Cursory Analysis Tool for the Economic Viability of Cold Thermal Energy Storage Systems

by

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Abstract

Due to large strain placed on the utility grid during times of high commercial and industrial electricity usage, more emphasis is being placed on reducing energy use during these peak times. One of the more popular methods of reducing peak energy usage is the application of cold thermal energy storage (CTES) systems. CTES systems utilize high efficiency chillers to create ice during times of low power consumption or decreased energy cost. This ice is then used to supplement building cooling capacity during peak energy consumption.

Although CTES is becoming more popular, frequency of implementation in the United States is still relatively low. Low implementation likely stems from the engineers' unfamiliarity with the system's design and the difficulty of performing the system's life cycle cost analysis. Though research may be done to overcome design unfamiliarity, the significant amount of time required to determine if CTES is economically viable for a project is still an obstacle. Thus, a simple time efficient initial analysis tool is needed. This report introduces an Excel based tool which provides a cursory project specific conservative economic analysis for the viability of CTES.

The tool outlined in this report incorporates the many variables which influence CTES design, including the cooling load profile, utility structure, equipment information, and the system configuration of the project. An example analysis demonstrating the capability of the tool is completed at the end of the report. The ability of the tool to quickly provide conservative payback results for CTES systems aids the designer in deciding whether or not to continue with further economic analysis.

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Dedication

I would like to dedicate this report to those who mean the world to me: my family, my professors, and the many friends I have had the honor of working alongside throughout my college education. I promise to never forget the lessons we have learned, memories we have made, and beers we have drunk. Without each and every one of you, my success would not be possible.

Chapter 1 - Introduction

As a larger portion of electricity generation is transitioning to renewable resources, such as wind and solar, electrical utilities are feeling the impact of significant grid dynamics created through the fluctuating electricity production rates from these energy sources (Asselt et al, 2018). The resulting strain felt by the utility grid during the highest commercial and industrial consumer electricity usage, also referred to as peak demand times, has placed greater emphasis on the reduction of energy consumption during these times. Strategies such as the use of batteries, proper installation and implementation of a building automation system (BAS), and distributed power generation have all been utilized for demand reduction to great effect (Oathout, 2016). Another proven approach for peak reduction, or the reduction of peak energy usage by a building or group of buildings, is cold thermal energy storage (CTES) systems. CTES systems utilize high efficiency chillers to create ice during times of low power consumption or decreased energy cost, both typically experienced at night. This ice is used to supplement building cooling capacity during peak energy consumption. Instead of running the chillers at a capacity to address peak load conditions at least a portion if not all the chilled water is directed through tanks holding the ice created during off peak demand times. Although CTES is becoming a more popular choice to reduce demand on the grid and provide utility savings to building owners around the United States, the frequency of new projects implementing these systems is still relatively low. This low implementation rate in new projects likely stems from two primary barriers: engineers' unfamiliarity with the system's design and the difficulty of performing the system's life cycle cost analysis. Though research may be done to overcome the hurdle of design familiarity and in-depth life cycle cost analysis tools exist for CTES systems, the significant amount of time required to determine if CTES is economically viable for a project is still an obstacle. To help overcome this, a simple, time efficient initial analysis tool is needed. This report introduces a tool which provides a simple project specific conservative economic analysis. This tool is intended to serve as a cursory analysis to assist the design team in making the decision to move further into more complex and time-consuming life cycle investigations of CTES. This report also compares three case studies using the tool to determine the viability of CTES for each application. Besides introducing the tool itself, this report introduces to the reader the importance of utility rate structures on the practicality of CTES as a design option as well as discusses CTES functionality, configuration options, advantages and disadvantages.

Utility Rates

Though CTES has many cost saving applications, its proper implementation depends on the load profile of the building, which is affected by how the building will be utilized and its occupancy schedule and the corresponding utility rate structure. The load profile of the building refers to the cooling needed to satisfy the building load each hour of a given day over an operational year. The utilization of the building refers to the behavior and activity level expected of the occupants during the hours of building occupancy (Oathout, 2016). The load will rise as the space increases in activity and occupant density. This increase in load is amplified the hotter the exterior conditions surrounding the building. CTES savings are enhanced in applications where large differences in load occur; therefore, it is important to correctly model the building load profile with applicable occupancy schedules. This large loading difference plays to the advantages of CTES systems, allowing the peak load to be reduced by shifting excess energy usage to times of otherwise lower energy usage throughout the day. CTES is most economically viable when the energy rate structure differs throughout the day. With this fluctuating rate structure, buildings which experience high occupancy during daytime working hours and little to no occupancy throughout the night will see large utility savings when utilizing CTES systems. This occupant schedule allows for large savings in utility costs from the utilization of CTES because the large cooling load seen during the day coincides with the highest energy rates while very little cooling load is experienced at night when energy is least expensive. Such facilities include offices, schools, court-halls, campus buildings, retail stores, subway stations, and places of worship (Habeebullah, 2007). These factors of building use and occupancy are easily modeled using programs such as TRACE700 by Trane, where a full building hourly load profile may be obtained.

The location and utility structure of the project have a very significant effect on the cost of utilities for a building. Due to the large variations in seasonal weather and energy production between regions within the United States, the amount charged by the utility company, and the different rate packages they offer, are unique to that physical area. According to Asselt et al (2018) within the article "Strategies to Increase Deployment of Renewables Using Cool Thermal Energy Storage,"

> *"many electric utilities are increasing the percentage of their electricity production to renewable energy sources (primarily wind and solar) to comply with legislative mandates or other driving factors. For example, electric utilities in California are being driven by a codified target of achieving 50% of electricity procured by retail sellers and publicly owned utilities originating from renewable sources by 2030. As more renewable energy generation is deployed, electric utilities have increasingly felt the impacts of significant grid dynamics created by the rapidly changing electricity production rates from*

renewable energy sources that occur coincidently with variations in the end-use electricity demand" (p.4).

Thus in the coming years, more utility companies will have to do things such as modify the utility structure to encourage users to find ways to decrease their energy use during peak use time. Locations with average outdoor temperatures requiring substantial cooling within buildings will be most likely targeted first because the air conditioning imposes a large electrical demand with few opportunities for reduction without sacrificing occupant comfort and productivity.

Utility providers offer different rate packages for commercial consumers which outline commercial utility charges. As a result of the daily energy demand approaching the limits of the on-line power generation capacity, rate packages often offer price differences between hours of high energy consumption (on-peak hours) and hours of low energy consumption (off-peak hours). This billing structure allows building owners to save money by implementing load shifting systems, such as CTES, while also freeing up more energy to be utilized by other customers during high consumption periods (McCullough, 1988). Since there are many different types of utility rate structures, the tool presented in this paper will concentrate on the most common structures.

In order to encourage reduced peak energy usage, a demand charge is commonly incorporated within utility rate packages for commercial customers. The demand charge ($/kW) is typically applied to the maximum energy usage (kW) during on-peak hours for a given payment period. Once the demand charge amount is determined, the full amount is charged every month within the payment period. Demand rate structures vary depending on the power provider, though in most instances significantly impact the end utility costs. This impact depends on the location of the utility provider as demand charges per billing period fluctuate greatly throughout the country, shown in Figure 1. Within the United States, it is common for electrical demand charges to account for half of the total electrical utility costs for a building (Oathout, 2016). Since CTES systems reduce the peak loads experienced throughout the day by shifting the cooling energy use to off-peak hours, the demand charge for a given payment period are greatly reduced, resulting in large savings throughout the year.

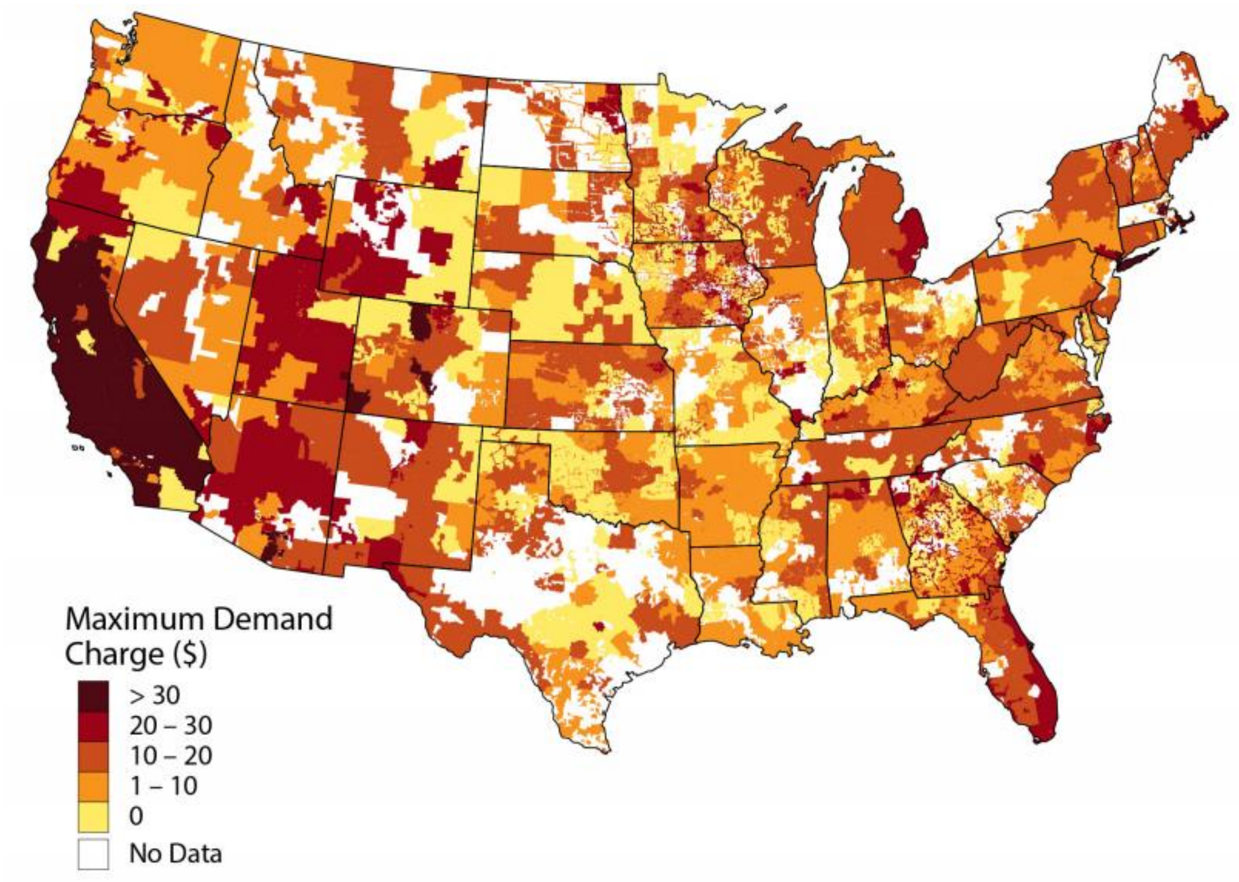


Figure 1. U.S. Maximum Demand Charges (McLaren, 2017)

Latent Energy Storage

To minimize building utility expenses, selecting the CTES system which provides the most economic benefit must be investigated. Latent energy storage is the most common form of thermal energy storage for HVAC applications. In the latent energy storage process, phase change material (PCM), acting as the storage medium, or material which retains a change in temperature changes phases during the charging (ice creation) and discharging (ice melting) processes in order to satisfy the required cooling load. This process allows latent energy storage to satisfy equivalent cooling loads to sensible energy storage, while requiring much smaller storage volume and maintaining nearly constant operation temperature (Eslami, 2017). PCMs such as eutectic salts or ice are commonly utilized as the storage material in latent energy storage systems.

When comparing the different storage materials for latent energy storage, ice has been the most popular within the HVAC industry. This is because plain water has “the highest latent heat of fusion of all common materials, high density, safety, appropriate fusion temperature (at sea level, the melting or freezing point of [32°F]) and insignificant cost,” (Kosi et al, 2015). Ice as a storage material within latent CTES may be further categorized into static processes, where heat transfer takes place via a solid surface, or dynamic processes, which allow the storage material and the heat transfer material to come in direct contact. The static processes of ice thermal storage include external and internal melt ice-on-coil, and encapsulated ice thermal storage systems, while the dynamic processes are comprised of ice slurry and ice-harvesting storage systems (Kosi et al, 2015).

Although there are multiple design types for CTES ice storage systems, the most common design within commercial building applications is the static process internal melt system (Kosi, 2015). In this static process, secondary coolant is circulated during the charging and discharging process, in order to freeze and melt the storage material, respectively. The storage material, commonly plain water, never leaves the storage tank with this design (Silvetti, 2002). Due to the simplicity of the internal melt design, its decreased initial cost when compared to the other ice melt designs, and its popularity for commercial building applications, internal ice melt is the focus of this report and the associated tool.

Full Load vs Partial Load Storage

Beyond the design decision to use static process internal melt, a designer must also consider full or partial load storage for each application. In full load storage, the entire building cooling load is handled by the CTES system during peak hours, as illustrated in Figure 2, where the peak hours, shown in bold, are from 8 am through 4 pm. This allows the chillers to charge the ice storage during off-peak hours when the cost of electricity is considerably less. Full load storage may be utilized to great affect when the cost per KWh is the primary economic factor in the monthly utility bill, where there is a large cost difference between the off-peak and on-peak hours (Habeebullah, 2007).

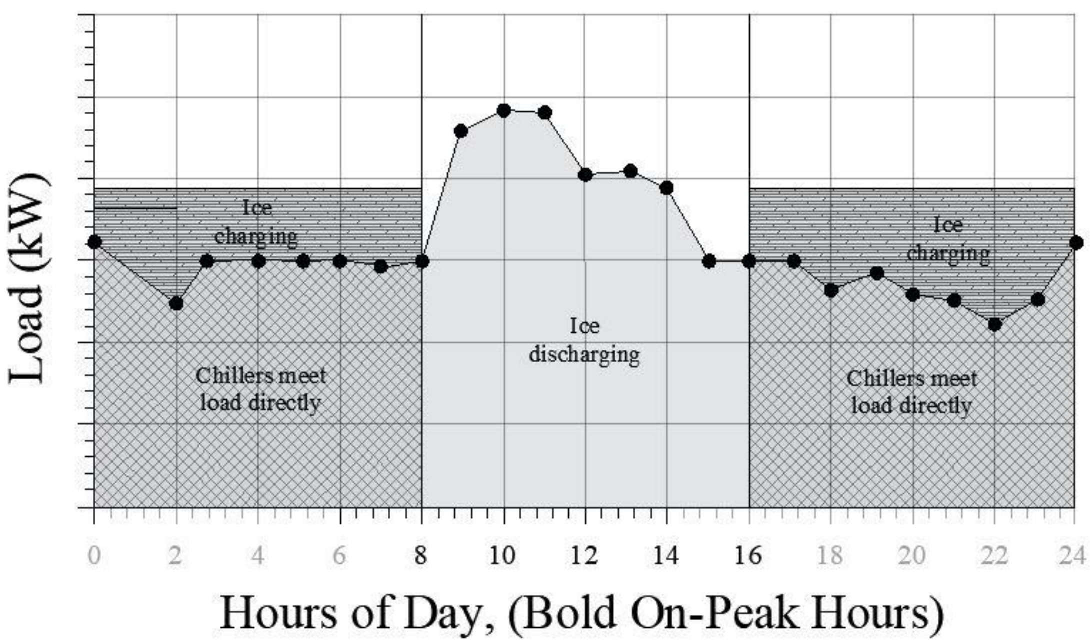


Figure 2. Full Load Storage Daily Load Profile

A more commonly utilized design scenario for CTES is partial load storage. In partial load storage, only a segment of the peak load is handled by the CTES system, as shown in Figure 3, where the designated peak hours no longer directly impact the function of the CTES system. This design allows for the building electricity consumption to be spread out uniformly throughout the day, effectively eliminating any large-scale spikes of energy usage. Fluctuation in energy use can prove to be very costly when the billing rates are structured so the highest demand charge for one payment period is applied to every month within the period. For example, a spike in a building's energy use on a hot summer day when air conditioning is in highest demand could require the same demand charge be paid for the next 12 months (assuming a 12 month payment period). Partial load storage is best employed when the demand charge costs would be the governing economic factor of the monthly utility bill (Habeebullah, 2007). Since demand charges are prevalent in commercial utility rates, partial storage has been chosen as the design scenario utilized within the analysis of this report and the associated calculation tool.

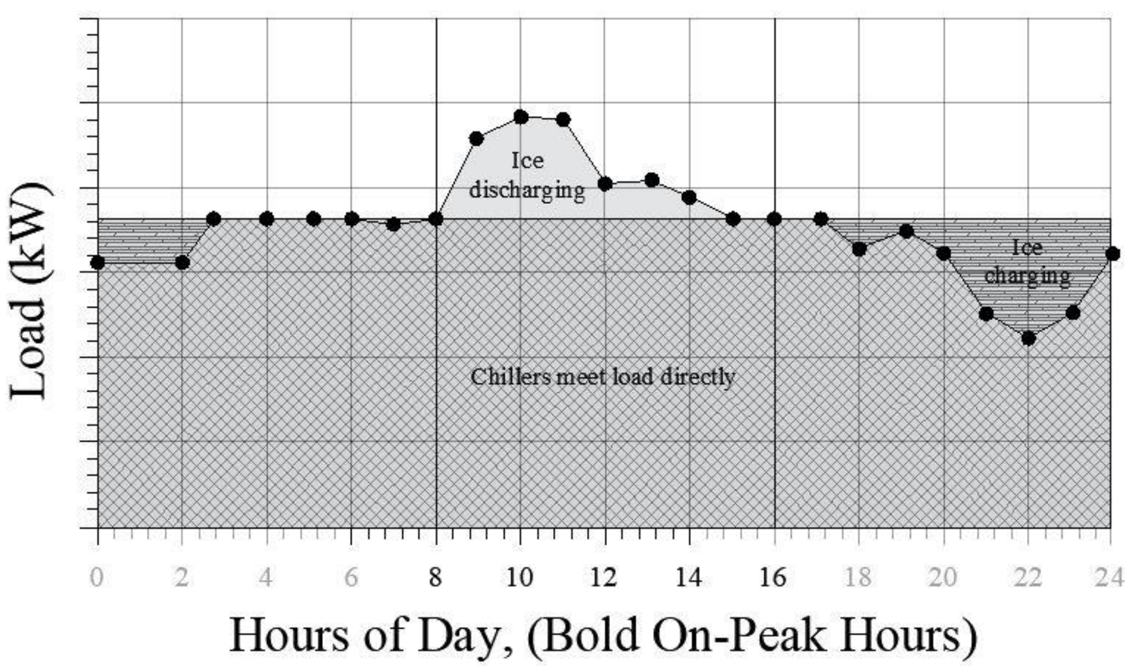


Figure 3. Partial Load Storage Daily Load Profile

CTES Equipment Configuration

There are two primary equipment configurations utilized within partial load CTES systems. The first uses separate building and CTES chiller(s), shown in Figure 4. In this design, the ‘Building Chiller(s)’ handle the normal (non-peak) building load and operate independently of the ‘CTES Chillers’, which handle the excess load occurring during the peak. This configuration allows CTES systems to be installed on existing projects without extreme alteration to the existing chiller system. The building chiller(s) and CTES chiller(s) each have their own respective life cycles, initial costs, maintenance costs, salvage values, and efficiencies.

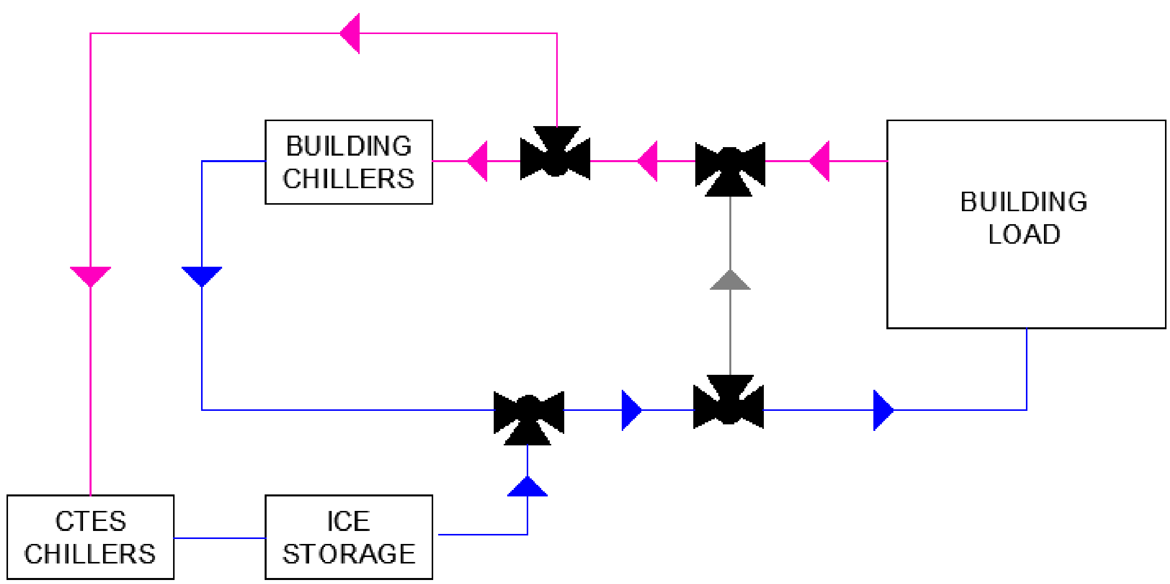


Figure 4. Separate Building and CTES Load Chillers

The second commonly used CTES equipment configuration uses a single chiller or set of chillers which handles both the building and the CTES loads, (Figure 5). In this design, the chiller(s) are able to produce two different water temperatures, at two different efficiencies, dictated based on function - charging the ice storage or handling the normal (non-peak) building load. These chiller(s) because of their more complex function have an increased initial cost and maintenance cost compared with other chillers. However, the chiller(s) life span in years is typically lower due to increased run hours handling both the building load and storage load but also because of the hours functioning at a lower efficiency.

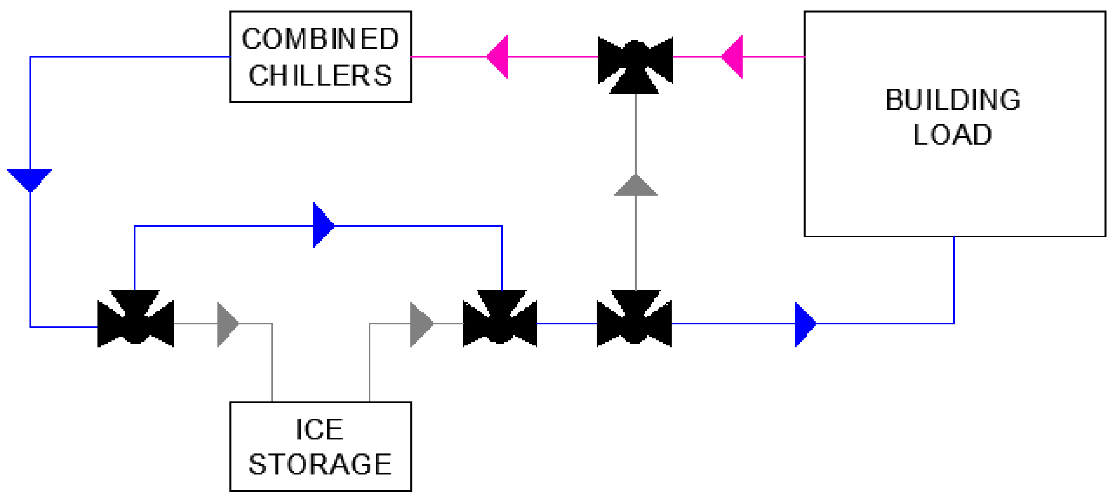


Figure 5. Combined Building and CTES Load Chillers

Advantages of CTES

The primary reason for employing CTES is the opportunity to reduce utility costs. This system can be used to shift the cooling load of the building to periods of reduced power consumption, thus reducing the impacts of cooling load peaks on the electrical system (Arcuri et al, 2017). These spikes in energy usage are discouraged by utility companies through the implementation of demand charges, or charges applied to the peak energy usage experienced per month. When demand charges are implemented within a utility structure, partial load CTES may be utilized to manage the power needed for building cooling, shifting the energy use to times of reduced consumption in order to create a more uniform electrical demand for the building. If the specified utility rate structure does not include a demand charge, full load CTES can be used to completely eliminate the building load during on peak hours, shifting this load to off peak hours where the utility costs are most likely reduced.

Besides the utility cost savings, the initial cost of CTES systems have also been found to be significantly less expensive than alternate electrical storage systems of equivalent cooling load (Rismanchi, B. et al, 2012). The chillers utilized for the production of ice within a CTES system need to be as efficient as possible to counteract the loss of efficiency accrued through the freezing process. This optimized efficiency leads to an increase in initial price for the chiller and must be combined with the cost of the ice storage banks, pipes, pump(s), and installation and construction costs. Even when considering these added costs involved with CTES system, the reduction in total required chiller capacity to cover the system peak load may result in initial cost savings for the cooling system as a whole. This savings is properly explained in an example from "Ice Thermal Storage: System Selection and Design" by J. M. McCullough (1988),

> *"[…] a church may have a cooling load of 50 Tons over a five-hour period, occurring once a week. Rather than installing a 50-ton system to operate for five hours to provide the 250 ton-hours of cooling, a five-ton system may be installed to operate and store cooling for 50 hours. The same total cooling capacity (250 ton-hours) is produced, and the system cost is substantially reduced, even when the cost of the storage equipment is included"* (p. 1).

As shown in the previous example, buildings with high load consumption during occupied hours and low consumption during non-occupied hours, such as schools, places of worship, retail stores, etc., are perfect utilizers of CTES.

Decreased environmental impact is also considered an advantage of CTES systems. According to Rismanchi, B. et al (2012) in "Energy, exergy and environmental analysis of cold thermal energy storage (CTES) systems,"

> *"[...] the importance of demand reduction and demand management has made the energy storage technologies a valuable technique to act as a balance between supply and demand of energy. Shifting electric expenditure to off-peak hours has a major ''Green'' benefit of decreasing source [fossil fuel] energy usage and consequently reducing the amount of emission"* (p. 2).

By shifting energy consumption to non-peak time periods, less fossil fuel energy sources are needed to supplement the energy produced by renewable sources during off-peak periods. Thus, the reduced peak energy usage ultimately results in a reduction in fossil fuel consumption, and therefore harmful emissions.

Disadvantages of CTES

Although CTES systems may have a lower initial cost, there are situations in which they are more expensive. The system requires high efficiency chillers (typically 85% efficiency or higher) to combat the loss of efficiency due to the production of ice within the storage banks. High efficiency chillers have a considerable increase in initial cost over standard efficiency chillers (typically 84% efficiency or lower) and require more maintenance to maintain peak efficiency. Commonly these costs are overcome by the savings in reduced chiller size. A small increase in maintenance costs may be experienced due to the ice storage, though this value will be minimal compared to the maintenance costs of the chillers themselves.

Another shortcoming of CTES is the increase in required system space. Although CTES has the potential to decrease the required chiller capacity, thus decreasing the physical size of the chiller(s), the additional requirement of multiple large ice storage tanks ultimately expands the footprint of the system. While these ice storage tanks require a larger mechanical room, this may be solved by externally locating the tanks above grade or burying the tanks below grade. If the ice banks are to be buried, the initial cost of the system must increase to account for the site excavation costs as well as an increase associated with more labor intensive maintenance.

Even though there are disadvantages associated with CTES systems, the utility saving advantages often outweigh the former. These cost savings are heavily affected by the provided utility package and the system design criteria, which may be simplified to common design conditions for this cursory analysis tool. These design criteria are considered in the CTES analysis tool introduced in Chapter 2, where design simplifications and constraints are explained in depth.

Chapter 2 - Tool

The CTES tool proposed within this report aims to provide the designer with a conservative economic analysis for a project to implement CTES. This worst case analysis is to serve as a cursory analysis to assist the design team in the decision to move ahead with more thorough, complex, and time consuming CTES economic investigations. The purpose of this chapter is to introduce the CTES tool which has been developed in excel and to provide a detailed walk through of the tool for the user.

Eight tabs are used to organize the required input, information, and results in the excel file. These tabs are color coded to demonstrate necessary information. The two red tabs require no user input and are there to display information such as version changes or step by step guides. The five green tabs require user input, such as project, utility, or equipment information. The single blue tab is used to differentiate the *Results* tab from the five previous user input tabs. The 48 remaining tabs which alternate between yellow and pink are reserved for monthly load calculation tabs which are only used by the tool for CTES load calculations and require no user interface. The two colors simply allow the user to easily identify which calculation tabs are a part of each month.

To provide a general overview of the arrangement, the tool starts with eight tabs of various colors to indicate their purpose. The first tab, *Change Log*, is colored in red and shows general changes between versions of the CTES tool. The *Read Me* tab, which is also red, follows afterwards displaying constraint information as well as a step by step guide on how to import a cooling load profile into the tool. Next are five green tabs which require user input. The *TRACE CLG Demand* tab allows the user to import in the cooling profile from TRACE700 by following the steps on the *Read Me* tab. The *Project Information* requires the input of general project information. The *Utility Input* tab is next and is the location where the user inputs utility information specific to the utility package. After this, the *Equipment Input* tab allows the user to specify key analysis information for the equipment such as efficiencies, life expectancy, and unit costs. The final green colored tab is the *Cooling Load Input*. This tab only requires user input if loads from TRACE700 were not imported into the *TRACE CLG Demand* tab. Finally, the *Results* tab, highlighted in blue, summarizes the information entered into the previous tabs and displays the economic analysis in a printable format. The red colored *Utility Calcs* tab displays the complete economic analysis calculations. The remainder of the tabs, -WEEK, -SAT, -SUN, -MON, display load calculations for each weekly design period for every month.

This chapter will discuss the assumptions and constraints pertaining to the tool, while also providing a brief overview of the functionality of the tool from the user's point of view. Besides tool functionality, this chapter will also discuss the life cycle cost analysis utilized. A more complete background on the economic calculations conducted by the tool are discussed in Appendix A.

Assumptions & Constraints

Since there are a range of different CTES systems and applications available, the tool presented in this report is limited to the following constraints to ensure functionality and to minimize complexity. It is important for these design limitations to be fully understood by the user before any data input has occurred. This section will cover the design restrictions utilized within the CTES tool in the same order as the workbook sheet tabs outlined above.

Load Profile Information

The load profile for a building is not generated by this tool but instead the modeling needs to be performed by the user prior to utilizing this tool as it is required input. There are many programs that can be used to attain the necessary information regarding the cooling load for the building. This tool has been formatted so the *Building cooling / heating demand* file exported from TRACE700 version 6.3.4 may be copied into the *TRACE CLG Demand* tab without edit (the first green tab at the bottom of the spread sheet), shown in Figure 6. When completing the economic calculations, the tool refers to this tab for the cooling loads broken down into Weekday, Saturday, Sunday, and Monday (headings highlighted in yellow within the figure). Monday is calculated separately since the loads on this day tend to increase as the building cooling systems compensate for the higher space temperatures programmed for weekend operation. The remaining information included in the exported TRACE700 file *Building cooling / heating demand* is not utilized within the tool's analysis and is only included in the tool for ease of exporting cooling demand from the TRACE700 software. If TRACE700 loads are not available and a different program is used to determine the load profile, the cooling loads may be manually input in the *Cooling Load Input* tab. This will be further explained in the *General Operation* section. The precision of the results obtained from this tool rely on the exported cooling loads being accurate. Therefore, it is good practice to check over the utilized load profile and assure that all input is correct and that building schedules, such as occupancy, lighting, etc., are used.

