

**LEVEL II ENERGY SURVEY AND ENGINEERING ANALYSIS  
CIVIC CENTER  
45175 WEST TEN MILE ROAD  
NOVI, MICHIGAN 48375**

*for*

**CITY OF NOVI  
45175 WEST TEN MILE ROAD  
NOVI, MICHIGAN 48375**

**AKT PEERLESS PROJECT NO. 6341E  
MONDAY, DECEMBER 14, 2009**

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## **1.0 INTRODUCTION**

The City of Novi retained AKT Peerless Environmental and Energy Services (AKT Peerless) to conduct a Level II Energy Survey and Engineering Analysis in order to prepare a Level II Energy Survey and Engineering Analysis Report of the building and associated property located at 45175 West Ten Mile Road in Novi, Michigan. AKT Peerless' scope of work and methodology is based on its proposal PF-10031, dated September 29, 2009, and the terms and conditions of the agreement.

AKT Peerless' scope of work for this Level II Energy Survey and Engineering Analysis is based on American Society of Heating, Refrigeration and Air-Conditioning Engineers' (ASHRAE's) *Procedures for Commercial Building Energy Audits* and Sections 5, 6, and 7 of ASHRAE's *Standard 105, Standard Methods of Measuring, Expressing and Comparing Building Energy Performance*. Though water use is not considered in the ASHRAE methods, a summary of water use is included in this report.

AKT Peerless' Level II Energy Survey and Engineering Analysis was performed for the benefit of the City of Novi, which may rely on the contents and conclusions presented in this report.

## **1.1 PURPOSE AND SCOPE**

The purpose of this report is to assist the Client in evaluating the property's current energy and cost efficiency relative to other, similar properties, and to identify and provide in depth analysis of the costs and savings potential of both low-cost/no-cost energy conservation measures as well as energy conservation capital improvements.

For this Level II Energy Survey and Engineering Analysis, property characteristics data was obtained from both the owner/operator of the subject property and from on-site observations and

measurements. All energy analysis was conducted in accordance with ASHRAE Procedures for Commercial Building Energy Audits and ASHRAE Standard 105.

Utility bills for a one to three-year period were summarized and reviewed for opportunities to obtain a better price through taking advantage of different utility rate classes. Monthly patterns were reviewed for irregularities. Irregularities are discussed and possible causes are proposed. Missing bills have been noted. It has also been noted if a bill reflects estimated energy consumption as opposed to actual energy consumption.

Energy and cost indices for each fuel or demand type, and their combined total, have been developed using methods specified in Sections 5, 6, and 7 of ASHRAE Standard 105. The Energy Utilization Index (EUI) and cost index are compared with the EUI of buildings having similar characteristics as reported by the Energy Information Administration (EIA) of the United States Department of Energy.

Target energy, demand, and cost indices have been derived for the subject building from either the review of data gathered by the EIA or from the experience and judgment of the Energy Analyst. The method used for generating the target EUI is discussed in the relevant narrative sections of the report.

A walk-through survey of the subject building has been conducted by the energy analyst in order to become familiar with its construction, equipment, operation, and maintenance. Mechanical and electrical system design, installed condition, maintenance practices, and operating methods have been reviewed. Key operating parameters have been measured and compared to design levels. Where the energy analyst considers discrepancies between design conditions and actual operating conditions to be noteworthy, they have been discussed in the relevant narrative section of the report. The report also includes an inventory of all major energy using equipment and typical floor plans which are included in Appendix F.

Energy conservation opportunities and preliminary costs and savings were identified, and those that were most likely to be of interest were reviewed with the subject property owner/operator. Energy conservation opportunities were then selected for further analysis and prioritized in anticipated order of implementation. The criteria used for prioritizing energy conservation opportunities are discussed in the relevant narrative sections of this report. Potential costs and savings were evaluated for each energy conservation opportunity. In order to account for interactions between energy conservation opportunities the energy analyst has assumed that modifications with the highest operational priority and/or the best return on investment will be implemented first. Software or calculations used for evaluating each energy conservation opportunity are noted in the discussion for each energy conservation measure. Software input and output data are included in Appendix G.

The description of each selected energy conservation opportunity also includes a discussion of the existing conditions in the subject building and why they are causing excessive energy use, an outline of each proposed measure's impact on occupant health, comfort, and safety, and a discussion of each measure's impact on occupant service capabilities, such as ventilation for late occupancy or year round cooling. Additionally, discussion of each energy conservation opportunity is accompanied by an estimation of each measure's anticipated impact on building

operations, maintenance costs, and non-energy operating costs, a description of any repairs that are required in order for a measure to be effective, an estimation of the expected life of the new equipment and the impact on the life of the existing equipment, and an outline of new skills that will be required for current and future operating staff.

For each practical measure, a financial evaluation of the energy conservation opportunity's investment potential has been prepared using the owner's/operator's chosen techniques and criteria. An economic evaluation has also been performed for the overall project. A discussion of any differences between the savings projected in this analysis and the estimated potential derived in the Level I analysis is also included, along with recommended measurement and verification methods that will be required in order to determine the actual effectiveness of the recommended measures.

Using this analysis energy conservation opportunities have been identified and it has been determined if further engineering analysis is recommended. All findings relating to this analysis are included in the relevant narrative sections of this Report.

## **1.2 USER PROVIDED INFORMATION AND DEVIATIONS FROM GUIDE**

ASHRAE *Procedures for Commercial Building Energy Audits* recommends that the Energy Analyst apply a consistent definition of building square footage to both the subject building and to similar buildings used for energy performance comparisons. AKT Peerless cannot evaluate the accuracy or consistency of building square footage measurements of similar buildings included in the comparison database. However, in order to improve the consistency and accuracy of building measurements and comparisons within the client's own building portfolio, a procedure for measuring the subject building square footage has been incorporated into the Basic Buildings Characteristics form provided to the client and located in Appendix A.

For this Level II Energy Survey and Engineering Analysis report the Energy Analyst has not verified the accuracy of building floor area as reported by the building owner/operator and has not verified that the building owner/operator's definition of building usage is consistent with the definitions used in the CBECS. Also, the energy analyst has not verified that the property owner/operator has reported all sources and records of energy consumed at the subject property. Potentially unreported information may include, but is not limited to, bills, meters, and types of energy consumed. Inaccurate information provided to the energy analyst and information not reported to the energy analyst may influence the findings of this preliminary report. Information provided by the owner/operator of the subject building or other client representatives is summarized in the Basic Building Characteristics form located in Appendix A and the utility bills and other energy invoices are included in Appendix E.

**1.3 ADDITIONAL SCOPE CONSIDERATIONS**

Items required by ASHRAE *Standard 105* and recommended by ASHRAE *Procedures for Commercial Building Energy Audits* are included within the Level II Energy Survey and Engineering Analysis. Additional “non-scope” considerations were addressed as part of AKT Peerless’ Level II Energy Survey and Engineering Analysis. These additional items are identified as follows:

1. A summary of greenhouse gas emissions related to building energy use has been included in this report (For calculation factors see ASHRAE *Standard 105, Additional Expressions of Energy Performance* included in Appendix C).

**2.0 PERSONNEL INTERVIEWED**

The following personnel from the facility were interviewed in the process of conducting the Level II Energy Survey and Engineering Analysis.

**Table 1  
Personnel Interviewed**

<b>Name and Title</b>	<b>Organization</b>	<b>Phone Number</b>	<b>Years Associated With Property</b>
Benny McCusker Facilities and Operations Director	City of Novi	(248) 735-5649	3

The Level II Energy Survey and Engineering Analysis was performed with the assistance and cooperation of the above referenced property contact. The Basic Building Characteristics request form, included in Appendix A, was completed with information provided during interviews with the property contact.

**3.0 PROPERTY DESCRIPTION**

This section summarizes physical characteristics and general use of the subject property.

**3.1 LOCATION**

The subject property is located at 45175 West Ten Mile Road in Novi, Michigan. Novi, Michigan is located in ASHRAE Climate Zone 5A.

**3.2 PROPERTY CHARACTERISTICS**

The subject property Primary Building Type is Public Assembly. General information pertaining to the subject building is summarized in the following table.

**Table 2  
Property Characteristics**

<b>Primary Building Type/ Occupancy</b>	<b>Region</b>	<b>Approximate Total Square Footage</b>	<b>Date of Construction</b>
Public Assembly	East North Central	65,800	1986

The original date of construction is 1986. The gross floor area is 65,800 square feet. The total conditioned area is 58,770 square feet. The conditioned area with heating only is 3,499 square feet and the conditioned area with cooling only is 295 square feet. The conditioned area that is both heated and cooled is 55,271 square feet. There are 2 conditioned floors above grade and 0 conditioned floors below grade.

The subject building has also been assigned a Building ID, 67, which will be used to reference the subject building during energy performance comparison to buildings within the same portfolio. Property characteristics have been entered into the Basic Building Characteristics form included in Appendix A.

### **3.3 BUILDING ENVELOPE**

This section contains basic information regarding the subject building envelope and construction.

#### **3.3.1 WALLS AND WALL INSULATION**

The above-grade building walls are primarily cinder block walls with face brick. There is also a large glass atrium that connects the two main structures of the civic center. The exterior wall height varies from approximately 27 feet to 13.5 feet, and the exterior wall perimeter is approximately 1,200 feet. The wall insulation could not be directly observed. However, it is assumed that the walls are un-insulated.

#### **3.3.2 ROOF AND ROOF INSULATION**

The roof types include glass (discussed further in skylight section), modified bitumen, and ballasted builtup roof or modified bitumen. The opaque roof area is grey, with no reflective surfaces. The roof insulation could not be directly observed. However, it is assumed that the roof is insulated with two inches of extruded polystyrene with an insulation value of R-14.

#### **3.3.3 FENESTRATION AND DOORS**

The building is equipped with dual-pane windows and doors. The window and door frames are metal. The surface area of the vertical windows and door openings is approximately 20% of the gross wall area, except for the atrium, which is approximately 100% glass.



### **3.4 HEATING, VENTILATING, AND AIR CONDITIONING**

Novi Civic Center is served by 4 air handling units with hot water and chilled water coils. Hot water is provided by a dedicated boiler and is pumped by constant speed hot water pumps. Chilled water is provided through a single chiller pumped by constant speed chilled water pumps. Each of the air handlers is interlocked to a return fan for concurrent operation. Two of the air handlers operate on variable speed drives, and two others operate on constant speed drive. Fresh air is modulated based on enthalpy controllers with a minimum preset value.

Domestic hot water is provided by a dedicated hot water heater with a dedicated pump.

The subject building includes VAV boxes with reheat, fan-powered VAV boxes, and sound traps.

Several exhaust fans serve toilets, janitor rooms, and similar spaces.

### **3.5 LIGHTING**

Interior lighting is primarily various forms of T-12 fixtures. There are also a variety of older specialty fixtures. Lighting is primarily controlled by manual switching. There has been some application of occupancy sensors throughout the building.

### **4.0 UTILITIES**

This section provides information on energy delivery to the subject property.

#### **4.1 ELECTRICITY**

The electricity provider is Detroit Energy. There is 1 electric meter. Electricity consumption is measured in kilowatt hours (kWh) and demand is measured in kilowatts (kW).

