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Quinsigamond Village Energy Research

An Interactive Qualifying Project Report

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Abstract

The Quinsigamond Village Community Center and nearby churches are currently facing financial stresses due to the escalating costs of operation and are looking for ways to reduce this burden. This project investigated methods of saving money for these churches by conducting audits of the buildings' energy usage and by exploring alternative energy sources. This research resulted in organization specific recommendations, including upgrades for lights, appliances, windows, and heating, for investing their resources to reduce overall energy expenditures.

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Father George J. Ridick – St. Catherine's of Sweden Church

Pastor Gloria Connery – Emanuel Lutheran Church

Ms. Alyce Brommels – Liaison – Emanuel Lutheran Church

Mr. Ernie Laurence Quinsigamond Village Community Center

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Alternative Energy Store – Hudson, MA

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1 Executive Summary

In a society that is always expanding and demanding more from its natural resources, it is important to conserve the resources and to find ways to sustain itself. Highly inefficient building designs, such as old church buildings, must be improved in order to increase energy efficiency and reduce emissions. The city of Worcester has approximately 97 churches within its boundaries (MagicYellow, 2006). With the costs of fuel and electricity on the rise, upgrading these types of buildings to make them more efficient will produce dramatic savings and keep these buildings operating. Consequently, this will lead to conservation of the Earth's natural resources and lowered greenhouse gas emissions. For this project, our goal was to provide recommendations to four churches and one community center to pursue higher efficiency energy systems through upgrades and renovations to the buildings. Our secondary goals were to spread the idea of alternative energy and find sources of funding to aid in implementing the recommendations.

An array of techniques was employed to assist in attaining our goals. We conducted energy audits of all the buildings to identify the energy inefficiencies within each building. These audits contained both behavioral and technical aspects. Data were collected from church officials to create building usage tables, as shown in Appendix 1.

The technical portion was performed by Bill Gordon, from Prism Consulting Inc., a lighting auditing company contracted out by National Grid, and us. The lighting audit was performed on each building except for the Bethlehem Covenant, which we could not enter. The audit showed us that all of the buildings had older, inefficient lighting fixtures. Steve Wyman of Wyman's HVAC was contacted to help with a heating audit of the Community Center. We obtained the energy usage of the appliances within each building to determine if it would be worthwhile to replace them. Windows were measured to determine the energy loss through them. Windows and doors were examined for air leakage. The Bethlehem Covenant and the Quinsigamond Village Community Center have direct south-facing roof space, making them the best suited for solar energy. The other buildings would require more equipment to align the panels properly, making them less ideal, although still feasible.

To follow through with our secondary objectives, we researched active and passive solar energy. Research into combined heat and power as another alternative energy possibility in the longer term was also performed. The results from this research consisted of case studies of different cogeneration systems implemented throughout the world. We looked at grants offered by the state and federal government that could potentially subsidize or completely cover the costs of some of the recommendations. Most of the applicable grants were offered by the Massachusetts Technology Collaborative. These include the:

- Small Renewables Initiative – supports the installation of 400-500 renewable systems (less than 10 kW) statewide
- Matching Grants for Communities – applicable towards clean energy for communitywide use
- Community Development Block Grants (not MTC) – provide communities throughout Massachusetts with resources to implement an array of community and economic development projects

These methods allowed us to provide the organizations with the best recommendations available.

After performing these audits and researching upgrades, renovations, alternative energy, and funding, a list of custom recommendations for each organization was produced. The following are prioritized recommendations for each of the buildings.

Bethlehem Covenant:

1. Change the temperature settings for the week and the weekends to a lower setting (ex. 62 to 55 degrees for the week and from 73-66 degrees on Saturday through Sunday)
2. Install programmable thermostats for all heating zones
3. Insulate the pipes coming out of the boiler to hinder the heat loss
4. Join Massachusetts Interfaith Power and Light's oil buying group to reduce oil costs.

Quinsigamond United Methodist Church:

1. Install programmable thermostats in the building
2. Add weather stripping to windows and doors
3. Consider the lighting proposal presented by National Grid
4. Replace the old refrigerators in the building (replace the smaller fridge in the pantry first)

St. Catherine's of Sweden Church:

1. Lower the thermostat settings from a constant 62 degrees to approximately 55 degrees
2. Consider the Prism Consulting lighting proposal
3. Raise the R-value of the current windows by either insulating them or adding storm windows.

Emanuel Lutheran Church:

1. Sign up with Massachusetts Interfaith Power and Light to receive the discount oil price of $1.989
2. Consider implementing the revised schedule for building usage
3. Replace the curtains in Fellowship Hall to provide for better insulation
4. Upgrade to programmable thermostats in the building
5. Insulate the pipes coming from the boiler room
6. Consider the Prism Consulting lighting proposal
7. Add storm windows or insulate the current windows

Quinsigamond Village Community Center:

1. Repair the broken windows on the second floor
2. Weather-strip doors and windows
3. Cover air conditioners during off seasons
4. Accept the lighting proposal for the new T-5s in the upstairs hall
5. Insulate the pipes bringing the heat to the upstairs hall
6. Add space heaters to upstairs to get a better recovery rate
7. Replace the old, inefficient appliances (A/C's, refrigerators, freezers)
8. Upgrade the windows by replacing them or adding insulation and storm windows
9. Check feasibility of adding insulation to walls and ceilings

We recommend that all the organizations develop an energy awareness education program for the users of the buildings and the community. In Appendix 4, there is a sample energy awareness program that provides a basic backbone that can be expanded on by the organizations. Through our findings, we also recommend that funding opportunities such as the Massachusetts Technology Collaborative Small Renewables Initiative and Matching Grants for Communities be explored by the organizations involved in this project.

In terms of alternative energy, both solar energy and combined heat and power are not economically feasible for these organizations at this time. The Bethlehem Covenant and the community center have feasible building orientation that would be suitable for solar power. Photovoltaic solar prices are currently high, therefore it would not be a sound decision to invest in this technology without substantial grant support. Passive solar is less expensive, easier to install, and is currently more feasible. Combined heat and power, specifically fuel cell technology, has not advanced far enough yet to be commercially available. Other cogeneration technologies are loud, large, and expensive and therefore not suitable for this area right now. In the future, cogeneration could be a wise decision for the Quinsigamond Village area, but it is not feasible at the current time.

Our recommendations, if implemented, should better prepare the five organizations to cope with the upcoming New England winters. The cost savings analysis provided should give them an idea of how to allocate their funds for making them more energy efficient and to reduce their energy costs.

2 Introduction

Throughout the last century the world's demand for petrol-based fuel has been increasing steadily. This increase in demand has been driven by China and the United States (CNN 2003). A theory written by M. King Hubbert stated that worldwide oil production would peak in 2000; this projection was not directly on target, but in 2004 the International Energy Agency had said, "Oil production is in decline in 33 of the 48 largest oil producing countries ...". If demand is increasing and supply is decreasing, the problem of market scarcity may arise. This may have been seen through the increase of oil prices. The cost of oil has risen from around $20/barrel in 1999 to around $60/barrel today (Department of Energy n.d.).

In Massachusetts the average price of gasoline has increased from $1.60/gallon to approximately $2.35/gallon in the last three years (massachusettsgasprices.com). The cost of heating fuel has also experienced a large increase during this same time period. This has had a large impact on both non-profit and low-margin organizations. Most of these organizations rely on donations and help from the users within the organization, causing the funding for heating costs to become increasingly difficult for these organizations. An initiative needs to be undertaken in order to assist these organizations in lowering the cost of operations so that they may continue to serve the communities in which they reside in.

This project focused on ways of helping the Quinsigamond Village Community Center and four surrounding churches with their energy crises. In order to better understand the problem facing these churches and to produce a plan of action, research was conducted on possible heat leakage in buildings and how to locate them through various energy audits. We also explored different forms of alternative energy and alternative energy options for feasibility purposes in our mid and long term plans.

Funding is necessary due the non-profit status of the organizations; they are very low margin and rely on members of the community for support.

This project was a unique one because while energy conservation has been studied in terms of residential areas and government buildings, previous studies have not included the area of non-government organizations and institutions of faith. This group of buildings is different from others due to their size and usage; they are often open to the public for special events. The project was also unique to WPI because until it was done, other Interactive Qualifying Projects have studied the feasibility of alternative energy in general, as well as in Worcester more recently; this project's focus was in the application of alternative energy to a specific sector, namely Quinsigamond Village.

The primary objective of this project was to present options to the community so that they may save money and survive harsh New England winters. The secondary objective was to research ways to cut greenhouse gas emissions from the churches by presenting them with options to favor alternative energy solutions. The secondary objective was accomplished indirectly through the primary objective due to the fact that increasing the energy efficiencies in each of the buildings reduced the emissions coming from the building.

Ultimately, this project's research shows the Community Center and the corresponding churches where they can find support to help them lower the costs of heating and power. This is done through the use of energy audits and the presentation of sources of potential funding opportunities to help them renovate the buildings to become more fuel-efficient. The project's results recommend alternative energy sources that will work well in the Quinsigamond Village area. To assist in the underwriting of the cost of these alternative energy sources, research into potential grants to help fund the implementation of these alternative energy sources is also documented.

3 Background

3.1 Introduction

Over the past year the drastic increase in cost of fossil fuels has had an enormous impact on a society that relies heavily on them for power, heat, transportation, and water. This burden is especially difficult for non-profit organizations such as churches and publicly owned community centers to deal with. These organizations receive the bulk of their income by donations from members, and receive limited support from the government to subsidize costs. Often, exemption from taxation is the only source of support from the government. Now with the costs of energy beginning to rise, it is becoming difficult for these groups to be able to economically survive winter in a climate as harsh as that of the northeastern United States. Churches and other non-profit organizations need help from their communities. Steps need to be taken to improve the physical structures of these houses of worship. One of the biggest heating factors for buildings such as churches is the large volume of open space common to churches; these buildings often have high ceilings and many places where heat can escape, such as single paned stained glass windows, large amounts of under-used space, and large un-insulated surfaces. Alternatives are available to help these buildings conserve energy and reduce the operating costs for the organization. The aforementioned alternatives can include increased insulation, reduced times of operations, design of an optimal heating schedule, and installation of more energy efficient appliances. With all solutions, the initial cost and payback period was a concern due to the financial standings of the organizations.

Our objective was to produce a plan of action for the members of the Quinsigamond Village to enable them to reduce energy expenditure and emissions in the short, mid, and long term futures. To develop a plan of action several items had to be understood: energy auditing, alternative energy and its feasibility, and available community-wide energy saving techniques. The short term goal included research into ways of reducing energy waste that required limited additional capital expense; a system of measuring problems and relative success of possible remedies to these problems. The mid-term goal consisted of finding ways in which the community could become less dependent on electricity or fossil fuels for energy. In searching for a solution to a decreased level of dependency on fossil fuels and electrical energy, different sources of alternative energy were investigated, including the feasibility of implementing them both in aspects of cost effectiveness and how well they worked in a specified geographical location. The long term goal of finding a potential community-wide energy system for the Quinsigamond Village included the options of new energy systems and their feasibility. The cost and payback period for each, and the amount of energy that each system could produce was also considered.

3.2 Energy Efficiency

The first step in improving the efficiency of a building's system is to uncover the problems of the current one; this is done through energy audits. There are several types and levels of energy audits that can be performed, each encompassing different aspects of energy usage. The two main categories of audits are technical and behavioral, with technical focusing on equipment and behavioral focusing on the users. The main goal of any energy audit is to discover if and where energy is being wasted in the facility being audited. Building design, heating, usage patterns, and heating equipment are examined to determine potential revisions in favor of increased energy efficiency.

Even in energy efficient buildings the misuse of heating, cooling, and lighting systems will still raise the costs. Facilities need not be heated, cooled, or illuminated when not in use. Rooms cannot be heated instantaneously; it may take an hour or more after being turned on for a cold boiler heating system to heat some larger rooms prior to events. Part of an energy audit is an analysis of the usage patterns of buildings. The usage patterns include the schedule of events and frequency of occupancy; this is the behavioral aspect of an audit.

The technical aspect of an audit examines existing lighting, building design, and HVAC (heating, ventilation, and air conditioning) systems and their efficiencies in the facility. Lighting often represents half of a building's electricity usage (EPA, 2000). Incandescent light fixtures are very inefficient compared to modern compact fluorescents and high intensity LEDs (light emitting diodes), which can save enough energy that payback will be seen in a short time. For example, exit signs can be replaced with LED versions that are up to 90% more energy efficient than current ones (EPA: Putting Energy into Stewardship).

According to the United States Department of Energy (DOE Energy Efficiency, n.d.), building design is also a crucial part of energy consumption, which is brought to focus during an energy audit. Outer wall insulation, doors, and windows are examined in order to determine if they should be reinforced or replaced. Single pane windows, doors, and walls without insulation are heat conductors that let heat out in the winter, and heat in during the summer. This wastes electricity used to cool the building in the summer and fuel used to heat the building in the winter.

The several different types and levels of energy audits are based on how the data are collected or analyzed. Walkthrough audits are the simplest and cheapest. Standard audits are the same as walkthrough audits in terms of data collection but more calculations are done on the data. The most complicated type of a technical audit employs computer software to analyze the data and requires a professional to be performed.

A walkthrough audit is the simplest form of energy audit. It consists of a visual inspection of each system (energyusernews.com Energy Audits, 2000). Energy consumption data (bills, etc) are also evaluated to analyze quantities and use patterns, as well as being compared to a benchmark industry standard for similar buildings. This form of audit is the least costly and the output of it usually suggests improvements in current systems. The findings can be used to warrant a future, more in-depth audit.

The standard audit is a more quantified approach; use and losses are measured based on operations, measurements, and patterns. Cost calculations based on efficiencies are used to calculate cost savings from improvements to each system. A cost analysis of recommended energy conservation measures is also included in this audit (energyusernews.com Energy Audits, 2000).