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	62.6	59.4	-842,138	132.2	-926,485	139.8	-307,095	56.5	-397,033	53.2	-1,037,310	128.2
2	61.9	58.7	-876,654	127.0	-939,437	137.9	-304,221	56.0	-405,676	52.4	-1,049,344	126.9
3	61.5	58.7	-893,165	126.5	-949,565	136.5	-308,680	55.1	-413,880	51.6	-1,053,117	126.3
4	61.4	58.8	-907,333	131.6	-956,834	135.1	-312,772	54.1	-432,697	50.8	-1,054,952	125.8
5	61.8	59.2	-919,423	132.2	-961,423	133.9	-325,140	53.2	-446,062	50.1	-1,051,040	125.2
6	62.8	60.2	-928,682	131.6	-962,967	132.9	-358,007	52.4	-461,168	49.6	-1,041,893	124.9
7	64.4	61.8	-921,452	130.9	-948,630	132.3	-381,042	51.9	-469,451	49.2	-1,024,237	124.9
8	66.4	63.8	-869,284	130.7	-901,945	132.0	-379,809	51.5	-469,051	49.0	-993,909	125.2
9	68.5	65.4	-404,642	134.9	-478,297	136.2	-347,276	51.3	-438,346	48.9	-727,157	129.9
10	70.4	66.2	-266,357	151.8	-320,999	149.1	-311,816	51.4	-400,814	49.2	-617,574	141.9
11	72.1	66.6	-200,440	169.0	-247,404	161.6	-283,457	52.1	-362,704	50.1	-536,821	152.0
12	73.1	66.2	-127,953	167.6	-194,916	155.5	-264,707	53.8	-332,018	51.8	-436,687	152.1
13	73.5	65.8	-265,621	169.8	-357,043	154.7	-253,184	55.9	-309,079	54.1	-520,847	153.4
14	73.3	65.7	-86,101	185.7	-150,556	165.5	-241,299	58.0	-284,605	56.3	-317,132	164.4
15	72.9	65.3	-87,507	202.8	-138,139	176.9	-235,847	59.6	-270,350	58.0	-254,428	176.2
16	72.3	64.9	-163,685	187.2	-271,576	162.4	-246,772	60.6	-277,443	59.1	-329,452	162.6
17	71.5	64.5	-393,442	182.4	-545,988	159.6	-257,658	61.3	-287,133	60.0	-579,502	159.9
18	70.4	64.3	-509,603	181.3	-659,610	158.2	-269,326	61.4	-299,949	60.1	-677,898	158.5
19	69.3	64.0	-602,080	176.7	-749,944	153.2	-285,171	59.7	-318,681	58.5	-762,161	153.5
20	68.1	63.2	-674,972	170.9	-814,731	149.8	-312,574	57.9	-347,103	56.6	-823,367	150.0
21	66.8	62.6	-664,286	163.6	-779,787	148.8	-340,475	56.9	-374,239	55.7	-787,390	149.0
22	65.6	61.8	-757,718	159.2	-859,424	146.5	-356,013	56.0	-391,214	54.9	-865,194	146.7
23	64.4	60.7	-799,493	155.2	-887,739	144.5	-369,315	55.1	-409,702	54.0	-892,845	144.6
24	63.4	59.8	-827,774	151.8	-905,332	142.6	-384,253	54.1	-423,624	53.2	-906,351	142.8
February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	61.9	57.8	-857,876	152.2	-907,430	143.2	-301,599	57.9	-382,322	55.1	-1,031,232	132.0
2	60.5	56.7	-882,822	148.9	-926,796	141.0	-301,280	57.4	-399,103	54.0	-1,046,882	130.2
3	59.4	56.1	-904,439	145.7	-944,566	139.0	-308,894	56.2	-410,142	52.9	-1,053,623	129.1
4	58.5	55.8	-923,049	142.9	-959,863	137.0	-316,031	55.0	-426,348	51.9	-1,058,414	128.0
5	57.9	55.4	-938,635	140.4	-971,477	135.3	-333,394	53.8	-437,931	51.0	-1,058,086	127.0
6	57.8	55.6	-950,563	138.2	-980,110	133.7	-369,935	52.7	-452,055	50.1	-1,054,138	126.0
7	58.3	56.3	-944,825	136.4	-973,405	132.4	-402,555	51.8	-470,758	49.3	-1,041,244	125.2
8	59.7	57.8	-857,451	135.2	-911,522	131.4	-386,722	51.0	-449,248	48.6	-1,000,096	124.8
9	61.9	59.6	-382,356	140.5	-480,541	135.4	-345,292	50.6	-413,580	48.4	-725,981	129.3
10	64.7	60.5	-256,708	159.7	-321,882	148.2	-309,620	50.5	-382,946	48.4	-613,653	141.0
11	67.6	61.5	-191,096	176.5	-252,946	160.8	-283,876	51.4	-356,019	49.4	-514,103	152.5
12	70.3	62.7	-126,289	172.1	-194,462	155.4	-262,169	53.2	-326,238	51.3	-434,232	152.3
13	72.5	64.1	-259,377	173.8	-347,220	156.5	-246,478	56.2	-298,610	54.4	-509,390	155.2
14	74.0	64.9	-87,549	191.2	-135,660	169.4	-230,823	59.3	-268,131	57.6	-303,186	168.3
15	74.5	64.9	-88,435	209.6	-121,373	181.6	-218,975	60.9	-248,046	59.4	-213,308	180.7
16	74.3	64.8	-160,035	194.7	-241,333	167.0	-226,779	62.5	-253,066	61.0	-302,093	167.2
17	73.8	64.6	-384,897	191.2	-505,469	164.3	-238,927	63.8	-264,414	62.4	-529,493	164.6
18	72.9	64.4	-485,438	191.0	-613,275	163.8	-248,479	64.5	-273,309	63.2	-624,295	164.1
19	71.7	64.5	-566,519	187.5	-698,476	160.7	-260,525	63.8	-286,962	62.5	-705,041	161.0
20	70.3	64.3	-632,691	180.1	-763,707	155.0	-283,634	61.2	-313,520	60.0	-769,322	155.3
21	68.7	63.5	-619,185	172.6	-733,846	153.1	-311,896	59.6	-340,974	58.4	-741,597	153.4
22	67.0	62.1	-733,640	165.6	-822,386	150.6	-334,140	58.5	-363,863	57.4	-828,281	150.8
23	65.2	60.6	-785,075	160.4	-856,645	148.2	-350,297	57.4	-382,801	56.3	-859,323	148.4
24	63.5	58.9	-820,715	155.8	-879,985	145.9	-365,578	56.2	-399,393	55.2	-880,619	146.1
March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.5	66.4	-750,796	162.8	-811,747	151.9	-262,727	61.9	-322,621	60.6	-947,264	144.5
2	69.7	65.4	-774,669	159.2	-832,170	149.1	-260,237	61.5	-332,209	59.5	-978,957	141.4
3	69.0	65.3	-795,781	155.9	-850,400	146.9	-266,358	60.6	-339,921	58.5	-976,226	140.3
4	68.5	65.1	-813,837	152.9	-864,459	145.1	-272,124	59.5	-346,678	57.5	-980,022	139.2

Change Log | Read Me | TRACE CLG Demand | Cooling Load Input | Project Information | Utility Input | Equipment Input | Results | Utility Calc ...

Figure 6. TRACE CLG Demand Tab

Demand Charge and Billing Period

This CTES analysis tool allows for the demand charge to be specified towards the top of the *Utility Input* tab, shown in Figure 7. The demand charge ($/kW) is typically applied to the maximum energy usage (kW) during on-peak hours for a given payment period. The user defined demand charge amount is applied to every month within the billing period. Only one demand charge value may be specified. This CTES analysis tool does not have the capacity to accommodate demand charges which change throughout the year which may be seen in some utility contracts.

For the economic calculations utilized within this tool, the billing period must be specified through a drop-down list on the *Utility Input* tab, shown in figure 7. This list provides the user with the billing options of monthly, quarterly, semi-annually, and annually. Independent of the billing option picked, the tool always counts January as the starting month, regardless of the option chosen. If a different starting month is specified within the desired utility package, the resulting economic analysis conducted by the tool will be incorrect.

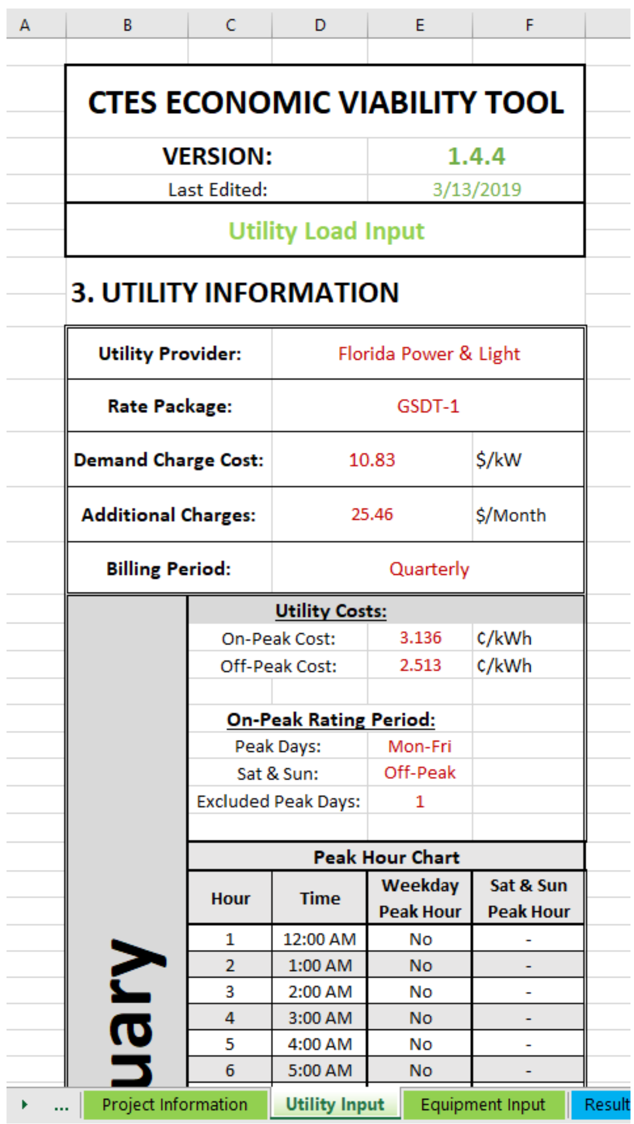


Figure 7. Utility Input Tab (A)

Excluded Days and Utility Peak Hours

On the *Utility Input* tab, the on-peak rate period must be specified for each month, highlighted with green in Figure 8. Within this set of inputs, the days where the on-peak hour utility price increase is applied may be defined. These days are referred to as “Peak Days” within the tool. By default, Monday through Friday must be on-peak days, while Saturday and Sunday have the option of being on-peak or off-peak days. The hours defined as on-peak or off-peak within the Peak Hour Chart will be used for all weekdays and cannot differ from Monday through Friday. The on-peak rating period section also allows for the number of excluded peak days within a given month to be stated. This number accounts for the peak days designated by the utility rate package in which increase pricing for specified hours does not apply. These days are omitted by the utility because of the reduced demand during national holidays. By default, all excluded peak days use the cooling load from the “Saturday” period. This assumption reduces the number of calculations performed by the tool, while retaining the same resulting accuracy of economic calculations.

When inputting the utility information specific to the user’s project, the on-peak hours of the day specified by the utility contract must be set. This information can be set through a yes/no dropdown menu under “Weekday Peak Hour” on the lower portion of the *Utility Input* tab, shown highlighted in yellow in Figure 8. This tool is configured to only work with static on-peak and off-peak hours as well as static cost values during these hours for each month. Therefore, this tool cannot be used if the utility package has ratcheting costs applied to on-peak hours (pricing changes throughout the day). If the utility package does not include a cost difference between on- or off-peak hours or if these hours are not specified, the same utility cost per kWh should be used for both on-peak and off-peak values as seen in Figure 8.

January

Utility Costs:		
On-Peak Cost:	3.052	¢/kWh
Off-Peak Cost:	2.429	¢/kWh
On-Peak Rating Period:		
Peak Days:	Mon-Fri	
Sat & Sun:	Off-Peak	
Excluded Peak Days:	1	

Peak Hour Chart			
Hour	Time	Weekday Peak Hour	Sat & Sun Peak Hour
1	12:00 AM	No	-
2	1:00 AM	No	-
3	2:00 AM	No	-
4	3:00 AM	No	-
5	4:00 AM	No	-
6	5:00 AM	No	-
7	6:00 AM	Yes	-
8	7:00 AM	Yes	-
9	8:00 AM	Yes	-
10	9:00 AM	Yes	-
11	10:00 AM	Yes	-
12	11:00 AM	No	-
13	12:00 PM	No	-
14	1:00 PM	No	-
15	2:00 PM	No	-
16	3:00 PM	No	-
17	4:00 PM	No	-
18	5:00 PM	No	-
19	6:00 PM	Yes	-
20	7:00 PM	Yes	-
21	8:00 PM	Yes	-
22	9:00 PM	Yes	-
23	10:00 PM	Yes	-
24	11:00 PM	No	-

Figure 8. Utility Input Tab (B)

Default Equipment Values

Since this is a preliminary analysis tool, in many instances, the user may not have established values associated with the costs, life, salvage value, and efficiency of the chiller(s). To resolve this issue, default values are provided on the *Equipment Input* tab for each variable in text boxes which pop up when the desired cell is selected. For the default costs of the normal and high-efficiency chillers, the values were taken from the average within the *RS Means Mechanical Cost Data 2017 (Gordian, 2017)*. The values regarding the ice banks were estimated using information from CALMAC (E. Rudolph, personal communication, March 6, 2019). Of course the more accurate the information for the specific project the more reliable the results.

Cost & Savings

It is important for the user to know this tool is meant to be an initial step in the CTES system selection process. The information displayed within the *Results* tab displays conservative figures based on the input data and the assumptions listed above. If the information and assumptions entered in the tool correctly apply to the desired project, the tool will quickly determine the upper bounds of payback period expected. The results from this tool show the expected payback period of the project under conservative conditions. Thus, a more complete economic analysis conducted later may provide a significantly reduced payback period for the project. It is up to the designer to decide if the conservative results produced from this tool are in an acceptable range for the project. If the user is accepting of these results, a full scale economic analysis still will need to be conducted.

System Configuration

As described in Chapter 1, the configuration of the system plays a crucial role in the life cycle cost analysis of CTES. These configuration variables include the CTES system option for either partial or full storage, as well as how the chillers are configured. The CTES tool described within this report only provides an analysis of CTES using partial storage. This storage option allows for the discharging ice tanks to only handle a segment of the peak building load, while distributing the CTES charging load equally throughout the day. This tool is also only valid for two different chiller configurations. The first valid configuration uses two sets of chillers – one set for handling the building load and the other set to address the CTES charging load. This configuration allows CTES systems to be installed on existing projects without extreme alteration to the existing chiller system. The second valid chiller configuration utilizes a set of chillers which provide cooling for the building and charging the CTES simultaneously. In this design, the chiller(s) are able to produce two different water temperatures, at two different efficiencies. The temperature of water would depend on whether its operation is charging the ice storage or handling the normal (non-peak) building load. Each of these specific system configurations were discussed in Chapter 1.

User Walkthrough

The following section provides a general walkthrough of the CTES tool. This walkthrough will follow the required steps needed to acquire accurate results from the analysis tool. As previously stated, this tool is meant to be an initial step in the analysis of CTES as a viable option for building cooling. Therefore, a full economic analysis will need to be completed once the designer is satisfied with this cursory analysis.

Initial Steps

When first opening the CTES tool Excel file, the user will be greeted with a box at the top of the page containing the title of the tool, the tool version, and the last time the content was edited. This is common among every tab in the CTES tool, as well as in the analysis results. It is displayed at the top of Figure 9. Besides the version information, Figure 9 illustrates the *Change Log* tab from the prospective of the user. This initial tab simply details the changes which have been made to the previous version of the tool, organized by the tab affected.

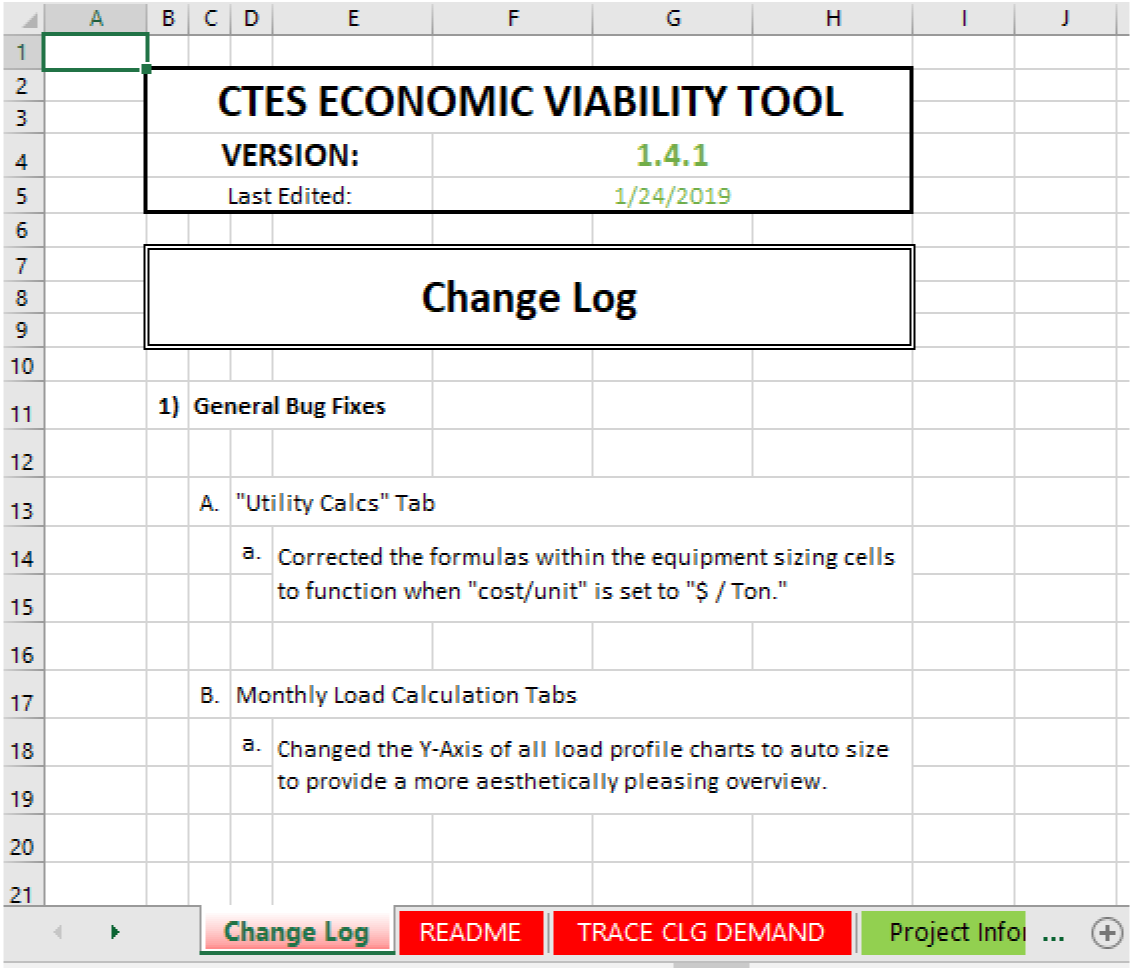


Figure 9. Change Log Tab

Once the *Change Log* tab has been read through, the *Read Me* tab should be opened, shown in Figure 10. This tab provides a disclaimer for the tool and emphasizes the design restriction of partial storage being the only valid storage option for this analysis to be accurate. Scrolling down on this tab reveals step by step instructions on how to export the building cooling load profile from TRACE700 and import this data into the CTES analysis tool.

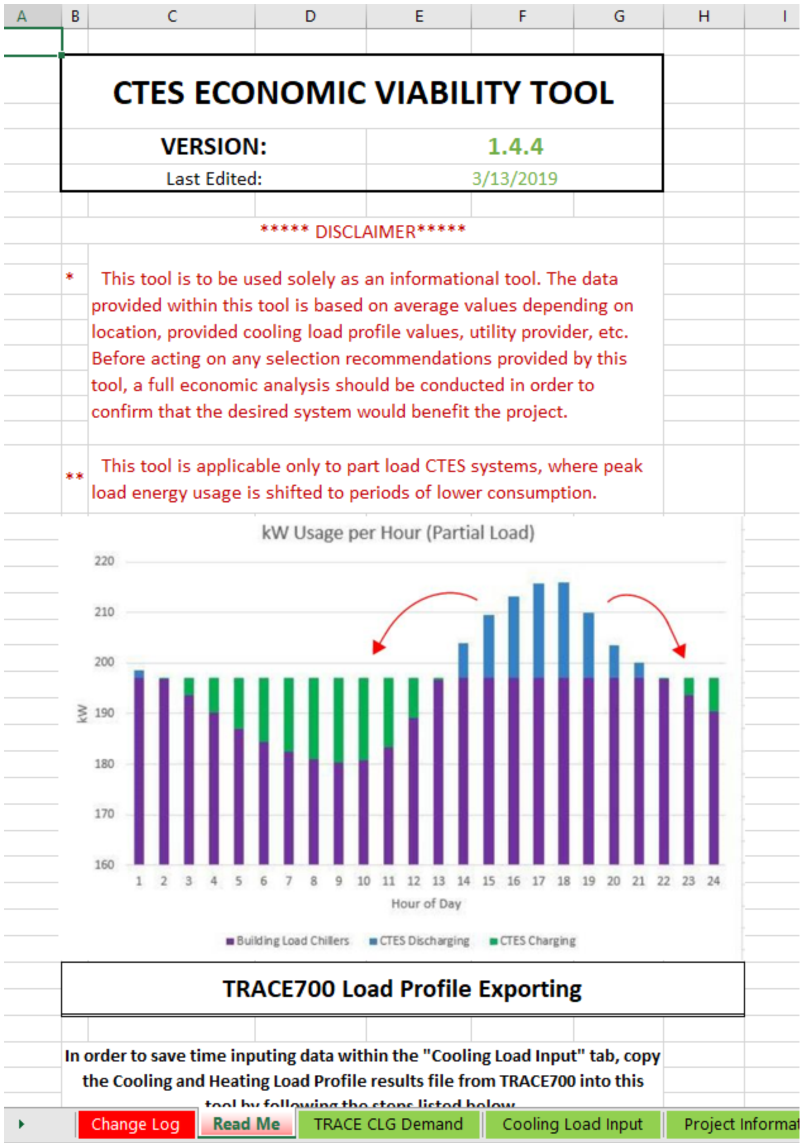


Figure 10. Read Me Tab

Importing Cooling Load Profile

To successfully import a cooling load profile from TRACE700 into the CTES analysis tool, the user must follow the steps presented on the *Read Me* tab. If a different program is used to determine the building cooling load profile, the load values must be manually entered, individually, on the *Cooling Load Input* tab, shown in Figure 11. This tab will automatically populate if data from TRACE700 is copied into the *TRACE CLG Demand* tab.

CTES ECONOMIC VIABILITY TOOL

VERSION:	**1.4.4**
Last Edited:	3/13/2019

Cooling Load Input

Note: If the "TRACE CLG DEMAND" tab was copied from the Trace700 Exported file, this section does NOT need any other user input. If a file was not exported, the Hourly Cooling Load profiles for each month must be inputed manually.

January			**Hourly Cooling Loads**			
Hour			**Weekday (Tons)**	**Saturday (Tons)**	**Sunday (Tons)**	**Monday (Tons)**
1	12	am	139.8	56.5	53.2	128.2
2	1	am	137.9	56.0	52.4	126.9
3	2	am	136.5	55.1	51.6	126.3
4	3	am	135.1	54.1	50.8	125.8
5	4	am	133.9	53.2	50.1	125.2
6	5	am	132.9	52.4	49.6	124.9
7	6	am	132.3	51.9	49.2	124.9
8	7	am	132.0	51.5	49.0	125.2
9	8	am	136.2	51.3	48.9	129.9
10	9	am	149.1	51.4	49.2	141.9
11	10	am	161.6	52.1	50.1	152.0
12	11	am	155.5	53.8	51.8	152.1
13	12	pm	154.7	55.9	54.1	153.4
14	1	pm	165.5	58.0	56.3	164.4
15	2	pm	176.9	59.6	58.0	176.2
16	3	pm	162.4	60.6	59.1	162.6
17	4	pm	159.6	61.3	60.0	159.9
18	5	pm	158.2	61.4	60.1	158.5
19	6	pm	153.2	59.7	58.5	153.5
20	7	pm	149.8	57.9	56.6	150.0
21	8	pm	148.8	56.9	55.7	149.0
22	9	pm	146.5	56.0	54.9	146.7

Read Me | TRACE CLG Demand | Cooling Load Input | Project Information

Figure 11. Cooling Load Input

Utilizing TRACE700, the building cooling load can be imported into the CTES analysis tool by following the five steps illustrated on the *Read Me* tab and shown in the following figures. Before beginning the import process, it is good practice to check if the utilization schedules used within the program are accurate and applicable to the project. Without accurate loads, the results from the CTES analysis tool will not be valid for the project. Once the file has been reviewed and the user is confident in the results, then proceed to step one, shown in Figure 12.

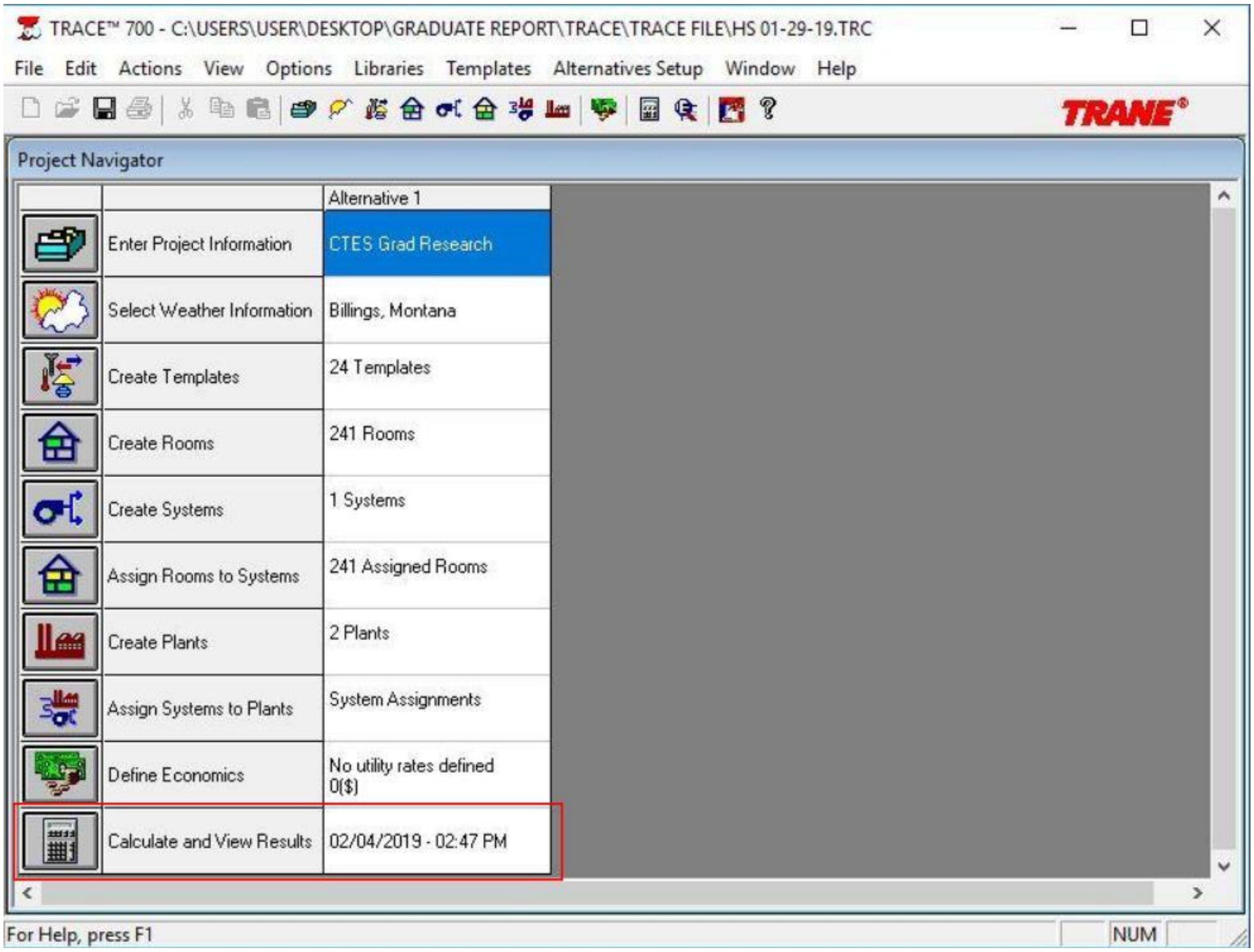


Figure 12. Importing Loads – Step One

The first step is for TRACE700 to calculate the loads by clicking the "Calculate and View Results" button. The "Calculate and View Results" screen will then open. The *Design*, *System*, and *Energy* alternative options should be check-marked. Start the calculation by clicking the "Calculate" button. Once the calculations are complete, click the "View Results…" button. This will open the "View Results" screen, shown in Figure 13.

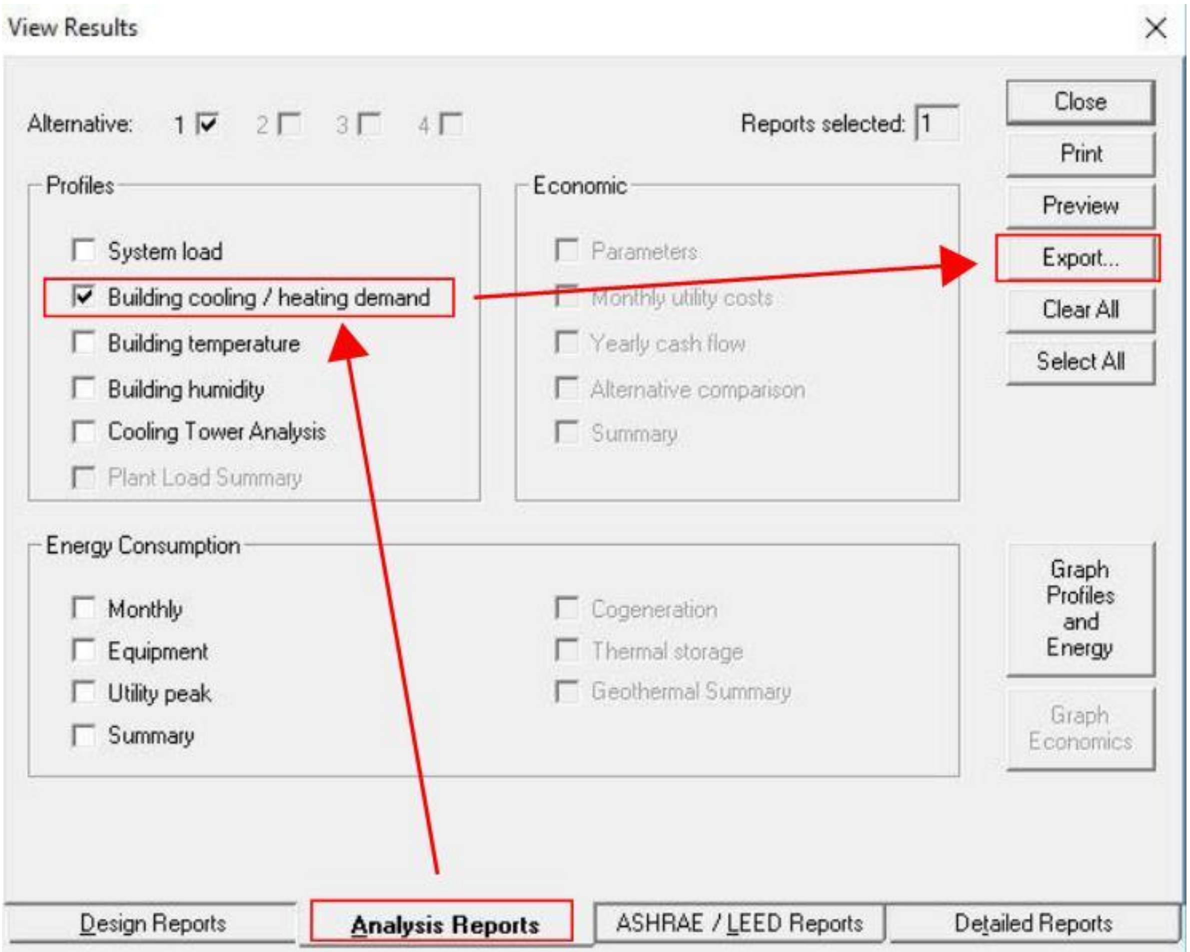


Figure 13. Importing Loads – Step Two

The second step of importing building loads from TRACE700 is to export the loads into an Excel file, illustrated in Figures 13 and 14. To do this, navigate to the "Analysis Reports" tab on the "View Results" screen. Once there, check-mark the box for *Building cooling / heating demand* and click on the "Export..." button. At this point, the "Report Export Options" screen will open, shown in Figure 14. Following the third step, change the *Export Format* dropdown menu to "Microsoft Excel (*.xls)" and select a save location. Click "Okay" and navigate to the exported Excel file.

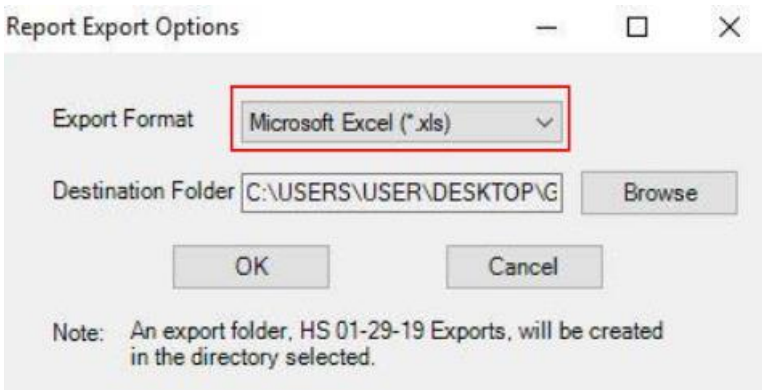


Figure 14. Importing Loads – Step Three

Next, proceeding with the fourth step, open the exported file and highlight all the rows starting with the “January” row, illustrated in Figure 15. Once the loads have been highlighted, right click and copy this information. Proceeding to step five, return to the CTES analysis tool and navigate to the *TRACE CLG Demand* tab. Highlight all the cells in this sheet by clicking the small triangle at the top left of the page, shown in Figure 16.