#### **4.2 NATURAL GAS**

The natural gas provider is Consumers Energy. There is 1 gas meter. Natural gas consumption is measured in therms.

#### **4.3 OIL/FUEL OIL/DIESEL/COAL/PROPANE**

Equipment requiring these fuel types is not used on the subject property.

#### **4.4 PURCHASED STEAM/HOT WATER/CHILLED WATER**

These sources of energy are not purchased for use on the subject property.

#### **4.5 ON-SITE RENEWABLE ENERGY GENERATION**

No renewable energy systems are present on the subject property.

## 5.0 CALCULATION OF ENERGY USE INDICES AND COST INDICES

The data measurement period for all energy analysis extends from October 2008 through September 2009.

Target energy consumption indices for each energy source have been developed by averaging energy performance of similar buildings evaluated by the CBECS. Explanations of data filters applied to CBECS data are included in the Comparison of Energy Performance form located in Appendix D.

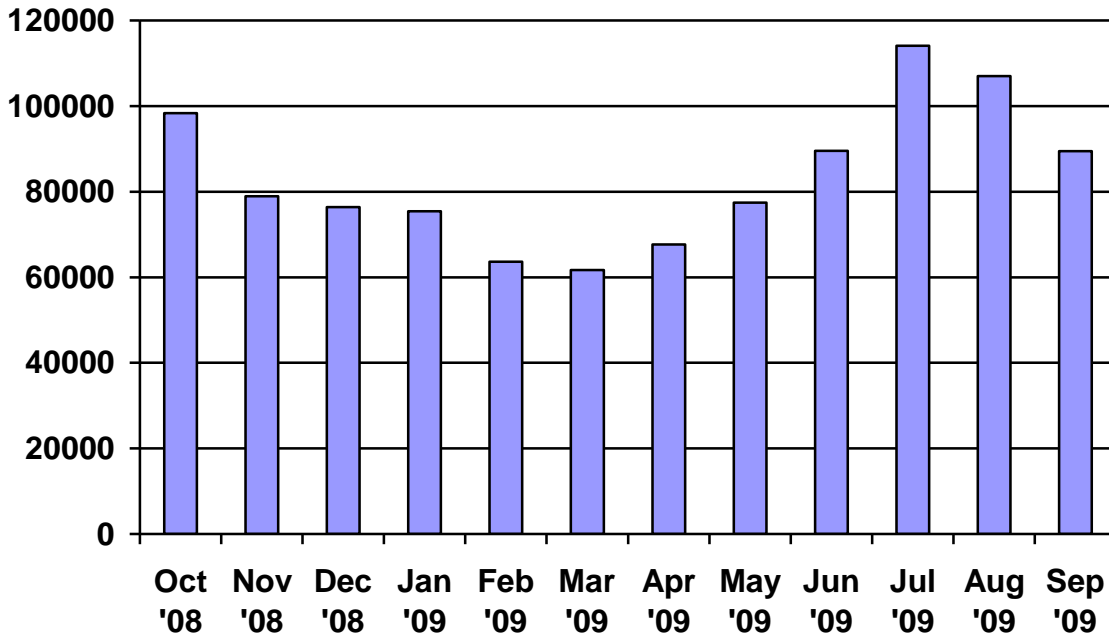
### 5.1 ELECTRICITY

For the time period covered by available records, historic electricity use is summarized in the table included below. Available energy consumption records did not contain exact dates for monthly billing periods. Consequently, billing period start and end dates have been estimated by the energy analyst. Also, billing information did not contain cost data. For the purpose of all economic calculations related to subject building electrical consumption, the energy analyst has assumed a price of \$0.10 per kWh.

**Table 3  
Electricity Consumption Records**

Account Number:	Date Start	Date End	Consumption	Estimate	Measured Demand	Consumption \$	Demand \$	Total \$
19382190024	10/1/2008	11/1/2008	98,320	<input type="checkbox"/>	0	\$9,832.00	\$0.00	\$9,832.00
19382190024	11/1/2008	12/1/2008	78,960	<input type="checkbox"/>	0	\$7,896.00	\$0.00	\$7,896.00
19382190024	12/1/2008	1/1/2009	76,400	<input type="checkbox"/>	0	\$7,640.00	\$0.00	\$7,640.00
19382190024	1/1/2009	2/1/2009	75,440	<input type="checkbox"/>	0	\$7,544.00	\$0.00	\$7,544.00
19382190024	2/1/2009	3/1/2009	63,600	<input type="checkbox"/>	0	\$6,360.00	\$0.00	\$6,360.00
19382190024	3/1/2009	4/1/2009	61,680	<input type="checkbox"/>	0	\$6,168.00	\$0.00	\$6,168.00
19382190024	4/1/2009	5/1/2009	67,680	<input type="checkbox"/>	0	\$6,768.00	\$0.00	\$6,768.00
19382190024	5/1/2009	6/1/2009	77,440	<input type="checkbox"/>	0	\$7,744.00	\$0.00	\$7,744.00
19382190024	6/1/2009	7/1/2009	89,520	<input type="checkbox"/>	0	\$8,952.00	\$0.00	\$8,952.00
19382190024	7/1/2009	8/1/2009	114,080	<input type="checkbox"/>	0	\$11,408.00	\$0.00	\$11,408.00
19382190024	8/1/2009	9/1/2009	107,040	<input type="checkbox"/>	0	\$10,704.00	\$0.00	\$10,704.00
19382190024	9/1/2009	10/1/2009	89,440	<input type="checkbox"/>	0	\$8,944.00	\$0.00	\$8,944.00

**Monthly Electricity Consumption (kWh), October 2008 - September 2009, Building ID 67**



No bills are missing. Electricity usage follows anticipated patterns. However, baseline energy consumption appears to be very high, even in the coldest months where electrical consumption is usually lowest. There may be large amounts of electricity consuming equipment operating unnecessarily. Further engineering analysis is required to perform a proper diagnosis of irregular building electrical consumption. Additional information regarding annual electricity cost, consumption, and demand is summarized in the following table.

**Table 4  
Electricity Consumption Indices and Cost**

Annual Electrical Consumption (kWh)	Average Monthly Demand (kW)	Average Cost/kWh (\$)	Average Cost/kW (\$)	Total Annual Electricity Cost (\$)	kWh/Square Foot
1,089,116	Not Available	\$0.10	Not Available	\$108,912	16.55

Total annual electrical consumption is 1,089,116 kWh. No average kW demand or kW cost calculations were performed because monthly kW readings and their accompanying cost information were not included on available utility records. Average cost per kWh on an annual basis is \$0.10. Total annual electricity cost is \$108,911.

The subject building consumes 16.55 kWh per square foot per year (square footage measurement excludes parking lot and other illuminated exterior spaces). The target use index, based on expected average performance as indicated by the CBECS, is 11.51 kWh per square foot per year. Subject building electrical consumption is greater than average.

The electric cost index per square foot per year is \$1.66. The target cost index, based on average electrical consumption, is \$1.15 per square foot per year. \$33,149.13 in annual savings is possible from meeting the target use index of 11.51 kWh per square foot per year. Additional analysis would be required to determine the feasibility of this facility achieving target energy performance.

AKT Peerless was not provided sufficient information to evaluate the feasibility of achieving a more favorable rate class.

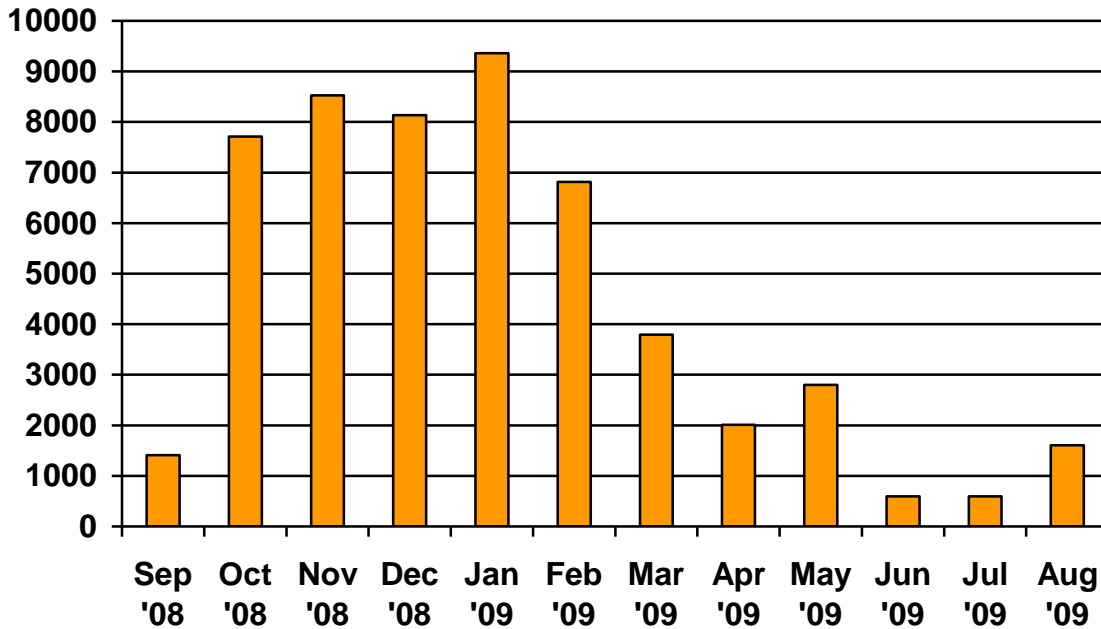
## 5.2 NATURAL GAS

For the time period covered by available utility records, historic natural gas use is summarized in the following table. Available energy consumption records did not contain exact dates for monthly billing periods. Consequently, billing period start and end dates have been estimated by the energy analyst. Also, natural gas cost data was only made available for the most recent billing period. For all natural gas cost calculations, the most recent rates have been applied to all previous billing periods.

**Table 5  
Natural Gas Consumption Records**

Account Number:	Date Start	Date End	Consumption	Estimate	Consumption \$	Demand \$	Total \$
100004993422	9/15/2008	10/15/2008	1,409	<input type="checkbox"/>	\$1,126.67	\$0.00	\$1,126.67
100004993422	10/15/2008	11/15/2008	7,710	<input type="checkbox"/>	\$6,165.12	\$0.00	\$6,165.12
100004993422	11/15/2008	12/15/2008	8,525	<input type="checkbox"/>	\$6,816.81	\$0.00	\$6,816.81
100004993422	12/15/2008	1/15/2009	8,135	<input type="checkbox"/>	\$6,504.96	\$0.00	\$6,504.96
100004993422	1/15/2009	2/15/2009	9,359	<input type="checkbox"/>	\$7,483.70	\$0.00	\$7,483.70
100004993422	2/15/2009	3/15/2009	6,814	<input type="checkbox"/>	\$5,448.65	\$0.00	\$5,448.65
100004993422	3/15/2009	4/15/2009	3,793	<input type="checkbox"/>	\$3,032.98	\$0.00	\$3,032.98
100004993422	4/15/2009	5/15/2009	2,008	<input type="checkbox"/>	\$1,605.65	\$0.00	\$1,605.65
100004993422	5/15/2009	6/15/2009	2,800	<input type="checkbox"/>	\$2,238.95	\$0.00	\$2,238.95
100004993422	6/15/2009	7/15/2009	596	<input type="checkbox"/>	\$476.58	\$0.00	\$476.58
100004993422	7/15/2009	8/15/2009	597	<input type="checkbox"/>	\$477.38	\$0.00	\$477.38
100004993422	8/15/2009	9/15/2009	1,604	<input type="checkbox"/>	\$1,282.60	\$0.00	\$1,282.60

**Monthly Natural Gas Consumption (Therms), September 2008 - August 2009,  
Building ID 67**



No bills are missing. Therm usage generally follows anticipated monthly patterns and no abnormalities were observed. Additional information regarding annual natural gas cost and consumption is summarized in the following table.

