CoolingLogic™: Changing the Way You Cool

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Introduction

We've invented a highly advanced form of artificial intelligence for the heating, ventilation, and air conditioning (HVAC) industry and it's (collectively) called CoolingLogic™. **Why should you care?** You should care because our patented and patent-pending technologies reduce electricity consumption of HVAC equipment tremendously, in almost any scenario, and nearly every structure has HVAC equipment. **What does it cost?** Our patented technology, in its most basic embodiment, can be implemented simply by changing some computer code, so it's very inexpensive and has an almost unbelievable return on investment.

According to the U.S. Department of Energy, heating, ventilation, and air conditioning (HVAC) costs account for approximately 48% of energy costs ("Department of Energy: Heating & Cooling", n.d.). Additionally, some buildings cannot meet the cooling demand needed due to initial design issues and/or maintenance issues. CoolingLogic™ helps to solve these and other problems, and is applicable for nearly every structure needing and/or using some form of cooling, regardless of geographical region, structure type, or use, with few exceptions.

Essentially, CoolingLogic™ is a series of control schemes, methods, and calculation techniques which equate to an artificial intelligence. Unlike other HVAC-related A.I. systems, CoolingLogic™ focuses on the ambient conditions, equipment, structure, and user settings, rather than simply on user behaviors. It is capable of turning a typical 13-SEER HVAC system into a system achieving SEER ratings as high as 65 SEER, with the cost per iteration only being that of some additional computer code and (optionally) a few low-cost temperature sensors. CoolingLogic™ does this by conditioning a structure when it is most cost-effective to do so, and by using the most cost-effective means to do so. It is understandable that these claims may sound too good to be true, so that's why we've spent considerable resources and effort to produce documents which substantiate these claims. If interested, please visit www.CoolingLogic.com for more information pertaining to CoolingLogic™, specifically, or visit the automation page of the website of my mechanical contracting and controls company, Johnson Heating and Cooling, LLC at https://cooljohnson.com/BuildingAutomation.html.

In 2016, Johnson Solid State, LLC was issued a patent for using the historical operational load of HVAC systems to precondition structures (U.S. Patent No. 9,447,985). In 2016, we also applied for a Continuation in Part (CIP) patent (U.S. Patent Application No. 20,160,348,936 A1). Additional patents and international patents are pending.

Since every building and climate is different, I discovered that using the historical operational load is a more accurate way to determine the preconditioning needed, rather than simply using temperatures alone. I also discovered a relationship between outdoor air temperature, indoor space temperature, outdoor damper position, mixed air temperature, supply air temperature, return air temperature, and operating status of the ventilation system (i.e. on, off, 50% on, etc.). This relationship helps to determine a specific building's thermal characteristics, which aids in determining the heat energy needed to be transferred for a specific future time period. Along with this, we use Newton's Law of Cooling to predict the space temperature of the structure for the future time period, based on many factors (including the future set point temperature desired by the building occupants, which could also be a default temperature if none is specified).

After a lot of calculus, we came up with an equation to predict the space temperature for a future time period. Next, we calculate a metric which represents the amount of heat transfer which will be needed during the next period (i.e. minute, hour or day). Once we know the next time period's heat transfer needs and we know exactly when heating or cooling will be needed, we can deliver the right amount of heat energy at the most optimal time.

There is a natural variation of outdoor air temperature during the day/night cycle where the temperature goes up until the "heat of the day", and then temperature goes down until dawn. Cooling a structure at dawn, rather than during the "heat of the day" is much less expensive. CoolingLogic™ harnesses the natural variation in outdoor air temperature by using artificial intelligence to precondition the structure during a time in which the cost per unit of heat transfer is the least expensive. Simply running a traditional refrigerant-based air conditioning system at dawn saves 30% of the energy per BTU of heat transfer. If considering outdoor air economization (which is the intake of outdoor air rather than the cooling of indoor air) the savings can be as high as 90%. But, CoolingLogic™ does not just precondition, it also can predict when conditioning will be needed, and cool or heat proactively, and at optimal times of the day/night.