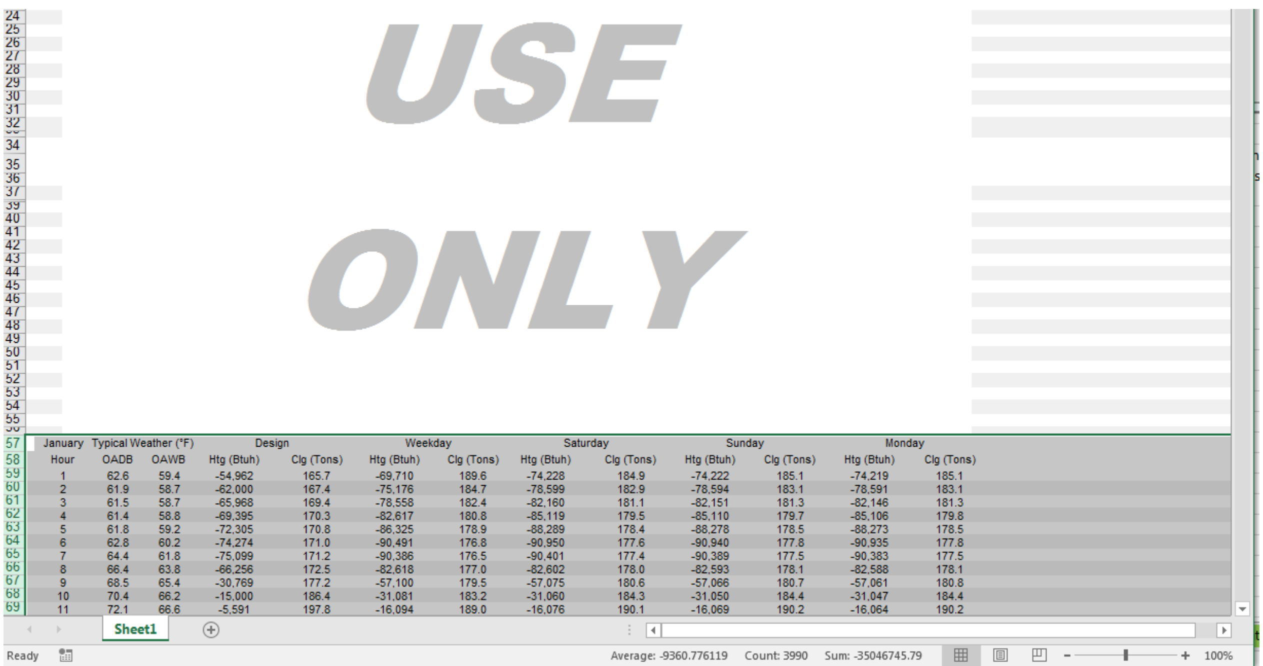
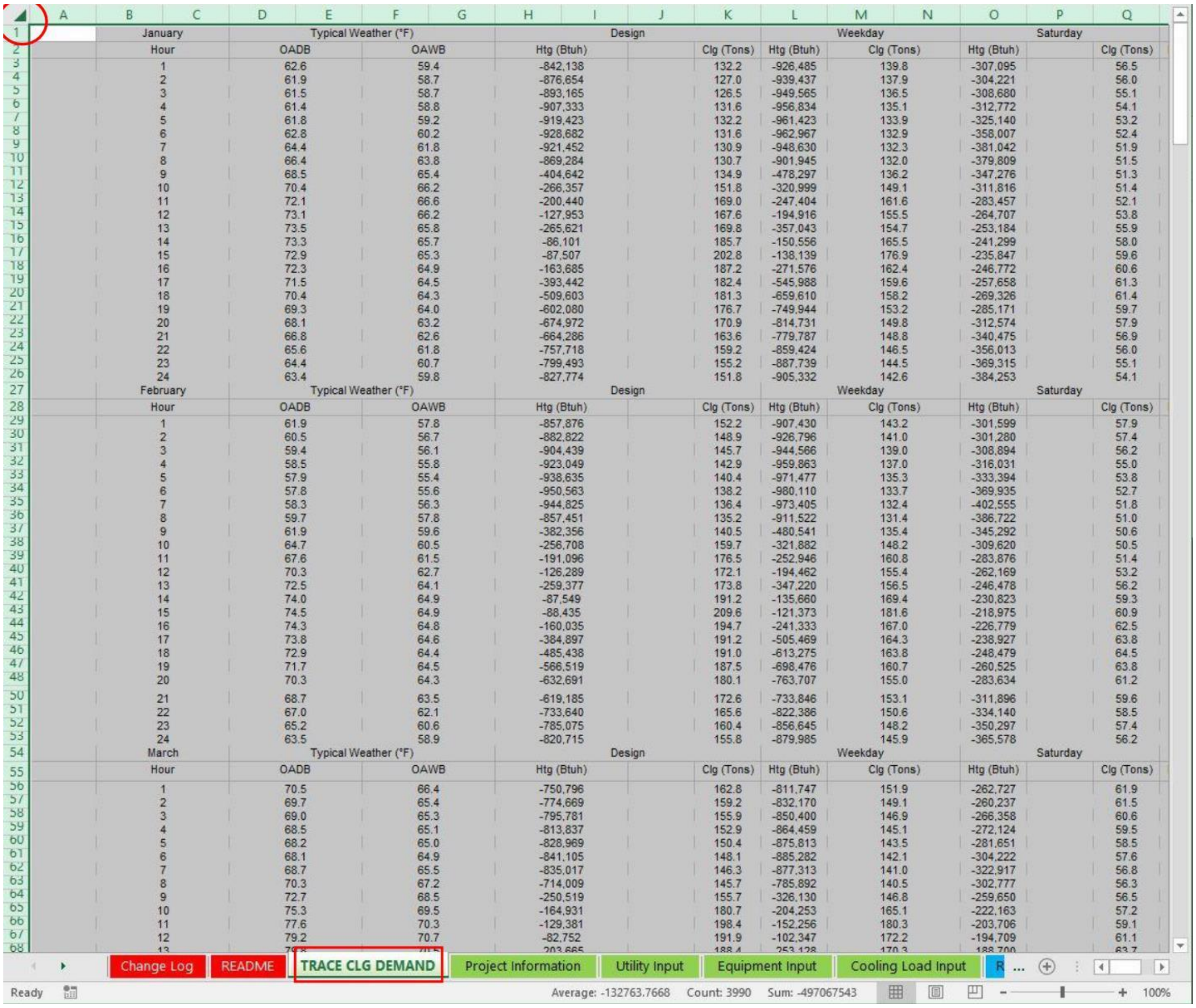


Figure 15. Importing Loads – Step Four



January	Typical Weather (°F)		Design		Weekday		Saturday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	62.6	59.4	-842,138	132.2	-926,485	139.8	-307,095	56.5
2	61.9	58.7	-876,654	127.0	-939,437	137.9	-304,221	56.0
3	61.5	58.7	-893,165	126.5	-949,565	136.5	-308,680	55.1
4	61.4	58.8	-907,333	131.6	-956,834	135.1	-312,772	54.1
5	61.8	59.2	-919,423	132.2	-961,423	133.9	-325,140	53.2
6	62.8	60.2	-928,682	131.6	-962,967	132.9	-358,007	52.4
7	64.4	61.8	-921,452	130.9	-948,630	132.3	-381,042	51.9
8	66.4	63.8	-869,284	130.7	-901,945	132.0	-379,809	51.5
9	68.5	65.4	-404,642	134.9	-478,297	136.2	-347,276	51.3
10	70.4	66.2	-266,357	151.8	-320,999	149.1	-311,816	51.4
11	72.1	66.6	-200,440	169.0	-247,404	161.6	-283,457	52.1
12	73.1	66.2	-127,953	167.6	-194,916	155.5	-264,707	53.8
13	73.5	65.8	-265,621	169.8	-357,043	154.7	-253,184	55.9
14	73.3	65.7	-86,101	185.7	-150,556	165.5	-241,299	58.0
15	72.9	65.3	-87,507	202.8	-138,139	176.9	-235,847	59.6
16	72.3	64.9	-163,685	187.2	-271,576	162.4	-246,772	60.6
17	71.5	64.5	-393,442	182.4	-545,988	159.6	-257,658	61.3
18	70.4	64.3	-509,603	181.3	-659,610	158.2	-269,326	61.4
19	69.3	64.0	-602,080	176.7	-749,944	153.2	-285,171	59.7
20	68.1	63.2	-674,972	170.9	-814,731	149.8	-312,574	57.9
21	66.8	62.6	-664,286	163.6	-779,787	148.8	-340,475	56.9
22	65.6	61.8	-757,718	159.2	-859,424	146.5	-356,013	56.0
23	64.4	60.7	-799,493	155.2	-887,739	144.5	-369,315	55.1
24	63.4	59.8	-827,774	151.8	-905,332	142.6	-384,253	54.1
February	Typical Weather (°F)		Design		Weekday		Saturday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	61.9	57.8	-857,876	152.2	-907,430	143.2	-301,599	57.9
2	60.5	56.7	-882,822	148.9	-926,796	141.0	-301,280	57.4
3	59.4	56.1	-904,439	145.7	-944,566	139.0	-308,894	56.2
4	58.5	55.8	-923,049	142.9	-959,863	137.0	-316,031	55.0
5	57.9	55.4	-938,635	140.4	-971,477	135.3	-333,394	53.8
6	57.8	55.6	-950,563	138.2	-980,110	133.7	-369,935	52.7
7	58.3	56.3	-944,825	136.4	-973,405	132.4	-402,555	51.8
8	59.7	57.8	-857,451	135.2	-911,522	131.4	-386,722	51.0
9	61.9	59.6	-382,356	140.5	-480,541	135.4	-345,292	50.6
10	64.7	60.5	-256,708	159.7	-321,882	148.2	-309,620	50.5
11	67.6	61.5	-191,096	176.5	-252,946	160.8	-283,876	51.4
12	70.3	62.7	-126,289	172.1	-194,462	155.4	-262,169	53.2
13	72.5	64.1	-259,377	173.8	-347,220	156.5	-246,478	56.2
14	74.0	64.9	-87,549	191.2	-135,660	169.4	-230,823	59.3
15	74.5	64.9	-88,435	209.6	-121,373	181.6	-218,975	60.9
16	74.3	64.8	-160,035	194.7	-241,333	167.0	-226,779	62.5
17	73.8	64.6	-384,897	191.2	-505,469	164.3	-238,927	63.8
18	72.9	64.4	-485,438	191.0	-613,275	163.8	-248,479	64.5
19	71.7	64.5	-566,519	187.5	-698,476	160.7	-260,525	63.8
20	70.3	64.3	-632,691	180.1	-763,707	155.0	-283,634	61.2
21	68.7	63.5	-619,185	172.6	-733,846	153.1	-311,896	59.6
22	67.0	62.1	-733,640	165.6	-822,386	150.6	-334,140	58.5
23	65.2	60.6	-785,075	160.4	-856,645	148.2	-350,297	57.4
24	63.5	58.9	-820,715	155.8	-879,985	145.9	-365,578	56.2
March	Typical Weather (°F)		Design		Weekday		Saturday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.5	66.4	-750,796	162.8	-811,747	151.9	-262,727	61.9
2	69.7	65.4	-774,669	159.2	-832,170	149.1	-260,237	61.5
3	69.0	65.3	-795,781	155.9	-850,400	146.9	-266,358	60.6
4	68.5	65.1	-813,837	152.9	-864,459	145.1	-272,124	59.5
5	68.2	65.0	-828,969	150.4	-875,813	143.5	-281,651	58.5
6	68.1	64.9	-841,105	148.1	-885,282	142.1	-304,222	57.6
7	68.7	65.5	-835,017	146.3	-877,313	141.0	-322,917	56.8
8	70.3	67.2	-714,009	145.7	-785,892	140.5	-302,777	56.3
9	72.7	68.5	-250,519	155.7	-326,130	146.8	-259,650	56.5
10	75.3	69.5	-164,931	180.7	-204,253	165.1	-222,163	57.2
11	77.6	70.3	-129,381	198.4	-152,256	180.3	-203,706	59.1
12	79.2	70.7	-82,752	191.9	-102,347	172.2	-194,709	61.1

Figure 16. Importing Loads – Step Five

Once the entire sheet has been highlighted, right click and paste the information copied from the exported TRACE700 load Excel file. The building load profile should now be correctly imported into the CTES analysis tool. The tool will refer to the cooling loads for the designated weekly periods of Weekday, Monday, Saturday, and Sunday to calculate the CTES loads and utility costs for the project.

Project Utilities

After successfully importing the cooling loads into the CTES tool, the user may move on to the *Project Information* tab, shown in Figure 17. This tab is for project information which may be helpful for documentation purposes, such as project name, number, location, etc. This information will be referenced on the *Results* tab for printing. Additional information for individual cells is provided in the form of a text box, shown in Figure 17 when working on this tab, as well as the *Utility Input* and *Equipment Input* tabs. This information includes a description of the cell content and expected values for the cell.

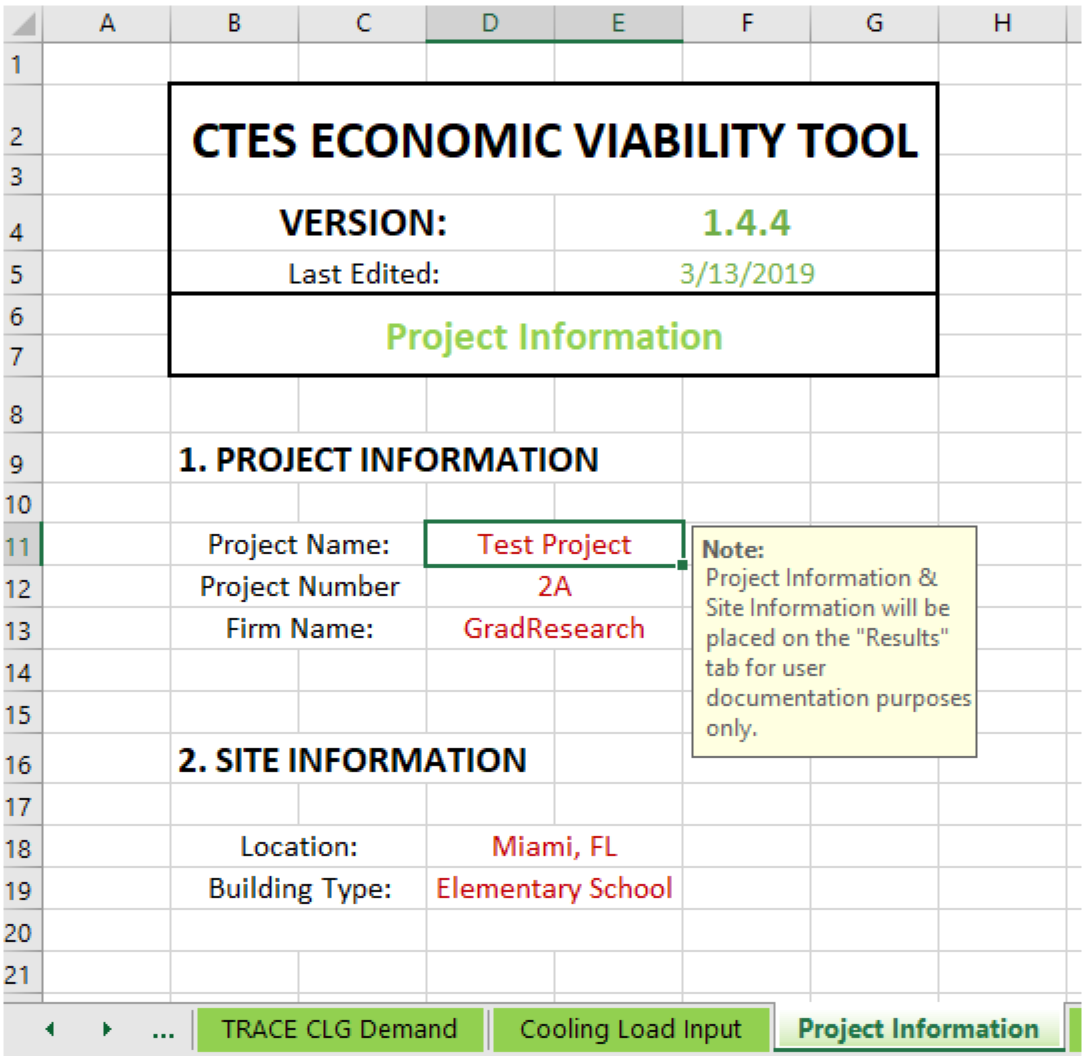


Figure 17. Project Information Tab

Once the general project information has been documented, the project utility information will need to be entered into the *Utility Input* tab, shown in Figure 18. On this tab, the utility provider and rate package may be specified. This information is only for documentation purposes and will be included in the *Results* tab but is not used as part of any calculations. The next pieces of utility information needed are the demand charge, additional monthly charges, and the billing period. The demand charge will be applied to the largest kW usage throughout a given billing period and then charged to each of the months within this period. The additional monthly charges include costs such as customer charges, storm charges, etc., which are applied to each month. The billing period may be selected through a drop down menu with the options of monthly, quarterly, semi-annually, and annually. Below the general monthly charges and the billing period are sections devoted to the utility costs and peak hour designations for each month, shown in Figure 18. Here, the on-peak and off-peak utility costs may be specified, in cents/kWh. Saturday and Sunday may be specified as on-peak days, days when the hourly on-peak utility cost applies, or off-peak. The number of excluded days for national holidays may also be entered per month in this area. Once the previous information is entered, the hours designated though the utility package as on-peak pricing may be entered using a dropdown menu with “yes” or “no.” As one scrolls down the spreadsheet, these options are replicated for every month.

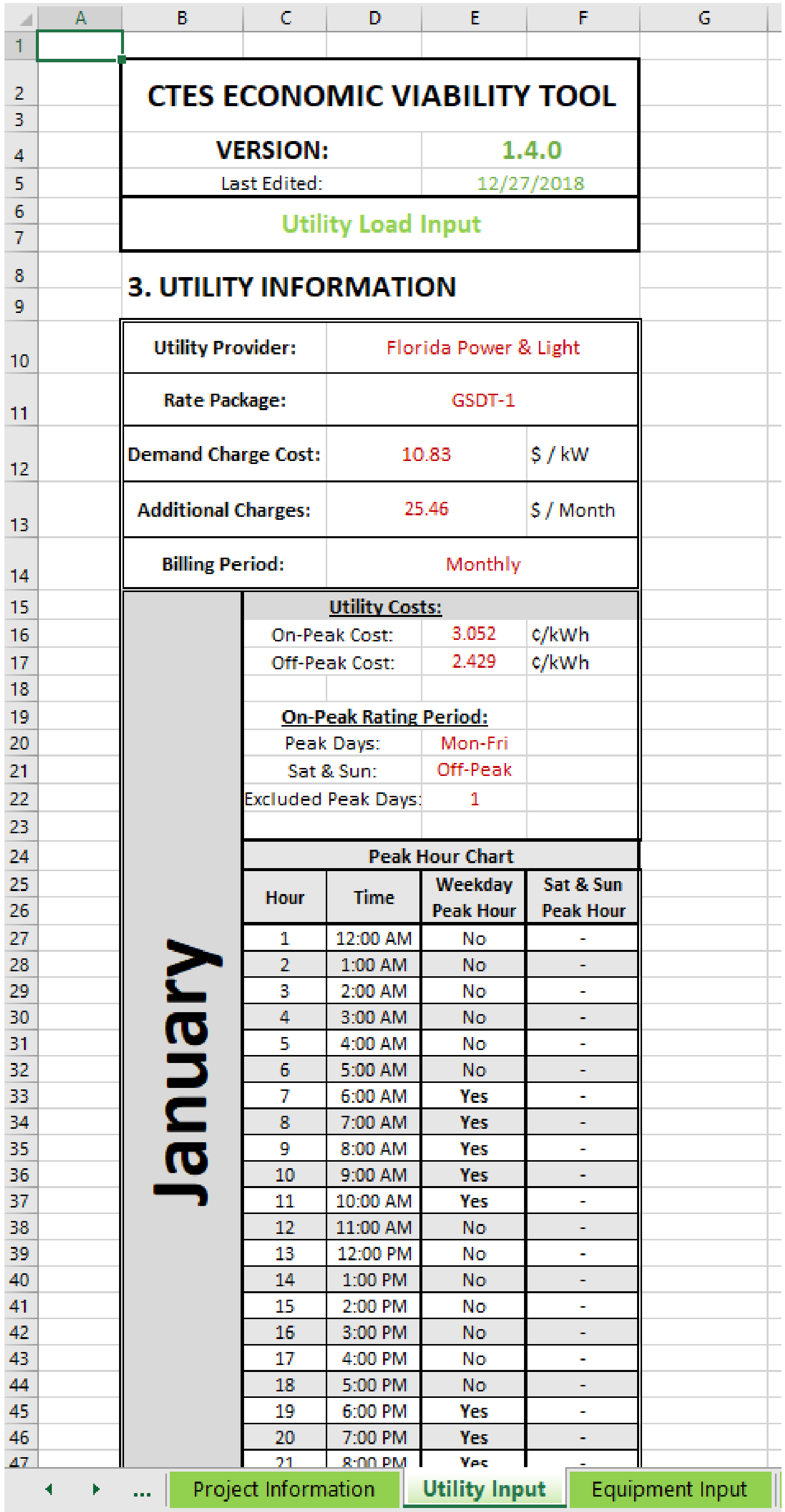
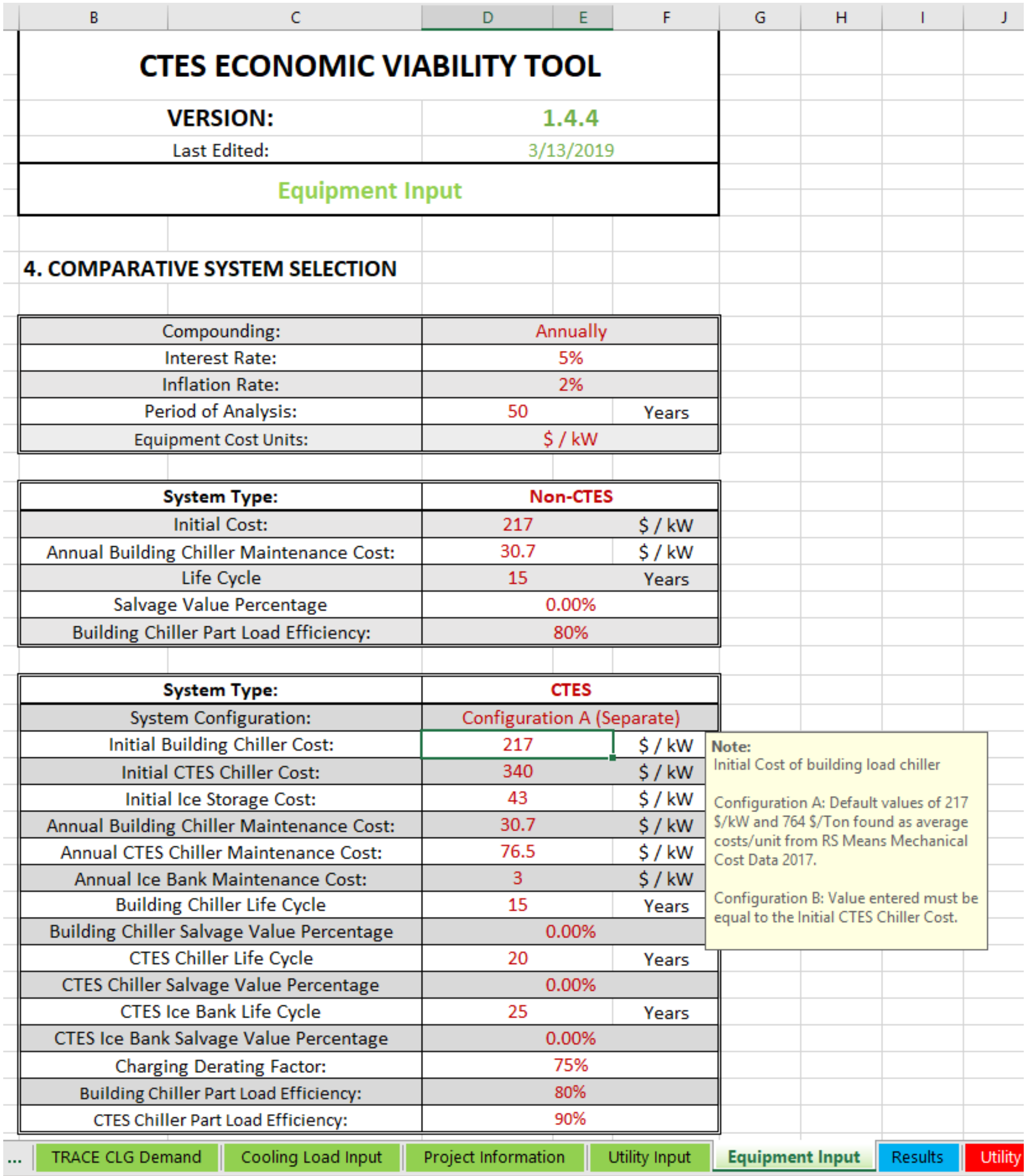


Figure 18. Utility Input Tab

Equipment Information

Once the utility content has been defined, the equipment information must be specified. This is done on the *Equipment Input* tab, shown in Figure 19. This tab is broken into three sections; economic information to be entered in the top most section, default non-CTES chiller system information in the middle section (the base system to which CTES is being compared), and CTES chiller system information in the bottom most section. The equipment cost units may be switched between $/kW and $/Ton if desired. Upon selecting a cell, default values will be provided within a text box, shown in Figure 19. These values were found through RS Means Mechanical Cost Data 2017 (Gordian,2017) and CALMAC data (E. Rudolph, personal communication, March 6, 2019). The salvage value for the systems may be included as a percentage of the initial cost, however, it is recommended for these values to remain at 0% for the conservative analysis. Besides the equipment cost information, the CTES system configuration needs to be specified. Configuration A specifies one chiller for handling the building load while a different chiller addresses the CTES charging load. Configuration B utilizes a set of chillers which provide cooling for the building and charging the CTES simultaneously. These configurations are detailed within Chapter 1 in Figures 4 and 5. These figures are also provided on the *Equipment Input* tab, below the editable information.



CTES ECONOMIC VIABILITY TOOL

VERSION:	1.4.4
Last Edited:	3/13/2019

Equipment Input

4. COMPARATIVE SYSTEM SELECTION

Compounding:	Annually	
Interest Rate:	5%	
Inflation Rate:	2%	
Period of Analysis:	50	Years
Equipment Cost Units:	$ / kW	

System Type:	Non-CTES	
Initial Cost:	217	$ / kW
Annual Building Chiller Maintenance Cost:	30.7	$ / kW
Life Cycle	15	Years
Salvage Value Percentage	0.00%	
Building Chiller Part Load Efficiency:	80%	

System Type:	CTES	
System Configuration:	Configuration A (Separate)	
Initial Building Chiller Cost:	217	$ / kW
Initial CTES Chiller Cost:	340	$ / kW
Initial Ice Storage Cost:	43	$ / kW
Annual Building Chiller Maintenance Cost:	30.7	$ / kW
Annual CTES Chiller Maintenance Cost:	76.5	$ / kW
Annual Ice Bank Maintenance Cost:	3	$ / kW
Building Chiller Life Cycle	15	Years
Building Chiller Salvage Value Percentage	0.00%	
CTES Chiller Life Cycle	20	Years
CTES Chiller Salvage Value Percentage	0.00%	
CTES Ice Bank Life Cycle	25	Years
CTES Ice Bank Salvage Value Percentage	0.00%	
Charging Derating Factor:	75%	
Building Chiller Part Load Efficiency:	80%	
CTES Chiller Part Load Efficiency:	90%	

Note:
Initial Cost of building load chiller

Configuration A: Default values of 217 $/kW and 764 $/Ton found as average costs/unit from RS Means Mechanical Cost Data 2017.

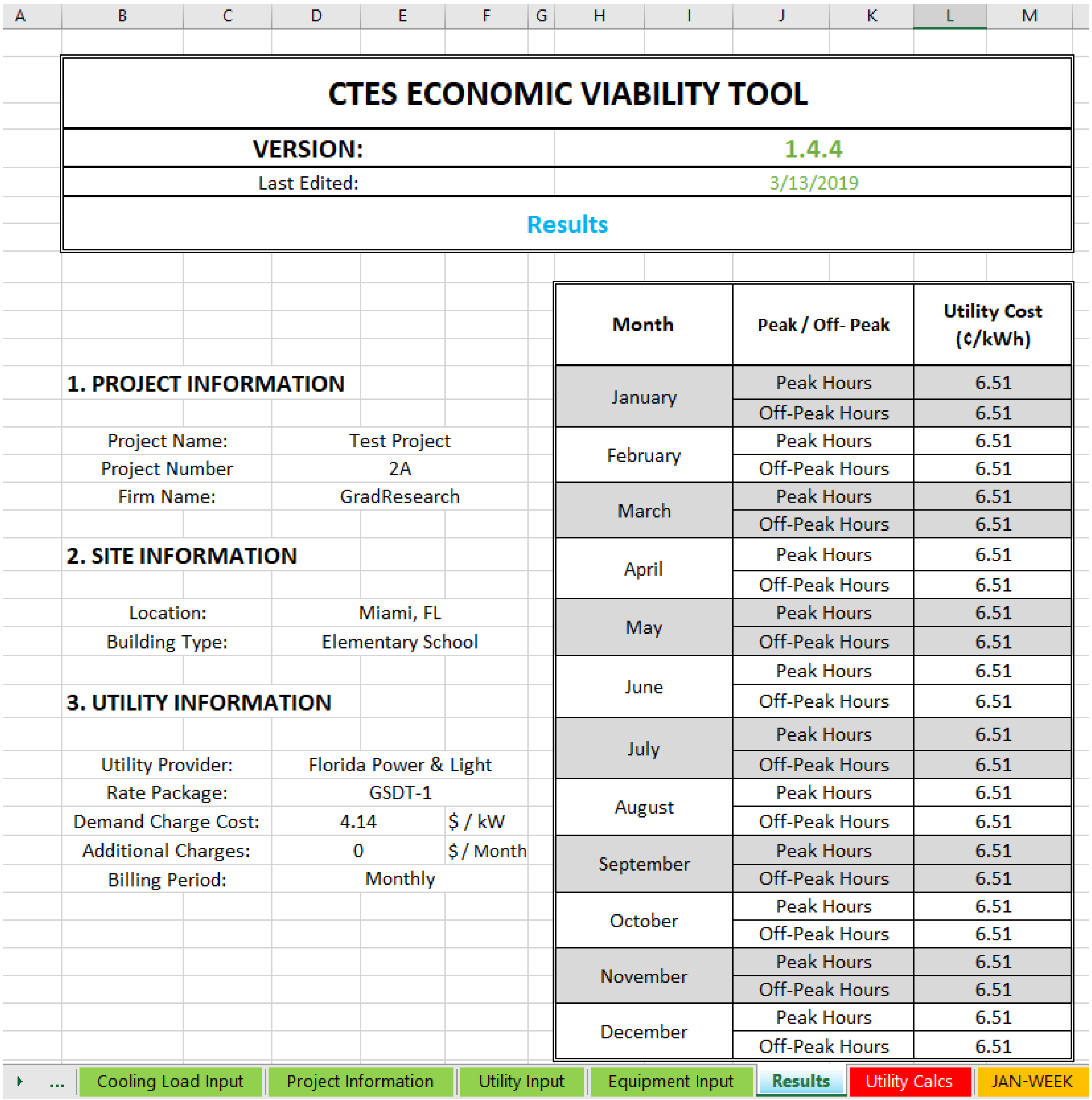
Configuration B: Value entered must be equal to the Initial CTES Chiller Cost.

Figure 19. Equipment Input Tab

Analysis Results

The final tab requiring user interaction, *Results*, presents the data entered for the analysis including project information, utility costs, equipment costs, economic values, etc., entered throughout the previous tabs (Figures 20, 21, and 22). This tab also presents a chart displaying the conservative monthly utility cost differences between the two systems – non-CTES and

CTES, the system costs, the net present and the equivalent uniform annual costs, as well as the payback period. This information is set up to print on two pages for documentation purposes.



CTES ECONOMIC VIABILITY TOOL

VERSION:	1.4.4
Last Edited:	3/13/2019

Results

1. PROJECT INFORMATION

Project Name:	Test Project
Project Number	2A
Firm Name:	GradResearch

2. SITE INFORMATION

Location:	Miami, FL
Building Type:	Elementary School

3. UTILITY INFORMATION

Utility Provider:	Florida Power & Light	
Rate Package:	GSDT-1	
Demand Charge Cost:	4.14	$ / kW
Additional Charges:	0	$ / Month
Billing Period:	Monthly	

Month	Peak / Off- Peak	Utility Cost (¢/kWh)
January	Peak Hours	6.51
	Off-Peak Hours	6.51
February	Peak Hours	6.51
	Off-Peak Hours	6.51
March	Peak Hours	6.51
	Off-Peak Hours	6.51
April	Peak Hours	6.51
	Off-Peak Hours	6.51
May	Peak Hours	6.51
	Off-Peak Hours	6.51
June	Peak Hours	6.51
	Off-Peak Hours	6.51
July	Peak Hours	6.51
	Off-Peak Hours	6.51
August	Peak Hours	6.51
	Off-Peak Hours	6.51
September	Peak Hours	6.51
	Off-Peak Hours	6.51
October	Peak Hours	6.51
	Off-Peak Hours	6.51
November	Peak Hours	6.51
	Off-Peak Hours	6.51
December	Peak Hours	6.51
	Off-Peak Hours	6.51

Figure 20. Results Tab (A)

4. COMPARATIVE SYSTEM SELECTION

Compounding:	Annually	
Interest Rate:	5%	
Inflation Rate:	2%	
Period of Analysis:	50	Years
Equipment Cost Units:	$ / kW	

System Type:	Non-CTES	
Initial Cost:	217	$ / kW
Annual Building Chiller Maintenance Cost:	30.7	$ / kW
Life Cycle	15	Years
Salvage Value Percentage	0.00%	
Building Chiller Part Load Efficiency:	80%	

System Type:	CTES	
System Configuration:	Configuration A (Separate)	
Initial Building Chiller Cost:	217	$ / kW
Initial CTES Chiller Cost:	340	$ / kW
Initial Ice Storage Cost:	43	$ / kW
Annual Building Chiller Maintenance Cost:	30.7	$ / kW
Annual CTES Chiller Maintenance Cost:	76.5	$ / kW
Annual Ice Bank Maintenance Cost:	3	$ / kW
Building Chiller Life Cycle	15	Years
Building Chiller Salvage Value Percentage	0.00%	
CTES Chiller Life Cycle	20	Years
CTES Chiller Salvage Value Percentage	0.00%	
CTES Ice Bank Life Cycle	25	Years
CTES Ice Bank Salvage Value Percentage	0.00%	
Charging Derating Factor:	75%	
Building Chiller Part Load Efficiency:	80%	
CTES Chiller Part Load Efficiency:	90%	

... Cooling Load Input | Project Information | Utility Input | Equipment Input | Results | Utili

Figure 21. Results Tab (B)

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$28,531	$28,449	$82	Yes	$82
February	$26,546	$26,528	$18	Yes	$18
March	$30,838	$30,725	$113	Yes	$113
April	$32,246	$31,800	$447	Yes	$447
May	$33,578	$33,105	$473	Yes	$473
June	$26,343	$25,308	$1,035	Yes	$1,035
July	$27,893	$26,940	$952	Yes	$952
August	$29,148	$27,914	$1,234	Yes	$1,234
September	$26,853	$25,524	$1,329	Yes	$1,329
October	$26,599	$25,358	$1,241	Yes	$1,241
November	$23,550	$22,834	$716	Yes	$716
December	$23,414	$22,763	$651	Yes	$651
				Annual Savings =	$8,290
				Months Running Per Year =	12

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$248,427	$35,146	$1,499,113	$58,264
CTES	$338,344	$47,317	$1,909,695	$74,221

Simple Payback =	49.53	Years

Cooling Load Input | Project Information | Utility Input | Equipment Input | Results | Utility Calcs

Figure 22. Results Tab (C)

Economic Analysis

As previously discussed, the initial cooling load profile data is to be calculated using TRACE700 or a similar program and brought into the tool. This daily load information is used to determine the load covered by the CTES system. The chiller(s) must address the remaining cooling load which results in energy consumption. The utility costs per month associated with operating these chillers is calculated within the *Utility Calcs* tab using the values entered on the

Utility Input tab. An in-depth explanation of these calculations is given in Appendix A. These total monthly utility costs for the Non-CTES and CTES systems, shown in black, are compiled in Table 1 to show the potential savings provided from CTES. This table compares the utility cost utilizing non-CTES and CTES systems to determine the savings per month, shown in green. If any savings are present, the CTES will be set to "on" in the next column and for the Net Present Value calculations within the next section. The economic analysis will take in to account how many months out of the year the CTES system is working and change the CTES life span accordingly.

