CoolingLogic™: Mosaic Christian Church
A Case Study

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Introduction

In 2016, David Johnson Jr. was contracted to design, build, and install a building automation system, provide mechanical plans, and perform an air balance report for Mosaic Christian Church, in Detroit, Michigan. Mr. Johnson is the inventor of the CoolingLogic™ technologies, which are owned by Johnson Solid State, LLC.

CoolingLogic™ technologies were utilized to tune the systems and achieve remarkable results: a **summer electricity consumption which is below that which is used in the winter.** These results are particularly impressive, because the structure's Manual J calculations dictated that eight four-ton air conditioning systems be installed, **with a Manual J cooling load calculation of 28.25 tons in total (310 square feet per ton)**. The lower electricity consumption in summer demonstrates that the cooling system actually used less electricity than that needed to operate the one Burnham Alpine boiler and a few high-efficiency pumps.

The church's electricity and gas usage are shown on the following page. Supporting documentation is available upon request.

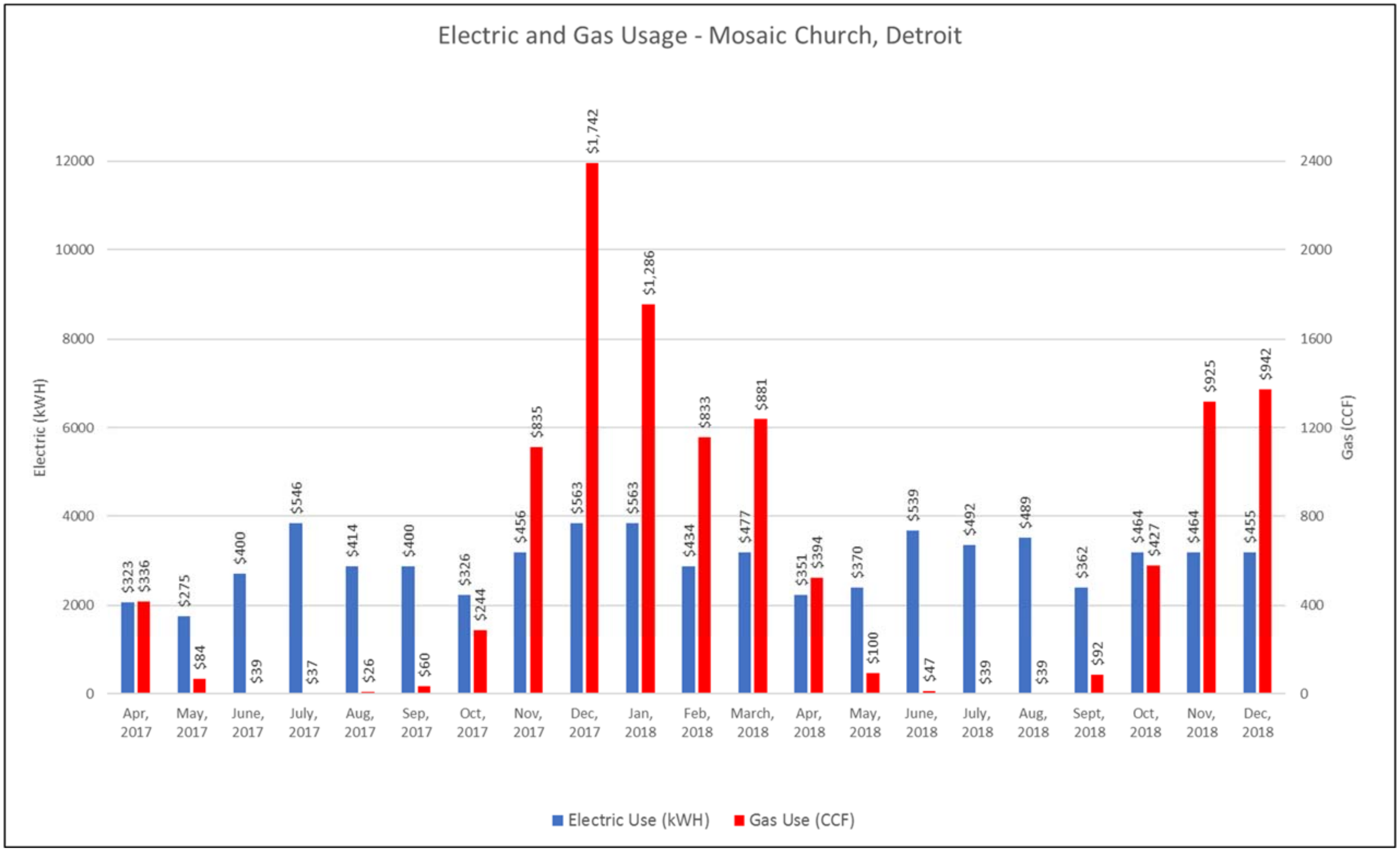

Figure 1: Graph of Electricity and Natural Gas Consumption and Cost for the Church

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Details on the Case Study Environment

Of important note is the fact that the operation of pre-cooling during the study was not dependent upon the upcoming occupancy schedule of the day, so essentially, the structure always pre-cooled as if it were going to be occupied each and every day. The structure was in fact usually occupied each and every day, as normal office hours for a portion of the structure are kept Monday to Friday, and was occupied during the weekend because of church service. Essentially, the pre-cooling allowed for comfortable temperatures inside the structure, whether it was occupied or not.

Moreover, these results were achieved at a structure that is not optimal for heating and cooling. The heating system at the church was designed to be extremely efficient. Significant engineering and consideration culminated in a system operation wherein the boilers provided for the lion's share of the heating load, therefore furnaces were only used for emergency situations or for when a very rapid