From a controls perspective, there is only one good way to effectively precondition a structure, and that is by considering the operational load/heat transfer metric. Two terms were used together in the previous sentence because they are arguably the same thing. Regarding preconditioning: essentially, it is not enough to know if it will be hot or cold on a particular day because there are other factors which impact the amount of heat transfer which will be needed to condition a structure. Indoor heat energy produced inside the structure (known as *IHEPIS* in the patent disclosures), the thermal heat transfer coefficient of the structure, the thermal mass of the structure, and other factors, all affect how the HVAC system(s) will need to act. Our patent portfolio "locks up" the most effective, accurate, and commercially viable means of predictive conditioning. The difference between an effective control scheme and an ineffective control scheme (for example, morning air purges) could be as much as a difference between energy savings of 30-80% versus only 5-30%, and that is considering that the alternative scheme to CoolingLogic™ is very skillfully implemented. In some cases, alternative preconditioning schemes can actually decrease the energy efficiency.

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Overview of CoolingLogic™

An easy way to understand CoolingLogic™ is to think of the term "load-shifting." Essentially, CoolingLogic™ shifts the cooling operation of HVAC systems from the "heat of the day" to a time when transferring energy is significantly less expensive. Outdoor air temperatures go up and down, typically directly correlated with the intensity of sun-light on that region of the earth: up after dawn, and down after the "heat of the day" (usually around 3:00 pm). This is a pretty reliable occurrence. Typical HVAC system operation is reactive, meaning that when the indoor air temperature goes up, the A/C comes on. It's easy enough to understand that as it gets hotter and hotter outside, the A/C runs more and more to maintain set point. CoolingLogic™ is proactive instead of reactive, meaning that instead of waiting for the outdoor air temperature to go up before cooling, it will cool during the coolest part of the day - when it is much less expensive. Additionally, CoolingLogic™ utilizes the thermal capacity of the structure (and the materials inside the structure) to "store cool".

One method of CoolingLogic™ is to utilize mathematically calculated heat transfer "metrics", based on historical and input data, in order to predict the next period's (i.e. the next day's) heating or cooling energy required. This is accomplished using complex algorithms which accurately predict:

1. The next day's average space temperature → Predicted Average Space Temperature (*PAST*).
2. The amount of heat energy that the HVAC systems will need to transfer (or produce) for the next day → *NTotal_heat_transferred*.
3. The optimal time period(s) during the next day to cool or heat the structure, when the outdoor air is most suitable (causing the HVAC system to operate proactively instead of reactively).
4. Properties of the structure and its components, including a thermal capacity metric. **This is done automatically, without user input.**

The process then heats or cools the structure, using either outdoor air alone or mechanical methods, at the optimal time of day. The structure retains the "hot" or "cold" depending on it's thermal capacity and system operation. Hence, less heating or cooling is needed at non-optimal times of the day (such as at the "heat of the day"), when it would be more expensive to run HVAC equipment to cool. Therefore, energy costs are greatly reduced.

As we have calculated, a typical big-box store such as Home Depot could save between 30% and 80% in energy costs if CoolingLogic™ were in use (dependent on many factors). Consider the electricity consumption differences between cooling at the different times of the day. *Figure 1* below exemplifies the temperature swings that take place between the day and night. Cooling in the early morning, in this example, would be much more efficient.

