Energy Efficient Building Research and Greenhouse Design for Westhampton, MA

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Introduction

For the last two years, several students from the Smith College Picker Engineering Program have assisted the town of Westhampton during the design process for their new town library building. The goal for this project was to suggest simple and affordable solutions to make the building as energy efficient as possible. There were several building constraints that makes the building challenging to design, and they include

- Surrounding landscape has significant slope
- Construction and maintenance budget
- The library will attached to an existing building (the Parsonage)
- The new library must aesthetically match to the surrounding town area

This year, a computer model was written to analyze the energy performance of the building based on the architects designs. This model shows which building features contribute to heat loss or heat gain (see 'Energy Performance' section). Also, several alternative heating solutions that utilize solar energy have been suggested (see 'Alternative Heating').

Library Design

Above are the AutoCAD drawings, created by the library's architects (Tappe Associates, Inc.), of the different viewpoints of the library. Using these drawings and a laser cutter, a 3-D cardboard model was constructed of the library.

Energy Efficient Building
Necessary Features

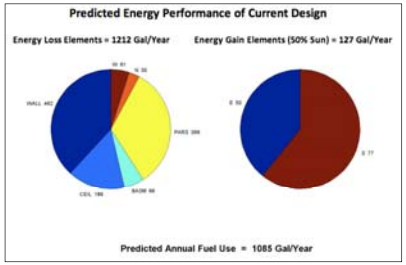
There are numerous ways to improve the energy efficiency of a building, but for this project we focused on the following building features that had the most significant affect;

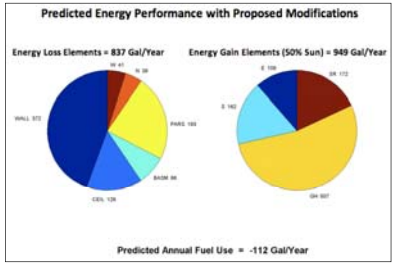
- *Building layout*
  - Since wall surface area contributes to energy consumption, a building should be designed to be the simplest shape as possible
- *Window placement and area*
  - Due to the suns position, certain sides of the building have significantly more energy gain than others. For example, energy loss can be reduced by reducing the window area on the north side and increasing on the south side
- *Insulation*
  - Using material with higher R-values (thermal resistance) for the walls, floors, and ceilings reduces the amount of heat that escapes the building, thus reducing the energy required to warm the building to a comfortable temperature
- *Thermal mass*
  - Materials that are heated during the day but then slowly let off stored heat, such as concrete or sand, can be used to continue warming the building after sunset
- *Roof design*
  - To prevent the library from overheating during the summer months (and reduce the energy required for air conditioning), a 2 ft. roof overhang shades windows from the sun during the day

Energy Performance

A computer model (written in MATLAB), was used to monitor the building's energy performance for the varying library designs. The program tracks the suns position to determine the available solar energy each day throughout the year. Based off the building features, such as wall surface and window area, the program calculates the buildings energy gain during the day. Furthermore, the buildings energy loss is calculated based on a material's R-value. These energy values were converted to the more familiar units of oil (specifically #2 heating oil burned to a 90% efficient furnace), in order for the library committee to see the cost to maintain comfortable indoor temperature.

Pie charts were created to visually see which elements of the building contributed to energy loss and gain. For each figure, the left pie chart shows which elements have a net energy loss and the right pie chart shows which elements have a net energy gain. Loss and gain values are added to estimate the annual energy use. The computer model made it simple to adjust the library design and see how the overall energy performance would change.



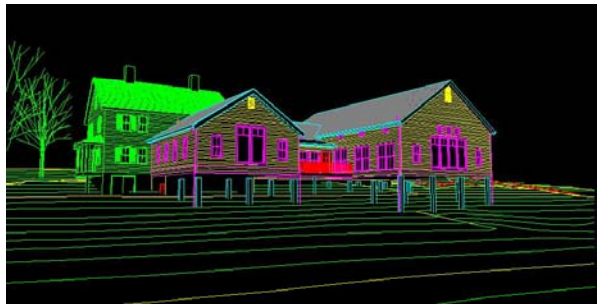


Computer Model of Energy Performance

The figures are an example of one energy analysis for which the architects original design was compared to a proposed design, for which the following design changes were suggested;

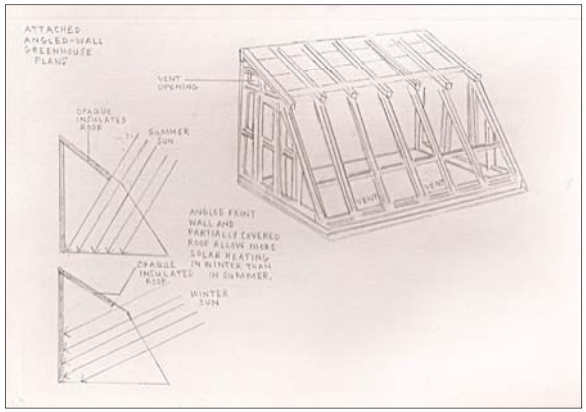
1. Increase window area on new south walls to 30-50%, add overhang to block summer sun.
2. Decrease window are on the north, west, and *especially* the east sides.
3. Isolate the 2nd floor of the Parsonage to reduce heat loss.
4. Create a sunspace from the Parsonage porch (only if cost effective).
5. Add a 400 sqft greenhouse with a solar powered blower to circulate warm air into the library.

If these steps are implemented effectively, the energy required to heat the library was estimated to drop from over a 1000 gallons heating oil per year (6-9 gallons per winter day) to near zero gallons on many winter days.



Library Design

Above is another AutoCAD drawing of the architect's design, except shown as a 3-D image. The architects proposed having the library constructed on stilts to reduce initial construction cost, but after providing energy analysis that showed that this would increase the building's energy consumption (and heating cost), the design was altered to have the building be constructed with a concrete foundation.



Greenhouse

By using quality materials and integrating design elements from the main structure, these attached lean-to greenhouses could provide increased solar gain while remaining aesthetically pleasing.

Alternative Heating

Since windows only have a solar energy gain on certain sides of a building and increase the buildings heat loss when the sun is not present, they cannot be relied upon for a net energy gain necessary to warm the building.

Greenhouse - The structure would be a south-facing lean-to style built onto the library addition that is east of the parsonage. This style is easier to construct because its foundation is built off the existing library foundation and increases the solar gain compared to a freestanding greenhouse, which allows more solar energy to pass through. We recommend the glazing area of the structure to be between 300 to 500 sq. ft. for optimal solar gain. The greenhouse would not extend past the 2 to 3 ft. roof overhang in order to stay protected from falling ice and snow. If the library committee decided to allow access to this building, agriculture activity must be limited in order to prevent humidity in the structure.

Porch Sunroom – Since the porch on the south side of the parsonage is not open to the public, this area was considered for building a sunroom that performs just like a greenhouse. The porch could provide at least 140 sq. ft of vertical glazing area. This will only provides a third of the energy compared to the greenhouse, yet this is still more energy than what could be provided by regular windows.

Hot Air Roof Panels – Similar to a greenhouse, these roof-attached panels generate hot air from solar energy. An 8' wide panel provides is sufficient for a 500 sq. ft. room with 8' tall ceilings. Since the total square footage of the library is over 5000 sq. feet with varying ceiling heights, it was estimated that the library would need between 10 to 15 panels to provide solar heat to the building.

Special Thanks to

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