Re-Purposing the Buildings of the Sacred Heart Church Campus in Southbridge, Massachusetts

A project in
Sustainable Design
at the Thayer School of Engineering
Dartmouth College, Hanover, New Hampshire

June 2017

William A. Bittinger, *Urban Developer, Hanover NH*

Benoit Cushman-Roisin, *Professor of Engineering Sciences, Dartmouth College, Hanover NH*

Pamela Paquin, *Southbridge Resident and Entrepreneur*

Calin Ackerman, Catherine E. Berghuis, Ralf H. Carestia, Kelsey P. Catano,
Jennifer R. Cunningham, Amaris A. De La Rosa-Moreno, Zoe M. Dinneen, Eleanor G. Dowd,
Matthew V. Durkin, Meredith A. Gurnee, O. Renata Hegyi, Christian N. Kwisanga,
Jessica B. Link, Carolyn J. McShea, Nayantara S. Patel, Holly A. Patterson, Kelsey E. E. Phares,
David J. Polashenski, Zoe A. Rivas, Sarah L. Rote, Tara M. Simmons, Marie Josée Uwayezu,
Alexandria V. Vasques, *Students*

Danielle Castley, *Heat Teaching Assistant*

Michael A. Baicker, Xiu Yi (Suey) Chen, Nidhi N. Mahambre, Rita Tu, *Team Teachings Assistants*

With thanks to Father Peter Joyce of the Diocese of Worcester for accommodating our several visits and requests, to Rosemary Scrivens of the Town of Southbridge for providing essential documents, and to the following architects who served on the advisory Review Board: Patrick Kane (East Hardwick VT), Karolina Kawiaka (White River Junction VT and Senior Lecturer at Dartmouth College), and John D. Wilson (Senior Lecturer at Dartmouth College)

For inquiries regarding this document, please contact
William A. Bittinger (1-603-208-8810, wabittinger@gmail.com) or
Professor Benoit Cushman-Roisin (1-603-646-3248, Benoit.Cushman.Roisin@dartmouth.edu).

TABLE of CONTENTS

Executive Summary

The Diocese of Worcester is no longer making use of its Sacred Heart Church and attending buildings in Southbridge, Massachusetts. For the sake of historical preservation, these buildings should not be demolished but rather repurposed in ways that meet the needs of local residents, the Town of Southbridge, and the broader community.

With repurposing as a primary objective and at the suggestion of urban developer William A. Bittinger, Professor Benoit Cushman-Roisin assigned the challenge to the students of his course *Sustainable Design* at Dartmouth College (Hanover, NH) in Spring 2017. The present document reports on the ideas, designs and analyses generated by the students under the supervision of teaching assistants, a Review Board consisting of several architects, and, mostly, William A. Bittinger and Benoit Cushman-Roisin. Pamela Paquin, a long-time Southbridge resident and entrepreneur, and Father Peter Joyce of the Diocese of Worcester also contributed to the guidance provided to the students.

The class of 23 students was divided into several groups, tackling the separate buildings (church, school, rectory, convent, and power plant) but also collaborating across groups to maximize the symbiosis between the several redesigns. The overall vision of the repurposed campus is a location that fosters a sense of community belonging among locals through culture, wellness, and entrepreneurship.

The outcome is a detailed plan that transforms the Sacred Heart campus as follows: The school becomes the Garden of Eden greenhouse and indoor farm, the convent is transformed into Our Daily Bread Bakery, the rectory serves as a bed and breakfast with a sports bar in the basement, the power plant is converted into a brewery, and the church building becomes the St. Francis Performance Hall and Restaurant. All redesigns include energy and water efficiency, with several buildings achieving LEED-Gold certification. Energy efficiency is achieved by high-performance building thermal envelopes, a geothermal system with heat pumps, some photovoltaic panels, and Energy Star appliances. A rainwater collection system on the church's roof with accompanying underground cistern should meet the water needs of the greenhouse in the former school building. Ideas have also been generated for the outdoor portions of the campus in order to make the campus inviting to the community and to create a better connection with the bordering river.

The various design decisions along the way were guided by so-called triple bottom line principles so that the new set of structures and activities simultaneously generate societal, business, and environmental benefits. The societal benefits take the form of job creation and wholesome activities for the local population, of all ages and ethnicities; the business benefits are return on the investment and a revenue stream for the Town of Southbridge; the environmental benefits are a lower carbon footprint achieved by energy efficiency and water conservation. The whole should also attract tourists and contribute to the community revival effort begun by the Town of Southbridge.

Job creation potential under the proposed repurposing is as follows:

- St Francis Performance Hall & Restaurant (former church): 20 full-time and 15 part-time
- St Benoit Brewery (former power plant): 3 full-time, 2 part-time
- Garden of Eden Greenhouse (former school): 17 full-time and 9 part-time
- Bed-and-Breakfast and Sports Bar (former rectory): 8 full-time and 6 part-time
- Our Daily Bread Bakery: 6 full time and 8 part time
- Campus-wide, housed in greenhouse building: 12 full-time.

The total projected employment is 66 full-time and 40 part-time positions.

1. Introduction

1.1. The Sacred Heart Church Campus

At the beginning of the twentieth century, the community around Southbridge, Massachusetts had an increasing population of French-Canadian immigrants who worked for the American Optical Company. To serve the growing community, the Catholic Diocese of Worcester created in 1908 a new parish in Southbridge. This led to the acquisition of a 4-acre parcel on Charlton Street that would become the Sacred Heart Church complex. The cluster of buildings consists of a church, a rectory, a convent, a school, and a small power plant (Figure 1-1).

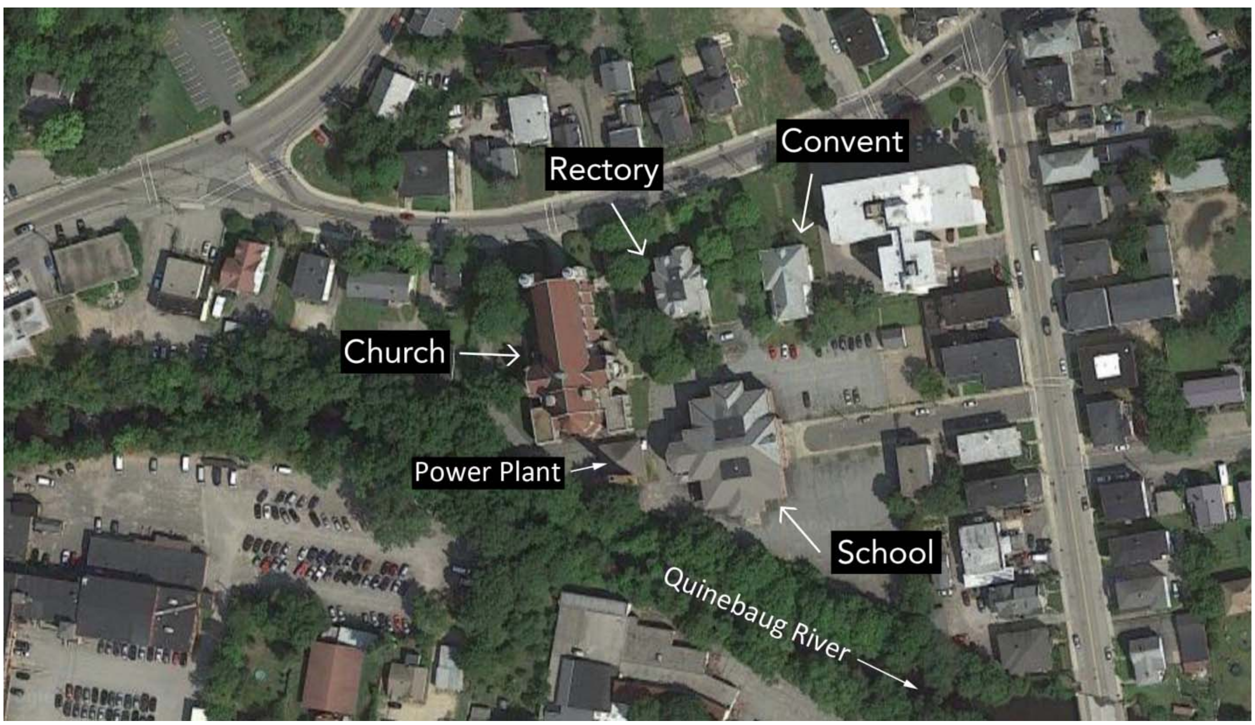


Figure 1-1. *Aerial view of the Sacred Heart Church campus.*

The buildings were erected between 1909 and 1926[1]. Their architectural style is Colonial Revival, with the exception of the church, which is Neo-Gothic. In 1989 the buildings were officially listed on the National Register of Historic Places[2].

[1] Construction began in 1909, the school was completed in 1910, followed by the convent in 1911 and rectory in 1912; the church was completed in 1926.
[2] https://npgallery.nps.gov/NRHP/AssetDetail/298c56c4-8d94-440a-8c09-9b818ee756f7/?branding=NRHP

The Sacred Heart Parish prospered until Southbridge experienced an economic downturn associated with the closing of the American Optical Company factory in 1984. This economic downturn created increasing financial difficulties for the parish, and in May 2010 the Sacred Heart Parish was merged with Notre Dame Church located half a mile away on Main Street[3] (Figure 1-2). It was eventually closed in 2011 due to deteriorating buildings and large operating costs[4]. At the present time, the Diocese of Worcester has indicated that it wishes to let go of its Sacred Heart Church campus.

1.2. Historical Background

Worcester County was originally home to the Nipmuck and Mohegan tribes, whose territories were divided by the Quinebaug River. Southbridge was settled by Europeans in 1730, and in 1816 it became officially recognized as the "Second Religious Society of Charlton", nicknamed "Honest Town". Power from the river was ideal for sawmills and gristmills in the 1700's, and textile mills in the 1800's. Irish and French Canadian immigrants settled in Southbridge immediately after the civil war, and Polish, Greek and Italian immigrants continued to settle there through the 1930's[5].

The American Optical Company was officially formed in Southbridge in 1869 by the Wells family, and it brought industry and prosperity to the region for over a century. It continued to profit even during the depression, and many of its workers were instrumental to defense work during World War II. At its peak, the American Optical Company was the world's largest manufacturer of ophthalmic products, employing over 6,000 people across the world.[6] This coupled with the success and rapid growth of the industrial revolution attracted many settlers of different nationalities for work, allowed a development of a variety of neighborhoods near industry and in the more rural, agricultural areas as well as. It promoted a historical downtown with Victorian architecture and large, shady streets. Rapid growth took place in the 1950's, but the town's infrastructure met the demands of the growing population. The Town of Southbridge thrived in this economic growth, and by the 1960's it had a movie theater, a radio station and an airport. More immigrants arrived in the 1970's, this time from Puerto Rico, Laos and Vietnam.

Unfortunately the American Optical Company closed in 1984 causing a major loss of manufacturing jobs, and the Town of Southbridge has been struggling ever since. The

---

[3] http://www.telegram.com/article/20110318/NEWS/110319632
[4] Kush, Bronislaus B. "Sacred Heart Church in Southbridge to Close." *Telegram.com*. Telegram.com, 18 Mar. 2011. Web. 29 May 2017.
[5] http://www.ci.southbridge.ma.us
[6] http://www.opticalheritagemuseum.org/AOEventsSlideshoprintablefile.pdf

Southbridge Hotel and Conference Center now stands in the place once occupied by the American Optical Company (Figure 1-2).

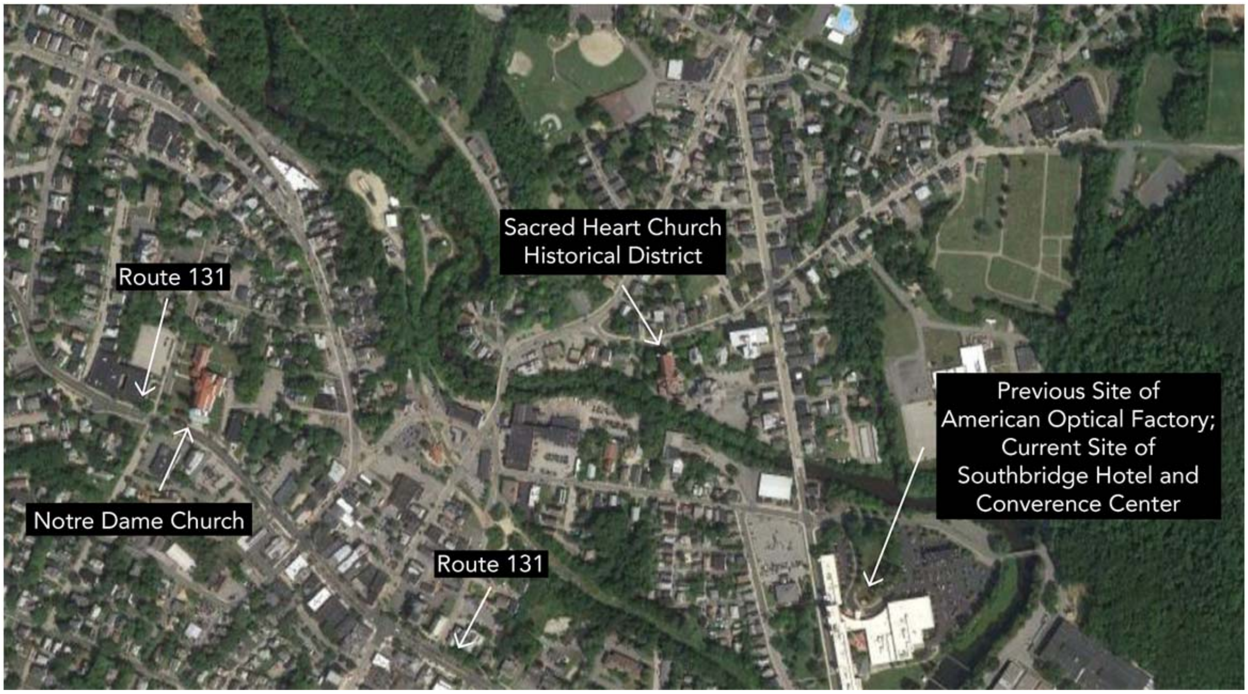


Figure 1-2. *Aerial view of Southbridge, placing the Sacred Heart Church campus in relation to the former site of the American Optical Company.*

The population of Southbridge reached its peak in the 1950's, and today the town of is much smaller, with approximately 17,000 residents (16,719 according to the 2010 census). Yet it has retained the amenities of a city. Southbridge has a diverse population with 78% White, 3% Black, 1% American Indian, 2% Asian, <1% Pacific Islander, 13% other including mixed races[7] (Figure 1-3). About 31% are of Hispanic origin, with a majority of Puerto Rican descent. The population density is 800 people per square mile, and the median household income is $33,913.[8]

[7] http://www.city-data.com/city/Southbridge-Massachusetts.html
[8] https://www.census.gov/quickfacts/table/PST045216/00

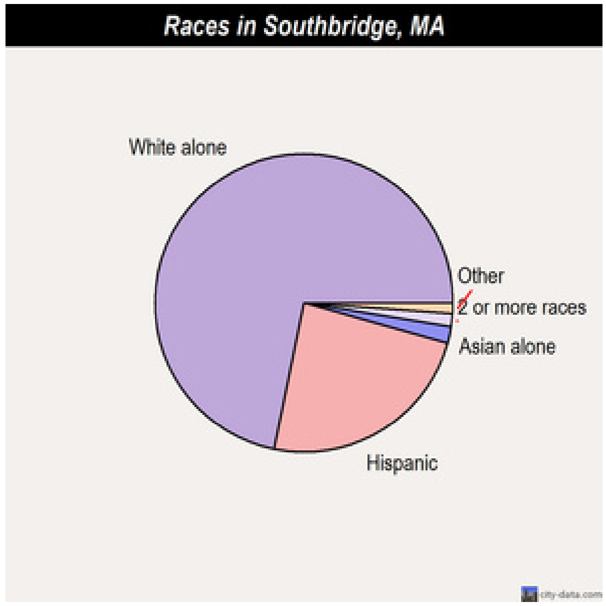


Figure 1-3. *Population profile in Southbridge, MA.*

1.3. Aspirations of the Town of Southbridge

A town that relies heavily on manufacturing jobs suffers greatly when its major employer disappears. There has been a shift into other industry sectors such as education, healthcare and social assistance[2], with still 18% of the current jobs in manufacturing. However, of the 5,700 jobs in Southbridge, only 32% are held by Southbridge residents because many lack the "training, education and skill sets to fill jobs in the new industries."[2] Nonetheless, today, the Town of Southbridge has many existing amenities including, but not limited to, a middle/high school, three elementary schools, private catholic school, public library, YMCA, full service hospital, state conservation area, art center with galleries and theatre, and an airport[9].

The stagnant economy and high unemployment have led to an increase in crime, mainly caused by an increasingly prevalent drug market. To change this, the Town of Southbridge developed in 2013 a Master Plan, which outlines six main development goals[10]. These include (1) promoting health, safety and wellness, (2) education for all, (3) improving housing and neighborhoods, (4) improving downtown and increase economic development, (5) ensure environmental sustainability and (6) increase community pride. Our proposed design will be centered about these core objectives.

[9] "About Southbridge." *About Southbridge | Southbridge MA*. N.p., 24 Mar. 2014. Web. 29 May 2017.

[10] *Volume I – Southbridge Master Plan*. Prepared by Community Preservation Associates with Community Circle, Martha Lyon Landscape Architecture, LLC; and AECOM, 4 Sept. 2003. (Available from the Town of Southbridge, Mass)

Subsequently, in 2016, the Town of Southbridge collaborated with RKG Associates, Inc. to create the Southbridge Economic Development Plan[11], which provides a more detailed strategic plan to address issues and opportunities. A major feature of the Economic Development Plan was to develop a community brand for Southbridge. The process identified and reinforced the unique character of the community. The aim is the creation of a sense of arrival, a sense of place, a sense of shared visual memory, and community ethos.

More importantly, the Plan identified four so-called Opportunity Areas (Section 3.8), the third of which labeled "Downtown" includes the Sacred Heart Church campus on its northern side, across the river from North Street, itself one block north of Main Street (Figure 1-4).