temperature increase was needed. The 399,000 BTU Burnham Alpine boiler has its firing rate modulated by the automation system and a high difference in temperature to and from the boiler is maintained via advanced programming in the automation system. The automation system communicates with the boiler's Sage 2 controller via its Modbus interface. Despite these measures directed at energy savings, the building's gas usage was high during winter months, indicative of the structure's lack of proper insulation.

The Mosaic Christian Church is located at 80 W Alexandrine St, Detroit, MI 48201, which is in downtown Detroit. Ambient temperatures at this location tend to be relatively higher than in other areas of equivalent latitude which are west of Detroit, because of the effect due to being in the city. The structure is likely over a hundred years old and is of wooden construction with a combination of lath board and drywall on the interior of the structure. The structure is uninsulated and has some single pane windows on its exterior. The first floor is elevated and the basement floor is about four or five feet below grade. The structure is roughly 145' long by 68' wide, being approximately 9,860 square feet per floor. The entire first floor is utilized and approximately half of the basement is utilized, while the other half is used for storage. The actual utilized floor space which is not used for storage is approximately 15,000 square feet. The LoopCad software noted the calculated conditioned space of the first floor as being roughly 8,765 square feet.

The structure has the following equipment servicing a total of five forced air HVAC zones:

Table 1: Equipment List

Quantity	Equipment Type	Manufacturer and model #
9	Furnace (5 Ton Drive)	Rheem- R92PA1151524MSA
8	A/C Condensing Units (4 Ton)	Rheem- RA1348AC1NB
1	Centrifugal Fan (18”) 5,000 CFM	Fantech- FKD18XL
1	Ceiling Exhaust Fan- 5,000 CFM	Dayton- 20VD08
1	Condensing Boiler- approx. 94%	Burnham- APL-399
9	Cassette Pumps (0.75 amps)	Grundfos- UPS1558FC
1	Cassette Pump (1.3 - 1.8 amps)	Grundfos- UPS2699
1	Variable Frequency Drive	For Centrifugal Fantech Fan
2	24VAC Servers (approx. 30 watts)	For Automation System
3 or 4	Electric Water Heaters	5 gallon +/-, under the Sinks

Additional equipment information may be found on the air balance report and other various documents relating to the project (see Appendix).

