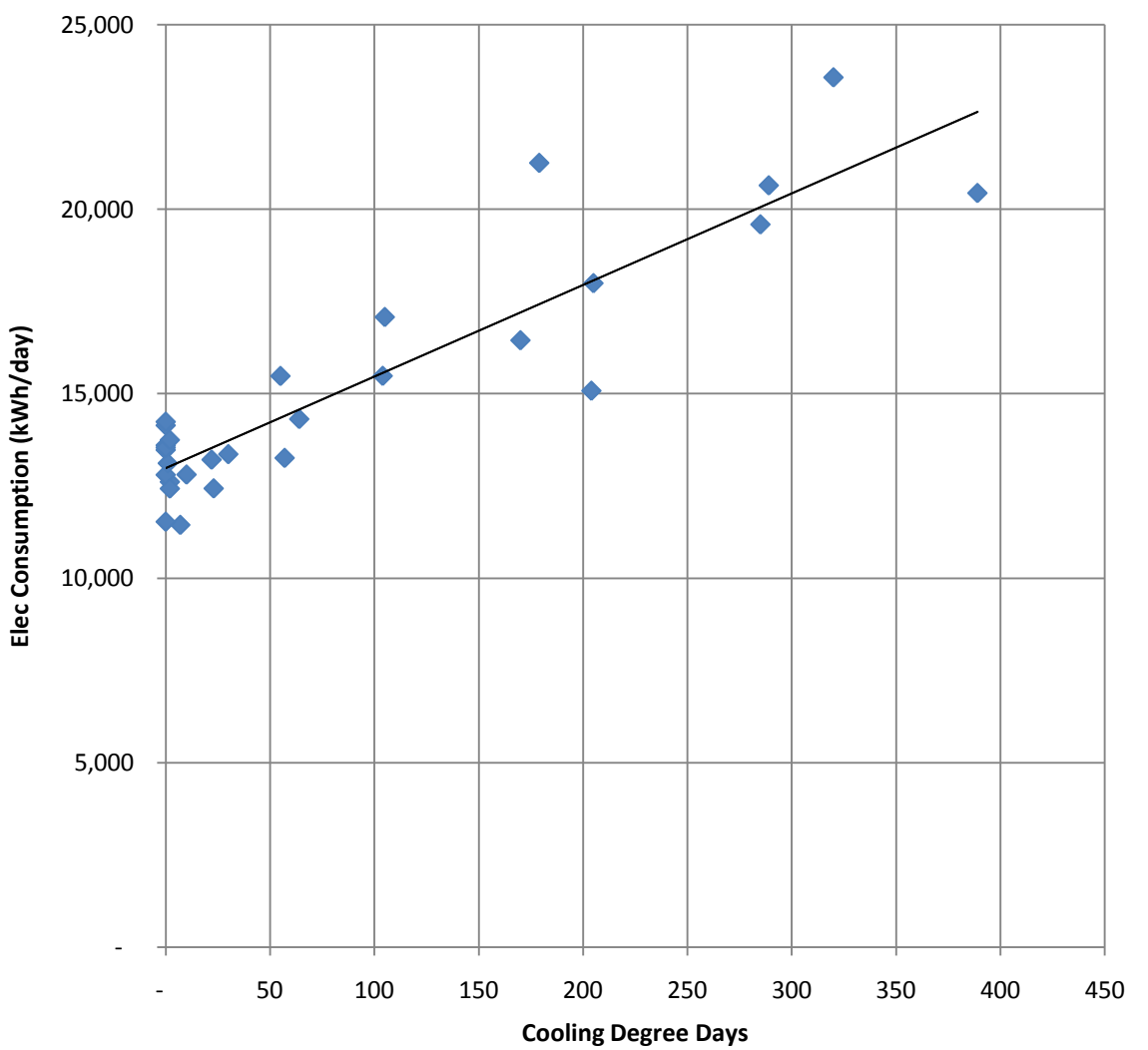
	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	23,572
Aug-08	179	21,254
Sep-08	105	17,078
Oct-08	10	12,809
Nov-08	2	12,613
Dec-08	-	12,803
Jan-09	-	14,143
Feb-09	-	13,476
Mar-09	-	13,604
Apr-09	30	13,361
May-09	57	13,260
Jun-09	55	15,480
Jul-09	204	15,080
Aug-09	289	20,645
Sep-09	64	14,315
Oct-09	7	11,445
Nov-09	2	12,430
Dec-09	1	13,117
Jan-10	-	14,240
Feb-10	-	13,541
Mar-10	2	13,748
Apr-10	23	12,434
May-10	104	15,483
Jun-10	205	17,994
Jul-10	389	20,438
Aug-10	285	19,588
Sep-10	170	16,448
Oct-10	22	13,213
Nov-10	-	11,532
Dec-10	-	-