**Table 6  
Natural Gas Consumption Indices and Cost**

<b>Annual Natural Gas Consumption (Therms)</b>	<b>Average Cost/Therm (\$)</b>	<b>Total Annual Natural Gas Cost (\$)</b>	<b>Therms/Square Foot</b>
58,302	\$0.800	\$46,620	0.89

Total natural gas consumption is 58,302 therms. Average cost per therm on an annual basis is \$0.80. Total annual natural gas cost is \$46,619.

The subject building consumes 0.89 therms per square foot per year (square footage measurement excludes parking lot and other illuminated exterior spaces). The target use index, based on expected average performance as indicated by the CBECS, is 0.61 therms per square foot per year. Subject building natural gas consumption is higher than average.

The natural gas cost index per square foot per year is \$0.71. The target cost index, based on average consumption levels, is \$0.49 per square foot per year. \$14,480.75 in annual savings is possible from meeting the target use index of 0.61 therms per square foot per year.

Additional analysis would be required to determine the feasibility of this facility achieving target energy performance. AKT Peerless was not provided sufficient information to evaluate the feasibility of achieving a more favorable rate class.

### **5.3 OIL/FUEL OIL/DIESEL/COAL/PROPANE**

Equipment requiring these fuel types is not used on the subject property.

### **5.4 PURCHASED STEAM/HOT WATER/CHILLED WATER**

These sources of energy are not purchased for use on the subject property.

## **6.0 CALCULATION OF CARBON EMISSION EQUIVALENCIES FROM BUILDING ENERGY USE**

Based on data gathered from the United States Environmental Protection Agency (USEPA) eGRID database, the subject building is located in eGRID electric utility subregion RFCM. This grid's conversion factor is 0.74. The annual electric use is 1,089,116 kWh. The subject property's electrical consumption has resulted in greenhouse gas emissions equivalent to 810.90 metric tonnes of carbon dioxide. Greenhouse gas emissions from electrical consumption are based on emissions data measured at the electrical generating facilities serving consumers located in the specified eGRID utility subregion, and therefore greenhouse gas emissions reflect the mix of fuel sources used by the regional electrical utilities serving the subject property.

Natural gas consumption by the subject building has resulted in greenhouse gas emissions equivalent to 309.58 metric tonnes of carbon dioxide. Emissions factors for natural gas consumption are based on data gathered from the 2009 United States Greenhouse Gas Inventory, Annex 2.

Total greenhouse house gas emissions from building energy use are equivalent to 1,120.48 metric tonnes of carbon dioxide.

## **7.0 ENERGY PERFORMANCE BENCHMARK**

The subject property's EUI (expressed in units of kBtu/ft<sup>2</sup>/yr) is compared to the Energy Performance Benchmarks of other buildings of similar characteristics. Benchmarks may be expressed as therms/ft<sup>2</sup>/yr, kWh/ft<sup>2</sup>/yr or kBtu/ft<sup>2</sup>/yr (also called EUI). AKT Peerless obtains comparison EUIs (benchmarks) from the following sources:

- "Table C5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels for Non-Mall Buildings, 2003" prepared by the Energy Information Administration of the United States Department of Energy.

- A statistical analysis of the Commercial Building Energy Consumption Survey (CBECS) prepared by the Energy Information Administration of the United States Department of Energy.

Table C5 is a simple lookup table that is presented in Appendix F. The statistical analysis of the CBECS filters the database based on region, building use, size, and year of construction (refer to Appendix D). This filtered data set is used to calculate the benchmarks for each energy source, as well as an overall benchmark EUI. The benchmarks shown in the portfolio summary are derived from the statistical analysis described in this section.

**Table 7**  
**Energy Performance Benchmark**

	<b>Actual Building</b>	<b>Statistical Benchmarks</b>	<b>Table C5</b>
<b>kWh/ft<sup>2</sup>/yr</b>	<b>16.55</b>	<b>11.51</b>	
<b>Therms/ft<sup>2</sup>/yr</b>	<b>0.89</b>	<b>0.61</b>	
<b>EUI</b>	<b>140.63</b>	<b>100.37</b>	<b>101.7</b>

## **8.0 ENERGY STAR RATING**

Based on statistical models employed by the Energy Star program of the United States Department of Energy the subject building is estimated to receive an Energy Star score of 44. A building qualifying for Energy Star certification must have a minimum score of 75. Therefore, the subject property is not a candidate for Energy Star certification.

## **9.0 ENERGY MODELING**

Hour-by-hour energy use in the subject building has been simulated with eQuest energy modeling software. The eQuest simulation engine is DOE-2, which is a set of energy simulation programs developed for the United States Department of Energy by the Lawrence Berkeley National Laboratory's Simulation Group.

DOE-2 calculates the hourly energy use and energy cost of a commercial or residential building given information about the building's climate, construction, operation, utility rate schedule, and HVAC equipment. Using the program, designers can determine the choice of building parameters that improve energy efficiency while maintaining thermal comfort and cost-effectiveness.

## **10.0 ENERGY CONSERVATION OPPORTUNITIES**

AKT Peerless has identified 4 potential energy conservation measures (ECMs). ECMs have been prioritized according to return on investment, and it is assumed that ECMs with the greatest

investment returns will be implemented first. Savings may be different if a different implementation sequence is followed.

### **10.1 ECM 1 – LIGHTING RETROFIT**

Energy savings from lamp fixtures can be accomplished by two ways. First, inefficient lamps are replaced by more efficient lamps. Second, automatic controls ensure that lamps are switched off when they are not intended to be in use. Improvements include replacing old fixtures having inefficient T-12 lamp tubes and magnetic ballasts with fixtures having more efficient T-8 lamp tubes and electronic ballasts. Since T-8 lamps produce more light, it is also possible to reduce the number of lamps per fixture for further electrical savings. Further improvements include timers for fixtures in atrium, waiting area, and various Center corridors. In order to obtain maximum energy savings when embarking on a lighting retrofit, it is important first obtain an overall lighting design.

### **10.2 ECM 2 – VARIABLE FREQUENCY DRIVES ON AIR HANDLING UNITS**

Variable frequency drives are devices that can modulate the speed of electric motors.

Heating, ventilation and air-conditioning systems are typically designed to meet a building's loads at peak conditions. However, most buildings operate at full load conditions for only short periods of time. This means that the building is operating with oversized equipment throughout the rest of the year. The fans and pumps that drive the HVAC systems are some of the largest consumers of electric power in the building. These include chilled water and hot water distribution pumps, cooling tower fans, air handling unit fans and ventilation fans.

Substantial energy savings can be achieved if the speed of these electric motors can be reduced in response to changing load conditions. Since the power draw of electric motors is proportional to the cube of its rotational speed, very large reductions in power consumption can be achieved through relatively small reductions in speed. For example, if the rotational speed of an electric motor is reduced by one half, the corresponding electricity use will be only one eighth of the original power draw.

### **10.3 ECM 3 – CARBON DIOXIDE SENSORS**

Outdoor air is required for to provide fresh oxygen, to dilute contaminants and to ensure sufficient building pressurization to prevent infiltration of air into buildings. The building HVAC system maintains indoor air quality by constantly exhausting a certain percentage of the indoor air and replacing it with fresh air from outside. Additional energy must be expended to condition this outside air before it is circulated through the building. Depending on the season it must either be heated and humidified or cooled and dehumidified. At present, the HVAC system draws in a constant volume of outside air.

The quantity of fresh air required to provide sufficient ventilation depends on factors such as the number of occupants and the type of space usage. Further, as building occupancy also usually varies during different periods of the day, it is not necessary to provide a constant amount of fresh air at all times. Hence, fresh air provided can be varied based on building occupancy. A simple solution is to use carbon dioxide (CO<sub>2</sub>) sensors to monitor the CO<sub>2</sub> level in the occupied



spaces or the return air at the AHUs and use it as an indicator of occupancy to vary the outdoor airflow. The CO2 level can be set at a predetermined value, and the proportion of the outdoor and return airflow quantities varied to maintain this set point.

#### 10.4 ECM 4 – DUCT REDESIGN EVALUATION

Portions of the current ductwork in the mechanical room are undersized, have too many bends, and have poorly designed fittings. This increases the resistance the fan must overcome and requires much larger fans than necessary. The fans in this system have relatively long hours of operation and are among the largest consumers of electricity in the in the whole building. Improving the ductwork according to the standards recommended by Sheet Metal and Air Conditioning Contractors Association will reduce resistance that the fan has to overcome and can substantially reduce the electrical consumption of a motor. Improvements can include resizing undersized ductwork, installing turning vanes within duct elbows, and using standard fitting whenever possible.

A detailed engineering study would be required to determine the cost for retrofitting the ductwork at the Civic center, which could vary widely (estimates put it somewhere between \$50,000 and \$150,000). The cost of this study is estimated to be \$27,700.

#### 10.5 ECM SUMMARY

The following table summarizes expected savings from all proposed energy conservation opportunities. Savings are based on the implementation order presented above. Savings may be different if a different implementation sequence is followed:

ECM Description	ECM	Additional First Cost (\$)	KWH Annual Savings (KWh)	KWH Annual Savings (\$)	KW Demand Reduction (KW)	KW Demand Reduction (\$)	Therm Annual Savings (Therms)	Therm Annual Savings (\$)	Total Annual Savings (\$)	GHG Reduction (Metric Tonnes)
Replace motors with variable frequency drives	ECM1	\$35,501	263,780	\$26,378	24.00	\$0	(388)	(\$310)	\$26,068	193.1
Retrofit T-12 Lighting with T-8	ECM2	\$86,360	141,000	\$14,100	24.00	\$0	(3,227)	(\$2,582)	\$11,518	87.2
C02 Monitors	ECM3	\$1,800	210,720	\$21,072	0.00	\$0	(8,426)	(\$6,741)	\$14,331	111.2
Duct Work Redesign Evaluation	ECM4	\$27,700	78,930	\$7,893	3.96	\$0	0	\$0	\$7,893	58.4
<b>Totals</b>		<b>\$151,361</b>	<b>694430</b>	<b>\$69,443</b>	<b>51.96</b>	<b>\$0</b>	<b>(12,041)</b>	<b>(\$9,633)</b>	<b>\$59,810</b>	<b>449.9</b>

#### 10.6 ECM FINANCIAL EVALUATION

The following table summarizes the anticipated investment performance of the selected ECMs:

Energy Cost Reduction Measure (ECM)	ID	Study Period	Additional First Cost	Annual Savings	Monthly Savings	Simple Payback (yrs)
Replace motors with variable frequency drives	ECM1	10	\$35,501	\$26,068	\$2,172	1.4
Retrofit T-12 Lighting with T-8	ECM2	10	\$86,360	\$11,518	\$960	7.5
C02 Monitors	ECM3	10	\$1,800	\$14,331	\$1,194	0.1
Duct Work Redesign Evaluation	ECM4	10	\$27,700	\$7,893	\$658	3.5
<b>Totals</b>		<b>\$40</b>	<b>\$151,361</b>	<b>\$59,810</b>	<b>\$4,984</b>	

### 10.7 ECM MEASUREMENT AND VERIFICATION

On-going monitoring of energy bills and monthly energy consumption trends is recommended throughout the proposed retrofit process.