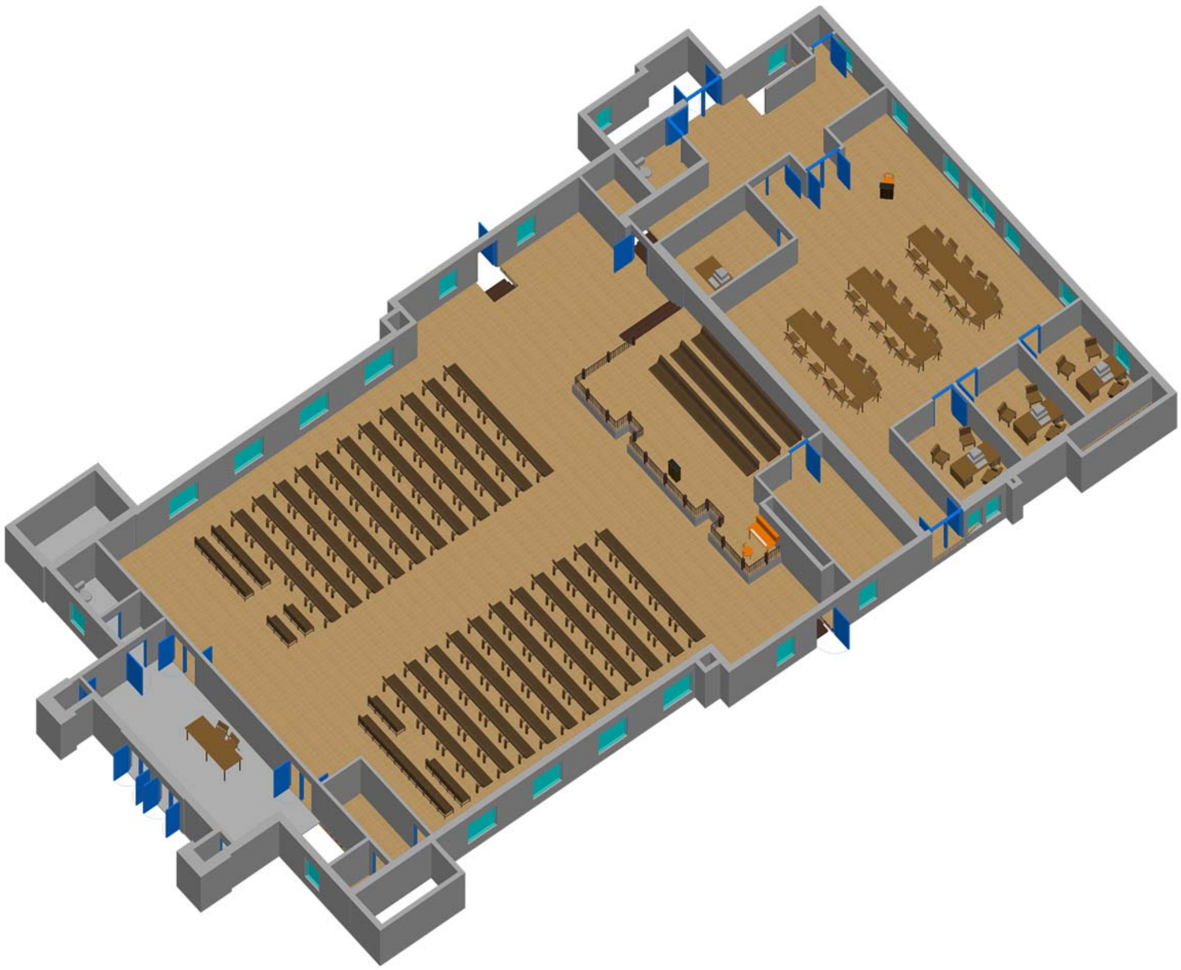

Figure 2: CAD Model of Church's 1st Floor

Eight out of nine furnaces service the first floor are paired so that each pair services a respective zone and utilizes the same ducting as the other in the pair. The furnaces do not run, however, except in the case that church service is in session, and/or refrigerant-based cooling is needed, and/or emergency or quick temperature increase is required. Essentially, the furnaces do not ever come on, except that they energize their blower motors while church service is occurring. The one furnace which services the basement cycles its blower motor, as is needed, to heat the basement and has no provision for refrigerant- based cooling. Three of the four pairs of furnaces servicing the first-floor service the sanctuary, with the one pair servicing the rooms behind the pulpit and sanctuary.