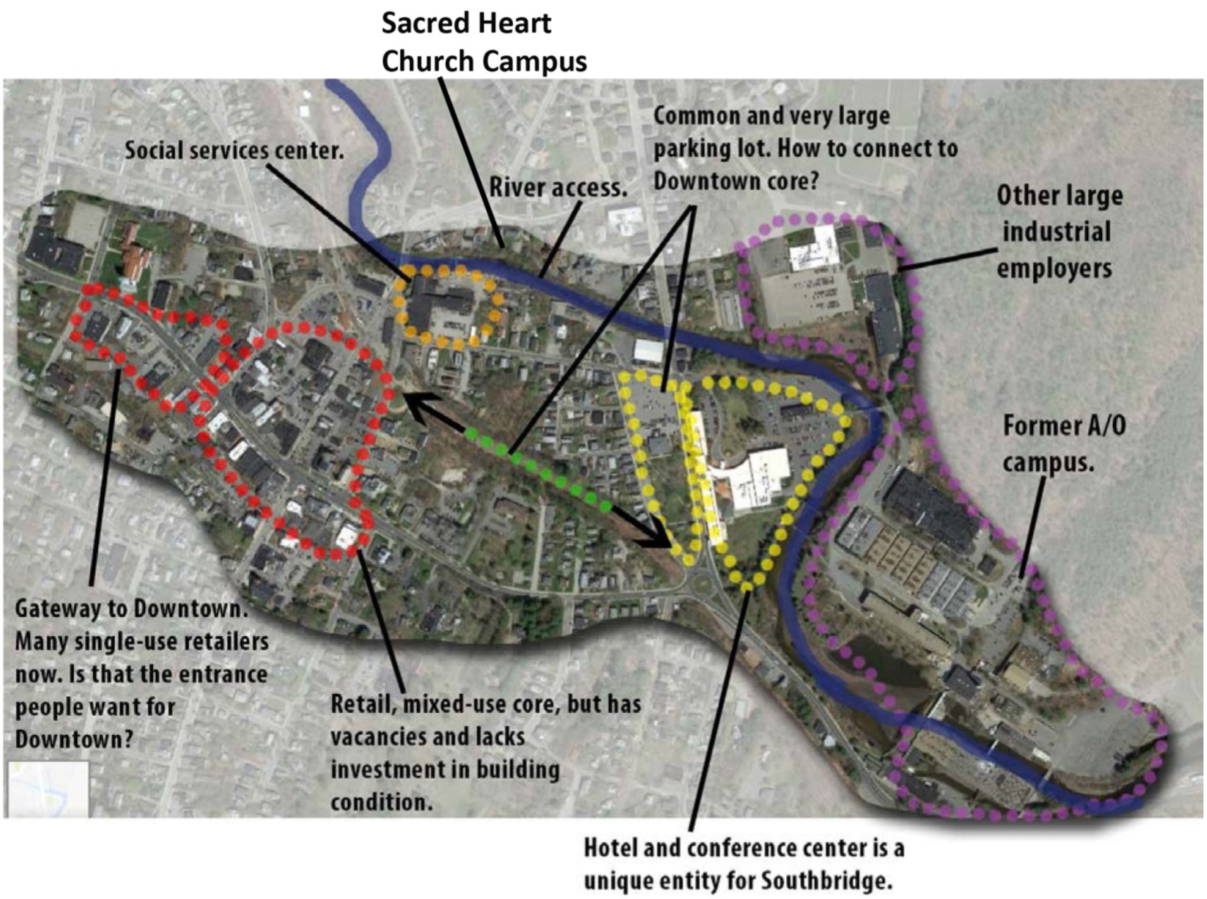


Figure 1-4. *The Downtown Opportunity Area identified in Southbridge's 2016 Economic Development Plan.*

The Economic Development Plan makes the following remarks about this area of town:

[11] *Southbridge Economic Development Plan – A Town of Opportunity*, RKG Associates, Inc., December 2016. (available from the Town of Southbridge, Mass)

> "Downtown Southbridge is full of opportunities for economic revitalization. There are a number of buildings in Downtown that have first and second floor vacancies, offering opportunities for new businesses to enter the market and upper story office or residential conversions. While building maintenance is needed, the historic building stock provides a visually appealing and consistent streetscape along Main Street. The relatively low rents mean a lower barrier to entry, particularly for new business owners looking to open up what may be their first storefront or restaurant. Based on the retail market assessment presented earlier in this report, there are opportunities to attract customers to Downtown if a quality product is offered and marketed effectively.
>
> Additionally, the Downtown has a unique ambiance due to a combination of factors including the grand historic buildings, the rolling landscape of Main Street which creates a dramatic backdrop, and an urban feel that results from the current uses and users of the establishments. While there are a number of uses that detract from this, there are also a number of very unique establishments that form a strong foundation in Downtown. These include the Vienna, an Austrian themed restaurant and Inn, the Starlight, a hybrid gallery and bar with live music five days a week, and the Metro Bistro with live French music and song.
>
> On the eastern edges of Downtown are the Southbridge Hotel and Conference Center and several large industrial areas (A/O and Schott), as well as the Southbridge Common. Approximately half-way between there is the Southbridge Art Center. The challenge is how to better connect these assets to the Downtown Core, particularly the hotel and conference center. This could be accomplished through signage and streetscape, marketing at the hotel, and a pedestrian/bike connection using the existing utility corridor (green dots in Figure 1-4). A connection between these assets, including better access to the river, and the Downtown Core would bring additional patrons to Downtown businesses."

While the Sacred Heart Church Campus is not mentioned by name in these remarks, it clearly falls under the scope of buildings with "vacancies", "historic building stock", and places with "opportunities to attract customers to Downtown if a quality product is offered and marketed effectively." Also noted is the mention of "including better access to the river" by creating a "connection between these assets".

More broadly, the Economic Development Plan stresses the need to generate employment opportunities for both the local and adjacent populations with the expectation of a revenue stream for the Town.

2. The Church Building

Student Team: Catherine E. Berghuis, Jennifer R. Cunningham, Amaris A. De La Rosa-Moreno, Matthew V. Durkin, Meredith A. Gurnee, and Holly A. Patterson
Teaching Assistant: Xiu Yi (Suey) Chen

2.1. Description of Current Building

The church building was erected in 1926, the last of the buildings on the Sacred Heart campus. Its style is neo-gothic (Figure 2-1). When the Sacred Heart Parish was merged with the Notre Dame parish located on Main Street, 185 households worshiped there regularly. The most recent inspection, in November 2003, reported a capacity of 600 people.

Figure 2-1. *Exterior of the Sacred Heart Church building.*

The building is listed on the National Register of Historic Places and as such should be preserved rather than demolished and replaced. Since there is no longer a need for it to serve as a place of worship, a re-purpose should be sought.

The exterior dimensions of the building are shown in Figure 2-2.

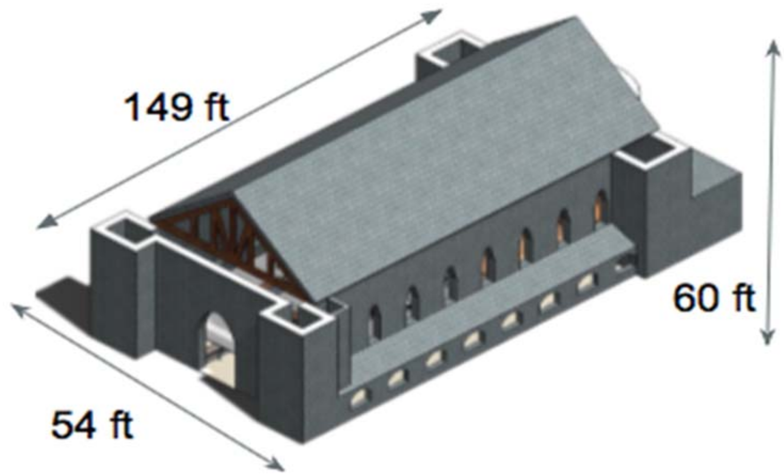


Figure 2-2. *A simplified computer generated model of the church exterior showing the major external dimensions.*

2.2. Brainstorming, Specifications, and Selection

We began generating and sharing ideas for repurposing the church independently and as a class, to determine how our designs could integrate with other groups to create a thriving campus.

The first idea was inspired by the AVA Gallery in Lebanon, NH. Part of the building would be converted into an open space for local artists to display their work while another part of the building would be devoted to private workshops and spaces for artists to come and be creative. A second idea was to turn the church into a sports club with a large court area, weights and machines, a climbing wall, and some workout rooms that would offer community classes. A third idea was to make a brewery within the church. This last idea followed the suggestion of Pamela Paquin who mentioned the lack of safe night life in the area and noted that a neighboring town had a successful brewery. A performance hall was another option for the church, with the hope of creating a permanent event space in town that would attract local and guest musicians. Our last idea was to make an open plan restaurant that doubles as a farmers' market with several booths offering varied types of food and a set menu available throughout the week.

To decide which of these repurposes would be the most appropriate, we implemented a decision matrix (Table 2-1) by which we evaluated the various ideas against 13 criteria that we believed were important for these uses to meet. We established these criteria from reading the Southbridge Master Plan and supplemented them with suggestions from the Review Board. We scored the 5 repurposing ideas by giving them either a score of 1 if they met the criterion or a score of 0 if they did not. After completing this process, the restaurant and the entertainment hall scored highest with 10 points each. Because the church is such a large space, we decided to move forward with a combination of both of these ideas.

Ideas versus Criteria	**Sports Club**	**Art Gallery**	**Brewery**	**Restaurant**	**Entertainment Hall**
Would the Diocese of Worcester approve? (x2)	1	1	0	1	1
Would it help the aging population?	1	0	0	0	0
Would it revive manufacturing?	0	0	1	0	0
Would it create jobs?	1	0	1	1	0
Would it increase the value of Southbridge real estate?	1	1	1	1	1
Would it contribute to the Southbridge rebranding effort?	0	1	1	1	1
Would it support local artists?	0	1	0	0	1
Would it support the growing Hispanic population?	0	0	0	0	0

Would it complement other proposed businesses on the campus?	0	1	1	1	1
Is there existing competition in Southbridge or nearby?	0	1	1	1	1
Would it help slow the exodus of younger residents?	0	0	1	1	1
Would meet sustainable design criteria such as energy efficiency?	1	1	1	1	1
Is the remodeling economically feasible?	1	1	1	1	1
Totals	**7**	**9**	**9**	**10**	**10**

Table 2-1. *Selection matrix scoring the various ideas against 13 criteria.*

2.3. Re-Purposing into a Performance Hall and Restaurant

After establishing the new function of the space, we needed to settle on a layout for the new interior. We came up with four ideas and implemented a similar decision matrix to decide on a final layout (Table 2-2). Of the four configurations, two were single story while the other two involved two stories. We considered factors like aesthetics, acoustics, capacity, square footage, and flexibility of the space. Each configuration received a score ranging from 1 to 5 depending on the extent to which it responded to the corresponding factor.

This second decision matrix led to the selection of a two-story space with a mezzanine as optimal because it could increase the capacity and square footage of the building without compromising the beautiful high ceilings and aesthetics of the interior.

Floor Configurations versus Criteria	Two Full, Separate Stories	U-Shaped Balcony	Split One Story	One Story Combined
Aesthetics / Historical Preservation	1	4	2	3
Acoustics	3	4	2	1
Total Capacity	4	3	1	2
Total Square Footage	4	3	1	2
Ease of Use for Large Events / Space Flexibility	1	3	2	4
Totals	**13**	**17**	**8**	**12**

Table 2-2. *Selection matrix scoring the various indoor configurations against 5 criteria.*

The next step was to settle on some specifications for the repurposed building. Table 2-3 below lists the various specifications that we thought were important and the ways to implement them. These specifications are quantitative criteria that we expect for the repurposed building to meet through its new functions.

We aim to establish a comfortable indoor temperature range, which for most people extends from 68°F (20 °C) to 78 °F (25 °C) and 20% - 80% humidity, according to ASHRAE standards[12]. This would be implemented by upgrading the building's heating system and thermal envelope. This includes increasing the insulation R-values of the walls, ceiling, windows, and doors and installing geothermal units in the basement (Section 2.6 below). Additionally, the acoustics of the large space inside the church would need to be considered so that it ranges from 42 to 72 dBa, a comfortable range for restaurant settings[13].

To modify the space into a restaurant and performance hall, we specified the capacity, vertical transportation, and number of restrooms for the size of the building. While the potential crowd capacity is large, we expect the average capacity to be about 200 individuals. In order to meet fire codes and handicap accessibility, we will add in one more stairway and an elevator. There

[12] Norbert Lechner, *Heating, Cooling, Lighting*. John Wiley & Sons, 4th Ed., 2015 (page 72).
[13] "Acoustics in Restaurants." Ceilings & Interior Systems Construction Association. <http://www.cisca.org/files/public/Acoustics%20in%20Restaurants%20Final.pdf>

will be two restrooms, with 5 toilets in each and 5 urinals in the one designated for men[14]. Roles and responsibilities to run the operations can be distributed among 15 part-time and 20 full-time employees between the performance hall and the restaurant.

Specifications	**Means of Implementation**
Building Overall	
Comfort	Temperature range: 68°F (20°C) to 78°F (25°C) Humidity range: 20% - 80 %
Acoustics	42 dBa - 72 dBa
Water Collection System	~ 600,000 gallons/year
Energy Consumption	~ 30,000 kWh per year
Restaurant and Performance Hall	
Building Capacity	Total: 800 people Average: 200 people
Restaurant Capacity	Dining Area: 2475 sq-ft Seats: 120 seats
Fire Code	2 stairs with single hinged doors
Handicap	1 elevator
Restrooms	10 toilets per gender, 5 urinals
Employment Opportunities	15 part-time positions; 20 full-time positions

Table 2-3. *List of specifications with their means of implementation.*

The constraints of our model include broad considerations and goals. Town needs, as specified in the Southbridge Master Plan (mentioned earlier in Section 1.3), motivated the creation of a design that provides a space for local artists, community gatherings, employment opportunities, and tourist attractions. Since the building is registered as a national historic building, the new design must respect the history and physical outer structure of the old church. The current materials in the building influence the amount and type of insulation that should be added in order to achieve an ideal thermal envelope and acoustic levels.

[14] County, Fairfax, ed. "International Plumbing Code." IPC P2-07/08, Part II (n.d.): n. pag. 2008. Web. <https://www.iccsafe.org/cs/codes/Documents/2007-08cycle/FAA/IPC.pdf>

In order to make a solid long-term investment in the renovations, our design plans to achieve LEED Gold certification (Section 2.6). Weather and solar irradiation will influence the heating and cooling, and the water catchment system.

We propose to call the repurposed building, with its green energy and water features, the St. Francis Performance Hall and Restaurant, in honor of Saint Francis of Assisi who had a deep respect for the environment.

2.4. Floor Plans

As outlined above, we considered several designs to combine the restaurant and performance hall and ultimately settled on having the performance hall on the exiting main floor with the stage at the location of the present sanctuary and the restaurant be a U-shaped mezzanine on the opposite end from the stage, starting with what is currently the choir loft. This way, people dining upstairs in the restaurant could enjoy the event happening below and in front. The non-stage part of ground floor (where pews used to be) would be multipurpose space ready for a variety of events. The basement is intended mainly as storage and space for the energy components.

2.4.1. Basement

The Basement (Figure 2.3) will house equipment for the energy delivery system, including a series of heat pumps and an enthalpy recovery wheel (more on this in Section 2.6). The area that is not needed for the energy equipment can be used for storage, mainly storage of tables, chairs, removable dance floor, benches or other items that could be used to transform the ground floor into any type of set up.

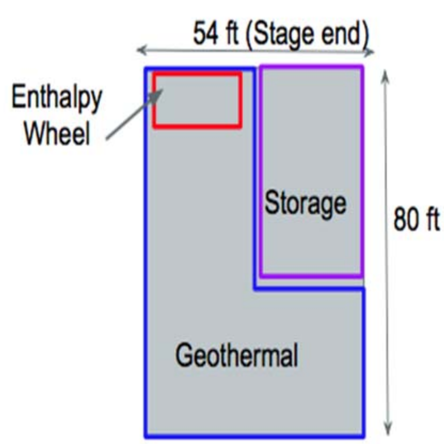


Figure 2-3. *Basement floor plan.*

2.4.2. Side Rooms on Main Floor

There are two side rooms flanking the sanctuary, one of which was the sacristy and the other a multi-purpose room. We propose that the former sacristy with more direct outdoor access be turned into small offices for the restaurant management and the opposite room be converted into restrooms.

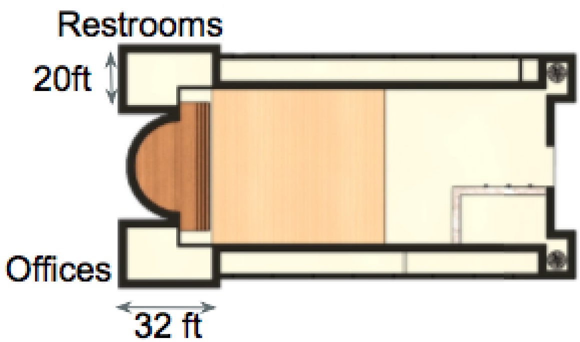


Figure 2-4. *Proposed use of side rooms.*

2.4.3. Performance Hall

The performance stage (Figure 2-5) is located on the South end where the sanctuary used to be. The floor should be raised somewhat. The main area of the ground floor where pews are currently located is intended to be a multipurpose space. This can include, as depicted in Figure 2-5, a dance floor, a seating area, and a bar on the side. When no performance is held, the dance and seating areas can be configured for other events such as an exhibit, an antique show, or a farmers' market.

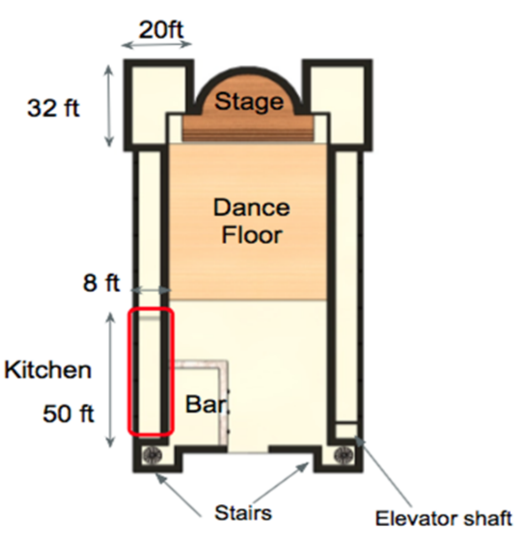


Figure 2-5. *Performance hall layout.*

2.4.4. Kitchen

We suggest that the kitchen serving the upstairs restaurant be located on the left (East side) behind the bar (Figure 2-5). We recommend that the appliances comply with the federal Energy Star program, and we accounted for this in our building energy analysis. Figure 2-6 below is a schematic showing how the various appliances could fit in the kitchen.

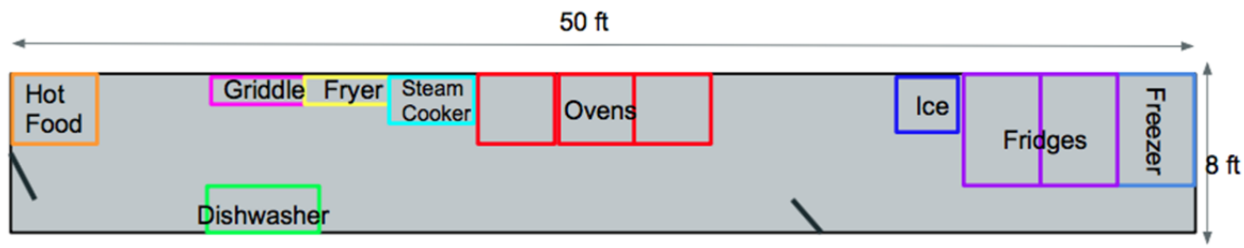


Figure 2-6. *Kitchen layout.*

2.4.5. Restaurant

The restaurant will be a U-shaped mezzanine in the back of the performance hall, including what is now the choir loft and extending laterally. It will consist of a standing bar section in the middle of the U, and the sides will be designated as seating areas (Figure 2-7).

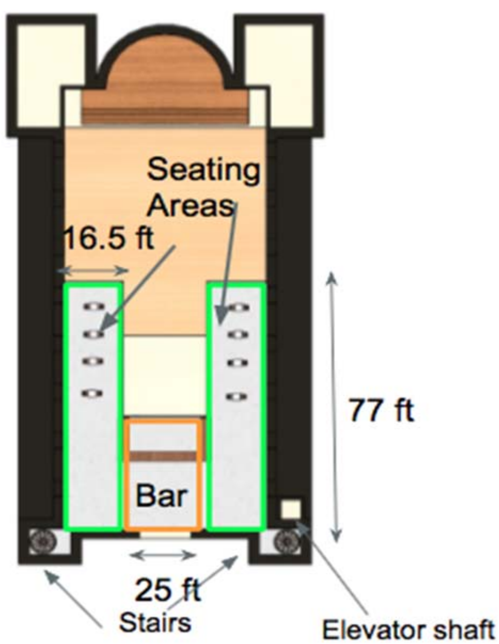


Figure 2-7. *Restaurant floor plan.*

2.4.6. Outside

For the outside area adjacent to the church, we propose a brick terrace situated on the right when facing the front entrance of the church on Charlton Street (Figure 2-8). We suggest putting lawn chairs out on the terrace and enclosing the area with a fence to allow people to socialize outdoors. The idea of an outdoor extension is to display activity to passerbys, thereby communicating to them that there is something lively happening and inviting to join. In other words, it would serve as an attractor.