### 11.0 DOCUMENTATION REVIEW

Prior to the Level II Energy Survey and Engineering Analysis, relevant documentation was requested that could aid in the knowledge of the subject property’s historic energy use. The review of submitted documents does not include comment on the accuracy of such documents or their preparation, methodology, or protocol. The following documents were available for review while performing the Level II Energy Survey and Engineering Analysis:

- Electric Utility Bills
- Natural Gas Utility Bills
- USEPA eGRID Database
- 2009 United States Greenhouse Gas Inventory, Annex 2
- USEPA Climate Leaders Calculator for Low Emitters
- 2003 Commercial Building Energy Consumption Survey

No other documents were provided for review. Annual energy consumption is also summarized in the Energy Performance Summary form, included in Appendix B. All utility bills and invoices are included in Appendix D.

### 12.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this report is to assist the Client in evaluating the property's current energy and cost efficiency relative to other, similar properties, and to identify and provide in depth analysis of the costs and savings potential of both low-cost/no-cost energy conservation measures as well as energy conservation capital improvements. AKT Peerless' scope of work is based on ASHRAE's "*Procedures for Commercial Building Energy Audits*" and ASHRAE Standard 105 "*Standard Methods of Measuring, Expressing and Comparing Building Energy Performance*."

The combined annual EUI for the subject building is 140.63 kBtu per square foot per year. The annual energy cost index is \$2.36 per square foot per year. Reduction of all fuel (non-electrical), and electrical energy consumption to target levels indicated in Section 5 could result in an EUI of 100.38 kBtu per square foot per year and a possible annual cost index of \$1.64 per square foot per year. If all recommended ECMs are implemented, anticipated total savings are \$53,652.

### **13.0 LIMITATIONS**

Analysis of potential energy cost savings are based on the assumption that future average energy costs will remain the same as the average energy costs calculated from energy bills and energy invoices provided for the purpose of conducting this Level II Energy Survey and Engineering Analysis.

AKT Peerless accepts responsibility for the competent performance of its duties in executing this assignment and preparing this report in accordance with the normal standards of the profession, but disclaims any responsibility for consequential damages. Although AKT Peerless believes the results contained in herein are reliable, AKT Peerless cannot warrant or guarantee that the information provided is exhaustive, or that the information provided by the Client, third parties, or the secondary information sources cited in this report is complete or accurate.

Should additional information become available to the Client that differs significantly from our understanding of conditions presented in this report, AKT Peerless requests that such information be forwarded immediately to our attention so that we may reassess the conclusions provided herein and amend this project's scope of services as necessary and appropriate.

Nothing in this report constitutes a legal opinion or legal advice. For information regarding individual or organizational liability, AKT Peerless recommends consultation with independent legal counsel.

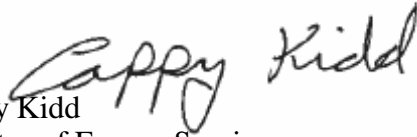
**14.0 SIGNATURES**

Report submitted by:

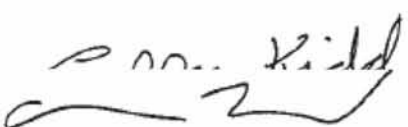


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## **APPENDICES**

### **Appendix A**

## **ASHRAE STANDARD 105, BASIC BUILDING CHARACTERISTICS**

## BASIC BUILDING CHARACTERISTICS

Building ID 67  
 Address 45175 West Ten Mile Road  
 City, State, ZIP Code Novi , Michigan , 48375  
 Gross Floor Area<sup>1</sup> 65,800  
 Number of Conditioned Floors: Above Grade: 2 Below Grade: 0  
 Primary year of construction<sup>2</sup> 1986

### BUILDING TYPE 3 (PERCENT OF GROSS FLOOR AREA)

<b>Office</b>	<input checked="" type="checkbox"/> Owner Occupied <input type="checkbox"/> Leased—1–5 Tenants <input type="checkbox"/> Leased—5+ Tenants <input type="checkbox"/> Bank/Financial <input type="checkbox"/> Courthouse <input type="checkbox"/> Other—Define _____	<b>Health Care</b>	<input type="checkbox"/> Nursing Home/Assisted Living <input type="checkbox"/> Psychiatric <input type="checkbox"/> Clinic/Outpatient <input type="checkbox"/> Active Treatment Hospital <input type="checkbox"/> Other—Define _____
<b>Hotel/Motel</b>	<input type="checkbox"/> Motel (No Food) <input type="checkbox"/> Hotel <input type="checkbox"/> Hotel/Convention <input type="checkbox"/> Other—Define _____	<b>Retail</b>	<input type="checkbox"/> Dry-Cleaning/Laundromat <input type="checkbox"/> Supermarket/Food Market <input type="checkbox"/> General Merchandise <input type="checkbox"/> Shopping Mall without Tenant Loads <input type="checkbox"/> Shopping Mall without Tenant Lighting Loads <input type="checkbox"/> Shopping Mall <input type="checkbox"/> Specialty Shop <input type="checkbox"/> Bakery <input type="checkbox"/> Other—Define _____
<b>Apartment</b>	<input type="checkbox"/> General Occupancy <input type="checkbox"/> Seniors Only <input type="checkbox"/> Dorm/Fraternity/Sorority <input type="checkbox"/> Other—Define _____	<b>Assembly</b>	<input type="checkbox"/> Theatre <input type="checkbox"/> Library <input type="checkbox"/> Convention Center <input type="checkbox"/> Museum/Gallery <input type="checkbox"/> Church/Synagogue <input type="checkbox"/> Arena/Gym <input type="checkbox"/> Arena/Rink <input type="checkbox"/> Nightclub <input type="checkbox"/> Other—Define _____
<b>Education</b>	<input type="checkbox"/> Primary <input type="checkbox"/> Pre-School/Daycare <input type="checkbox"/> Secondary <input type="checkbox"/> College/University <input type="checkbox"/> Other—Define _____	<b>Other</b>	<input type="checkbox"/> Laboratory <input type="checkbox"/> Warehouse <input type="checkbox"/> Warehouse—Refrigerated <input type="checkbox"/> Recreation/Athletic Facility <input type="checkbox"/> Post Office/Center <input type="checkbox"/> Transport Terminal <input type="checkbox"/> Multi-Use Complex
<b>Food Services</b>	<input type="checkbox"/> Restaurant—Full Service <input type="checkbox"/> Fast Food <input type="checkbox"/> Take Out <input type="checkbox"/> Lounge <input type="checkbox"/> Other—Define _____		
<b>Auto Services</b>	<input type="checkbox"/> Service/Repair <input type="checkbox"/> Sales <input type="checkbox"/> Other—Define _____		
<b>Public Order</b>	<input type="checkbox"/> Jail/Penitentiary <input type="checkbox"/> Fire/Police Station		

1. GROSS FLOOR AREA is all floor area contained within the outside finished surface of permanent outer building walls including basements, mechanical equipment floors, and penthouses.

## **Appendix B**

# **ASHRAE STANDARD 105, ENERGY PERFORMANCE SUMMARY**

## ENERGY PERFORMANCE SUMMARY

Energy Type	Source of Energy Data	Energy Use Numerical Value	Units	Conversion Multiplier to kBtu (kWh)	Energy, kBtu/yr (kWh/yr)	Energy Cost, \$
1. Electricity—Purchased	Bills	1,089,116	kWh	3.143	3,423,093	\$108,912
2. Natural gas	Bills	58,302	Therm	100	5,830,165	\$46,620
3. Steam						
4. Hot water						
5. Chilled water						
6. Oil # _____						
7. Propane						
8. Coal						
9. Thermal—On-Site Renewable						
10. Other						
11. Electricity—On-Site Generated						
12. Thermal or Electricity—Exported						
<b>Total Energy</b> <sup>1</sup> sum of 1 to 11 minus 12					<b>A: 9,253,258</b>	
<b>Net Energy</b> <sup>2</sup> Sum of 1 to 11 minus 9 and solar PV-generated kWh in 11					<b>B: 9,253,258</b>	<b>C: \$155,531.15</b>

<sup>1</sup>The Total Energy is the sum of all energy used in the building, plus on-site generated electricity from renewable sources or from sources other than fuels covered in items 2–8, minus exported energy. Under a net metering agreement, the electric utility meter may record the purchased energy minus the exported energy.

<sup>2</sup>The Net Energy is the sum of the purchased energy minus sold or exported energy (thus accounting for both on-site generated energy used in the building and energy exported from the site).

## ENERGY AND COST INDICES

Total Energy Index (A ÷ Gross Floor Area)	140.63	kBtu/ft <sup>2</sup> /yr·yr (kWh/m <sup>2</sup> ·yr)
Net Energy Index (B ÷ Gross Floor Area)	140.63	kBtu/ft <sup>2</sup> /yr·yr (kWh/m <sup>2</sup> ·yr)
Energy Cost Index (C ÷ Gross Floor Area)	\$2.36	\$/ft <sup>2</sup> ·yr (\$/m <sup>2</sup> ·yr)



## **Appendix C**

# **ASHRAE STANDARD 105, ADDITIONAL EXPRESSIONS OF ENERGY PERFORMANCE**

## Additional Expressions of Energy Performance

### Specification of Comparison of Normalizing Factors

Name of Additional Factor or Characteristic for Normalization (for performance comparison, all factors shown must be specified)	Type of Factor: Occupancy, Building, Weather, Energy, User-Specified	Value of Factor: Numeric or Logical (for performance comparison, factors not applicable must be shown as "N/A.")	Unit of Factor, if needed, or notes
Number of full-time equivalent workers	Occupancy		
Number of full-time equivalent students	Occupancy		
Number of licensed hospital beds	Occupancy		
Food service seating capacity	Occupancy		Seats
Number of personal computers	Occupancy		
Weekly hours of operation	Occupancy		Hours/ Week
Annual months of operation	Occupancy		Months/ Year
Computer center/network/comm. area	Building		Percent of Floor Area
Annual average W/sq ft (W/sq mtr) for computer center and comm. Area	Building		W/sq ft (W/sq mtr)
Percent of gross floor area heated	Building		Percent of Floor Area
Percent of gross floor area cooled	Building		Percent of Floor Area
Heating degree-days (base 65F/18C)	Weather		Degree- Days
Cooling degree-days (base 65F/18C)	Weather		Degree- Days
Parking garages	Building		Sq Ft (Sq Mtr)
Natatorium space	Building		Sq Ft (Sq Mtr)
Natatorium present or not	Building		Yes or No, 1 or 0
Annual peak electric demand	Energy		kW
Electricity generation capacity	Energy		kW
Annual electricity generation	Energy		kWh/yr

**Additional Numerical Expressions of Energy Use Performance**

TOTAL ENERGY: kBtu (kWh) Total from Form 2 (provide note if other energy total is used)	Factor or Characteristic for Normalization	Expression of Energy Performance (numerical value)	Units of Performance
<b>Examples:</b>	Factors	Might include factors such as licensed beds for hospitals, number of annual transactions for retail stores, number of students for schools.	
	Corresponding Units of Performance	Could be kBtu/yr (kWh/yr) per bed for hospitals, per each transaction for retail stores, per student for schools.	