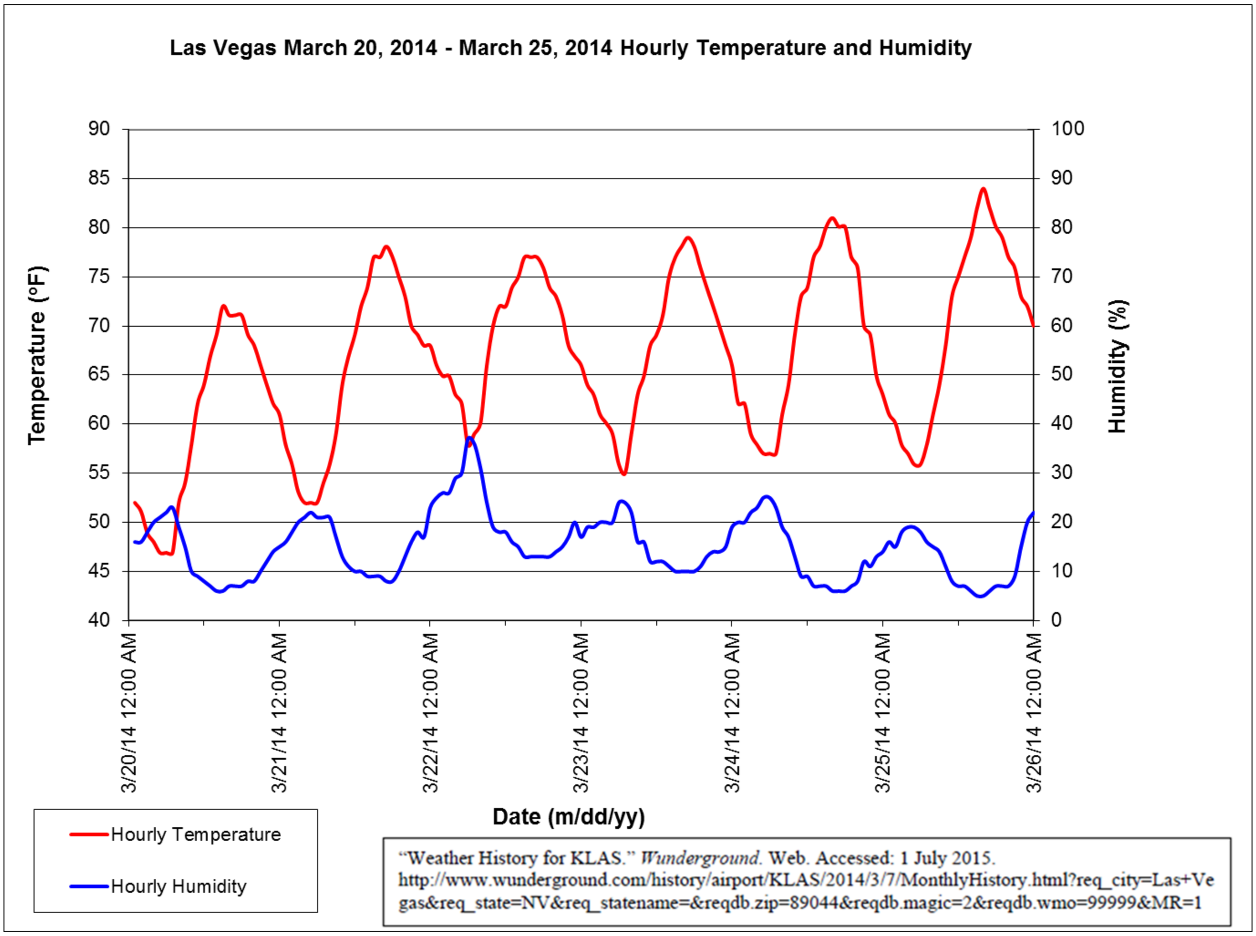

Figure 1: *Example Temperature/Humidity Swings from Day/Night Cycle*

Frequently Asked Questions

1. What about humidity?
   - Humidity is not a problem, but rather a good thing. As the outdoor air with higher relative humidity (RH) is injected into the building and is heated by the materials and things inside the structure, the RH of that same air drops as it increases in temperature.
   - Air with higher RH increases the thermal heat transfer coefficient of the air, so cool air with higher RH can feel "cooler" than dry air of the same temperature.
   - Cooling with outdoor air does not cause condensation inside the structure.
   - HVAC equipment doesn't need to dehumidify the air because CoolingLogic™ almost perfectly predicts the amount of energy needed to heat or cool the structure - meaning (typically) no "conventional" heating or refrigerant-based cooling is needed. If the conventional, refrigerant-based A/C doesn't come on, then the HVAC system(s) will not be dehumidifying the air.