Table 1. Annual CTES Savings

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$19,361	$18,649	$711	Yes	$711
February	$18,531	$17,822	$710	Yes	$710
March	$20,160	$19,469	$690	Yes	$690
April	$23,171	$20,319	$2,851	Yes	$2,851
May	$23,674	$20,821	$2,853	Yes	$2,853
June	$21,418	$18,691	$2,727	Yes	$2,727
July	$23,534	$18,077	$5,456	Yes	$5,456
August	$23,855	$18,479	$5,376	Yes	$5,376
September	$22,769	$17,358	$5,411	Yes	$5,411
October	$22,263	$17,210	$5,052	Yes	$5,052
November	$19,838	$14,715	$5,123	Yes	$5,123
December	$19,845	$14,725	$5,120	Yes	$5,120
				Annual Savings =	$42,083
				Months Running Per Year =	12

The next step in the economic analysis is to calculate the expected equipment size for the non-CTES and CTES systems. These calculations are completed in Table 2. The equipment sizes for the CTES and non-CTES systems will not be equal since the equipment are sized based on the maximum block load experienced and the CTES system reduces these maximum loads. The estimated load size, either in kW or Tons as specified on the *Equipment Input* tab, for each item is determined by the maximum hourly energy consumption experienced throughout the year, respective to each equipment type. These maximum energy values are then multiplied by the cost values, either in $/kW or $/Ton, specified in the *Equipment Input* tab to find the first cost, and annual maintenance cost of the equipment.

Table 2. Equipment Sizing Cost

Equipment Sizing Cost						
CTES	**Item**	**Size (kW)**	**First Cost ($/kW)**	**First Cost**	**Annual Maintenance Cost ($/kW)**	**Annual Maintenance Cost**
No	Building Chillers	1145	217	**$248,427**	30.7	**$35,146**
Yes	Building Chillers	605	217	**$131,273**	76.5	**$46,278**
Yes	CTES Chillers	271	340	**$92,106**	76.5	**$20,724**
Yes	Ice Banks	2674	43	**$114,965**	3	**$8,021**

After the equipment size is determined, the following equations and associated variables are used to calculate the net present cost for the system. The real interest rate is first found by subtracting the nominal interest rate by the inflation rate provided within the *Equipment Input* tab. Equation 1 is then used to find the effective annual interest rate. Once this is found, the net present cost of each piece of equipment is calculated using Equation 2, when the period of analysis is less than the life of the equipment, or Equation 3, when the period of analysis is greater than the life of the equipment. The values used within these equations are explained in Table 3.

$$ie = \left(1 + \frac{i}{x}\right)^{x} - 1 \qquad \textbf{Equation 1}$$

$$NPC = P + K * P\left[\frac{1}{(1+ie)^{n}}\right] + M\left[\frac{1-(1+ie)^{-n}}{ie}\right] - SV\left[\frac{1}{(1+ie)^{n}}\right] \qquad \textbf{Equation 2}$$

$$NPC = P + K * P\left[\frac{1}{(1+ie)^{n}}\right] + M\left[\frac{1-(1+ie)^{-n}}{ie}\right] + \Sigma\left(P\left[\frac{1}{(1+ie)^{Lm}}\right]\right) - \Sigma\left(SV\left[\frac{1}{(1+ie)^{Lm}}\right]\right) \qquad \textbf{Equation 3}$$

Table 3. Net Present Cost Analysis Variables

P =	Purchase Cost ($)	m =	Expected Equipment Life Cycle Length (Years)
M =	Annual Maintenance Cost ($)	L =	Equipment Life Cycles Completed Within Period of Analysis
SV =	Equipment Salvage Value ($)	K =	Equipment Life Cycle Progress During Incomplete Life Cycle
ie =	Effective Interest Rate (%)		
n =	# of period = (Compoundings per year) x (Years)		
i =	Real interest rate = nominal interest rate – inflation rate		
x =	Compoundings per Year		

These equations were found by altering the net present cost equation to fit all of the variables within a life cycle cost analysis. This includes incorporating the number of completed life cycles within the period of analysis, along with the initial cost and material salvage values which accompany them, and value of the equipment life if the life cycle is not fulfilled in this period. For the CTES chillers and ice banks, the life cycle is adjusted based on the number of months the CTES system is in use throughout the year. This adjusted life cycle is then used throughout the calculation to determine the number of completed life cycles and the progress of any uncompleted life cycle. For example, a set of chillers serving the CTES ice tanks may have an expected life cycle of 10 years before unit replacement is needed and the period of analysis for this example is 45 years. This chiller set successfully completes four full life cycles within this period, while the fifth life cycle remains incomplete. This incomplete cycle needs to be taken into consideration separately since the equipment still has five years of expected life available at the end of the analysis period. In the equations listed above, the four completed life cycles would represent the "L" value, while the incomplete life cycle progress ratio, K, would be found by dividing the incomplete life cycle's completed time by the expected life cycle of the equipment. This would result in a life cycle progress ratio, K, of 0.5 for the example described above. These calculations are completed independently for the building chillers, CTES chillers, and ice banks to achieve a net present cost for each. These values are then added together resulting in the total net present cost of the CTES system. If the equipment configuration has been specified to "Configuration B (Combined)" on the *Equipment Input* tab, then the CTES chiller calculation used the life cycle length of the lower efficiency building chiller. This is because the chiller will be used more often to handle the building load at a lesser efficiency.

The last calculations completed within the economic analysis are for the Equivalent Uniform Annual Costs (EUACs), and Simple Payback. After the net present cost of both systems are found, the EUAC is calculated for both using the future value equation, shown below in Equation 4.

$$\boldsymbol{EUAC = NPC\left[\frac{ie(1+ie)^n}{(1+ie)^n-1}\right]} \qquad \textbf{Equation 4}$$

Finally, with this annual cost, the Simple Payback can be calculated. By subtracting the non-CTES system EUAC from the CTES system EUAC, the system cost difference may be found. This information, used in conjunction with the annual savings found from Table 1, may be used within Equation 5 to find the Simple Payback.

$$\textbf{Simple Payback} = \frac{\textbf{System Cost Difference}}{\textbf{Annual Savings}} \qquad \textbf{Equation 5}$$

These results, along with the utility and equipment values specific to this project, are summarized within the *Results* tab, which may be printed for user documentation. Now that the assumptions and constraints pertaining to the tool, as well as the functionality of the tool, are known, two case studies are evaluated and are discussed in depth in Chapter 3.

Chapter 3 - Case Study Analysis

In this chapter, two case studies will be discussed. The same elementary school building is used in all comparisons. The school building has a floor area of approximately 163,000 square feet and serves a year round school application therefore it is scheduled for full occupancy throughout the entire year. The load profiles resulting from the building skin and internal sources are calculated using TRACE700 and are provided in Appendices B-D. To simplify the load calculation process, the loads due to ventilation and infiltration are not included in the load profiles for these examples. Three cities of different climate types from the ASHRAE Climate Zones, shown in Figure 23 are used for the analysis in both case studies - Miami Florida (Very Hot, Humid), Kansas City Missouri (Mixed, Humid), and Billings Montana (Cold, Dry). The different regions provide a large variation in cooling loads for the proposed school building which will exhibit the impact of cooling demand on the practicality of CTES systems. The variable that changes between the two case studies is the utility rates applied. As presented in prior chapters, utility rate structures are a very influential component on the justification of CTES systems. Using the building load profile for the school in three climate zones two different utility rate structures are applied for comparison. To ensure the analysis is as realistic as possible, utility rates from Florida Power and Light and NorthWestern Energy are used. These utility providers were chosen since they are the largest commercial utility providers in Florida and Montana respectively and provide very different rate structures. Florida and Montana were chosen for the utility package locations due both states experiencing largely different climatic conditions and the limitations on each state’s utility grid resulting from different population densities. The equipment information will remain the same for both case studies, shown in Table 4, and will remain independent of project location. Keeping the building construction and equipment information constant while varying the location and utility rate package is intended to demonstrate which variables are more influential when designing CTES systems.

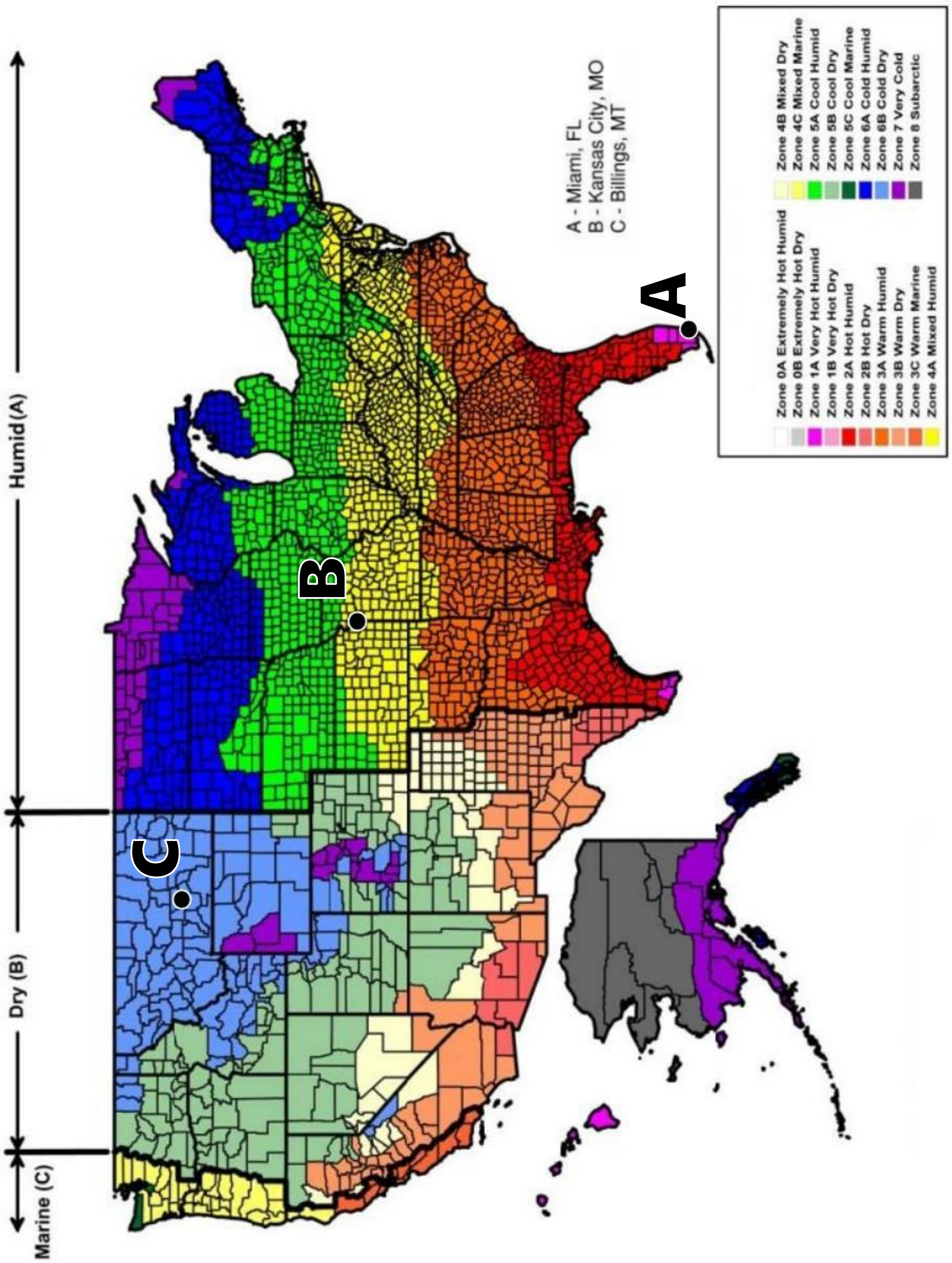


Figure 23. ASHRAE Climate Zones

(Figure modified from ASHRAE, 2017)

Table 4. Equipment Input Information

Compounding:	Annually	
Interest Rate:	5%	
Inflation Rate:	2%	
Period of Analysis:	50	Years
Equipment Cost Units:	$ / kW	

System Type:	**Chiller**	
Initial Cost:	217	$ / kW
Annual Building Chiller Maintenance Cost:	30.7	$ / kW
Life Cycle	15	Years
Salvage Value Percentage	0.00%	
Building Chiller Part Load Efficiency:	80%	

System Type:	**Chiller w/ CTES**	
System Configuration:	Configuration B (Combined)	
Initial Building Chiller Cost:	340	$ / kW
Initial CTES Chiller Cost:	340	$ / kW
Initial Ice Storage Cost:	200	$ / kW
Annual Building Chiller Maintenance Cost:	76.5	$ / kW
Annual CTES Chiller Maintenance Cost:	76.5	$ / kW
Annual Ice Bank Maintenance Cost:	3	$ / kW
Building Chiller Life Cycle	15	Years
Building Chiller Salvage Value Percentage	0.00%	
CTES Chiller Life Cycle	15	Years
CTES Chiller Salvage Value Percentage	0.00%	
CTES Ice Bank Life Cycle	25	Years
CTES Ice Bank Salvage Value Percentage	0.00%	
Charging Derating Factor:	75%	
Building Chiller Part Load Efficiency:	80%	
CTES Chiller Part Load Efficiency:	90%	

Case Study #1 – Florida Power & Light

The first case study will use the GSDT-1 commercial utility rate package since the building used for the analysis falls under the medium commercial load as defined by the Florida Power and Light utility provider. This package specifies a demand charge of $10.83/kW with $25.46 of additional fees per month. The billing period for this case study has been chosen to be monthly, in lieu of quarterly, semi-annually, or annually. Monthly was selected since this billing period option provides the least CTES savings per year; experiencing around 33 percent less savings than the semi-annually billing period, which sees the largest savings. The on-peak hours are designated as follows; On-peak hours of 6AM to 10AM and 6PM to 10PM for November 1st through March 31st, on-peak hours of 12PM to 9PM for April 1st through October 31st. Off-peak hours are used for all other time periods. Excluded on-peak days include Thanksgiving day, Christmas day, New Year's day, Memorial Day, Independence Day, and Labor Day. The utility costs for on-peak and off-peak hours of each month are given in Table 5. This information remains constant for each of the 3 locations used within the case study. The following sections discuss the results of the CTES economic analysis conducted by the CTES tool.

Table 5. GSDT-1 Utility Costs

Month	Peak / Off- Peak	Utility Cost (¢/kWh)
January	Peak Hours	3.136
	Off-Peak Hours	2.513
February	Peak Hours	3.136
	Off-Peak Hours	2.513
March	Peak Hours	3.136
	Off-Peak Hours	2.513
April	Peak Hours	3.136
	Off-Peak Hours	2.513
May	Peak Hours	3.136
	Off-Peak Hours	2.513
June	Peak Hours	3.876
	Off-Peak Hours	2.546
July	Peak Hours	3.876
	Off-Peak Hours	2.546
August	Peak Hours	3.876
	Off-Peak Hours	2.546
September	Peak Hours	3.876
	Off-Peak Hours	2.546
October	Peak Hours	3.136
	Off-Peak Hours	2.513
November	Peak Hours	3.136
	Off-Peak Hours	2.513
December	Peak Hours	3.136
	Off-Peak Hours	2.513

1A - Miami, Florida

The first city chosen for this case study is Miami, Florida. This city lies in the "Very Hot, Humid" section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 91°F dry bulb and 78.2°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 680 tons. The more complete monthly load profile data calculated using TRACE700 for the elementary school located in Miami, Florida, is provide in Appendix B. Using the utility package information from GSDT-1 of Florida Power and Light, and the equipment information previously specified in Table 4, the following results are found, shown in Table 6. By utilizing CTES, the system could provide annual savings of approximately $36,400 per year with the CTES system running 12 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $90,000 and a net present cost increase of approximately $1,162,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 32 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 6. Economic Analysis Results - 1A

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$18,468	$17,953	$515	Yes	$515
February	$17,610	$17,258	$353	Yes	$353
March	$20,160	$19,469	$690	Yes	$690
April	$21,808	$20,127	$1,681	Yes	$1,681
May	$22,601	$20,821	$1,780	Yes	$1,780
June	$21,418	$16,930	$4,487	Yes	$4,487
July	$22,300	$17,830	$4,470	Yes	$4,470
August	$23,855	$18,479	$5,376	Yes	$5,376
September	$22,516	$17,139	$5,377	Yes	$5,377
October	$22,263	$17,210	$5,052	Yes	$5,052
November	$17,878	$14,494	$3,384	Yes	$3,384
December	$17,532	$14,307	$3,224	Yes	$3,224
				Annual Savings =	$36,391
				Months Running Per Year =	12

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$248,427	$35,146	$1,499,113	$58,264
CTES	$338,344	$75,023	$2,661,266	$103,431

Simple Payback =	31.93	Years

1B - Kansas City, Missouri

The second city chosen for this case study is Kansas City, Missouri. This city lies in the "Mixed, Humid" section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 96°F dry bulb and 77°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 665 tons. The load profile data calculated using TRACE700 for the elementary school located in Kansas City, Missouri, is provide in Appendix C. Using the utility package information from GSDT-1 of Florida Power and Light, and the equipment information previously specified in Table 4, the following results are found, shown in Table 7. By utilizing CTES, the system could provide annual savings of approximately $32,300 per year with the CTES system running 12 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $80,000 and a net present cost increase of approximately $1,071,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 33 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 7. Economic Analysis Results - 1B

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$13,764	$13,671	$93	Yes	$93
February	$13,207	$13,082	$124	Yes	$124
March	$14,815	$14,639	$177	Yes	$177
April	$18,589	$17,062	$1,527	Yes	$1,527
May	$21,234	$19,411	$1,823	Yes	$1,823
June	$20,083	$15,662	$4,422	Yes	$4,422
July	$22,432	$17,856	$4,576	Yes	$4,576
August	$22,169	$16,851	$5,319	Yes	$5,319
September	$20,070	$14,873	$5,197	Yes	$5,197
October	$18,347	$13,950	$4,397	Yes	$4,397
November	$13,539	$11,128	$2,411	Yes	$2,411
December	$11,876	$9,649	$2,227	Yes	$2,227
				Annual Savings =	$32,294
				Months Running Per Year =	12

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$234,623	$33,193	$1,415,816	$55,026
CTES	$313,950	$70,196	$2,486,428	$96,636

Simple Payback =	33.15	Years

1C – Billings, Montana

The third city chosen for this case study is Billings, Montana. This city lies in the "Cold, Dry" section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 91°F dry bulb and 66°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 705 tons. The load profile data calculated using TRACE700 for the elementary school located in Billings, Montana, is provide in Appendix D. Using the utility package information from GSDT-1 of Florida Power and Light, and the equipment information previously specified in Table 4, the following results are found, shown in Table 8. By utilizing CTES, the system could provide annual savings of approximately $30,900 per year with the CTES system running 12 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $70,000 and a net present cost increase of approximately $957,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 31 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 8. Economic Analysis Results - 1C

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$12,533	$12,388	$145	Yes	$145
February	$12,421	$12,212	$210	Yes	$210
March	$13,110	$12,962	$149	Yes	$149
April	$16,831	$15,427	$1,404	Yes	$1,404
May	$18,808	$17,268	$1,540	Yes	$1,540
June	$18,345	$14,056	$4,289	Yes	$4,289
July	$21,719	$16,995	$4,724	Yes	$4,724
August	$20,708	$15,423	$5,285	Yes	$5,285
September	$17,543	$12,856	$4,687	Yes	$4,687
October	$17,145	$12,940	$4,205	Yes	$4,205
November	$11,295	$9,119	$2,176	Yes	$2,176
December	$10,100	$8,029	$2,071	Yes	$2,071
				Annual Savings =	$30,884
				Months Running Per Year =	12

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$222,565	$31,487	$1,343,054	$52,198
CTES	$292,809	$64,739	$2,299,730	$89,380

Simple Payback =	30.98	Years

Case Study #2 – NorthWestern Energy

The second case study uses the ESS-1 commercial utility rate package from the NorthWestern Energy utility provider since this utility rate package is set for buildings of medium commercial load and utilizes a constant utility charge throughout each month. This package specifies a demand charge of $4.14/kW with no additional ancillary fees per month besides the consumption charges. The billing period for this case study is monthly to match the prior case study ensuring all things are held equal beside the utility billing rate structure. On-peak hours are not specified, nor is there a cost difference in on-peak and off-peak hours, therefore off-peak hours are used for all time periods with a utility cost of 6.51 ¢/kWh. Excluded on-peak days include Thanksgiving day, Christmas day, New Year’s day, Memorial Day, Independence Day, and Labor Day. The equipment information for the study remains the same as the first case study and is provided in Table 4. This information remains constant for each of the 3 locations used within the case study. The following sections discuss the results of the CTES economic analysis conducted by the CTES tool.

2A - Miami, Florida

The first city, Miami, Florida, remains the same as in the first case study. This city lies in the “Very Hot, Humid” section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 91°F dry bulb and 78.2°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 680 tons. The load profile data calculated using TRACE700 for the elementary school located in Miami, Florida, is provide in Appendix B. Using the utility package information from ESS-1 of NorthWestern Energy, and the equipment information previously specified in Table 4, the following results are found, shown in Table 9. By utilizing CTES, the system could provide annual savings of approximately $8,300 per year with the CTES system running 12 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $90,000 and a net present cost increase of approximately $1,162,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 140 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 9. Economic Analysis Results - 2A

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$28,531	$28,449	$82	Yes	$82
February	$26,546	$26,528	$18	Yes	$18
March	$30,838	$30,725	$113	Yes	$113
April	$32,246	$31,800	$447	Yes	$447
May	$33,578	$33,105	$473	Yes	$473
June	$26,343	$25,308	$1,035	Yes	$1,035
July	$27,893	$26,940	$952	Yes	$952
August	$29,148	$27,914	$1,234	Yes	$1,234
September	$26,853	$25,524	$1,329	Yes	$1,329
October	$26,599	$25,358	$1,241	Yes	$1,241
November	$23,550	$22,834	$716	Yes	$716
December	$23,414	$22,763	$651	Yes	$651
				Annual Savings =	$8,290
				Months Running Per Year =	12

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$248,427	$35,146	$1,499,113	$58,264
CTES	$338,344	$75,023	$2,661,266	$103,431

Simple Payback =	140.18	Years

2B - Kansas City, Missouri

The second city chosen, Kansas City, Missouri remains the same as in the first case study. This city lies in the "Mixed, Humid" section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 96°F dry bulb and 77°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 665 tons. The load profile data calculated using TRACE700 for the elementary school located in Kansas City, Missouri, is provide in Appendix C. Using the utility package information from ESS-1 of NorthWestern Energy, and the equipment information previously specified in Table 4, the following results are found, shown in Table 10. By utilizing CTES, the system could provide annual savings of approximately $7,600 per year with the CTES system running 9 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $79,000 and a net present cost increase of approximately $1,048,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 138 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 10. Economic Analysis Results - 2B

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$21,486	$21,525	-$39	No	-
February	$19,927	$19,960	-$33	No	-
March	$22,886	$22,913	-$28	No	-
April	$27,272	$26,854	$418	Yes	$418
May	$31,308	$30,808	$500	Yes	$500
June	$24,449	$23,388	$1,060	Yes	$1,060
July	$27,996	$27,003	$992	Yes	$992
August	$26,705	$25,415	$1,290	Yes	$1,290
September	$23,481	$22,126	$1,354	Yes	$1,354
October	$21,635	$20,516	$1,119	Yes	$1,119
November	$17,918	$17,458	$460	Yes	$460
December	$15,672	$15,253	$419	Yes	$419
				Annual Savings =	$7,614
				Months Running Per Year =	9

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$234,623	$33,193	$1,415,816	$55,026
CTES	$313,950	$70,196	$2,463,795	$95,757

Simple Payback =	137.65	Years

2C – Billings, Montana

The third city chosen, Billings, Montana, remains the same as in the first case study. This city lies in the "Cold, Dry" section of the ASHRAE Climate Zones, previously shown in Figure 23, and uses a design outside air temperature of 91°F dry bulb and 66°F wet bulb from the TRACE700 version 6.3.4 weather profile database. The design peak cooling load for this location is 705 tons. The load profile data calculated using TRACE700 for the elementary school located in Billings, Montana, is provide in Appendix D. Using the utility package information from ESS-1 of NorthWestern Energy, and the equipment information previously specified in Table 4, the following results are found, shown in Table 11. By utilizing CTES, the system could provide annual savings of approximately $7,400 per year with the CTES system running 9 months out of the year. The difference in cost between the systems resulted in a first cost increase of around $70,000 and a net present cost increase of approximately $935,000 over the analysis period when utilizing CTES. This cost increase compared with the yearly savings resulted in a payback period of 126 years. The needed values associated with the net present cost equation are detailed in Appendix A.

Table 11. Economic Analysis Results - 2C

Monthly Utility Cost				CTES On During Month?	Cost/Month w/ CTES Savings
Month	Non-CTES	CTES	CTES Savings		
January	$19,442	$19,455	-$13	No	-
February	$18,591	$18,596	-$5	No	-
March	$20,187	$20,219	-$32	No	-
April	$24,609	$24,225	$385	Yes	$385
May	$27,753	$27,332	$421	Yes	$421
June	$21,998	$20,946	$1,052	Yes	$1,052
July	$26,735	$25,668	$1,067	Yes	$1,067
August	$24,563	$23,238	$1,325	Yes	$1,325
September	$20,290	$19,061	$1,229	Yes	$1,229
October	$20,090	$19,015	$1,075	Yes	$1,075
November	$14,664	$14,236	$428	Yes	$428
December	$12,976	$12,582	$394	Yes	$394
				Annual Savings =	$7,375
				Months Running Per Year =	9

System	First Cost	Annual Maintainance Cost	Net Present Cost	Equivalent Uniform Annual Cost
Non-CTES	$222,565	$31,487	$1,343,054	$52,198
CTES	$292,809	$64,739	$2,278,462	$88,554

Simple Payback =	126.83	Years

Case Study Analysis

For the first case study described above using a utility package with differing on-peak and off-peak energy rates and high demand charges, the resulting payback periods for all three cities each exceed 35 years. The savings from CTES utilization for Miami, Kansas City, and Billings are $36,400, $32,300, and $30,900 per year, respectively. Miami Florida produced a CTES payback of 32 years, while Kansas City Missouri and Billings Montana resulted in payback periods of 33 and 31 years, respectively. These results from the first case study are summarized in Table 12. These payback periods should not be considered truly representative of the potential for CTES in these locations since this type of high demand charge utility package is not frequent in the Midwest and Northwest regions of the United States, where differing utility rate structures may be more or less beneficial to CTES systems, and many other options are available for utility rate packages within the Southeast. The second case study described above using a utility package with constant energy rates and low demand charges resulted in payback periods greater than 120 years for all three cities. The savings from CTES utilization for Miami, Kansas City, and Billings are $8,300, $7,600, and $7,400 per year, respectively. Miami Florida provided a CTES payback of 140 years, while Kansas City Missouri and Billings Montana resulted in payback periods of 138 and 127 years, respectively. For both the first and second case study, the resulting saving between the three cities of differing climactic zones showed little variance. This is due to the decision to not incorporate ventilation and infiltration loads into the load profiles for each area. If these were accounted for, the differences in saving between the three locations, and thus the payback periods for these locations, would most likely see larger spreads in the resulting values. Even with these accounted for, however, the savings due to demand charge would still account for the majority of influence on overall CTES savings. The results from the second case study are summarized in Table 12. Based on these results, it would not be recommended to proceed with more detailed analysis of CTES for any of these applications. This is not surprising considering the additional costs associated with a CTES system (initial and annual) require that there be significant enough saving in utility expense to justify its installation. When energy rates are nearly consistent night and day, the storage of energy does not pay for itself. This comparison reinforces the effectiveness of using this tool to confirm standard assumption in a time efficient manner.

Table 12. Case Study Summary

Case Study #1			
Utility Provider:		Florida Power & Light	
Utility package:		GSDT-1	
Demand Charge:		$10.83/kW	
Consumption Charge:		Varies (See Table 5)	
Designation	**Location**	**CTES Savings**	**Payback Period (Yrs)**
1A	Miami, FL	$36,400	32
1B	Kansas City, MO	$32,300	33
1C	Billings, MT	$30,900	31

Case Study #2			
Utility Provider:		NorthWestern Energy	
Utility package:		ESS-1	
Demand Charge:		$4.14/kW	
Consumption Charge:		6.51 ¢/kW	
Designation	**Location**	**CTES Savings**	**Payback Period (Yrs)**
2A	Miami, FL	$8,300	140
2B	Kansas City, MO	$7,600	138
2C	Billings, MT	$7,400	127

Considering the payback periods resulting from the two case studies, none of the proposed applications would be considered good options for the utilization of CTES because all payback periods exceed 30 years. Many owners would require a much shorter payback period of around 5-10 years to justify the investment, depending on the project. Recognizing the limitation of the tool as well as the fact it has been developed to error on the side of being conservative, the user should not immediately write off CTES in these applications. The projects which incorporate higher demand charges (Case Study 1) may be worthy of further exploration. These projects would most likely see a reduction of the total CTES payback period as the assumed variables become more defined in a more detailed CTES analysis. The second case study resulting in payback periods of over 100 years would most likely result in a non-favorable payback period even in more detailed analysis, thus wasting time and money spent on the analysis. These case studies show the value of this tool when considering CTES for an application.

Chapter 4 - Conclusion

The CTES analysis tool discussed within this report is created to aid in the decision to move further into more complex and time consuming life cycle investigations of CTES. To show the value and versatility of the tool, two case studies considering the same building in three cities of different climate zones are conducted applying two vastly different utility packages. After conducting the afore mentioned case studies, it could be easily concluded the utility package has a much larger effect on the payback period and overall effectiveness of CTES systems than does the climate. This result is one that is expected and well documented in literature regarding CTES systems and their successful implementation. Using this CTES analysis tool with any of the projects described in the two case studies, the designer would be able to quickly determine the resulting payback period of the system, allowing a quick decision on whether or not to continue with further economic analysis.

The tool is not without its limitations, as previously discussed. One such limitation is the demand charge input. The economic inputs are limited to one constant demand charge and does not accommodate ratcheting demand charges seen in some utility packages. Another shortcoming of the tool is in the billing period. Within the tool, the month which starts the first group of each billing period is always counted as January, while many utility packages specify other months to start the billing period. The next limitation of the tool is the input options of on- and off-peak hour utility costs. These on- and off- peak costs are set for each month but must remain constant during the respective month and throughout each day. Lastly, the tool is set up using average values from the *RS Means Mechanical Cost Data 2017 (Gordian, 2017)* and CALMAC data (E. Rudolph, personal communication, March 6, 2019). The values used will not correctly reflect all the price options available for the equipment and may result in incorrect payback periods if higher priced equipment is selected

Though this tool is functional in its current state, further development is needed to provide the user with more input options leading to more accurate results. The following are recommended to be implemented in future versions of this tool:

- The ability to select the starting month for the billing period. This would allow for more types of utility rate structures, which specify starting month other than January for the billing periods, to be utilized within the tool.
- The ability to apply separate ratcheting demand charges, as well as ratcheting on- and off-peak utility costs. This would also allow for more utility rate structures, which specified utility charges which fluctuate throughout the month or day, to be utilized within the tool.

Along with these additional features, a comparative analysis with less conservative CTES tools would help to display the accuracy of the cursory analysis tool itself. A selection of different more thorough and complex CTES analysis tools, such as those provided by CTES manufacturers or similar life cycle analysis tools currently used today, should be chosen for this comparative analysis to provide the most accurate results. Lastly, performing analysis using this tool on previous projects which have successfully utilized CTES would allow for an accurate comparison of the theoretical payback period attained in the tool results to the actual payback period of the project. These additions would further aid users in the cursory economic analysis of CTES by providing more consistent and accurate results.

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Appendix A - Tool Calculations

The CTES tool described within this report utilizes many calculations which automatically run in the background based on information entered into the input tabs. These calculations determine the load handled by CTES ice storage and the building chillers. The monthly utility costs are then found using the calculated load data and the specified utility information. Excel Visual Basics for Applications (VBA) is used to allow the excel calculations to automatically run whenever data is edited on the input sheets described in Chapter 2. This appendix will dive further into the calculations utilized by the CTES tool to provide daily load and monthly utility cost data for use in the economic analysis introduced in Chapter 2.

Daily Load Calculations

In order to correctly estimate the unit size and therefore unit cost of a CTES system, the amount of load handled by the CTES ice storage must be determined. To accomplish this, a table was created which pulls the cooling load profile data from the either the *TRACE CLG Demand* tab or the *Cooling Load Input* tab, depending on which was used to enter cooling load data. This table, shown in Table 13, determines the amount of energy (kW) dedicated to building load, CTES ice storage charging, and CTES ice discharging for every hour of the day.