Figure 2-8. *Proposed terrace location.*

An alternative idea is to display artwork or other eye-catching items to give a sense of the events going on inside and invite foot traffic.

The outside landscape will be planted with 25% native plants. Not only will this be beautiful, but it will also translate into LEED certification points.

2.5. Weekly Schedule

In order to cater to multiple constituencies in town as well as to draw a maximum of parties from out of town, we suggest to vary the activities in the main hall, according to a predictable weekly schedule (Table 2-4). This would help the local community thrive by utilizing local talents and bring to town musicians, artists or even guest chefs to help spark interest from outside Southbridge. A local artisan market could be held on the ground floor every Saturday and Sunday afternoons to entice people from around the area to come for produce and art.

Day of the Week	Main Hall	Mezzanine Restaurant
Sunday	Movies	Brunch
Monday	Town Gatherings or Cultural Events	*Closed*
Tuesday	Beer Tasting	Mom and Pop Kitchen
Wednesday	Art Displays	Trivia Night
Thursday	Comedy Night	Local Foods
Friday	Local Musicians	Local Foods
Saturday	Musical Guest	Rotating Foods

Table 2-4. *Proposed weekly schedule of activities.*

In addition to this weekly schedule, the performance hall and restaurant should be available to be rented for private gatherings, such as weddings.

2.6. Energy Analysis

2.6.1. Energy Consumption

With a structure this old, we decided it was best first to get an estimate for current heating energy usage. We estimated the current R-values for the walls, ceiling, windows, and doors in consultation with the instructor and literature values for the thermal properties of stone[15]. Next we estimated infiltration using common factors for similar structures. We also recognized that the air in the top of the church – more than 15 feet above ground level – likely circulated significantly less than the air low enough to escape through the doors. Next we considered that this circulation was likely higher when the structure was in use and the doors were opening and closing, than it was late at night when there was no activity and the doors were closed. Using this, and monthly heating degree-days, we were able to estimate the amount of heating required every month of the year[16]. We then interpolated publicly available solar heat gain factors to determine that the building receives significant solar gain that offsets some of the heating needs because of the large southern exposure[17]. However, the heating load was still

[15] "Sweep's Library:R Values of common hearth materials." *The Chimney Sweep*. The Chimney Sweep, Inc., n.d. Web. 02 May 2017. <https://chimneysweeponline.com/horvalue.htm>

[16] " MONTHLY DATA FOR SEP 2016." *HEATING DEGREE DAY DATA MONTHLY SUMMARY: CLIMATE PREDICTION CENTER-NCEP-NWS-NOAA*. NOAA, n.d. Web. 2 May 2017.<ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/Heating%20degree%20Days/Monthly%20City/2016/Sep%202016.txt>

[17] "Solar Heat Gain Factors (SHGFs) for selected latitudes of the Northern Hemisphere ." N.p., n.d. Web. 20 Apr. 2017. <http://engineering.dartmouth.edu/~d30345d/courses/engs44/SHGF-daily-totals.pdf>

substantial. In fact, we calculated that heating this building alone would take over 3.7 billion BTUs each year, or well over 250,000 BTUs per square foot per year just to keep the building warm enough.

With this in mind, we knew we needed to redesign radically the heating system and thermal envelope of the church in order to have a chance at a sustainable, financially sound design. In order to make a solid long-term investment in the renovations, our redesign is aimed to achieve LEED Gold certification according to the US Green Building Council.

First we set about determining our R-values through consultation with the professor, architects, and industry experts. We determined that we could realistically improve the windows from an R-value of 1.5 to 5.0, the walls from 4 to 35, and the roof from 13 to 55, while keeping the doors the same at an estimated R value of 5. All of these values were considered readily achievable given current building standards and commercially available materials.

Additionally we recommend controlled, forced air ventilation (now standard in all commercial buildings) and the installation of an enthalpy recovery wheel to retain approximately 80% of the heat and moisture of the air being ventilated. On the whole, this design saves a great deal of energy when coupled to the improved R-values[18].

We also decided that our redesign should include the addition of air conditioning for comfort in summer, especially as the climate continues to warm. This analysis uses cooling degree-days to calculate the cooling needs and adds the solar heat gain that needs to overcome in summer. We further realized that the adverse solar heat gain of summer can be reduced significantly by the addition of shades. The final design is an efficient cooling system that keeps people inside the building comfortable all year long.

Details of the energy analysis are available upon request. A month-by-month summary is provided in Table 2-5a below. The total energy demand for both heating and cooling of the building over the course of a climatological-average year is 1.3 billion BTUs.

[18] "Air Change Rates in typical Rooms and Buildings." *The Engineering ToolBox*. N.p., n.d. Web. 20 May 2017. <http://www.engineeringtoolbox.com/air-change-rate-room-d_867.html>

Church	Heating Need (BTUs)	Cooling Need (BTUs)	Total Heating & Cooling (BTUS)
January	280,573,707	0	280,573,707
February	194,183,246	0	194,183,246
March	109,341,978	0	109,341,978
April	45,122,694	28,772,169	73,894,863
May	0	33,027,312	33,027,312
June	0	42,168,032	42,168,032
July	0	88,669,459	88,669,459
August	0	82,115,670	82,115,670
September	0	37,275,658	37,275,658
October	30,990,627	0	30,990,627
November	110,248,752	0	110,248,752
December	238,588,564	0	238,588,564
Full Year	**989,049,569**	**312,028,301**	**1,301,077,870**

Table 2-5a. *Monthly heating and cooling needs of the church building after retrofits.*

2.6.2. Energy Procurement: A Geothermal System

The previous section addressed means by which the energy demand can be lowered, which is the top priority in the design of an energy efficient building. The second element is the meeting of the remaining energy need by an efficient, preferably renewable, energy system. For this, we propose the installation of a geothermal system with a set of water-to-air heat pumps and an enthalpy recovery wheel.

Such a system offers two benefits. First, geothermal energy is a carbon-free, renewable form of energy, and secondly water-to-air heat pumps provide an efficient means by which the temperature of the underground water can be either raised or lowered to the obtain air at the desired temperature to effect the heating or cooling of the building. The amount of electrical energy needed may be as low as one fifth of the amount of heat energy being converted from the source temperature to the delivery temperature.

Once wells are drilled and the capability of pumping water is installed, it becomes economical to size up the system to serve more than one building. Therefore, we have designed a system that serves simultaneously the church, the school turned greenhouse, and the rectory turned bed-and-breakfast. Because of the heat generated by its ovens, the convent turned bakery has no need for additional heating but will tap into the shared geothermal system for summer cooling[19].

[19] Because the geothermal system needs to be sized for the larger winter heating load, it happens to be oversized for the lower summer cooling load, and there is no problem plugging the bakery into the system for its share of air conditioning in summer.

For our geothermal system design, we decided to use a series of 5-ton Vertical TZV060 geothermal heat pumps[20]. These heat pumps have an energy efficiency ratio (EER) in cooling of 45 and a coefficient of performance (COP) in heating of 5.1, which means that in air-conditioning mode 1 Watt of electricity generates 45 BTUs of cooling per hour, and in heating mode 5.1 BTUs of heat energy is delivered for each BTU-equivalent of electricity consumed (= 17.4 BTUs/hr delivered for each Watt of electricity). Instead of a single powerful heat pump, we opted for a series of the smaller units mentioned above so that the number of heat pumps turned on at any one time can be adjusted according to need of the moment. This also permits the maintenance, repair or replacement of one unit without shutting the whole system down.

We calculated the amount BTUs of heating and cooling required for every building after retrofit (Table 2-5a above and Tables 2-5bcd below), and total for all buildings (Table 2-5e). Then, using the EER and COP of the heat pumps, we determined the number of kWh of electricity needed to run the system (Table 2-6).

Greenhouse (School)	**Heating Need (BTUs)**	**Cooling Need (BTUs)**	**Total Heating & Cooling (BTUS)**
January	159,430,008	0	159,430,008
February	126,464,761	0	126,464,761
March	152,812,267	0	152,812,267
April	70,513,632	0	70,513,632
May	0	17,167,933	159,430,008
June	0	59,899,606	126,464,761
July	0	87,945,724	152,812,267
August	0	91,114,293	70,513,632
September	0	60,782,050	159,430,008
October	31,093,180	0	31,093,180
November	89,993,561	0	89,993,561
December	169,521,591	0	169,521,591
Full Year	**799,828,999**	**316,909,606**	**1,116,738,606**

Table 2-5b. *Monthly heating and cooling needs of the school building after retrofits.*

[20] "5 Ton - Two Stage Digital Geothermal Heat Pump Package Unit Tranquility 22 Series - Vertical (Model # TZV060)." *WebReps B2B Wholesale*. N.p., n.d. Web. 20 May 2017. <http://www.webrepswholesale.com/product.jhtm?id=192106&tc=googleshopping&gclid=CjwKEAjwjPXIBRDhwICRg-DbgHISJADP6QXp_42xugDnZHgMcEh-9H_Bkkpip590E5sA_GiQz708_RoCLefw_wcB#.WSY8Kcm1vzJ>

Bed-n-Bkfst (Rectory)	Heating Need (BTUs)	Cooling Need (BTUs)	Total Heating & Cooling (BTUS)
January	49,972,427	0	49,972,427
February	43,725,873	0	43,725,873
March	30,642,541	0	30,642,541
April	23,166,351	442,669	23,609,020
May	8,312,343	3,984,022	12,296,365
June	491,855	8,804,197	9,296,052
July	98,371	19,034,773	19,133,144
August	0	18,542,918	18,542,918
September	2,016,604	8,115,601	10,132,205
October	13,771,929	737,782	14,509,710
November	25,969,922	0	25,969,922
December	46,283,517	0	46,283,517
Full Year	**244,451,732**	**59,661,962**	**304,113,694**

Table 2-5c. *Monthly heating and cooling needs of the rectory building after retrofits.*

Bakery (Convent)	Heating Need (BTUs)	Cooling Need (BTUs)	Total Heating & Cooling (BTUS)
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	17,167,933	17,167,933
June	0	59,899,606	59,899,606
July	0	87,945,724	87,945,724
August	0	91,114,293	91,114,293
September	0	60,782,050	60,782,050
October	0	0	0
November	0	0	0
December	0	0	0
Full Year	**0**	**7,418,556**	**7,418,556**

Table 2-5d. *Monthly heating and cooling needs of the convent building after retrofits.*

All Buildings	Heating Need (BTUs)	Cooling Need (BTUs)	Total Heating & Cooling (BTUS)
January	469,976,141	0	469,976,141
February	364,373,880	0	364,373,880
March	292,796,786	0	292,796,786
April	138,802,678	29,214,838	168,017,516
May	8,312,343	54,765,301	63,077,643
June	491,855	112,006,227	112,498,082
July	98,371	198,157,339	198,255,710
August	0	194,111,781	194,111,781
September	2,016,604	107,025,158	109,041,762
October	75,855,736	737,782	76,593,518
November	226,212,235	0	226,212,235
December	454,393,672	0	454,393,672
Full Year	**2,033,330,300**	**696,018,425**	**2,729,348,725**

Table 2-5e. *Monthly heating and cooling needs of all buildings combined.*

All Buildings	Heating Need (BTUs)	Electricity for Heating (kWh)	Cooling Need (BTUs)	Electricity for Cooling (kWh)	Total Electricity (kWh)
January	469,976,141	27,007	0	0	27,007
February	364,373,880	20,939	0	0	20,939
March	292,796,786	16,826	0	0	16,826
April	138,802,678	7,976	29,214,838	649	8,626
May	8,312,343	478	54,765,301	1,217	1,695
June	491,855	28	112,006,227	2,489	2,517
July	98,371	6	198,157,339	4,403	4,409
August	0	0	194,111,781	4,314	4,314
September	2,016,604	116	107,025,158	2,378	2,494
October	75,855,736	4,359	737,782	16	4,375
November	226,212,235	12,999	0	0	12,999
December	454,393,672	26,112	0	0	26,112
Full Year	**2,033,330,300**	**116,847**	**696,018,425**	**15,467**	**132,314**

Table 2-6. *Electricity needed to run the heat pumps.*

On the month of highest need (January), a total of about 470 million BTUs need to be delivered for 31 days, which translates into 15,160,521 BTUs/day = 631,688 BTUs/hour. Since each heat pump has a 5-ton capacity, which corresponds to 60,000 BTUs/hour, a minimum of 11 heat pumps are necessary. We recommend that a total of 16 heat pumps be installed to plan for particularly cold winter days and in the case of malfunctions.

Once we had determined the total number of heat pumps needed and the amount of heat to be exchanged by them, we were able to estimate the water flowrate at around 6 gal/min per 5-ton machine[21]. Taking the length of the piping as 100 feet (much deeper than the water table to account for friction in the pump and horizontal sections)[22], calculating the pumping power to horsepower, we estimated the electrical energy required to run the pumping system over a complete (climatologically average) year: 50,314 kWh.

For the church building alone, we estimated the need for an average of 23,402 BTU/ft^2 of electricity required to heat and cool the building. By today's standards for commercial buildings, this is a significant accomplishment given the major inefficiencies of the current building and its massive size. Note, however, that the previous number does not yet include electrical needs of the kitchen appliances, lighting and sound requirements for performances. These additional loads will be estimated in Section 2.7.2 below.

2.7. Other Analyses

2.7.1. Water

Since the redesigned church will include a kitchen and accommodate a relatively large number of patrons, water consumption is a major factor that needs to be assessed in the context of the ecological impact of the building. In order to meet the water consumption standards of LEED Gold certification, we had to reduce water usage from the previously functional church by 30%, reduce potable water use for irrigation by 100% (by integrating a water catchment system), and submeter indoor plumbing and domestic hot water. These three objectives are worth 5 points, 5 points, and 2 points, respectively.

The church building in its prior use as a place of worship did not meet building codes for restrooms. According to the International Plumbing Code by the American Restroom Association, churches must have 1 water closet (toilet) per 150 men, and 1 water closet per 75 women. Additionally, there must be 1 lavatory (sink) per 150 people, 1 drinking fountain per 1,000 people, and 1 service sink. If the Sacred Heart Church reached full occupancy during its heydays, these codes were not met. Our updated design of the church integrates a restaurant and performance hall into the space, which not only increases the occupancy but also changes its function. The repurposed building must now meet The American Restroom Association's

[21] "Open Loop vs. Closed Loop." *Geo Excel*. N.p., n.d. Web. 02 June 2017. <http://www.geoexcel.com/OpenLoopVsClosedLoop.htm>

[22] "Pumping Water - Required Horsepower." *The Engineering ToolBox*. N.p., n.d. Web. 20 May 2017.

guidelines for performance halls. This includes 1 water closet per 125 men, and 1 water closet per 65 women. Additionally, there must be 1 lavatory per 200 people, 1 drinking fountain per 500 people, and 1 service sink. Based on a maximum occupancy of 800 people, the redesigned space must include 4 lavatories, 7 toilets and 5 urinals for men, 13 toilets for women, 2 drinking fountains, and 1 service sink[23]. With the installation of low-flow toilets and sink taps (fountains and service sinks included), the water consumption for general use, still excluding the kitchen, is estimated at 92,955 gallons of water per year. The redesigned church will not only have additional bathrooms contributing to its water usage, but also has a commercial-size kitchen to serve the restaurant. Kitchen appliances include a dishwasher, steam cooker, and a watersense pre-rinse spray valve[24]. The dishwasher, a multi tank, high-temperature conveyor capable of washing 600 racks per day uses 97,000 gallons of water per year. The steam cooker which would cook 100 pounds of food per day consumes 133,000 gallons of water per year. Finally, the spray valve operating for over an hour each day consumes 7,000 gallons of water per year. This results in a total annual water usage for the kitchen of 144,000 gallons per year.

Obviously, the increase in water consumption does not correspond to a 30% reduction from the past, but to fulfill the LEED-Gold water requirement what matters is that the repurposed building be 30% more efficient in water consumption than a standard building of same function (on a per-square foot basis). A standard kitchen serving 200 people per night uses over one million gallons of water per year, 10 times our kitchen usage and almost double the total water consumption of the restaurant and performance hall[25]. Thus we can claim a 30% reduction. Table 2-7 summarizes the water needs for the redesigned church building.

	Water Consumption (gal/use)	Uses/Day	Water consumption (gal/day)	Water consumption (gal/year)
Kitchen	N/A	N/A	400	144,000
Sinks	1	150	150	45,000
Toilets	1.28	120	153.6	46,080
Fountains	0.25	25	6.25	1,875
Total Church Water Consumption				**236,955**

Table 2-7. *Water consumption estimate for the repurposed church.*

[23] County, Fairfax, ed. "International Plumbing Code." *IPC P2-07/08, Part II* (n.d.): n. pag. 2008. Web. <https://www.iccsafe.org/cs/codes/Documents/2007-08cycle/FAA/IPC.pdf>

[24] The pre-rinse spray valve reduces the required cleaning power of the dishwasher, reducing energy and water consumption needed if there were no pre-rinse.

[25] Rizaiza, Omar S. Abu, and Mahmoud H. Al-Osaimy. "A Statistical Approach for Estimating Irrigation Water Usage in Western Saudi Arabia." *Agricultural Water Management* 29.2 (1996): 175-85. <http://avidwatersystems.com/wp-content/uploads/2011/04/Water-Usage-Chart.pdf>

The church roof is extensive with a horizontal projection estimated at 28,472 ft^2. Because of its primary eastern and western slopes, it is not suitable for photovoltaic cells, but it is perfectly suitable for rainwater collection, which would garner a few additional LEED points. The water thus collected would need significant treatment to bring it to drinking standards, but a basic filtering system would render the water usable for flushing toilets, for outdoor irrigation and, mostly, for supplying water to the farming operation in the repurposed school building (Section 4). So, we decided to add a water catchment system to the church.

To determine the amount of water that can be collected, we started with the monthly rainfall data for Southbridge (Table 2-8, middle column) and the surface area of the church roof (28,472 ft^2) and assumed 80% efficiency of collection. From these values we could estimate the month to month maximum water collection on the church roof and obtain a total for an averaged year.

Month	Rainfall (inches)	Water Collected (gallons)
March	3.46	55,230
April	4.72	75,397
May	3.94	62,937
June	4.49	71,723
July	4.53	72,362
August	4.02	64,215
September	4.09	65,333
October	4.92	78,592
November	3.54	56,548
December	0.44	7,044
January	0.41	6,533
February	0.895	14,297
ANNUAL	**39.45**	**609,380**

Table 2-8. *Monthly precipitation over Southbridge and water collection potential from the church roof.*

When comparing these values to the greywater consumption of the church, we recognized the potential to provide water to other areas of campus, specifically the water intensive greenhouse in the repurposed school building. It is estimated that he greenhouse will need about 37,000 gallons of water per month to meet the demand of the farming operations. Since some months do not have much precipitation, a cistern must be sized in order to have the amount available when need arises. To determine the optimal cistern capacity, we combined the demand of the greenhouse, irrigation, and the restaurant and performance hall, to arrive at the numbers in Table 2-9.