State House

Appendix 4 Scatter Diagram: Electric Consumption v. Cooling Degree Days

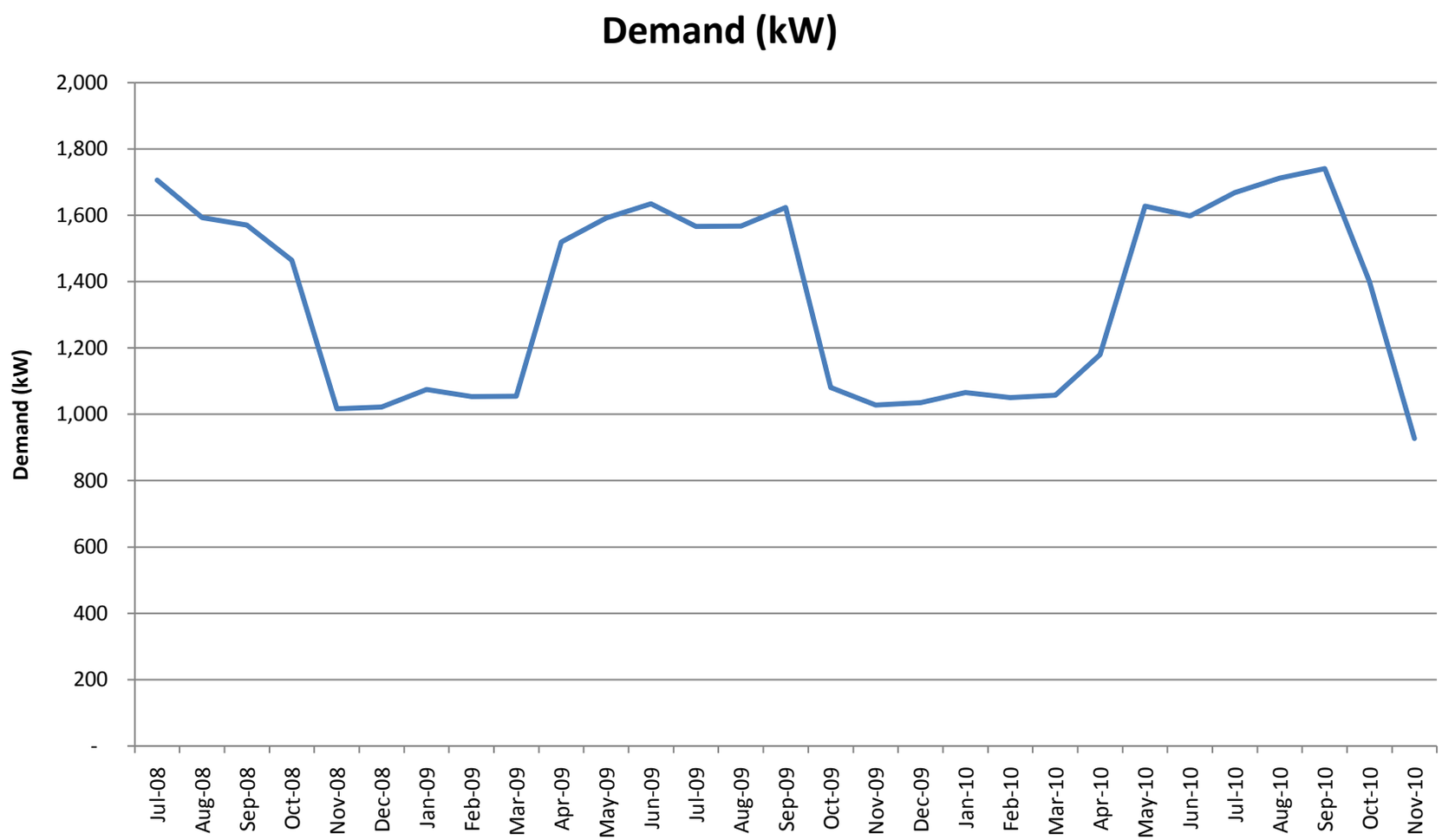
	Cooling Degree Days	Average elec Consumption per day (kWh/day)
Jul-08	320	23,572
Aug-08	179	21,254
Sep-08	105	17,078
Oct-08	10	12,809
Nov-08	2	12,613
Dec-08	-	12,803
Jan-09	-	14,143
Feb-09	-	13,476
Mar-09	-	13,604
Apr-09	30	13,361
May-09	57	13,260
Jun-09	55	15,480
Jul-09	204	15,080
Aug-09	289	20,645
Sep-09	64	14,315
Oct-09	7	11,445
Nov-09	2	12,430
Dec-09	1	13,117
Jan-10	-	14,240
Feb-10	-	13,541
Mar-10	2	13,748
Apr-10	23	12,434
May-10	104	15,483
Jun-10	205	17,994
Jul-10	389	20,438
Aug-10	285	19,588
Sep-10	170	16,448
Oct-10	22	13,213
Nov-10	-	11,532
Dec-10	-	-



State House

Appendix 5 - Power Demand

	Demand (kW)
Jul-08	1,706
Aug-08	1,593
Sep-08	1,570
Oct-08	1,464
Nov-08	1,017
Dec-08	1,022
Jan-09	1,075
Feb-09	1,053
Mar-09	1,054
Apr-09	1,519
May-09	1,592
Jun-09	1,634
Jul-09	1,566
Aug-09	1,567
Sep-09	1,623
Oct-09	1,081
Nov-09	1,028
Dec-09	1,035
Jan-10	1,065
Feb-10	1,050
Mar-10	1,057
Apr-10	1,180
May-10	1,627
Jun-10	1,598
Jul-10	1,668
Aug-10	1,712
Sep-10	1,741
Oct-10	1,400
Nov-10	927
Dec-10	



State House

Appendix 6 - Natural Gas Consumption

	Usage Begin Date	Consumption (therms)	Consumption (10^6 Btu)	Heating Degree Days	Days/Month	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	2/11/2008	36,745	3,675	934	29	126.7
Mar-08	3/11/2008	32,579	3,258	822	28	116.4
Apr-08	4/8/2008	23,744	2,374	462	29	81.9
May-08	5/7/2008	10,788	1,079	232	30	36.0
Jun-08	6/6/2008	1,913	191	27	34	5.6
Jul-08	7/10/2008	1,888	189	-	27	7.0
Aug-08	8/6/2008	1,765	177	-	33	5.3
Sep-08	9/8/2008	1,286	129	78	31	4.1
Oct-08	10/9/2008	1,346	135	356	26	5.2
Nov-08	11/4/2008	8,910	891	641	31	28.7
Dec-08	12/5/2008	21,898	2,190	902	34	64.4
Jan-09	1/8/2009	39,860	3,986	1,238	28	142.4
Feb-09	2/5/2009	44,211	4,421	894	32	138.2
Mar-09	3/9/2009	40,951	4,095	844	28	146.3
Apr-09	4/6/2009	22,378	2,238	447	30	74.6
May-09	5/6/2009	7,547	755	191	30	25.2
Jun-09	6/5/2009	2,056	206	78	38	5.4
Jul-09	7/13/2009	2,085	209	13	29	7.2
Aug-09	8/11/2009	1,196	120	5	29	4.1
Sep-09	9/9/2009	1,021	102	87	28	3.6
Oct-09	10/7/2009	1,159	116	398	28	4.1
Nov-09	11/4/2009	8,844	884	479	33	26.8
Dec-09	12/7/2009	11,944	1,194	961	30	39.8
Jan-10	1/6/2010	37,198	3,720	1,091	29	128.3
Feb-10	2/4/2010	38,487	3,849	864	29	132.7
Mar-10	3/5/2010	30,138	3,014	649	31	97.2
Apr-10	4/5/2010	16,005	1,601	355	29	55.2
May-10	5/4/2010	3,109	311	130	30	10.4
Jun-10	6/3/2010	1,398	140	18	33	4.2
Jul-10	7/6/2010	1,287	129	-	28	4.6
Aug-10	8/3/2010	1,791	179	6	30	6.0
Sep-10	9/2/2010	1,781	178	28	32	5.6
Oct-10	10/4/2010	1,479	148	298	28	5.3
Nov-10	11/1/2010	4,804	480	597	30	16.0