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2. Don't the occupants of the structure get too cold?
   - No, limits can prevent over-cooling; however, in many cases the limits will never even be reached.
   - Take a really close look at the space temperature of *Figure 4* below showing CoolingLogic™ in operation You'll notice that the temperature only drops by 1.1ºF after the structure reaches equilibrium, but also before the building becomes occupied - that's enough pre-cooling to avoid refrigerant-based cooling for an entire day in this case.

3. What if it's not cool enough outside to use outdoor air to cool?
   - In almost every location worldwide, there is usually some time when outdoor air can be used to cool - the seasons for doing so simply get pushed closer to the winter the closer to the equator one gets.
   - The hottest months of the year in Michigan, for example, have an average low of around 63ºF - which is plenty cool enough to use the outdoor air for cooling.
   - Even if ventilating with outdoor air is not a suitable solution for cooling, systems can still obtain savings of around 30% by using refrigerant-based cooling during the coolest part of the day rather than during the "heat of the day".

The following graphs show relationships between the values of outdoor air temperature (*ODAT*), space temperature (*ST*), elevated *ST*, the energy transfer metric, and the Energy Efficiency Ratio (EER). It's important to note that we have been very conservative with our numbers. Some of the data is real, and other data is calculated/estimated using mathematical modeling, laws of physics (Newton's Law of Cooling), etc. *Figures 2* and *3*, which do not show CoolingLogic™ incorporated into the systems, are pretty much "best-case scenarios" of what one might hope to find. Basically, those "best-case scenarios" are usually never evident in real-life scenarios. Conversely, the graph for the CoolingLogic™ (CL) scenario is not a best-case scenario (*Figure 4*). The CoolingLogic™ graph does not factor in "typical" roof-mounted exhaust systems, which typically have a much lower differential static pressure and may be twice as efficient as a typical ducted roof-mounted packaged HVAC unit, which is the basis for these calculations. Oftentimes, roof-mounted exhaust fans would also be incorporated to encourage the transfer of air and significantly lower the cost to do so. The lower cost per volume of air movement of roof-mounted exhaust fans, coupled with the efficiency of roof-mounted exhaust fans in removing the hot and stratified air near the ceiling of a tall structure, would cause CoolingLogic™'s efficiencies to increase even more.

As demonstrated by the figures below, the EER is greatly increased when CoolingLogic™ is used (EER is inversely proportional to electricity use).