Computer simulated auditing is the most expensive of the energy audit levels and requires the work of a professional. It is therefore usually used only on complex facilities. Computer software can predict facility performance improvements; accounting for environment issues such as weather, as well as creating a base of comparison from the current energy usage of the facility. The effects of any projected changes can be used to measure against the same base; charts and graphs are created based on this information. This type of audit generally produces the most accurate estimations of resultant savings (energyusernews.com Energy Audits, 2000).

3.2.1 Summary

There are several different types of energy audits and different scopes for each. An energy audit consists of two main scopes: behavioral and technical. The behavioral scope includes how the building is used by its occupants. The technical scope includes the efficiency of energy systems within the building. A walk through audit consists of examining the building and its energy systems, as well as energy consumption data such as bills; the output of it is suggested improvements to the current building to improve efficiency. The standard audit consists of the same data collection methods as the walkthrough audit, but has a more quantified data analysis, including cost analysis. Computer simulated auditing is relatively expensive, and consists of using software to analyze energy systems and devices within the building, and requires a paid professional to perform.

3.3 Alternative Energy

Alternative energy sources are often cleaner sources of energy that will ultimately be less expensive in the future compared to current common energy sources, such as coal, oil, and natural gas. The main factor to consider with alternative energy sources is their feasible application in an area for which they would be considered. Options are often limited because they are not economically reasonable in a given area. In a prior WPI IQP, research on the feasibility of implementing wind energy in an area such as Worcester showed that wind power was not a very feasible option. This is further backed up by the Department of Energy. The following wind power map below, Figure 1, shows that the feasibility of using wind power in Worcester is poor.

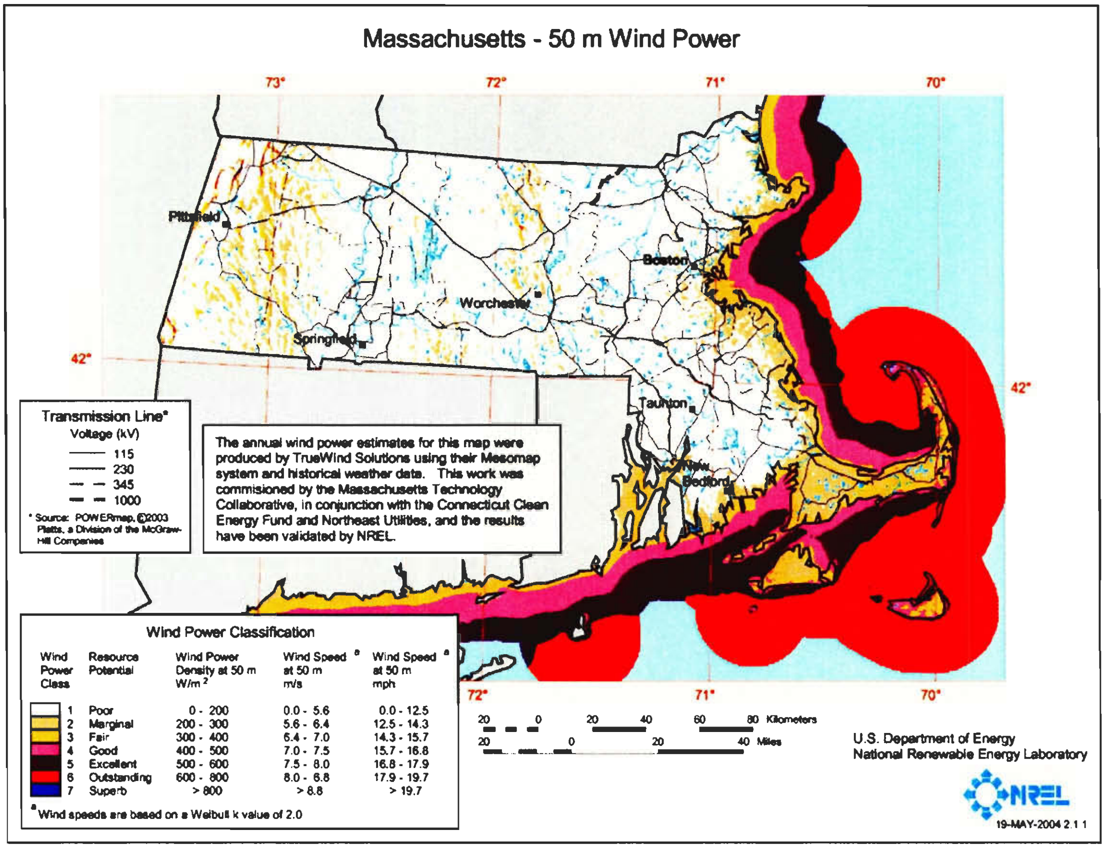


Figure 1: Wind Map of Massachusetts

Source: Department of Energy: Energy Efficiency and Renewable Energy

http://www.eere.energy.gov/windandhydro/windpoweringamerica/images/windmaps/ma_50m_800.jpg

The other available low cost and feasible solution is solar energy; the alternative energy aspect of this project focuses on solar energy.

3.3.1 Passive Solar Systems

Solar energy is energy gathered from the sun. There are many different types of solar energy systems, but for the most part they fall into two categories, passive and active. Passive systems use the sun's energy directly to provide heating or lighting in buildings. There are three different ways of using the passive system design; direct gain, indirect gain, and isolated gain ("Passive Solar Heating," 2005).

Direct gain is when the sun shines directly into a building and heats it up. This is usually done through windows that let the sunlight in while insulating it from the cold. This design is the most simple as it happens naturally in most buildings and it is shown in Figure 2 below.

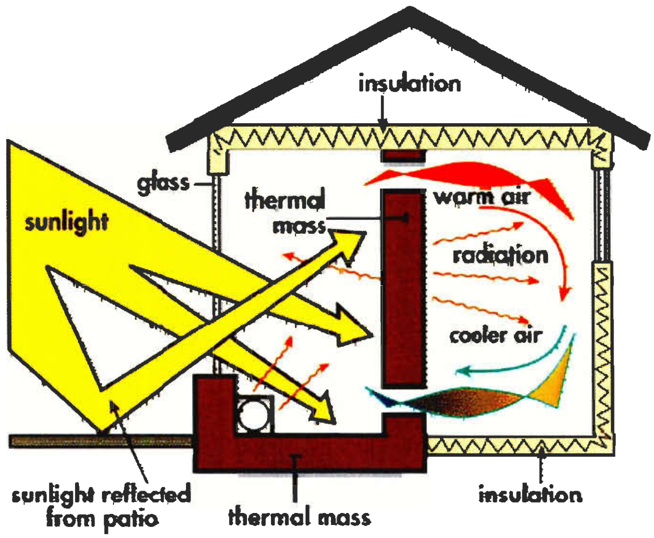


Figure 2: Direct Gain System
Source: California Energy Commission
http://www.consumerenergycenter.org/homeandwork/homes/construction/solardesign/direct.html

Indirect gain is when there is a thermal mass placed between the window and the living space or area that will be heated. A thermal mass is any material that has the ability to retain heat; its ideal thickness is between four and five inches. The most common materials are adobe, concrete, brick, or rock ("Passive Solar Design," n.d.). Indirect gain takes advantage of the concepts of thermodynamics; when air heats up, its molecules spread apart making it lighter than when the same molecules are packed closer due to being cooler. In this design the thermal mass has vents located at its top and bottom, the vents allow for circulation of warm air that would be trapped between the window and the thermal mass. The top vent allows the warm air located in between the window and the mass to circulate around the building while the bottom vent takes in the cold air and as it passes through the space between the window and the mass, it gets heated up and released by the top vent. This cycle goes on through the day while the thermal mass continues to absorb heat. Heat flows from warm or hot areas to cold areas so at night when the temperature in the building drops, the heat that was absorbed by the thermal mass slowly gets released and maintains the temperature of the building. Figure 3, below, displays the indirect gain concept.

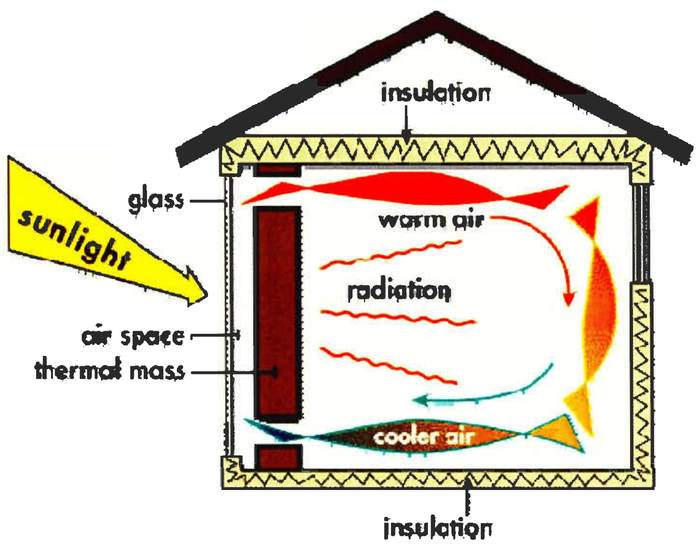


Figure 3: Indirect Gain System
Source: California Energy Commission
http://www.consumerenergycenter.org/homeandwork/homes/construction/solardesign/indirect.html

The third option is *isolated gain*. In this option there is a separate area, either a solar green house or a sunroom, which has as its purpose to collect heat during the day and deliver it through conventional loops to the areas that require heating. This technique reduces the energy required to heat the air but still needs energy to move this collection of warm air to the areas that require heating.

The quality of a passive solar system depends on the design of the building and the materials used during construction; the materials that are utilized should be ones that absorb heat and then slowly release it. It also depends on the region and surrounding buildings because this determines climate and the amount of direct sunlight that the building gets. A key detail to consider with passive solar systems is the orientation of the building. In the northern hemisphere it is preferred that there is a south facing window so that direct sunlight can come through it and heat up the interior of the building. For the New England climate, it would be better to have the longest walls of the building running from east to west, allowing for solar heating to enter the building during the winter and as little sun as possible during the summer ("Passive Solar Heating," 2005). Using the proper materials allows for heat transfer through the walls from the sunrays into the building and proper insulation allows the building to retain the heat in the evening and night times (McCluskey, 2005).

Other applications of the passive solar system include the ability to cool buildings and provide daytime lighting. Adding shade cloth or sunscreens to the windows of a building can stop up to eighty percent of the sun's heat from getting into the building ("Beating The Heat" n.d.). This will reduce the cooling load over the warmer months and thus decrease the amount of energy needed to cool a building. Another option for cooling is to install high performance windows with low-emissive coatings and low shading coefficients. Low-emissive coating reflects heat from the sun while allowing light to pass through and low shading coefficients pertain to the amount of heat penetrating through the window. A low shading coefficient means less heat gets through and this reduces the cooling load. Energy savings range anywhere from ten to fifty percent ("Shading: First," 1994). For daytime lighting purposes skylights and windows are used to brighten up the interior of the building. Another option for lighting during the day is to use clerestory widows; a row of windows located near the peak of the roof ("Passive Solar Heating," 2005).

Passive solar energy systems offer a low cost solution because they make use of building materials and the natural effects of sunlight. This, in effect, turns the entire building into part of the solar heating or lighting system. It is fairly easy to make these changes by modifying an existing structure or when planning a new structure. To make use of the solar heating process the building has to be well insulated. The windows have to be ones that have a low-emissive coating to retain the heat already inside the building. During the winter when it is usually cooler outside than it is inside, the windows do not let the heat escape. These windows serve a dual purpose in that in the summer they keep the heat from the sun from entering the building and this lowers the cooling load for the building. Daytime lighting utilizes skylights and windows to reduce the amount of lights needed to be turned on during the day. This solar energy will reduce the electric bill while providing higher quality lighting.

3.3.2 Active Solar Systems

Active solar systems use solar collectors which come as panels to collect the sun's energy and use either fans or fluids to distribute the heat into the building ("Heating Your Home," n.d.). If air is used to provide heating then the panels heat up the air usually located in a collector near the panels and fans are used to circulate the warm air into the interior of the building. If a fluid is used, then it goes through a heat exchange system where the heat is either transferred into water or air depending on the need of the heating system. The panels are black in color to allow maximum absorption of the sun's energy. For domestic water heating, as shown in Figure 4, the panels usually have pipes going through them that contain a non expanding fluid. This fluid gets heated up as it travels through the panels and then goes to a heat exchanger which transfers the heat into the water storage tank ("Active Solar Energy", 1997). This type of heating is not designed to be standalone. Usually a backup heating system is required when the solar system is not producing sufficient heat. This technology has been around for a long time and when incorporated with the current heating system be it oil or gas, the energy bill decreases by a significant amount.

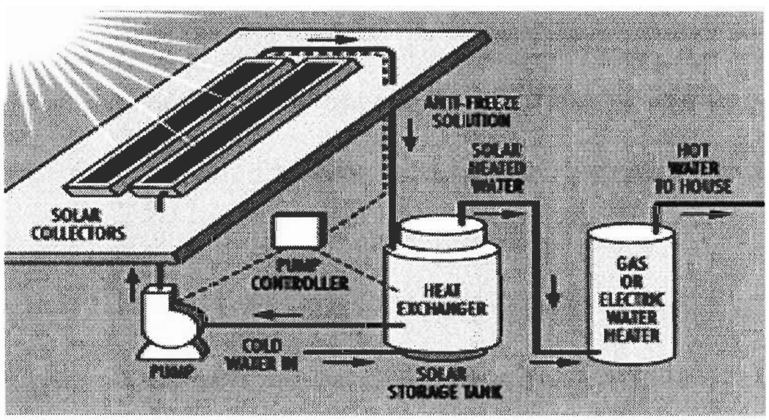


Figure 4: Water Heating System
Source: Solar Energy Society of Canada, Inc
http://www.newenergy.org/sesci/publications/pamphlets/active.html

The newer technology today is the photovoltaic cell that changes the energy from the sun into electricity ("Photovoltaic Solar," 1997). The size of the cell determines how much electricity the cell can produce. The larger the cell, the more surface area available for the sunlight to hit and this enables it to generate more electricity. Most photovoltaic cells come in sizes ranging from 1 to 10 square centimeters and generate 1 or 2 watts (DOE n.d.). The cells can be arranged into different configurations to produce any combination of voltage and wattage. An example of a photovoltaic array is shown in Figure 5. To generate more electricity, the panels contain arrays of cells; the greater the number of cells in a panel the larger the amount of wattage produced. Connecting a photovoltaic system to the grid requires and inverter to convert direct current to alternating current, a form more commonly used for powering household items, and a special electric meter.