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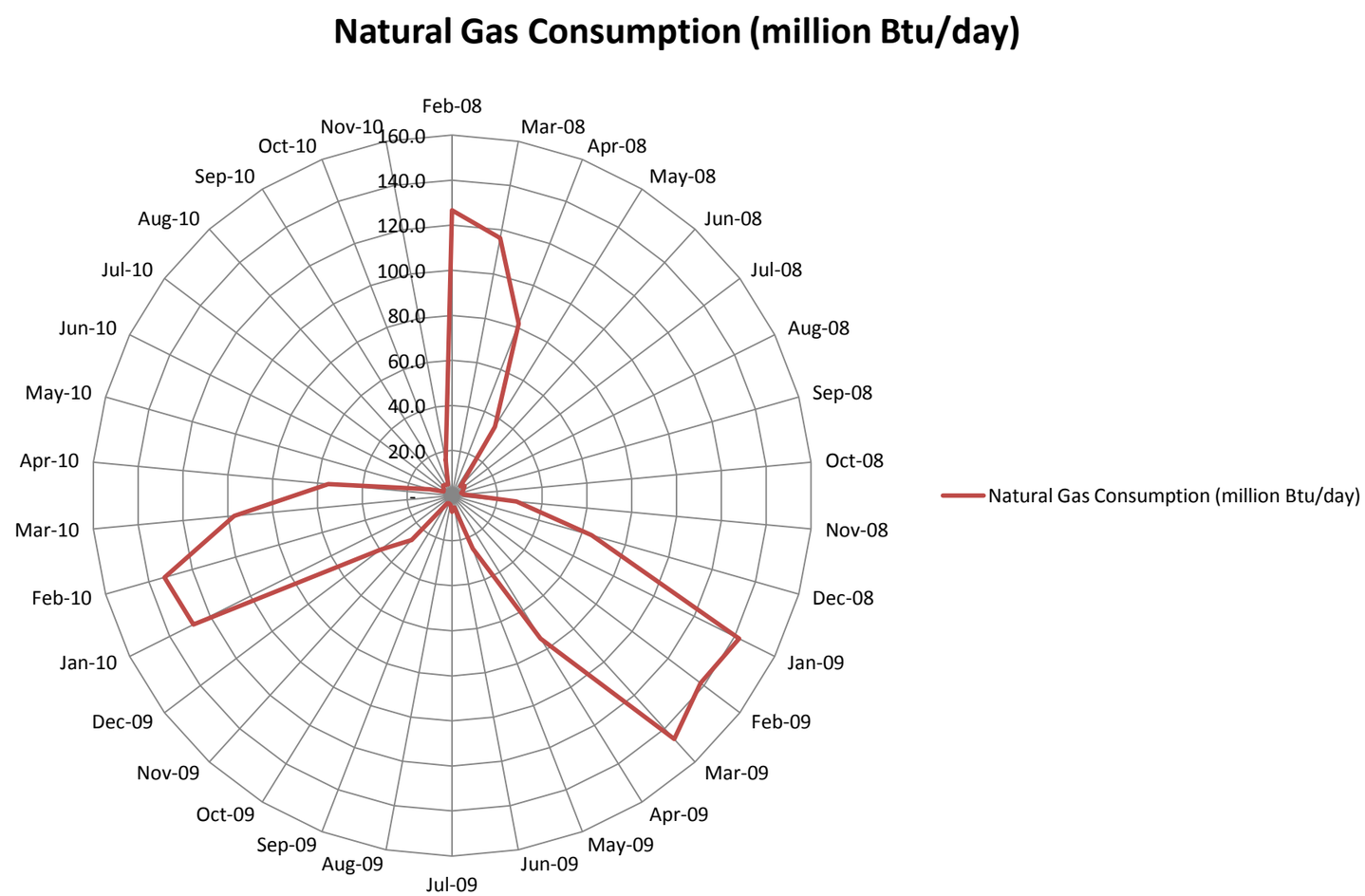
Appendix 7 - Natural Gas Radar Plot