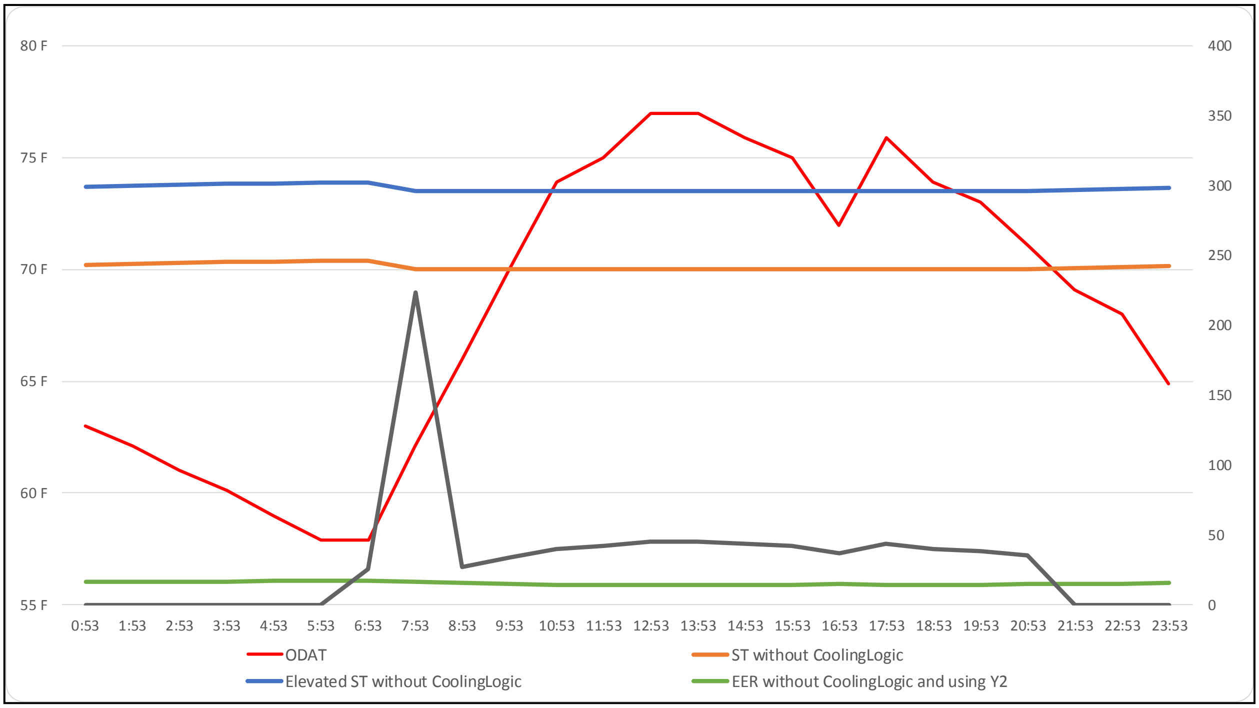

Figure 2: *Typical System with no inefficiencies, without CoolingLogic™, and using Y2. Calculated EER = 15.0*

Figure 3: *System with "high efficiency" control scheme, no inefficiencies, and no CoolingLogic™ (allowing for ODA economization and not using Y2). Calculated EER = 47.1*