Month	Rainfall (inches)	Greywater Use (gallons)	Total Water Use (gallons)	Sprinklers (gallons)	Total Demand (gallons)	Total with Greenhouse (gallons)	Net Storage in cistern (gallons)
March	3.46	4,761.60	22,005.35	0.00	4,761.60	12,768.16	12,768.16
April	4.72	4,608.00	21,295.50	2,742.86	7,350.86	30,345.96	43,114.12
May	3.94	4,761.60	22,005.35	10,971.43	15,733.03	9,504.14	52,618.26
June	4.49	4,608.00	21,295.50	13,714.29	18,322.29	15,700.53	68,318.79
July	4.53	4,761.60	22,005.35	13,714.29	18,475.89	16,185.89	84,504.68
August	4.02	4,761.60	22,005.35	6,857.14	11,618.74	14,896.34	99,049.53
September	4.09	4,608.00	21,295.50	2,742.86	7,350.86	20,282.40	99,049.53
October	4.92	4,761.60	22,005.35	0.00	4,761.60	36,129.99	99,049.53
November	3.54	4,608.00	21,295.50	0.00	4,608.00	14,239.61	99,049.53
December	0.44	4,761.60	22,005.35	0.00	4,761.60	-35,417.11	63,632.42
January	0.41	4,761.60	22,005.35	0.00	4,761.60	-35,928.27	27,704.15
February	0.895	4,300.80	19875.8	0.00	4,300.80	-27,704.16	0.0
ANNUAL	**39.45**	**47,001.60**	**217,214.10**	**50,742.86**	**97,744.46**		
					cistern size:	**13,241.00**	ft^3
						99,049	gallons

Table 2-9. *Cistern size optimization.*

To ensure net positive water storage for each month of the year, the cistern capacity must be 99,049 gallon, which is dictated by the need to have a supply during the winter months when there is no liquid water precipitation. By adding this water catchment and storage system, the performance hall and restaurant will eliminate the need to purchase approximately 98,000 gallons of water per year from the municipal distribution system.

The proposed placement for the underground cistern is at the corner of the church nearest to the school building (which will become the greenhouse). This placement will not require tree removal or substantial concrete removal during installation.

Although our rainwater collection system could have provided greywater to other buildings on the campus, we decided against recommending this because the cost and carbon footprint of installing additional piping and pumps to connect with the remaining buildings outweighs the savings associated with using greywater only for toilets. The brewery in the repurposed utility building behind the church (Section 3) will need much water, but this water must meet drinking standards, and water collected on a roof followed by basic filtration is not suitable.

2.7.2. Electricity

Restaurants consume about two and half times more energy per square foot than other commercial buildings[26]. Because of this, it is important to save as much energy as possible in this area. To determine which appliances we would need in the new kitchen, we contacted Molly's Restaurant and Bar in Hanover, New Hampshire, and modeled our kitchen after theirs. Using an excel model from Energy Star, we estimated the total amount of energy and water that the kitchen would use annually[27]. This came out to about 115,000 kWh and 144,000 gallons of water annually.

To estimate the electricity needs for concerts in the Performance Hall, we turned to the experience of the musical group Radiohead, which in 2008 hired a consultant to lower the carbon footprint of their tour. Two key aspects of this project were the sound and lighting. We recommend modeling the performance hall aspect of this building after the Radiohead concert, but obviously on a smaller scale. For this purpose we used ⅙ the scale of a Radiohead concert. Using this scale, we estimate that for the lighting and speakers of a concert, the St. Francis of Assisi Restaurant and Performance Hall would use about 15,600 kWh annually[28].

Additionally, it will take electricity to light the rest of the building. For this, we suggest using LED lights throughout. As an example, the performing arts center at the University of Florida is successfully lit using all LED lights. This method of lighting drastically reduces the amount of electricity used, and it is an obvious choice. Based on the method used by the University of Florida, we estimate that the lighting of the building will be about 1.5 kWh/ft^2/year. For our floor surface of 19,351ft^2, this comes to almost 30,000 kWh per year[29].

Overall, the energy usage breaks down as depicted in Table 2-10 and Figure 2-9.

---

[26] "Purchase Energy-saving Products." *ENERGY STAR Buildings and Plants | ENERGY STAR*. N.p., n.d. Web. 20 May 2017.
[27] "ENERGY STAR for Small Business: Restaurants." ENERGY STAR Buildings and Plants | ENERGY STAR. N.p., n.d. June 2017.
[28] *Killer Cars: The Energy Impact of a Radiohead Concert*. N.p., n.d. 20 May 2017.
[29] Miller, N. J., S. M. Kaye, P. M. Coleman, A. M. Wilkerson, T. E. Perrin, and G. P. Sullivan. "LED Lighting in a Performing Arts Building at the University of Florida." *Pacific Northwest National Laboratory*. US Department of Energy, n.d. 20 May 2017.

Units	Electricity for Heating & Cooling	Kitchen	Water Pumping	Concert Speakers	Concert Lighting	Other Lighting	TOTAL
kWh/yr	63,770	114,971	14,704	5,400	5,112	3,000	**206,957**
kBTU/yr	267,753	392,281	50,169	18,425	17,442	10,236	**756,306**
BTU/ft^2/yr	23,402	34,286	4,385	1,610	1,524	895	**66,103**

Table 2-10. *Overall energy numbers.*

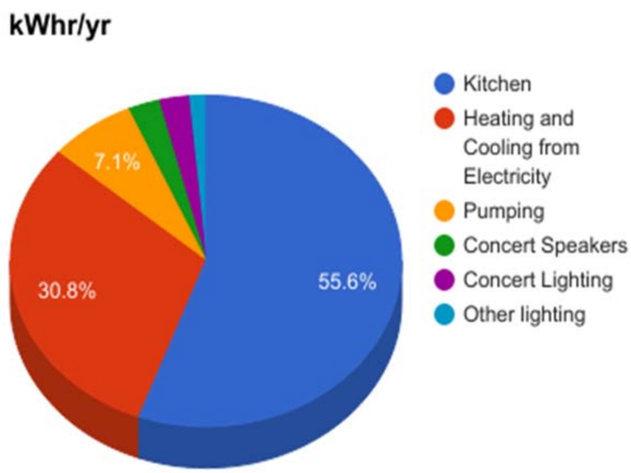


Figure 2-9. *Energy usage in the Performance Hall & Restaurant.*

As one can easily see, the kitchen creates the biggest energy need, followed by the heating and cooling system. However, both of these aspects of our design have been carefully designed to reduce energy usage as much as possible without sacrificing comfort or functionality. The use of energy-star appliances, LED lighting and sound systems greatly reduces the energy demand as did improving our insulation, using a geothermal heating and cooling system, adding an enthalpy wheel, and providing shading in the summer. As a result, we were able to drastically cut the energy usage compared to another building with the same square footage for a restaurant and concert hall[30] (Figure 2-10).

[30] "March 2016 U.S. Energy Use Intensity by Property Type Page 1 U.S. Energy Use Intensity by Property Type" *Energy Star Portfolio Manager*. Energy Star, n.d. Web. 20 May 2017. <https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf>

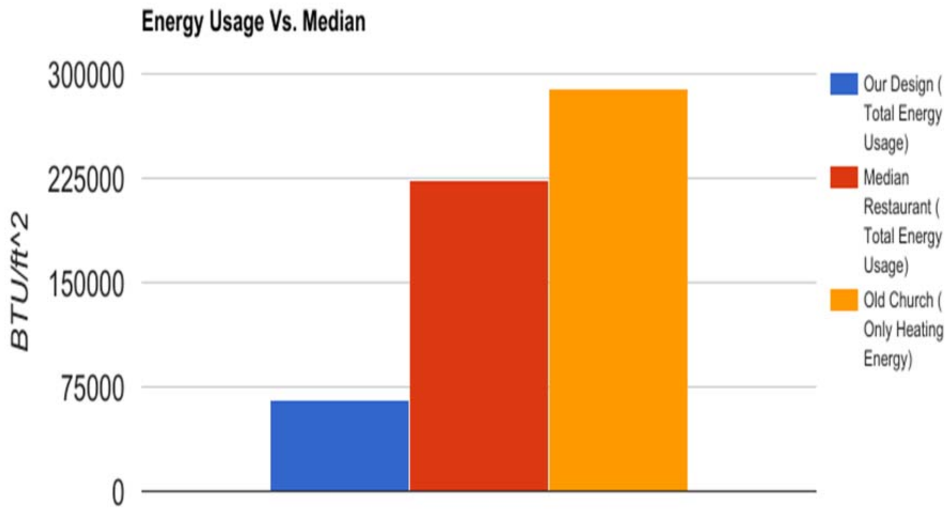


Figure 2-10. *Comparison of energy uses.*

Finally, we recommend purchasing all of the electricity through the *New England Green Start©* initiative which, for an extra 2.14 cents per kWh, certifies that all of its electricity comes from renewable sources. As a result the carbon footprint can be reduced to zero[31].

2.8. LEED Certification Analysis

The LEED certification system of the U.S. Green Building Council is a point system, with LEED-Gold certification obtained with a minimum of 60 points (out of a maximum of 110 points). The system has many sub-categories from which points may be gained. In order to determine an achievable goal, we researched comparable construction projects. We examined two churches, one in Atlanta, Georgia that was converted to a community hall and another in Orlando, Florida that was converted to a café, which earned LEED Gold and Silver, respectively. We used these two buildings as inspiration for our own energy goals since we are combining the two functions. By implementing some of their strategies such as water-efficient fixtures, energy-star appliances and recycling of building materials, we have decided seek LEED-Gold certification. Given the heating needs associated with the campus location in a northern state and the energy demand of a full-service restaurant, this is a challenging goal.

The following section covers the strategies we propose to garner the necessary points for LEED-Gold. The complete analysis can be found in Appendix A. Our rainwater catchment system (Section 2.7.1) will reduce potable water use for irrigation of the grounds by 100% and will be used as greywater in bathrooms throughout the building. Using techniques such as low-flow faucets, dual flush toilets and submetering throughout the performance hall will decrease our

[31] "Your Options & Pricing" *Your Options & Pricing | Mass Energy*. Mass Energy Consumer Alliance, n.d. Web. 02 June 2017. <https://www.massenergy.org/renewable-energy/pricing>

water use. We believe that in the energy and atmosphere category our geothermal system and enthalpy wheel will easily place us in the 39th percentile above the national median for similar buildings, gaining one quarter of the total points needed[32]. To obtain points in the material and resources category we will commit to purchasing sustainable equipment including energy efficient kitchen appliance. Additionally, 75% of all consumables and equipment that leaves the building will be recycled or reused so as to divert from adding to landfill. A major component of this section is also recycling existing building material during renovations, for example we plan to keep the red slate roof and stained glass windows. We propose the campus manager commits to purchasing Green Seal products for cleaning and follow correct disposal recommendations for hazardous material to ensure adequate indoor environmental quality. To develop a sustainable site we are aiming for a 10% reduction in typical commuter transport. To do this we propose preferred parking for electric vehicles, carpooling, and bike racks. Another component of this section is planting native vegetation onsite and reducing hazardous runoff into the nearby stream which will be particularly important during construction. Finally, we can gain points in the innovation and operations section by having one LEED accredited person employed on-site[33]. Given that this is a 'green' campus, we further suggest the site manager be LEED-certified.

In addition to all of these strategies, we recommend the digital monitoring, display and control of energy usage, water usage and air quality to track the performance of the building. The ability to do this makes a significant contribution to each sector and is critical to achieving LEED-Gold certification. Implementing all aforementioned strategies brings a total of 66 points and thus ensures Gold certification[34]. More than 50% of the points come from energy & atmosphere and water efficiency due to our advanced geothermal system, enthalpy wheel, and water collection system (Figure 2-11).

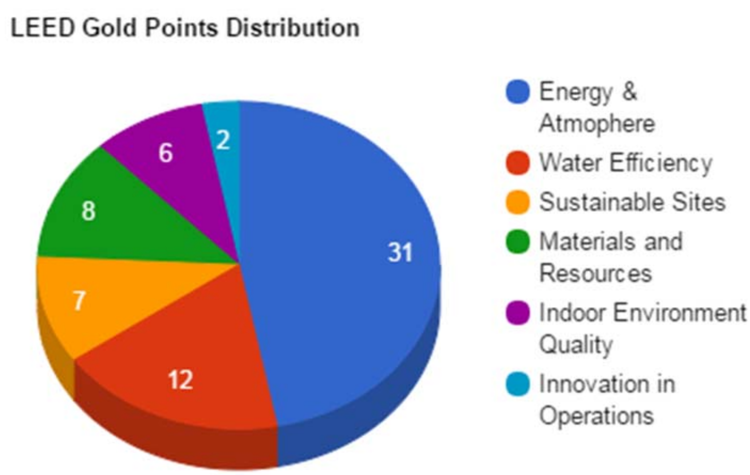


Figure 2-11. *LEED points distribution to attain Gold certification.*

[32] *Green Building Operations and Maintenance*. Washington, DC: U.S. Green Building Council, 2010.
[33] *Green Building Operations and Maintenance*. Washington, DC: U.S. Green Building Council, 2010.
[34] *Green Building Operations and Maintenance*. Washington, DC: U.S. Green Building Council, 2010.

2.9. Environmental Benefits

Our total reduction in environmental impact is significant; our design has approximately one third of the impact of a median restaurant-concert venue (Figure 2-12)[35]. Our energy efficient design, coupled with choosing to pay more to be provided with carbon-free electricity means that compared with the median building for our square footage and usage, we save 336,661 kWh/yr of electricity every year[36]. This is equivalent to 367 metric tons of CO_2 or driving a standard car from Los Angeles to New York City 190 times each year[37].

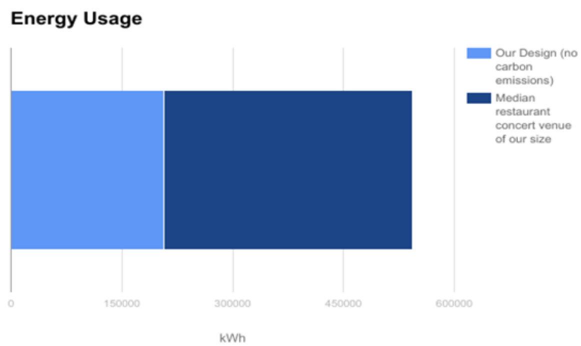


Figure 2-12. *Comparative energy use.*

In terms of water savings, the addition of the water catchment system will save 98,000 gallons of water each year; this is equivalent to 20,000 office water coolers[38].

2.10. Social Benefits

The social benefits from the St Francis Performance Hall and Restaurant will satisfy many of the town's needs as outlined in the Southbridge Master Plan. The new restaurant and performance hall will help generate 20 full time and 15 part time employees, which will boost economic development within the town and increase the overall quality of life. Additionally the town of Southbridge will benefit from the tax collected through the restaurant and performance hall operations. This facility will provide a safe social venue with family friendly events and our diverse range of restaurant menus and cultural events will ensure cultures thrive in the community. The performance hall will help the development of aspiring artists in the

[35] "March 2016 U.S. Energy Use Intensity by Property Type Page 1 U.S. Energy Use Intensity by Property Type ." *Energy Star Portfolio Manager*. Energy Star, n.d. Web. 20 May 2017. <https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf>.
[36] "March 2016 U.S. Energy Use Intensity by Property Type Page 1 U.S. Energy Use Intensity by Property Type ." *Energy Star Portfolio Manager*. Energy Star, n.d. Web. 20 May 2017. <https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf>.
[37] "Greenhouse Gas Equivalencies Calculator." *EPA*. Environmental Protection Agency, 24 Jan. 2017. Web. 20 May 2017.
[38] "15L & 11L Water Cooler Bottles" *15L & 11L Water Cooler Bottles : Neverfail*. N.p., n.d. Web. 05 June 2017.

community. We envision the restaurant and performance hall will become a focal point for the town with an outdoor area that provides a place where people can mingle while avoiding the no loitering rule that is enforced downtown. Our overall goal is to enhance community pride in Southbridge and enhance the Southbridge brand.

2.11. Economic Considerations

2.11.1. Estimated Cost of Retrofit

The repurposing of the church into the St Francis Restaurant and Performance Hall will necessitate major renovations, water damage repairs, and equipment purchase. Table 2-11 below is an attempt at calculating what the cost may be.

Component	Cost	Component	Cost	Component	Cost
Walls (+ 31R)	$ 24,240	Balcony	$ 123,585	Bar	$ 46,610
Ceiling (+ 42R)	$ 26,562	Kitchen	$ 50,000	Performance Hall	$ 26,400
Windows (5R)	$ 25,000	Elevator	$ 20,000	Restrooms	$ 17,165
Door (5.1R)	$ 25,000	Staircase	$ 3,500	Cistern	$ 18,500
16 5-Ton Geothermal Units	$ 88,000	General Repairs and Acoustics, Water damage	$ 1,762,725	Labor (2 years)	$ 1,102,400
Enthalpy Wheel	$ 425,000			**TOTAL**	**$ 3,788,038**

Table 2-11. *Estimated renovation costs.*

Since the building is a national historic building, insulation to maintain the thermal envelope cannot be added to the outside. Instead, the walls and ceiling must be padded and the windows and doors must be replaced to increase R-values to the desired levels. Using materials with high R-values will reduce the added thickness of the walls and added weight to the ceilings. For example, using combinations of polystyrene structural insulated panels (SIPS), which add R5 per 1-in thickness, and polyisocyanurate SIPS, which adds R7.7 per 1-in thickness, could limit additional thickness to 5 inches and 6 inches to the walls and ceiling, respectively[39]. Triple-pane windows would provide the best insulation and resistance to heat flow.[40] The renovation should include exterior doors that are also energy-efficient[41]. As mentioned in Section 2.6.2, the heating system should include sixteen 5-ton heat pump units and an enthalpy wheel.

In addition to general restorations and repairs, we estimated costs for the major modifications necessary to add an indoor balcony[42], an extra staircase[43], an elevator[44], restrooms[45], and labor costs. Installing the equipment for a bar, kitchen, and performance hall will also require significant investments according to our initial estimates. The cistern[46] for the water catchment system requires purchase and installation. It will, however, contribute to future savings and sustainability.

2.11.2. Estimated Annual Costs and Revenues

Variable costs depend on St. Francis of Assisi's performance level and outputs. Table 2-12 below itemizes and estimates expected annual costs.

Type	Unit Price	Base Amount	Cost
Commercial Electricity Rate with *New England Green Start©* surcharge	7.38 ¢/kWh + 2.4¢/kWh = 9.78¢/kWh	206,957 kWh/year	$ 20,240.39

[39] "Insulation Types and Tips" *Houselogic*. National Association of Realtors. <https://www.houselogic.com/organize-maintain/home-maintenance-tips/insulation-types/>
[40] Maynard, Nigel F. "The Latest Highly Insulating Windows Are Almost as Efficient as a Wall" *Residential Architect*. A Journal of the American Institute of Architects. <http://www.residentialarchitect.com/technology/products/the-latest-highly-insulating-windows-are-almost-as-efficient-as-a-wall_o>
[41] Wilson, Alex. "The Challenge of Exterior Doors" *Building Green.* <https://www.buildinggreen.com/blog/challenge-exterior-doors>
[42] "Second Story Balcony Additions" *Modernize*. <https://modernize.com/home-ideas/17699/second-story-balcony-additions>
[43] "Build Stairs or Railing Costs." True Cost Guide. *Home Advisor.* <http://www.homeadvisor.com/cost/stairs-and-railings/build-stairs-or-railings/>
[44] "Cost to install an elevator." Indoor Cost Guides. *Fixr.* <https://www.fixr.com/costs/elevator-installation>
[45] "Install a Toilet Costs." True Cost Guide. *Home Advisor.* <http://www.homeadvisor.com/cost/plumbing/install-a-toilet/>
"Bathroom Stall Prices." Cost Guides. *Improve Net by Craftjack.* <http://www.improvenet.com/r/costs-and-prices/bathroom-stalls>
Lewinski, John Scott. "Urinal Installation." Home Improvement. *Men's Health.* <http://www.menshealth.com/best-life/why-your-home-needs-urinal>
[46] "Underground Water Tanks." Water Storage Tanks. *Plastic-Mart.* <http://www.plastic-mart.com/category/200/underground-water-tanks>

Water	$ 3.24-6.27 per 100 cubic-ft	27,141.3 cubic-ft	$ 1,291
Employee wages	$15.00 - $25.00+ per hour	15 part-time, 20 full-time (split across campus)	$ 702,000
Meals Sales Tax (MA Commonwealth)	6.25% Restaurant Revenue	$ 3,926,000 / year	$ 245,375
Meals Sales Tax (Town of Southbridge)	0.75% Restaurant Revenue	$ 3,926,000 / year	$29,445
		Total Annual Costs	**$ 998,351**

Table 2-12. *Estimated annual costs.*

As mentioned in Section 2.7.2, the restaurant and performance hall can function solely on renewable energy through a local utility company with the *New England Green Start©* surcharge added to the commercial electricity rate. If the building consumes 206,957 kWh/year, then the yearly cost of electricity will be $20,240, approximately $5,000 more than the rate without the surcharge. Water rates are established by and paid to the Town of Southbridge[47]. Rates increase within established intervals, currently from $3.24 - $6.27 per 100 gallons, depending on consumption level each business quarter. The minimum wage in Massachusetts is currently $11.00 per hour. However, this is below the living wage for individuals living in Southbridge (Suffolk County)[48]. For the St. Francis of Assisi's business plans to align with the economic plans of the Town of Southbridge, hiring local manpower is important, and providing them fair wages is imperative. Since some employees will be shared amongst the campus, the wages estimate above is for the contribution of the restaurant and performance hall.