Table 13. Daily CTES Load Calculations

	B	C	D	E	F	G	H	I	J	K	L	M	N
2	JUNE			WEEKDAY		Partial Load CTES							
3	Hour			Cooling Load		Chillers		Load Handled		Hour			Utility Peak Hour
4								CTES	Chiller				
5				(Tons)	(kW)	Building Load (kW)	CTES Charging Load (kW)	(kW)	(kW)				
6	1	12	am	71.6	251.9471	251.9471	222.9653	0.0000	474.9124	1	12	am	No
7	2	1	am	69.5	244.3859	244.3859	230.5265	0.0000	474.9124	2	1	am	No
8	3	2	am	67.6	237.7391	237.7391	237.1734	0.0000	474.9124	3	2	am	No
9	4	3	am	66.3	233.1672	233.1672	241.7453	0.0000	474.9124	4	3	am	No
10	5	4	am	64.9	228.3491	228.3491	246.5634	0.0000	474.9124	5	4	am	No
11	6	5	am	63.7	224.1289	224.1289	250.7836	0.0000	474.9124	6	5	am	No
12	7	6	am	63.1	221.8077	221.8077	253.1047	0.0000	474.9124	7	6	am	No
13	8	7	am	179.0	629.4106	474.9124	0.0000	154.4982	474.9124	8	7	am	No
14	9	8	am	171.1	601.6979	474.9124	0.0000	126.7854	474.9124	9	8	am	No
15	10	9	am	190.8	671.0150	474.9124	0.0000	196.1026	474.9124	10	9	am	No
16	11	10	am	208.8	734.2128	474.9124	0.0000	259.3004	474.9124	11	10	am	No
17	12	11	am	213.0	749.1946	474.9124	0.0000	274.2821	474.9124	12	11	am	No
18	**13**	**12**	**pm**	**198.0**	**696.4770**	**474.9124**	**0.0000**	**221.5646**	**474.9124**	**13**	**12**	**pm**	**Yes**
19	**14**	**1**	**pm**	**220.1**	**773.9180**	**474.9124**	**0.0000**	**299.0056**	**474.9124**	**14**	**1**	**pm**	**Yes**
20	**15**	**2**	**pm**	**232.1**	**816.4016**	**474.9124**	**0.0000**	**341.4891**	**474.9124**	**15**	**2**	**pm**	**Yes**
21	**16**	**3**	**pm**	**204.2**	**718.2463**	**474.9124**	**0.0000**	**243.3339**	**474.9124**	**16**	**3**	**pm**	**Yes**
22	**17**	**4**	**pm**	**197.0**	**692.9601**	**474.9124**	**0.0000**	**218.0477**	**474.9124**	**17**	**4**	**pm**	**Yes**
23	**18**	**5**	**pm**	**80.5**	**283.2471**	**283.2471**	**191.6653**	**0.0000**	**474.9124**	**18**	**5**	**pm**	**Yes**
24	**19**	**6**	**pm**	**81.4**	**286.3771**	**286.3771**	**188.5353**	**0.0000**	**474.9124**	**19**	**6**	**pm**	**Yes**
25	**20**	**7**	**pm**	**79.5**	**279.4841**	**279.4841**	**195.4284**	**0.0000**	**474.9124**	**20**	**7**	**pm**	**Yes**
26	**21**	**8**	**pm**	**77.8**	**273.4703**	**273.4703**	**201.4422**	**0.0000**	**474.9124**	**21**	**8**	**pm**	**Yes**
27	**22**	**9**	**pm**	**75.1**	**263.9748**	**263.9748**	**210.9377**	**0.0000**	**474.9124**	**22**	**9**	**pm**	**Yes**
28	23	10	pm	73.1	257.0466	257.0466	217.8659	0.0000	474.9124	23	10	pm	No
29	24	11	pm	71.4	251.1031	251.1031	223.8093	0.0000	474.9124	24	11	pm	No
30							Total CTES (kW) :	2334.4095					
31	Charging Capacity Derating factor =				0.750		Needed PL Input (kW) :	3112.5461					
32	"Equalization Factor" =				0.29309001		Aquired PL Input (kW) :	3112.5461					
33							Needed - Aquired =	0					
34								Non CTES kWh =	10619.76				
35								CTES kWh =	11397.90				

The table arrangement and process to determine the required building load, ice storage charging load, and ice storage discharging load are outlined below. There are four separate spreadsheets used for each month – one for Weekday, Saturday, Sunday, and Monday. The first three columns (B, C, and D, where column A is unused) of these spreadsheets are dedicated to the hours of each day. Column E brings in data from the cooling load profile data from the either the *TRACE CLG Demand* tab or the *Cooling Load Input* tab. Column F then converts the Tons of cooling from Column E into kW. The chiller building load (Column G of Table 13) is calculated for every hour of the day using Equation 6, with the variables defined in Table 14. This equation finds the corrected average cooling load after the ice storage derating and the equalization factors

(DF and EF, respectively) have been considered. The ice storage factor is present to account for the increase in load needed to charge the ice for a given discharging load value. The equalization factor is a value set and altered by the Excel Solver which allows the increase in load due to the ice storage charging to be equally spread throughout the hours of the day. This value will be altered by Excel until the total sum of the charging loads (after the deration factor has been applied) and discharging loads (Columns H and I, respectively) are equal (shown in Rows 31 and 32). Using Table 13 as the example, the equalization factor which forces the charging and discharging loads to be equal (after the deration factor has been applied) is found to be 0.293 (shown in Row 32). This, along with a deration factor of 0.75 and an average cooling load of 442.5 kW, provides a corrected average cooling load of 474.9 kW.

$$\textbf{Corrected Average Cooling Load} = [(\mathbf{1} - \boldsymbol{DF}) * \boldsymbol{EF} * \boldsymbol{Avg\ CL}] + \boldsymbol{Avg\ CL} \qquad \textbf{Equation 6}$$

Table 14. Daily CTES Load Variables

Avg CL =	**Daily average of the original cooling loads (Column F)**
CL =	**Hourly calculated building cooling load (Column G)**
DF =	**Derating Factor**
EF =	**Equalization Factor**

This corrected average cooling load (474.9 kW) is compared with the current hour's cooling load (251.9 kW for the first hour of the day, Row 6), seen in Column F. If the corrected average is larger than the current cooling load, which is the case for the first hour of the day, the current cooling load is used for the required building load, shown in Column G. If not, the corrected average cooling load is used in place of the building load. This occurs in the eighth hour of the day, Row 13.

After the building load is calculated, the ice discharge load (Column I), or the load handled by the ice while discharging, is calculated using Equation 7. If this calculation results in a negative number, a zero is used in its place representing no load handled by the ice storage during this hour. For example, the ice discharging load for the first hour of the day would be found by subtracting the current hour's cooling load (251.9 kW) by the corrected average cooling load (474.9 kW), which would return a negative value, resulting in an ice discharging load of 0 kW. The ice discharging load for the eighth hour of the day, however, would be found by subtracting the current hour's cooling load by the corrected average cooling load, 629.4 kW and 474.9 kW, respectively, resulting in a discharging load of 154.5 kW. Once the building load and the ice storage discharging load are determined, the CTES charging load, or the load required from the CTES chillers to create the needed capacity of ice, is calculated. This charging load (Column H) is calculated every hour by subtracting the corrected average cooling load by the previously calculated building cooling load (Column G). Continuing the example for the first hour of the day, a charging load of 223 kW is attained by subtracting the corrected average cooling load (474.9 kW) from the previously calculated building load (251.9 kW). A charging load of 0 kW is obtained for the eighth hour of the day by subtracting the corrected average cooling load (474.9 kW) from the previously calculated building load (474.9 kW). Finally, Column J represents the combined load. This value is determined by simply adding the calculated building and ice storage charging loads for each hour of the day and is expected to be equal to the corrected average cooling load previously calculated in Equation 6. For our example at the first hour of the day, the building cooling load value of 251.9 kW is added to ice charging load value of 223 kW to attain the value of 474.9 kW listed in Column J. For the eighth hour of the day, the building cooling load value of 474.9 kW is added to the ice charging load value of 0 kW to also attain a total cooling load value of 474.9 kW.

$$\textbf{Hourly Ice Discharge Load} = \textbf{CL} - (\textbf{Corrected } \boldsymbol{Avg\ CL}) \qquad \textbf{Equation 7}$$

The charging capacity derating factor, DF (shown in Column F, Row 31), is pulled from the *Equipment Input* tab and is user specified. The total kWh usage for CTES and non-CTES systems are shown below the table in Rows 34-35 and show the increase in energy usage due to the ice charging derating factor. Lastly, the on- and off-peak hours are shown in Column N and are pulled from the *Utility Input* tab.

Monthly Utility Costs

The daily load information found in the previous section is then used in the calculation of the monthly utility costs for the Non-CTES and CTES systems. Figures 24 and 26 show this calculation for Non-CTES and CTES systems, respectively. The peak hour utility usage table (shown in Columns M-T of Figures 24 and 26) summarized the peak hour utility usage pulled from the daily load calculation tabs. This table is copied further to the right, shown in Figures 25 and 27, and is edited to summarize the non-peak hour utility usage. The purpose of these tables are to make the rest of the Excel calculation easier by summarizing the needed information in one convenient place for each month. From this information, the comparative system economic calculation table (Columns B-I) can be formed. This table specifies the maximum energy usage (Column B), total on-peak usage (Column D), total off-peak usage (Column E), total on-peak cost (Column F), total off-peak cost (Column G), total cost per day type (Column H), and number of day types per month (Column I) for each weekly period and is replicated for every month. The monthly demand peak (Rows 41 and 401, respectively) then pulls the largest peak energy usage from Column C. The monthly on-peak utility usage (Rows 42 and 402, respectively) then calculate the total on peak utility usage by multiplying the total peak usage (Column D) with the respective day types per month (Column I) for each weekly period and adds the resulting values. The monthly off-peak utility usage (Rows 43 and 403, respectively) perform the same calculation with the total off peak usage (Column E) and the respective day types per month. The total monthly utility usage (Rows 44 and 404, respectively) simply add the values from the previous two rows. The total monthly cooling cost (Rows 45 and 405, respectively) is calculated by multiplying each weekly period's total daily energy cost (Column H) with their respective number of occurring day types per month. The billing period (shown in Rows 47 and 407, respectively) is pulled from the *Utility Input* tab. This billing period determined how the months are grouped when calculating the billing period peak demand (Rows 48 and 408, respectively). The groups always use January as the starting month of the first group. The specific monthly demand cost (Rows 49 and 409, respectively) are calculated by multiplying the peak billing period demand, found in the previous row, with the demand charge, specified on the *Utility Input* tab. This demand cost is then added with any additional monthly charges, (Rows 50 and 410, respectively) which are also pulled from the *Utility Input* tab. The total utility cost for the specific month (Rows 52 and 412, respectively) are then calculated by adding the total monthly cooling cost, the monthly demand cost, and the additional monthly charges calculated in the previous rows. These values are then summarized in the Monthly Utility Cost table, shown in Table 1, for Non-CTES and CTES systems to compare the savings occurring each month. These economic calculations continue in Chapter 2.

COMPARATIVE SYSTEM ECONOMIC CALCULATIONS:

Month:	**January**		**System Type:**	**Chiller**			
Day Type	Highest Peak Usage (kW)	Total Peak Usage (kW)	Total Off-Peak Usage (kW)	Total Peak Cost ($/kWh)	Total Off-Peak Cost ($/kWh)	Total Cost Per Day ($/kWh)	Day Type # per Month
Weekday	710.27182	6391.8749	9193.74927	$200	$231	$431	18
Saturday	0	0	5871.556918	$0	$148	$148	4
Sunday	0	0	5655.490446	$0	$142	$142	4
Monday	674.70767	6231.9022	8911.038491	$195	$224	$419	4
Excluded Days	0	0	15585.62415	$0	$392	$392	1

Monthly Demand Peak:	710	**kW**
Monthly Peak Utility Usage:	139,981	**kWh**
Monthly Off-Peak Utility Usage:	262,825	**kWh**
Total Monthly Utility Usage:	402,807	**kWh**
Total Monthly Cooling Cost:	$10,994.62	**$ / kWh**

Billing Period:	Quarterly	
Highest Billing Period Demand Peak:	793	kW
January Demand Cost:	$8,584.92	
Additional Monthly Charges:	$25.46	

Total January Utility Cost:	$19,605.00

January

Peak Hour Utility Usage

Weekday		**Saturday**		**Sunday**		**Monday**	
Peak Hour	**Utility Usage (kW)**	**Peak Hour**	**Utility Usage (kW)**	**Peak Hour**	**Utility Usage (kW)**	**Peak Hour**	**Utility Usage (kW)**
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
Yes	581.5990688	No	0	No	0	Yes	549.0682
Yes	580.4121319	No	0	No	0	Yes	550.3431
Yes	598.5239094	No	0	No	0	Yes	570.8287
Yes	655.5848006	No	0	No	0	Yes	623.6694
Yes	710.2718181	No	0	No	0	Yes	668.3773
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
Yes	673.6526175	No	0	No	0	Yes	674.7077
Yes	658.6620444	No	0	No	0	Yes	659.4533
Yes	654.0461788	No	0	No	0	Yes	654.8375
Yes	644.0231563	No	0	No	0	Yes	644.7705
Yes	635.0991494	No	0	No	0	Yes	635.8465
No	0	No	0	No	0	No	0

Figure 24. Non-CTES Monthly Utility Calculations (A)

	V	W	X	Y	Z	AA	AB	AC	AD	AE
28										
29	January									
30	Off - Peak Hour Utility Usage									
31	Weekday		Saturday		Sunday		Monday		Excluded Peak Day	
32–33	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)
34	No	614.5695375	No	248.1577281	No	233.9584463	No	563.3554	No	248.1577281
35	No	606.2609794	No	246.0915788	No	230.1778325	No	557.7724	No	246.0915788
36	No	599.97461	No	242.1790831	No	226.7049431	No	555.3985	No	242.1790831
37	No	593.9080438	No	237.8709419	No	223.3639356	No	552.8928	No	237.8709419
38	No	588.4129656	No	233.7826038	No	220.3306525	No	550.5629	No	233.7826038
39	No	584.0608638	No	230.5295175	No	218.0007394	No	549.0242	No	230.5295175
40	Yes	0	No	228.1116831	No	216.3741963	Yes	0	No	228.1116831
41	Yes	0	No	226.2653369	No	215.2751806	Yes	0	No	226.2653369
42	Yes	0	No	225.430085	No	215.1432988	Yes	0	No	225.430085
43	Yes	0	No	225.9576125	No	216.3741963	Yes	0	No	225.9576125
44	Yes	0	No	229.0788169	No	220.1108494	Yes	0	No	229.0788169
45	No	683.7635613	No	236.3762806	No	227.89188	No	668.4653	No	236.3762806
46	No	680.0708688	No	245.7838544	No	237.8269813	No	674.4439	No	245.7838544
47	No	727.5043831	No	254.8837038	No	247.5422794	No	722.8446	No	254.8837038
48	No	777.7074169	No	261.7855219	No	255.0155856	No	774.5423	No	261.7855219
49	No	713.7447075	No	266.4013875	No	259.9391756	No	714.6239	No	266.4013875
50	No	701.611575	No	269.6544738	No	263.5439469	No	702.8864	No	269.6544738
51	No	695.2372844	No	270.09408	No	264.2912775	No	696.644	No	270.09408
52	Yes	0	No	262.5328525	No	256.9498531	Yes	0	No	262.5328525
53	Yes	0	No	254.3122156	No	248.99298	Yes	0	No	254.3122156
54	Yes	0	No	250.1359563	No	245.0365238	Yes	0	No	250.1359563
55	Yes	0	No	246.1795	No	241.3877919	Yes	0	No	246.1795
56	Yes	0	No	242.0032406	No	237.5192569	Yes	0	No	242.0032406
57	No	626.9224731	No	237.9588631	No	233.7386431	No	627.5819	No	237.9588631

Figure 25. Non-CTES Monthly Utility Calculations (B)

COMPARATIVE SYSTEM ECONOMIC CALCULATIONS:

Month:	January		System Type:	Chiller w/ CTES			
Day Type	Highest Peak Usage (kW)	Total Peak Usage (kW)	Total Off-Peak Usage (kW)	Total Peak Cost ($/kWh)	Total Off-Peak Cost ($/kWh)	Total Cost Per Day ($/kWh)	Day Type # per Month
Weekday	655.84267	6531.5811	9139.931875	$205	$230	$435	18
Saturday	0	0	5893.964173	$0	$148	$148	4
Sunday	0	0	5682.168827	$0	$143	$143	4
Monday	639.11213	6361.5874	8890.103464	$199	$223	$423	4
Excluded Days	0	0	15671.51296	$0	$394	$394	1

Monthly Demand Peak:	656	kW
Monthly Peak Utility Usage:	143,015	kWh
Monthly Off-Peak Utility Usage:	262,055	kWh
Total Monthly Utility Usage:	405,070	kWh
Total Monthly Cooling Cost:	$11,070.39	$ / kWh

Billing Period:	Quarterly	
Highest Billing Period Demand Peak:	720	kW
January Demand Cost:	$7,799.27	
Additional Monthly Charges:	$25.46	
Total January Utility Cost:	$18,895.13	

January

Peak Hour Utility Usage

Weekday		Saturday		Sunday		Monday	
Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
Yes	647.5933785	No	0	No	0	Yes	629.1072
Yes	647.4614966	No	0	No	0	Yes	629.2489
Yes	649.4739163	No	0	No	0	Yes	631.5251
Yes	655.8140154	No	0	No	0	Yes	637.3963
Yes	655.8426672	No	0	No	0	Yes	639.1121
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
No	0	No	0	No	0	No	0
Yes	655.8426672	No	0	No	0	Yes	639.1121
Yes	655.8426672	No	0	No	0	Yes	639.1121
Yes	655.6430574	No	0	No	0	Yes	639.1121
Yes	654.5293882	No	0	No	0	Yes	639.1121
Yes	653.5378319	No	0	No	0	Yes	638.7493
No	0	No	0	No	0	No	0

Figure 26. CTES Monthly Utility Calculations (A)

	V	W	X	Y	Z	AA	AB	AC	AD	AE
388										
389	January									
390	Off - Peak Hour Utility Usage									
391	Weekday		Saturday		Sunday		Monday		Excluded Peak Day	
392–393	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)	Peak Hour	Utility Usage (kW)	Peak Hour	Utility U:	Peak Hour	Utility Usage
394	No	651.2567435	No	246.328749	No	237.2365507	No	630		
395	No	650.3335704	No	246.3023968	No	236.8164825	No	630.0744	No	246.3023968
396	No	649.6350849	No	245.867675	No	236.430606	No	629.8106	No	245.867675
397	No	648.961022	No	245.3889927	No	236.0593829	No	629.5322	No	245.3889927
398	No	648.3504577	No	244.9347329	No	235.7223514	No	629.2733	No	244.9347329
399	No	647.8668908	No	244.5732789	No	235.4634722	No	629.1024	No	244.5732789
400	Yes	0	No	244.3046306	No	235.2827452	Yes	0	No	244.3046306
401	Yes	0	No	244.099481	No	235.1606323	Yes	0	No	244.099481
402	Yes	0	No	244.0066753	No	235.1459788	Yes	0	No	244.0066753
403	Yes	0	No	244.0652894	No	235.2827452	Yes	0	No	244.0652894
404	Yes	0	No	244.4120899	No	235.6979289	Yes	0	No	244.4120899
405	No	655.8426442	No	245.2229192	No	236.5624878	No	639.1121	No	245.2229192
406	No	655.8426442	No	246.2682052	No	237.6463138	No	639.1121	No	246.2682052
407	No	655.8426442	No	246.328749	No	237.6463138	No	639.1121	No	246.328749
408	No	655.8426442	No	246.328749	No	237.6463138	No	639.1121	No	246.328749
409	No	655.8426442	No	246.328749	No	237.6463138	No	639.1121	No	246.328749
410	No	655.8426442	No	246.328749	No	237.6463138	No	639.1121	No	246.328749
411	No	655.8426442	No	246.328749	No	237.6463138	No	639.1121	No	246.328749
412	Yes	0	No	246.328749	No	237.6463138	Yes	0	No	246.328749
413	Yes	0	No	246.328749	No	237.6463138	Yes	0	No	246.328749
414	Yes	0	No	246.328749	No	237.6463138	Yes	0	No	246.328749
415	Yes	0	No	246.3121658	No	237.6463138	Yes	0	No	246.3121658
416	Yes	0	No	245.848137	No	237.6321964	Yes	0	No	245.848137
417	No	652.6292919	No	245.3987617	No	237.2121282	No	637.831	No	245.3987617

Figure 27. CTES Monthly Utility Calculations (B)

Appendix B - Miami Load Profile Data

BUILDING COOL HEAT DEMAND

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	62.6	59.4	-842,138	132.2	-926,485	139.8	-307,095	56.5	-397,033	53.2	-1,037,310	128.2
2	61.9	58.7	-876,654	127.0	-939,437	137.9	-304,221	56.0	-405,676	52.4	-1,049,344	126.9
3	61.5	58.7	-893,165	126.5	-949,565	136.5	-308,680	55.1	-413,880	51.6	-1,053,117	126.3
4	61.4	58.8	-907,333	131.6	-956,834	135.1	-312,772	54.1	-432,697	50.8	-1,054,952	125.8
5	61.8	59.2	-919,423	132.2	-961,423	133.9	-325,140	53.2	-446,062	50.1	-1,051,040	125.2
6	62.8	60.2	-928,682	131.6	-962,967	132.9	-358,007	52.4	-461,168	49.6	-1,041,893	124.9
7	64.4	61.8	-921,452	130.9	-948,630	132.3	-381,042	51.9	-469,451	49.2	-1,024,237	124.9
8	66.4	63.8	-869,284	130.7	-901,945	132.0	-379,809	51.5	-469,051	49.0	-993,909	125.2
9	68.5	65.4	-404,642	134.9	-478,297	136.2	-347,276	51.3	-438,346	48.9	-727,157	129.9
10	70.4	66.2	-266,357	151.8	-320,999	149.1	-311,816	51.4	-400,814	49.2	-617,574	141.9
11	72.1	66.6	-200,440	169.0	-247,404	161.6	-283,457	52.1	-362,704	50.1	-536,821	152.0
12	73.1	66.2	-127,953	167.6	-194,916	155.5	-264,707	53.8	-332,018	51.8	-436,687	152.1
13	73.5	65.8	-265,621	169.8	-357,043	154.7	-253,184	55.9	-309,079	54.1	-520,847	153.4
14	73.3	65.7	-86,101	185.7	-150,556	165.5	-241,299	58.0	-284,605	56.3	-317,132	164.4
15	72.9	65.3	-87,507	202.8	-138,139	176.9	-235,847	59.6	-270,350	58.0	-254,428	176.2
16	72.3	64.9	-163,685	187.2	-271,576	162.4	-246,772	60.6	-277,443	59.1	-329,452	162.6
17	71.5	64.5	-393,442	182.4	-545,988	159.6	-257,658	61.3	-287,133	60.0	-579,502	159.9
18	70.4	64.3	-509,603	181.3	-659,610	158.2	-269,326	61.4	-299,949	60.1	-677,898	158.5
19	69.3	64.0	-602,080	176.7	-749,944	153.2	-285,171	59.7	-318,681	58.5	-762,161	153.5
20	68.1	63.2	-674,972	170.9	-814,731	149.8	-312,574	57.9	-347,103	56.6	-823,367	150.0
21	66.8	62.6	-664,286	163.6	-779,787	148.8	-340,475	56.9	-374,239	55.7	-787,390	149.0
22	65.6	61.8	-757,718	159.2	-859,424	146.5	-356,013	56.0	-391,214	54.9	-865,194	146.7
23	64.4	60.7	-799,493	155.2	-887,739	144.5	-369,315	55.1	-409,702	54.0	-892,845	144.6
24	63.4	59.8	-827,774	151.8	-905,332	142.6	-384,253	54.1	-423,624	53.2	-906,351	142.8

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	61.9	57.8	-857,876	152.2	-907,430	143.2	-301,599	57.9	-382,322	55.1	-1,031,232	132.0
2	60.5	56.7	-882,822	148.9	-926,796	141.0	-301,280	57.4	-399,103	54.0	-1,046,882	130.2
3	59.4	56.1	-904,439	145.7	-944,566	139.0	-308,894	56.2	-410,142	52.9	-1,053,623	129.1
4	58.5	55.8	-923,049	142.9	-959,863	137.0	-316,031	55.0	-426,348	51.9	-1,058,414	128.0
5	57.9	55.4	-938,635	140.4	-971,477	135.3	-333,394	53.8	-437,931	51.0	-1,058,086	127.0
6	57.8	55.6	-950,563	138.2	-980,110	133.7	-369,935	52.7	-452,055	50.1	-1,054,138	126.0
7	58.3	56.3	-944,825	136.4	-973,405	132.4	-402,555	51.8	-470,758	49.3	-1,041,244	125.2
8	59.7	57.8	-857,451	135.2	-911,522	131.4	-386,722	51.0	-449,248	48.6	-1,000,096	124.8
9	61.9	59.6	-382,356	140.5	-480,541	135.4	-345,292	50.6	-413,580	48.4	-725,981	129.3
10	64.7	60.5	-256,708	159.7	-321,882	148.2	-309,620	50.5	-382,946	48.4	-613,653	141.0
11	67.6	61.5	-191,096	176.5	-252,946	160.8	-283,876	51.4	-356,019	49.4	-514,103	152.5
12	70.3	62.7	-126,289	172.1	-194,462	155.4	-262,169	53.2	-326,238	51.3	-434,232	152.3
13	72.5	64.1	-259,377	173.8	-347,220	156.5	-246,478	56.2	-298,610	54.4	-509,390	155.2
14	74.0	64.9	-87,549	191.2	-135,660	169.4	-230,823	59.3	-268,131	57.6	-303,186	168.3
15	74.5	64.9	-88,435	209.6	-121,373	181.6	-218,975	60.9	-248,046	59.4	-213,308	180.7
16	74.3	64.8	-160,035	194.7	-241,333	167.0	-226,779	62.5	-253,066	61.0	-302,093	167.2
17	73.8	64.6	-384,897	191.2	-505,469	164.3	-238,927	63.8	-264,414	62.4	-529,493	164.6
18	72.9	64.4	-485,438	191.0	-613,275	163.8	-248,479	64.5	-273,309	63.2	-624,295	164.1
19	71.7	64.5	-566,519	187.5	-698,476	160.7	-260,525	63.8	-286,962	62.5	-705,041	161.0
20	70.3	64.3	-632,691	180.1	-763,707	155.0	-283,634	61.2	-313,520	60.0	-769,322	155.3
21	68.7	63.5	-619,185	172.6	-733,846	153.1	-311,896	59.6	-340,974	58.4	-741,597	153.4
22	67.0	62.1	-733,640	165.6	-822,386	150.6	-334,140	58.5	-363,863	57.4	-828,281	150.8
23	65.2	60.6	-785,075	160.4	-856,645	148.2	-350,297	57.4	-382,801	56.3	-859,323	148.4
24	63.5	58.9	-820,715	155.8	-879,985	145.9	-365,578	56.2	-399,393	55.2	-880,619	146.1

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.5	66.4	-750,796	162.8	-811,747	151.9	-262,727	61.9	-322,621	60.6	-947,264	144.5
2	69.7	65.4	-774,669	159.2	-832,170	149.1	-260,237	61.5	-332,209	59.5	-978,957	141.4
3	69.0	65.3	-795,781	155.9	-850,400	146.9	-266,358	60.6	-339,921	58.5	-976,226	140.3
4	68.5	65.1	-813,837	152.9	-864,459	145.1	-272,124	59.5	-346,678	57.5	-980,022	139.2

5	68.2	65.0	-828,969	150.4	-875,813	143.5	-281,651	58.5	-352,394	56.7	-975,037	138.3
6	68.1	64.9	-841,105	148.1	-885,282	142.1	-304,222	57.6	-364,956	55.8	-968,764	137.3
7	68.7	65.5	-835,017	146.3	-877,313	141.0	-322,917	56.8	-376,318	55.2	-949,308	136.7
8	70.3	67.2	-714,009	145.7	-785,892	140.5	-302,777	56.3	-334,174	54.7	-866,724	136.5
9	72.7	68.5	-250,519	155.7	-326,130	146.8	-259,650	56.5	-284,280	55.0	-544,704	143.1
10	75.3	69.5	-164,931	180.7	-204,253	165.1	-222,163	57.2	-242,080	55.8	-402,555	159.5
11	77.6	70.3	-129,381	198.4	-152,256	180.3	-203,706	59.1	-223,019	57.7	-315,258	173.1
12	79.2	70.7	-82,752	191.9	-102,347	172.2	-194,709	61.1	-214,072	59.8	-234,670	170.2
13	79.8	70.5	-203,665	188.4	-253,128	170.3	-188,700	63.7	-207,376	62.5	-320,397	170.2
14	79.7	70.2	-71,851	208.9	-84,436	185.2	-183,420	66.6	-202,225	65.5	-135,774	185.2
15	79.4	70.1	-77,861	227.2	-91,409	199.0	-181,913	68.3	-200,223	67.2	-128,423	199.2
16	78.9	69.6	-141,694	211.7	-190,818	182.4	-195,004	70.0	-213,217	68.9	-211,897	182.9
17	78.3	69.3	-354,024	208.2	-427,728	177.0	-207,509	71.2	-225,121	70.2	-437,498	177.5
18	77.5	69.0	-441,226	208.0	-531,755	175.7	-217,043	71.8	-235,023	70.8	-539,648	176.2
19	76.6	68.5	-515,186	203.6	-616,303	172.0	-229,404	71.0	-248,702	70.1	-618,055	172.5
20	75.6	68.9	-571,260	195.2	-681,911	166.1	-248,051	68.6	-269,192	67.7	-682,825	166.5
21	74.5	68.8	-546,133	188.1	-651,917	162.6	-266,334	66.1	-288,416	65.2	-653,670	162.9
22	73.4	68.6	-636,876	177.6	-738,752	159.1	-284,154	64.4	-305,747	63.5	-739,767	159.4
23	72.4	67.9	-681,380	172.2	-772,911	156.3	-300,232	63.0	-320,836	62.2	-773,509	156.6
24	71.4	67.2	-711,655	167.5	-794,380	153.8	-311,082	61.8	-334,929	61.0	-794,688	154.0

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.6	68.0	-712,395	166.2	-783,880	155.3	-251,572	63.1	-306,909	62.3	-834,337	158.1
2	72.0	67.3	-734,386	162.4	-799,691	152.1	-248,543	62.8	-316,657	61.2	-923,236	144.4
3	71.6	67.4	-755,532	159.0	-820,137	149.6	-254,025	61.9	-323,712	60.2	-941,271	143.0
4	71.5	67.3	-773,869	156.0	-833,424	147.5	-258,718	60.8	-329,242	59.2	-946,452	141.9
5	71.7	67.4	-789,177	153.4	-844,323	145.9	-266,653	59.9	-333,213	58.4	-940,323	141.0
6	72.4	68.0	-801,505	151.2	-850,095	144.6	-280,308	59.1	-336,052	57.7	-931,426	140.3
7	73.5	69.2	-748,638	149.7	-807,121	143.8	-281,484	58.5	-318,519	57.2	-880,385	139.9
8	74.9	70.2	-617,344	151.1	-702,804	144.5	-250,161	58.6	-273,853	57.4	-774,214	140.9
9	76.5	70.2	-203,304	165.7	-262,501	153.1	-219,829	59.2	-237,572	58.0	-467,405	149.8
10	78.0	70.7	-141,797	194.0	-165,220	175.3	-194,476	60.9	-210,357	59.7	-342,531	169.6
11	79.4	71.0	-113,750	210.6	-130,830	190.1	-183,698	62.8	-199,543	61.8	-285,071	183.2
12	80.5	71.1	-74,697	201.8	-87,754	180.0	-176,690	64.3	-192,432	63.2	-192,658	178.1
13	81.2	71.5	-193,661	194.6	-227,237	173.3	-172,200	65.9	-188,576	64.9	-276,201	173.3
14	81.5	71.3	-67,367	215.3	-78,495	187.7	-172,597	68.0	-188,075	67.0	-127,134	187.8
15	81.3	71.6	-73,277	233.2	-87,899	203.2	-175,733	70.4	-190,861	69.7	-120,419	203.5
16	81.0	72.0	-134,877	218.6	-183,950	187.0	-183,135	72.2	-197,852	71.3	-204,801	187.6
17	80.4	71.5	-341,108	215.6	-407,855	180.8	-190,483	73.4	-205,522	72.4	-417,572	181.4
18	79.6	71.2	-424,534	215.2	-506,060	178.9	-201,972	73.8	-216,889	72.9	-509,918	179.4
19	78.6	71.2	-496,044	210.0	-592,564	175.3	-215,753	73.1	-232,193	72.2	-594,265	175.8
20	77.6	71.2	-551,619	201.6	-654,951	169.3	-235,848	70.8	-253,672	70.0	-655,919	169.6
21	76.5	70.5	-527,478	193.9	-624,565	165.9	-251,912	68.2	-270,248	67.4	-626,382	166.2
22	75.4	69.9	-608,376	183.3	-711,938	162.5	-271,959	66.7	-293,153	66.0	-712,792	162.8
23	74.3	69.4	-645,263	176.6	-745,133	158.8	-283,604	65.0	-302,879	64.3	-745,488	159.1
24	73.4	68.9	-675,996	171.6	-768,329	156.2	-296,593	63.6	-317,598	62.9	-768,660	156.5

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	75.2	70.3	-696,509	168.3	-750,239	158.5	-236,007	64.8	-283,733	64.7	-801,088	172.0
2	74.3	69.5	-719,569	164.3	-767,933	155.9	-234,144	64.6	-296,228	63.3	-841,973	157.6
3	73.5	69.1	-740,631	160.6	-784,450	153.3	-240,868	63.5	-306,097	62.2	-881,781	146.7
4	72.9	68.9	-760,447	157.5	-804,972	150.5	-247,427	62.4	-314,116	61.1	-916,241	144.9
5	72.5	68.7	-777,002	154.8	-818,415	148.5	-257,294	61.3	-320,780	60.2	-912,921	143.7
6	72.2	68.8	-790,185	152.5	-832,117	146.7	-269,901	60.4	-326,569	59.3	-908,735	142.6
7	72.1	69.1	-714,397	151.4	-783,390	145.6	-268,353	59.6	-300,814	58.7	-853,039	142.0
8	72.6	68.7	-582,077	153.6	-683,032	146.2	-241,861	59.7	-265,708	58.8	-752,558	142.9
9	74.2	68.1	-191,991	170.7	-255,217	155.4	-217,983	60.2	-232,653	59.3	-448,570	152.3
10	76.4	69.4	-133,197	199.9	-157,574	177.6	-191,276	61.9	-206,315	61.1	-331,848	172.0
11	78.9	70.8	-108,450	215.8	-127,600	192.6	-180,093	63.9	-194,560	63.3	-264,959	186.0
12	81.2	72.0	-71,502	207.1	-84,500	183.0	-172,846	66.1	-186,727	65.4	-178,482	181.5
13	82.7	72.7	-187,184	198.1	-219,821	176.2	-168,492	67.8	-183,012	67.1	-266,768	176.3