## **Appendix D**

# **ASHRAE STANDARD 105, COMPARISON OF BUILDING ENERGY PERFORMANCE**

## COMPARISON OF ENERGY PERFORMANCE

### Building Identification

Building ID	67	Comparison Start Date
Address	45175 West Ten Mile Road	Comparison End Date
City, State, Country, ZIP Code	Novi, Michigan 48375	
Gross Floor Area from Form 1	65,800	ft <sup>2</sup> (m <sup>2</sup> )
Total Energy Index from Form 2	140.63	kBtu/ft <sup>2</sup> /yr·yr (kWh/m <sup>2</sup> ·yr)
Net Energy Index from Form 2	140.63	kBtu/ft <sup>2</sup> /yr·yr (kWh/m <sup>2</sup> ·yr)
Cost Index from Form 2	\$2.36	\$/ft <sup>2</sup> ·yr (\$/m <sup>2</sup> ·yr)

<b>Documented Comparison</b>	Access point of report describing analytical methods	URL or other: See section 8
<b>Access Information</b>	Access point of comparison data base used for analytical method	URL or other: <a href="http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html">http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html</a>

### Comparison Data Basic Statistics—Provide for ALL METHODS

Comparison Factor Name/Description	Units	Mean	Maximum	Minimum
Gross Floor Area	Sq Ft	45983.33	86000	17250
Year of Construction	Years	1,981	2001	1950

For additional factors, attach additional sheet(s).

### Data Filters Used for Analysis—Provide for ALL METHODS

Comparison Factor Name/Description*	Units	Filter Criteria
Census Region		“East North Central”
Building Use		“Public assembly”
Gross Floor Area	Sq Ft	15800 < Gross Floor Area < 115800
Year of Construction	Years	1936 < Year of Construction < 2036

For additional factors, attach additional sheet(s).

\*Initial data filters are a square foot range of 10,000 square feet above and below the subject building’s actual square footage and a year of construction 20 years before and after the subject building’s actual year of construction. If the initial data filters do not return a minimum of 12 data points, the data filters are widened until they return at least 12 data points.

## **Appendix E**

### **Utility Bills / Consumption Records**

## Electric Consumption

AccountNumber:	Date Start	Date End	Consumption	Estimate	Measured Demand	Consumption \$	Demand \$	Total \$
19382190024	9/1/2009	10/1/2009	89,440	<input type="checkbox"/>	0	\$8,944.00	\$0.00	\$8,944.00
19382190024	8/1/2009	9/1/2009	107,040	<input type="checkbox"/>	0	\$10,704.00	\$0.00	\$10,704.00
19382190024	7/1/2009	8/1/2009	114,080	<input type="checkbox"/>	0	\$11,408.00	\$0.00	\$11,408.00
19382190024	6/1/2009	7/1/2009	89,520	<input type="checkbox"/>	0	\$8,952.00	\$0.00	\$8,952.00
19382190024	5/1/2009	6/1/2009	77,440	<input type="checkbox"/>	0	\$7,744.00	\$0.00	\$7,744.00
19382190024	4/1/2009	5/1/2009	67,680	<input type="checkbox"/>	0	\$6,768.00	\$0.00	\$6,768.00
19382190024	3/1/2009	4/1/2009	61,680	<input type="checkbox"/>	0	\$6,168.00	\$0.00	\$6,168.00
19382190024	2/1/2009	3/1/2009	63,600	<input type="checkbox"/>	0	\$6,360.00	\$0.00	\$6,360.00
19382190024	1/1/2009	2/1/2009	75,440	<input type="checkbox"/>	0	\$7,544.00	\$0.00	\$7,544.00
19382190024	12/1/2008	1/1/2009	76,400	<input type="checkbox"/>	0	\$7,640.00	\$0.00	\$7,640.00
19382190024	11/1/2008	12/1/2008	78,960	<input type="checkbox"/>	0	\$7,896.00	\$0.00	\$7,896.00
19382190024	10/1/2008	11/1/2008	98,320	<input type="checkbox"/>	0	\$9,832.00	\$0.00	\$9,832.00

## Natural Gas Consumption

AccountNumber:	Date Start	Date End	Consumption	Estimate	Consumption \$	Total \$
100004993422	8/15/2009	9/15/2009	1,604	<input type="checkbox"/>	\$1,282.60	\$1,282.60
100004993422	7/15/2009	8/15/2009	597	<input type="checkbox"/>	\$477.38	\$477.38
100004993422	6/15/2009	7/15/2009	596	<input type="checkbox"/>	\$476.58	\$476.58
100004993422	5/15/2009	6/15/2009	2,800	<input type="checkbox"/>	\$2,238.95	\$2,238.95
100004993422	4/15/2009	5/15/2009	2,008	<input type="checkbox"/>	\$1,605.65	\$1,605.65
100004993422	3/15/2009	4/15/2009	3,793	<input type="checkbox"/>	\$3,032.98	\$3,032.98
100004993422	2/15/2009	3/15/2009	6,814	<input type="checkbox"/>	\$5,448.65	\$5,448.65
100004993422	1/15/2009	2/15/2009	9,359	<input type="checkbox"/>	\$7,483.70	\$7,483.70
100004993422	12/15/2008	1/15/2009	8,135	<input type="checkbox"/>	\$6,504.96	\$6,504.96
100004993422	11/15/2008	12/15/2008	8,525	<input type="checkbox"/>	\$6,816.81	\$6,816.81
100004993422	10/15/2008	11/15/2008	7,710	<input type="checkbox"/>	\$6,165.12	\$6,165.12
100004993422	9/15/2008	10/15/2008	1,409	<input type="checkbox"/>	\$1,126.67	\$1,126.67

## **Appendix F**

### **Table C5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels for Non-Mall Buildings, 2003**



**Table C5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels for Non-Mall Buildings, 2003**

Principal Building Activity	Energy Intensity for Sum of Major Fuels (thousand Btu/square foot)			
	North-east	Mid-west	South	West
Education	101.6	86.3	75.5	77.6
Food Sales	Q	219.1	187.7	Q
Food Service	Q	218.8	283.4	243.8
Health Care	212.2	205.6	169.8	179.6
Inpatient	Q	272.2	226.7	246.8
Outpatient	Q	124.4	60.9	115.3
Lodging	Q	109.0	96.9	103.7
Retail (Other Than Mall)	65.0	102.7	68.7	63.2
Office	101.2	108.8	87.0	72.1
Public Assembly	Q	101.7	93.2	91.2
Public Order and Safety	Q	Q	Q	Q
Religious Worship	52.1	52.8	38.3	27.6
Service	79.8	85.0	66.3	80.0
Warehouse and Storage	41.6	74.7	26.7	39.0
Other	Q	Q	Q	Q
Vacant	Q	Q	Q	Q

**Appendix G**  
**CBECS Data Set Buildings**

<b>Building ID</b>	<b>Census Division</b>	<b>Building Use</b>	<b>Sq Footage</b>	<b>Date Constr.</b>	<b>Ann kWh</b>	<b>Ann Nat Gas</b>	<b>Adj Weight</b>	<b>EUI</b>
112	East North Central	Public assembly	21,000	1970	454920	23517	776.54	144358.306763886
317	East North Central	Public assembly	24,750	1996	422880	0	278.18	16217.2371580121
590	East North Central	Public assembly	24,000	1950	360989	9726	864.37	79388.5837210483
1053	East North Central	Public assembly	70,000	1999	191540	106974	220.48	35752.2004878629
1062	East North Central	Public assembly	57,000	1998	2377893	38938	80.08	16869.0218763733
1623	East North Central	Public assembly	50,000	1999	1720233	49176	92.84	20029.3665805728
2324	East North Central	Public assembly	55,000	1968	1061166	97444	199.06	48371.9361074822
2848	East North Central	Public assembly	57,000	1955	128722	45793	184.27	16223.8402847593
3351	East North Central	Public assembly	75,000	1982	1985921	58430	404.15	67999.3823330107
4009	East North Central	Public assembly	17,250	1957	58080	5143	3110.9	128488.097835594
4508	East North Central	Public assembly	86,000	1993	1274195	20080	87.12	6438.32333698605
4531	East North Central	Public assembly	20,250	1981	391954	6016	402.35	38525.2022105086
4867	East North Central	Public assembly	25,000	2001	75640	2443	404.15	8121.53457088
5780	East North Central	Public assembly	43,500	1995	896293	114332	363.08	120954.48232288
6202	East North Central	Public assembly	64,000	1968	1067809	33368	203.6	22205.647704825

## **Appendix H**

### **Glossary**

**Barrel:** A volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons.

**Bottled Gas, LPG, or Propane:** Any fuel gas supplied in liquid form, such as liquefied petroleum gas, propane or butane. It is usually delivered by tank truck and stored near the building in a tank or cylinder until used.

**Btu (British Thermal Unit):** A unit of energy consumed by or delivered to a building. A Btu is defined as the amount of energy required to increase the temperature of 1 pound of water by 1 degree Fahrenheit, at normal atmospheric pressure. Energy consumption is expressed in Btu to allow for consumption comparisons among fuels that are measured in different units. (See Btu Conversion Factors and Metric Conversion Factors.)

**Btu Conversion Factors:** The Btu conversion factors used for the CBECS are shown in the following table. Only the Natural gas factor differed between the 199 and 2003 surveys.

Energy Source	Btu Equivalent	Unit
Electricity	3,413	kilowatt hour
Natural Gas (1999)	1,027	cubic foot
Natural Gas (2003)	1,031	cubic Foot
Distillate Fuel Oils (Nos. 1, 2, and 4)	138,690	Gallon
Residual Fuel Oils (Nos. 5 and 6)	149,690	Gallon

**Sources:** Energy Information Administration, *Annual Energy Review 2004*.

Note: A Btu of district hot water has been converted into equivalent pounds of steam with the conversion of 1,000 Btu hot water approximately =1 pound steam.

