Energy Conservation Action Study
For the
Bedford Unitarian Universalist Church

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10/5/2009

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Summary:
The Bedford Unitarian Universalist Church complex is about to undertake renovations, including architectural and systems upgrades. Each of the areas (New and Sanctuary) under consideration has different needs, but there are overriding issues that may be universal as well as specific measures for each section. It is of particular interest to determine steps to be taken for the sanctuary, since it is both poorly insulated and inefficiently heated. The goal of this study is to outline and prioritize the most important and most cost effective measures that should be included in the plan for envelope and systems renovation.

The sanctuary extends to the northeast from the new addition, and therefore has little help from solar heat gain in winter. Because the sanctuary is built over a basement/crawl space, which is uninsulated, unsealed and contains uninsulated ducts, and because the attic is essentially uninsulated because of massive bypass areas, there are ample opportunities for energy savings without affecting the historical aspects of the building. It is important to begin to look at the sanctuary as a whole – including the entire envelope and systems, rather than piecemeal, as has been previously attempted. This will result in a more satisfactory product and far greater energy savings.

The table below summarizes the main recommendations in simplified form. Although simple payback does not capture the full value of savings over future years, it does give an idea of the value in today's dollars and a today's energy costs. Note that by combining measures as a package, the overall payback is less than six years. The measures in the table as well as many others are discussed in this report.

ENERGY EFFICIENCY MEASURE	INITIAL COST	ANNUAL SAVINGS	SIMPLE PAYBACK YEARS
Replace Boilers with high eff condensing	$15,000	$2500	6
Instrumented Air Sealing	$5000	$2174	2.3
Add Tapered 2" avg Spray urethane to basement walls	$6000	$1520	3.9
Additional attic insulation to R-38 complete	$5250	$864.00	6.1
Duct insulation and sealing	$4500	$694	6.5
Energy Efficient Lights (NSTAR Rebate included)	$5000	$479	10.4
Add Storm windows in Sanctuary ($10/sf)	$660	$139	47.5
High performance package	$51910	$9143	5.7

Introduction:
The Bedford Unitarian Universalist Church Church complex is planning renovations, including architectural and systems upgrades. The complex consists of the new addition, containing offices, the large fellowship hall, and five classrooms and kitchen downstairs, and the connected Sanctuary building which has one very large and several balcony spaces for assembly as well as basement and bell tower. Each of these two structures has different fundamental energy needs due to construction, occupancy and current systems.

Because the new addition is recently constructed, complying with new energy codes, there are few immediate opportunities for energy improvements in the building itself. But it does share the same heat generation system as the Sanctuary, and thus equipment savings from improvements in the system will be applicable to both buildings. Since the opportunities for energy savings are large in the sanctuary, we will concentrate on the sanctuary for building envelope improvements.

The goal of this study is to outline and prioritize the most important and most cost effective measures that should be included in the plan for envelope and systems renovation.

Context:
It is prudent to consider investments in energy savings that may not have been considered cost effective a few years ago. Fuel prices are climbing steeply and paybacks for energy measures have shortened.

We recommend looking at the potential life cycle of the measure under consideration, and using today's maximum cost for energy in calculating payback and life cycle costs. Though costs will surely increase, if it makes sense today, it will make more sense in the future. In addition, the life of the measure (30 + years for building envelope or distribution systems, 20 years for equipment), provides a variable measure for payback. Given an equivalent initial cost and annual savings, we want to spend more of the budget on systems with long life.

We recommend prioritizing measures as follows:

A. Higher priority should be given to essential (safety and health) measures.
B. Next in priority will be the immediately cost-effective energy measures (low hanging fruit).

C. Next will be those measures that may have a longer life and a longer payback.
D. Then, shorter life measures with good payback.
E. Finally, environmental or stewardship issues that may not have a payback, but are desirable for other reasons (such as green power purchase, recycling systems, etc.)

It is the practice of The Hickory Consortium to approach the building from a holistic perspective. The evaluation process proceeds for the outside toward the inside of the building, beginning with the site, then the building envelope, then the interior spaces, delivery systems and finally equipment. This approach provides a comprehensive analysis of the entire building, and leads to maximum efficiency at the least cost by reducing the building loads before sizing the distribution system and equipment. To that end, the following outline categorizes the issues and measures under consideration.