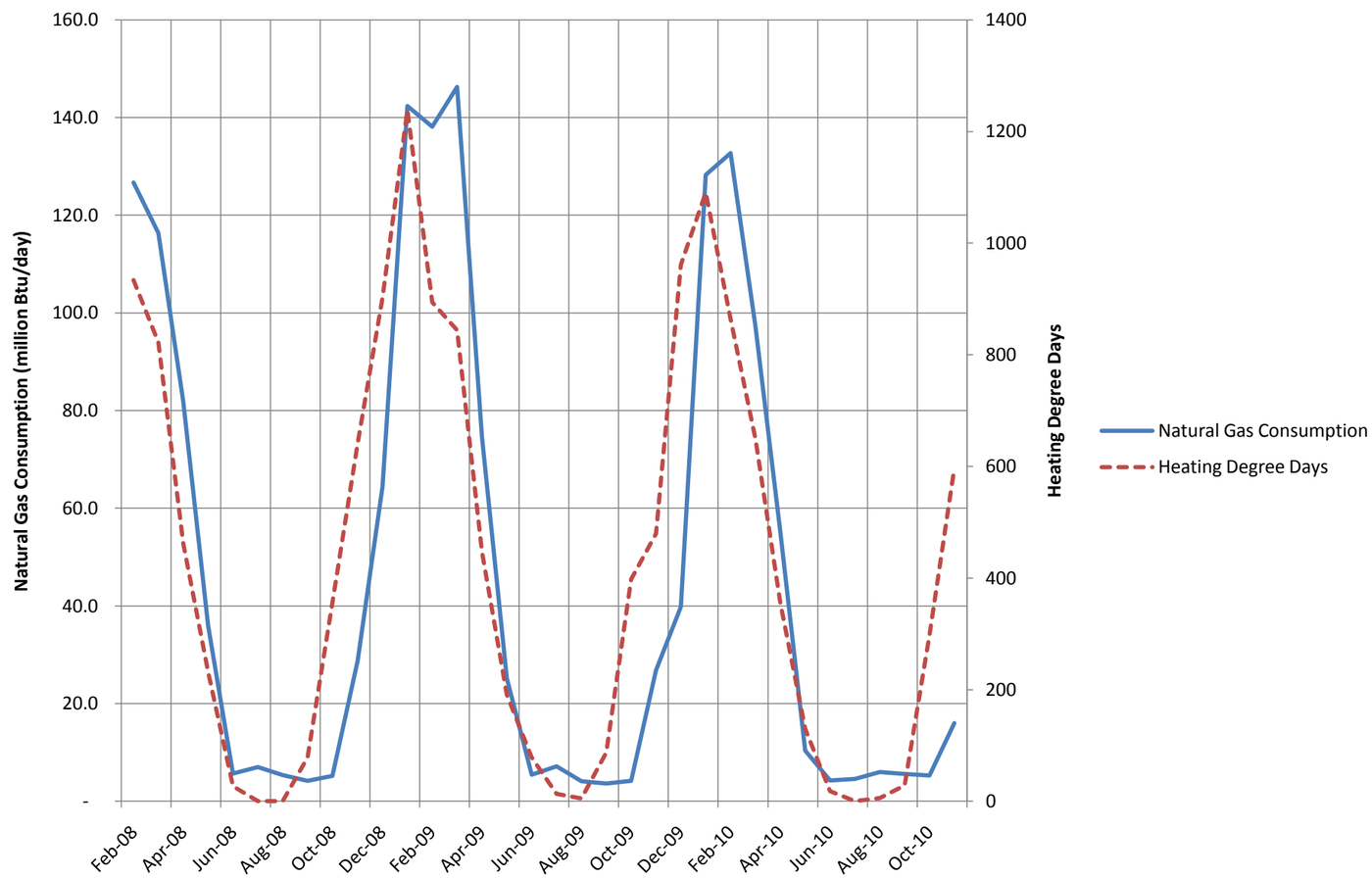
	Usage Begin Date	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	2/11/2008	126.7
Mar-08	3/11/2008	116.4
Apr-08	4/8/2008	81.9
May-08	5/7/2008	36.0
Jun-08	6/6/2008	5.6
Jul-08	7/10/2008	7.0
Aug-08	8/6/2008	5.3
Sep-08	9/8/2008	4.1
Oct-08	10/9/2008	5.2
Nov-08	11/4/2008	28.7
Dec-08	12/5/2008	64.4
Jan-09	1/8/2009	142.4
Feb-09	2/5/2009	138.2
Mar-09	3/9/2009	146.3
Apr-09	4/6/2009	74.6
May-09	5/6/2009	25.2
Jun-09	6/5/2009	5.4
Jul-09	7/13/2009	7.2
Aug-09	8/11/2009	4.1
Sep-09	9/9/2009	3.6
Oct-09	10/7/2009	4.1
Nov-09	11/4/2009	26.8
Dec-09	12/7/2009	39.8
Jan-10	1/6/2010	128.3
Feb-10	2/4/2010	132.7
Mar-10	3/5/2010	97.2
Apr-10	4/5/2010	55.2
May-10	5/4/2010	10.4
Jun-10	6/3/2010	4.2
Jul-10	7/6/2010	4.6
Aug-10	8/3/2010	6.0
Sep-10	9/2/2010	5.6
Oct-10	10/4/2010	5.3
Nov-10	11/1/2010	16.0



State House

Appendix 8 - Natural Gas Consumption v. Heating Degree Days

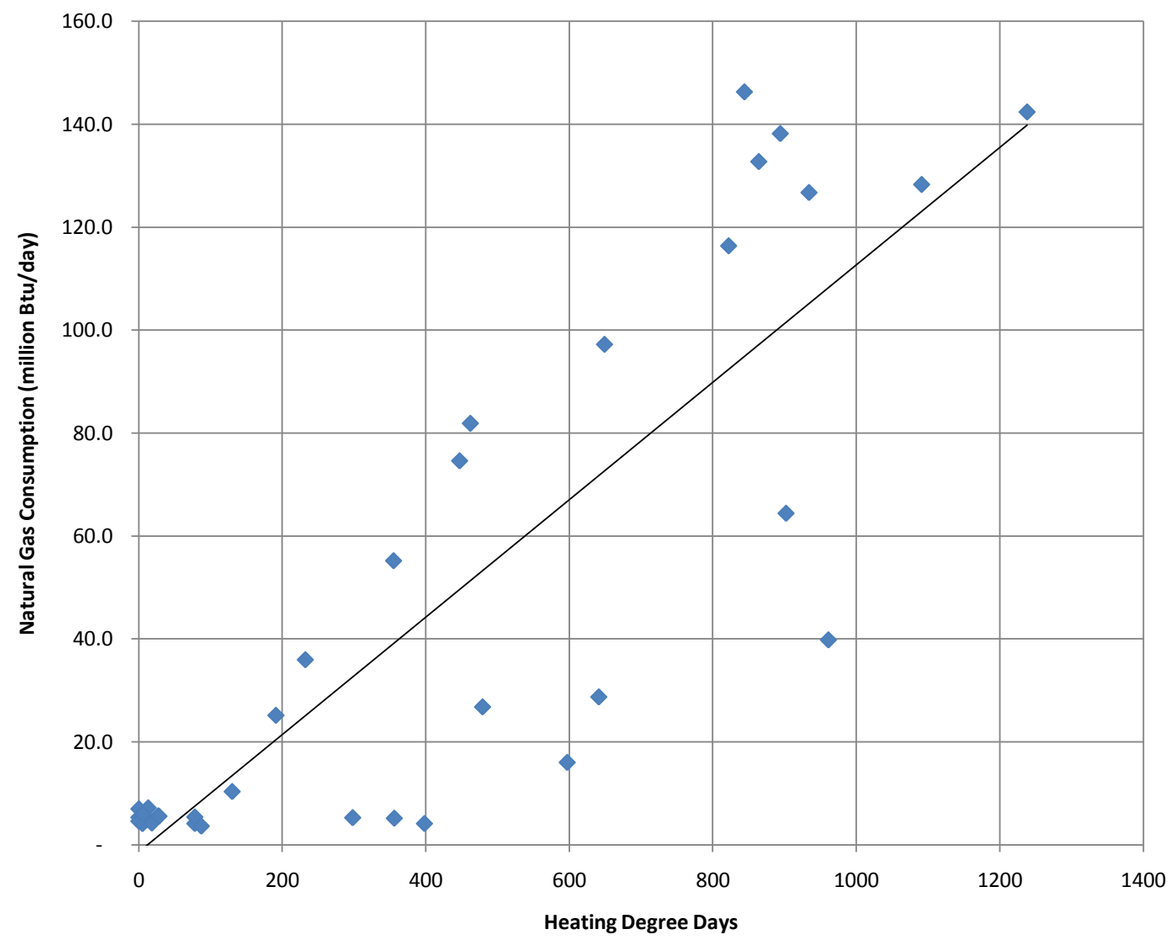
	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	126.7
Mar-08	822	116.4
Apr-08	462	81.9
May-08	232	36.0
Jun-08	27	5.6
Jul-08	-	7.0
Aug-08	-	5.3
Sep-08	78	4.1
Oct-08	356	5.2
Nov-08	641	28.7
Dec-08	902	64.4
Jan-09	1,238	142.4
Feb-09	894	138.2
Mar-09	844	146.3
Apr-09	447	74.6
May-09	191	25.2
Jun-09	78	5.4
Jul-09	13	7.2
Aug-09	5	4.1
Sep-09	87	3.6
Oct-09	398	4.1
Nov-09	479	26.8
Dec-09	961	39.8
Jan-10	1,091	128.3
Feb-10	864	132.7
Mar-10	649	97.2
Apr-10	355	55.2
May-10	130	10.4
Jun-10	18	4.2
Jul-10	-	4.6
Aug-10	6	6.0
Sep-10	28	5.6
Oct-10	298	5.3
Nov-10	597	16.0