The restaurant will need to pay sales tax on meals. Massachusetts Department of Revenue collects a 6.25% sales tax on the price of all meals. The "Local Option Sales Tax on Meals," a special tax program in which Southbridge participates, is collected along with the state sales tax of meals and the funds are typically disbursed to the town on a quarterly basis[49].

Based on our suggested calendar of events, we have estimated the gross revenue based on price ranges common for a full-services restaurant and types of events that we envision in the

[47] "Water & Sewer Rate Schedule" Town of Southbridge. Oct. 6, 2016. <http://www.ci.southbridge.ma.us/sites/southbridgema/files/file/file/2016-17_water_sewer_rates_0.pdf>
[48] "Living Wage Calculation for Suffolk County, Massachusetts." Living Wage Calculator. <http://livingwage.mit.edu/counties/25025>
[49] Walczak, Jared. "Punching the Meal Ticket: Local Option Meals Taxes in the States" *Tax Foundation*. <https://taxfoundation.org/punching-meal-ticket-local-option-meals-taxes-states/>

performance hall. The entrance to the restaurant and performance hall are separate; while restaurant patrons will be able to view events occurring in the performance hall, they will need to pay the event fee to join. The breakdown of expected crowd sizes, cost per individual, and gross revenue is included in Table 2-13 below.

Day of Week	Restaurant	Crowd Size	Est. Gross Revenue per Week	Performance Hall	Crowd Size	Est. Gross Revenue per Week
Monday	Closed	0	$0	Town gatherings or community events	0	$0
Tuesday	Kitchen	360	$9,000	Beer Tasting	240	$12,000
Wednesday	Trivia Night	360	$ 9,000	Art Displays	200	$ 2,000
Thursday	Local Foods	480	$ 9,000	Comedy Night	200	$ 3,000
Friday	Local Foods	480	$ 12,000	Local Musician	200	$ 3,000
Saturday	Rotating Foods	480	$ 12,000	Musical Guest	200	$ 4,000
Sunday	Brunch	60	$ 1,500	Movies	40	$ 400
ANNUAL TOTAL for each component			**$ 2,886,000**			**$ 1,268,800**
	ANNUAL TOTAL for both components					**$ 4,154,800**

Table 2-13. *Estimated annual gross revenues.*

While St. Francis of Assisi has a maximum occupancy of 800 people, we expect an occupancy of 200 people in average (Section 2.3). Since the restaurant has 120 seats, our model assumes that the remaining 80 people are participating in events in the performance hall during each crowd turnover. For the restaurant, we assume that a customer will spend an average of $25 on a fine-dining experience[50]. The performance hall has more flexibility on the types of events and attractions that can be hosted, as it is less costly to run than a restaurant. The event space can host luxury events, especially to attract tourists, or run small-scale events that benefit the local community.

[50] "Restaurant Industry Operations Report." 2014. National Restaurant Association.

3. The Power Plant Building

Student Team: Calin Ackerman, Kelsey P. Catano, Christian N. Kwisanga, Nayantara S. Patel, Tara M. Simmons, and Alexandria V. Vasques
Teaching Assistant: Rita Tu

3.1. Description of Current Building

Located in the rear of the church is a power plant (Figures 3-1 and 3-2) built of the same brick as the school, rectory and convent. It is the smallest of the five buildings on the Sacred Heart Church campus and currently houses two boilers (Figure 3-3) that were used to heat both school and church but which have remained unused since 2010. For this purpose, it is equipped with a large external smokestack (Figures 3-1 and 3-2). The floor area is 30' x 30', thus providing 900 ft^2 of interior space.

Figure 3-1. *Power plant – East facing view.*

Figure 3-2. *Power plant.*
West facing view, with loading dock.
The church building is seen in the rear.

Figure 3-3. *Inside view of power plant (as of Spring 2017).*

The power plant has a deceptively short outer wall, as the floor inside is approximately 6 feet deeper than the outside ground level, providing an estimated clearance of 16 feet in the center under the tallest point of the roof. The power plant has a walk-up entrance as well as a garage door/loading dock on the west side of the building (Figure 3-2).

3.2. Re-Purposing into a Brewery

With its brick walls, many windows, tall smokestack, and loading dock, the structure has the general appearance of a 19th Century factory building. This identification should ideally be preserved in a re-purpose.

The decision for the repurposing of the power plant was relatively straightforward. Once it was decided that some of the other buildings would serve food and drinks and after local resident Pamela Paquin related that craft beers produced in microbreweries enjoy a good degree of popularity in the area, it became evident that a new function for the small, factory-looking structure should be a micro-brewery.

The building already contains a loading dock approximately 20 ft from the church and 300 ft from the rectory, which will have a restaurant and sports bar, respectively. This proximity is ideal for easy delivery of freshly brewed beer in kegs. On the West-facing side is an entry door, but the building would require installation of an additional entry way (with handicap access) on the East side as depicted in renderings (Section 3.4.1). It is envisaged that the building would accommodate tours. To highlight the church heritage of the place, it is proposed to name it the St. Benoit Brewery.

The available interior floor space for beer production is 900 ft^2. Brewery equipment, which would have to be sized by an installation company, would be placed diagonally toward the center (Figure 3-4). Inner walls to enclose an employee break room and a unisex bathroom should be erected.

In order to meet brewery standards, a few updates need to be made to the structure along with a few conventional requirements to fulfill a typical employment space, as listed in Table 3-1.

Already existing	Need to be installed	Potentially needed
Adequate ceiling height	Finished and waterproof flooring	Water filter
Windows for natural lighting	Handicap access ramp	Refrigeration
Standard electrical supply	Fan and flue for ventilation into smokestack	Adequate drainage system

Table 3-1. *Brewery building requirements.*

Using the “golden rule” for breweries of 1 sq ft of production space equals 1 barrel of beer per year[51], we project an annual production of 900 barrels of beer. The major pieces of equipment are the following: mash vessel, lauter tun, brew kettle, whirlpool, liquor tanks, and brewer’s platform.

3.3. Floor Plans

After consultation with a micro-brewer to learn about the arrangements of the various pieces of equipment in a small brewery, we arrived at the following floor plans (Figure 3-4).

[51] <http://microbrewr.com/how-big-should-my-brewery-be/>

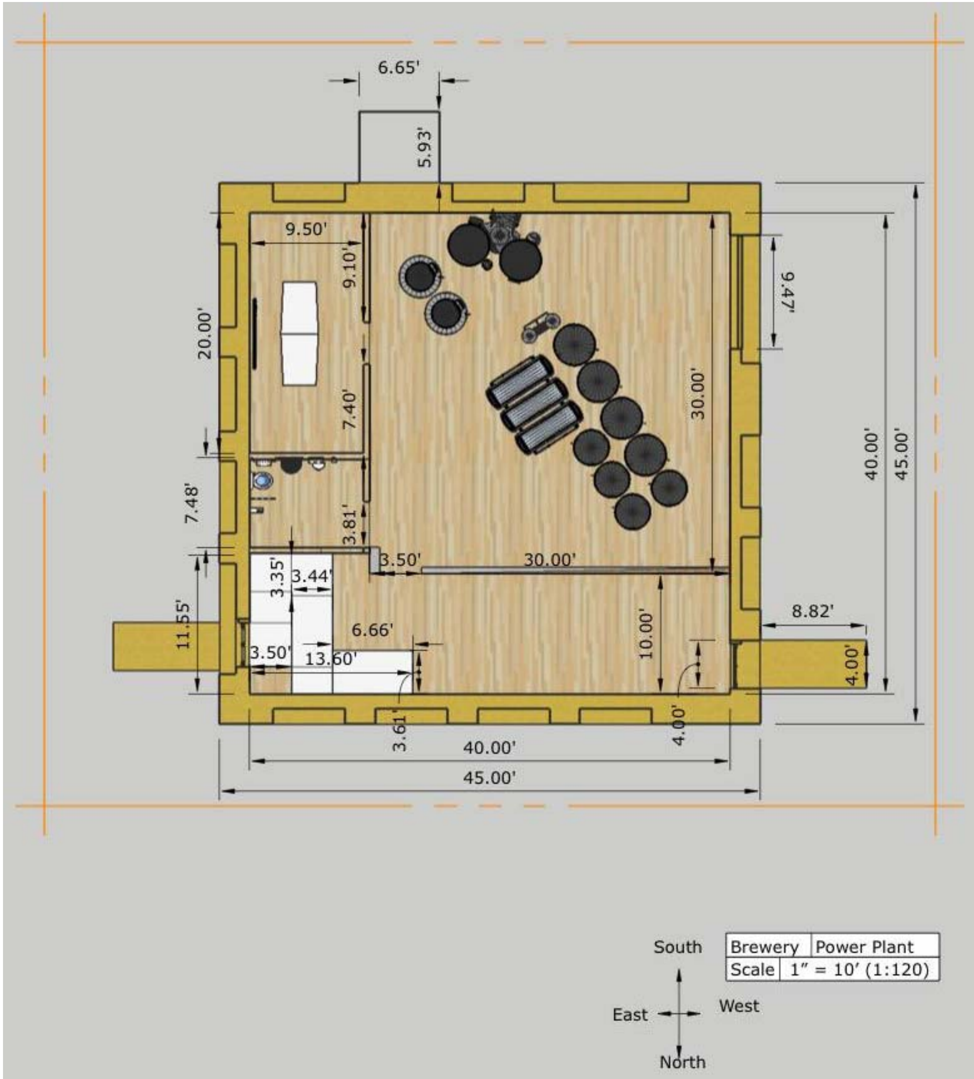


Figure 3-4. *Floor plans of brewery including handicap ramps, employee break room, and unisex bathroom. A second internal handicapped ramp on the right side is not pictured. The elements in grey and dark grey are the brewing equipment. The employee break room is in the southeast corner (top right).*

3.3.1. 3D Renderings

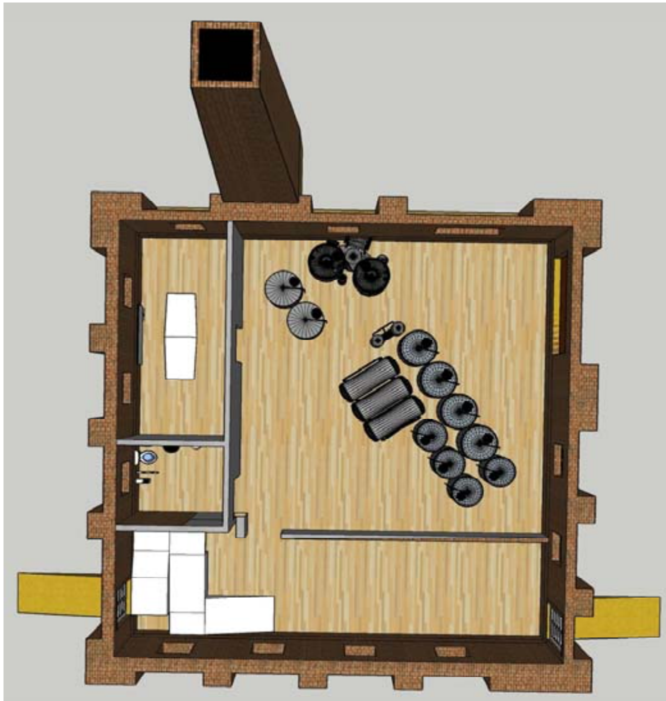


Figure 3-5. *Bird's eye view of brewery layout.*

Figure 3-6. *North-West view of brewery, without roof.*

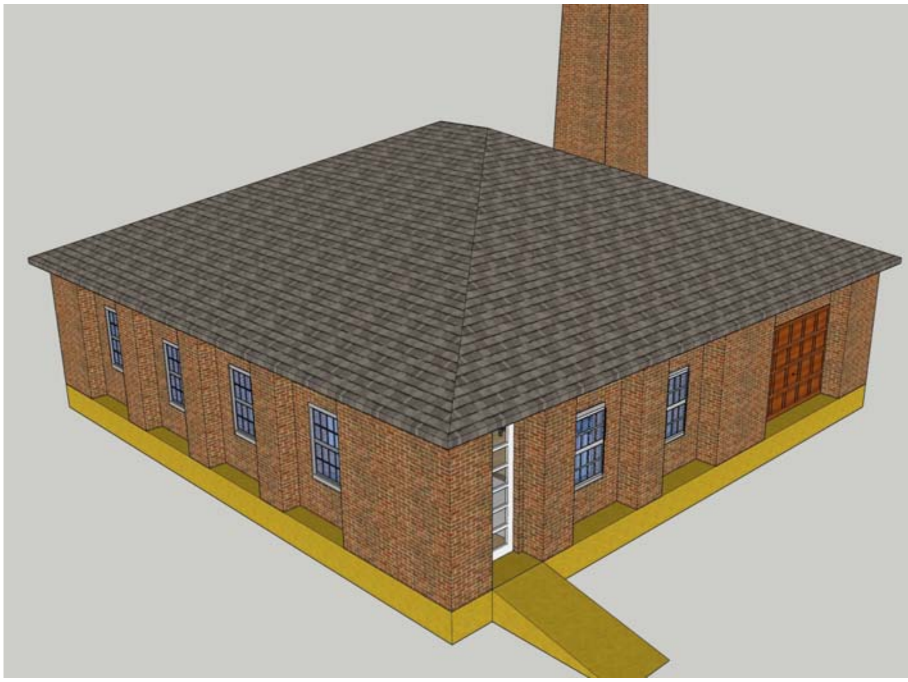


Figure 3-7. *North-West view of brewery, with roof included.*

3.4. Energy Analysis

3.4.1. Energy Consumption

To produce 900 barrels of beer annually, the brewery will need 139,500 gallons of water per year (see Section 3.5.1. below). The energy required to boil 139,500 gallons of water per year is 1.644×10^8 BTUs/year. As boiling water is extremely energy intensive, this is by far the largest energy need compared with all other energy needs of brewing operations, and we may ignore the other energy needs in comparison.

3.4.2. Energy Procurement

The heat to boil the water would come from propane. Converted into propane[52], the aforementioned amount of energy needed is 1,800 gallons of propane per year. Assuming the propane is stored in a 1,000 gallon tank outside the building, we estimate that the brewery will require 2 propane tank refills per year at an annual cost of about $4,140 (assuming $2.30 per gallon).

[52] At standard compression for delivery trucks, propane holds 91,300 BTUs/gallon.

3.5. Other Analyses

3.5.1. Water

Using the brewing equation that the production of 1 barrel[53] of beer requires 5 barrels = 155 gallons of water, the brewing operations will require 139,500 gallons of water per year in order to produce 900 barrels of beer annually. With an additional 20,700 gallons of water per year for the bathroom and breakroom, the total water usage of the brewery amounts to 160,200 gallons of water per year.

3.5.2. Ingredients and Materials

For the production of 900 barrels of beer, the necessary ingredients are 31,500 lbs of barley, 13,500 lbs of grain, some yeast, and a variety of maintenance chemicals in small quantities.

In addition, it is anticipated that some business may be made by selling beer-related items during tours, such as hats, T-shirts, coozies, shot glasses, flasks *etc*. for an estimated $2,400 of merchandise per year at 60% markup ($1,500 procurement costs).

3.6. Environmental Benefits

The building may benefit from an improved thermal envelope, but the heat generated by the brewing process (chiefly during the boiling stage) may mitigate the need for heating in winter. Relative comfort in summer may be accomplished simply by opening windows.

The carbon footprint of the building will be intimately linked to that of the fuel used for the boiling process. Assuming that propane is used for convenience, 1,800 gallons would be combusted each year (see Section 3.4.2 above), emitting 10.3 metric tons of CO_2 each year[54].

Avoidance of this greenhouse gas emission can be achieved by using biomass-derived ethanol or methanol as the combustion fuel, but such fuels may not be available in the area in the necessary quantity. Using firewood as the fuel is not recommended because it would necessitate a storage shed, a different boiling equipment, and additional labor.

---

[53] In the US, a barrel of beer holds 31 gallons.
[54] Combustion of one gallon of propane emits 5.74 kg of CO_2.

3.7. Social Benefits

The brewery is expected to employ five people, two of which on a part-time basis (Table 3-2 below). The brewery will need a master brewer as well as additional brewery staff. The brewery will also host tours through the facility, which would require part-time guides.

Job Position	Number of People
Master Brewer (full time)	1
Brewery Staff (full time)	2
Tour Guides (part time)	2
TOTAL	**5**

Table 3-2: *Employment by the St. Benoit's Brewery.*

The brewery will offer Bed-and-Breakfast guests the opportunity to 'Become a Brewer' for a day, an initiative that teaches guests the beer-making process and would contribute to make the Sacred Heart campus an experiential learning location with a destination feel. The brewery can also offer tours during working hours, helping to create a town brand and contribute to the overall campus experience in addition to generate revenue by sales of tourist-type items (hats, T-shirts, cozies, and the like).

3.8. Economic Considerations

3.8.1. Estimated Cost of Retrofit

Before installing the brewing equipment, the space needs to be emptied of is current contents, and one must build two access ramps, inside walls, and a bathroom. The smokestack may require a good sweep before being put to a new use. Estimated costs for these elements may be around $100,000. As mentioned earlier, this building needs no added wall insulation, and it appears that the current roof is still adequate.

A brewery equipment installation company[55] is recommended to appropriately size the brewery tanks within the given space. A list of brewery components was mentioned at the end of Section 3.2, and the typical initial investment microbrewery equipment is around $200,000.

3.8.2. Estimated Annual Costs and Revenues

Annual Costs

The estimated annual costs are tabulated below:

Type of expenses	**Specific Expenses**	**Quantity**	**Annual Cost**
Employment	Brewmaster	1	$100,000
	Brewery staff	2	$120,000
	Part-time tour guides	2	$50,000
Ingredients[56]	Barley	31,500 lbs	$22,044
	Grain	13,500 lbs	$9,447
	Yeast	---	$3,600
	Maintenance chemicals	---	$300
	Water	160,200 gal	$241
Energy	Propane	1,800 gal	$4,140
	Electricity	20,000 kWh	$2,400
Maintenance		---	$20,000
Merchandise (hats, T-shirts, *etc*. wholesale)			$1,500
		TOTAL	**$333,672**

Table 3-3. *Estimated annual costs of operation.*

The total yearly cost to operate the brewery at 900 barrels of beer per year is estimated at $333,672.

Annual Revenues

Wholesale of beer by the barrel will generate:

(900 barrels/year) x (672 cups/barrel) x ($0.88/cup) + $13,000 = $545,224 / year.

If, on the other hand, the beer is sold entirely by the cup within the bar and restaurant, the total revenue comes to:

(900 barrels/year) x (672 cups / barrel) x ($5.00/cup) + $13,000 = $3,037,000 / year.

Realistically, the brewery will wholesale approximately half of its beer and sell the rest to the bar and restaurant, therefore the combined sales revenue totals:

($545,224/2) + ($3,037,000/2) = $1,791,112 / year.