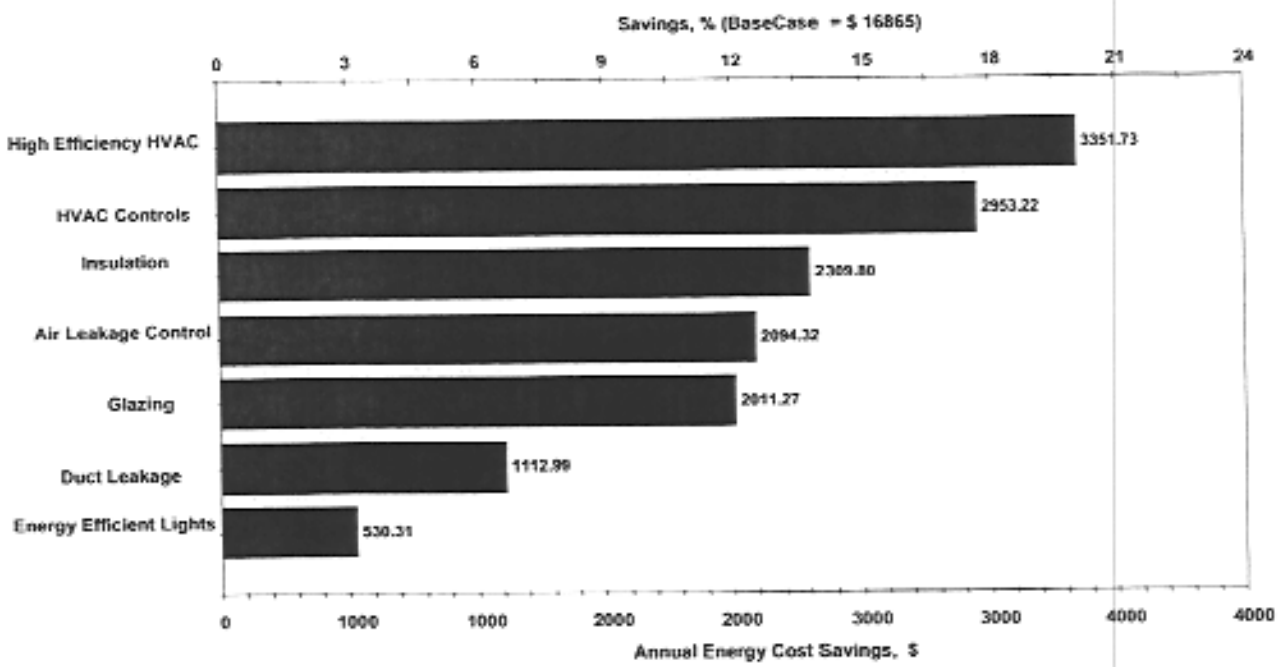
1. Site:
Although little can be done about the site, there are great advantages to the original orientation of the church, notably the south orientation of the new wing roof, which makes solar collectors a potential opportunity. The site also appears to have good drainage, an asset which allows certain approaches to insulation and moisture control.

2. Envelope:
Much of the building envelope in the sanctuary is lacking in insulation. The upper walls probably have no insulation, basements do not have any useful insulation. Window glazing is mostly single, with low R-value, either single glazed with storm windows or none. Windows are also a significant source of air leakage, which has a dramatic effect on energy use and comfort. The chart below shows some of the opportunities to save energy in the Sanctuary Building. In modeling the building, we assumed that there was no insulation in most of the walls above grade, and that the roof had R-12 (4" of fiberglass) on average. It is likely that the roof is really insulated to a lower level due to voids and large bypass areas. The basement area contains uninsulated ducts and ample air leakage sites. The cold air that leaks in at the bottom is pulled up through the building by the hot air leaking out at the top. Leaks from the duct s are lost to the cold air of the basement.

The current boiler system is, at most, 69% efficient, while modern equipment can be as high as 95%, with 93% common for boilers of this size.

Airsealing is the most cost-effective measure in most buildings and Bedford Unitarian Universalist Church is no exception. Envelope leaks in the attic and basement have the largest effect on air leakage and energy consumption, due to the nature of the driving forces (wind and temperature), which are greatest at the top and bottom of a building. Sealing air leaks also helps minimize potential problems with moisture migration and condensation in the building envelope.

Figure 1 The Sanctuary Building



Insulation has priority because this may be the best opportunity for a while to improve the envelope of the building. In the many areas where insulation should be added, the increase in performance can outweigh other measures because we're starting from a low value and there are additional benefits in air leakage control which result from using foam insulation. Looking ahead, the envelope will be with the building for a very long time. While other measures may have a 20 year lifetime or less, the envelope of the building will continue until it is renovated again. This may well be 50 years or more. In the meantime, energy costs are skyrocketing, making the highest levels of insulation cost-effective.