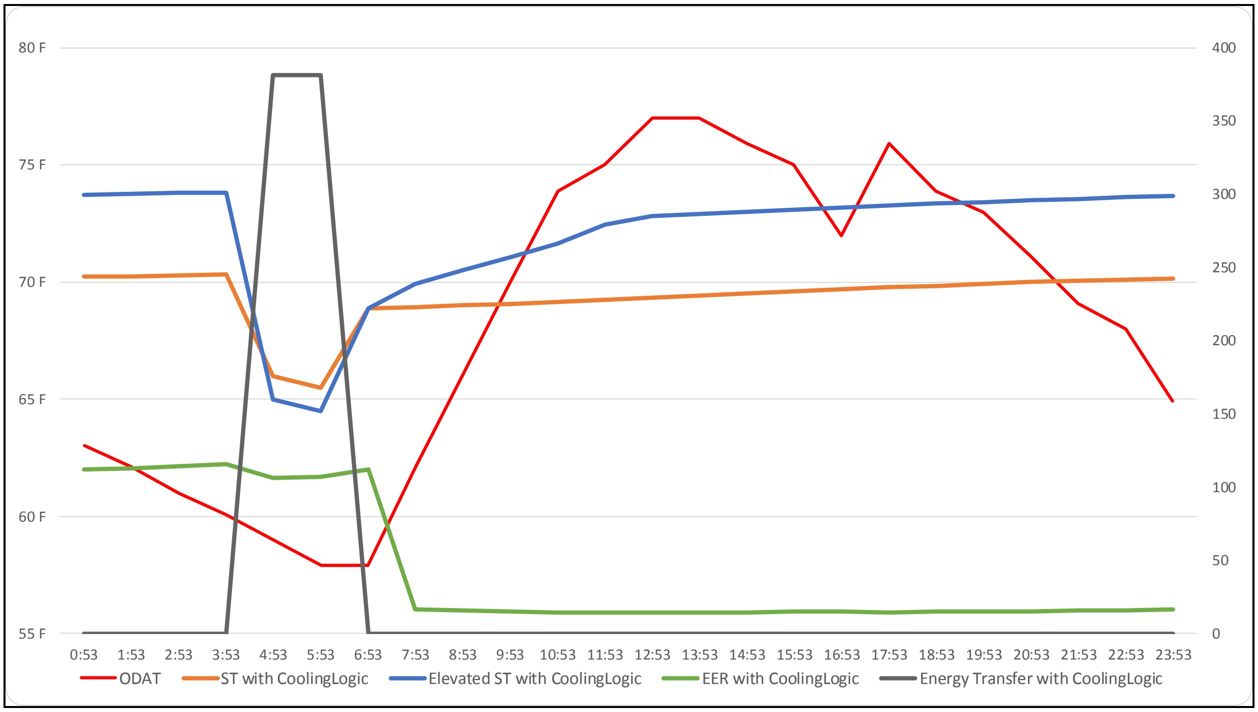

Figure 4: *System with CoolingLogic™ and no inefficiencies in fan operation. Calculated EER = 106.6*

If you are interested in obtaining the original file used to create the above charts, with the equations (and values) embedded, those can be provided.

Financial, Energy, Statistical, and Data Tables

The following two tables show the savings that could be realized using CoolingLogic™ in the residential and commercial markets, respectively.

While reviewing the total annual savings offered by CoolingLogic™, please understand that the average square-footage of the typical commercial building used in the calculations is set to 15,536 square feet. This is a very important consideration because many commercial structures have much greater square footage than 15,536 square feet, and therefore larger savings could be realized.

Residential Sector	Georgia (Atlanta)	Michigan (Detroit)	Nevada (Las Vegas)	New York (New York)
State Population [14]	10,214,860	9,922,576	2,890,845	19,795,791
Total Residential KW [9]	57,178,165,790	33,527,330,428	11,927,992,556	49,968,617,464
Single-dwelling structures (typical homes) [12]	2,107,317	2,988,818	432,437	3,198,486
Single-dwelling structures KW	23,510	9,849	21,145	10,650
Multi-dwelling structures and mobile homes [12]	974,420	1,245,461	395,020	4,480,821
Multi-dwelling structures KW	7,837	3,283	7,048	3,550
Price per KW [17]	$0.1164	$0.1446	$0.1293	$0.2007
Total annual electricity costs (single-dwelling structures only)	$2,736.56	$1,424.23	$2,734.05	$2,137.46
% of electricity due to A/C [10]	48%	48%	48%	48%
Annual electricity costs due to A/C (single dwelling structures only)	$1,313.55	$683.63	$1,312.34	$1,025.98
Estimated reduction in A/C electricity consumption due to CoolingLogic™ (single dwelling structures only)	30%-80% Configuration dependent	30%-80% Configuration dependent	30%-80% Configuration dependent	30%-80% Configuration dependent
Annual electricity costs saved due to CoolingLogic™ (single-dwelling structures only)	$394.07 - $1,050.84 Configuration dependent	$205.09 - $546.90 Configuration dependent	$393.70 – $1,049.88 Configuration dependent	$307.79 – $820.78 Configuration dependent
Annual repair costs saved due to CoolingLogic™ (single-dwelling structures only)	$50 +/-	$50 +/-	$50 +/-	$50 +/-
Annual amortized life-cycle value saved due to CoolingLogic™ (single-dwelling structures only)	$50 +/-	$50 +/-	$50 +/-	$50 +/-
Annual total estimated / calculated savings due to CoolingLogic™ (single-dwelling structures - "typical home")	**$497.07 - $1,150.84**	**$305.09 - $646.90**	**$493.70 - $1,149.88**	**$407.79 - $920.78**

The proportion of KW per home is different for single-dwelling structures than it is for multi-dwelling structures. The factor used is that single-dwelling structures are attributed three times the energy consumption of multi-dwelling structures, per dwelling. For example; one single-dwelling structure, in these calculations, is attributed an energy consumption which is equal to three multi-dwelling structures. The base-line reference of energy per dwelling was derived from the United States Census Bureau's report on the number and types of dwellings [12], and also a U.S. Energy Information Administration report on the amount of electrical energy used in the residential sector per State [9].