---

[55] <www.specificmechanical.com>

[56] <www.northernbrewer.com/brewing/brewing-ingredients/beer-yeast/dry-yeast>

Selling beer and brewing related items to tourists can generate $2,400 ($1,500 worth of merchandise sold at 60% markup).

Annual Profits

The annual profits are the annual revenues minus the annual expenditures:
$1,791,112 + $2,400 – $333,672 = $1,449,840, close to $1.5 million.

4. The School Building

Student Team: Zoe M. Dinneen, Eleanor G. Dowd, O. Renata Hegyi, Jessica B. Link, Carolyn J. McShea, and David J. Polashenski
Teaching Assistant: Michael Baicker

4.1. Description of Current Building

The school building (Figure 4-1) originally opened in 1910 and was first run by the Sisters of Nicolet, who also ran the Notre Dame Parish School[57]. It is a two-story brick building; the second largest on campus after the church, at about 25,000 square feet[58].

Figure 4-1. *The façade of the school building, facing east.*

At its center is a large, two-story gymnasium (Figure 4-2) that contains boarded-up skylights, and is flanked on its north and south sides by a symmetric set of classrooms, on two levels. At present, the building is presumed to contain asbestos paneling and lead paint; it also has extensive water damage, as well as a host of structural stability issues. Its basement and first floors currently house a flea market, which grosses approximately $80,000 per year[59].

[57] https://npgallery.nps.gov/NRHP/AssetDetail/298c56c4-8d94-440a-8c09-9b818ee756f7/?branding=NRHP
[58] From our group's on-site measurements
[59] From conversation with Father Peter Joyce

Figure 4-2. *The gymnasium inside the school building.*
(Photo taken from the balcony opposite the stage)

The floor plans of the building in its current state are shown in Figure 4-3 below.

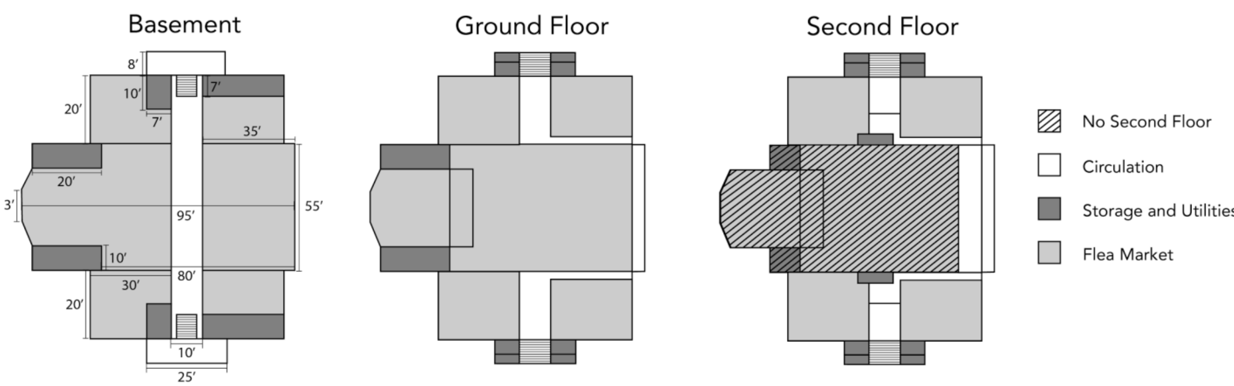


Figure 4-3. *The current floor plans of the school building[60].*

4.2. Brainstorming, Specifications, and Selection

The project description was broad and the space seems widely adaptable, which gave us wide latitude to imagine new uses for the building. The two driving constraints of our ideas were firstly the requirement that the property be profitable for the Town of Southbridge and secondly that we should complement the Town's larger redevelopment plans. We produced

[60] Plans by Carolyn McShea; drawn using our group's on-site measurements.

quantifiable specifications that would allow us to rank our several ideas, and weighted the specifications proportionally to their importance. The building had to have a revenue greater than $80,000 (current revenue), with preference given to stimulating the local economy rather than a profitable business that does not cater to Southbridge specifically. In terms of energy use, we created a self-imposed constraint of net-zero operational energy use, and ranked ideas according to their likely ease of meeting this goal. In line with Southbridge's rebranding of the town, we wanted the building to be aesthetically pleasing, both internally and externally, and bring in traffic to the town. Furthermore, a key driving specification was ensuring our building integrated with the other buildings in the complex and having a holistic approach to the Sacred Heart Church complex. We also wanted the school building to integrate with the wider urban environment and be a long-term fixture in Southbridge; so longevity was a specification.

The constraints of the redesign were in many ways addressed in our specifications, such as our self-imposed energy goals of net zero. Further constraints are the physical building itself, as it is relatively structurally sound but likely cannot support heavy masses on any floor aside from the basement. The building is also on the National Register of Historic Building and as such we cannot change the existing exterior of the building, only the interior or adding minor extensions to the building. The building also has limited utilized natural light and passive heating right now, which served as a constraint once we decided on our final decision. Finally, we were asked by the larger complex to accommodate office space for the entire complex's administration in our building and this became an inflexible constraint to our building.

Our group's goal was to address the many issues facing Southbridge with a community-centric center that could best utilize the massive space of the school to provide a place for all citizens to interact, learn, and grow. We learned from our visits to the site, as well as speaking with local resident Pamela Paquin, urban developer Bill Bittinger, and several architects. Based on our knowledge of the town, and some hopes and ideas from Pamela Paquin and Bill Bittinger, we considered what options would best suit the varied needs and populations of the town.

We considered that our repurposed building would draw four different kinds of users from Southbridge: local residents, children and youth, elderly people, and a "new" population of middle-class commuters who often drive down Main Street every day, and use Southbridge more as a thoroughfare than a destination.

We separated our main ideas into three main categories: those having to do with entertainment, education, and art, with the hope that we could combine many of these functions under one roof, considering the massive size of our space.

For entertainment, we considered the ideas of a bed and breakfast, a pop-up store, and an exercising space. The idea of providing greater opportunities for entertainment for many of the people who live just outside of Southbridge was very much one of Pamela Paquin's hopes. We also considered how we could incorporate art with entertainment, possibly by turning the building into an arts center or concert hall. The category that most inspired our group was turning the school into a place of education for the community once again. We considered the ideas of a vocational school, a greenhouse, a workshop space ("maker's space"), and an after-school care facility.

Specification	Weight		Greenhouse	Vocational school	Afterschool center	Art Center	Workshop Space	Popup store	Exercising Space	Concert Hall	Bed & Breakfast
Ability to generate revenue	1		7	0	5	5	5	9	7	8	10
Benefit provided to the community economically	2		6	8	5	2	2	6	3	4	6
Ease of ahieving net zero energy usage	1		9	8	8	8	5	8	5	6	7
Aesthetics	1		9	7	7	10	7	5	9	9	9
Compliments other buildings-holistic compound	3		10	5	3	4	3	7	6	2	5
Community engagment	2		8	10	9	10	8	5	5	3	1
Help rebrand Southbridge	1		6	6	6	8	7	6	6	8	9
Ability to bring in traffic	1		8	4	4	8	4	6	6	9	8
Integration with local urban environment	1		7	7	8	8	6	6	6	6	6
Longevity	1		7	9	9	7	7	4	7	7	8
TOTAL			111	92	84	90	70	87	80	73	86

Table 4-1. *Decision matrix for the school building.*

Ultimately, the evaluation of our several ideas against the pre-stated specifications and constraints (Table 4-1 above) led us to select the transformation of the school into a multi-purpose "Green school," complete with a greenhouse as well as work spaces, and rooms where farmers' markets and other community events could be held. The next best ideas were the vocational school or arts center, the former of which we felt wouldn't be able to bring in enough outside traffic/revitalization power, and the latter of which we felt may not be economically beneficial or compliment other buildings in the compound.

4.3. Re-Purposing into Greenhouse and Indoor Farm

The greenhouse is proposed to be the building's main function, considering it is the project that best aligned with our goals of benefiting the people and economy of Southbridge, while also complementing the other buildings on the Sacred Heart Church campus. Once we spoke with the other groups about their directions for their projects, we determined that utilizing our space to grow food for the neighboring restaurant, bed & breakfast, and bakery while simultaneously providing a fresh, green space to be enjoyed by all throughout the year was the best route for the former school building. We also acknowledged the amount of income we could receive from growing high-demand specialty crops, such as mushrooms, in the school's expansive basement—something we wouldn't be able to do with any of our other ideas.

To echo the Catholic past of the Sacred Heart Church campus, we decided to name our new building the Garden of Eden.

4.3.1 Basement

The multi-room basement is currently used as flea market, filled with everything from clothing to home appliances. There is very limited sunlight, and the walls are mostly bare brick. In terms of design, the basement is fairly traditional with 10-ft ceilings, concrete flooring, and boxy rooms. Instead of spending a large part of our energy and budget reworking the constraints of the space, we chose to capitalize on its limitations. The basement will be dedicated to growing highly lucrative crops that thrive in dark and damp environments: oyster mushrooms. Mushrooms grow best in a humid climate, and thus we chose to block out the sun and contain the moisture with opaque paneling that would ultimately be a room within a room. This design ensures that the mushroom growing space won't cause water damage. We abided by the customs of state of the art mushroom farming, and installed shelving to maximize the vertical space. Figure 4-4 below gives an idea of what the space would look like, with vertical stacking to maximize use of space.

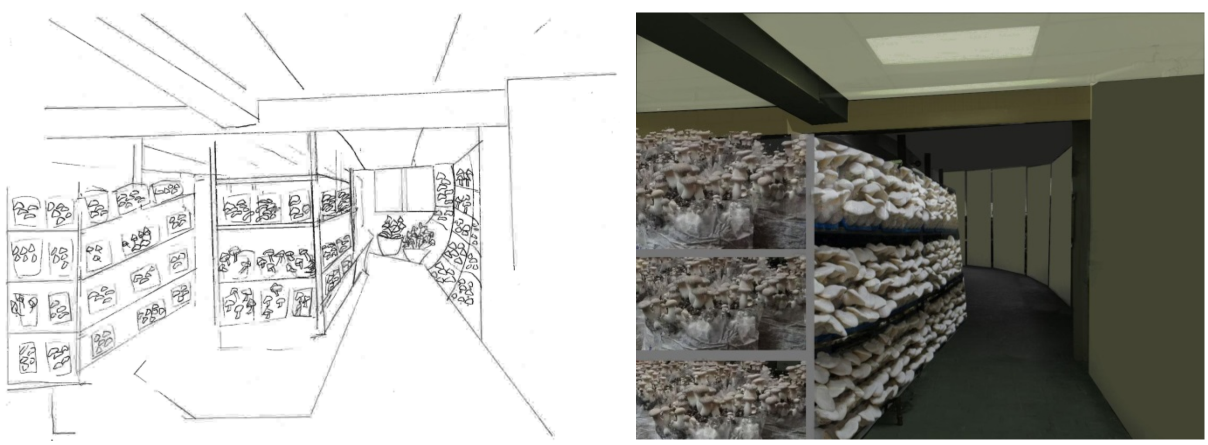


Figure 4-4. *Growing mushrooms indoors on an intensive scale.*

4.3.2 Gymnasium

The Gymnasium is the heart of the building, both because it is at the center of the structure and because it is two-story high. Its prior uses were those of gymnasium, sports hall (its floor has lines of a basketball court and other markings), performance hall (with a stage on the west end – center in Figure 4-2), and space for graduation ceremonies. Today, the gym is being used for storage, and its floor is cluttered.

The breadth and height of the room make it ideal as a place for community gathering, and our proposal is to re-purpose it for engagement and education. The skylights are currently covered over; so, to brighten the space we would return the skylights to their initial state. There would be rows of vertical hydroponics, a living wall, and a space for the community hang out space (Figure 4-5).

Figure 4-5. *The gymnasium repurposed as space for engagement and education.*

We cut a balcony into the 2nd floor on the north side (right sides in both panels of Figure 4-5), so that the administrative offices (more on this below) could overlook the community garden. Below the balcony we propose demonstrative aquaponics that will both serve as a nutrient source for the soil and educational exhibit for children. The redesign is meant to create a large inviting space that brings together the community around sustainable growing and education.

4.3.3 North Classrooms on First Floor

The first-floor classrooms will be transformed into a farmers market and experiential learning centers. In the farmers market we will sell a combination of our produce and local artisans. The idea is to ignite local commerce in Southbridge and make a green school a destination location in Southbridge. The experiential learning center echoes the school's origin and will be a modernized space to hold afterschool programs and summer camps that focus on education by doing.

As these classrooms may serve different users and purposes through the year, those rooms need to have flexible floor spaces and movable furniture.

4.3.4 North Classrooms on Second Floor

As a part of the greater campus, we wanted to designate some of our space to administrative work. We are housing some administrators in a modernized office space converted from a classroom. We cut out a balcony that overlooks the gymnasium to engage the administrators in our greenhouse.

4.3.5 South Classrooms on First and Second Floors

The south side gets the most sunlight, and this advocates for the transformation of these classrooms on both floors into growing spaces. To maximize space we will be installing vertical hydroponics. As is common indoor growing, we will also be taking advantage of LED lights to keep our production consistent throughout the year. We plan to grow herbs and greens, such as kale, basil, arugula, and lettuce. Other possibilities may be considered in an effort to cater to the ethnic makeup of the local population.

4.3.6 Southside Greenhouse Addition

Currently on the south side facing the river, the lower wall is rather bare, and we thought of augment this side with a protruding greenhouse (Figure 4-6). This glass addition will capture much sunlight and serve to provide a humid climate for different varieties of crops. We see this addition as a great educational tool, as well as a source of heat and humidity for the building. The adjoining wall between the greenhouse and the building will be a trombe wall to best utilize the direct solar heat gain harvested in the greenhouse.

Figure 4-6. *Proposed greenhouse addition on the south side of the school building.*

4.4. Floor Plans

Figure 4-7 below the repurposed floor plans in order to implement the ideas outlined in the previous section. Table 4-2 lists the various rooms, their square footage and their attribution.

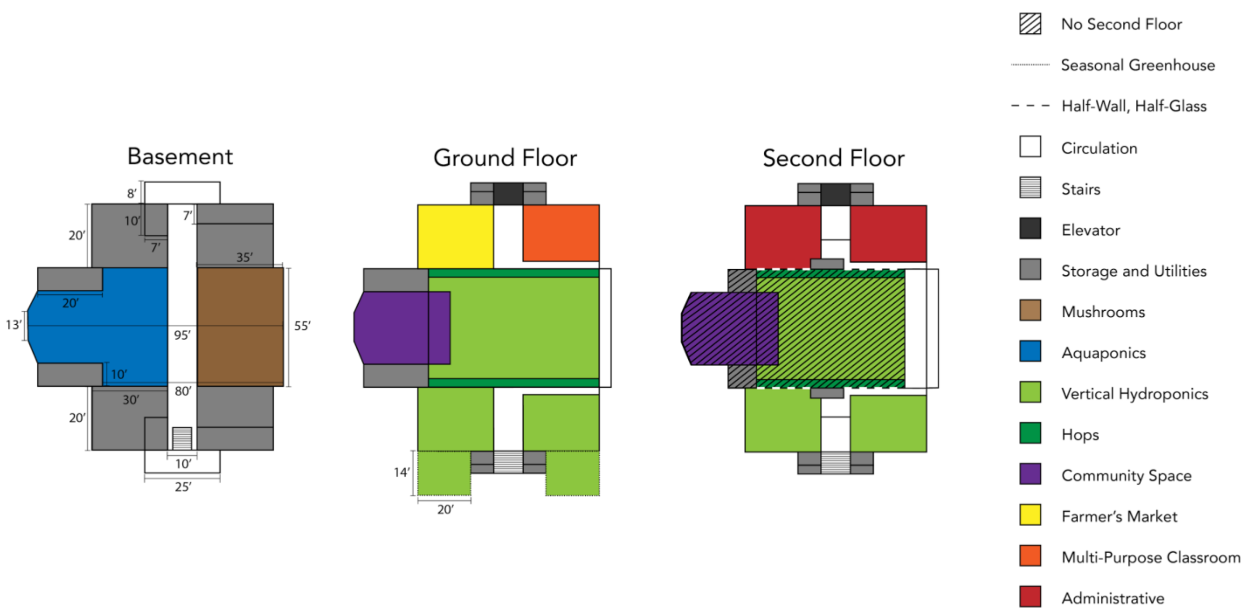


Figure 4-7. *Floor plan of the school building repurposed as a greenhouse and indoor farm.*

Room or Space		Square Footage	Use
Basement	Room 1 – South	900	
	Room 2 – South	700	Storage
	Hallway	1050	
	Large Room – West	2820	Aquaponics
	Large Room – East	1925	Mushrooms
	Room 3 – North	900	Storage & Staging
	Room 4 – North	1050	Storage & Staging
	Bathrooms	300	---
1st Floor	Classrooms 1 & 2 (South)	1995	Hydroponics: Greens & Herbs
	Classroom 3	1050	Education & Event Space
	Classroom 4	1050	Admin
	Gymnasium – Main Floor	4345	Engagement & Education Hydroponics & Aquaponics
	Gymnasium – Stage	1170	Hangout Space
2nd Floor	Classrooms 1 & 2 (South)	1970	Hydroponics: Greens & Herbs
	Classroom 3	1050	Education & Event Space
	Classroom 4	1050	Admin

Table 4-2. *Square footage and repurposed uses of the various spaces in the school building.*

4.5. Food Production

4.5.1. Proposed Food System

We propose to grow food indoors because with the appropriate technology, indoor farming can be a very efficient and profitable operation that would meet the needs of the Southbridge community by providing jobs, supplying healthy produce, and serving as a great educational opportunity for both young and old. Indoor farming has many benefits compared to traditional farming. Vertical hydroponics can increase yield 75-fold and utilize 90% less water than outdoor farms[61]. There is no need for pesticides or fungicides, since the plants are grown in a controlled indoor environment. Vertical hydroponics is scalable, highly modular, and can be operated in any building, including this brick structure. Wide-spectrum energy-efficient LED grow lights can be used to supplement or even entirely replace the need for natural light while improving yield[62]. Production can proceed year round.

To illustrate the efficiency of indoor vertical hydroponics, we calculated that the space allocated to hydroponics in our design could yield as much produce as 1.13 acres of an outdoor iceberg lettuce farm in California. [An outdoor iceberg lettuce farm in California yields 32,000 lbs. per acre[63]. With the amount of space allocated for vertical hydroponics in our design, we would be able to produce 35,312 lbs. of fresh greens and herbs per year. This is the equivalent of 35,312/32,000 = 1.13 acres of the iceberg lettuce farm's production.]

To supplement the nutrients for the plants and further reduce water use, our design ties the water supply of the grow towers to tilapia aquaculture tanks. Water can be cycled between the plants and the fish, essentially creating a large aquaponics system. Microbes convert the fish excrement into fertilizer for the plants and the plants purify the water that returns to the fish by removing the organic materials (Figure 4-8)[64].