What are the insulation measures that will make sense for this building? It may be economical to add insulation to the upper walls of the Sanctuary but because of the sporadic use of the main sanctuary this area is unlikely to be a cost-effective area for adding insulation. The prime target for insulation is the basement walls, which are largely uninsulated. Generally, people think of basement walls as losing very little heat because they are mostly underground. However, much of the wall is actually above grade, exposed to outdoor air temperatures, with large gaps for air intrusion. And the first few feet below ground are also subject to cold exterior temperatures which stay cold even on warm days. Further, all of the heating equipment and most of the piping and ductwork are contained in the basement areas. Though these should all be insulated, they will still lose large amounts of heat to their surroundings. If the floor above is insulated, the waste heat from ducts, pipes and equipment is lost to the ground and outdoors, but if the basement walls are insulated, the waste heat goes toward heating the occupied spaces. Sealing the basement walls is also particularly effective at reducing cold air leakage into the building.

The best way to insulate these lower wall areas is using spray urethane foam, which adheres well to both wood (in the sill area), and the masonry or stone of the foundation. It is a closed cell foam, so moisture cannot migrate from inside and condense on the walls. It also provides a degree of moisture protection from sources outside the foundation. In occupied spaces, it must be covered with sheetrock, here it may only need a fire retardant spray layer. The large hole where a window has been removed for access to storage should be rebuilt by a competent builder with an insulated, tight, removable access door. Great improvement in usability and efficiency will accrue.

Once the basement walls are sealed, it will be necessary to cover the floor with a moisture barrier. There are several ways to achieve this, but the simplest is to lay down a layer of polyethylene and cover it with ½" peastone or sand to protect it. It would be best for the building to pour a concrete slab.

The ceiling and roof can also benefit from additional insulation (where insulation levels are low or non-existant). The Sanctuary is partially insulated but insulating at the ceiling plane (below the attic), appears to make the most sense. Here Icynene or equivalent open celled foam is recommended, because it can be applied even when fiberglass is present. The goal is to insulate the smallest area which provides a complete blanket for the heated spaces. If the belfry floor is insulated

and an additional door is located at the top of the access stairs, it is possible to fully insulate the ceiling plane. Some framing work may be necessary to achieve a continuous blanket. Care in detailing this insulation will help to avoid missing some of the complex corners and hidden areas of this plane. Though it may also be possible to insulate higher in the area, the presence of cell phone equipment makes this more difficult. The cellphone equipment does not need to be part of the heated envelope of the building, so the floor of the attic is the target as the best place to insulate and airseal. There is room for 10" -12" of insulation in the floor, and there appears to be only 6" in some areas. Again, because of the airsealing capabilities of foam, the insulation will have a larger impact on savings than the apparent increase in R-value.

Air leakage control is very important in all buildings, but in the sanctuary, it is by far the most important measure for energy savings. Because of the height of the building, its age, and the complexity of construction and airflow between floors, this building has the potential for losing great amounts of heat to the wind. In order to solve this problem, instrumented weatherization is recommended. This is the process of testing the building with a blower door (a big fan in the doorway that can measure the leakage area), sealing the holes and retesting. This permits the contractor to seal the large holes first, and stop sealing when the additional work would have little effect. In this case, the primary insulation tasks of foam insulation for the attic and crawl space walls must be done before airsealing is attempted.

Air leakage control will be tested with a blower door to see how well the sealing has been done. This will also give us an idea whether we may have achieved enough air sealing to require mechanical ventilation rather than the fresh air currently provided (at great cost) through leakage. If it is necessary, the solution is relatively simple, since it will only involve adding a fresh air intake to the return side of the fan coils providing heat. Since use is sporadic, this should provide ample fresh air without great cost.

Another area of great potential is window glazing for those that do not currently have storm windows. Some of the balcony area windows have storms, and there may be other storm windows in storage. If properly applied, these will dramatically reduce infiltration of wind, and create a better thermal barrier and a warmer inside surface for greater comfort.

The overall goal for the sanctuary is to enclose all the heated spaces with at least some insulation. The current sporadic insulation leaves big airflow holes and heat leakage areas which can be addressed comprehensively.

3. Interior spaces

Moving from the outside toward the interior of the building, we next consider the interior spaces, their occupancy and their needs. Heating controls may be useful if we can establish regular patterns of use, which would allow scheduling of heating and temperature setback. Care should be taken to establish zones based on occupancy patterns, so, for example, the east balcony can be heated independently of the west, and meetings can be scheduled so that the heating can be controlled based on a calendar and time.

Lighting

Although lighting is low on the list in the rankings of energy efficient strategies in figure 1, lighting uses electricity, while the heating measures use fossil fuels. Because electricity is very expensive, a small energy savings can be a large dollar savings.