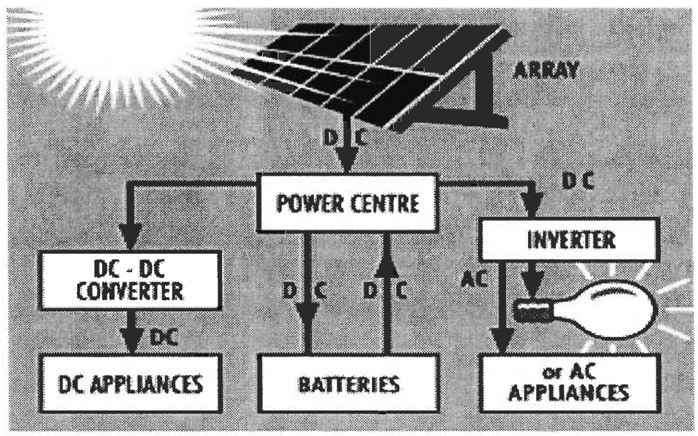


Figure 5: Photovoltaic System
Source: Solar Energy Society of Canada Inc.
http://www.newenergy.org/sesci/publications/pamphlets/photovoltaic.html

The inverter converts the direct current into alternating current which is the same as what is available at household electrical sockets. The inverters have a large range in price and quality, so purchase depends on the user's needs. The photovoltaic industry is growing quickly and photovoltaic systems are becoming more efficient and cost effective. The Sharp Corporation has developed a photovoltaic power generation system for housing ("Photovoltaic Power," 2001). The system is comprised of a series of 155 square mm cells that produces a total of 151 watts. The cells are easily adapted to roof tops of varying types and include a power conditioner and storage converter which let the user determine the output of the system and allow for easy integration into the current system. Depending on need, multiple modules can be used. This technology was developed in Japan where a module costs about $652 ("Photovoltaic Power", 2001). For this price the power conditioner and storage converter are sold separately; the power conditioner costs between \$2341 and \$3219, while the storage converter costs about \$317. The payback period is long, upwards of fifteen years based upon current energy costs. This depends on the amount of time sun hits the panels, the costs of fuels, and maintained efficiency of the cells. The payback is not only monetary but also environmental; solar only uses energy that will be sent to earth as long as the sun keeps burning. Due to its lack of moving parts, the life of the product can be upwards of thirty years ("Photovoltaics (PV)," n.d.). The cells are always producing energy as long as the sunlight is available to them. Other than the immediate cost and long payback period there is no real disadvantage of installing photovoltaic panels.

Another type of a solar active system is a reservoir solar system in which the body of water acts as the thermal mass and collects or stores the energy of the sun as hot water. For this type of system a large amount of water is required. It works by having a solar heat exchanger that transfers heat from the sun into the water at the lower end of the reservoir and another heat exchanger located at the higher end of the reservoir to transfer the heat to another system ("The solar reservoir" n.d.). Depending on how much heat is transferred the water temperature rises accordingly. To get the energy from the reservoir another heat exchange system is used, usually at a different location from the first heat exchange system. The second exchange system transfers heat to wherever it is needed. An advantage of this system is that water is great for storing energy but the disadvantage is that it requires a large amount of water and this depends on the configuration of the location where it is being considered for application.

3.3.3 Summary

Solar energy is a virtually unlimited energy resource that can be used for many things, and it provides a clean source of energy. Most applications of solar energy that pertain to buildings involve heating and powering. For the heating option there are two types of system that can be used; the passive system and active system. The passive system uses the energy supplied by the sun directly to either heat up directly or store heat to be used later to heat up an area. Most of the techniques used for passive system involve the designing of buildings to retain heat via building materials and orientation. Implementing this type of system in a current building may involve retrofitting most of the building which could be quite costly but there are some options available in terms of high performance windows, insulation, and better heat circulation methods. The other type is the active system which first converts the solar energy into heat and then sends it to a heat exchange system that transfers the heat into another medium, either air or water for domestic use. The active systems use panels that are black in color to absorb solar energy and transfer it to either a fluid for a closed loop system or air which is then circulated into the living space. The cost of this type of system mainly depends on the amount of paneling that is required to power the project's need, but it does reduce the amount of energy required for heating by other sources like a boiler which uses gas. This reduces the energy bill while reducing the amount of pollutants being released into the air.

Photovoltaic cells are used to produce electricity in an active solar system, which converts the sun's energy into electricity which can be used for lighting purposes or powering up appliances and devices in a building. It is a good source of electricity since it is cleaner, requires little maintenance, and can last for a very long time. The photovoltaic cells should be oriented in the southern direction for maximum collection of the sun's energy. The cost of this technology is rather high, and the payback period could be rather lengthy; but it is an option that could generate revenue by selling the excess power that is not needed to the grid companies.

Knowing the different types of technologies available and how much they cost helps to determine what the best possible solution would be. It also enables the possible incorporation of two or more technologies to create a hybrid that might be a better solution for the project rather than using just one type of technology. The most expensive and largest of potential projects is cogeneration, a large plant that may heat and power a whole community.

3.4 Cogeneration

Cogeneration is the simultaneous production of heat and power in a single thermodynamic process. It is a much more efficient process than a conventional power plant. Figure 6, below, displays the difference between the two types of plants. Many of these systems place the electricity generation equipment, the turbine or the engine, first in the system. The system then uses a waste heat recovery boiler to capture the excess heat caused by the reaction. The captured heat can then be used to satisfy heating requirements, provide cooling using advanced absorption cooling technology, and can even generate more electricity with a steam turbine. These systems can even satisfy compressed air requirements by bleeding high pressure air off the compressor stage of a combustion turbine. Almost all cogeneration utilizes hot air and steam for the process fluid, although certain types of fuel cells also lead to cogeneration. These turbines and engines can be operated using a variety of fuels. The fuels can range from conventional fossil fuels to biomass and geothermal.

Figure 6: Cogeneration Concept
Source: Combined Heat and Power
http://www.chp-info.org

3.4.1 Benefits

These cogeneration systems achieve efficiencies ranging from fifty to seventy percent. This is a huge improvement over conventional fossil-fuel burning systems, which are currently only at thirty-three percent (Cogeneration n.d.). Cogeneration not only has benefits for the users of the system, but also for the environment. Fewer emissions of nitrous oxides, sulfur dioxide, mercury, particulate matter, and carbon dioxide are produced because the system is more efficient, and in turn less fossil fuel is needed. The reduction of carbon dioxide is important because it is the leading greenhouse gas contributing to climate change (Cogeneration n.d.). The concept of reusing steam to produce power has been around for centuries; medieval smokejacks were devices that turned a spit by a fly or wheel using rising gases coming through a chimney (Merriam Webster Online, n.d.). In the nineteenth century, excess steam was used to power steam engines, the uses of one processes' waste products have been used for centuries. Our nation's first commercial power plant was a cogeneration plant that was designed and built by Thomas Edison in 1882 in New York. Today, cogeneration can be seen throughout the world for the efficient production of heat and power. This is the result of intensive collaboration between the government and many industry giants using advanced materials and computer-aided design techniques. There has been a dramatic increase in the efficiency and reliability of new generations of turbines and reciprocating engines, while still reducing costs and emissions of pollutants. Figure 7 below, shows the increased thermal efficiency of cogeneration while inversely driving down carbon dioxide emissions (Roarty, 1999).

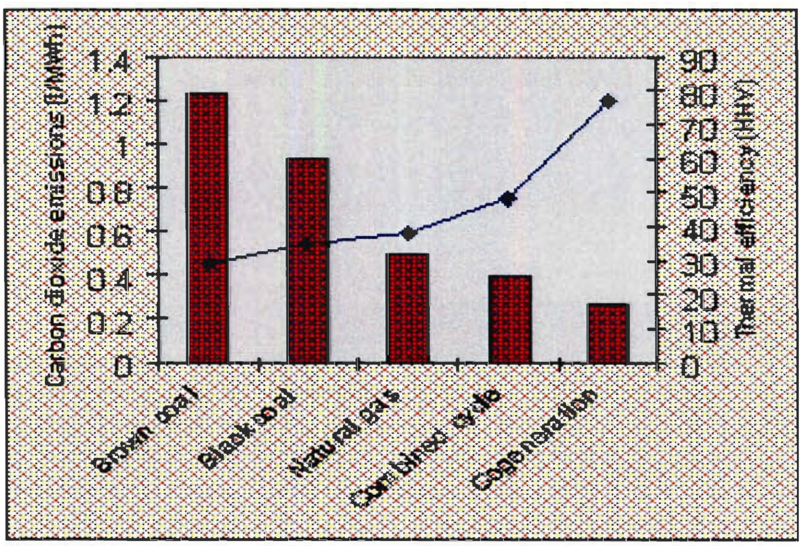


Figure 7 Thermal Efficiency and CO2 Emissions Technology Breakdown

There are five different types of cogeneration plants available now. The most of basic of which is the backpressure power plant. In this plant, electricity and heat are generated in a dynamic steam turbine, and are delivered to the owners of the plant. Another main component of the backpressure power plant is the steam boiler, which can be designed to fire solid, liquid or gaseous fuels. Another type of plant is the extraction condensing plant. This works by generating electricity while some of the steam is extracted to also generate heat. The next type of plant is a gas turbine heat recovery boiler plant. In this type of plant, there is heat generated by the hot flue gases of the turbines.

Natural gas, oil, or a hybrid of both is commonly used to power these types of plants.

A more recent type of cogeneration plant is the combined cycle power plant. In this type of plant, there are usually two turbines. The exhaust heat and steam from the first turbine are used to power the second turbine which allows for more power and efficiency. Lastly, there is the reciprocating engine power plant. This plant works through the use of a reciprocating engine, such as a diesel engine, which is combined with a heat recovery boiler where it supplies steam to a steam turbine to generate both electricity and heat. (Combined Heat and Power, n.d.)

The technologies of cogeneration are poised to satisfy a significant portion of the United States' growing electricity needs. Today, cogeneration accounts for about ten percent of the nation's electricity (http://www.cogeneration.net), while continuing to meet its thermal demands (http://www.aceee.org).

3.4.2 Case Studies

There are many places in the nation which have already implemented cogeneration and are reaping the benefits. One such example of a cogeneration plant can be found in Long Island, NY. The State University of New York at Stony Brook has a cogeneration plant that serves the university and nearby university hospital's electrical power, heating, and cooling needs. The university community itself is composed of around 17,000 students and 10,000 employees and the hospital contains roughly 900 beds. The energy being delivered is clean and efficient, as well as being delivered at a much more competitive price. According to SUNY Stony Brook,

> "The plant is a simple one that provides 280,000 pounds of steam per hour to the university for its heating and cooling needs. The plant also generates approximately 40 megawatts of electricity, satisfying all of the university's power needs. Excess capacity is sold to the Long Island Power Authority." (http://www.eserc.stonybrook.edu/brentwood/1998/cogeneration/home.html)

The university enjoys a large return on its investment. The plant's main source of electrical power is derived from a jet engine turbine which runs on natural gas, but it can also be run on #2 oil if necessary. It is a cogeneration plant because it produces energy from the jet turbine driving an electric generator and the excess heat that is given off from the turbine is used for heating the campus. In this way the efficiency of the plant is in the range of eighty percent, compared to the forty percent of the engine alone. The plant also has a strict control on its emissions. The emissions of the plant can be seen in Table 1. Figure 8 below displays the schematic of the SUNY Stony Brook plant.

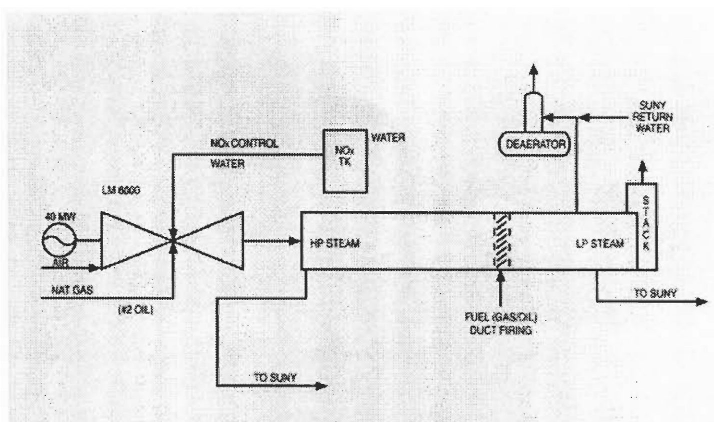


Figure 8: Cogeneration Schematic
Source: State University of New York in Stony Brook
http://www.eserc.stonybrook.edu/brentwood/1998/cogeneration/home.html

Pollutant	Control	PPM
SO2	Low Sulfur Fuel	Negligible
NOx	Water Injection	25 ppm
CO	None	50 ppm
Particulates	None	Negligible

Table 1: Stony Brook Plant Emissions

Source: State University of New York in Stony Brook
Source: http://www.eserc.stonybrook.edu/brentwood/1998/cogeneration/home.html

Another example of cogeneration can also be found at San Diego State University. The university is benefiting in many ways. Before the cogeneration plant, it was buying 5 million kilowatt hours (kwh) per month at the rate of 16 cents per kWh. This would translate out to a monthly power bill of $800,000. However, since January 2003 when the plant went live with two Taurus 60 solar turbines, SDSU was able to produce a combined 14 megawatts of energy. This was more than enough to power the campus' peak load of 12 megawatts. The excess heat created when producing the electricity is then used to provide heating and cooling to the campus. The current cogeneration plant, gives San Diego State the ability to produce power at a lower price, producing net savings to the university. The cost to produce this power depends on the cost of the gas used to run the turbines. The savings that they are collecting formerly were used for paying back the loan that they received for the construction of the plant. As that loan gets paid off, these savings can be used in many other ways to benefit the school. According to Bill Lekas, an administrative analyst at the school, "the cogeneration plant produces enough energy at any given point to power around 12,000 homes Not only does the campus produce its own power, we even generate extra that could be sold." (DeLory 2004).