14	83.3	72.9	-65,111	218.5	-75,252	192.0	-167,215	70.0	-181,489	69.3	-121,403	192.2
15	83.2	73.1	-71,075	236.6	-84,436	209.2	-171,050	73.0	-184,789	72.3	-113,011	209.6
16	82.9	72.5	-128,877	221.9	-171,375	193.2	-173,239	75.1	-186,948	74.4	-192,031	193.8
17	82.4	72.6	-330,049	218.8	-390,227	186.7	-176,659	76.1	-190,529	75.4	-395,745	187.3
18	81.8	72.9	-412,005	218.7	-481,846	184.8	-184,201	76.7	-197,892	76.1	-484,295	185.3
19	81.1	72.8	-481,288	213.8	-558,188	181.2	-196,619	76.3	-210,709	75.6	-559,976	181.7
20	80.2	72.6	-532,398	205.8	-610,446	175.0	-215,143	74.1	-229,737	73.5	-611,220	175.4
21	79.2	72.5	-512,161	198.3	-580,683	171.7	-230,436	71.6	-246,732	71.1	-581,543	172.0
22	78.2	71.9	-592,251	186.7	-669,550	167.1	-249,399	69.5	-265,650	69.0	-670,011	167.4
23	77.2	71.6	-629,375	180.1	-705,207	164.0	-266,873	68.1	-279,356	67.5	-705,592	164.3
24	76.2	71.1	-656,850	174.0	-727,407	160.7	-275,919	66.6	-289,974	66.1	-727,762	160.9

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	78.0	74.2	-209,713	72.4	-212,696	71.6	-224,602	69.8	-267,951	68.9	-279,742	68.5
2	77.1	73.6	-208,101	71.9	-226,779	69.5	-243,884	67.9	-276,816	67.0	-290,487	66.7
3	76.4	73.1	-212,701	70.0	-247,835	67.6	-258,561	66.4	-287,438	65.7	-300,917	65.3
4	75.9	72.8	-216,655	68.3	-257,101	66.3	-270,989	65.2	-297,452	64.4	-315,407	64.1
5	75.5	72.6	-224,679	66.8	-267,701	64.9	-286,961	64.1	-306,584	63.4	-323,005	63.1
6	75.4	72.9	-231,070	65.4	-288,757	63.7	-294,574	63.2	-313,466	62.5	-329,838	62.2
7	75.7	73.1	-212,046	65.0	-256,202	63.1	-269,266	62.6	-287,659	61.9	-289,809	61.7
8	76.6	73.3	-738,930	164.1	-741,222	179.0	-234,692	62.9	-250,790	62.2	-770,785	175.6
9	78.0	72.6	-535,923	170.3	-622,247	171.1	-207,828	63.8	-222,384	63.2	-639,602	168.5
10	79.8	73.0	-214,920	204.8	-303,170	190.8	-182,051	65.9	-195,733	65.3	-368,845	189.4
11	81.6	73.3	-92,883	228.3	-161,688	208.8	-171,370	68.6	-184,832	68.4	-316,037	204.1
12	83.3	74.3	-56,645	234.2	-87,523	213.0	-166,283	70.9	-180,521	70.4	-265,437	207.8
13	84.7	76.0	-92,494	218.7	-106,300	198.0	-163,210	72.5	-177,402	72.0	-250,578	196.4
14	85.6	76.9	-55,508	242.3	-66,135	220.1	-161,554	74.4	-174,951	73.9	-161,292	217.7
15	86.0	77.0	-47,282	254.9	-54,427	232.1	-164,378	77.4	-176,925	76.9	-103,431	231.8
16	85.8	77.5	-111,208	231.1	-150,643	204.2	-167,470	79.4	-178,466	78.9	-188,565	205.4
17	85.5	77.5	-329,589	226.6	-386,801	197.0	-171,921	80.5	-180,319	80.1	-399,222	198.1
18	85.0	77.6	-117,482	92.3	-144,253	80.5	-177,094	80.9	-185,062	80.5	-144,328	80.8
19	84.2	77.2	-123,581	93.5	-154,033	81.4	-186,763	80.5	-195,186	80.1	-154,120	81.6
20	83.3	77.0	-140,843	92.1	-168,342	79.5	-200,326	78.5	-209,561	79.2	-168,416	79.7
21	82.3	77.1	-141,413	90.1	-163,707	77.8	-218,405	76.1	-228,580	77.1	-163,809	77.9
22	81.2	76.3	-169,167	85.8	-186,502	75.1	-233,010	73.7	-243,595	74.2	-186,584	75.2
23	80.1	75.6	-185,611	82.5	-203,354	73.1	-247,383	71.9	-259,567	71.3	-203,469	73.2
24	79.0	75.0	-194,490	79.8	-211,434	71.4	-260,508	70.4	-271,259	70.0	-211,746	71.5

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	78.2	73.7	-207,461	76.4	-212,378	72.1	-225,324	69.6	-268,129	68.8	-279,317	68.4
2	77.6	73.5	-220,987	74.3	-225,748	70.1	-243,574	67.9	-276,373	67.1	-289,868	66.7
3	77.2	73.4	-233,904	72.1	-243,549	68.2	-256,924	66.6	-285,470	65.8	-297,826	65.4
4	77.1	73.4	-242,932	70.4	-253,625	67.0	-267,880	65.4	-293,230	64.7	-307,935	64.4
5	77.3	73.7	-253,449	68.8	-260,968	65.7	-280,915	64.5	-299,998	63.8	-314,613	63.5
6	78.1	74.9	-263,651	67.5	-277,119	64.6	-285,484	63.7	-303,393	63.1	-318,772	62.8
7	79.2	76.0	-224,940	67.0	-249,569	64.1	-262,350	63.2	-280,047	62.6	-282,303	62.4
8	80.7	76.9	-705,945	186.1	-731,292	183.6	-225,566	63.7	-241,294	63.1	-760,144	178.0
9	82.3	76.6	-571,360	185.5	-606,644	175.6	-198,950	65.0	-213,097	64.4	-626,456	171.2
10	84.0	76.6	-281,779	212.5	-289,147	197.6	-176,487	67.3	-189,942	66.8	-364,593	193.9
11	85.4	76.9	-148,822	235.3	-153,976	215.4	-168,073	70.3	-181,245	70.2	-309,268	208.6
12	86.6	77.4	-95,384	241.6	-81,370	219.9	-164,006	72.4	-177,670	72.0	-253,922	212.0
13	87.4	78.4	-115,130	226.7	-104,255	202.5	-161,317	73.8	-174,853	73.3	-238,304	200.2
14	87.6	78.5	-80,789	249.4	-64,313	223.6	-159,155	75.3	-172,363	74.9	-156,080	220.1
15	87.5	78.1	-49,484	261.1	-53,321	234.5	-160,177	77.8	-172,528	77.4	-102,228	233.2
16	87.1	77.9	-108,473	235.9	-146,870	205.0	-165,513	79.5	-176,443	79.3	-184,361	205.4
17	86.5	77.9	-325,778	230.9	-383,599	197.2	-170,741	80.5	-178,733	80.3	-395,857	197.6
18	85.6	77.0	-116,393	93.4	-143,972	80.3	-176,271	80.7	-183,890	80.5	-144,046	80.4
19	84.6	77.0	-122,150	94.7	-154,638	81.1	-187,132	80.2	-195,867	80.0	-154,724	81.1
20	83.5	77.0	-138,796	93.3	-168,761	79.2	-200,284	78.3	-209,145	79.9	-168,834	79.3
21	82.3	76.5	-138,482	91.4	-164,896	77.4	-218,563	75.7	-228,846	76.9	-164,999	77.4
22	81.2	75.6	-165,392	87.3	-187,410	74.7	-234,201	73.4	-244,981	73.9	-187,499	74.7

23	80.0	74.9	-181,288	83.9	-204,247	72.7	-247,398	71.8	-258,727	71.2	-204,352	72.8
24	79.0	74.2	-189,246	81.1	-212,163	71.3	-259,640	70.3	-271,302	69.9	-212,468	71.3

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	77.7	73.5	-207,232	75.9	-217,125	73.4	-226,842	71.1	-266,216	70.1	-279,404	69.5
2	77.5	73.8	-220,659	73.9	-227,031	71.4	-245,022	69.4	-276,160	68.4	-292,185	67.9
3	77.7	74.3	-233,453	71.8	-243,488	69.4	-255,183	68.0	-282,016	67.1	-299,918	66.6
4	78.1	74.7	-242,028	70.2	-251,179	68.0	-262,948	66.8	-288,399	66.0	-304,852	65.5
5	78.9	75.8	-252,173	68.7	-258,207	66.7	-272,693	65.9	-290,877	65.1	-307,784	64.6
6	79.9	76.5	-262,294	67.4	-266,231	65.9	-278,082	65.1	-293,940	64.4	-308,517	63.9
7	81.1	77.9	-234,569	66.6	-250,699	65.3	-262,341	64.6	-277,629	63.9	-279,892	63.6
8	82.4	78.9	-712,927	183.9	-726,385	190.2	-224,347	65.0	-238,316	64.3	-732,573	185.1
9	83.7	78.0	-552,393	185.1	-563,052	183.1	-195,792	66.0	-209,551	65.3	-595,745	174.9
10	85.0	77.7	-261,341	221.8	-236,011	213.1	-176,502	68.4	-189,905	67.7	-342,987	206.5
11	86.2	77.8	-133,430	249.0	-123,708	235.8	-167,668	71.1	-180,852	70.7	-279,805	226.4
12	87.2	77.4	-81,878	260.6	-61,222	246.4	-163,513	73.7	-175,998	73.3	-225,034	235.7
13	88.0	77.6	-108,467	249.3	-90,512	234.4	-159,663	76.0	-171,786	75.9	-209,603	230.1
14	88.4	78.3	-57,120	269.5	-58,493	252.2	-156,728	78.6	-168,504	78.5	-109,648	251.1
15	88.6	79.4	-43,861	279.7	-47,448	260.4	-155,103	80.9	-166,276	80.7	-89,421	260.4
16	88.4	78.9	-76,245	251.0	-87,712	225.7	-159,063	82.8	-169,040	82.5	-114,033	226.9
17	87.7	78.8	-106,173	94.1	-126,451	84.3	-163,817	84.1	-173,648	83.6	-126,501	84.7
18	86.7	78.2	-113,788	96.5	-135,270	85.4	-171,516	84.3	-178,370	86.1	-135,342	85.7
19	85.4	77.6	-125,830	96.2	-152,777	84.5	-184,888	83.4	-191,627	85.9	-152,856	84.7
20	83.8	77.3	-143,190	96.3	-168,722	82.4	-201,729	83.1	-209,063	83.5	-168,792	82.6
21	82.3	76.4	-138,719	95.6	-164,144	79.8	-221,008	79.8	-228,898	79.5	-164,233	79.9
22	80.7	75.5	-168,023	90.6	-191,487	77.0	-235,933	76.7	-246,397	88.6	-191,592	77.2
23	79.4	74.2	-182,589	86.9	-203,922	74.9	-248,513	74.3	-261,438	73.0	-203,998	75.0
24	78.4	73.6	-189,221	83.5	-212,215	73.0	-259,179	71.8	-270,151	71.1	-212,472	73.2

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	76.4	72.5	-215,188	74.7	-226,067	70.6	-245,780	68.2	-281,735	67.0	-300,508	66.5
2	76.2	72.7	-230,536	72.8	-241,744	68.7	-261,463	67.0	-291,597	65.8	-309,778	65.4
3	76.4	73.1	-242,375	71.1	-259,680	67.1	-269,460	65.9	-298,162	64.8	-315,118	64.4
4	76.9	73.9	-249,524	69.5	-266,927	66.0	-280,566	65.0	-303,361	63.9	-319,845	63.5
5	77.8	74.9	-260,066	68.1	-272,159	65.1	-289,125	64.2	-306,747	63.2	-322,215	62.8
6	78.9	76.2	-271,081	67.0	-285,752	64.3	-290,128	63.6	-306,400	62.6	-321,647	62.3
7	80.2	77.4	-258,151	66.2	-271,940	63.8	-283,648	63.2	-301,945	62.2	-302,938	62.0
8	81.6	79.0	-728,047	186.9	-742,883	183.5	-243,366	63.2	-261,589	62.2	-791,625	172.3
9	83.0	78.4	-565,839	183.6	-590,649	176.5	-207,860	63.9	-224,278	63.0	-638,139	168.6
10	84.3	77.6	-253,019	220.3	-267,624	206.0	-183,808	65.7	-198,656	64.9	-361,853	192.0
11	85.4	77.2	-135,521	244.7	-149,912	226.4	-174,350	68.3	-188,955	67.5	-282,636	215.2
12	86.3	77.2	-83,702	256.7	-67,420	239.1	-169,171	70.7	-183,802	70.0	-230,389	228.1
13	86.8	76.8	-103,585	248.4	-93,807	228.7	-166,207	73.6	-180,356	73.3	-229,706	223.6
14	87.0	77.0	-55,544	269.5	-62,239	248.3	-163,694	75.9	-177,755	75.8	-136,706	244.6
15	86.8	77.0	-44,769	279.1	-51,447	255.1	-162,781	77.5	-175,931	77.2	-93,956	254.5
16	86.3	76.5	-79,536	247.7	-96,276	218.2	-170,303	78.9	-182,517	78.5	-122,466	219.4
17	85.4	76.7	-113,247	92.5	-136,908	81.3	-183,667	80.1	-194,535	79.5	-136,959	81.6
18	84.3	76.2	-121,606	94.2	-148,712	81.9	-196,331	80.2	-205,830	79.6	-148,789	82.2
19	83.0	75.6	-137,468	93.4	-165,501	80.4	-208,725	78.8	-220,389	78.2	-165,569	80.6
20	81.6	75.0	-155,910	91.0	-182,411	77.7	-226,050	76.2	-239,713	75.5	-182,485	77.9
21	80.2	74.7	-149,635	88.5	-177,624	75.5	-242,230	73.4	-256,407	72.8	-177,737	75.7
22	78.9	73.6	-177,108	85.8	-203,236	73.3	-255,224	71.7	-271,149	71.2	-203,347	73.5
23	77.8	72.6	-192,239	83.1	-214,307	71.3	-264,784	69.8	-281,857	69.3	-214,440	71.4
24	76.9	72.3	-199,754	80.4	-224,891	69.7	-273,912	68.3	-291,644	67.8	-225,151	69.8

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.6	68.4	-247,923	69.6	-257,647	66.0	-280,709	64.7	-318,547	62.8	-341,253	62.2
2	71.9	68.2	-264,163	68.1	-282,915	64.5	-291,449	63.7	-333,167	61.9	-349,483	61.3
3	71.3	67.9	-274,381	66.7	-293,917	63.2	-309,317	62.8	-342,745	61.0	-356,695	60.4
4	71.0	67.9	-291,027	65.4	-311,017	62.3	-321,557	61.9	-349,933	60.2	-362,671	59.7

5	70.9	67.8	-302,947	64.2	-324,114	61.5	-327,470	61.1	-356,445	59.5	-368,241	58.9
6	71.3	68.5	-309,054	63.2	-328,942	60.9	-332,091	60.5	-362,533	58.9	-374,183	58.4
7	72.6	69.6	-304,937	62.4	-322,114	60.4	-332,761	59.9	-363,108	58.4	-363,118	58.0
8	74.4	71.6	-791,072	167.7	-803,441	164.6	-298,210	59.5	-324,208	58.1	-966,037	144.6
9	76.6	72.7	-640,716	162.5	-692,621	156.8	-257,010	59.6	-282,146	58.2	-792,607	149.6
10	78.8	73.3	-315,833	196.4	-370,513	182.5	-230,692	60.3	-253,759	59.0	-523,197	176.9
11	80.7	73.6	-183,434	227.3	-202,006	208.3	-213,265	62.5	-234,621	61.3	-416,572	197.4
12	81.9	73.7	-95,758	245.8	-96,617	223.7	-199,743	65.3	-221,210	64.1	-301,891	211.8
13	82.3	73.6	-117,481	239.5	-105,924	217.2	-189,046	68.6	-209,195	67.4	-256,825	212.2
14	82.2	73.2	-64,020	261.0	-70,663	236.9	-183,009	70.4	-201,829	69.3	-169,431	232.2
15	81.9	72.7	-49,984	270.1	-59,651	242.6	-183,698	71.4	-201,169	70.4	-119,335	241.5
16	81.4	73.0	-87,345	236.7	-114,588	202.8	-196,818	72.6	-213,554	71.7	-141,017	204.1
17	80.7	72.9	-125,800	88.0	-152,924	76.0	-212,990	73.6	-227,507	72.7	-152,988	76.4
18	79.8	72.3	-138,707	89.1	-167,872	76.0	-226,212	73.2	-240,634	72.3	-167,970	76.3
19	78.8	71.9	-157,799	87.3	-185,313	74.1	-241,044	71.7	-256,384	70.8	-185,404	74.4
20	77.7	71.8	-177,171	85.0	-202,614	71.1	-257,403	68.8	-274,753	67.9	-202,704	71.3
21	76.6	71.3	-174,466	81.1	-198,965	69.9	-272,476	67.2	-293,057	66.3	-199,063	70.1
22	75.5	70.7	-200,901	77.8	-224,085	68.3	-283,681	65.9	-305,822	65.2	-224,216	68.4
23	74.4	69.9	-213,913	75.2	-236,023	66.9	-295,039	64.8	-318,461	64.1	-236,214	67.1
24	73.4	69.2	-222,552	72.6	-254,557	65.8	-305,440	63.8	-329,589	63.1	-255,079	65.9

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.3	68.2	-271,263	67.0	-278,187	64.2	-289,667	63.2	-337,006	60.9	-351,216	60.1
2	71.4	67.7	-282,064	65.8	-294,504	62.8	-300,729	62.3	-345,986	60.2	-361,205	59.4
3	70.7	67.3	-300,018	64.5	-305,791	61.9	-320,868	61.5	-355,094	59.5	-368,991	58.8
4	70.1	67.1	-312,907	63.4	-325,898	61.1	-330,303	60.8	-362,823	58.8	-377,609	58.1
5	69.7	66.7	-319,689	62.4	-334,504	60.4	-337,030	60.0	-370,425	58.1	-384,286	57.5
6	69.4	66.4	-325,143	61.5	-340,620	59.7	-342,887	59.3	-375,409	57.5	-392,844	56.9
7	69.3	66.6	-319,749	60.7	-336,469	59.1	-348,361	58.7	-381,792	56.9	-386,399	56.4
8	69.8	66.9	-908,476	152.4	-900,206	150.8	-328,453	58.2	-361,279	56.5	-996,623	141.3
9	71.3	67.6	-737,250	157.4	-748,855	152.3	-293,649	57.9	-325,334	56.3	-869,834	145.7
10	73.5	67.9	-382,579	188.5	-428,667	176.9	-265,398	58.2	-295,202	56.7	-583,123	167.4
11	75.9	68.6	-218,690	220.2	-241,978	201.5	-244,267	59.9	-272,261	58.4	-474,136	190.4
12	78.1	69.8	-122,798	240.1	-136,675	217.1	-227,234	62.6	-253,890	61.2	-402,009	203.0
13	79.6	70.6	-123,146	234.6	-127,506	210.0	-211,855	65.4	-236,241	64.0	-350,427	201.5
14	80.1	70.4	-87,228	256.1	-78,018	228.1	-203,257	67.0	-226,035	65.7	-231,818	221.8
15	80.0	70.6	-55,983	263.7	-66,476	234.2	-201,699	67.9	-222,291	66.7	-151,278	232.3
16	79.7	70.3	-93,381	228.6	-129,610	194.2	-214,130	68.9	-234,167	67.7	-162,788	195.3
17	79.3	70.7	-132,866	84.4	-161,857	72.8	-229,778	69.7	-247,378	68.6	-162,319	73.2
18	78.7	70.9	-150,211	85.0	-178,009	72.6	-242,300	69.3	-260,497	68.3	-178,184	72.8
19	77.9	71.5	-171,854	82.8	-198,185	70.5	-259,811	67.4	-279,108	66.4	-198,296	70.7
20	77.1	71.0	-189,352	80.2	-213,700	68.0	-273,217	65.2	-294,753	64.2	-213,837	68.1
21	76.2	70.7	-186,270	76.7	-208,296	67.3	-286,691	64.2	-310,750	63.3	-208,444	67.4
22	75.2	69.9	-214,112	73.5	-233,545	66.1	-298,087	63.3	-323,269	62.5	-233,698	66.2
23	74.2	69.3	-226,640	71.4	-244,734	65.0	-311,037	62.5	-332,273	61.6	-245,119	65.2
24	73.2	68.6	-235,746	69.4	-268,571	64.1	-325,292	61.7	-342,879	60.9	-268,972	64.2

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	69.2	65.1	-290,439	64.9	-304,449	62.1	-310,401	61.1	-363,751	58.5	-381,477	57.7
2	68.5	64.5	-302,442	63.8	-314,755	60.9	-329,941	60.3	-372,503	57.8	-391,397	57.0
3	67.8	64.1	-323,669	62.7	-334,262	60.0	-344,073	59.6	-381,455	57.2	-404,341	56.4
4	67.3	63.7	-332,572	61.6	-347,838	59.3	-350,895	58.9	-392,039	56.6	-412,696	55.9
5	66.9	63.5	-339,433	60.6	-354,593	58.6	-357,786	58.2	-399,383	56.0	-429,103	55.3
6	66.7	63.3	-344,105	59.7	-360,468	57.9	-365,131	57.5	-404,096	55.4	-436,826	54.8
7	66.6	63.1	-340,592	59.0	-357,556	57.4	-368,763	57.0	-407,797	54.9	-432,340	54.5
8	67.3	63.9	-984,117	148.1	-984,336	145.2	-359,600	56.5	-400,578	54.5	-1,019,125	137.5
9	69.2	65.6	-812,651	152.6	-842,878	149.4	-328,061	56.2	-377,070	54.3	-906,597	142.0
10	71.9	66.9	-510,943	180.6	-523,581	171.8	-293,069	56.2	-340,722	54.4	-641,722	161.4
11	74.6	68.3	-274,698	209.9	-283,463	194.0	-266,336	57.3	-310,950	55.6	-519,513	179.1
12	76.5	68.8	-153,102	232.0	-182,958	209.9	-248,315	59.6	-286,812	57.9	-433,487	194.7
13	77.2	68.6	-133,149	227.5	-150,872	202.1	-234,370	61.9	-266,304	60.3	-415,610	193.8

14	77.2	68.7	-93,471	249.7	-91,273	220.7	-223,633	63.8	-251,940	62.4	-286,979	212.4
15	76.9	68.5	-64,717	257.7	-74,307	225.9	-219,759	64.6	-245,718	63.3	-215,446	223.7
16	76.5	68.2	-99,732	220.8	-151,878	187.3	-232,398	65.5	-256,268	64.3	-231,892	188.0
17	76.0	68.1	-136,542	81.6	-172,676	70.3	-246,447	66.3	-267,770	65.1	-173,905	70.5
18	75.3	68.1	-157,330	82.2	-189,444	69.8	-260,511	65.9	-282,520	64.8	-189,676	69.9
19	74.6	68.4	-180,379	80.1	-213,161	67.4	-280,343	63.8	-304,647	62.7	-213,366	67.5
20	73.7	68.2	-199,075	77.2	-232,971	65.4	-300,881	62.1	-325,814	61.1	-233,179	65.5
21	72.8	67.9	-197,683	73.6	-226,871	64.9	-318,988	61.4	-342,120	60.4	-227,055	65.0
22	71.9	67.1	-227,931	71.1	-252,939	63.8	-333,349	60.6	-354,359	59.7	-253,163	63.9
23	71.0	66.5	-239,598	69.0	-264,810	62.9	-344,772	59.9	-364,531	59.0	-265,467	62.9
24	70.1	65.8	-254,613	67.2	-296,555	62.0	-355,278	59.2	-373,599	58.3	-296,957	62.1

Appendix C - Kansas City Load Profile Data

BUILDING COOL HEAT DEMAND

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	34.7	30.1	-1,176,605	100.1	-1,202,756	110.5	-453,020	41.8	-798,265	37.2	-1,397,962	99.2
2	32.6	28.2	-1,205,281	95.5	-1,217,508	109.1	-456,358	40.6	-816,657	36.6	-1,411,041	99.3
3	30.8	26.6	-1,217,859	92.7	-1,231,412	107.9	-465,736	39.4	-835,058	36.0	-1,417,758	99.2
4	29.2	25.4	-1,228,841	98.7	-1,244,369	106.4	-508,209	38.1	-853,007	35.3	-1,398,707	98.7
5	28.1	24.4	-1,236,220	99.6	-1,255,421	104.9	-590,383	36.9	-868,952	34.5	-1,383,293	98.0
6	27.3	23.9	-1,240,296	99.2	-1,265,400	103.5	-662,695	35.8	-883,635	33.8	-1,369,926	97.2
7	27.1	23.8	-1,229,229	98.6	-1,260,869	102.1	-712,963	34.8	-895,438	33.1	-1,354,783	96.4
8	27.6	24.4	-1,205,919	97.8	-1,251,204	101.1	-783,618	34.0	-904,622	32.5	-1,344,000	95.9
9	29.0	25.8	-768,984	101.2	-843,688	103.1	-792,245	33.3	-883,645	32.0	-1,082,050	98.5
10	31.1	27.7	-573,039	111.2	-670,506	111.2	-762,324	32.9	-845,629	31.7	-964,442	107.0
11	33.9	29.5	-450,213	123.0	-564,954	117.7	-722,192	32.9	-794,360	31.8	-805,608	113.0
12	36.9	31.4	-355,539	129.8	-467,163	117.4	-665,953	33.2	-728,013	32.2	-615,860	114.9
13	39.9	33.4	-431,569	132.9	-561,408	115.2	-619,052	33.9	-678,955	33.1	-632,921	114.5
14	42.6	35.1	-285,093	147.1	-426,176	125.5	-602,191	35.6	-651,717	34.9	-468,926	125.0
15	44.8	36.3	-261,747	156.9	-413,581	135.7	-596,216	37.6	-636,578	37.0	-467,465	135.6
16	46.2	37.3	-365,209	141.1	-577,256	124.1	-595,859	39.1	-634,768	38.6	-625,012	124.2
17	46.7	37.5	-678,116	140.0	-868,522	120.9	-600,345	39.6	-641,686	39.1	-881,854	121.0
18	46.4	38.1	-823,726	138.1	-988,350	117.7	-616,890	38.8	-663,909	38.3	-997,024	117.7
19	45.7	38.3	-950,955	132.6	-1,088,363	117.4	-657,110	38.8	-703,855	38.4	-1,092,627	117.3
20	44.5	37.7	-1,051,260	129.3	-1,136,439	116.9	-692,637	38.8	-729,587	38.5	-1,137,560	116.8
21	43.0	36.7	-1,020,755	127.4	-1,081,609	117.0	-712,130	38.7	-742,913	38.4	-1,083,712	116.9
22	41.1	35.4	-1,109,128	124.3	-1,145,149	115.8	-738,396	38.5	-757,574	38.3	-1,145,649	115.7
23	39.1	33.8	-1,144,592	121.5	-1,167,575	114.7	-760,694	38.1	-771,846	37.9	-1,168,017	114.6
24	36.9	32.0	-1,166,553	118.8	-1,182,840	113.5	-778,705	37.7	-787,753	37.5	-1,183,264	113.4
February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	31.5	28.1	-1,183,580	120.9	-1,222,111	111.5	-464,618	41.6	-819,377	37.0	-1,409,404	98.9
2	29.8	26.6	-1,199,174	117.9	-1,236,408	109.8	-468,301	40.3	-839,582	36.2	-1,422,346	98.7
3	28.4	25.5	-1,212,471	115.2	-1,248,773	108.0	-477,906	38.8	-857,916	35.4	-1,428,818	98.2
4	27.6	24.8	-1,223,902	112.7	-1,259,392	106.3	-523,534	37.5	-873,587	34.6	-1,410,883	97.5
5	27.3	24.6	-1,233,052	110.4	-1,267,904	104.7	-608,936	36.2	-886,539	33.8	-1,393,458	96.7
6	27.6	25.0	-1,237,814	108.5	-1,274,505	103.2	-668,423	35.1	-896,872	33.1	-1,379,997	95.9
7	28.4	25.9	-1,227,395	106.9	-1,264,839	102.0	-722,059	34.2	-904,309	32.5	-1,358,285	95.3
8	29.8	27.4	-1,177,950	105.7	-1,236,689	101.0	-785,114	33.5	-892,342	32.0	-1,331,634	94.9
9	31.5	29.2	-712,342	108.5	-809,246	103.4	-762,619	33.1	-849,189	31.8	-1,052,509	97.9
10	33.5	31.1	-530,381	120.3	-636,396	112.5	-723,919	32.9	-800,608	31.8	-931,338	107.4
11	35.7	32.4	-434,187	134.1	-530,278	120.0	-684,034	33.2	-749,044	32.2	-769,573	114.3
12	37.9	33.5	-343,647	138.8	-444,913	120.0	-639,881	33.9	-699,209	32.9	-596,727	116.8
13	39.9	34.5	-423,414	141.1	-545,568	117.8	-602,024	34.9	-660,146	34.0	-617,778	116.3
14	41.7	35.4	-304,571	156.4	-415,067	128.0	-584,274	36.6	-636,665	35.8	-460,507	126.8
15	43.0	36.1	-252,929	166.3	-407,152	138.2	-586,469	38.7	-626,209	38.0	-463,500	137.5
16	43.8	36.7	-360,604	150.6	-570,484	127.4	-585,447	40.6	-624,003	40.0	-617,985	126.9
17	44.1	36.6	-655,463	149.6	-855,202	125.3	-585,243	41.6	-626,065	41.1	-871,488	124.9
18	43.8	36.4	-783,590	149.1	-962,099	122.6	-589,990	41.2	-637,097	40.7	-974,578	122.2
19	43.0	36.5	-897,415	145.0	-1,054,844	120.1	-616,441	40.2	-663,938	39.8	-1,062,548	119.7
20	41.7	36.2	-999,985	137.8	-1,122,622	119.2	-665,458	39.9	-706,379	39.6	-1,124,140	118.8
21	39.9	34.7	-987,801	135.0	-1,082,397	118.8	-706,889	39.6	-738,874	39.3	-1,084,655	118.4
22	37.9	33.1	-1,087,042	131.0	-1,154,935	117.0	-741,199	39.0	-762,582	38.8	-1,155,382	116.6
23	35.7	31.4	-1,129,149	127.3	-1,181,837	115.4	-773,190	38.4	-785,347	38.2	-1,182,262	115.1
24	33.5	29.5	-1,156,000	123.9	-1,200,203	113.8	-796,598	37.7	-805,719	37.5	-1,200,609	113.4
March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	38.9	33.8	-1,123,685	130.8	-1,149,113	119.4	-424,237	45.9	-718,500	41.4	-1,369,048	107.2
2	36.7	31.9	-1,143,759	127.0	-1,167,401	117.6	-427,822	44.8	-742,523	40.6	-1,384,657	106.9
3	34.8	30.2	-1,160,831	123.5	-1,184,893	115.9	-438,070	43.4	-766,137	39.7	-1,390,617	106.4
4	33.1	28.9	-1,175,655	120.4	-1,201,462	114.0	-470,164	42.0	-787,966	38.8	-1,369,742	105.6

5	31.9	27.7	-1,187,737	117.6	-1,216,326	112.1	-533,091	40.6	-807,871	37.9	-1,352,858	104.5
6	31.1	27.2	-1,196,302	115.2	-1,229,382	110.4	-584,294	39.4	-825,442	37.0	-1,337,103	103.5
7	30.9	27.1	-1,187,438	113.2	-1,225,777	108.8	-598,198	38.2	-839,769	36.2	-1,327,568	102.5
8	31.4	27.8	-1,077,808	111.8	-1,161,871	107.5	-581,351	37.1	-805,460	35.5	-1,282,706	101.8
9	32.9	29.2	-597,211	116.9	-719,573	110.0	-623,387	36.4	-753,177	35.0	-992,037	105.1
10	35.1	30.5	-440,515	132.6	-562,520	119.4	-642,278	36.0	-710,845	34.8	-855,879	114.8
11	38.0	32.4	-355,708	147.3	-459,012	127.2	-606,110	36.2	-666,144	35.1	-667,897	122.2
12	41.2	34.9	-274,905	150.3	-380,083	127.1	-569,281	36.9	-625,291	35.9	-507,583	124.3
13	44.4	37.2	-329,133	150.6	-473,671	125.6	-524,674	38.4	-576,204	37.5	-552,440	124.5
14	47.3	39.0	-210,355	167.7	-330,298	138.0	-498,929	41.2	-546,869	40.4	-396,101	137.4
15	49.6	40.4	-179,002	179.5	-313,411	148.7	-483,321	43.7	-528,694	43.0	-380,691	148.4
16	51.1	41.5	-267,745	163.9	-471,643	136.2	-480,201	45.6	-522,003	44.9	-527,776	136.1
17	51.6	42.1	-535,419	163.3	-766,770	134.4	-481,331	46.7	-517,962	46.1	-796,772	134.3
18	51.3	42.3	-638,018	164.0	-867,250	133.0	-481,523	46.9	-521,824	46.3	-888,139	133.0
19	50.5	42.4	-736,201	160.2	-952,723	129.7	-502,655	45.7	-546,292	45.2	-959,967	129.6
20	49.3	42.0	-835,105	154.0	-1,024,033	128.2	-547,247	44.9	-587,746	44.5	-1,028,491	128.1
21	47.7	41.2	-851,506	147.6	-988,492	127.6	-587,015	44.4	-627,767	44.0	-993,420	127.6
22	45.7	39.6	-977,056	142.7	-1,074,430	125.7	-618,102	43.7	-659,631	43.4	-1,075,206	125.6
23	43.5	38.0	-1,032,775	138.2	-1,104,301	123.9	-650,712	43.0	-681,497	42.7	-1,104,600	123.9
24	41.2	35.9	-1,070,988	133.9	-1,124,132	122.3	-686,324	42.3	-704,949	42.1	-1,124,420	122.2