As can be seen in the plans for the structure (Figure 3), the centrifugal fan provides for supply-side injection of outdoor air into three of the four first-floor zones. The novel supply-side injection of a "jetted, high-velocity air stream" causes a negative pressure region adjacent to the injection point of the jetted, high-velocity air stream, which in turn induces a strong draft of air to flow from the return air duct to the supply air duct without

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the need to operate the blower motors of the furnaces. The relatively strong draft of air is important because it allows for the air in the supply air ducting, downstream of the outdoor air injection point, to become mixed and tempered before leaving the supply duct via the air terminals. Additionally, it is important to this structure, specifically, that the draft be induced because a temperature-sensitive pipe organ sits just in front of the return air grilles for three of the four pairs of furnaces which service the first floor. There is not an outdoor air injection fan associated with the pair of furnaces which service the back half of the church, as that area relies on infiltration cooling from the other areas. Because the furnaces generally do not need to run for heating, cooling, or ventilation, they see little use and typically only run their blower motors during church service to avoid the rare time when they might be off and then turn on during church service.

In the center of the sanctuary is the Dayton ceiling exhaust fan. The Dayton fan is a low differential pressure fan that blows air from the sanctuary to the church's attic space, thus acting as a power-exhaust for the whole system. The attic space is ventilated, so the attic is cooled by the relatively cooler air from the sanctuary each time the process ventilates. Advanced programming in the automation system, which could be implemented into a thermostat, controls the process.