According to Energy.gov, approximately 48% of residential energy consumption is due to heating and cooling systems [10]. Since not every residence in the U.S. has central air conditioning, and since the term "energy consumption" is seemingly inappropriate, since electricity costs exceed that of natural gas in many areas, it seems reasonable to use 48% as a conservative baseline for residential electricity consumption due to air conditioning.

To find the energy per single-dwelling structure, and per multi-dwelling structure, the following is used, respectively; $E1 = T / (S + 1/3 * M)$; $E2 = T / (3 * S + M)$; Where, E1 = energy per single-dwelling structure, E2 = energy per multi-dwelling structure, T = total energy, S = number of single-dwelling structures, M = number of multiple dwelling structures.

Commercial Sector	Georgia (Atlanta)	Michigan (Detroit)	Nevada (Las Vegas)	New York (New York)
State population [14]	10,214,860 (3.18%)	9,922,576 (3.09%)	2,890,845 (0.90%)	19,795,791 (6.16%)
Total commercial annual KW [15]	46,598,300,157	37,337,254,340	9,407,581,353	76,550,163,529
Total number of commercial structures per state [13]	177,971	172,879	50,366	344,897
Annual KW per Commercial structure	261,831	215,973	186,784	221951
Total Commercial Square footage Statewide [13]	2,764,906,607	2,685,848,144	782,486,176	5,358,319,792
Average square footage per structure	15,536	15,536	15,536	15,536
Electricity per square foot KW	16.85	13.90	12.02	14.29
Price per KW [18]	0.1036	0.1087	0.0947	0.1614
Total annual electricity costs (per average commercial structure)	$27,125.69	$29,299.32	$17,688.48	$21,806.43
% of electricity due to A/C	48%	48%	48%	48%
Electricity costs due to A/C (per average commercial structure)	$13,020.33	$11,268.62	$8,490.47	$17,194.97
Estimated reduction in A/C electricity consumption due to CoolingLogic™ (per average commercial structure)	30%-80% Configuration dependent	30%-80% Configuration dependent	30%-80% Configuration dependent	30%-80% Configuration dependent
Annual electricity costs saved due to CoolingLogic™ (per average commercial structure)	$3,906.10- $10,416.26 Configuration dependent	$3,380.59- $9,014.90 Configuration dependent	$2,547.14 - $6,792.38 Configuration dependent	$5,158.49 - $13,755.98 Configuration dependent
Total # of 10-ton cooling systems	4	4	4	4
Square feet per ton (approximate)	388	388	388	388
Annual repair costs saved due to CoolingLogic™ (per average commercial structure)	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00
Amortized life-cycle value saved due to CoolingLogic™ (per average commercial structure)	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00	$100 +/- per unit = $400.00
Annual total estimated / calculated savings due to CoolingLogic™ per sq. ft. (per average commercial structure)	**$0.30 - $0.72**	**$0.27 - $0.63**	**$0.22 - $0.49**	**$0.38 - $0.94**
Annual total estimated / calculated savings due to CoolingLogic™ (per average commercial structure)	**$4,706.10 - $11,216.26**	**$4,180.59 - $9,814.90**	**$3,347.14 - $7,592.38**	**$5,958.49 - $14,555.98**

Data on commercial buildings per State was difficult to find. Such as this is the case, we've based our calculations on the national averages divided by State population to derive the number of commercial buildings per State. Likewise, we've used national averages of square footage to determine our calculations. According to statistical data [13], the national average square footage of a commercial building is equal to 15,536 sq. ft., when the total square footage of commercial floor space is divided by the total number of commercial buildings. We used 10-ton HVAC systems as a baseline, since some buildings will have larger-capacity systems and some will have smaller-capacity systems.

