Massachusetts Interfaith Power and Light

In Depth Case Study: Boston Synagogue, Boston MA

A view from the front of Boston Synagogue with the new Heat Pump

Boston Synagogue (previously known as Charles River Park Synagogue) is a small, lay-led synagogue located in the heart of the Old West End near Massachusetts General Hospital. The building was constructed in 1971. It is a single-story structure, with a dramatic pitched "skylight" roof over the Sanctuary. The exterior and much of the interior has architectural block walls. The interior spaces include a Sanctuary with linked Social Hall, office wing, large lobby, restrooms and a kitchen. A small basement provides space for mechanical equipment. The synagogue, which is used year round, had been using the original air conditioning and heating until 2008.

INITIAL CONDITIONS

Air Ducts in the Sanctuary

Before the changes, the synagogue used ***steam heat*** that was imported from Trigen. (See appendix for details on Trigen heating). The synagogue uses no oil or gas. Domestic hot water is heated by electricity. Stoves are electric. The heating system was located in the basement and dispersed heat throughout the building through air ducts. The treated air was pushed through the air ducts by a large fan system in the basement. (See picture at right.) For many years the system worked reasonably well, but there were problems that burdened the synagogue. The building took a very long time to

Air Ducts in Basement

heat and cool, primarily because both systems needed to travel through the basement and go through large air ducts to reach the sanctuary. Because the synagogue had manual thermostats, this lag-time required that someone be there about an hour ahead of time to turn up the thermostat so that the building would be comfortable for a service or meeting.

Manual Thermostats of old system

Non-programmable thermostats result in a superfluous amount of energy use, as people will often turn them up too high or forget to turn them down. This had been costing the synagogue money.

The original 30 ton ***air conditioning*** system had two units on the roof that provided cooled air produced by a compressor in the basement. A fan would blow air through the same ducts that were used for steam-generated heat. The system was functioning, but it was at the end of its useful life. Repairs were becoming increasingly frequent and very costly. The air conditioner was leaking refrigerants so it required annual recharges. The total cost of repairs for the air conditioning from July 2006 to June 2007 was $10,453; from July 2007 to June 2008 it was $5,275.

The old air conditioning roof top system, linked to the basement compressor.

It was clear that action needed to be taken, but upgrading to a new system would require a very large upfront payment for which the synagogue did not have the money at the time. Because the system could function with routine albeit expensive repairs, the board believed it would be easier to keep the same system for the time being.

All this changed in June, 2008 when the air conditioning system completely gave out.

Portable Air Conditioning Unit

Boston Synagogue called its air conditioning maintenance firm, that fortunately had its own professional engineers, to have a look and investigate the options. According to the engineers, repairing the old system was no longer possible. Also, the leaking fluid contained CFC's (Chlorofluorocarbons) that were harmful to Earth's ozone layer. The decision was made not to repair the system. The heat of summer forced the synagogue to purchase makeshift portable air conditioning unit. The portable unit was enough to keep small rooms comfortable, but it was not effective in cooling large areas such as the sanctuary and the social hall.

CHANGE

At this point, it was obvious to members of the synagogue's board that a good, long-term investment in cooling was needed. The MIP&L *Environmental Stewardship Assessment* report from 2004 had recommended a high efficiency air conditioning unit. The synagogue decided to investigate. The AC maintenance firm was asked for recommendations about potential air conditioning units. The recommended new cooling systems would cost over $100,000. Actions would include removal of the old compressor and fan from the basement and installation of new ones in their place. If the new systems were set up in the basement, then they would be able to run air through the existing air ducts. Unfortunately, the compressor in the basement was built into the structure of the synagogue during its construction; removal would be very costly. The cost proposed for the removal of the old system and installation of the new ones was equivalent to about one year's budget for all synagogue operations. The synagogue did not wish to take out such a large loan, and they began to look for less expensive options that did not necessarily require the deconstruction of the old steam system.

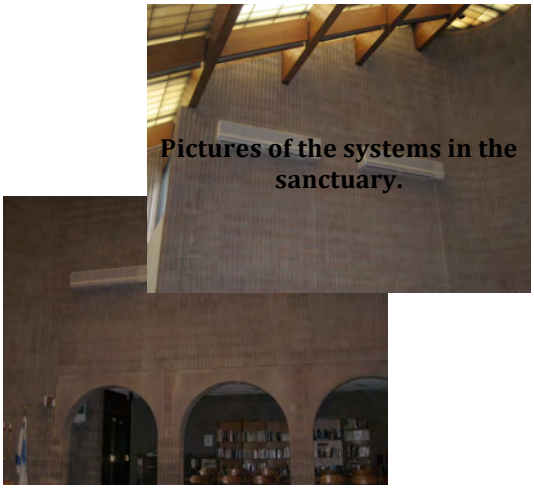
During the summer of 2008, board members began to look into alternative options. An article in *The Boston Globe* about ductless systems presented the idea that it would be possible to bypass the need to go into the basement by installing a ductless system on the

roof. Originally, board members thought that ductless systems operated like a single room air conditioners (and therefore would be inadequate to handle the synagogue's load requirement). However, in the process of doing research on the web, the synagogue chairperson's son discovered that there was at least one ductless vendor that was selling a larger capacity multi-room system working off a single heat pump. (See back for details on system). Potentially, this larger system could support the necessary HVAC load. More importantly, with a ductlesess system, demolition costs could be avoided because the new system would not require space in the basement.