State House

Appendix 9 - Scatter Diagram - Natural Gas Consumption v. Heating Degree Days

	Heating Degree Days	Average natural gas consumption per day (10^6 Btu/day)
Feb-08	934	126.7
Mar-08	822	116.4
Apr-08	462	81.9
May-08	232	36.0
Jun-08	27	5.6
Jul-08	-	7.0
Aug-08	-	5.3
Sep-08	78	4.1
Oct-08	356	5.2
Nov-08	641	28.7
Dec-08	902	64.4
Jan-09	1,238	142.4
Feb-09	894	138.2
Mar-09	844	146.3
Apr-09	447	74.6
May-09	191	25.2
Jun-09	78	5.4
Jul-09	13	7.2
Aug-09	5	4.1
Sep-09	87	3.6
Oct-09	398	4.1
Nov-09	479	26.8
Dec-09	961	39.8
Jan-10	1,091	128.3
Feb-10	864	132.7
Mar-10	649	97.2
Apr-10	355	55.2
May-10	130	10.4
Jun-10	18	4.2
Jul-10	-	4.6
Aug-10	6	6.0
Sep-10	28	5.6
Oct-10	298	5.3
Nov-10	597	16.0



State House

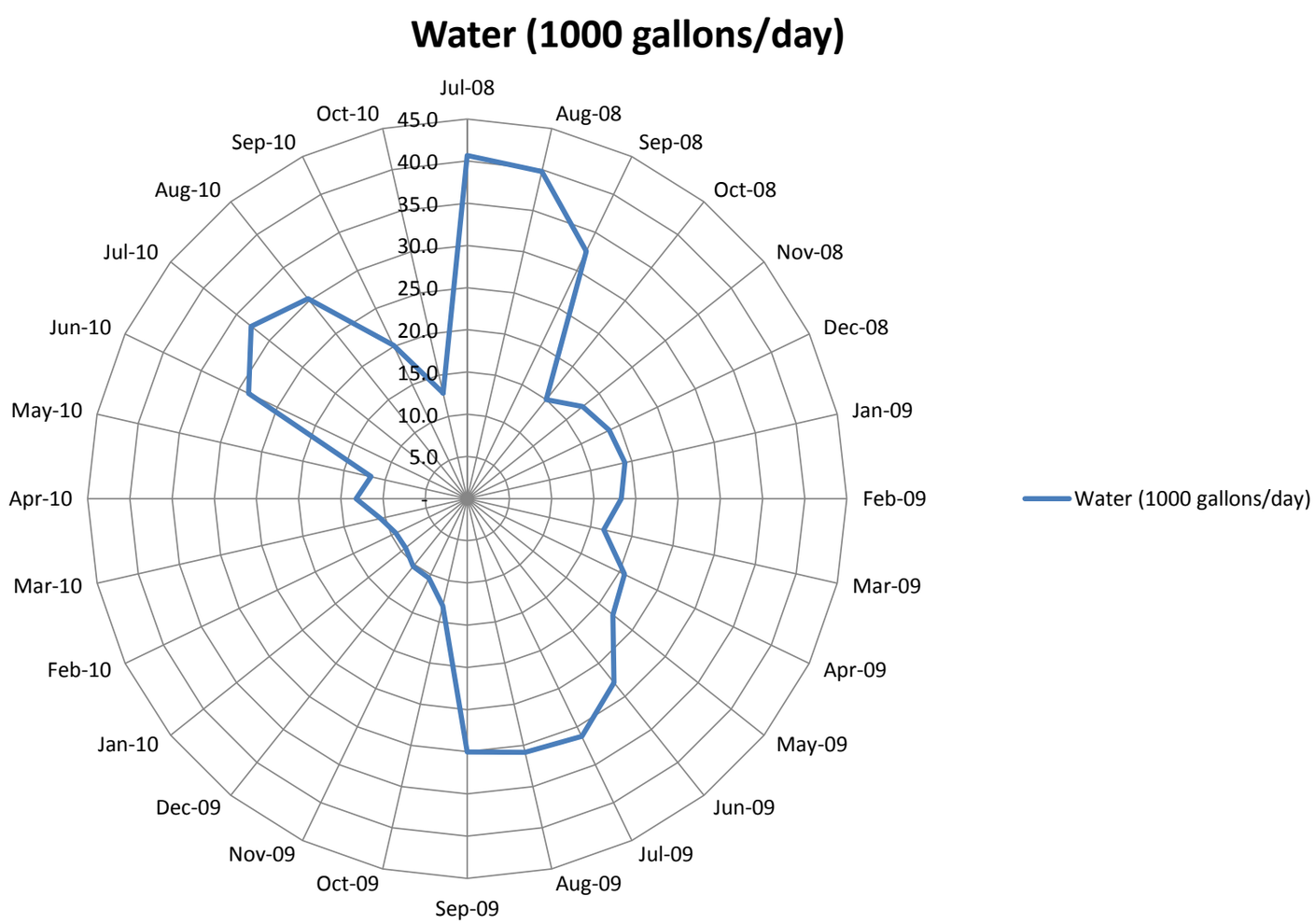
Appendix 10 - Water Consumption

Month	End Date	Number of Days in Cycle	Water Consumption (1000 gallons)	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	7/24/2008	31	1,260	40.6	320
Aug-08	8/24/2008	30	1,193	39.8	179
Sep-08	9/23/2008	30	976	32.5	105
Oct-08	10/23/2008	41	614	15.0	10
Nov-08	12/3/2008	34	595	17.5	2
Dec-08	1/6/2009	29	542	18.7	-
Jan-09	2/4/2009	28	537	19.2	-
Feb-09	3/4/2009	30	548	18.3	-
Mar-09	4/3/2009	32	531	16.6	-
Apr-09	5/5/2009	29	600	20.7	30
May-09	6/3/2009	33	729	22.1	57
Jun-09	7/6/2009	30	837	27.9	55
Jul-09	8/5/2009	29	907	31.3	204
Aug-09	9/3/2009	32	987	30.8	289
Sep-09	10/5/2009	30	901	30.0	64
Oct-09	11/4/2009	29	378	13.0	7