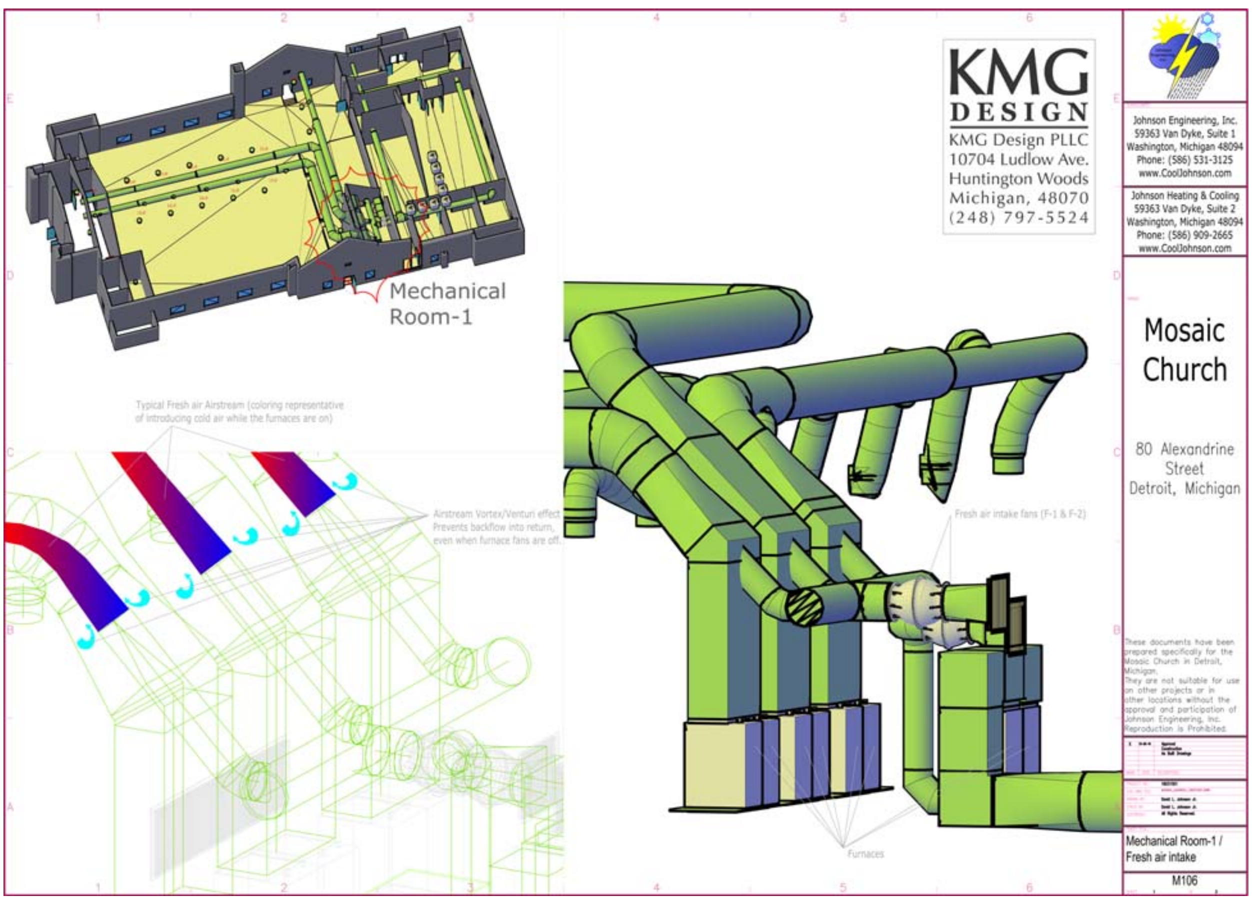

Figure 3: Mechanical Plan M-106

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As can be seen by the plans for the (zoned) in-floor heating system, the highly efficient system heats the first floor from the floor upward, so excessive heat is not lost due to stratified air. Combined with techniques to encourage greater Delta-T between inlet and outlet temperature of the boiler, and that the boiler's firing rate is controlled to "hit the sweet spot" on the boiler's burn efficiency, the system obtains near-ideal use of natural gas heat and saves the church significant expense due to heating costs.

Implementation of CoolingLogic™ Technologies at Mosaic Christian Church

The automation system at the church was built and programmed to utilize the teachings and methodologies of the CoolingLogic™ technologies. A CO_2 sensor was employed to measure indoor CO_2 levels and maintain acceptable ventilation. The overall system was controlled via servers running code that controlled the mechanical equipment. For the initial code setup, a plurality of sensors and real-time run-time calculations measured equipment operation and complex multivariable calculous operations determined systems and building performance. Base-line tuning was established and the operation of the systems were manually set to function such that benefit would be realized based on static parameters and settings which were established based on the teachings of the CoolingLogic™ technologies. Additional benefit (energy reduction) would be realized by using non-static parameters and settings (i.e. a "full-blown" CoolingLogic™ embodiment). Additionally, with a "full-blown" CoolingLogic™ embodiment, the installation would be self-regulating and universally "drop-in ready". For this installation I spent a week emulating what CoolingLogic™ can and would do better, and automatically.

Measurements and calculations establish that the structure's *AB* is approximately -23. *AB* is the difference of the outdoor temperature minus the indoor temperature, at the point (equilibrium point) at which the indoor temperature neither increases nor decreases, while the HVAC systems are in their normal state (inactive). An *AB* of -23 indicates that the equilibrium point for the church, if a setpoint and indoor air temperature are at 68ºF, would be 45ºF. Therefore, at 45ºF outdoor air temperature, the structure would neither heat nor cool if the HVAC and boiler systems were not operational. This value was obtained passively, with the equipment operating normally, and was performed over the course of only a few days. A seasonal variation of this value may occur, but AB is calibrated each day in various embodiments.

Implementation of CoolingLogic™ Technologies Elsewhere

For residential systems, i.e. furnace-based systems, an additional fan could be utilized to inject outdoor air directly into the supply air stream of the furnace (patent-pending). A furnace with a built-in fan could prove beneficial, however, it could be understood that adding any height to a furnace's profile may make furnace replacement projects problematic, so in considering the replacement market, it might make sense to supply furnaces with a separate fan (as part of a kit) which can be installed on the side of the furnace or supply ducting because supply-side injection of outdoor air would be the most efficient means to inject air.

For rooftop units with economizers, CoolingLogic™ could increase the SEER value of the equipment significantly when used in conjunction with a CoolingLogic™ thermostat as part of a "kit". For best results, the blower motor should at least have two speeds of operation, one speed at 100% and the other at 50%. The 50% speed would be preferable because of the lower differential static pressure, resulting in much more efficient transfer of heat per unit of electricity consumption.

Additional information about CoolingLogic™ may be found at: www.CoolingLogic.com. Additional information about the system at Mosaic Christian Church, and images of the automation system, may be found at: https://cooljohnson.com/Building-Automation-Systems-Michigan/Detroit/Mosaic-Christian.html. Attached to this report are the energy bills for the church, the Manual J calculation, the in-floor heating layout, the air balance report, etc.

A site visit to Mosaic Christian Church to evaluate the facility and equipment can be arranged upon request.