As a result of this web review, the synagogue asked its trusted air conditioning maintenance firm if it would be possible to install these new systems in their building, and whether they would be effective.

The company replied that a 15-ton system should keep the synagogue at a comfortable temperature except in extreme weather conditions; and that in most cases, a 10-ton system would provide adequate cooling capacity. For heating, a full 15 tons was recommended. Due to the ductless system's (a) lower aggregate tonnage compared to the old system, and (b) high efficiency variable speed compressor, the company suggested that the synagogue would see substantial energy savings, helping to pay for the system. The provider also told them that a synagogue in the North Shore had had ductless systems installed and that they were very happy with the results.

Heat Pump from Sanctuary
See also photo on page 1



Pictures of the systems in the sanctuary.

Based on this advice, and after looking at the North Shore synagogue's system in operation, the synagogue decided to proceed with the ductless system, in two phases (to save money). In Phase I, the synagogue approved the installation of a 15 ton heat pump, but with 10 tons of air handler capacity (4 units @ 2.5 tons each). It believed that this would provide adequate capacity in most circumstances; and that the synagogue could rely on the old Trigen steam system on very cold winter days.

Based on how this system worked in practice, the synagogue would consider a future Phase II installation of an incremental 5 tons of air handler capacity (representing a 50% increase in HVAC capacity). This would enable the use of the full 15 ton heat pump capacity installed in Phase I, and hopefully reduce substantially the need for supplementary Trigen steam heat.

In late August 2008, the Phase I 15-ton heat pump was installed on top of the roof (pictured above at left) and was connected to the four 2.5-ton systems that push out air cooled or heated by the pump. There are two air handlers on each side of the sanctuary. (See photos at right). The congregation chose to install them on the sides of the sanctuary because they are close to where people usually sit, but are not in a place where they will interfere with the synagogue's interior appearance In addition to installing a new heat pump, a programmable thermostat was installed to control the system. This installation solved many of the problems experienced with the manual thermostat, including time on-and-off. (See photo at left.)

EXPERIENCE TO DATE

The synagogue's initial experience with the Phase I system was that it provided excellent cooling during the August-September 2008 time horizon (with the only issue being that on high-load days, the fan needed to be kept on high setting in order to provide adequate cooling at the rear of the building; this could be fixed in Phase II with by installing the

two additional 2.5 ton air handlers in the rear). This also proved to be true during the summer of 2009.

With respect to heating: as anticipated, during the winter of 2008-2009, the synagogue continued to use costly steam from Trigen in addition to the heat received from the ductless systems to heat the building.

Based on these experiences from this initial year of just using the 10 tons of capacity, the board of trustees decided in July 2009 to proceed with Phase II, in which two extra 2.5 ton units were installed near the back of the sanctuary. By having the additional 5 tons of heating power (which was installed in July 2009), the congregation believes that they will not have to rely on expensive Trigen steam for heating anymore except on extremely cold days.

QUANTITATIVE OUTCOME

Water Heater

A review of data from the synagogue's last three fiscal years (August-July) yields several conclusions. First and most important, Boston Synagogue was able to reduce total energy use after making the switch. The average Btu use before the switch for both the air conditioning and steam heat was about 6.54×10^8 Btus per year. After the change, the synagogue has only used about 3.95×10^8 Btu's per year. This is a 40% decrease. The higher number is actually higher because not all of those Btu's from steam make it to the synagogue, as some heat is lost on the way due to line loss. The synagogue has seen an increase in electricity consumption as it has come to rely more on the new systems. Before the summer of 2008, the synagogue averaged about 53,400 kWh a year. During the fiscal year of 2008-2009, the synagogue required 64,450 kWh. The average cost of electricity from 2006-2007 and 2007-2008 was $6,254. This cost jumped to $8,463 in the 2008-2009 fiscal year, about 35%.

The synagogue has witnessed a decrease in steam use as heat is now being provided by the new systems. Before the summer of 2008, the synagogue averaged about 279.5 Mlb a year. During the fiscal year of 2008-2009, the synagogue required only 104 Mlb of steam. The average cost of steam from 2006-2007 and 2007-2008 was $9,506. This cost fell to $3,047 in the 2008-2009 fiscal year. This was nearly a 70% decrease, and is expected to decrease further with additional units installed, see below.