Nov-09	12/3/2009	34	356	10.5	2
Dec-09	1/6/2010	28	288	10.3	1
Jan-10	2/3/2010	28	262	9.4	-
Feb-10	3/3/2010	33	310	9.4	-
Mar-10	4/5/2010	30	317	10.6	2
Apr-10	5/5/2010	29	382	13.2	23
May-10	6/3/2010	33	386	11.7	104
Jun-10	7/6/2010	29	834	28.8	205
Jul-10	8/4/2010	30	983	32.8	389
Aug-10	9/3/2010	32	969	30.3	285
Sep-10	10/5/2010	29	584	20.1	170
Oct-10	11/3/2010	31	398	12.8	22

State House

Appendix 11 - Radar Plot of Water Consumption by Month

Month	Water Consumption (1000 gallons/day)
Jul-08	40.6
Aug-08	39.8
Sep-08	32.5
Oct-08	15.0
Nov-08	17.5
Dec-08	18.7
Jan-09	19.2
Feb-09	18.3
Mar-09	16.6
Apr-09	20.7
May-09	22.1
Jun-09	27.9
Jul-09	31.3
Aug-09	30.8
Sep-09	30.0
Oct-09	13.0
Nov-09	10.5
Dec-09	10.3
Jan-10	9.4
Feb-10	9.4
Mar-10	10.6
Apr-10	13.2
May-10	11.7
Jun-10	28.8
Jul-10	32.8
Aug-10	30.3
Sep-10	20.1
Oct-10	12.8



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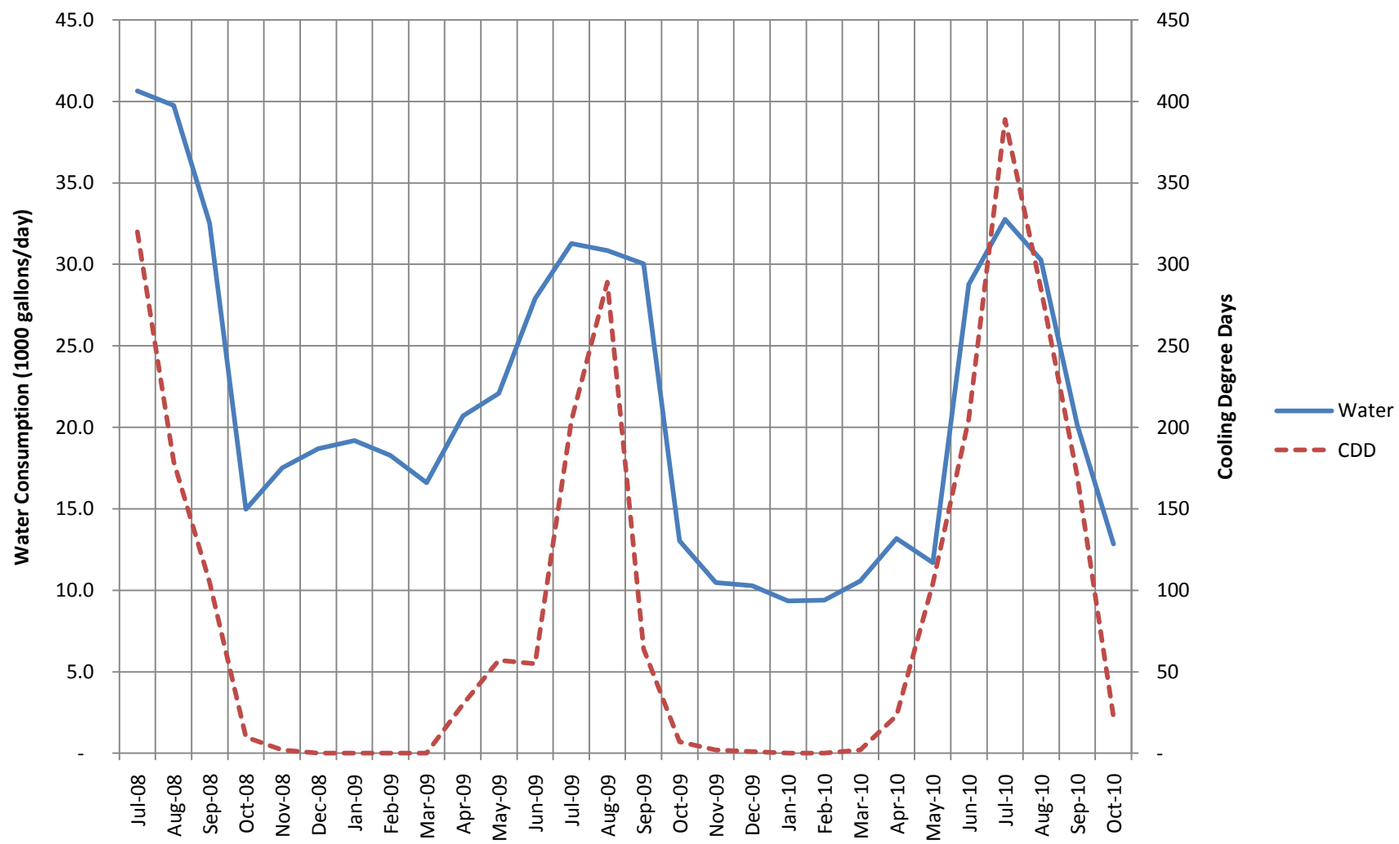
Appendix 12 - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	40.6	320
Aug-08	39.8	179
Sep-08	32.5	105
Oct-08	15.0	10
Nov-08	17.5	2
Dec-08	18.7	-
Jan-09	19.2	-
Feb-09	18.3	-
Mar-09	16.6	-
Apr-09	20.7	30
May-09	22.1	57
Jun-09	27.9	55
Jul-09	31.3	204
Aug-09	30.8	289
Sep-09	30.0	64
Oct-09	13.0	7
Nov-09	10.5	2
Dec-09	10.3	1
Jan-10	9.4	-
Feb-10	9.4	-
Mar-10	10.6	2
Apr-10	13.2	23
May-10	11.7	104
Jun-10	28.8	205
Jul-10	32.8	389
Aug-10	30.3	285
Sep-10	20.1	170
Oct-10	12.8	22