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	51.2	45.0	-948,854	149.0	-1,001,713	133.4	-355,900	53.4	-499,192	49.8	-1,302,605	123.0
2	49.4	43.7	-971,913	144.8	-1,026,112	131.3	-359,254	52.5	-522,065	48.6	-1,319,396	121.9
3	48.1	42.7	-993,055	141.0	-1,048,104	129.3	-369,680	51.1	-557,634	47.5	-1,316,936	121.2
4	47.3	42.1	-1,011,023	137.6	-1,066,827	127.2	-379,107	49.7	-599,669	46.4	-1,281,354	120.3
5	47.0	42.1	-1,021,359	134.7	-1,082,160	125.3	-418,472	48.4	-625,156	45.5	-1,248,291	119.3
6	47.4	42.6	-1,031,299	132.1	-1,093,338	123.7	-467,372	47.2	-640,308	44.6	-1,239,712	118.3
7	48.5	43.9	-956,091	130.3	-1,044,128	122.3	-456,963	46.2	-611,018	43.8	-1,187,530	117.6
8	50.3	45.8	-819,566	131.2	-946,453	122.1	-412,650	45.8	-561,441	43.7	-1,109,208	118.2
9	52.6	47.2	-349,040	140.7	-481,129	126.9	-372,362	45.6	-506,478	43.7	-794,933	123.7
10	55.3	49.1	-220,812	163.1	-312,883	140.6	-330,899	45.8	-449,202	44.1	-619,346	137.0
11	58.0	50.3	-155,937	175.9	-241,364	151.7	-312,441	46.6	-421,744	45.0	-427,628	147.6
12	60.7	52.3	-84,246	177.5	-170,418	152.0	-303,803	47.9	-395,114	46.5	-304,251	150.7
13	63.0	53.4	-142,323	172.6	-260,144	148.2	-289,484	50.4	-365,543	49.1	-342,702	148.7
14	64.8	54.6	-73,171	193.7	-151,849	164.0	-271,847	53.4	-334,593	52.2	-225,375	164.7
15	65.9	55.3	-78,130	209.1	-147,360	174.2	-270,791	55.7	-319,454	54.7	-179,982	175.2
16	66.3	55.4	-152,904	192.0	-271,187	157.0	-278,078	57.2	-316,099	56.3	-276,022	157.9
17	66.1	55.1	-389,468	188.1	-561,422	154.7	-286,383	58.3	-318,245	57.4	-563,082	155.5
18	65.2	54.6	-485,342	188.1	-669,335	153.8	-292,283	58.7	-323,034	57.9	-670,210	154.5
19	63.9	54.0	-566,487	184.3	-754,320	150.0	-304,135	57.6	-336,104	56.8	-754,340	150.6
20	62.2	52.9	-636,178	177.3	-819,814	145.9	-328,019	55.6	-361,970	54.9	-819,834	146.5
21	60.1	52.5	-628,670	169.3	-792,372	144.4	-362,325	54.3	-401,408	53.6	-792,391	144.9
22	57.8	50.9	-762,579	162.5	-896,002	141.8	-398,949	53.2	-445,225	52.6	-896,020	142.2
23	55.5	49.1	-821,575	156.3	-939,701	139.5	-437,464	52.1	-481,631	51.5	-939,719	139.9
24	53.2	47.1	-871,090	151.2	-968,486	137.1	-475,058	51.0	-517,731	50.5	-968,503	137.5

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	65.7	58.2	-744,350	164.2	-822,349	149.4	-281,917	60.3	-344,925	59.0	-1,191,279	141.3
2	64.2	57.3	-774,911	159.5	-846,825	145.7	-283,261	59.9	-358,964	57.8	-1,167,231	139.3
3	62.9	56.7	-802,969	155.5	-877,426	143.1	-292,995	58.7	-371,525	56.6	-1,149,914	138.3
4	62.0	56.4	-826,547	151.9	-901,174	140.8	-301,990	57.5	-382,411	55.5	-1,097,666	137.2
5	61.4	56.3	-846,325	148.8	-918,731	138.9	-314,391	56.2	-391,636	54.4	-1,063,972	135.9
6	61.2	56.4	-843,280	146.2	-922,777	137.1	-341,022	55.1	-402,111	53.3	-1,054,260	134.7
7	61.7	57.2	-748,203	145.7	-865,179	136.1	-327,965	54.4	-374,921	52.7	-990,457	134.2
8	63.3	58.2	-617,509	147.5	-770,585	136.5	-306,479	54.3	-334,980	52.7	-902,921	135.1
9	65.7	59.3	-210,330	164.2	-319,413	143.1	-275,546	54.4	-298,073	52.9	-516,372	142.2
10	68.6	61.0	-127,589	190.7	-191,734	161.4	-242,200	55.0	-265,149	53.5	-337,043	159.1
11	71.8	62.9	-86,957	205.0	-138,488	173.8	-228,522	56.3	-251,170	54.9	-208,217	171.4
12	74.7	64.1	-51,671	207.3	-76,029	173.7	-218,995	57.9	-241,097	56.6	-121,445	173.7
13	77.1	65.2	-99,856	199.1	-143,318	166.6	-209,540	60.3	-230,332	59.0	-158,345	167.6

14	78.7	65.9	-57,623	222.1	-73,795	185.2	-202,794	63.0	-222,132	61.8	-85,994	186.5
15	79.2	65.3	-63,561	236.6	-79,502	197.8	-199,064	65.4	-218,150	64.3	-83,727	199.1
16	79.0	65.2	-116,477	217.2	-167,906	178.5	-203,804	67.5	-222,918	66.4	-171,502	179.5
17	78.4	64.6	-328,283	211.5	-413,622	172.8	-209,229	68.9	-227,820	67.9	-414,649	173.7
18	77.5	64.2	-415,726	211.3	-517,716	171.8	-215,396	69.6	-234,904	68.6	-517,738	172.6
19	76.2	63.6	-481,213	207.6	-597,987	169.5	-225,922	69.4	-246,499	68.4	-598,006	170.3
20	74.7	63.0	-531,054	199.3	-659,157	164.8	-242,253	67.8	-265,808	66.9	-659,176	165.4
21	73.0	62.6	-514,549	193.8	-625,615	161.0	-263,647	65.2	-287,465	64.2	-625,634	161.5
22	71.1	61.5	-606,212	180.6	-726,812	157.3	-289,040	63.5	-312,558	62.6	-726,830	157.8
23	69.2	60.4	-657,283	173.7	-773,829	153.8	-308,669	61.7	-332,325	60.9	-773,846	154.3
24	67.4	59.2	-698,649	168.1	-803,407	151.1	-329,682	60.3	-353,684	59.5	-803,424	151.6

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.2	63.9	-234,692	70.0	-240,634	67.5	-263,012	64.9	-311,019	63.6	-332,538	63.1
2	68.5	63.0	-234,427	69.0	-263,510	64.9	-291,360	63.5	-328,217	62.2	-348,700	61.8
3	67.2	62.0	-242,341	67.0	-288,170	63.2	-308,841	62.1	-343,646	60.9	-364,020	60.5
4	66.2	61.5	-249,974	65.1	-309,881	61.4	-335,488	60.9	-357,837	59.7	-377,832	59.3
5	65.6	61.1	-260,399	63.4	-336,291	60.0	-347,542	59.7	-369,813	58.6	-388,993	58.2
6	65.3	61.3	-256,778	62.0	-340,102	58.8	-346,100	58.6	-372,439	57.6	-387,015	57.2
7	65.8	61.7	-231,197	62.0	-300,459	58.4	-314,401	58.1	-339,188	57.1	-338,086	56.8
8	67.0	62.1	-924,602	152.1	-924,679	162.0	-279,521	58.1	-299,731	57.1	-1,015,696	145.0
9	68.9	63.1	-546,961	166.3	-711,072	158.2	-248,282	58.6	-268,349	57.6	-792,375	147.4
10	71.2	64.5	-151,353	200.5	-278,241	174.3	-221,329	59.8	-240,171	58.9	-453,398	170.5
11	73.9	65.9	-59,671	220.8	-125,015	189.1	-209,126	61.3	-228,658	60.4	-378,305	184.2
12	76.5	67.4	-46,306	226.3	-69,995	194.3	-199,445	62.8	-218,519	62.0	-291,134	189.9
13	78.9	69.3	-88,693	213.1	-110,995	181.7	-191,632	64.9	-209,377	64.1	-256,457	181.7
14	80.7	70.2	-48,887	238.6	-63,833	205.5	-186,926	67.5	-203,597	66.8	-151,858	205.8
15	82.0	70.6	-39,833	251.4	-50,719	218.0	-183,230	70.3	-198,911	69.6	-80,306	220.1
16	82.4	70.7	-102,315	225.8	-151,416	190.9	-187,902	72.7	-200,790	71.9	-160,201	193.1
17	82.2	69.8	-327,308	220.6	-397,700	184.6	-192,777	74.3	-203,346	73.6	-402,987	186.5
18	81.5	69.4	-123,857	89.4	-155,782	75.4	-198,458	75.1	-208,560	74.4	-155,796	76.0
19	80.5	69.2	-125,686	91.1	-163,325	76.5	-207,418	75.0	-218,378	74.3	-163,350	77.0
20	79.2	68.7	-143,068	89.7	-175,980	75.4	-222,241	74.0	-236,343	73.3	-175,999	75.9
21	77.6	68.4	-136,925	87.8	-168,920	73.3	-241,489	71.0	-257,364	70.4	-168,939	73.7
22	75.8	67.7	-172,278	83.8	-199,972	70.5	-260,280	68.7	-278,120	68.2	-199,991	70.9
23	73.9	66.7	-196,311	79.9	-224,820	68.7	-280,090	67.2	-299,386	66.6	-224,839	69.1
24	72.0	65.0	-209,803	76.9	-236,259	66.7	-292,715	65.3	-313,511	64.8	-236,285	67.1

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	78.6	70.1	-206,460	76.6	-205,658	73.2	-216,430	70.7	-257,571	69.9	-268,514	69.3
2	76.9	69.0	-224,130	74.7	-220,739	71.1	-232,832	68.7	-267,471	68.2	-280,869	67.7
3	75.6	68.0	-233,783	72.5	-235,415	69.3	-253,012	67.2	-281,470	66.6	-299,087	66.2
4	74.6	67.0	-243,890	70.4	-255,454	67.4	-266,133	65.8	-293,424	65.3	-310,674	64.9
5	73.9	66.9	-259,323	68.8	-263,985	65.6	-280,128	64.5	-303,856	64.0	-320,407	63.7
6	73.7	67.0	-263,141	67.4	-276,942	64.4	-295,764	63.4	-311,659	63.0	-326,905	62.7
7	74.1	67.5	-215,416	67.4	-254,815	63.9	-270,773	62.9	-286,214	62.4	-286,941	62.2
8	75.4	68.2	-843,118	186.5	-874,750	184.4	-239,808	63.0	-253,935	62.5	-884,057	181.3
9	77.3	69.1	-581,995	189.8	-626,734	175.6	-217,006	63.4	-230,318	63.0	-694,064	168.8
10	79.7	70.5	-192,106	220.7	-195,813	196.0	-198,086	65.1	-211,832	64.8	-366,684	192.0
11	82.3	71.8	-98,796	241.4	-96,948	210.4	-187,587	67.0	-201,001	66.6	-289,589	204.0
12	85.0	73.4	-50,394	247.2	-58,650	214.0	-179,984	68.9	-193,114	69.1	-249,939	208.6
13	87.4	74.8	-85,613	233.3	-100,111	201.8	-174,263	71.7	-186,716	72.0	-213,360	201.2
14	89.3	75.7	-49,299	255.9	-56,266	224.7	-168,534	74.8	-180,571	74.9	-107,351	224.7
15	90.5	76.4	-37,497	266.9	-44,920	235.3	-163,502	77.2	-175,409	77.3	-68,949	236.4
16	90.9	76.1	-90,008	240.3	-122,104	204.8	-161,224	79.2	-171,877	79.3	-131,205	205.8
17	90.7	75.8	-303,623	234.3	-359,402	197.7	-165,336	80.9	-173,198	80.9	-364,144	198.6
18	90.1	75.3	-116,853	93.6	-140,086	80.7	-169,261	82.0	-175,678	83.2	-140,097	81.0
19	89.0	74.6	-117,380	95.4	-144,544	81.9	-175,657	81.6	-181,900	84.1	-144,557	82.1
20	87.7	74.9	-126,991	94.0	-156,562	81.0	-187,077	80.6	-193,669	83.1	-156,574	81.2
21	86.0	74.7	-118,565	92.2	-145,579	79.8	-205,262	78.7	-212,094	80.8	-145,593	80.0
22	84.2	73.7	-151,987	89.1	-174,631	76.5	-218,878	75.6	-227,321	77.0	-174,643	76.7

23	82.3	72.5	-172,828	85.1	-194,190	74.2	-233,729	74.3	-246,223	85.8	-194,203	74.4
24	80.4	70.9	-183,390	83.1	-202,324	72.4	-246,781	72.3	-258,863	71.0	-202,336	72.6

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.1	64.5	-226,443	72.4	-236,758	68.4	-259,334	66.2	-299,694	64.8	-319,474	64.3
2	70.3	63.1	-244,159	69.6	-258,602	66.3	-282,504	64.8	-316,168	63.5	-335,965	63.0
3	68.8	62.3	-265,735	67.6	-286,205	64.5	-297,730	63.5	-330,958	62.3	-350,871	61.8
4	67.7	61.2	-278,006	65.8	-300,321	63.2	-320,587	62.4	-345,779	61.1	-364,655	60.7
5	67.1	60.6	-296,050	64.2	-323,256	61.7	-336,958	61.2	-356,894	60.0	-375,526	59.6
6	66.8	60.8	-309,126	62.9	-342,422	60.5	-346,745	60.1	-373,487	59.0	-384,206	58.6
7	67.3	61.4	-265,693	62.3	-314,027	59.7	-328,156	59.3	-355,172	58.1	-351,705	57.8
8	68.6	62.3	-879,767	171.4	-928,682	171.6	-290,453	59.1	-313,445	58.0	-1,031,682	151.2
9	70.6	63.0	-595,656	174.1	-664,217	164.4	-255,416	59.1	-274,793	58.1	-774,639	150.8
10	73.2	64.1	-198,131	213.4	-224,792	192.2	-225,932	60.2	-243,487	59.2	-436,291	182.7
11	76.1	65.7	-87,472	236.4	-96,342	209.1	-212,082	62.1	-230,974	61.1	-323,555	200.6
12	78.9	67.4	-46,940	249.3	-57,373	222.1	-201,084	64.2	-219,781	63.3	-255,871	214.4
13	81.5	68.9	-84,079	240.9	-96,443	212.4	-191,809	67.1	-209,760	66.3	-217,890	211.1
14	83.5	70.0	-46,567	262.6	-55,931	234.1	-185,996	69.9	-202,520	69.1	-107,793	234.9
15	84.9	70.6	-36,790	272.7	-46,189	243.3	-180,420	72.0	-195,581	71.2	-58,193	246.0
16	85.3	70.3	-72,269	242.4	-88,792	206.9	-181,097	73.9	-195,439	73.0	-96,280	209.3
17	85.1	69.8	-108,813	89.7	-135,934	77.3	-189,132	75.5	-202,077	74.7	-135,946	77.9
18	84.4	69.3	-116,897	91.7	-146,476	78.5	-196,679	76.3	-208,160	75.6	-146,495	79.1
19	83.3	68.6	-130,510	91.6	-163,040	77.9	-209,075	75.9	-221,170	75.2	-163,057	78.4
20	81.8	69.3	-149,411	89.5	-177,725	76.4	-223,280	74.6	-236,186	73.9	-177,744	76.8
21	80.1	69.0	-142,043	87.5	-168,686	74.0	-240,038	71.5	-254,499	70.9	-168,705	74.4
22	78.1	68.2	-176,463	85.8	-201,123	71.5	-256,273	69.6	-272,649	69.0	-201,141	71.9
23	76.1	67.1	-196,360	81.7	-218,866	69.5	-270,914	67.9	-288,302	67.2	-218,884	69.9
24	74.0	66.1	-211,502	78.4	-233,239	67.8	-285,396	66.2	-304,338	65.7	-233,270	68.2

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	65.4	60.5	-278,215	66.4	-297,860	62.5	-316,543	61.5	-368,767	59.2	-385,318	58.5
2	63.6	58.9	-302,253	64.6	-326,171	60.8	-336,559	60.3	-385,553	58.2	-402,554	57.5
3	62.1	57.8	-317,180	63.0	-346,722	59.5	-364,321	59.1	-402,325	57.1	-417,304	56.4
4	61.0	57.0	-343,469	61.5	-372,764	58.4	-377,991	58.0	-415,825	56.1	-436,460	55.4
5	60.3	56.5	-354,828	60.2	-386,497	57.2	-392,209	56.9	-427,402	55.0	-452,770	54.4
6	60.0	56.7	-362,915	59.0	-399,085	56.2	-403,189	55.9	-436,941	54.1	-463,952	53.5
7	60.5	57.4	-346,467	58.1	-387,856	55.4	-402,081	55.0	-438,783	53.2	-452,379	52.8
8	61.8	58.5	-1,035,614	150.3	-1,116,278	143.0	-365,033	54.3	-402,929	52.6	-1,243,948	133.7
9	63.9	59.4	-734,734	153.8	-842,718	144.7	-325,512	54.0	-362,583	52.4	-1,028,578	139.2
10	66.5	60.3	-282,348	191.7	-377,902	171.5	-293,482	54.1	-328,119	52.5	-671,159	163.7
11	69.4	61.5	-119,100	218.7	-192,727	193.3	-271,100	55.5	-307,908	54.0	-543,014	183.2
12	72.3	63.1	-55,868	236.5	-91,942	209.4	-252,610	58.3	-288,116	56.9	-426,969	197.5
13	75.0	64.8	-92,815	229.2	-131,636	202.9	-232,492	61.9	-262,303	60.6	-342,923	198.1
14	77.1	66.1	-53,648	252.0	-68,401	222.8	-216,803	64.3	-242,526	63.0	-191,824	221.9
15	78.4	66.8	-43,231	261.2	-55,897	230.1	-210,742	65.7	-232,272	64.6	-81,197	231.8
16	78.9	67.0	-81,254	227.6	-110,670	191.2	-216,437	67.1	-236,584	66.1	-119,243	193.2
17	78.6	67.3	-125,526	83.7	-157,185	71.5	-229,574	68.5	-247,259	67.5	-157,354	72.1
18	77.9	67.2	-139,116	85.1	-173,489	72.1	-238,992	68.8	-257,011	67.8	-173,513	72.6
19	76.8	66.9	-160,042	84.0	-189,860	70.8	-250,553	67.9	-268,711	66.9	-189,882	71.3
20	75.3	66.9	-181,340	81.5	-210,608	68.1	-270,363	65.3	-290,662	64.4	-210,629	68.5
21	73.5	66.0	-173,504	78.2	-201,655	66.7	-289,927	63.6	-313,451	62.7	-201,676	67.1
22	71.5	64.8	-213,909	74.4	-239,514	65.1	-309,750	62.4	-334,469	61.5	-239,539	65.5
23	69.4	63.2	-233,274	71.5	-258,315	63.9	-331,332	61.4	-351,704	60.5	-258,343	64.2
24	67.3	61.6	-247,770	68.9	-287,742	62.7	-351,000	60.3	-368,612	59.5	-287,802	63.0

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	53.0	46.2	-375,082	58.1	-405,271	54.3	-426,963	53.6	-551,557	50.7	-567,137	50.5
2	51.0	44.9	-406,704	56.4	-441,975	52.8	-447,409	52.6	-574,076	49.9	-590,419	49.7
3	49.2	43.5	-432,871	54.8	-459,550	51.7	-464,935	51.5	-600,536	49.0	-614,628	48.8
4	47.7	42.2	-449,773	53.4	-474,597	50.5	-478,176	50.3	-626,683	48.1	-635,650	48.0

5	46.6	41.3	-462,289	52.0	-487,986	49.4	-489,140	49.2	-648,001	47.2	-655,117	47.1
6	45.9	40.8	-467,970	50.8	-497,429	48.3	-498,509	48.1	-666,373	46.4	-672,145	46.3
7	45.7	40.9	-461,070	49.8	-495,769	47.3	-510,228	47.0	-680,266	45.5	-671,359	45.5
8	46.6	42.0	-1,285,286	129.4	-1,327,023	124.2	-494,678	46.1	-653,733	44.8	-1,328,938	119.8
9	49.2	43.6	-1,058,086	134.9	-1,149,036	129.0	-479,242	45.5	-606,461	44.5	-1,163,825	124.8
10	53.0	45.4	-604,115	164.1	-751,471	151.0	-477,214	45.4	-557,983	44.5	-805,452	145.9
11	57.5	47.9	-370,272	190.4	-472,383	165.6	-443,480	46.0	-509,947	45.2	-696,331	157.4
12	62.1	50.3	-185,529	209.9	-335,303	181.4	-417,847	47.5	-463,047	46.8	-547,875	168.5
13	65.9	52.8	-171,031	206.4	-257,284	175.5	-393,822	50.1	-426,227	49.5	-517,962	171.9
14	68.5	54.2	-76,130	227.8	-183,262	195.6	-365,617	52.6	-391,203	52.1	-307,769	192.6
15	69.4	54.3	-57,466	236.5	-158,744	203.4	-351,120	54.7	-374,605	54.2	-197,183	203.4
16	69.2	53.9	-102,995	199.0	-230,440	167.5	-348,557	56.1	-369,214	55.6	-265,859	168.8
17	68.5	53.2	-154,963	73.9	-212,697	62.2	-347,647	56.9	-369,626	56.4	-213,324	62.7
18	67.4	53.2	-178,510	74.1	-232,661	60.7	-359,418	55.8	-382,877	55.4	-232,806	61.0
19	65.9	53.6	-206,801	71.8	-262,255	58.9	-385,537	54.5	-406,892	54.1	-262,401	59.2
20	64.1	53.4	-231,763	68.1	-290,781	58.0	-420,164	54.0	-441,535	53.7	-290,923	58.2
21	62.1	52.6	-239,841	65.8	-276,820	57.7	-452,240	53.6	-469,793	53.2	-276,959	57.9
22	59.8	51.0	-285,482	63.5	-315,721	56.6	-476,325	53.0	-495,349	52.7	-315,871	56.9
23	57.5	49.6	-317,767	61.5	-356,081	55.7	-498,647	52.3	-520,086	52.0	-356,305	55.9
24	55.2	48.0	-352,258	59.7	-386,171	54.7	-524,024	51.5	-544,771	51.3	-386,351	54.9

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	45.6	40.5	-463,229	51.3	-487,835	48.3	-508,133	47.9	-674,129	45.6	-680,011	45.5
2	44.0	39.2	-480,994	50.1	-503,756	47.2	-538,548	47.1	-690,486	45.0	-696,404	44.9
3	42.7	38.0	-493,872	49.0	-516,393	46.2	-552,977	46.2	-706,318	44.4	-712,353	44.3
4	41.8	37.4	-501,121	47.9	-525,643	45.3	-571,282	45.3	-721,031	43.8	-727,164	43.7
5	41.2	36.6	-506,884	46.8	-540,246	44.4	-612,294	44.5	-733,924	43.1	-740,047	43.0
6	40.9	36.6	-518,779	45.9	-579,843	43.6	-633,357	43.7	-745,207	42.5	-751,099	42.4
7	41.4	37.0	-539,410	45.1	-600,552	42.9	-669,268	43.0	-752,744	41.9	-743,876	41.9
8	42.5	38.4	-1,341,989	120.6	-1,368,085	116.1	-671,093	42.4	-749,973	41.5	-1,369,142	114.0
9	44.3	40.2	-1,170,036	125.8	-1,226,952	121.2	-645,871	42.0	-718,075	41.2	-1,233,436	119.2
10	46.6	41.7	-785,444	148.4	-858,029	141.6	-618,002	41.8	-670,508	41.2	-881,865	139.1
11	49.2	43.3	-555,938	165.2	-680,228	151.4	-573,904	42.1	-616,730	41.5	-759,955	148.6
12	51.7	44.9	-396,894	193.8	-449,469	163.3	-523,883	42.9	-563,031	42.4	-618,687	155.5
13	54.0	46.6	-328,342	190.5	-440,862	162.0	-497,869	44.7	-527,692	44.3	-589,326	159.2
14	55.8	47.4	-195,449	209.4	-298,092	179.6	-480,164	47.0	-507,571	46.6	-415,170	178.2
15	57.0	48.2	-146,392	217.0	-241,851	188.4	-473,561	48.9	-498,218	48.5	-274,593	188.5
16	57.4	48.1	-219,813	178.5	-346,756	154.7	-473,181	49.9	-496,678	49.6	-364,399	155.8
17	57.2	48.3	-201,847	65.5	-272,226	55.3	-484,297	49.4	-507,239	49.1	-272,760	55.6
18	56.6	48.5	-233,975	64.0	-301,135	53.2	-514,206	48.2	-535,977	47.9	-301,179	53.5
19	55.6	48.4	-274,417	61.0	-336,974	52.4	-557,912	48.0	-576,560	47.8	-337,016	52.6
20	54.3	47.9	-317,016	58.8	-355,592	51.6	-582,443	47.8	-599,212	47.6	-355,623	51.9
21	52.7	46.7	-306,693	57.6	-340,113	51.3	-604,510	47.5	-615,834	47.3	-340,209	51.6
22	51.0	45.3	-357,836	55.8	-390,418	50.4	-621,199	47.2	-629,756	47.0	-390,520	50.7
23	49.2	43.9	-395,009	54.2	-440,371	49.6	-638,875	46.7	-646,348	46.6	-440,480	49.8
24	47.3	42.1	-441,508	52.8	-474,457	48.8	-656,093	46.2	-663,667	46.0	-474,556	49.0

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	28.2	25.0	-607,876	42.0	-662,386	38.8	-734,740	39.0	-872,558	37.2	-879,118	37.1
2	26.8	23.7	-642,204	40.8	-701,615	37.8	-781,387	38.1	-888,098	36.6	-894,879	36.5
3	25.7	22.8	-662,089	39.6	-753,096	37.0	-807,309	37.4	-903,156	36.0	-910,025	35.9
4	25.0	22.1	-722,682	38.6	-817,118	36.2	-819,658	36.6	-916,344	35.4	-923,280	35.3
5	24.8	22.0	-764,123	37.6	-828,584	35.4	-828,917	35.8	-930,546	34.7	-933,139	34.7
6	25.1	22.5	-791,682	36.8	-835,594	34.7	-842,427	35.1	-940,295	34.2	-940,535	34.1
7	26.1	23.6	-786,254	36.2	-842,527	34.2	-866,068	34.5	-944,195	33.7	-930,416	33.7
8	27.5	25.1	-1,427,322	104.0	-1,448,454	100.5	-888,390	34.0	-944,368	33.3	-1,449,055	99.8
9	29.4	27.0	-1,295,572	108.7	-1,327,621	104.9	-882,974	33.7	-921,752	33.1	-1,328,906	104.1
10	31.6	28.8	-942,359	128.6	-1,010,568	123.4	-841,182	33.7	-878,986	33.1	-1,030,887	122.3
11	33.8	30.4	-746,833	140.7	-829,535	132.9	-785,627	33.9	-822,396	33.5	-875,989	131.4
12	36.0	31.9	-573,018	156.9	-690,844	138.4	-722,051	34.5	-756,654	34.1	-785,997	135.9
13	37.9	33.3	-501,511	164.2	-606,110	136.9	-677,275	35.5	-708,906	35.2	-707,821	135.2

14	39.3	34.1	-370,933	183.8	-476,742	156.2	-660,553	37.3	-685,427	37.0	-565,501	154.3
15	40.3	34.5	-265,393	189.3	-407,739	164.3	-660,140	39.0	-680,517	38.8	-453,534	164.6
16	40.6	35.0	-353,692	156.2	-523,555	135.7	-673,437	39.9	-687,496	39.7	-538,839	136.9
17	40.4	35.0	-277,533	56.7	-345,622	45.9	-697,693	39.3	-706,959	39.1	-347,640	46.2
18	39.7	34.9	-322,360	53.9	-397,571	44.5	-740,119	39.4	-749,833	39.2	-400,579	44.7
19	38.6	34.3	-379,491	50.9	-456,744	43.6	-774,790	39.4	-782,192	39.3	-458,612	43.8
20	37.2	33.3	-410,079	49.3	-492,114	42.8	-797,711	39.3	-804,237	39.2	-492,911	43.0
21	35.5	31.9	-426,408	48.1	-505,610	42.4	-813,524	39.1	-820,070	39.0	-507,708	42.6
22	33.7	30.1	-509,466	46.4	-584,209	41.5	-826,951	38.7	-833,531	38.6	-585,008	41.6
23	31.7	28.6	-584,277	44.8	-635,792	40.6	-841,576	38.3	-848,207	38.2	-636,013	40.8
24	29.9	26.8	-611,304	43.4	-671,341	39.8	-856,892	37.8	-863,581	37.7	-672,055	40.0

Appendix D - Billings Load Profile Data

BUILDING COOL HEAT DEMAND

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	26.0	22.3	-1,269,187	86.0	-1,277,668	99.8	-497,106	36.1	-907,959	31.6	-1,519,486	88.6
2	24.7	20.8	-1,293,469	81.9	-1,288,428	98.5	-510,982	34.9	-921,193	31.1	-1,528,527	89.2
3	23.5	19.6	-1,302,083	79.3	-1,298,175	97.4	-538,993	33.7	-934,413	30.7	-1,523,232	89.4
4	22.5	18.8	-1,309,673	85.3	-1,307,330	96.3	-626,815	32.7	-947,123	30.2	-1,489,312	89.3
5	21.8	18.1	-1,315,844	87.0	-1,315,190	95.1	-719,518	31.7	-958,182	29.6	-1,460,434	88.9
6	21.4	17.7	-1,319,704	87.1	-1,321,882	94.0	-781,471	30.9	-967,802	29.1	-1,443,833	88.4
7	21.2	17.8	-1,307,870	86.8	-1,313,826	92.9	-865,102	30.2	-976,027	28.6	-1,434,030	88.0
8	21.8	18.3	-1,291,896	86.6	-1,301,781	92.1	-877,911	29.6	-980,737	28.2	-1,424,487	87.8
9	23.5	20.1	-866,430	88.9	-892,126	93.9	-867,503	29.0	-966,890	27.8	-1,139,804	90.2
10	26.0	22.1	-655,752	98.0	-708,009	102.0	-840,469	28.7	-930,629	27.6	-947,984	98.7
11	29.0	24.6	-537,482	107.5	-610,446	108.3	-797,087	28.7	-875,504	27.7	-794,474	104.7
12	32.0	26.9	-431,898	113.7	-515,295	108.1	-737,122	28.9	-805,235	28.1	-604,178	106.2
13	34.5	28.3	-517,347	118.1	-603,376	106.3	-702,587	29.7	-750,381	29.0	-652,423	105.6
14	36.2	29.4	-388,674	131.4	-469,019	116.2	-682,174	31.2	-724,501	30.6	-508,174	115.9
15	36.8	29.6	-354,041	139.6	-468,656	125.3	-681,337	32.7	-719,979	32.2	-503,542	125.2
16	36.7	29.4	-485,075	125.0	-648,202	112.8	-686,120	33.6	-729,157	33.1	-686,435	112.7
17	36.2	29.3	-815,898	123.0	-950,223	108.0	-701,234	33.1	-749,985	32.7	-964,252	107.9
18	35.5	29.5	-979,873	118.6	-1,093,539	106.8	-754,060	33.0	-797,246	32.7	-1,103,892	106.8
19	34.5	28.9	-1,117,846	114.2	-1,185,953	106.3	-797,505	33.1	-829,451	32.8	-1,189,301	106.2
20	33.3	28.4	-1,188,958	112.3	-1,226,706	105.7	-826,726	33.0	-851,604	32.8	-1,227,131	105.6
21	32.0	27.2	-1,145,295	110.8	-1,169,569	105.3	-845,955	32.9	-866,011	32.7	-1,170,766	105.1
22	30.5	25.9	-1,220,457	108.1	-1,229,701	104.2	-867,709	32.6	-877,335	32.4	-1,230,089	104.1
23	29.0	24.7	-1,248,702	105.9	-1,250,256	103.1	-882,273	32.3	-889,213	32.2	-1,250,627	103.0
24	27.5	23.5	-1,265,387	103.7	-1,261,983	102.1	-894,833	32.0	-901,814	31.8	-1,262,338	101.9
February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	22.4	18.0	-1,259,823	109.6	-1,291,123	102.7	-505,036	36.9	-916,240	32.4	-1,527,177	90.1
2	22.0	18.0	-1,272,217	106.9	-1,302,703	100.7	-508,105	35.4	-933,008	31.6	-1,537,176	90.1
3	22.3	18.1	-1,282,641	104.3	-1,309,879	99.0	-530,958	34.0	-945,155	30.9	-1,531,008	89.8
4	23.0	18.7	-1,291,840	102.0	-1,313,586	97.5	-601,555	32.7	-953,185	30.2	-1,495,695	89.4
5	24.3	20.6	-1,300,280	100.0	-1,313,912	96.1	-704,081	31.7	-956,650	29.6	-1,461,176	88.9
6	25.9	22.4	-1,305,714	98.2	-1,311,111	95.1	-756,243	31.0	-955,967	29.2	-1,435,048	88.7
7	27.9	24.4	-1,294,631	96.7	-1,291,745	94.3	-836,139	30.4	-951,373	28.9	-1,415,318	88.6
8	30.0	26.4	-1,268,478	95.6	-1,263,474	94.0	-839,918	30.1	-937,546	28.8	-1,392,617	88.9
9	32.2	28.6	-798,436	97.7	-823,629	96.7	-801,895	30.0	-891,500	28.8	-1,082,018	92.2
10	34.3	30.2	-583,921	108.6	-635,442	106.5	-761,700	30.2	-840,712	29.1	-875,139	102.3
11	36.2	31.0	-486,433	121.9	-538,208	114.5	-718,876	30.6	-784,980	29.7	-714,708	110.0
12	37.9	31.9	-385,143	127.9	-447,238	114.6	-665,281	31.3	-725,892	30.5	-538,016	111.9
13	39.1	31.9	-470,116	131.3	-547,812	112.4	-628,513	32.4	-681,748	31.6	-602,753	111.2
14	39.9	31.8	-345,875	145.6	-422,615	123.4	-621,318	34.2	-661,565	33.6	-465,773	122.5
15	40.2	32.0	-332,244	154.8	-424,741	133.2	-620,680	36.1	-658,021	35.5	-465,105	132.5
16	39.8	32.0	-418,292	138.8	-586,360	120.8	-626,869	37.4	-664,579	36.9	-634,333	120.3
17	38.7	31.0	-720,947	137.7	-884,902	117.4	-633,524	37.8	-677,448	37.3	-901,519	117.0
18	37.0	29.9	-862,850	136.0	-1,016,819	113.2	-658,106	36.6	-708,892	36.2	-1,027,185	112.8
19	34.8	28.7	-990,160	131.8	-1,130,690	112.1	-717,094	36.2	-762,487	35.9	-1,135,686	111.7
20	32.4	27.1	-1,100,165	125.2	-1,194,957	111.0	-769,044	35.9	-801,504	35.6	-1,195,781	110.6
21	29.8	24.8	-1,078,234	122.7	-1,150,946	110.1	-810,811	35.3	-832,458	35.1	-1,152,012	109.8
22	27.3	22.8	-1,167,936	118.9	-1,224,615	108.2	-843,550	34.7	-859,647	34.5	-1,224,995	107.8
23	25.1	20.7	-1,204,805	115.5	-1,253,614	106.3	-875,104	34.0	-882,477	33.8	-1,253,980	106.0
24	23.4	19.3	-1,228,308	112.4	-1,271,642	104.5	-897,157	33.2	-904,131	33.0	-1,271,940	104.1
March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	26.5	22.4	-1,238,643	114.8	-1,250,031	106.2	-481,768	39.2	-860,941	34.7	-1,503,405	94.3
2	24.5	20.5	-1,257,888	111.3	-1,268,107	104.3	-487,228	37.7	-883,332	33.8	-1,517,903	94.2
3	22.8	19.1	-1,275,266	108.0	-1,284,017	102.6	-501,155	36.2	-904,785	32.9	-1,514,152	93.8
4	21.5	18.0	-1,289,981	104.9	-1,298,420	100.9	-558,217	34.8	-924,261	32.1	-1,482,889	93.1