3.4.3 Conclusion

The idea of reusing waste energy from one process would naturally lead to using the excess heat from power generation for some other process. Heating seems like a natural choice; if groups of people can generate their own power and electricity at a much higher efficiency than those from whom they purchase energy, a switch may be a good idea. Cogeneration has high efficiency which may lead to lower costs.

3.5 Chapter Conclusion

The combination of these ideas will lead to the final recommendations for the Quinsigamond Village and will allow them to decrease operating expenses and provide peace of mind that they are doing their part in preserving the environment. Many of the available options for the Quinsigamond Village will require some capital to fund the project. Costs may potentially put the project out of reach, and thus funding will need to be discussed to aid the churches.

4 Methodology

4.1 Introduction

The research done for this project allowed us to determine recommendations that could be created to assist the four churches and community center in the Quinsigamond Village in making a decision to ultimately reduce costs and emissions. These recommendations are organized by the time it would take to implement; the short term suggestions are given to make small building modifications to decrease heat loss, mid-term suggestions include the possibility of implementation of alternative energy, and long term suggestions are ideas for community-wide upgrades.

This project has much of its base in qualitative studies; we have conducted interviews, examined case studies, and taken part in participant observation. Through this practice we analyzed our results to find meaningful data. The data we sought to gather from this design included usage patterns and ideas on how to implement our plans. The project had quantitative study as well; we looked at past energy bills to set a benchmark and determine what sort of funds would be available if costs were cut.

4.2 Current Inadequacies

In order to determine current inadequacies in the energy systems and what their cost impacts are, it was necessary to gather behavioral usage patterns of the churches, and technical data of the buildings. Behavioral data included utilization of the churches and, if available, when energy systems were powered on and off. Technical data included building structure, heating, and electrical system efficiency.

Behavioral audits consisted of interviews with church members to determine the current scheduling in order to see how it may be possible to optimize building usage efficiency. Interviews were conducted with each organization's main liaison, to determine the typical weekly building usage, heating zones, lighting usage, and things not on the schedule or in other archival data. Also, church officials were interviewed to determine the logistics for the creation a potential new, more energy efficient schedule for each church.

Technical audits for the scope of the project included an analysis of building structure, lighting and heating systems, and electrical devices. Specifics were gathered about the existing system of each building such that it may be weighed against an upgraded one. This was combined with our data from observing the system, the fuel bills and efficiency ratings, to determine the usage of the system to enable us to prioritize upgrades. The windows and doors of the buildings were examined to determine the extent of heat loss and the possibility of upgrades to them. The lighting systems were examined by means of a free lighting audit provided by National Grid. Mr. Bill Gordon of Prism Consulting, Inc. went through each building noting each lighting system and determined if they could be replaced and by what. The data Bill Gordon gathered were then analyzed by a team of engineers at Prism and a proposal was sent out to each of the buildings. The heating systems of each were looked at by us to determine inefficiencies within them. In the community center, Fellowship Hall was inspected by Wyman's HVAC to propose a more efficient system for the hall. High drain equipment was looked at to determine the electrical draw, and then evaluated against newer equipment. The technical audit was an examination of the systems equipment to improve overall efficiency

4.3 Alternative Energy Solutions

Energy use was established based on the energy bills for the past few years. We were able to gather energy bills up to three years for the buildings. These data provided a baseline against which improvements could be considered as well as capacity and seasonal requirements. These data are considered as input for alternative energy systems.

To determine the quality and cost effectiveness of alternative energy sources, we contacted many professionals in the alternative energy field. We interviewed solar power professionals of the Alternative Energy Store in Hudson, MA and the Solar Store in Auburn, MA to question the feasibility of implementing new alternative energy sources, such as photovoltaic, active, and passive solar systems. We also visited Clark University to inspect the cogeneration plant that it houses. An interview with A. Roy Cordy, chief engineer, and Richard Clark, plant manager, gave us the history, cost, and system specifics of the plant at Clark. Information about the life, cost, and energy production of the different solutions was found via existing data on these products as well as through some of the answers we received from the solar professionals. Through these combinations we were able to produce a savings percentage compared to the current systems, expected costs including time-value of money and trends in fuel prices, and payback periods with all these factors in mind.

To give recommendations for alternative energy sources for the Quinsigamond Village buildings, we needed to know a few things such as the energy costs of the churches, potential savings of implementing these new sources of energy, and steps to go about implementing them. The community needed to know the costs and benefits of any proposed project because they have a priority to survive with the existing conditions before attempting to plan for the future. Once we knew if an alternative was cost effective, we could then look at the quality and life span of each possible alternative to show the churches possible benefits such as reduced cost and emissions. With this information available, we were able to confidently recommend which alternative would be best suited to each building.

4.4 Sources of Funding

The required evidence needed to find sources of internal funding for the project included a look at the church's budgets to see how much money was being spent and how much was available to be allocated to the various improvements suggested. To find sources of external funding, we researched organizations working on energy efficiency and alternative energy solutions that were willing to offer support for a project of similar size.

Finding funding from within the churches required us to examine current energy bills to determine where funds were going for their energy costs. This was gathered from collected energy bills and budget reports. These bills were then analyzed to generate a graphical display of potential savings for each recommendation. To collect data about external sources of funding, we looked at case studies which provided us with some information about organizations, such as the Massachusetts Technology Collaborative, that funded projects in similar situations. These were indexed later in the report to provide an overview of the different possibilities available.

Knowing what the sponsors had available and were willing to invest into the project allowed us to make suggestions that fell within the specific needs and capabilities of each sponsor. Finding outside sources of funding increased the ability of the sponsors to implement the recommendations.

4.5 Section Summary

These techniques used to collect data ranged from interviews, to observations, to looking at existing data. This data also had a degree of overlap showing that the topics were intertwined, so this data needed to be sorted out for each category. This information then converged to allow us to create useful recommendations to the Quinsigamond Village churches and community center, based upon finding energy inefficiencies and fixing them. This data provided potential alternative energy solutions and ways to fund our recommendations. By answering the given research questions, we were able to give recommendations we felt confident in. Knowing where energy is being spent excessively allowed us to encourage the buildings to make small repairs to reduce on energy expenditures. Knowing the most feasible alternative energy sources provided us with information about what technologies worked in the area and if they were within a price range the organizations can afford. Finally, finding what sources of funding were available allowed the project to be scaled in a manner to fall within the limitations of the churches and the community center.

5 Results and Analysis

Each of the buildings involved in this project was unique and the data collected was analyzed knowing that each organization had its own inefficiencies. The analysis shows these differences and allows for the recommendations to be unique for each of the project's participants.

5.1 Energy Audit

5.1.1 Usage

Building Utilization

One of the aspects of energy audits as conducted was the utilization of the buildings for the various activities occurring within them. Building usage charts were created base upon schedules received from the organizations and interviews with staff. These charts located in Appendix 1 show space usage of the buildings in a typical week of operation. All of the buildings have varying usage schedules that range from seldom to constant use. Buildings like the community center and the Emanuel Lutheran Church, which are in constant use, had their schedules examined to determine what changes could be made to reduce down time between events. The staff members were asked if any events had to remain in the same time slot. This influenced the recommendation for a new schedule, if at all possible.

Area utilization showed when heating zones would need to be at a higher temperature to suit their users. These data can be set into programmable thermostats to optimize building temperatures. The temperature for many of the rooms was set higher than 70 degrees Fahrenheit when is use. Money would be saved if the temperature was reduced. For each degree the average temperature is dropped the oil bill is reduced by 4% (ase.org, 2000).

5.1.2 Electricity Draw

One of the aspects of our energy audits was to identify inefficient appliances and recommend their replacement or removal. All of the buildings contained refrigeration units, some commercial and some residential types. With the information available on the residential refrigerators, analysis was done to determine cost of use. Table 2, below, displays the analysis of the refrigerators in the United Methodist Church and the community center.

Current Refrigerators	UMC	UMC	QVCC	QVCC
Brand	Hotpoint	Hotpoint	Westinghouse	GE
Size (cu. ft.)	20.6	13.6	12	15.6
Adjusted Annual Consumption	892 kWh	1,475 kWh	1606 kWh	910 kWh
Cost/year to run	$81.00	$134	$145	$83

Table 2: UMC & QVCC Refrigerator Statistics

The energy use was calculated using adjusted values found at Home Energy Magazine online. The cost per year was calculated by inputting data to a calculator from Consumer Reports. A detailed analysis of the expected savings with some suggested replacements is located in Appendix 2. These refrigerators are used in addition to larger commercial models. Data were not easily available for them. What was found, through Dave Johnson, was that the commercial models in the community center were all greater than 20 years old. According to a report on best practices for churches prepared by City Green, refrigeration and freezer units that are more than 10 years old are low in efficiency standards (CityGreen, 2003). Electricity costs and emissions from the power plants can be reduced by replacing or removing the refrigerator.

An audit was performed by Prism Consulting Inc., who is sub-contracted by National Grid, on the lighting systems. The audit looked at the lighting fixtures, taking into account the light output, quality, and energy usage to determine if a better alternative was available. The results from this audit can be found in Appendix 2 under the Lighting section. Each building has the current fixtures as well as suggested replacements. This gives a KWH savings per year and a cost savings per year. The lighting audit was done on all the buildings except for the Bethlehem Covenant Church because we could not gain access to the building.

5.1.3 Windows

Part of the architectural design of the buildings analyzed included a substantial amount of area of the buildings' envelopes that were covered by windows. Windows are a major heat sink in a building, especially buildings such as churches which have large stained glass windows. Of all the different types of windows, the greatest amount of heat loss occurs through single paned windows, which have an R-Value of about 0.91. R-Value pertains to the level of insulation of a material. The lower the R-Value, the greater the heat transmission through the material resulting in increased energy required to either raise or maintain a certain temperature difference. Adding storm windows to single paned windows can increase the R-Value to about 2, reducing the amount of heat lost through the windows. As part of our walk-through audit we took measurements of the single paned windows and noted any metal framed and double paned windows. Each square foot of single paned window has an hourly loss of 33 BTUs when there is a 30 degree

Fahrenheit temperature difference. A single pane with storm windows lowers this loss to 15 BTUs. This is calculated from the heat loss formula shown in Appendix 2. Furthermore, the organizations can save on installation costs by having volunteers from the community insulate the windows.

Community Center

The main floor of the building has a total of twenty one windows. These windows are single-hung windows meaning that the top part of the window is fixed while the bottom part moves up and down. They have wooden frames and thus over time air leakage occurs between the top and bottom part of the window. Two of the windows had air conditioning units installed which lacked covers on the outside and had a draft coming from the units. All the windows lacked storm windows thus increasing the heating load of the main floor. The total area of the windows was approximately 149 square feet.

The high ceiling combined with the windows renders the second floor of the building a huge heating load for the boiler and present radiators. When the heat is turned up for an event, the recovery rate of the room is only 3 degrees an hour. There are broken windows and air conditioning units that also lack covers on the outside. The total area of the single paned windows is about 160 square feet.

The second floor would save 164 gallons of oil each heating season by adding storm windows. At current oil prices this translates to about $400. Downstairs is similar, saving 150 gallons of fuel and $350 per heating season.

Bethlehem Covenant

The sanctuary of this building is a vast hall with a second level that provides extra seating for the members of the congregation. The stained glass windows run from the second level to about three feet off the floor of the first level and are equipped with storm windows. Measurements of these windows were therefore unnecessary. The building also has children's classrooms, a play room, an events hall, a kitchen, and offices all of whose windows are equipped with storm second panes.

St. Catherine's of Sweden

Saint Catherine's of Sweden is newer compared to the other buildings we are working with and includes large stained glass windows and clerestory windows for lighting. It has approximately 886 square feet of single paned windows some of which have metal frames. Reinforcing these with storm windows would save over 900 gallons of #2 oil; at current oil prices this can save up to $2200 per heating season. There is a hall that is separate from the church that is used for events, some offices, and Sunday school. This area has 189 square feet of double-paned windows with storm windows, not including the clerestory ones. We were unable to get on the roof make accurate measurements.

Lutheran Church

The Lutheran Church is a large building with extensive window areas. The nave has single-paned stained glass windows covering an entire wall. The chapel also has stained glass windows that are single-paned. Between the chapel and the library lies a hall that has single paned windows on both sides. The hall makes very good use of passive solar but there is a large amount of heat loss as well. The building also has classrooms that have windows with metal frames. As a temporary fix church members have covered the windows with plastic and wooden frames to create a second pane. This has worked very well as the rooms are much warmer than before base on our observations. The approximate area of single paned windows in the building was 1500 square feet. This number excludes the windows in the fellowship hall which from our understanding Massachusetts Interfaith Power and Light is going to be working on. It also excludes all the windows in the classrooms. If the 1500 square feet of windows in the building are fitted with storm windows with an R-value of 3, a total of $3,700 per year will be saved (derived from formula in appendix 2).