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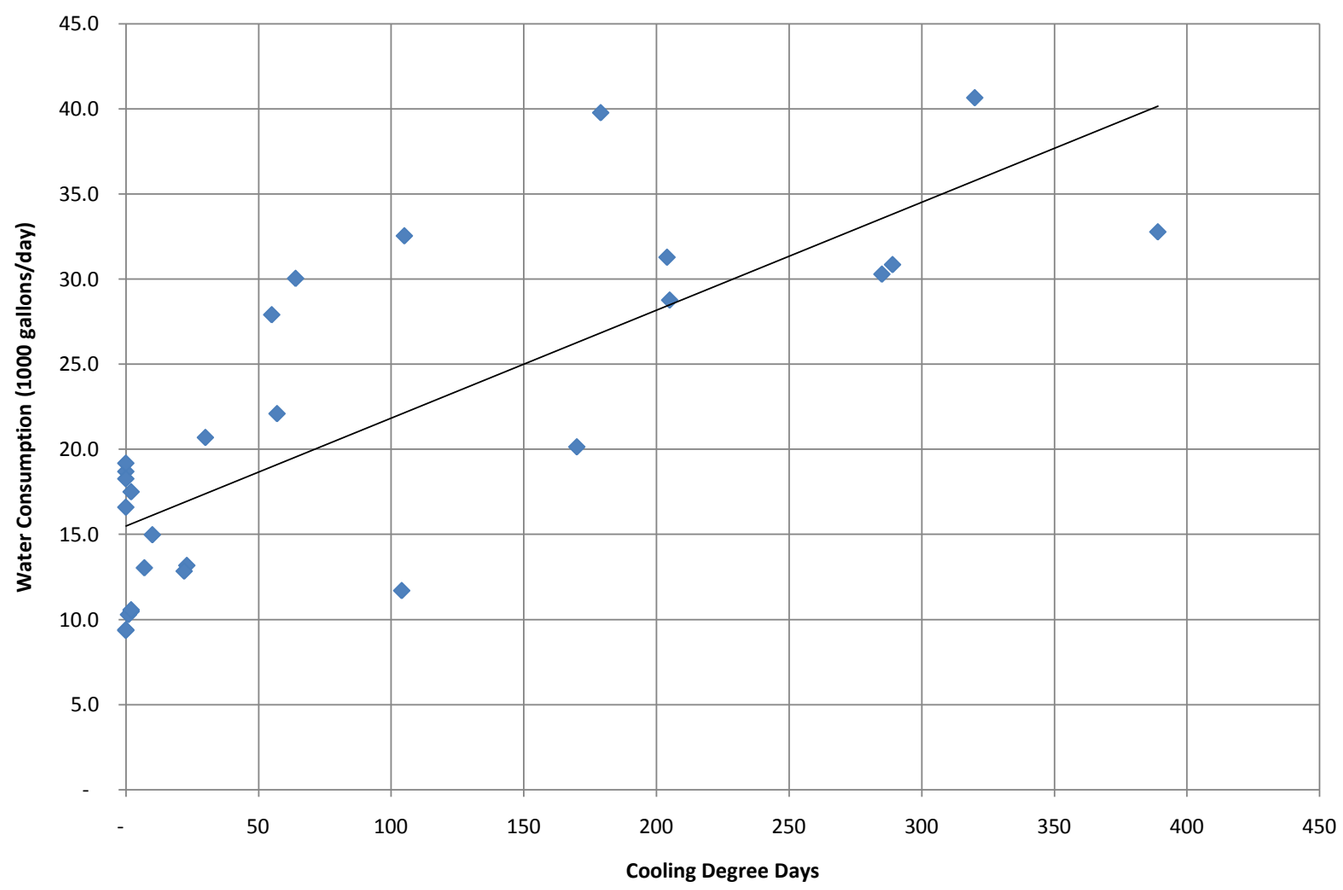
Appendix 13 - Scatter Diagram - Water Consumption v. Cooling Degree Days

Month	Water Consumption (1000 gallons/day)	Cooling Degree Days
Jul-08	40.6	320
Aug-08	39.8	179
Sep-08	32.5	105
Oct-08	15.0	10
Nov-08	17.5	2
Dec-08	18.7	-
Jan-09	19.2	-
Feb-09	18.3	-
Mar-09	16.6	-
Apr-09	20.7	30
May-09	22.1	57
Jun-09	27.9	55
Jul-09	31.3	204
Aug-09	30.8	289
Sep-09	30.0	64
Oct-09	13.0	7
Nov-09	10.5	2
Dec-09	10.3	1
Jan-10	9.4	-
Feb-10	9.4	-
Mar-10	10.6	2
Apr-10	13.2	23
May-10	11.7	104
Jun-10	28.8	205
Jul-10	32.8	389
Aug-10	30.3	285
Sep-10	20.1	170
Oct-10	12.8	22