**Source:** *Methodological Issues in the Nonresidential Buildings Energy Consumption Survey* (September 1983), p. 173-175

**CDD:** See Cooling Degree-Days (CDD).

**Census Region and Division:** A geographic area consisting of several states defined by the U.S. Department of Commerce, Bureau of the Census. See following table:

Region	Division	States
Northeast	New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont
	Middle Atlantic	New Jersey, New York, and Pennsylvania
Midwest	East North Central	Illinois, Indiana, Michigan, Ohio, and Wisconsin
	West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota
South	South Atlantic	Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia

	East South Central	Alabama, Kentucky, Mississippi, and Tennessee
	West South Central	Arkansas, Louisiana, Oklahoma, and Texas
West	Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming
	Pacific	Alaska, California, Hawaii, Oregon, and Washington

**Cogeneration:** The simultaneous production of electric and thermal energy in on-site, distributed energy systems; typically, waste heat from the electricity generation process is recovered and used to heat, cool, or dehumidify building space. Neither generation of electricity without use of the byproduct heat, nor waste-heat recovery from processes other than electricity generation is included in the definition of cogeneration. (See Electricity Generation.)

**Commercial:** In the CBECS, commercial refers to any building that is neither residential (used as a dwelling for one or more households), manufacturing/industrial (used for processing or procurement of goods, merchandise raw materials or food), nor agricultural (used for the production, processing, sale, storage, or housing of agricultural products, including livestock). At least 50 percent of the floor space must be used for purposes other than these for a building to be considered “commercial.”

**Commercial Building:** A building with more than 50 percent of its floor space used for commercial activities. Commercial buildings include, but are not limited to, the following: stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings were included except for buildings on sites with restricted access, such as some military bases. Agricultural buildings, residences, and manufacturing/industrial buildings are excluded. Since 1995, parking garages and commercial buildings on manufacturing sites have also been excluded. For a list of building types, see [“Description of types of buildings.”](#) ( See Building , Commercial, and Principal Building Activity.)

**Conditional Energy Intensity:** Total consumption of a particular energy source(s) or fuel(s) divided by the total floorspace of buildings that use the energy source(s) or fuel(s), i.e., the ratio of consumption to energy source-specific floorspace. This measure is used in the fuel-specific detailed tables.

**Consumption:** The amount of energy used in, or delivered to, a building during a given period of time. Unless otherwise noted, all consumption statistics are site energy consumption, which includes electric utility sales to commercial buildings but excludes electrical system and district heat energy losses. Statistics are presented on an annual basis for the survey calendar year. Site consumption is the amount of energy delivered to the site (building); no adjustment is made for the fuels consumed to produce electricity or district sources. Site consumption is also referred to as net energy. Primary consumption is the amount of site consumption plus losses that occur in the electricity generation process.

Data on energy consumption were not collected by end uses separately. For example, although it might be known that electricity was used in some buildings for heating, the consumption of electricity reported for those buildings would typically include other uses of electricity as well (such as lighting and water heating). Total consumption is reported as well as “Consumption per Square Foot”—the aggregate ratio of total consumption for a particular set of buildings to the total floor space of those buildings; and “Consumption per Worker”—the aggregate ratio of total consumption to total number of workers (main shift). (See Btu, Conversion Losses, Energy Supplier, Expenditures, Floor space, and Workers (Main Shift).)

**Cooling Degree-Days (CDD):** A measure of how hot a location was over a period of time, relative to a base temperature. In this report, the base temperature is 65 degrees Fahrenheit, and the period of time is one year. The cooling degree-day is the difference between that day’s average temperature and 65 degrees if the daily average is greater than 65; it is zero if the daily average temperature is less than or equal to 65. Cooling degree-days for a year are the sum of the daily cooling degree-days for that year.

**Cubic Foot (cf):** As a natural gas measure, the volume of gas contained in a cube with an edge that is 1 foot long at standard temperature and pressure (60 degrees Fahrenheit and 14.73 pounds standard per square inch.) The thermal content varies by the composition of the gas. (See Natural Gas and Btu Conversion Factors.)

**Degree-Days 45-Year Average:** The average of the total annual heating and cooling degree-days (base, 65 Degrees Fahrenheit) in each NOAA Division, for the 45 years, 1931 through 1975. Computed from the Division’s daily temperature averages for each year in question and used to assign individual buildings to climate zones. (See NOAA Division and Climate Zone.)

**Electricity:** Electric energy supplied to a building by a central utility via power lines or from a central physical plant in a separate building that is part of the same multibuilding facility. Electric power generated within a building for exclusive use in that building is specifically excluded from the definition of electricity as an energy source.

**Electricity Generation:** As an energy end use, the onsite production of electricity by means of electricity generators on either a regular or emergency basis. (See **Energy End Use and Electricity**.)

**Energy Intensity:** The ratio of consumption to unit of measurement (floor space, number of workers, etc.) Energy intensity is usually given on an aggregate basis, as the ratio of the total consumption for a set of buildings to the total floor space in those buildings. Conditional energy intensity and gross energy intensity are presented. The energy intensity can also be computed for individual buildings. (See **Conditional Energy Intensity** and **Gross Energy Intensity**.)

**Energy-Related Space Functions:** The use of space in the building for one or more of three specific functions: commercial food preparation, activities requiring large amounts of hot water, and separate computer areas. (See **Commercial Food Preparation, Separate Computer Area, and Activities with Large Amounts of Hot Water**.)

**Energy Source:** A type of energy or fuel consumed in a building. In the CBECS, information about the use of electricity, natural gas, fuel oil, district heat, district chilled water, propane, wood, coal, and solar thermal panels in commercial buildings was obtained from the building

respondent. In most tables, wood, coal, and solar thermal panels are included in the “Other” category under “Energy Sources.” (See **Electricity, Natural Gas, Fuel Oil, District Heat, District Chilled Water, Liquefied Petroleum Gas [LPG], Propane, Wood, Coal, and Solar Thermal Panels.**)

**Energy Source-Specific Floorspace:** Total floorspace of those buildings that use a particular fuel, for example, total floorspace in buildings that use natural gas. (See **Conditional Energy Intensity.**)

**Floorspace:** All the area enclosed by the exterior walls of a building, both finished and unfinished, including indoor parking facilities, basements, hallways, lobbies, stairways, and elevator shafts. For aggregate floorspace statistics, floorspace was summed or aggregated over all buildings in a category (such as all office buildings in the United States). (See **Square Footage.**)

**Fuel Oil:** A liquid petroleum product used as an energy source that is less volatile than gasoline. Fuel oil includes distillate fuel oil (Nos. 1, 2, and 4), residual fuel oil (Nos. 5 and 6), and kerosene.

**Gallon:** A volumetric measure equal to 4 quarts (231 cubic inches) used to measure fuel oil. One barrel equals 42 gallons.

**Geothermal Heat Pump:** See **Ground Source Heat Pump.**

**Government Owned:** A building owned by a Federal, State, or local government agency. The building may be occupied by agencies of more than one government and may also be shared with nongovernment establishments.

**Gross Energy Intensity:** Total consumption of a particular energy source(s) or fuel(s) by a group of buildings, divided by the total floorspace of those buildings, including buildings and floorspace where the energy source or fuel is not used, i.e., the ratio of consumption to gross floorspace. (See **Conditional Energy Intensity.**)

**Gross Floorspace:** Total floorspace of a group of buildings, regardless of which end uses are present or which energy sources or fuels are used within the buildings. (See **Energy Source-Specific Floorspace** and **Gross Energy Intensity.**)

**Heating Degree-Days (HDD):** A measure of how cold a location was over a period of time, relative to a base temperature. In CBECS, the base temperature used is 65 degrees Fahrenheit, and the period of time is one year. The heating degree-day is the difference between that day’s average temperature and 65 degrees if the daily average is less than 65; it is zero if the daily average temperature is greater than or equal to 65. Heating degree-days for a year are the sum of the daily heating degree-days for days that year.

**Imputation:** A statistical method used to generate values for missing items, designed to minimize the bias of estimates based on the resulting data set. In this survey, missing responses were generated using a procedure known as a “hot-deck imputation” which uses random resampling from similar nonmissing cases to generate values for missing cases.



**Intensity:** The amount of a quantity per unit of measurement (floorspace, number of workers, etc.) This is a method of adjusting either the amount of energy consumed or expenditures spent, for the effects of various building characteristics, such as size of the building, number of workers, or number of operating hours, to facilitate comparisons of energy across time, fuels, and buildings. (See **Conditional Energy Intensity, Energy Intensity, Expenditures, and Gross Energy Intensity**)

**Kilowatthour (kWh):** A unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,413 Btu. (See **Btu.**)

**Liquefied Petroleum Gas (LPG):** Any fuel gas supplied to a building in liquid form. Propane is the usual LPG, but gases such as butane, propylene, butylene, and ethane are also LPG. For this report, any LPG reported was assumed to be propane. (See **Energy Source, Propane, and Natural Gas.**)

**LPG:** See **Liquefied Petroleum Gas (LPG).**

**Major Fuels:** The energy sources or fuels for which consumption and expenditures data are collected. These fuels or energy sources are: electricity, fuel oil, natural gas, district steam, and district hot water. (See **Energy Source.**)

**Manufacturing:** As an energy end use, any of the energy-using operations required for manufacturing/industrial processes. (See **Energy End Use.**)

**Metric Conversion Factors:** Estimates are presented in customary U.S. units. Floorspace estimates may be converted to metric units by using the relationship: 1 square foot is approximately equal to 0.0929 square meters. Energy estimates may be converted to metric units by using the relationship: 1 Btu is approximately equal to 1,055 joules; one kilowatthour is exactly equal to 3,600,000 joules; and one gigajoule ( $10^9$  joules) is approximately 278 kilowatthours (kWh).

**Multibuilding Facility:** A group of two or more buildings on the same site owned or operated by a single organization, business, or individual. Examples include university campuses and hospital complexes.

**Multistage Area Probability Sample:** A sample design executed in stages with geographic “clusters” of sampling units selected at each stage.

**Natural Gas:** Hydrocarbon gas (mostly methane) supplied as an energy source to individual buildings by pipelines from a central utility company. Natural gas does not refer to liquefied petroleum gas (LPG) or to privately owned gas wells operated by a building owner. (See **Energy Source, Liquefied Petroleum Gas (LPG), and Propane.**)

**NOAA Division:** One of the 356 weather divisions designated by the National Oceanic and Atmospheric Administration (NOAA) that encompass the 50 contiguous United States and the District of Columbia. These divisions usually follow county borders to encompass counties with similar weather conditions. However, the NOAA division does not follow county borders when weather conditions vary considerably within a county, as is likely to be the case when a county

borders the ocean or contains high mountains. A State contains an average of seven NOAA divisions; a NOAA division contains an average of nine counties. (See **Climate Zone**.)

**Nongovernment Owned:** Owned by an individual or a group, such as a private business, a nonprofit organization, a privately-owned utility company; or a church, synagogue, or other religious organization. The building may be occupied by more than one agency and may be owner occupied, nonowner occupied or unoccupied.

**Nonowner Occupied:** Refers to a building that actually “does not have the owner or the owners’ business located at the site.” (If both the owner and other tenants are in a building, the building would be classified as owner occupied. Just because someone else is there, in and of itself, does not mean the building is nonowner occupied.)