United Methodist Church

Like most of the other buildings the United Methodist Church is one building with a sanctuary, offices, a hall, kitchen, and classrooms. All the stained glass windows in the church have storm windows but the bathroom and classroom windows are single paned. The building has 127 square feet of the single paned windows.

5.1.4 Building Extremities

Technology and energy economics have changed dramatically since the churches of Quinsigamond Village were built. In the past, there was no such thing as centralized heating, insulating factors of building materials were not known or paid attention to, and oil was much cheaper. Although the process of analyzing wall and roof insulation was beyond the scope of our abilities, it is safe to say that upgrading insulation on the roofs and walls of the churches would save money on heating and cooling costs, though initial costs may be substantial.

5.1.5 Fuel Usage and Cost

The churches in Quinsigamond Village are paying different rates for oil, even though most of them get oil from the same company. The United Methodist, Bethlehem Covenant, and the Emmanuel Lutheran Church are all supplied by Peterson Oil. St. Catherine's of Sweden is buying oil from Al's Oil. Due to participant confidentiality, the rates of some of the organizations will not be mentioned. Listed below, in Table 3, are the current rates for oil companies servicing Worcester:

Oil Company	Town	Rate	Updated date
AL'S OIL SVC	SHREWSBURY	$2.399	1/31/2006
HARVEY'S DISCOUNT OIL	WORCESTER	$2.340	1/31/2006
PETROLEUM SERVICE OF WORCESTER	WORCESTER	$2.490	1/31/2006
RADIO OIL CO	WORCESTER	$2.479	1/31/2006
C K SMITH & CO	WORCESTER	$2.290	1/31/2006
PETERSON OIL SVC	WORCESTER	$2.340	1/24/2006
PIONEER OIL CO	WORCESTER	$2.500	1/31/2006
SUPER HEET INC	WORCESTER	$2.290	1/31/2006

Table 3: Local Oil Prices

Source: http://newenglandoil.com/massachusetts/zone10.asp?x=0
New England Oil Prices

Through Massachusetts Interfaith Power and Light, churches in Worcester can buy into a group oil buying pool, and receive a discounted rate. Currently Mass Energy is supplying members of MIP&L for a rate of $1.989 per gallon.

5.2 Solar

5.2.1 Photovoltaic Solar

The appropriate size and scale for a solar electric power system is a function of the building to be served and the electric energy needs. The monthly kilowatt-hours used in all five buildings ranged from 400 to 5280 KWH, meaning that if installed the systems size and requirements would different. The collected energy bills began to provide a glimpse into the needs of each building. Some inconsistent data needed to be normalized and this was done through the traveling average of usage. As a general trend in most of the churches more energy was used in the summer months due to air conditioning and fan usage and an increased load on refrigerators. This is advantageous because there are more hours of direct sunlight during that period. Base load was calculated based upon the traveling average and was used to estimate the size of a future system.

The solar systems that would be sufficient to power the buildings range from 7-20 kilowatts determined from the base loads of each building. Some of the highest production rate panels available produce 300 watts and have a size of about 26 square feet. The size and space requirements are as shown in Table 4.

Emanuel Lutheran	20 KW	67 panels	1742 Sq. ft.
United Methodist	8 KW	27 panels	702 Sq. ft.
Bethlehem Covenant	7 KW	24 panels	624 Sq. ft.
Community Center	10 KW	34 panels	884 Sq. ft.
St. Catherine's	8 KW	27 panels	702 Sq. ft.

Table 4: Sizes for Active Solar Photovoltaic arrays for the respective buildings

This is just a general estimate but if solar is going to be used general consumptions should be lowered as much as possible. At the moment, solar power is an expensive process to initiate. Their funds would be better utilized by following the recommendations to reduce the current electrical use.

The active solar panels would need to be mounted in an area with unobstructed southern exposure, such as a roof. The system would need an inverter and a special meter to be connected to the grid. This would require installation by a professional which will be part of initial costs. There is talk of using plastics in the future to produce solar energy which would reduce costs drastically.

Currently, if the prices of both the system and fuel stay constant, the payback period for the system would be upwards of 20 years. Figure 9 shows that if fuels prices rise or if funding is obtained the time for payback changes substantially.

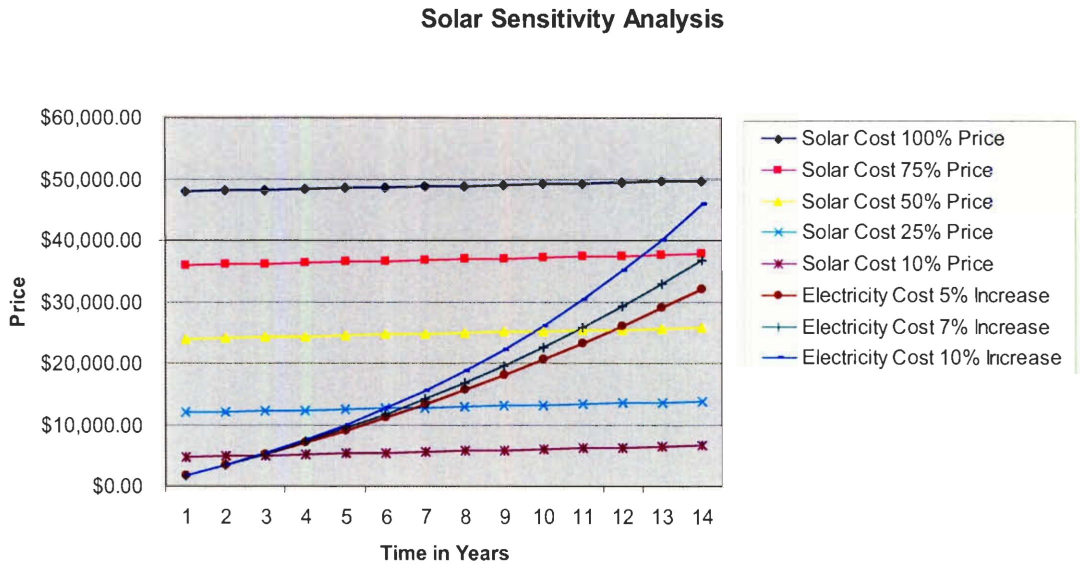


Figure 9: Payback Sensitivity of a 10 kW Solar System

5.2.2 Passive Solar

A re-circulating panel needs to be attached to the south facing external wall or ceiling of the room that requires heat. Many contain a small photovoltaic panel to power the fan that circulates air into the room. Installation requires creating dryer vent sized holes for air to circulating into the panel and mounting the panel onto the exterior surface.

A 1.5 kW passive panel can cost about $1,550 but can start receiving payback quickly as it can produce around 5120 BTU per hour when it has direct sunlight. Each panel can save over 41 gallons of #2 oil per year, and if the price of oil is $2.40 per gallon, yearly savings can be around $100 per panel. Figure 10 shows the payback depending on funding and rate of price increase of fuel.

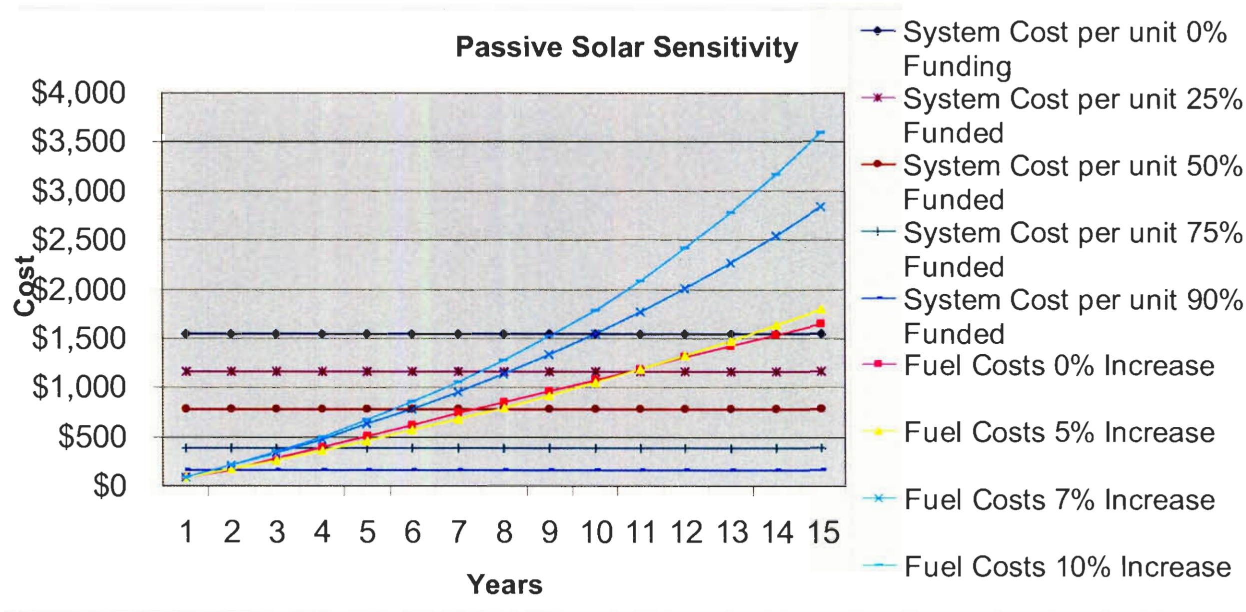


Figure 10: Payback Sensitivity of a 1.5 kW Passive Panel

5.3 Combined Heat and Power

The idea of cogeneration can be applied in a few ways in the community of Quinsigamond Village. One way that a cogeneration plant can be introduced is by having a central plant in the village that will service many of the higher consumption buildings in the area. Using a map of the area, some of the estimated load points, the high consumption buildings, include:

- Emanuel Lutheran Church
- Quinsigamond School
- Quinsigamond Village Community Center
- Quinsigamond Mall (to be completed in a few years)

Another option for the area is to install smaller plants at the separate load points. For example, the base load of power for the United Methodist Church is about 800 kWh a month, which is not enough to make it a load point or a worthy candidate for its own small cogeneration plant. But, if this is combined with the Quinsigamond School which is adjacent to it, the two buildings make up a good load point in which a small plant could be considered to provide both buildings electricity and heating. The technologies that would be appropriate for the smaller plants would be the fuel cell technology or the reciprocating engine. According to the California Energy Commission, reciprocating engines have a range from 5 kW, residential backup power, to up to 7 MW generators. This technology would be useful for the larger scale load points, such as the planned mall and some of the businesses within the village that need power constantly throughout the day. The fuel cell technology is still in its finalization stage before it is made commercially available to the public. There are four primary fuel cell technologies: phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), solid oxide fuel cells (SOFC), and proton exchange membrane fuel cells (PEMFC) (www.energy.ca.gov). Out of these four, the SOFC technology is the most suitable for the local installations. It has an electrical range from 1 kW to 10 MW. It also has an electrical efficiency ranging from 45-60%, which is just for electricity, but including the thermal portion, its efficiency as a cogeneration plant can be as high as 90%.

5.4 Funding

After extensive research for opportunities to fund some of our recommendations, the main source that was found was the Massachusetts Technology Collaborative. This organization offers a Matching Grants for Community program and a Small Renewables Initiative. The Matching Grants for Communities works in the following manner, for every dollar a consumer spends on renewables through the Clean Energy Choice program, MTC will match it in two ways:

1. Up to one dollar will go to the consumer's community for renewable energy educational materials or projects.
2. Up to one additional dollar will go to low-income renewable and energy efficiency projects

Interested parties can sign up online through the Clean Energy Choice website which is located in Appendix 6.

The next available option is the Small Renewables Initiative. This initiative is supporting the installation of 400-500 renewable systems with rebates of up to $50,000 (less than 10 kW) statewide. The renewable energy generation system(s) must be located at residential, commercial, industrial, or institutional facilities that are connected to one of the investor-owned electric distribution utilities in Massachusetts. These rebate awards may be used to facilitate the installation of distributed renewable energy generation projects on existing buildings (retrofits) or in conjunction with new construction/major renovation/addition projects. The applicant may be a public or a private entity but must be the facility owner or occupant, and must be the electric utility customer of record (Massachusetts Technology Collaborative, 2006).

Another option available is the Community Development Block Grants, which provide communities throughout Massachusetts with resources to implement an array of community and economic development projects. These grants are made possible through the U.S. Department of Housing and Urban Development and are applicable only towards the Community Center.

6 Recommendations and Conclusions

6.1 Organization Specific Recommendations

6.1.1 Bethlehem Covenant Church

Recommendation 1: Lower average building temperature

The Bethlehem Covenant Church uses a very large amount of oil for a building with relatively little use. If the average temperature of the building were to be reduced by 5%, immediate savings will follow. During the week the thermostat should be lowered from 62 to 57 degrees Fahrenheit. On Sunday the temperature should be lowered from 73 to 68 degrees Fahrenheit. This step alone would produce estimated savings of $2000 per year based upon savings estimates from the Alliance to Save Energy (ASE.org 2000).

Recommendation 2: Join an oil buying group

Joining an oil buying group would enable the church to reduce oil costs. These oil buying groups are able to provide members with oil prices that are much lower than the average price by buying in bulk amounts. Currently Massachusetts Interfaith Power and Light works with a group that can provide oil at $1.989 per gallon for member congregations.

Recommendation 3: Install programmable thermostats

The Installation of programmable thermostats within the Bethlehem Covenant Church is another way to reduce oil consumption. They would enable the temperature to be set much lower during hours when the building is not in use and for the temperature to be comfortable while in use.

Recommendation 4: Insulate exposed pipes

Insulating pipes within the Bethlehem Covenant Church prevents heat from escaping before it reaches the intended area. This is especially true with the pipes in the basement coming from the hot water boiler.