1. Some of the lighting is high efficiency, but all of the lighting should be. This particularly applies to the spotlights (theater lighting), for the sanctuary, which could be improved.
2. Exit signs should be of the high efficiency LED type.
3. The use of high efficiency T-5 lighting where possible allows good light quality and low wattage. T5 fluorescent lamps are thinner, more efficient, and offer a higher intensity of light output than T8 lamps.
4. Recommend getting NSTAR to provide technical services and a lighting rebate. http://www.nstaronline.com/business/energy_efficiency/electric_programs/engservices.asp

4. Heat distribution

The Sanctuary uses forced air, with air heated by water from two boilers, and delivered through uninsulated ducts.

1. The Sanctuary boiler system is highly inefficient by comparison to a standard system, with a boiler efficiency of less than 70%.
2. The fan coil system is a good approach to rapidly heating a large space, and that part of the system should be kept as

is, with the proviso that if the system is refurbished, savings can be achieved with modern fan design.

3. The main Sanctuary room has little need for zoning, being an all or nothing proposition, so the control strategy will be to program controls for known times of occupancy and to know how long it takes to reach comfort temperatures at various outdoor temperatures, so the setbacks can be overridden manually when off schedule.
4. It would be wise to evaluate the upper balcony zoning to see if there can be at least three zones (west, north and east) which can be independently controlled.
5. Controls for the heating system should be updated to modern programmable controls, which will allow greater flexibility in matching the heating cycle to the occupancy. It may be reasonable to consider a simple building wide energy management system, which can control all zones from a central point (See HVAC Controls, below).
6. Currently, the Sanctuary has inefficient boilers, which are well beyond their usable life. It is highly recommended to go to high efficiency condensing boilers such as the Weil Mclain Ultra or the Lochinvar Knight, which should be sized to provide heat for a smaller load, once insulation and airsealing is done. Though uncommon as a practice, it would be worthwhile to insulate the building first, <u>then</u> test the boiler under winter conditions to see how big it needs to be. This will simply entail running the boiler to maintain indoor temperature while measuring outdoor temperature, while monitoring gas use. The boiler will then be sized to meet the minimum expected outdoor temperatures. This will provide more reliable and efficient sizing than calculations based on area or rules of thumb.

5. HVAC controls
   A. We all know that simplicity is critical to controlling a system that has several component parts and multiple schedules. In the simplest case, it will be necessary to have several automatic set-back thermostats.
   B. Manual control systems will become unwieldy with many zones.
   C. It is well worth considering a central computer controlled control system for the Sanctuary and new wing. These systems are becoming much simpler to use and far less

expensive than previously, and the advantages in control and monitoring are significant.

6. If cooling is desired for offices or other spaces, the best system is the mini split cooling system. These small systems do not have ductwork, but have a console mounted high on an interior or exterior wall. Cooling is very high efficiency, variable speed and quiet. These also are available with environmentally friendly refrigerants.

Cost-effectiveness Table:

In the table below, the recommended measures are shown along with estimated costs, simple payback, and life cycle savings over 30 years. Included are window storms with long payback but improved comfort and potentially much larger savings if the use profile of the sanctuary balcony changes. This table represents those measures which are generally applicable to the building, and can be used as a guide for planning the project. Caution should be exercised, since estimates of costs are rough estimates, and actual costs may vary widely, particularly in the current building and commodities climate.

The last column shows the estimated minimum life cycle savings of each measure over 30 years. This value does not include energy escalation, which may be rapid, but it does show the potential savings at today's costs. Looking at the last row, the total package, including all measures listed in the table, would have a simple payback of under six years.

ENERGY EFFICIENCY MEASURE	INITIAL	ANNUAL	REPLACEMENT		SIMPLE PAYBACK	Present Value of SAVINGS
	COST	SAVINGS	LIFE	COST	YEARS	LCC for 30 Yrs:
Base Case R-0 walls. R-11 Roof, high infiltration, no basement or duct insulation, some storm windows						
Replace Boilers with high eff condensing	$15,000	$2500	15	15000	6	$55,696
Instrumented Air Sealing	$5000	$2174	50	n/a	2.3	$47600
Add Tapered 2" avg Spray urethane to basement walls	$6000	$1520	50	n/a	3.9	$35792
Additional attic insulation to R-38 complete	$5250	$864.00	50	n/a	6.1	$22185
Duct insulation and sealing	$4500	$694	30	n/a	6.5	$18182
Energy Efficient Lights (NSTAR Rebate included)	$5000	$479	10	n/a	10.4	$13404
Add Storm windows in Sanctuary ($10/sf)	$660	$139	20	n/a	47.5	$9324
High performance package	$51910	$9143	40	n/a	5.7	$231117