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Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Remarks
Chiller	CH-1	Boiler Room	Carrier	19XRV5757465LDH64	Centrifugal	750 tons	2008	23	2031	0.58 kW/ton	-	Variable-speed
Chiller	CH-2	Boiler Room	Trane	CVHE-080G-AQ	Centrifugal	800 tons	1988	23	2011	0.8 kW/ton	-	-
Chiller	CH-3	Archive / Vault	RAE	33AOCD15-S	Semi-hermetic	15 tons	2001	20	2021	0.8 kW/ton	Archives	-
Pump	CHW-P1	Boiler Room	Bell and Gossett	6BC	Centrifugal	1500 gpm at 35 feet (20 hp)	1988	20	Expected life has been exceeded	-	-	-
Pump	CHW-P2	Boiler Room	Bell and Gossett	6BC	Centrifugal	1500 gpm at 35 feet (20 hp)	1988	20	Expected life has been exceeded	-	-	-
Pump	CHW-P3	Boiler Room	Bell and Gossett	6BC	Centrifugal	1125 gpm at 75 feet (40 hp)	1988	20	Expected life has been exceeded	-	-	Variable-speed
Pump	CHW-P4	Boiler Room	Bell and Gossett	6BC	Centrifugal	1125 gpm at 75 feet (40 hp)	1988	20	Expected life has been exceeded	-	-	Variable-speed
Pump	CDW-P1	Boiler Room	Bell and Gossett	6G	Centrifugal	100 hp	1988	20	Expected life has been exceeded	-	-	-
Pump	CDW-P2	Boiler Room	Bell and Gossett	6G	Centrifugal	100 hp	1988	20	Expected life has been exceeded	-	-	-
Pump	HW-P1	Boiler Room	Bell and Gossett	6BC	Centrifugal	1075 gpm at 45 feet (20 hp)	2008	20	2028	-	-	-
Pump	HW-P2	Boiler Room	Bell and Gossett	6BC	Centrifugal	1075 gpm at 45 feet (20 hp)	2008	20	2028	-	-	-
Pump	HW-P3	Boiler Room	Bell and Gossett	6BC	Centrifugal	1075 gpm at 45 feet (20 hp)	2008	20	2028	-	-	-
Pump	HW-P4	Boiler Room	Bell and Gossett	5E	Centrifugal	895 gpm at 75 feet (25 hp)	2008	20	2028	-	-	Variable-speed
Pump	HW-P5	Boiler Room	Bell and Gossett	5E	Centrifugal	895 gpm at 75 feet (25 hp)	2008	20	2028	-	-	Variable-speed
Pump	HW-P6	Boiler Room	Bell and Gossett	5E	Centrifugal	895 gpm at 75 feet (25 hp)	2008	20	2028	-	-	Variable-speed
Cooling Tower	CT-1	Roof	Baltimore Aircoil (BAC)	3648A-2	Induced draft, 2 cell	(2) 50 hp	2008	22	2030	-	-	-
Boiler	B-1 thru B-5	Boiler Room	DeDietrich	GTE519A	Natural gas-fired hot water	3,935,000 Btu/hr output each	2008	22	2030	90%	-	-
Air Handling Unit	AHU-1	Boiler Room	Trane	-	-	30 hp	1990	25	2015	-	Great Hall Hearing Rms	-
Air Handling Unit	AHU-2	Annex SB2 8-2	Trane	-	-	20 hp	1990	25	2015	-	East Side Annex	-
Air Handling Unit	AHU-3	Annex SB-48	Trane	-	-	20 hp	1990	25	2015	-	West Side Annex	-
Air Handling Unit	AHU-4	Annex SB 50-1	Trane	-	-	20 hp	1990	25	2015	-	Mech. Room Makeup Air	-
Air Handling Unit	AHU-5	BF 527	Trane	-	-	25 hp	1990	25	2015	-	House Chamber	-

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Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Remarks
Air Handling Unit	AHU-6	Dome BF 550-1	Trane	-	-	7-1/2 hp	1990	25	2015	-	Senate Chamber	-
Air Handling Unit	AHU-7	Rm 500	Trane	-	-	7-1/2 hp	1990	25	2015	-	Senate Reception	-
Air Handling Unit	AHU-8	BF 553	Trane	-	-	2 hp	1990	25	2015	-	Govenors Suite	-
Air Handling Unit	AHU-9	BF 553	York	-	-	10 hp	1990	25	2015	-	Lt. Governors Suite 280	-
Air Handling Unit	AHU-10	EWSB 17	Trane	-	-	7-1/2 hp	1990	25	2015		Gardner Auditorium	-
Air Handling Unit	AHU-11	WWSB 71	Joy Fan	-	-	20 hp	1990	25	2015	-	West Wing A and F	-
Air Handling Unit	AHU-12	WWSB 64	Trane	-	-	10 hp	1990	25	2015	-	Museum	
Air Handling Unit	AHU-13	WWSB 64	Trane	-	-	10 hp	1990	25	2015	-	Library	-
Air Handling Unit	AHU-14	EWSB 21	Trane	-	-	7-1/2 hp	1990	25	2015	-	East Wing	-
Air Handling Unit	AHU-15	BF 535A	McQuay	-	-	7-1/2 hp	1990	25	2015	-	Senate President	-
Air Handling Unit	AHU-16	EWSB 37-2	Trane	-	-	5 hp	1990	25	2015	-	Coal Pocket	-
Air Handling Unit	AHU-17	WWSB 64-2	Trane	-	-	5 hp	2000	25	2025	-	West Wing Switchgear	-
Air Handling Unit	AHU-18	WWSB 64-2	Trane	-	-	5 hp	2000	25	2025	-	Archives	-
Air Handling Unit	AHU-19	EWSB 37-1	Trane	-	-	10 hp	1990	25	2015	-	Coal Pocket	-
Air Handling Unit	AHU-20	EWSB 37-1	Trane	-	-	20 hp	1990	25	2015	-	Coal Pocket	-
Air Handling Unit	AHU-21	Attic	Trane	-	-	-	1990	25	2015	-	Room 443-445	-
Air Handling Unit	AHU-22	Security 13	Trane	-	-	-	1990	25	2015	-	Room 46	-
Air Handling Unit	AHU-23	Annex 443	Trane	-	-	-	1990	25	2015	-	Rooms 443-01-10	-
Air Handling Unit	AHU-24	Annex 445	Trane	-	-	-	1990	25	2015	-	NA	-
Air Handling Unit	AHU-25	Annex 446	Trane	-	-	-	1990	25	2015	-	Rooms 446-01-06	-
Air Handling Unit	AHU-26	Annex 437	Trane	-	-	-	1990	25	2015	-	Hearing Room	-
Air Handling Unit	AHU-27	Annex 436	Trane	-	-	-	1990	25	2015	-	Office 436	-

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Appendix 14 - Existing Equipment Matrix

Equipment Type	Designation	Location	Manufacturer	Model	Type	Capacity	Year Installed	ASHRAE Median Life (years)	Expected Year of Replacement	Efficiency	Area Being Supplied	Remarks
Air Handling Unit	AHU-28	EWB 064	Trane	-	-	-	1990	25	2015	-	Senate TV Room 064	-
Air Handling Unit	Split AHU-5	Rm 521	Climatrol	-	-	-	1990	25	2015	-	Rm 427/9	-
Air Handling Unit	AHU	Attic Rm 528	York	-	-	2 hp	1990	25	2015	-	NA	-
Air Handling Unit	AHU-1	Attic Rm 528	York	-	-	3 hp	1990	25	2015	-	NA	-
Air Handling Unit	AHU-3	Attic Rm 536	Trane	-	-	-	1990	25	2015	-	NA	-