6.1.2 Emanuel Lutheran Church

Recommendation 1: Join oil buying group

The Emanuel Lutheran Church is currently paying $2.40 per gallon of oil as shown by their oil bills. Joining the Massachusetts Interfaith Power and Light oil buying group would lower the church's oil cost 21%, or a yearly savings of $5000.

Recommendation 2: Install insulating blinds in Fellowship Hall

Insulating blinds increase the R-value of the area that they cover to prevent heat loss at night and allow passive gain of heat during the day. These blinds can have an R-value of 5. The 80 square feet of single paned windows in the room would cost $300 for cellular shades. The Savings would be $160 per year resulting in a payback period of less than 2 years, as derived from the formula in appendix 2.

Recommendation 3: Upgrade lighting in Fellowship Hall

The lighting in the Fellowship hall is made up of six 400 watt mercury vapor lamps. These lights should be upgraded to T-5 fluorescent lights that put out similar light with only 250 watts of power. These lights will be funded 80% by National Grid along with any other lighting upgrade presented by Prism Consulting.

Recommendation 4: Revise Schedule

The revision of the schedule of events for the Emanuel Lutheran Church was not as successful as originally thought. The times and places of where the events occur presented problems in trying to make the schedule even better. In Appendix 1, the rescheduling of one event is shown, the only event that can really be considered. Though, the church might want to consider renting out available space when the heat and electricity are already running.

Recommendation 5: Install programmable thermostats

Programmable thermostats will allow for the temperature of the rooms to be better regulated, since they are not dependent on humans. The thermostats will allow for the temperature to be lower while the building is not in use while ensuring that the temperature is comfortable when staff arrives.

Recommendation 6: Install storm windows

In the long run, all of the church's single paned windows should be fitted with storm windows to increase the overall R-value without reducing the aesthetics of the building.. There will be great savings but the up-front cost may also be very high.

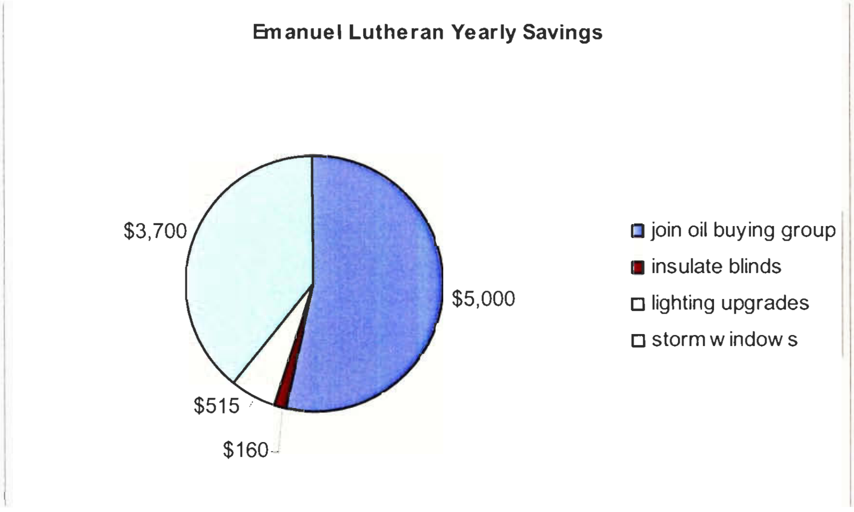


Figure 11 Emanuel Lutheran Savings Breakdown

6.1.3 Quinsigamond Village Community Center

Recommendation 1: Repair windows

Some of the windows on the second floor of the community center are cracked or broken. These windows should be replaced to create a barrier between the inside air and the outside air.

Recommendation 2: Add weather-stripping to doors and windows

There are other sources of air leakage in the building; some of the windows and doors are very drafty. This lets in outside air, affecting the room's temperature. Weathering stripping is a cheap fix to lower the amount of draft in the building.

Recommendation 3: Cover air conditioners when not in use

In the winter the air conditioning units are allowing cold air to penetrate into the building. By covering the units with a heavy blanket less heat will escape the building.

Recommendation 4: Consider the Prism Consulting lighting recommendations

The 455 watt mercury vapor lights on the second floor should be replaced with T5 Fluorescent lighting suggested by Prism Consulting. This type of lighting is more efficient and would save $165/year on energy bills. The 50 watt incandescent bulb upstairs should be replaced with a compact fluorescent bulb to save $19/year on electricity.

Recommendation 5: Insulate pipes

The insulating of the pipes that provide steam the second floor will lower the amount of heat that does not reach the second floor heaters. These pipes are in the process of being insulated, though the process should be done before the next winter.

Recommendation 6: Install natural gas space heaters

Natural gas heaters will allow the upstairs area to have a much faster recovery rate; the current rate is 3 degrees Fahrenheit per hour. A representative heating contractor said that, if installed, the natural gas space heaters could enable a recovery rate of 15-20 degrees Fahrenheit per hour.

Recommendation 7: Replace Refrigerators

Most of the refrigerators in the community center are over 20 years old. They are fairly inefficient and could be upgraded to newer, more efficient models. The residential refrigerators should be replaced to experience a savings of $159 per year. This step could be done over time, starting with the oldest one first. The electricity savings for the commercial refrigerators, though, could not be calculated to exact amounts due to lack of specifications.

Recommendation 8: Install Storm Windows

The single paned windows in the Quinsigamond Village Community Center have an area of 160 square feet upstairs and 148 square feet downstairs. Installing storm windows would decrease the amount of heat loss through the windows.

Recommendation 9: Check feasibility of adding insulation to walls and ceilings

It was not in our ability to check the building's design, but the walls seemed poorly insulated. It may be worth while in the long run to check what types of insulation could be added. It will be a costly remodel but overall savings may prove worthwhile.

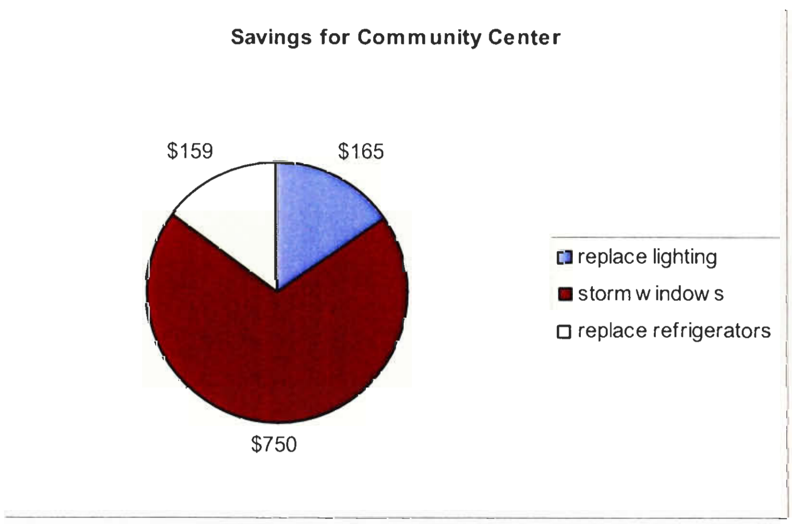


Figure 12 QVCC Savings Breakdown

6.1.4 Saint Catherine's of Sweden Church

Recommendation 1: Lower Temperature

The Thermostat in the chapel on the Saint Catherine's of Sweden Church was set at a constant temperature of 63 degrees Fahrenheit. This is an unnecessarily high for times when the building is not used. When not in use the building could be kept at a much lower temperature. If the temperature was lowered to 52 while not in use the average temperature would be 8 degrees cooler, this would result in savings of $1200 per year (ASE.org 2000).

Recommendation 2: Replace lighting

Much of the lighting throughout the church buildings is made up of incandescent and fluorescent lighting. This should be updated as described in the Prism Consulting proposal. 80% of the costs are covered by National Grid. The total savings on electricity bills for lighting upgrades is $528 per year.

Recommendation 3: Add Storm windows to church building

The main church building has 886 square feet of single paned stained glass windows. Adding storm windows will increase the insulation factor thus decreasing the amount of heat needed to warm up the room.

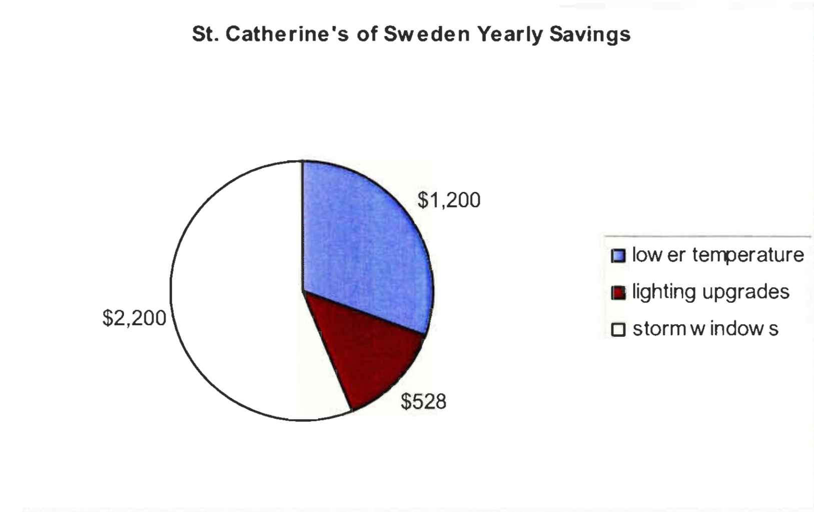


Figure 13 St. Catherine's of Sweden Savings Breakdown

6.1.5 United Methodist Church

Recommendation 1: Replace lighting

Most of the lights in the United Methodist Church are not as efficient as they could be. The lights in the Fellowship Hall are double-switched which will create a high installation price for the upgrade. This is not a large problem due to the 80% funding from National Grid. The total yearly savings in electricity of recommended lighting upgrades is $445.

Recommendation 2: Add weather stripping to windows and doors

Many of the doors and windows were drafty, allowing cold outside air in. Fixing this problem would be inexpensive and it would make a difference in the heating cost of the building.

Recommendation 3: Install programmable thermostats.

The Church should install programmable thermostats in each of the five zones. This would enable the staff to set back the temperature while the room is not in use. It would also eliminate human error by automatically turning down heat after an event. The thermostats would allow staff to better control heating in the building.

Recommendation 4: Upgrade old appliances

The church contains several older refrigerators that are very inefficient. Newer Energy Star rated refrigerators should replace the existing ones. A savings analysis of replacing these refrigerators can be found in Appendix 2. The newer refrigerators would have a payback period of 3-4 years.

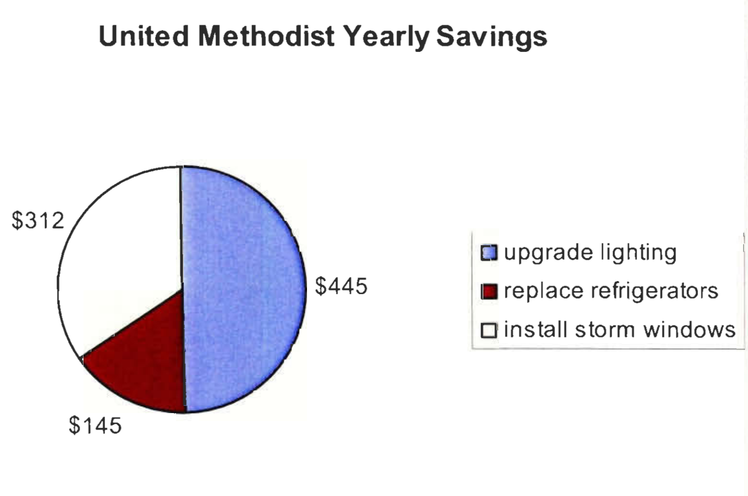


Figure 14 UMC Savings Breakdown

6.2 General Recommendations

6.2.1 Basic Improvements

There are areas that needed work which were common to all the churches. All of the buildings could make use of a water heater blanket. This would allow the water in the tank to stay hot longer and would use less energy. There are many outer doors spread throughout the buildings that would save money simply by replacing or installing weather stripping to create a better seal around the door.

6.2.2 Energy Awareness

An important measure of energy conservation and increased energy efficiency is to give the users in the community a better awareness of what is happening with energy. To do this, we recommend an energy education/awareness program be implemented by the churches and the community center. If members of the congregation and the staff are knowledgeable of the energy crisis and what could be done, hopefully they will make a conscious effort to decrease the amount of energy that is being wasted. The simplest of things could be done by the users of the buildings that could lead to differences in the energy bills. Some of these measures include turning off the lights when not in use or monitoring what temperature the thermostats are set at. The churches and the community center should do this by putting up posters and flyers on energy awareness around the building, especially the higher use areas. Some of the posters located in Appendix 4 are prime examples of effective visual aids to get people's attention and making them more aware of the situation. Some visual reminders placed near light switches, thermostats, office equipment, etc, should be placed to make certain that the users are reminded to turn off equipment or monitor what they are using. Each of the buildings should also follow the role of the Emanuel Lutheran Church and set up an Energy Task Force that meets once a month to discuss improvements to the buildings, building and equipment utilization, funding for capital projects, and different ways to expand on the energy awareness program. The churches could also help out even more by educating their parishioners. A half a page on energy and conservation tips each week in the weekly newsletters or an announcement on a fun energy fact at the end of service would go a long way in educating the public and spreading the message of conservation and efficiency. Having an educated community on the importance of energy conservation is an important aspect of this project. To change the "energy behavior" of people, it is necessary that we educate them and make them aware of what is going on.

6.2.3 Solar

Using solar is currently not a cost effective solution to the growing energy problem. It currently is not logical for those organizations that have difficulties with mere operating costs to buy into active solar power until prices are reduced. Cutting edge technologies look to drastically reduce the price by using less efficient panels that are far less expensive to manufacture. Table 1 in Appendix 3 shows time to pay back expenses of a 10 kW photovoltaic system, depending on system cost and fuel cost. It would be in the best interest for the organizations to wait for the next generation of solar power before investing in it.