The average total cost for all HVAC systems in the 2006-2007 and 2007-2008 fiscal years was $15,761. ($23,756.43 if the costs of the repairs to the system are included). This dropped to $11,510 ($11,683.82 with repairs) in the fiscal year of 2008-2009. This is a 27% reduction. While these are already significant savings, when the unusually cold winter of 2008-2009 is taken into consideration in terms of degree-days, the savings increase even more.[1] Adjusted for degree-days of Aug 2008-Jul 2009 in comparison with the median of the past 14 years, the cost of running the HVAC systems for the 2008-2009 fiscal year was only $7,735. These figures led the congregation to the conclusion that putting in the extra two systems should be enough to heat the building without the assistance of steam. If they could reduce their steam use to zero, then they would be saving roughly $3,000 a year, while experiencing an increase of about $1,000. (All 2009 $s.)

Note: Trigen will be retained for "backup' on super cold days at nominal cost (ca. $90/month).

Although the reduction in carbon emissions was not as large as the reduction of energy bills, the synagogue did manage to reduce their pollution. Before the installation in the summer of 2008, the synagogue emitted about 100,000 pounds of CO_2 per year on average. During the fiscal year of 2008-2009, the synagogue only emitted about 90,756

[1] For a discussion of Degree Days, and a means of tracking Utility Use & Cost, go to MIP&L's web site — www.MIPandL.org — and click on the Everyday Stewardship link. Then downloand the Utility Use & Cost *EES Brief*. Then go to Home or Congregation *Energy Use & Efficiency* links, and follow the directions to get an Excel form for tracking your home or congregation's utility use and cost AND to determine your carbon footprint.

pounds of CO_2. There are two main reasons that the reduction in pollution was not as great as the reduction in energy bills. The first reason is that the steam used to heat the synagogue is a byproduct of a separate process, meaning that reduction in use does not necessarily result in a reduction of pollution. The second reason is that the electricity providers for the synagogue (as well as most of Massachusetts) rely largely on burning fossil fuels to generate electricity. When electricity produced from renewable sources begins to fill the grid, Boston Synagogue will experience a further reduction in carbon emissions.

TECHNICAL APPENDIX

Mitsubishi: The units installed are from Mitsubishi's PKFY series. These systems are lightweight and compact compared to most air systems of similar power. The Mitsubishi PKFY also has some of the lowest sound ratings in its class, so it is very quiet. This is particularly important because sound easily bounces off the concrete walls of the sanctuary. Maintenance is relatively easy as well. The filters on the wall can be easily removed, washed, or replaced and can be reached easily with a ladder. A key feature of the system is that it can both heat and cool. Thus, there is no need to install separate systems to heat and cool the building. Heat pumps also work efficiently, because they simply transfer heat, rather than burn fuel to create it. A heat pump has the capacity to do this because it uses an inverter-driven compressor. This compressor essentially allows the system to run the thermal process forwards or backwards. The process works by evaporating and condensing a refrigerant through a series of coils. When the refrigerant condenses it emits heat, and when it evaporates, it absorbs heat. An inverter-driven compressor can both condense and evaporate the refrigerant so that the coils can be cooled or heated. Also, the particular refrigerant used, R-410A, does not harm the ozone layer if leaked. The synagogue installed an air-source heat pump (takes air from above ground) rather than a ground-source (geothermal) because installation and repairs are less expensive, as excavation is not required.

Trigen: Trigen is the steam provider of Boston Synagogue. Its name comes from the term "trigeneration" which refers to the plant producing power, heat in the winter (through steam), and chilled water in the summer (by using hot steam to run an absorption process). The company exports steam to the synagogue from their nearby power plant on Kneeland St. The imported steam heats up air that then circulates through the building. Although the power plant is very close to the synagogue, there is still some heat loss taking place as the steam travels through underground pipes, meaning not all of the heat produced makes it to the destination and efficiency drops. The Trigen billing process is complex. Like most energy companies, their billing system is tiered, so the less steam one uses, the more one pays per Mlb of steam. This is largely because transport and meter reading costs are independent of amount of steam used. Every bill should clearly state the cost per Mlb for each tier and how many Mlbs were used that month. As a smaller house of worship, Boston Synagogue suffers from this system. Also, there is a minimum fee of roughly $80 per month, so even if no steam is used, the synagogue is still charged. Unlike most energy companies, Trigen has to take manual readings of the steam used every month. This is not so bad if the meter is on the outside of the building. Unfortunately, Boston Synagogue's meter is on the inside of the building. If a representative from Trigen is unable to get inside the building for a meter reading, then the synagogue is charged based on the previous year's use and the average temperature for the month. If no steam is used, but the representative is unable to set up an appointment, then the synagogue will be charged full price because Trigen cannot be sure when certain amounts of steam were used. This is a problem because the price of steam fluctuates. Once the heat pump system had been installed, it did not occur to give Trigen a key or install an outdoor reader. Also, in order for the synagogue to officially discontinue use of steam, Trigen must put the system under lock and key. These issues will be addressed going forward.

Conversions:

1. 1 kwh = 3,142 Btu
2. 1 kwh = 1.2 lb CO_2 per year

3. 1 Mlb Steam = 1,687,000 Btu
4. 1 Mlb Steam = 129 lb CO_2 per year

This case study was prepared by Russell Foxworthy, August 2009.