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Conclusion

Many traditional schools of thought or preconceived notions of industry professionals may have been broken or redirected by the CoolingLogic™ technologies and the documentation pertaining to the technologies. Humidity, traditionally seen as an energy “drainer” by professionals in the refrigeration industry, may now be seen as an ally to saving energy. Additionally, humidity during the cooling season, which has traditionally been seen as a bad thing (concerning human factor considerations) may now be seen as a good thing. Perspectives on thermal capacities of many may shift from simply considering the air to now considering all matter inside the structure’s outermost boundaries. Also, the term “thermal heat transfer coefficient” will likely be the subject of many more conversations. As in life, when thoughtful consideration is given to a matter before a decision is due, it’s likely that the outcome will be more desirable. CoolingLogic™ saves energy because it transfers precisely the right amount of energy at precisely the right time, and uses precisely the best mode of energy transfer to do so.

CoolingLogic™ offers additional benefit in terms of “reducing the links in the chain” of the things which must operate efficiently for systems to attain the highest possible transmission of heat energy. An HVAC system rarely operates at the listed performance of the system because there are many components to HVAC systems whose single inefficiency in operation affects the total efficiency of the system as a whole. For example: coils may become loaded, refrigerant charges may be less than optimal, and motors may have failed. Inherently, CoolingLogic™ is significantly advantageous in maintaining extremely high levels of operation with only few components affecting efficiency when compared to conventional refrigerant-based cooling methods. CoolingLogic™ reduces energy consumption, reduces wear and tear on HVAC equipment, increases the life-span of HVAC equipment, reduces repair expenses, reduces service expenses, and has many other considerations of consequence. In many cases, CoolingLogic™ increases indoor air quality significantly because it may “flush” a structure with outdoor air, thereby reducing CO_2 and hazardous VOCs in the indoor air.

For energy providers: in future years, CoolingLogic™ will play a significant role in both reducing load demands and in reducing peak load demands in their service area.

Disclaimer

This document has been produced and provided to you with the intention of showing the benefit of CoolingLogic™. This document has been prepared in good faith; however, we take no responsibility for anything contained in this document which may be factually incorrect. This document is not to be used to make any financial or business decisions.

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About the Charts

Using the example structure given in the White Paper for CoolingLogic™, it's reasonable to assume that a big-box store (i.e. Home Depot) may have a thermal capacity of around 500 tons/∆ degree. Also, using the rate of temperature change calculations given in the white paper for CoolingLogic™, it can be calculated that such a structure would have a heat absorption (due to the intake of outdoor air and also due to conduction) of 1.681 tons/hr/degree in difference in temperature between *YODAT* (a variable from the first CIP of CoolingLogic™) and space temperature (*ST*).

For our calculations we used the *AB* (a variable from the first CIP of CoolingLogic™) derived from a field-installed system at a building in downtown Detroit, MI. The structure had an *AB* of around -23 degrees F. In many respects the structure used to obtain *AB* was a very poor choice because (1) it has no insulation in its walls or ceiling; (2) it does not directly intake outdoor air; and (3) its *IHEPIS* (a variable from the first CIP of CoolingLogic™) was pretty low. At this time we do not have enough data to confidently provide a "typical" *AB* value; however, the *AB* of this building is -23, so we've rounded to make the math a little easier and we've used an *AB* of -20 in our calculations. While this value may have error, I can say that it does seem reasonable/conservative considering that I've seen other structures with much lower *AB* values. All in all, I consider -20 to be a reasonable/conservative *AB* value. For the energy efficiency ratio (EER) of the HVAC systems we used a value/rating of 14. While all of this complex math and information is very challenging to comprehend for those not in the HVAC industry and/or who are engineers, I'll simply state that we've used very conservative numbers.

Referenced data and equations can be found in the CoolingLogic™ White Paper, and in the patent Continuation In Part (CIP) which are on our website www.CoolingLogic.com. Much of the referenced data is located in the appendix and is very "thick" to read, but provides a decent proof for the value added because of the learning A.I.

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