A much more reasonable solar solution lies in the use of passive solar. It is a much cheaper alternative because it requires much less technology. The suns heat can be used to heat rooms or the domestic hot water. These systems are much easier to install and some do not need to be wired to the buildings electrical system. A passive solar system is scalable because each panel can be independent from one another. As money comes available these panels can be installed. Each 1.5 kW passive panel can save 41 gallons of fuels per year (calculated in Appendix 3).

6.2.4 Combined Heat and Power

Unfortunately, district wide combined heat and power is an idea that is still years off for this area. A project of this magnitude would take a major feasibility study done on the area. Factors such as the ground underneath the village, the existing piping, a feasible location for a central power plant, and others like these limit the amount that can be done on a district level for the community. The technologies available today come at a steep price and when the cost of installation is included, the price rises significantly. By looking at Appendix 5, some highlighted case studies performed in the United States involving mostly large universities. They show how much power is being generated, the amount of heat being dispersed, and the costs to install and maintain these rather large plants. At the moment, Quinsigamond Village is better off excluding cogeneration as a way to sustain itself, unless an extensive feasibility study is performed and concludes otherwise.

However, for some individual buildings in the area, the concept of cogeneration on a much smaller scale could benefit them. Cogeneration technology is steadily improving in terms of bringing it down to a residential level. In Appendix 5, the specifications on a 1 kW fuel cell cogeneration plant are available. A plant of this magnitude would be ideal in some of the smaller, lesser used churches. With the 93% combined efficiency of electricity and thermal outputs, and 40% CO_2 reductions, these systems would save the churches on both their fuel and electricity bills and even give them the possibility of selling back to the grid and profiting. For the larger loads, such as the Emanuel Lutheran Church, the Community Center, the combination of the Quinsigamond School and Methodist Church, and some of the factories in the village, a higher output fuel cell would suit the buildings more appropriately. The base electricity loads that these buildings create require a more powerful system. This is still pending on advancements made on these technologies. The fuel cell is still relatively expensive and this should be looked at again in the near future when prices have fallen and improvements in the technology made. Also, this should also be considered after a more extensive study is done on the buildings' capabilities to incorporate the technology into their systems.

Appendix 1: Behavioral Audit

Bethlehem Covenant **Space Use by Day of Week**

Space	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Sanctuary							
Morning	830am-12pm						
Afternoon							
Evening							
Fellowship Hall							
Morning							
Afternoon							
Evening						615pm-8pm	
Meeting Lounge							
Morning							
Afternoon							
Evening					7pm-830pm		

Kitchen (used directly after service for refreshments)

Quinsigamond Methodist Church

Space Use by Day of Week

Space	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Sanctuary

Morning	10:30am- 11:30am						
Afternoon							
Evening							

Secretary's Office

Morning		9am - 12pm		9am - 12pm		9am - 12pm	
Afternoon							
Evening							

Meeting Room (not used frequently)

Kitchen (not used frequently)

Nursery

Morning	9:30am - 10:30am						
Afternoon							
Evening							

Classrooms

Morning	9:30am - 10:30am						
Afternoon							
Evening							

Quinsigamond Community Center

Space Use by Day of Week

Space	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Kitchen

Morning							
Afternoon		245pm-5pm	245pm-5pm	245pm-5pm	245pm-5pm	245pm-5pm	
Evening							

Main room

Morning		9am	9am	9am	9am	9am	
Afternoon		to	to	to	to	to	2pm-5pm
Evening		5pm	9pm	5pm	5pm	5pm	

Upstairs Events Hall

Morning	10am-2pm						
Afternoon							2pm-5pm
Evening					6pm-8pm		

*Upper Hall heats up at 3 degrees/hr.

Office (on all day)

St. Catherine of Sweden **Space Use by Day of Week**

Space	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Church Building							
Morning	9am-11am	9am-11am	9am-11am	9am-11am	9am-11am	9am-11am	9am-11am
Afternoon							
Evening							
Hall (all under 1 thermostat)							
Morning							
Afternoon							
Evening		7pm-10pm	7pm-10pm		7pm-10pm		

Classrooms (used for Sunday School during service on Sundays)

Emanuel Lutheran Church **Space Use by Day of Week**

Space	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Nave

Morning	930am-1030am						
Afternoon							
Evening							

Chapel

Morning	8am-8:45am						
Afternoon							
Evening				7pm-8pm			

Choir

Morning	9am-930am						
Afternoon							
Evening					7pm-9pm		

Office

Morning		9am-2pm	9am-2pm	9am-2pm	9am-2pm	9am-2pm	
Afternoon							
Evening							

Office

Morning		9am-2pm	9am-2pm	9am-2pm	9am-2pm	9am-2pm	
Afternoon							
Evening							

Parlor(Fireside)

Morning	930am-1045am						
Afternoon							
Evening	7pm-8pm		7pm-10pm				

Library - used as a closet

CLASS WING

Nursery

Morning	930am-1030am						
Afternoon							
Evening							

Classrooms

Morning	930am-1145am						
Afternoon							
Evening		7pm -					

		9pm(2x/month)					

Fellowship Hall

Morning	1030am-11am						
Afternoon			12pm-3pm	**Move Monday activity here from 330pm - 6pm			
Evening		5pm-730pm	630pm-830pm	6pm-10pm	5pm-9pm		

Appendix 2: Technical Audit

Formulas Used

Heat Production
1 kWh = 3412 BTU

1 gallon #2 oil Produces 135000 BTU

The R-value of the insulator is defined to be 1 / thermal conductance per inch.
This means that R is an abbreviation for the complex unit combination **hr*ft.^{2}* °F / BTU**

Heat loss
A * ΔT / R-Value = BTU/ HR

Area (sq. ft.) * Difference in Temperature (°F) / R-Value of Object = Heat Loss in BTUs/Hour

Windows

Savings in Gallons of Oil per Hour by Changing from Single Pane (r-value .91) to Double Pane (r-value 2)

		Temperature Difference										
		10	15	20	25	30	35	40	45	50	55	60
Building	**Community Center**	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.12	0.13	0.14	0.16
	Saint Catherine	0.15	0.23	0.30	0.38	0.46	0.53	0.61	0.68	0.76	0.84	0.91
	Lutheran	0.26	0.39	0.51	0.64	0.77	0.90	1.03	1.16	1.29	1.42	1.54
	Methodist	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.13

Lighting

The following tables are an analysis of the lighting fixtures in the buildings along with the suggested replacements from Prism Consulting, Inc. The final two columns display the KWH per year that would be saved and the amount of money that would be saved per year.

Quinsigamond United Methodist Church

Area	Current Wattage	Recommended Wattage	QTY	Hours/Yr	KWH savings/Yr	Cost Savings/Yr
Main Hall	70	45	18	1,040	468	$56
Kitchen	70	45	7	1,040	182	$22
Janitor Closet	70	45	1	520	13	$2
Ladies Room	70	45	1	520	13	$2
Mens Room	70	45	1	520	13	$2
Classroom 1	70	45	8	1,040	208	$25
Classroom 2	70	45	6	1,040	156	$19
Classroom 3	70	45	6	1,040	156	$19
Exits	40	2.8	5	8,736	1625	$195
Back Hall	70	45	2	1,040	52	$6
Plate Room	123	100	1	520	12	$1
Sitting Room	140	89	2	1,040	106	$13
Foyer	65	15	4	1,040	208	$25
Front Entry	100	22	2	1,040	162	$19
Secretaries Office	70	45	4	1,040	104	$12
Ladies Room	70	45	2	520	26	$3
Mens Room	70	45	2	520	26	$3
Copy Room	70	45	1	1,040	26	$3
Office 1	70	45	4	1,040	104	$12
Pastor's Office	70	45	2	1,040	52	$6
		Total	**79**		**3712**	**$445**

Bethlehem Covenant

Area	Current Wattage	Recommended Wattage	QTY	Hours/Yr.	KWH savings/Yr.	Cost Sav
2ND FLOOR HALL	455	234	6	1040	1379	$1
2ND FLOOR HALL	50	24	1	1040	162	$1
		Total	**7**		**1541**	**$1**

Emanuel Lutheran Church

Area	Current Wattage	Recommended Wattage	QTY	Hours/Yr.	KWH savings/Yr.	Cost Savings/Yr.
Fellowship Hall	290	177	8	1,040	940	$113
Stage	100	22	6	1,040	487	$58
Exits	40	2.8	4	8,736	1,300	$156
Over Sink	100	22	1	520	41	$5
Side Door	60	15	1	520	44	$5
Men's Room	70	45	2	520	26	$3
Ladies Room	70	45	2	520	26	$3
Handicap Bath	70	45	1	520	13	$2
Altar	50	24	6	520	81	$10
Church	150	22	20	520	1,331	$160
		Total	**51**		**4,289**	**$515**

St. Catherines of Sweden

Area	Current Wattage	Recommended Wattage	QTY	Hours/Yr	KWH Savings/Yr
Front Foyer	110	66	2	1040	92
Crying Room 1	60	15	3	1040	140
Crying Room 2	60	15	3	1040	140
Main Church	75	15	15	1040	936
Main Church	75	15	16	1040	998
Bathroom	60	15	2	520	47
Small Hallway	60	15	1	1040	47
Small Room of Church	60	15	2	520	47
Loft	60	15	8	520	187
Building 2 Basement	140	89	12	1040	636
Kitchen	140	89	5	1040	265
2nd Floor Hallway	140	89	14	1040	743
2nd Floor Foyer	140	89	1	1040	53
Chair Room	140	89	1	520	27
Girls Room	56	37	2	520	20
Boys Room	56	37	2	520	20
		Total	**89**		**4398**

Equipment

Current Refrigerators	UMC	UMC	QVCC	QVCC
Brand	Hotpoint	Hotpoint	Westinghouse	GE
Size (cu. ft.)	20.6	13.6	12	15.6
Adjusted Annual Consumption	892 kWh	1,475 kWh	1606 kWh	910 kWh
Cost/year to run	$81.00	$134	$145	$83

United Methodist Church Comparison

Analysis

Larger Refrigerators		(suggested replacement)	**Smaller Refrigerators**	(suggested replacement)
Model	Hotpoint (20.6)	Bisque Kenmore	Hotpoint (13.6)	Sanyo SR1030
kWh/yr.	892	432	1475	331
Cost/yr.	$81.00	$39.00	$134.00	$29.99
Savings/yr.		$41		$104
Payback period (years)		13.39		3.93

QVCC Refrigerator Comparison

Analysis

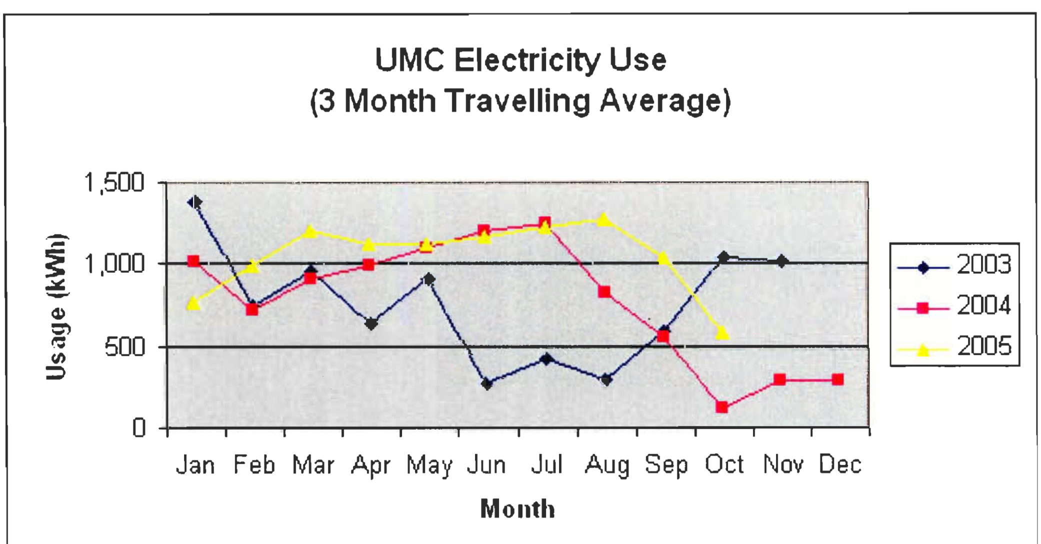
Larger Refrigerators			**Smaller Refrigerators**	
Model #	General Electric	Bisque Kenmore	Westinghouse	Sanyo SR1030
kWh/yr.	910	432	1606	331
Cost/yr.	$83.00	$39.00	$145.00	$29.99
Savings/yr.		$44		$115
Payback period (years)		12.48		3.56