**Owner Occupied:** Refers to a building that has the owner or the owner’s business represented at the site.

**Ownership and Occupancy:** Ownership refers to the individual, agency, or organization that owns the building. Building ownership is grouped into Government ownership (Federal, State, or local) and Nongovernment ownership (a private business or nonprofit organization owned by a group or an individual). Occupancy refers to the individual, agency, or organization that leases or holds the space on a full-time basis. (See **Owner Occupied** and **Nonowner Occupied**.)

**Percent of Floorspace Cooled:** The percentage of a building’s square footage that is cooled to meet the comfort requirements of the occupants.

**Percent of Floorspace Heated:** The percentage of a building’s square footage designed to be heated to at least 50 degrees Fahrenheit.

**Primary Sampling Unit (PSU):** A sampling unit selected at the first stage in a multistage area probability sample. A PSU typically consists of one to several contiguous counties—for example, an MSA with surrounding suburban counties.

**Principal Building Activity:** The activity or function occupying the most floorspace in a building. The categories were designed to group buildings that have similar patterns of energy consumption. Examples of various types of principal activity include office, health care, lodging, and mercantile and service. (See [Description of CBECS Building Types](#) for a complete list and definitions of each.)

**RSE or Relative Standard Error:** A measure of the reliability or precision of a survey statistic. Variability occurs in survey statistics because the different samples that could be drawn would each produce different values for the survey statistics. The RSE is defined as the standard error (the square root of the variance) of a survey estimate, divided by the survey estimate and multiplied by 100. For example, an RSE of 10 percent means that the standard error is one-tenth as large as the survey estimate. Tables of RSEs are provided for each of the CBECS Detailed Tables.

**Square Footage:** Floorspace, in units of square feet. One square foot is approximately equal to 0.0929 square meters. (See **Floorspace**.)

**Standard Error:** A measure of the precision of an estimate, equal to the square root of the variance. (See **Variance** and **RSE or Relative Standard Error**.)

**Vacant:** A building was considered vacant if 50 percent or more of the floorspace was not occupied by any tenant or establishment at the time of the interview. A vacant building may contain occupants who are using up to 50 percent of the floorspace. For all buildings, data were collected on whether the building had any floorspace that was vacant for three or more consecutive months and on the number of months the building was in use. (See **Principal Building Activity**.)

**Variance:** A measure of the variability of a set of observations that are subject to some chance variation, equal to the expected squared difference between a single observation and the average of all possible observations obtained in the same manner. The variance is the square of the standard error of estimates. The variance indicates the likely difference between the value computed from the CBECS sample and the average of the values that could have been computed from all possible samples that might have been obtained by the same sample selection process. (See **Standard Error**.)

**Weight:** The number of buildings in the United States that a particular building in the sample represents. To estimate the total value of an attribute (such as square footage) in the U.S. commercial buildings population as a whole, each sample building's value is multiplied by the building's weight. Summing (aggregating) the weighted sample values provides an estimate of the national total.

**Year Constructed:** The year in which the major part or the largest portion of a building was constructed.

**APPENDIX I**

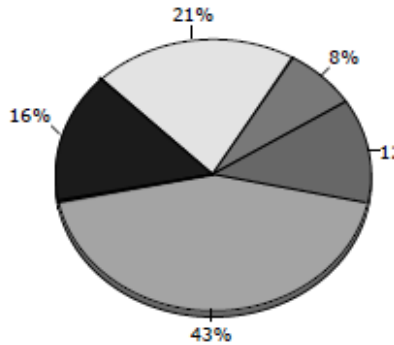
**SOFTWARE INPUT AND OUTPUT DATA/MANUAL CALCULATIONS**

**Annual Energy Consumption by Enduse**

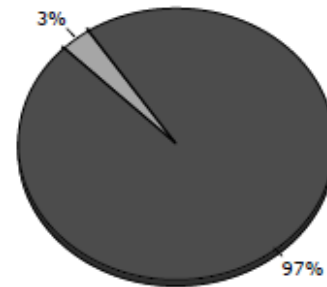
	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	182.7	-	-	-
Heat Reject.	3.0	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	4,654.3	-	-
HP Supp.	-	-	-	-
Hot Water	-	151.8	-	-
Vent. Fans	497.7	-	-	-
Pumps & Aux.	142.3	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	87.2	-	-	-
Task Lights	-	-	-	-
Area Lights	243.6	-	-	-
<b>Total</b>	<b>1,156.5</b>	<b>4,806.2</b>	-	-

- Area Lighting
- Exterior Usage
- Water Heating
- Refrigeration
- Task Lighting
- Pumps & Aux.
- Ht Pump Supp.
- Heat Rejection
- Misc. Equipment
- Ventilation Fans
- Space Heating
- Space Cooling

Project/Run: NOVI CIV



**Electricity**



**Natural Gas**

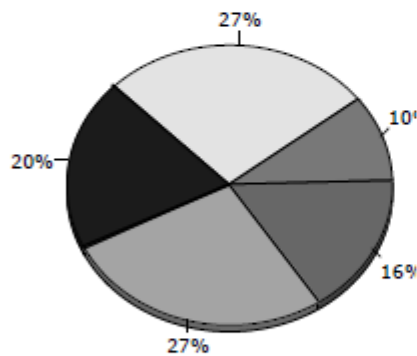


**Annual Energy Consumption by Enduse**

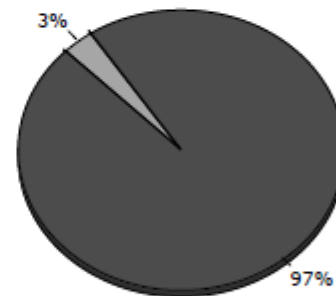
	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	177.97	-	-	-
Heat Reject.	2.72	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	4,693.2	-	-
HP Supp.	-	-	-	-
Hot Water	-	151.9	-	-
Vent. Fans	237.33	-	-	-
Pumps & Aux.	143.85	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	87.22	-	-	-
Task Lights	-	-	-	-
Area Lights	243.63	-	-	-
<b>Total</b>	<b>892.72</b>	<b>4,845.0</b>	-	-

- Area Lighting
- Exterior Usage
- Water Heating
- Refrigeration
- Task Lighting
- Pumps & Aux.
- Ht Pump Supp.
- Heat Rejection
- Misc. Equipment
- Ventilation Fans
- Space Heating
- Space Cooling

Project/Run: NOVI CIVIC

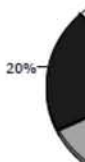


**Electricity**



**Natural Gas**

- Area
- Task
- Mis



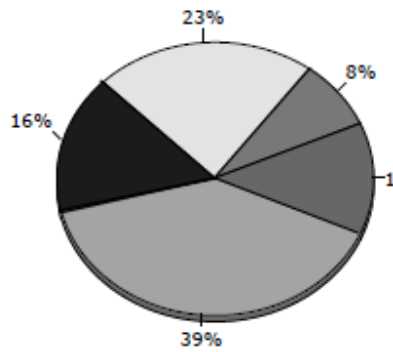


**Annual Energy Consumption by Enduse**

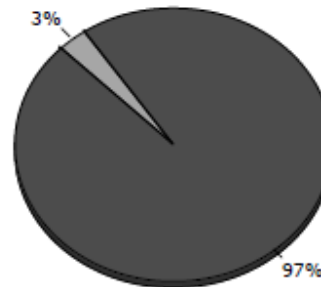
	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	175.6	-	-	-
Heat Reject.	2.8	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	4,801.2	-	-
HP Supp.	-	-	-	-
Hot Water	-	151.8	-	-
Vent. Fans	416.2	-	-	-
Pumps & Aux.	140.3	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	87.2	-	-	-
Task Lights	-	-	-	-
Area Lights	243.6	-	-	-
<b>Total</b>	<b>1,065.8</b>	<b>4,953.1</b>	-	-

- Area Lighting
- Exterior Usage
- Water Heating
- Refrigeration
- Task Lighting
- Pumps & Aux.
- Ht Pump Supp.
- Heat Rejection
- Misc. Equipment
- Ventilation Fans
- Space Heating
- Space Cooling

Project/Run: NOVI CIVIC C



**Electricity**



**Natural Gas**

- Area
- Task
- Misc



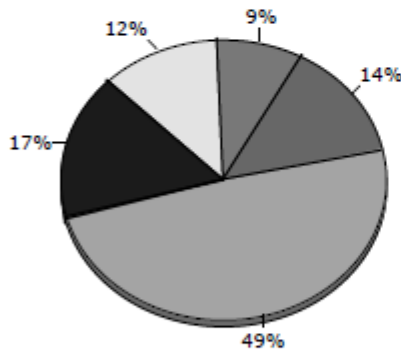


**Annual Energy Consumption by Enduse**

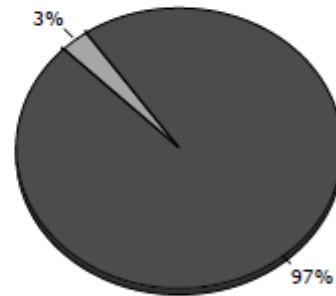
	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	171.1	-	-	-
Heat Reject.	2.7	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	5,015.7	-	-
HP Supp.	-	-	-	-
Hot Water	-	151.9	-	-
Vent. Fans	494.1	-	-	-
Pumps & Aux.	138.8	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	87.2	-	-	-
Task Lights	-	-	-	-
Area Lights	121.3	-	-	-
<b>Total</b>	<b>1,015.2</b>	<b>5,167.7</b>	-	-

- Area Lighting
- Exterior Usage
- Water Heating
- Refrigeration
- Task Lighting
- Pumps & Aux.
- Ht Pump Supp.
- Heat Rejection
- Misc. Equipment
- Ventilation Fans
- Space Heating
- Space Cooling

Project/Run: NOVI CIVIC CI

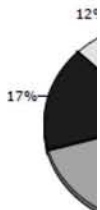


**Electricity**



**Natural Gas**

- Area
- Task
- Misc.

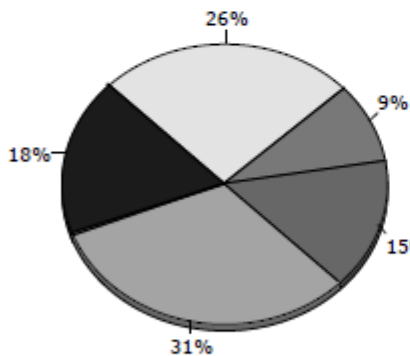


**Annual Energy Consumption by Enduse**

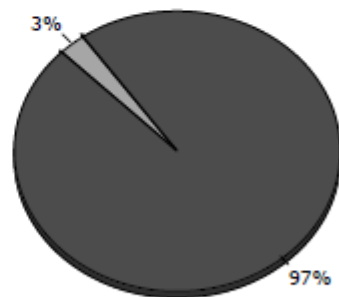
	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	173.20	-	-	-
Heat Reject.	2.82	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	5,497.0	-	-
HP Supp.	-	-	-	-
Hot Water	-	151.8	-	-
Vent. Fans	297.41	-	-	-
Pumps & Aux.	141.51	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	87.22	-	-	-
Task Lights	-	-	-	-
Area Lights	243.63	-	-	-
<b>Total</b>	<b>945.78</b>	<b>5,648.8</b>	-	-

- Area Lighting
- Exterior Usage
- Water Heating
- Refrigeration
- Task Lighting
- Pumps & Aux.
- Ht Pump Supp.
- Heat Rejection
- Misc. Equipment
- Ventilation Fans
- Space Heating
- Space Cooling

Project/Run: NOVI CIVIC C

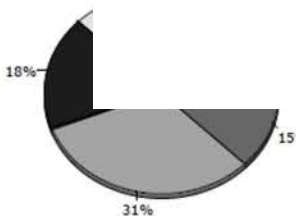


**Electricity**



**Natural Gas**

- Area
- Task
- Misc



**Electricity**



**Natural Gas**

**APPENDIX J**  
**UNDERSTANDING DEMAND CHARGES**

## Understanding Demand Charges

Demand charges are an unrecognized component of commercial energy bills that can have a large impact on a facility's operating cost. It is extremely important to be aware of demand charges because they set a baseline per kilowatt charge for what a facility will pay for their electrical service every month.