---

[61] http://www.basicknowledge101.com/subjects/verticalfarming.html
[62] https://brightagrotech.com/zipfarm/
[63] https://coststudyfiles.ucdavis.edu/uploads/cs_public/92/af/92af15bd-a003-4e2e-a796-fc33e253edb8/lettuceicecc09.pdf
[64] https://www.theaquaponicsource.com/what-is-aquaponics/

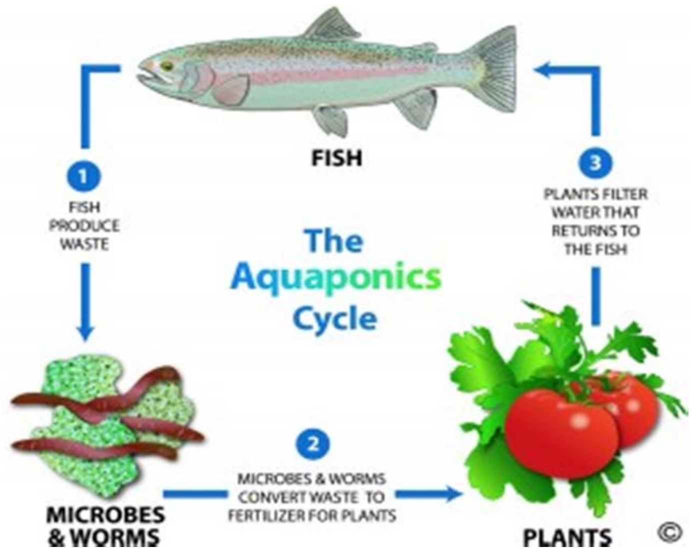


Figure 4-8. *Illustrated aquaponics cycle.*

Besides vertical hydroponics and aquaponics, we also decided on growing specialty mushrooms indoors. Specialty mushrooms such as oyster and shiitake are highly lucrative crops that can be produced indoors at both small and medium scales[65]. Mushrooms don't require much light, can be induced to fruit every 3 weeks, and can be sold at a relatively high market price.

We also added a seasonal greenhouse extension to the southern side of the building, which can be used as a community space where children and senior citizens can have plots and grow food together. This addition is for community engagement purposes, not for profitability. The produce grown in the greenhouse will go directly to the community and will not be sold on the market. The final piece of our food system is beer hops grown on the outside southern wall to be used by the power plant turned brewery on campus.

4.5.2. Selected Produce and Expected Yields

When deciding what and how much of what to produce, we took into consideration the limitations and opportunities of the school building, the specifications and constraints of the larger campus, the efficiency of indoor production systems for various crops, and the economic value of the product. We had several ideas that seemed like an excellent choice from an economic perspective, but which turned out to be infeasible due to the specifications and constraint of our design. For example, we dismissed cannabis as a viable option due to our concern that the Diocese of Worcester would not deem it acceptable. We also dismissed

[65] https://www.profitableplants.com/how-to-make-60000-yearly-growing-gourmet-mushrooms/

truffles as a viable option, because truffles are symbiotic with live tree roots and therefore cannot be effectively grown indoors[66]. Another highly lucrative crop we dismissed was saffron, due to similar indoor growing constraints. Saffron cannot be grown vertically and requires much land to be grown profitably[67,68]. We ran into similar hurdles with legumes, gourds, and fruits.

Production Quantities Generator					
5344	Square feet of growing space				
1,497	# of towers				
5	5' or 7' Towers				
Greenhouse	Greenhouse or Indoor				
50	% greens				
50	% herbs				
Number of Towers		**Cycle Time (wks)**	**Quantity per Tower (oz or lbs)**		
749	Herbs	3.6	40	8322	oz per week
212	Greens	3.6	3.5	206	lbs per week
Total Greens lbs./wk			206.1		$/yr @ $10/lb
Total Greens lbs./yr (50 wks)			10305.6		103055.5556
Total Herbs oz./wk			8322.2	lb/yr	$/yr @ $10/lb
Total Herbs oz./yr (50 wks)			416111.1	26006.9	260069.4444

Table 4-3. *Screenshot of the output of the Bright Agrotech Calculator.*
The Calculator's estimates are conservative, assuming a 10% loss of seedling to produce.

In the end we settled on growing an assortment of herbs and greens, the exact ratio of which was determined by the yield calculator tool of Bright Agrotech[69], a company that designs and builds vertical hydroponic farming technology. Table 4-3 above summarizes the optimal assortment. Herbs and greens that grow particularly well in vertical hydroponic conditions include lettuce, basil, mint, rosemary, thyme, cilantro, chives, arugula, kale, and sage, among others[70].

The growing space was calculated in the following manner: We assumed that 80% of the area of the rooms dedicated to growing crops would actually be used for plants, the rest being walking space and storage. Of the former gym space, 50% was slated for growing space. This

66 http://trufficulture.com.au/what_are_truffles.html
67 http://smallbusiness.chron.com/grow-saffron-profit-75770.html
68 http://www.thedailybeast.com/articles/2009/07/14/the-10000-spice
69 https://brightagrotech.com/production-estimates-calculator/
70 https://cdn2.hubspot.net/hubfs/466960/Web_Crop%20Guide%20and%20Possibilites_v2-1.pdf

approach yielded a total growing space of 5,344 ft^2, half of which dedicated to herbs and the other half to mixed greens. The calculator gave an annual yield of 26,000 lbs/year of herbs and 10,305 lbs/year of greens, for a total annual yield from hydroponic operations of 35,312 lbs.

FISH

The estimated tank volume for the fish tanks is calculated using 80% of the basement room allocated to aquaculture space (Table 4-2) plus 10% of the former gym occupied by 4ft-deep tank, and the result is an estimated total tank volume of 80,505 gallons. Tilapia fish take 6 months to grow to market size and 100 pounds of fish can be raised in a 300 gallon tank[71]. This means 100/300 x 2 = 0.67 pound of tilapia per gallon per year. With a yield of 0.67 pound per gallon per year, our system should provide an annual yield of 80,505 x 0.67 = 53,670 lbs per year.

MUSHROOMS

The room spaces used for growing mushrooms are given in Table 4-2. Assuming that 80% of this space is used for mushroom cultivation, we arrive at a total of 2,825 ft^2. According to the website Profitable Plants, 500 ft^2 of growing area can produce 12,000 lbs of oyster mushrooms. This equates to 24 lbs per square foot per year[72]. We looked at another indoor oyster mushroom farmers' blog and came up with similar production numbers for our design[73]. We are thus confident that our system could produce an annual yield of 2,825 ft^2 x 24 lbs/ft^2 = 67,800 lbs per year.

The following table summarizes the estimated annual production for each of the selected crops. These yield values are just estimates based on our sources and can be further optimized by considering the exact plants grown and obtaining more expert opinion.

Crop	Area used to grow it	Annual yield intensity	Annual Production (lbs)
Oyster mushroom	2825 ft^2	24 lbs/ ft^2	67,800
Herbs	2672.25 ft^2	3.8 lbs/ ft^2	26,007
Mixed greens	2672.25 ft^2	9.7 lbs/ft^2	10,305
Fish: Tilapia	80,505 gallons	0.67 lbs/gallon	53,670

Table 4-4. *Summary of annual yield for each crop.*

71 http://americanpreppersnetwork.com/2011/02/aquaponics-101-part-five-fish-to-water.html
72 https://www.profitableplants.com/how-to-make-60000-yearly-growing-gourmet-mushrooms/
73 https://www.chelseagreen.com/blogs/indoor-oyster-mushrooms-small-spaces/

4.5.3. Food System Campus Synergies

The Garden of Eden food system was designed with particular consideration for symbiosis with the other buildings (Figure 4-9). St. Francis Performance Hall and Restaurant, Our Daily Bread Bakery, and the Bed and Breakfast will all be able to directly benefit from the Garden of Eden's indoor farm: They will be able to purchase locally produced, fresh produce right on campus. The rest of the fresh produce may be sold to the community at the Garden of Eden's own farmer's market or sold on the wholesale Boston market. In return, the indoor farm will use as fertilizer of soil substrate their pre-consumer food waste and coffee grounds.

Another synergy was developed with the proposed St. Benoit brewery. The brewery will receive hops grown on the outside of the building and in return supply the Garden of Eden with spent grains for mushroom substrate and carbon dioxide (which is a byproduct of the fermentation process). This CO_2 will be used to supply the photosynthesis needs of the plants grown indoors.

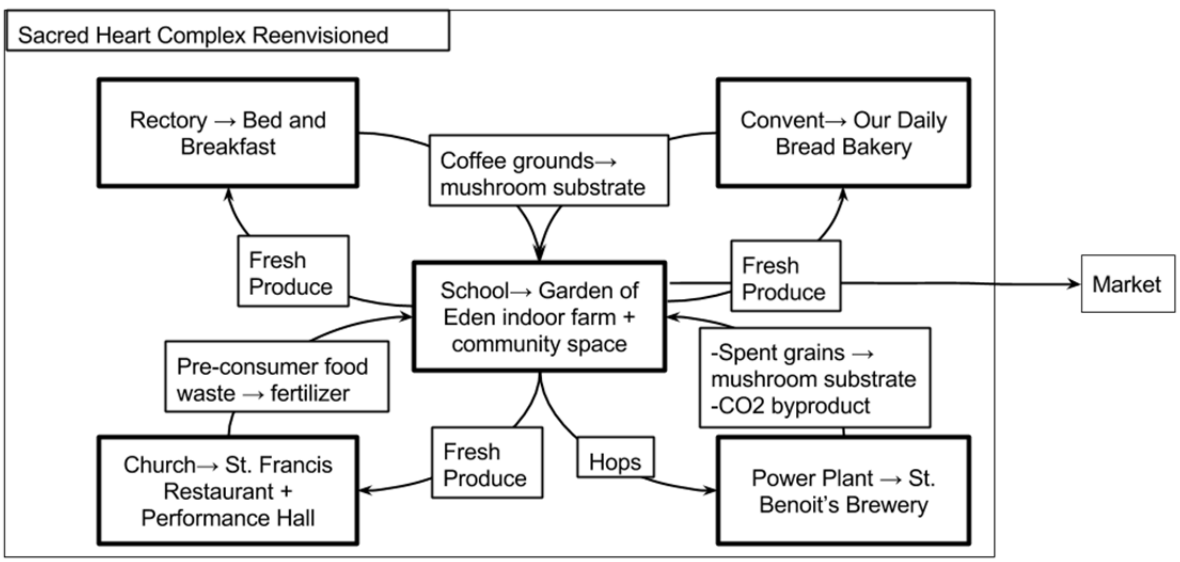


Figure 4-9. *Food system material flow between campus buildings and the Garden of Eden.*

4.6. Energy Analysis

Synergies between the other campus buildings and the Garden of Eden were explored not just in the food system, but also in the energy and water infrastructures (Figures 4-10 and 4-11). The electricity needs of the Garden of Eden will be met with a combination of rooftop and carport solar PV and the electric grid, as will be explained later in Section 4.6.2. The space heating and cooling needs will be met with a large ground source heat pump system located underneath of the St. Francis Restaurant and Performance Hall (formerly the Church). This heat pump will supply the heating and cooling needs of the whole campus. The electricity to run the heat pump will also come from the solar PV systems and the grid. To keep tilapia fish at the requied temperature of 85-100 °F, Our Daily Bread Bakery will be supplying 100 °F water in a closed loop system to heat the tanks. The bakery will have waste heat from their ovens which they are designing to recover both for space heating purpose and to provide the Garden of Eden with hot water. The hot water will be in a closed system and will heat the tanks through a heat exchanger. The cool water will cycle back to the bakery to be reheated.

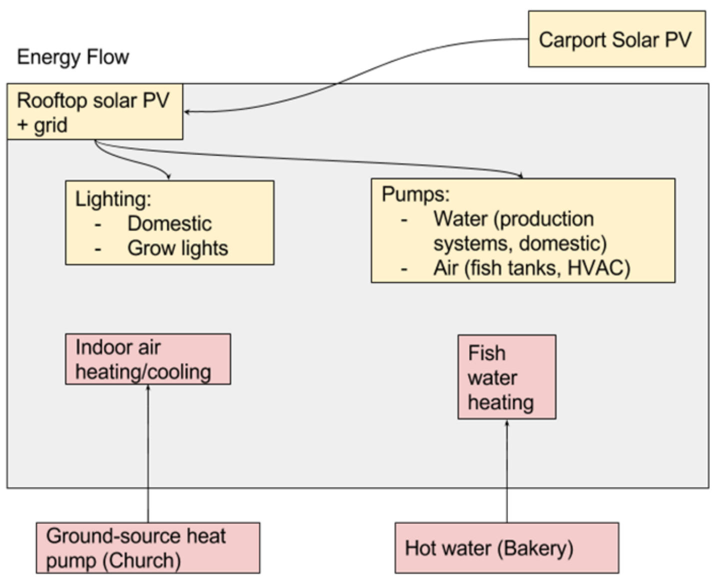


Figure 4-10. *Energy supply and loads of the Garden of Eden. Hydraulic system (red), electricity (yellow).*

The water infrastructure of the Garden of Eden consists of three sources: rooftop rainwater harvesting, rainwater stored in the former church's cistern, and mains water supplied by the local utility. Rainwater can be utilized by all the growing operations and for most domestic needs, which minimizes the need for mains water. As explained in Section 4.5.1, water will be cycled between the fish tanks and the hydroponic grow towers.

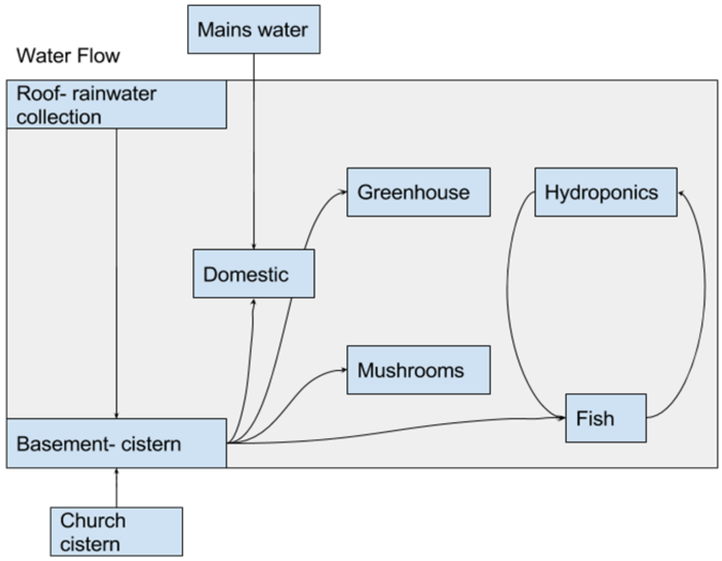


Figure 4-11. *Water supply and loads of the Garden of Eden.*

4.6.1. Electricity Demand

The electrical loads of the building are divided into five main categories: grow lights, building lights, ground source heat pump, fish tank aerators, and water pumps. Grow lights consume the most electricity in the whole building (Figure 4-12). This is due to the fact that they use the full spectrum of solar radiation, not just what humans need to read by. Oyster mushrooms and tilapia also need grow lights, but since they do not photosynthesize, they need much less specialized lighting. Figure 4-12 lumps all grow lights together for all production systems, but it is worth noting that the largest consumer is the grow lights for the hydroponically grown plants. The total estimated electrical load for the building is 617,375 kWh/year.

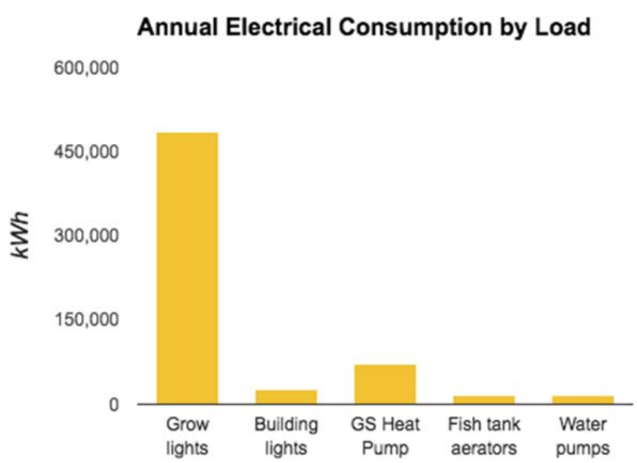


Figure 4-12. *Projected electrical consumption by load category.*

4.6.2. Electricity Supply

Keeping the goal of net zero energy in mind, we attempted to meet all the electrical demand with a carbon neutral source: solar photovoltaics. To start, we suggest covering the southern side of the roof with polycrystalline silicon cell with efficiency[74] of 148 W/m^2, but this would supply only 3.3% of the total annual demand! So, we suggest adding solar panels to two parking lots, one across the river and one next to the school building. In order to utilize the lots without having to displace parking, we designed solar carport structures (Figures 4-13 and 4-14). The carports protect the cars from rain and snow while generating electricity. Their curved shape allows snow to slide off, keeping the panels functional throughout the Massachusetts winter. The total area of parking lots utilized this way is 4000 m^2, allowing for the generation of 506,916 kWh/year. The rooftop solar together with the solar carports could account for 82% of the demand. This means that 18% of the demand will still have to be met by the grid. For details on the solar supply calculation see Appendix B.1.

Figure 4-13. *Solar carport illustration.*

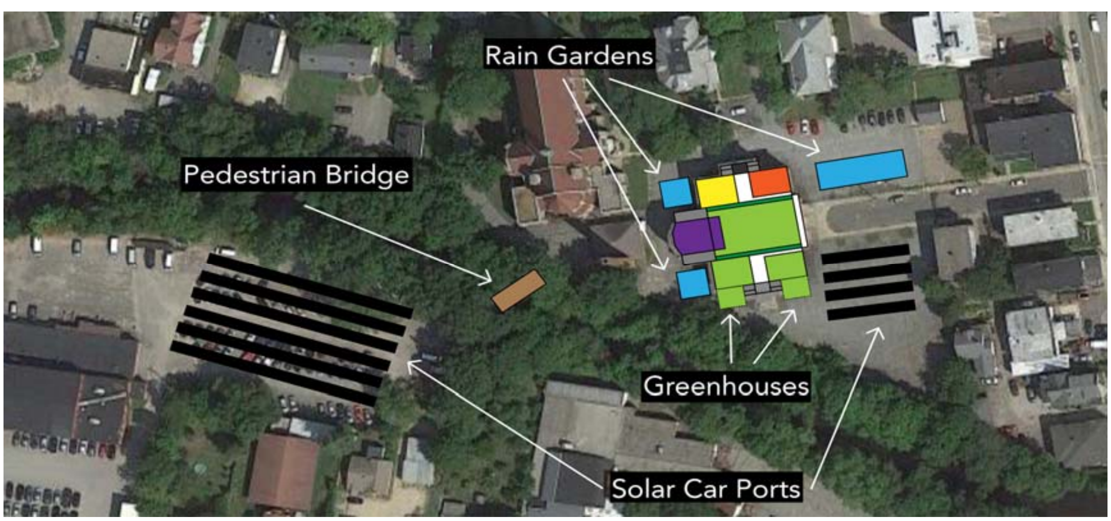


Figure 4-14. *Map of proposed green infrastructure additions to the Sacred Heart campus.*

[74] https://www.civicsolar.com/product/canadian-solar-maxpower-cs6x-310p-310w-poly-slvwht-1000v-solar-panel

4.6.3. Heating and Air-Conditioning

In order to calculate the total heating and cooling energy requirements for our building, we conducted a first order heat load calculation taking into account thermal loss (or gain) due to conduction, infiltration, and passive solar heat gain factors with the given roof, wall, and window surface area of the structure. Given that the school building was initially constructed in the early 1900s, we assumed that the structure was not very energy efficient. Our initial heat load calculation (Appendix B.2) assumed the building currently has R-values of R15 for the roof, R10 for the walls, and R0.9 for the single pane windows it the structure with an infiltration rate of twice per three hours. Under this scenario, our calculations indicate that supplemental heating would be required for every month except July and August.

During our renovations of the structure, we would hope to significantly improve this thermal performance by increasing the R-values to R60 for the roof, R40 for the walls, installing triple-pane, R5.9 windows, and reducing the infiltration rate to once every three hours. In doing so, we forecast an energy surplus in June, July, August, and September during which supplemental cooling would be necessary (Appendix B.3). The remaining eight months of the year will require supplemental heating. We can do an additional calculation of the energy required for cooling during these four summer months using the cooling degree-days for the region[75] (Appendix B.4). By adding together the energy required for supplemental heating during eight months of the year and for supplemental cooling for the other four, we find the improved structure will require just over 2.1 billion BTUs annually for space heating and cooling needs. By dividing by the total square footage of the building (25,000 ft^2), we find that approximately 84,000 BTUs per square foot will be required for the annual space heating and cooling of this building, which is a good number. We plan on meeting these needs by interfacing with a campus-wide ground source heat pump designed and operated by the church group.