Appendix 3: Solar Energy

Electricity Usage

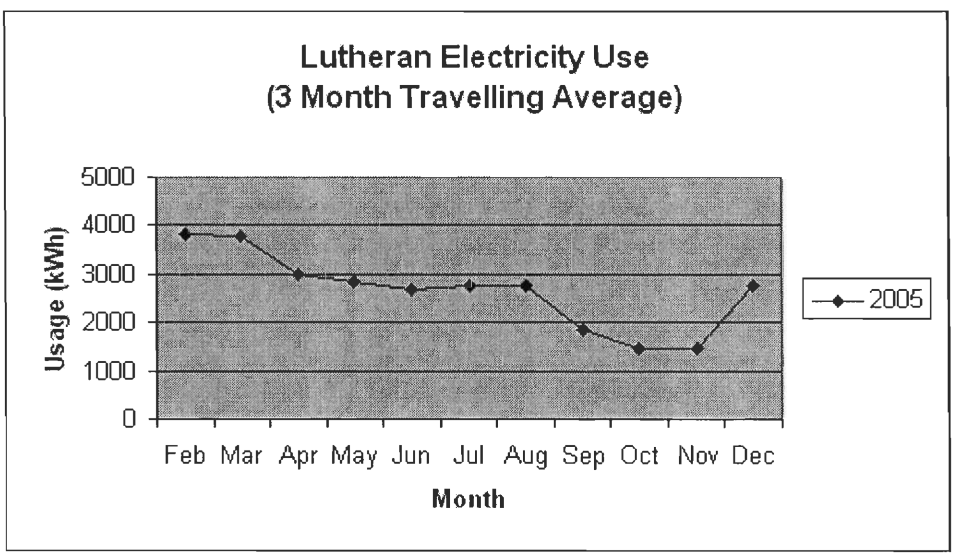
United Methodist

	2003			2004			2005		
	kWh	**Traveling Avg.**	Estimated or Actual Reading (Period)	**kWh**	**Traveling Avg.**	Estimated or Actual Reading (Period)	**kWh**	**Traveling Avg.**	Estimated or Actual Reading (Period)
Jan	1920		Estimated (32 Days)	320	1,013	Actual (33 Days)	400	773	Estimated (33 Days)
Feb	1280	1,387	Estimated (31 Days)	880	720	Actual (25 Days)	1440	987	Actual (28 Days)
Mar	960	747	Estimated (29 Days)	960	907	Estimated (32 Days)	1120	1,200	Estimated (28 Days)
Apr	0	960		880	987	Estimated (29 Days)	1040	1,120	Estimated (30 Days)
May	1920	640		1120	1,093	Actual (28 Days)	1200	1,120	
Jun	0	907	Actual (32 Days)	1280	1,200	Estimated (30 Days)	1120	1,173	Estimated (28 Days)
Jul	800	267	Estimated (29 Days)	1200	1,253	Estimated (32 Days)	1200	1,227	
Aug	0	427	Actual (30 Days)	1280	827	Estimated (34 Days)	1360	1,280	Estimated(32 Days)
Sep	480	293	Estimated (29 Days)	0	560	Actual (28 Days)	1280	1,040	Estimated (28 Days)
Oct	400	587	Actual (33 Days)	400	133	Estimated (31 Days)	480	587	Actual (119 Days)
Nov	880	1,040	Actual (28 Days)	0	293	Actual (32 Days)	0	800	Estimated (29 Days)
Dec	1840	1,013	Estimated (35 Days)	480	293	Actual (32 Days)	1920	907	Actual (69 Days)
AVG	873	752		733	773		1256	1221	



Emanuel Lutheran

	2005	Traveling Average	2006
Jan	3280		3920
Feb	5280	3813	
Mar	2880	3787	
Apr	3200	2987	
May	2880	2853	
Jun	2480	2693	
Jul	2720	2747	
Aug	3040	2773	
Sep	2560	1867	
Oct	0	1467	
Nov	1840	1440	
Dec	2480	2747	
AVG	2720		



Community Analysis

Active Solar (Photovoltaic)

Solar Calculations

	Base Load(kW/mo.)	Likely Need	Percentage Need	Panels	Cost for panels	Plus installation	Production (in kWh/ Month)	Watt Production	Actual System Production
Emanuel	1840	2000	37.74%	68	$84,085.91	$28,000.00	1907	20377	15283
QVCC		1000	18.87%	34	$42,042.96	$17,000.00	954	10189	7642
Bethlehem	650	700	13.21%	24	$29,430.07	$17,000.00	668	7132	5349
St Catherine	811	800	15.09%	27	$33,634.37	$17,000.00	763	8151	6113
Methodist	800	800	15.09%	27	$33,634.37	$17,000.00	763	8151	6113
	4101	5300	100.00%				5054	54000	40500

This chart shows the current need in a photovoltaic system, the amount of 300 watt panels, cost of the system, and the panels production in terms of kWh/ month, theoretical watt production and actual.

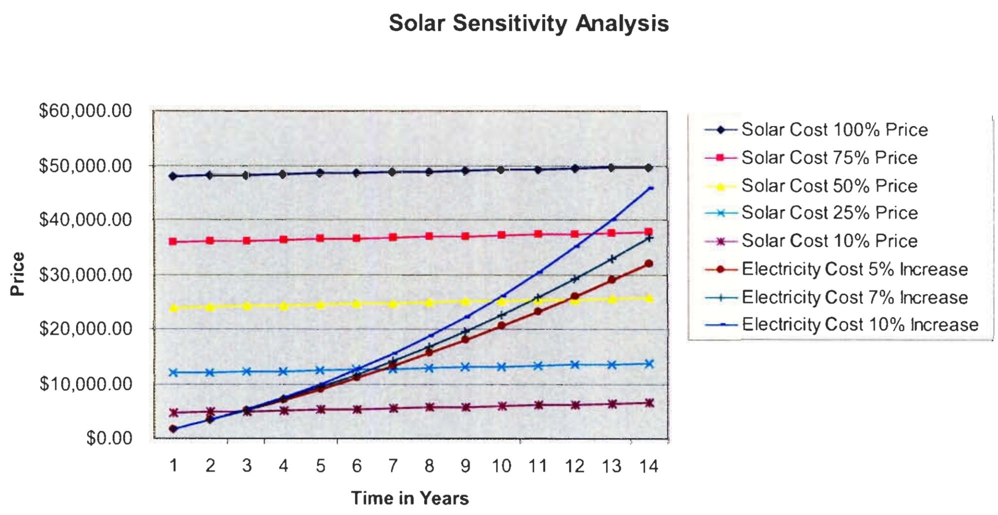
Building	Cost without incentive	Possible incentive	Cost after incentive	25% Funded	50% Funded	75% Funded	90% Funded
Emanuel	$112,085.91	$67,268.73	$44,817.18	$84,064.43	$56,042.96	$28,021.48	$11,208.59
QVCC	$59,042.96	$45,849.06	$13,193.90	$44,282.22	$29,521.48	$14,760.74	$5,904.30
Bethlehem	$46,430.07	$24,962.26	$21,467.81	$34,822.55	$23,215.03	$11,607.52	$4,643.01
St Catherine	$50,634.37	$28,528.30	$22,106.06	$37,975.77	$25,317.18	$12,658.59	$5,063.44
Methodist	$50,634.37	$28,528.30	$22,106.06	$37,975.77	$25,317.18	$12,658.59	$5,063.44

This table shows the total cost to the church given different amounts of funding.

300	Watt Production
20	Panels / Palette
9	Palettes
75%	System efficiency
40500	Watt Production
40.5	KW Production
	Hrs Producing
4.1	Electricity/ day
30.4	days/ mo
5054	KWH / MO
$24,758.63	Cost/ palette
$222,827.67	**Net Cost**
$0	Incentives
$222,827.67	Total Cost
$.18	$/KWH over lifetime

300	Watt Production
20	Panels / Palette
9	Palettes
75%	System efficiency
40500	Watt Production
40.5	KW Production
	Hrs Producing
4.1	Electricity/ day
30.4	days/ mo
5054	KWH / MO
$24,758.63	Cost/ palette
$222,827.67	**Net Cost**
$206,278.04	Incentives
$16,549.63	Total Cost
$.01	$/KWH over lifetime

These table show cost per kWh over the lifetime of the panel.



The chart the varying time of payback given different electric rate increases, and different amounts being funded

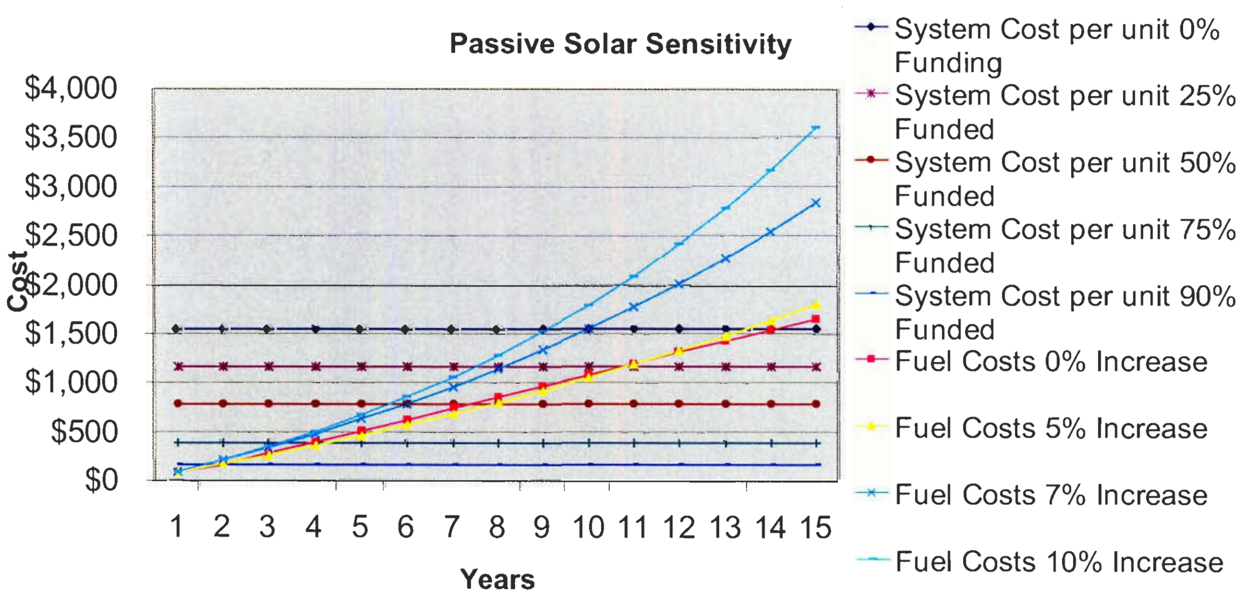
10 KW Production	
1.65	palettes
20	per palette
6.2	ft
4.2	ft
859	sq ft

This table shows the space usage of a 10 kW photovoltaic solar installation

Passive Solar

		Alt Energy Store
1.5	kW	Specs
4	hrs/day	Sun Trek Energy
274	heating Days/year	
1643.63	kWh/year	
3412	BTU/kWh	
5608048.5	BTU/year	
135000	BTU/Gal #2 Oil	
41.5	Gal #2 Oil/year saved	
$2.01	$/Gal Fuel	
$83	$/year saved	

This chart shows the yearly savings by installing a 1.5 kW passive air heating system.

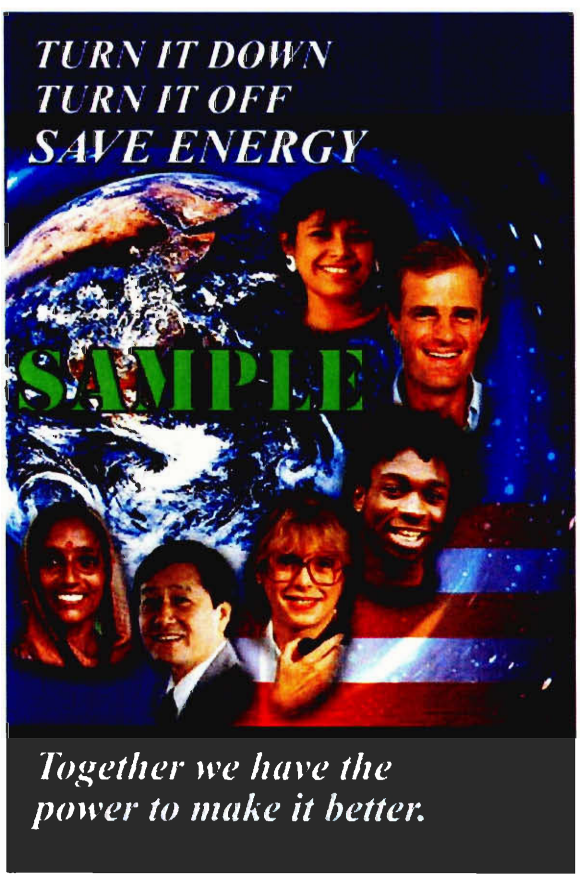


This chart shows varying payback periods depending on different amounts of funding and change in fuel costs.

Appendix 4: Energy Education

Sample steps for community education:

1. Put up posters and flyers on energy awareness around the building, especially the higher use areas. (See examples below)
2. Each of the buildings should also follow the role of the Emanuel Lutheran Church and set up an Energy Task Force that meets once a month to discuss improvements to the buildings, building and equipment utilization, funding for capital projects, and different ways expand on the energy awareness program.
3. Set up a half a page on energy facts and conservation tips each week in the weekly newsletters
4. An announcement on a fun energy fact at the end of service would go a long way in educating the public and spreading the message of conservation and efficiency.

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URCESOFTHI
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KETHELETTERSONTHISCH
ARTSOMEJUSTGETSMALLERANDSMALLER.
use energy wisely!

Appendix 5: Cogeneration

Guide to Combined Heat and Power Systems for Boiler Owners and Operators

http://www1.eere.energy.gov/industry/bestpractices/pdfs/guide_chp_boiler.pdf

Whole Building Design Guide: Fuel Cell Technology

http://www.wbdg.org/design/fuelcell.php

1 kW kerosene run Cogeneration System implemented in Japan

http://www.ebara.co.jp/en/news/news20040427.html

Database of case studies provided by Dept. of Energy

http://www.eere.energy.gov/de/casestudies/

European combined heat and power statistics

http://www.chp-info.org/

Case study on Southampton in England

http://www.iea-dhc.org/download/KN1640%20Southampton%20v2.pdf

International District Energy resources

http://districtenergy.org/

Appendix 6: Funding Information

Application for Matching Grants for Communities (web-based)

https://www375.ssldomain.com/NewEnglandGreen/enroll.cfm

Application for Small Renewables Initiative

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