Demand charges can be based on the previous month's usage or the previous year's peak fifteen minutes of consumption. For example, the electric utility bill of a two rink Michigan ice arena from August 28, 2009 through September 28, 2009 showed a demand charge of \$7,067.55 out of a total bill of \$15,682.28. In this case, the demand charge was billed at \$13.75 per kw and accounted for 45% of the bill. In general, all of the energy conservation measures that lower energy consumption also help to reduce peak demand. More specifically, measures like an automated ice plant management system or a dedicated smaller chiller for summertime air conditioning of the building aim to reduce the demand charge.

The two major components of an electric utility bill for most commercial buildings are an electricity consumption charge and an electricity demand charge. Electricity consumption is measured in kilowatt-hours (kWh) and electricity demand is measured in kilowatts (kW). Consumption and demand refer to distinct aspects of a building's energy profile, but both represent a substantial portion of a building's electric utility charges.

Electricity consumption, measured in kWh, is a measurement of the actual amount of energy a facility consumes over the course of an entire billing period. A kilowatt-hour equals one thousand watt-hours. A watt-hour is the total energy consumed by using energy at the rate of one watt for a period of one hour. If energy is consumed at a rate of one thousand watts for one hour, total consumption is one kWh. If energy is consumed at a rate of one thousand watts for two hours, total consumption is two kWh. kWh consumption is increased by inefficient equipment, which consumes energy at a faster rate than efficient equipment, and it is also increased by operating equipment for longer periods of time than is necessary.

Electricity demand, measured in kW, is a measurement of a facility's maximum rate of electricity consumption. Demand measurements are used by the utility company in order to properly size the equipment associated with a facility's connection to the electric grid. For example, a facility with higher electric demand will require a larger transformer. A facility's demand is primarily influenced by equipment inefficiencies and operating practices that allow large amounts of equipment to run simultaneously. If multiple pieces of inefficient equipment are running simultaneously, demand is increased. Demand can be decreased by either increasing equipment efficiency, or by scheduling equipment operation to minimize simultaneous operation.

Substantial savings opportunities are likely to be available through implementing improved demand management strategies.

The load watcher program offered by DTE has an initial cost of \$1,000 and a month charge of \$40. It offers facilities an easy way to monitor their demand charge and to be alerted if a facility is approaching an electricity consumption peak.

**APPENDIX K**  
**VARIABLE FREQUENCY DRIVES**

## Variable frequency drives (VFD)— what they are and how they work

Variable frequency drives are devices that can modulate the speed of electric motors.

Heating, ventilation and air-conditioning systems are typically designed to meet a building's loads at peak conditions. However, most buildings operate at full load conditions for only short periods of time. This means that the building is operating with oversized equipment throughout the rest of the year. The fans and pumps that drive the HVAC systems are some of the largest consumers of electric power in the building. These include chilled water and hot water distribution pumps, cooling tower fans, air handling unit fans and ventilation fans.

Substantial energy savings can be achieved if the speed of these electric motors can be reduced in response to changing load conditions. Since the power draw of electric motors is proportional to the cube of its rotational speed, very large reductions in power consumption can be achieved through relatively small reductions in speed. For example, if the rotational speed of an electric motor is reduced by one half, the corresponding electricity use will be only one eighth of the initial power draw.

### How variable frequency drives work

Variable frequency drives can change the frequency of the input alternating current and therefore change the rotational speed of the electric motor.

*Alternating current travels in sine waves. The number of sine wave cycles per second is called frequency, expressed in hertz (Hz). In the United States, alternating current is delivered at 60 Hz. In most of the rest of the world, alternating current is delivered at 50 Hz. The stationary component of electric motors consists of a number of windings called poles. Poles always come in pairs. Typical induction motors are constructed with 2, 4, 6, 8, 10 and 12 pole configurations. If you change either the frequency of the current or the number of poles, you will change the rotational speed of the motor.*

The synchronous speed of an induction motor is based on the supply frequency of the electric currents and the number of poles in the motor winding. This is expressed in the formula

$$W = 2 (60) (f)/N$$

where W = pump shaft rotational speed  
f = frequency  
N = number of poles

Examples:

A 2 pole induction motor at 60 Hz will rotate at a theoretical speed of 3,600 rpm

A 2 pole induction motor at 50 Hz will rotate at a theoretical speed of 3,000 rpm

A 4 pole induction motor at 60 Hz will rotate at a theoretical speed of 1,800 rpm

A 4 pole induction motor at 50 Hz will rotate at a theoretical speed of 1,500 rpm

Variable frequency drives convert alternating current into direct current and then back into alternating current at a variety of different frequencies. There are no moving parts in a variable frequency drive.

The main components of VFD consist of

1. Rectifier converts alternating current into direct current

2. Intermediate Circuit stabilizes the direct current
3. Inverter converts the direct current back into alternating current with a wide and variable range of frequencies
4. Control Circuit controls and coordinates the functions of the previously listed components and provides protective functions for the VFD as a whole

Savings Potential... First the system must lend itself to the application. Once that has been established then the larger the motor the greater the savings potential of VFDs. Originally, VFDs were available for only the largest triple phase induction motors. However, in recent years, the technology has advanced to the point that there are VFDs for triple phase and single phase motors all the way down to fractional horsepower applications.

## **LIGHTING RETROFITS, MISMATCHED BALLASTS AND OVERLIT SPACES: THE COMMON PITFALLS OF RELAMPING PROJECTS**

Replacing older inefficient lighting with new high efficiency lamps is only one element of an effective lighting retrofit strategy. Designing the new lighting system to provide the optimum lighting levels for each task being performed is even more important. A lighting level that is too high can be just as problematic as lighting level that is too low. The Illuminating Engineering Society of North America has established guidelines for lighting intensity levels for various tasks. For example, overlighting an office space can cause glare that makes it harder to read computer monitors. The recommended lighting level for desktops in office spaces is 30 foot-candles per square foot, but often light levels after retrofits will be twice as high. A more extensive list of IESNA recommended lighting levels is included at the end of this section.

### **THE CORRECT CHOICE OF BALLASTS:**

Lamps offer a broad range of options for color temperatures and color rendering index, but for optimal performance, they must be paired with the correct ballast. Ballasts are designed for a wide variety of performance objectives. Making the correct choice of ballasts can reduce energy consumption, extend lamp life, and provide ways to adjust lighting levels. Making the wrong choice in ballasts can have the opposite impact.

A common mistake made in relamping projects is to attempt to save money by leaving the old ballast in place when changing from T12 fluorescent lamps to T8 fluorescent lamps. The assumption is that the old ballast is still working so there is no point in changing it. The problem is that T12 fluorescent lamps are typically designed to operate with magnetic ballasts while T8 lighting is designed to operate with electronic ballasts. Attempting to drive T8 lamps with magnetic ballasts will result in premature lamp failure. AKT Peerless energy auditors encountered situations in the lower corridors of the ice arena and the administrative offices of the Public Service Building where a lighting retrofit has resulted in a mixture of magnetic and electronic ballasts driving a T8 lighting system. The common refrain is that ‘these new lights burn out all the time’.

Choosing the right ballast for the application has a significant impact on lamp life, and therefore, impacts maintenance costs. For example, instant-start ballasts can be used in long burn applications but considerably shorten lamp life in applications where the lights are frequently turned on and off. Programmed rapid-start ballasts are designed to work in conjunction with occupancy sensors.

Other considerations when designing a new lighting system include opportunities to utilize daylighting, occupancy sensors, dimming and multi-level switching. Occupancy sensors typically reduce electric consumption in offices spaces by 25%, in bathrooms by 60% to 80%, in break rooms by 35%, and in locker rooms by 60% to 80%.



**EXAMPLE OF OVERLIGHTING IN A MUNICIPAL BUILDING RETROFIT**

One city in Michigan recently purchased a large quantity of T-8 fluorescent lamps and ballasts as part of a lamp replacement program. The first of their buildings to be completely relamped was their courthouse. The relamping was implemented on the basis of a one-for-one replacement. For example; a fixture with four, 4' T12 lamps with magnetic ballasts was converted to four T-8 lamps with electronic ballasts. Typically, that exchange would result in a 40% reduction in electrical consumption. However it will also result in a higher lighting level than anticipated.

Random light meter readings taken in the main floor office at desktop level in the courthouse indicated lighting levels of 95 to 118 foot-candles per square foot. This is between three and four times higher than the lighting level recommended by the Illuminating Engineering Society of North America. If the lighting retrofit had been designed to meet the illumination levels recommended by the IESNA, it is likely that only half of the original lamps and ballasts would be needed. The resulting energy savings in the latter case would have been in the range of 60% to 70% instead of 40%. Additional savings beyond the basic reduction in energy could have been achieved by use of occupancy sensors and daylighting of certain areas.

Since the recently purchased ballasts are not programmed rapid start, they cannot be used in conjunction with occupancy sensors. In this case, the best recommendation would be that the purchased ballasts be used only in areas where the lights will be burning for long periods of time. The appropriate ballast for use in conjunction with occupancy sensors will have to be an additional purchase. This example underscores the advantage of completing a more detailed lighting analysis and design for all of the interior spaces scheduled for relamping.

**Recommended Light Levels**

(Based on IES guidelines, expressed in average maintained footcandles.)

<b>Auditorium (assembly)</b>		Competition and events	
	1	50-100	
0		<b>Libraries (reading)</b>	
<b>Classrooms/Lecture Rooms</b>		30	
Regular desk work, study halls		<b>Lounge and Waiting Areas</b>	
30		10	
Lecture rooms (audience)		<b>Offices</b>	
30		Paperwork (#2 pencil; 8pt-10pt print)	
Marker boards	5	30	
Chalk boards, demonstration areas		Computer user (vertical fc)	5
50-100		Accounting, bookkeeping (on paper)	
<b>Corridors, Lobbies, and Stairways</b>		30	
5-10		Conference areas	5
<b>Food Service Facilities</b>		<b>Rest Rooms</b>	5
Food preparation task areas		<b>Shop Areas</b>	
50		Rough to medium bench/machine work	
<b>Gymnasiums</b>		30-50	
General		<b>Storage Areas</b>	
30		10-3	