5	20.7	17.5	-1,300,164	102.2	-1,310,018	99.1	-645,510	33.5	-942,199	31.3	-1,455,157	92.2
6	20.5	17.2	-1,307,062	100.0	-1,318,874	97.5	-713,536	32.3	-956,550	30.5	-1,441,980	91.2
7	21.0	17.9	-1,295,878	98.1	-1,310,147	95.9	-809,067	31.3	-965,916	29.8	-1,431,592	90.3
8	22.5	19.2	-1,197,389	96.8	-1,254,897	94.8	-828,922	30.5	-925,368	29.2	-1,385,102	89.9
9	24.9	21.5	-699,872	100.7	-802,567	96.9	-783,431	30.1	-871,112	28.9	-1,052,676	92.6
10	27.9	23.2	-507,849	114.8	-616,199	106.1	-750,768	29.9	-827,059	28.9	-853,904	102.1
11	31.2	25.4	-433,618	130.2	-528,774	113.7	-716,943	30.2	-781,764	29.3	-702,767	109.3
12	34.5	27.3	-346,226	133.5	-451,896	113.4	-678,699	30.9	-740,536	30.1	-541,958	110.8
13	37.5	29.2	-426,665	136.2	-557,516	111.5	-639,629	32.0	-694,523	31.3	-610,595	110.3
14	39.8	30.6	-307,992	151.7	-424,873	122.7	-627,197	34.1	-666,346	33.4	-469,297	121.9
15	41.3	31.4	-259,289	162.2	-415,302	133.3	-618,927	36.3	-657,877	35.7	-464,133	132.8
16	41.9	31.7	-364,620	147.8	-566,634	122.1	-613,623	38.0	-653,918	37.5	-615,453	121.7
17	41.6	32.5	-652,753	147.4	-858,973	120.1	-602,185	39.2	-648,333	38.7	-877,987	119.8
18	40.8	32.2	-768,475	147.7	-961,059	118.4	-598,678	39.2	-647,496	38.9	-975,606	118.1
19	39.5	32.1	-862,227	143.5	-1,048,659	115.3	-625,311	38.1	-671,190	37.8	-1,058,464	114.9
20	37.8	31.3	-967,497	137.4	-1,124,795	114.3	-690,153	37.8	-721,869	37.5	-1,128,396	114.0
21	35.8	29.7	-990,721	132.1	-1,092,809	114.0	-739,282	37.4	-764,137	37.2	-1,095,640	113.7
22	33.5	28.1	-1,113,234	127.3	-1,174,356	112.1	-777,677	36.8	-795,186	36.6	-1,175,623	111.8
23	31.2	26.2	-1,166,554	122.9	-1,204,997	110.4	-813,490	36.2	-822,054	36.0	-1,205,822	110.1
24	28.8	24.0	-1,202,238	118.7	-1,225,687	108.7	-838,227	35.5	-844,835	35.3	-1,226,204	108.4

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	41.6	35.8	-1,093,846	133.0	-1,094,966	122.1	-400,852	47.3	-642,362	43.4	-1,423,829	110.8
2	39.6	34.6	-1,117,428	128.7	-1,118,277	119.9	-405,934	46.2	-678,728	42.4	-1,439,924	110.2
3	37.8	33.2	-1,135,253	124.7	-1,139,684	117.9	-416,902	44.9	-707,994	41.4	-1,420,706	109.7
4	36.4	32.1	-1,152,156	121.2	-1,158,772	115.9	-442,187	43.5	-738,111	40.4	-1,372,941	108.8
5	35.3	31.3	-1,166,284	118.1	-1,174,191	114.0	-497,288	42.1	-759,622	39.4	-1,343,580	107.8
6	34.6	30.8	-1,176,679	115.4	-1,187,403	112.1	-552,931	40.8	-777,088	38.5	-1,333,605	106.7
7	34.4	30.6	-1,088,239	113.5	-1,136,698	110.6	-527,586	39.7	-742,296	37.7	-1,270,570	105.8
8	35.0	30.9	-951,092	114.2	-1,047,370	110.0	-483,324	39.0	-685,501	37.3	-1,211,331	105.9
9	36.8	32.2	-478,355	122.6	-593,297	113.8	-461,634	38.5	-637,265	37.0	-870,708	110.5
10	39.6	33.9	-338,232	143.4	-407,407	125.2	-473,269	38.3	-591,024	37.1	-642,983	121.8
11	43.0	35.8	-283,143	154.9	-337,529	135.4	-506,748	38.8	-563,798	37.7	-513,645	131.7
12	46.6	38.2	-181,123	157.5	-252,856	135.2	-475,401	40.1	-525,285	39.1	-384,765	133.6
13	50.0	40.5	-240,557	156.1	-350,699	134.3	-437,151	42.8	-482,583	41.9	-424,185	134.1
14	52.7	42.3	-120,894	173.9	-220,943	149.3	-403,381	46.0	-445,326	45.2	-302,112	149.5
15	54.5	43.4	-99,255	186.6	-217,175	159.0	-392,225	48.3	-432,476	47.6	-286,957	159.3
16	55.2	43.7	-197,703	171.2	-354,515	143.0	-386,143	49.7	-425,099	49.0	-389,711	143.4
17	54.9	43.3	-453,310	169.0	-653,223	141.0	-380,773	50.7	-417,837	50.1	-664,055	141.4
18	54.3	43.0	-559,097	169.7	-760,577	140.0	-380,628	51.2	-416,007	50.6	-769,699	140.4
19	53.2	42.6	-649,671	166.5	-843,568	136.5	-398,676	50.1	-429,784	49.5	-850,827	136.8
20	51.7	42.8	-742,775	161.3	-913,000	132.7	-440,094	48.2	-469,330	47.7	-913,303	133.0
21	50.0	42.3	-738,370	152.9	-887,349	131.7	-495,223	47.4	-532,919	46.9	-887,370	132.0
22	48.0	40.9	-894,522	146.8	-992,494	129.2	-537,182	46.4	-578,967	46.0	-992,514	129.4
23	45.9	39.3	-968,082	140.9	-1,035,741	127.1	-572,394	45.4	-618,553	45.1	-1,035,760	127.3
24	43.7	37.6	-1,016,867	136.0	-1,063,072	124.9	-604,224	44.4	-646,155	44.1	-1,063,090	125.1

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	52.8	45.4	-908,124	146.8	-936,786	135.0	-337,696	53.2	-442,196	50.3	-1,359,889	124.0
2	50.6	43.7	-943,538	142.1	-976,137	131.6	-342,593	52.6	-467,057	49.2	-1,379,184	122.9
3	48.7	42.3	-973,918	137.8	-1,005,394	129.3	-354,580	51.3	-511,025	48.0	-1,342,451	122.2
4	47.3	41.3	-1,000,136	134.0	-1,029,423	127.0	-364,601	49.9	-546,906	46.8	-1,284,731	121.2
5	46.4	40.8	-1,021,947	130.7	-1,049,951	125.0	-402,439	48.5	-576,700	45.7	-1,251,302	120.1
6	46.1	41.0	-985,164	128.0	-1,036,589	123.0	-428,420	47.2	-588,389	44.7	-1,208,231	118.9
7	46.5	41.2	-875,835	127.7	-971,297	122.1	-411,461	46.5	-551,180	44.1	-1,150,729	118.8
8	47.8	42.1	-742,144	129.5	-879,039	122.2	-377,581	46.2	-503,760	44.1	-1,091,661	119.7
9	49.7	42.8	-292,711	143.2	-415,441	127.7	-345,427	46.0	-463,329	44.1	-692,626	125.8
10	52.2	43.6	-175,745	164.7	-262,575	142.0	-314,502	46.0	-424,265	44.2	-470,787	139.3
11	55.0	45.0	-130,047	177.4	-214,792	152.4	-302,749	46.6	-406,847	45.0	-357,030	149.6
12	57.9	46.8	-68,544	178.5	-148,425	152.4	-288,596	47.8	-382,553	46.4	-255,680	152.0
13	60.8	48.4	-121,169	173.3	-230,802	147.8	-279,445	50.4	-351,925	49.1	-268,213	148.5

14	63.2	49.9	-64,856	195.7	-131,279	164.4	-260,660	53.3	-319,827	52.1	-140,092	165.4
15	65.2	50.6	-69,714	211.5	-126,432	175.0	-257,634	55.4	-301,890	54.4	-130,289	176.0
16	66.4	51.5	-139,861	193.4	-239,417	157.5	-261,948	57.2	-296,050	56.2	-241,647	158.2
17	66.8	52.0	-370,337	189.0	-517,383	154.5	-266,307	58.4	-295,238	57.4	-517,406	155.1
18	66.5	52.3	-463,850	189.4	-622,991	153.8	-270,315	59.0	-298,981	58.1	-623,012	154.3
19	65.6	52.2	-535,115	186.2	-702,394	152.3	-278,696	58.9	-307,851	58.1	-702,414	152.9
20	64.2	51.8	-595,714	178.7	-764,757	147.9	-297,845	57.3	-328,089	56.5	-764,775	148.3
21	62.3	51.7	-583,990	173.4	-727,146	145.0	-324,561	55.3	-353,815	54.5	-727,164	145.4
22	60.1	50.8	-722,913	162.8	-834,231	141.7	-356,355	53.9	-388,707	53.1	-834,249	142.1
23	57.7	49.3	-794,712	156.5	-886,070	139.5	-384,446	52.8	-431,312	52.1	-886,088	139.8
24	55.2	47.1	-846,677	151.1	-917,710	137.1	-410,007	51.6	-468,071	50.9	-917,727	137.4

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	57.5	52.3	-292,050	61.8	-304,474	59.5	-340,765	57.8	-400,749	55.8	-416,763	55.1
2	55.9	51.0	-297,276	61.0	-337,583	57.4	-375,154	56.4	-419,820	54.4	-441,983	53.8
3	54.6	49.6	-307,169	58.9	-372,720	55.5	-401,961	54.9	-437,344	53.1	-464,259	52.5
4	53.6	48.8	-318,400	56.8	-405,185	53.9	-417,392	53.6	-455,036	51.8	-482,123	51.2
5	53.0	48.6	-340,198	54.9	-423,572	52.5	-430,633	52.3	-471,547	50.6	-498,254	50.1
6	52.8	48.9	-328,955	53.5	-405,858	51.4	-408,033	51.3	-450,615	49.6	-486,078	49.1
7	53.4	49.1	-291,820	53.3	-356,252	51.0	-368,118	50.8	-406,841	49.2	-432,009	48.8
8	55.0	50.2	-1,225,991	134.4	-1,194,817	130.2	-330,826	50.8	-377,704	49.2	-1,298,921	125.0
9	57.5	51.5	-767,740	145.8	-872,017	136.5	-293,465	51.1	-337,874	49.6	-1,043,657	132.3
10	60.6	53.2	-246,764	176.4	-383,764	157.0	-261,964	51.7	-308,174	50.3	-705,186	152.2
11	63.9	55.0	-72,099	195.3	-187,033	171.0	-246,435	52.8	-290,077	51.5	-568,264	163.5
12	67.0	56.9	-51,761	201.8	-97,336	177.5	-236,884	54.7	-275,193	53.4	-447,577	171.6
13	69.5	58.2	-94,813	190.7	-140,222	167.7	-227,606	57.3	-257,520	56.2	-383,871	167.4
14	71.2	59.4	-52,578	217.6	-71,039	190.9	-215,442	60.4	-241,591	59.4	-194,042	190.9
15	71.8	59.3	-42,510	232.1	-54,102	202.4	-210,796	62.7	-232,688	61.7	-84,864	204.1
16	71.5	59.3	-117,530	205.3	-172,037	176.0	-219,992	64.8	-237,799	63.9	-181,805	178.0
17	70.9	59.1	-356,232	201.4	-441,290	170.5	-229,143	66.2	-246,004	65.3	-445,060	172.3
18	69.9	58.2	-140,535	81.6	-176,044	68.4	-236,132	66.8	-254,226	66.0	-176,056	68.9
19	68.6	57.9	-145,111	83.3	-183,737	69.1	-246,471	66.6	-266,256	65.8	-183,751	69.6
20	67.0	57.6	-163,805	81.9	-200,681	67.9	-263,526	65.6	-284,449	64.7	-200,694	68.3
21	65.2	57.3	-162,002	79.9	-190,455	65.6	-286,072	62.7	-308,294	61.9	-190,469	66.0
22	63.3	56.1	-201,280	75.5	-235,051	63.2	-314,697	60.7	-338,529	59.9	-235,064	63.6
23	61.3	55.0	-238,281	71.3	-265,471	61.5	-340,729	59.1	-364,739	58.4	-265,486	61.8
24	59.3	53.8	-258,896	67.8	-298,813	59.5	-373,395	57.3	-389,213	56.6	-298,850	59.8

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	69.5	57.9	-265,390	69.4	-223,136	69.6	-234,210	67.2	-281,336	66.3	-298,666	66.0
2	66.9	56.0	-287,121	67.5	-250,463	66.8	-261,205	65.4	-296,177	64.7	-315,112	64.3
3	64.7	55.0	-309,325	65.2	-275,864	64.6	-281,082	63.6	-312,938	62.8	-332,966	62.5
4	63.1	54.0	-328,595	63.1	-292,158	62.8	-306,772	61.8	-335,839	61.1	-355,608	60.8
5	62.1	54.1	-342,000	61.2	-317,517	61.3	-335,609	60.2	-353,121	59.5	-372,953	59.2
6	61.7	54.2	-322,990	59.7	-324,771	59.6	-334,733	58.8	-352,368	58.1	-369,748	57.9
7	62.4	54.6	-264,348	59.6	-283,867	59.0	-302,946	58.1	-318,439	57.5	-321,485	57.3
8	64.4	55.6	-1,040,983	150.7	-957,573	168.1	-269,351	57.9	-285,297	57.2	-1,002,383	160.7
9	67.4	57.5	-662,570	163.7	-663,548	161.1	-239,266	58.2	-255,146	57.6	-724,069	157.5
10	71.3	59.4	-252,036	197.2	-226,948	182.1	-217,036	59.6	-232,070	59.0	-393,710	178.5
11	75.5	60.9	-110,439	220.1	-102,005	197.7	-201,323	61.5	-216,039	61.0	-307,836	189.7
12	79.8	63.0	-53,362	229.7	-57,476	203.1	-188,462	64.0	-203,221	63.5	-251,512	197.1
13	83.7	64.5	-87,072	217.9	-98,199	193.9	-179,250	67.7	-194,894	67.5	-199,092	192.6
14	86.7	66.1	-48,097	244.0	-52,905	219.3	-170,679	70.8	-185,342	70.9	-96,546	218.5
15	88.7	66.7	-36,195	256.3	-41,618	232.1	-163,579	73.5	-176,908	73.8	-58,597	232.2
16	89.4	66.1	-88,565	228.4	-110,524	200.7	-160,501	75.7	-172,175	75.8	-119,996	201.5
17	89.0	65.3	-303,198	222.0	-346,575	193.3	-165,722	77.7	-174,320	77.5	-347,461	194.0
18	88.0	64.7	-117,969	88.2	-138,345	78.1	-169,450	78.5	-177,005	78.3	-138,353	78.2
19	86.4	64.5	-119,813	90.0	-141,981	79.2	-177,146	78.6	-184,490	78.2	-141,989	79.4
20	84.2	65.4	-136,533	88.8	-155,831	78.3	-191,169	77.6	-198,334	77.2	-155,839	78.5
21	81.5	65.0	-131,899	86.8	-144,366	77.4	-208,898	76.1	-217,203	75.7	-144,375	77.6
22	78.6	63.7	-167,822	83.8	-176,809	74.2	-225,092	72.9	-235,390	72.5	-176,817	74.4

23	75.5	61.6	-192,604	79.0	-197,683	71.4	-244,090	70.2	-258,383	69.7	-197,691	71.5
24	72.5	59.8	-213,125	75.9	-215,213	69.2	-264,612	68.1	-281,011	67.7	-215,222	69.3
August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	61.5	49.2	-268,286	64.4	-281,054	62.8	-307,372	61.1	-355,168	59.1	-373,830	58.4
2	58.8	47.0	-301,887	62.4	-309,467	60.6	-329,013	59.6	-381,181	57.7	-397,884	57.1
3	56.8	46.1	-328,952	60.0	-344,175	58.9	-363,780	58.2	-400,931	56.4	-417,467	55.7
4	55.5	45.6	-364,453	58.0	-371,877	57.3	-385,518	56.8	-424,061	55.1	-438,001	54.4
5	55.0	46.2	-384,912	56.3	-398,896	55.8	-403,818	55.5	-438,314	53.8	-456,080	53.2
6	55.5	47.0	-401,093	54.8	-411,617	54.5	-415,201	54.2	-448,980	52.6	-472,007	52.0
7	56.8	48.2	-341,490	53.9	-372,685	53.5	-386,917	53.2	-419,530	51.6	-427,267	51.1
8	58.8	49.6	-1,072,113	139.0	-1,093,720	142.7	-343,218	52.8	-373,487	51.3	-1,308,136	130.8
9	61.5	51.8	-699,876	146.7	-787,834	141.4	-303,767	52.7	-331,852	51.2	-1,016,218	136.9
10	64.6	52.6	-259,504	187.4	-302,390	171.4	-270,040	53.1	-298,317	51.6	-605,752	165.0
11	67.9	54.4	-101,551	212.2	-147,303	192.4	-254,412	54.4	-283,695	53.0	-504,020	183.1
12	71.2	56.2	-50,651	228.6	-72,835	207.2	-239,332	56.9	-267,562	55.6	-390,031	196.6
13	74.3	57.3	-87,811	222.2	-117,525	200.3	-220,737	60.4	-246,047	59.2	-282,109	198.9
14	77.0	58.3	-47,456	245.8	-58,102	221.4	-205,849	63.0	-228,838	61.9	-92,222	222.8
15	79.0	59.4	-37,605	256.2	-47,642	230.4	-197,732	64.9	-217,799	63.8	-58,849	233.3
16	80.3	59.9	-73,846	225.1	-93,998	192.3	-199,858	66.7	-218,054	65.7	-99,064	194.6
17	80.7	59.6	-116,450	82.4	-142,993	71.1	-210,490	68.4	-225,987	67.4	-143,006	71.7
18	80.3	59.4	-127,386	84.6	-155,232	72.4	-217,093	69.3	-231,996	68.4	-155,249	72.9
19	79.0	58.9	-144,902	84.4	-171,203	71.8	-225,882	69.0	-241,535	68.1	-171,219	72.3
20	77.0	59.0	-167,377	82.2	-187,606	70.6	-240,662	68.2	-257,324	67.3	-187,622	71.0
21	74.3	58.3	-161,771	80.1	-175,115	68.8	-258,393	65.9	-277,317	65.0	-175,131	69.2
22	71.2	56.0	-200,761	75.6	-215,689	66.1	-279,760	63.7	-300,765	62.8	-215,706	66.5
23	67.9	54.0	-231,755	71.6	-238,497	64.5	-300,983	62.2	-323,093	61.4	-238,513	64.9
24	64.6	51.5	-251,978	68.4	-262,299	62.6	-322,903	60.5	-346,505	59.8	-262,349	63.0
September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	51.3	44.1	-382,920	55.9	-410,279	53.4	-424,056	52.6	-541,583	49.9	-564,349	49.7
2	49.3	42.8	-413,724	54.0	-439,367	51.8	-444,954	51.5	-570,754	49.0	-589,750	48.8
3	47.6	40.8	-448,660	52.3	-457,529	50.6	-462,225	50.4	-596,789	48.0	-612,540	47.9
4	46.1	40.0	-468,266	50.7	-473,309	49.4	-476,338	49.2	-622,246	47.1	-635,650	47.0
5	45.1	38.9	-482,319	49.3	-486,135	48.3	-487,518	48.1	-646,178	46.2	-656,371	46.1
6	44.4	38.6	-489,412	48.0	-495,939	47.2	-497,120	47.0	-667,824	45.3	-673,703	45.2
7	44.2	38.5	-467,300	46.9	-484,215	46.2	-500,151	46.0	-671,415	44.5	-660,449	44.5
8	45.1	39.1	-1,355,053	123.3	-1,387,544	121.8	-468,586	45.1	-630,264	43.9	-1,390,516	117.6
9	47.6	40.5	-1,048,965	129.9	-1,148,591	127.0	-444,196	44.6	-577,273	43.5	-1,156,550	123.1
10	51.3	42.8	-533,490	161.9	-691,932	150.3	-453,149	44.4	-535,170	43.5	-795,172	145.8
11	55.7	45.2	-340,283	187.5	-420,949	167.0	-427,854	45.2	-494,918	44.4	-714,228	157.8
12	60.0	47.6	-151,633	207.0	-270,292	182.5	-395,852	47.0	-449,828	46.3	-519,576	172.3
13	63.8	50.1	-149,636	202.3	-235,088	177.9	-374,130	50.3	-409,147	49.7	-455,865	175.0
14	66.2	51.2	-69,435	223.5	-163,124	197.8	-345,003	52.8	-370,886	52.3	-240,277	197.2
15	67.1	51.5	-52,359	232.7	-112,010	204.0	-325,489	54.2	-349,076	53.7	-162,448	204.9
16	66.9	51.1	-95,668	196.1	-190,992	167.3	-325,371	55.6	-344,830	55.2	-239,801	168.9
17	66.2	50.9	-150,911	72.4	-198,130	61.7	-327,199	56.8	-345,152	56.4	-198,181	62.2
18	65.2	50.6	-171,782	73.4	-214,367	61.3	-333,093	57.0	-351,009	56.6	-214,427	61.7
19	63.8	51.1	-195,962	71.6	-238,998	60.0	-351,090	55.9	-369,913	55.5	-239,058	60.3
20	62.0	50.8	-225,769	69.1	-267,690	57.6	-382,304	53.9	-402,059	53.5	-267,751	57.9
21	60.0	49.7	-223,675	65.4	-263,098	57.0	-424,264	53.1	-442,533	52.8	-263,158	57.3
22	57.9	48.5	-286,294	62.4	-308,383	55.8	-464,557	52.3	-480,168	52.0	-308,444	56.1
23	55.7	47.2	-330,330	59.9	-348,435	54.7	-491,123	51.5	-509,485	51.3	-348,543	55.0
24	53.4	45.3	-362,141	57.8	-381,443	53.7	-516,923	50.7	-537,069	50.4	-381,524	53.9
October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	47.1	38.5	-469,754	50.5	-458,167	49.9	-463,479	49.1	-623,814	46.7	-630,863	46.5
2	44.8	36.6	-491,617	49.1	-478,359	48.5	-483,000	48.2	-648,453	46.0	-655,239	45.9
3	42.7	35.0	-508,247	47.7	-496,100	47.4	-500,433	47.2	-671,978	45.3	-677,811	45.2
4	41.0	33.8	-519,548	46.3	-510,805	46.3	-526,951	46.2	-693,740	44.5	-699,715	44.4

5	39.8	32.6	-528,234	45.0	-523,009	45.3	-563,539	45.1	-713,667	43.7	-719,742	43.6
6	39.0	32.3	-538,368	43.8	-537,558	44.2	-595,576	44.1	-731,264	42.9	-737,405	42.8
7	38.7	32.3	-543,367	42.8	-547,267	43.3	-631,150	43.2	-745,860	42.1	-735,595	42.1
8	39.4	33.0	-1,413,410	115.3	-1,432,611	116.2	-636,081	42.3	-728,622	41.4	-1,434,720	113.4
9	41.6	34.7	-1,170,274	121.0	-1,227,583	121.1	-621,982	41.7	-691,019	40.9	-1,232,369	118.5
10	44.8	36.8	-768,160	147.5	-826,702	142.8	-586,890	41.4	-644,751	40.7	-862,575	139.4
11	48.8	38.7	-529,521	168.0	-614,568	152.6	-545,513	41.5	-589,234	40.9	-762,890	149.1
12	53.0	41.2	-348,402	195.9	-405,949	170.0	-503,057	42.6	-539,869	42.0	-588,609	158.0
13	57.0	42.7	-286,818	191.4	-354,356	164.6	-469,828	45.0	-502,748	44.5	-526,392	161.9
14	60.3	44.6	-167,655	212.0	-236,309	182.9	-446,637	47.5	-470,805	47.0	-304,996	182.2
15	62.4	46.3	-133,570	219.6	-197,871	191.4	-435,955	49.2	-456,783	48.8	-226,831	191.6
16	63.1	46.3	-193,173	181.2	-295,585	156.0	-428,900	50.5	-450,576	50.2	-303,249	157.1
17	62.9	46.6	-180,948	66.1	-237,185	56.6	-428,667	51.1	-451,663	50.7	-237,224	56.9
18	62.1	47.2	-207,829	65.1	-261,310	54.8	-443,141	50.0	-465,522	49.7	-261,345	55.1
19	60.8	47.9	-245,945	63.3	-292,485	53.1	-473,553	49.0	-492,931	48.7	-292,520	53.4
20	59.1	47.4	-281,445	59.6	-318,881	52.5	-508,545	48.9	-526,090	48.6	-318,913	52.8
21	57.0	46.3	-288,219	58.1	-301,476	52.4	-531,741	48.7	-549,950	48.4	-301,512	52.6
22	54.7	44.4	-346,135	56.1	-347,559	51.6	-552,136	48.3	-568,422	48.1	-347,595	51.8
23	52.2	42.6	-384,394	54.2	-390,255	50.8	-573,367	47.9	-588,224	47.7	-390,335	51.1
24	49.6	40.7	-437,794	52.5	-433,662	50.0	-599,828	47.4	-608,722	47.2	-433,746	50.3

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	27.3	23.9	-611,327	37.9	-696,331	37.4	-756,875	37.6	-886,042	36.0	-892,521	35.9
2	25.6	22.5	-642,971	36.7	-754,908	36.5	-806,669	36.9	-902,605	35.5	-909,295	35.4
3	24.1	21.2	-701,453	35.6	-818,800	35.7	-822,102	36.1	-918,839	34.9	-925,630	34.8
4	22.9	19.9	-763,298	34.6	-836,103	35.0	-836,297	35.4	-934,226	34.3	-941,107	34.2
5	22.0	19.2	-822,407	33.7	-849,370	34.2	-850,203	34.6	-948,530	33.6	-955,480	33.6
6	21.4	18.7	-858,297	32.9	-865,959	33.4	-871,560	33.8	-960,676	33.0	-967,678	33.0
7	21.2	18.4	-852,543	32.2	-883,322	32.7	-903,539	33.1	-976,064	32.4	-962,856	32.4
8	22.0	19.1	-1,535,527	95.5	-1,542,984	97.0	-933,541	32.4	-982,965	31.8	-1,543,535	96.7
9	24.1	21.3	-1,366,048	100.0	-1,392,728	101.2	-923,127	32.0	-962,119	31.4	-1,404,075	100.9
10	27.3	23.7	-962,810	120.9	-1,024,743	120.7	-881,827	31.8	-920,309	31.3	-1,045,686	120.1
11	31.0	26.7	-768,256	132.8	-847,015	129.0	-822,480	31.9	-859,912	31.5	-912,412	128.0
12	34.8	29.5	-595,305	152.1	-708,111	134.5	-751,308	32.4	-786,322	32.0	-800,314	132.5
13	37.9	31.9	-509,683	156.7	-617,600	133.5	-703,887	33.5	-735,064	33.2	-720,634	132.3
14	40.1	33.0	-332,620	175.1	-451,341	153.1	-687,973	35.6	-713,126	35.3	-507,345	152.8
15	40.8	33.4	-261,584	180.1	-372,448	160.9	-686,741	37.2	-706,865	37.0	-398,861	161.6
16	40.6	33.3	-379,333	147.3	-505,515	130.6	-703,239	37.8	-715,706	37.6	-513,515	131.8
17	40.1	33.0	-294,517	51.9	-354,238	43.4	-730,020	37.2	-739,330	37.0	-354,382	43.7
18	39.2	33.0	-347,828	48.7	-405,002	42.3	-774,828	37.4	-782,656	37.3	-405,418	42.5
19	37.9	32.6	-406,703	46.6	-460,352	41.5	-800,339	37.6	-807,230	37.4	-460,707	41.7
20	36.5	31.3	-442,121	45.0	-500,829	40.8	-817,924	37.6	-824,423	37.5	-500,878	41.0
21	34.8	29.9	-476,248	43.9	-506,454	40.5	-828,820	37.5	-835,272	37.4	-506,541	40.7
22	32.9	28.4	-570,506	42.3	-590,520	39.7	-841,469	37.2	-847,959	37.1	-590,743	39.9
23	31.0	26.7	-629,875	40.8	-645,108	39.0	-855,276	36.9	-861,814	36.8	-645,201	39.2
24	29.1	25.2	-658,203	39.5	-691,798	38.3	-869,998	36.5	-876,599	36.4	-692,343	38.5

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	8.0	6.3	-899,018	30.3	-957,178	29.1	-958,415	29.4	-1,072,521	27.6	-1,080,435	27.4
2	7.6	6.0	-947,096	29.5	-968,415	28.1	-968,790	28.4	-1,084,105	26.7	-1,092,213	26.6
3	7.9	6.3	-957,604	28.6	-975,470	27.2	-978,029	27.4	-1,099,585	25.9	-1,099,955	25.8
4	8.7	7.2	-966,373	27.6	-985,993	26.3	-996,080	26.5	-1,104,026	25.2	-1,104,374	25.1
5	10.0	8.4	-983,680	26.7	-1,018,430	25.5	-1,029,769	25.7	-1,104,846	24.6	-1,105,187	24.4
6	11.8	10.1	-1,017,247	25.9	-1,046,506	24.9	-1,054,040	25.1	-1,102,550	24.1	-1,102,880	24.0
7	13.9	12.4	-1,040,079	25.2	-1,041,657	24.6	-1,053,755	24.7	-1,097,334	23.8	-1,084,820	23.7
8	16.1	14.8	-1,597,448	84.6	-1,589,004	84.6	-1,046,197	24.6	-1,089,500	23.7	-1,589,497	83.1
9	18.5	16.8	-1,477,732	88.3	-1,469,675	88.9	-1,031,927	24.6	-1,074,060	23.8	-1,471,010	87.3
10	20.8	19.0	-1,107,594	106.6	-1,116,059	107.7	-1,001,517	24.8	-1,042,201	24.2	-1,142,310	105.9
11	22.9	21.0	-887,892	116.3	-928,305	116.5	-935,132	25.4	-972,382	24.9	-979,522	114.4
12	24.6	22.3	-734,522	125.3	-815,391	121.5	-878,850	26.2	-907,776	25.7	-903,094	119.1
13	25.9	23.5	-690,724	133.9	-773,213	120.8	-831,425	27.3	-855,399	26.9	-864,390	118.9

14	26.8	23.9	-490,649	154.3	-555,117	137.0	-817,293	28.8	-832,363	28.4	-615,486	135.5
15	27.1	24.1	-409,551	160.3	-482,744	145.0	-818,542	30.3	-826,957	30.0	-508,874	144.8
16	26.7	23.9	-530,319	131.3	-625,780	117.6	-833,597	30.6	-841,579	30.3	-637,224	118.1
17	25.5	22.7	-426,269	42.6	-488,682	37.3	-882,964	30.8	-891,016	30.5	-489,074	37.3
18	23.7	21.4	-495,485	39.9	-542,438	36.2	-933,828	31.0	-941,331	30.7	-542,727	36.2
19	21.4	19.2	-547,275	38.5	-573,710	35.2	-966,686	31.0	-974,264	30.7	-583,149	35.2
20	18.7	16.8	-599,597	37.1	-633,006	34.2	-986,937	30.7	-994,582	30.5	-644,100	34.2
21	15.9	14.0	-628,460	35.9	-682,601	33.4	-1,004,639	30.3	-1,012,521	30.1	-683,673	33.4
22	13.3	11.4	-747,136	34.5	-802,557	32.4	-1,022,665	29.8	-1,030,468	29.6	-803,540	32.4
23	10.9	9.2	-811,985	33.3	-881,005	31.4	-1,041,306	29.2	-1,049,191	29.0	-881,406	31.5
24	9.1	7.5	-887,194	32.1	-939,758	30.5	-1,058,135	28.4	-1,066,126	28.2	-940,052	30.5