4.7. Water Analysis

Our building will be water intensive due to the high yield of the hydroponic and aquaponic systems. We estimate our total demand to be 530,000 gallons/year, with 71% of this being used in mushroom production, hydroponic system and aquaponic system, and the remaining 29% being domestic use (toilets and building demands). The total demand is dependent on what is actually being grown, and so there is flexibility in this. The water need for food production does not need to be at drinking standard and can be met through rain water collection followed by basic filtering, and only 1% of the domestic water demand requires clean

[75] http://www.degreedays.net for heating and cooling degree-days for the nearby Worcester airport.

drinking water. Therefore, most of our demand can be met with filtered rainwater, which greatly reduces the energy impact of our water demand. A full breakdown of our water demand can be seen in Figure 4-15. Detailed demand calculations can be found in Appendix C.

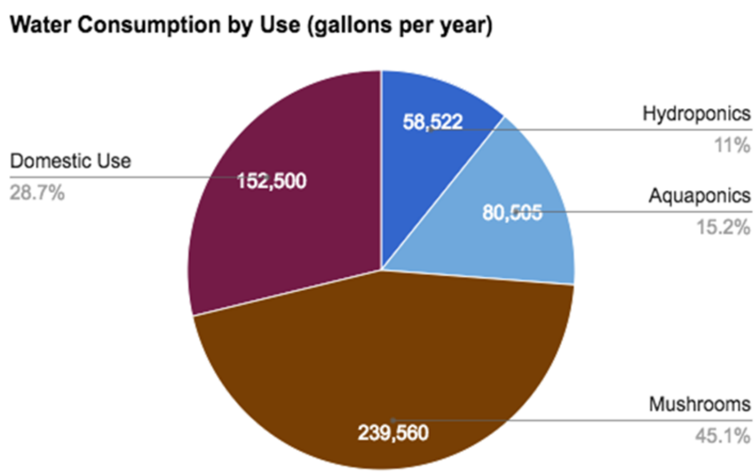


Figure 4-15. *The operational water demand, totaling 531,100 gallons/year.*

The water supply to our building will be three-fold. The minimal clean water demand will be met through mains supply, meaning the building will be connected to the town's plumbing system. 254,000 gallons/year will be collected by a rainwater collection system on our roof. The system will collect from the entirety of the 910 m^2 roof and we will store the water in two 18m^3 cisterns in the basement, assuming a two-week storage requirement. The total supply for the system accounts for an 80% efficiency in the rain and uses the rainfall in Southbridge to estimate the supply. Rainfall in Southbridge is relatively constant throughout the year, with a maximum rainfall of 4.93 inches in October, and a minimum of 3.58 inches in February, suggesting that no long-term storage will is required. A full breakdown of the rainwater supply calculations can be seen in Appendix C.5. To meet the remaining 276,000 gallons/year demand, we will interface with the Church building's rainwater collection system and pump the water to our building as required.

4.8. Environmental Benefits

We were not able to meet our group's goals of achieving net-zero carbon emissions. However, our facility still has a very positive environmental impact on the Town of Southbridge by performing much more efficiently than the majority of similarly-sized, historic buildings in the area.

The PV cells over the building and parking areas are able to provide for 82% of the electric demand, but the 110,459 kWh of electricity that must purchased from the grid will ultimately lead to the emission of 77.65 metric tons of CO_2/year. We surmise that these emissions may be offset by the uptake of hydroponics and aquaponics operations inside the building.

Rain gardens surrounding the perimeter of the building will help prevent localized flooding due to storm water runoff immensely. For each 1-inch rainfall event, the rain gardens will help to slowly infiltrate 27,000 gallons of water.

4.9. Social Benefits

The Garden of Eden will benefit the community in various ways, as this was one of our aims throughout the brainstorming and design process. The greenhouse and growing facilities will provide a place of ecological education for families, schools, and after-school programs. It will provide a year-round warm and opening space for all members of the community, particularly the large elderly population of Southbridge. We hope that its enticing features will make our facility an inspiring gathering place for the disparate populations of the town.

Finally, our largest social impact will be our employment: Our plans should result in the hiring of 17 full-time employees (including 10 full-time farmers), as well as 9 part-time employees and 12 shared employees with the rest of the campus (Table 4-5). Providing these citizens with jobs will directly benefit the economy of the town.

Job functions	Full time	Part time	Shared across campus
Farm Manager	1		
Farmers (hydroponics & mushrooms)	10	5	
Aquaponics Technicians	2		
Staging/Packing Clerk	2		
Sales Representative	1		
Administrator	1		
Senior Management			2
Educators		2	
Custodians		2	2
Community Organizer			1
Marketing			1
Landscaper			1
Legal			1
Financial/Accounting/Grant Managers			4
TOTAL	**17**	**9**	**12**

Table 4-5. *Breakdown of number of employees by functions.*

4.10. Economic Considerations

4.10.1. Anticipated Revenue

Revenue comes from selling our produce. Naturally, the total income for the Garden will depend on the yield and the market price at which that produce can be sold. The yield estimates are summarized in Table 4-4 and the price points used are in Table 4-6. For the price point of the assorted herbs and greens category, we chose to use the price of basil. Some herbs and greens sell for more than that and some sell for less. Mixed salad greens sell for about the same, so we thought it would be good price point while keeping the analysis as simple as possible[76].

	Wholesale price ($/lb)	Retail price ($/lb)
Tilapia[77]	$3	$4
Oyster mushrooms[78]	$6	$12
Assorted herbs & greens[79]	$10	$13

Table 4-6. *Price points used for revenue estimates.*

To estimate how much revenue the indoor farming operation could generate, we considered three cases: selling all produce at the wholesale price, selling all produce at the retail price, and selling 70% at the wholesale price with the remaining 30% at retail price. The results are summarized in Table 4-7. The 70%-30% scenario is based on the assumption that we would be able to sell about 30% of the produce at retail price directly to the Southbridge community at our weekly farmers market. The rest of the produce would be sold to other campus buildings or the larger central Massachusetts and Boston markets at the wholesale price. In this scenario, the revenue would be about $1.1 million, 14 times higher than the current income from the flea market ($80,000).

The most lucrative crop is oyster mushrooms. In a later analysis (Section 4.10.4), we show revenue, capital and operating costs, and electrical and water demand would change if only mushrooms were produced in the whole building.

[76] http://www.cabbige.com/blog/market-pricing-trends-lettuce-spring-mix
[77] http://articles.baltimoresun.com/1999-04-08/news/9904080055_1_mattson-tilapia-fish
[78] https://www.profitableplantsdigest.com/top-12-faqs-about-growing-gourmet-mushrooms-for-profit/
[79] https://attra.ncat.org/calendar/question.php/how-do-i-price-my-farm-products-when-selling-to-restaurants

Projected Annual Revenues	100% sold at wholesale price	100% sold at retail price	70% sold at wholesale price and 30% at retail price
Tilapia	$161,011	$214,681	$177,112
Oyster mushrooms	$406,800.00	$813,600.00	$528,840
Assorted herbs & greens	$363,120	$482,950	$399,000
TOTAL	$930,930.71	$1,511,230.55	**$1,105,000**

Table 4-7. *Projected annual revenue by product based on pricing scenario.*

4.10.2. Operating and Capital Costs

Salaries:

The largest operating cost is that of salaries at $33,000 per employee, the Southbridge median income[80]. For the calculation of salaries, the employee count was: 17 full-time employees at 100%, 9 part-time employees at 50%, and 12 campus-shared employees at 25% (see Table 4-5 above). This yields $808,500.

Electricity:

The electricity rate in Southbridge[81] is $0.0738/kWh. The annual electrical deficit after the supply from solar PV is subtracted from the demand is 110,459 kWh. The annual spending on grid electricity is thus 0.0738 x 110,459 = $8,151.87.

Water:

All the water demand can be met by rainwater harvested either by the Garden of Eden or the St. Francis Restaurant and Performance Hall. However, about 1% of the need has to meet drinking standards and will have to come from municipal supply, 0.01 x 152,500 x 0.133681 = 60.96 ft^3 per year. The cost of this water is $3.24 per cubic foot for the first 500 ft^3 per quarter. The resulting cost is 60.96 ft^3 x $3.24/$ft^3$ = $661 annually.

Food production systems:

● The cost of operating a tilapia aquaculture system is about $1.25 per lb of fish produced[82]. This cost includes heating, filtration, and perhaps even labor costs. For our system that means

80 https://en.wikipedia.org/wiki/Southbridge,_Massachusetts
81 http://www.electricitylocal.com/states/massachusetts/southbridge/
82 http://articles.baltimoresun.com/1999-04-08/news/9904080055_1_mattson-tilapia-fish

$1.25/lb x 53,670lb/year = $67,087 per year. Since we are accounting for labor separately and getting heating from the bakery and filtration from connection with hydroponics system, this cost is probably overestimated.

● Operating costs for the mushroom farm arise mainly from the cost of substrate. Substrate costs $7.31 per week for a 16 ft^2 system[83]. This means 7.31 x 52/16 = $23.7 per ft^2 per year or $67,115 per year for 2,825 ft^2. A large amount of this cost may be offset in parts or in whole by relying on by-products from operations in neighboring campus buildings, particularly from brewery operations (Figure 4-9).

● Since both tilapia and mushroom farming operating costs are likely largely overestimated, we assume that the sum would include the operating costs of the hydroponics as well. The total operating costs for the food systems then comes out to be $67,087 + $67,115 = $134,202 per year.

Heating and Cooling:

The cost of heating is the cost of electricity needed to run the ground source heat pump to produce the needed heating and cooling BTUs. The total electricity needed to run the pump to meet the annual heating and cooling needs of the Garden of Eden is 73,161 kWh. At the grid electricity rate of $0.0738 per kWh, this heating and cooling costs come out to 0.0738 x 73,161 = $5,399 annually.

Table 4-8 below summarizes the annual operating costs.

Annual Operating Cost	
Electricity	$ 8,152
Water	$ 661
Salaries	$ 808,500
Food production maintenance	$ 134,000
Heating and cooling	$ 5,399
TOTAL	**$ 956,712**

Table 4-8. *Annual operating costs.*

Capital costs of the repurposing are broken into four categories: retrofitting, water system, PV system, and food production. The total investment required is estimated to be around $6.8 million (Table 4-9). The costs are distributed roughly evenly between the categories, but the retrofitting is the most expensive first cost. This category includes the thermal insulation of the

[83] https://www.chelseagreen.com/blogs/indoor-oyster-mushrooms-small-spaces/

building envelope, repair to the damaged infrastructure, installation of new mechanical equipment, moisture-proofing of the building to ensure that the indoor growing can be done safely and responsibly, re-opening the skylights, and replacement of a section of the northern second floor wall with glass.

The cost of the greenhouse addition on the south side of the building is folded into the food production system costs, which otherwise includes the costs of setting up vertical hydroponics, aquaponics, and mushroom growing systems. The cost for the water system is based on the size of the cistern needed while the PV system includes the costs of not only the panels but also all associated systems such as inverters, carport structures, labor, *etc*[84].

Capital Costs	
Retrofitting	$2.3M
Water system	$1.0M
PV system	$1.9M
Food production	$1.6M
TOTAL	**$6.8M**

Table 4-9. *Capital costs.*

4.10.3. Potential Grants and Investors

To meet our capital costs, we investigated potential grants and investors that would support the startup of the business. One opportunity is an EEA Agricultural Energy grant, which “funds agricultural energy projects in an effort to improve energy efficiency and the adoption of alternative energy”[85]. Such a grant would provide $175,000 towards startup costs of PV and heating distribution systems. The project would also be suitable for grants from the U.S. Department of Agriculture, which can provide up to $1 million in startup investment. These grants, while helpful, would not cover the entirety of the startup costs, and we expect requiring an outside investor or philanthropist for the financing of the Garden of Eden.

4.10.4. Mushroom-Only Scenario

The Review Board suggested that we explore the possibility of optimizing profitability by focusing exclusively on mushroom farming in our grow spaces (total of 13,955 ft^2). We

---

[84] A breakdown of how the capital costs were calculated can be found in the students’ original report and is available upon request from Professor Cushman-Roisin at Dartmouth College.

[85] http://www.mass.gov/eea/agencies/agr/about/divisions/ag-energy.html

simulated this scenario and observed that the annual revenue would increase by more than the annual operating costs, thereby improving profitability. The capital cost would drop by 40%, in large part due to the elimination of the aquaponic and hydroponic systems and the downsizing of the solar carports. One major benefit of this scenario is that the building would achieve net-zero energy. This goal could be met with only 980 m^2 of solar carport PV, a sharp reduction from the 4000 m^2 used in our multi-use design. On the downside, water demand would increase significantly. Results are summarized in Table 4-9 below.

	Mixed Operations	Mushrooms Only	Difference
Annual Revenue	$1,105,021	$2,612,376	+136.41%
Annual Operating Costs	$956,712	$1,514,054.71	+58.26%
Capital Costs	$6,824,630	$4,091,222	-40.05%
Water demand (gallons)	531,088	1,335,884	+151.54%
Electrical demand (kWh)	617,375	172,146	-72.12%
% energy from renewable resource	82.11%	100%	+21.79%

Table 4-9. *Key metrics for exclusive mushroom farming versus mixed-operations design.*

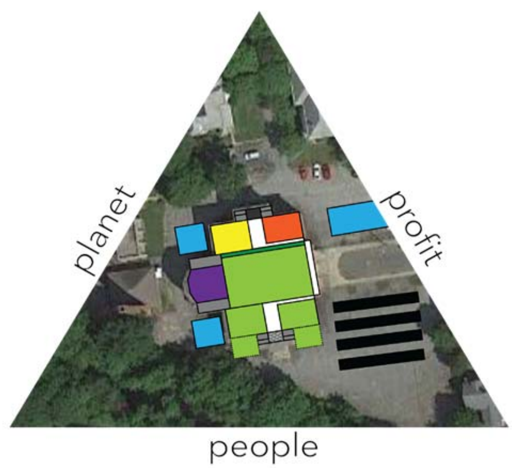
A downside to this scenario is that the mushroom theme does not address the main goals of engaging the community and providing a variety of fresh produce to the campus and town. Growing mushrooms for profit would come at the cost of eliminating the inviting, cozy, educational space planned in place of the old gymnasium and would make the view from the administrative offices uninspiring and dull. The farmer's market would also draw fewer people, and the Garden of Eden would not be able to brand itself as a multi-use, exciting, educational community space. Further, it would no longer be a "garden," like the name suggests, as there would be no greenery indoors. Since one of the main goals of this repurposing project is to help re-brand the town of Southbridge and create a community space, we continue to recommend a mixed-operations design as a superior alternative to a simple commercial mushroom farming operation.

4.11. Summary

In summary, we believe that converting the former school of the Sacred Heart Church Campus into a four-season indoor, hydroponics greenhouse is a practical and feasible way to address the economic, social, and environmental concerns for the benefit of Southbridge.

We have shown that this business model which focuses on the year-round production of mushrooms, salad greens, herbs, and tilapia fish would be capable of grossing in excess of $1.1 million of revenue annually. This business and the communal jobs of the full campus after renovation would provide over 30 good paying jobs to the Southbridge community which is in desperate need of new business investments.

In addition, the fresh locally sourced produce will be of great benefit to the local community. By investing in improving the thermal envelope of the structure, using energy efficient lighting, installing an extensive photovoltaic solar array, and partnering with the other campus buildings on a ground source heat pump, it is possible to source most of the energy needs of the building onsite. All of the space heating and cooling energy requirements would be met by utilizing the campus wide ground source heat pump and over 80% of the electric requirements could be produced by the photovoltaic cells. Overall, the conversion of the existing school into an energy efficient, year-round growing space would greatly benefit the people, economy, and environment of Southbridge.



5. The Rectory Building

Student Team: Calin Ackerman, Kelsey P. Catano, Christian N. Kwisanga, Nayantara S. Patel, Tara M. Simmons, and Alexandria V. Vasques
Teaching Assistant: Rita Tu

5.1. Description of Current Building

The rectory building (Figure 5-1a) housed the pastor and other priests serving the Sacred Heart Parish. It is situated on the East side of the church with the façade facing Charlton Street (Figure 5-1b). With a footprint of 4105 square feet, its size is intermediate between that of the school and convent.

Figure 5-1a. *Exterior of the rectory building.* ***Figure 5-1b.*** *Rectory façade, facing street.*
side along driveway separating it from the convent.

The first floor of the rectory housed the parish offices, the kitchen, living room and dining areas (Figure 5-2). The bedrooms, arranged as suites, were located on second floor and part of the third floor. A stately and centrally located staircase leads from the main floor to the first floor (Figure 5-3). There is a secondary and narrow stairway leading from the kitchen to the rear of the first floor, which was intended for maid service.

Figure 5-2. *Views of the rectory's main floor: office, dining room, and living room.*

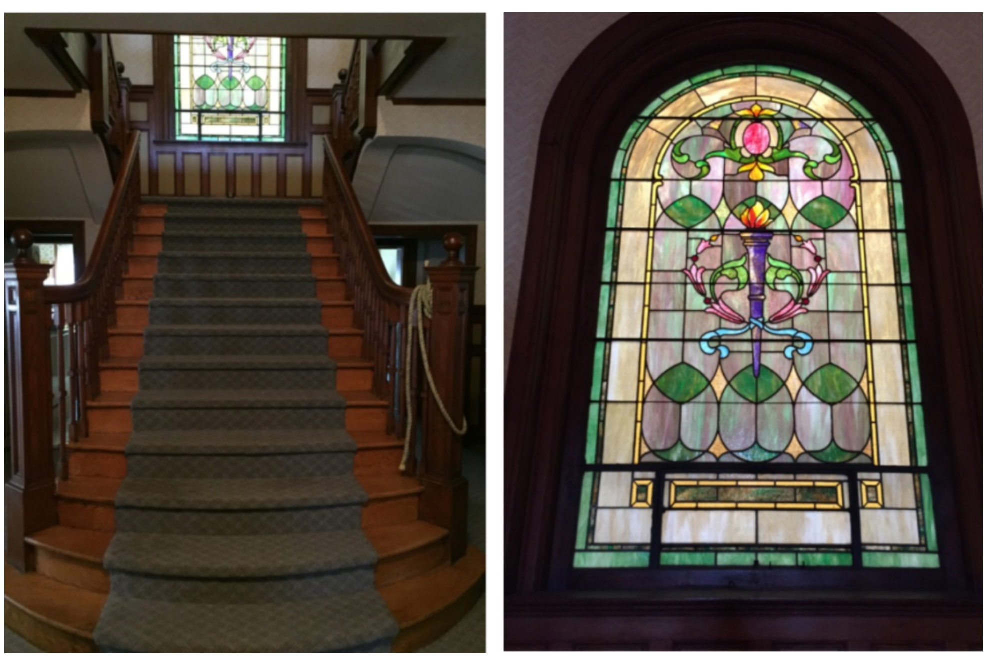


Figure 5-3. *The master staircase leading to the first floor and its accompanying stained glass window.*

The basement and the undeveloped part of the third floor were used mainly for storage and electrical-mechanical systems. The last pastor lived in the rectory until 2007, and it has remained vacant since. Father Peter Joyce mentioned that a caretaker for the property would be moving in sometime in Summer 2017. Even though the rectory has been vacant, the building has been temperature controlled to preserve the architectural and design features such as the stained glass windows and extensive wood work and paneling.

5.2. Brainstorming, Specifications, and Selection

Ideas for the repurposing of the campus were guided by the challenges facing Southbridge: missing community pride and spirit, educational failings, degraded urban fabric, economic stagnation, and social welfare needs. The specifications and constraints were broken down into five categories in order to account for these needs (Figure 5-4).

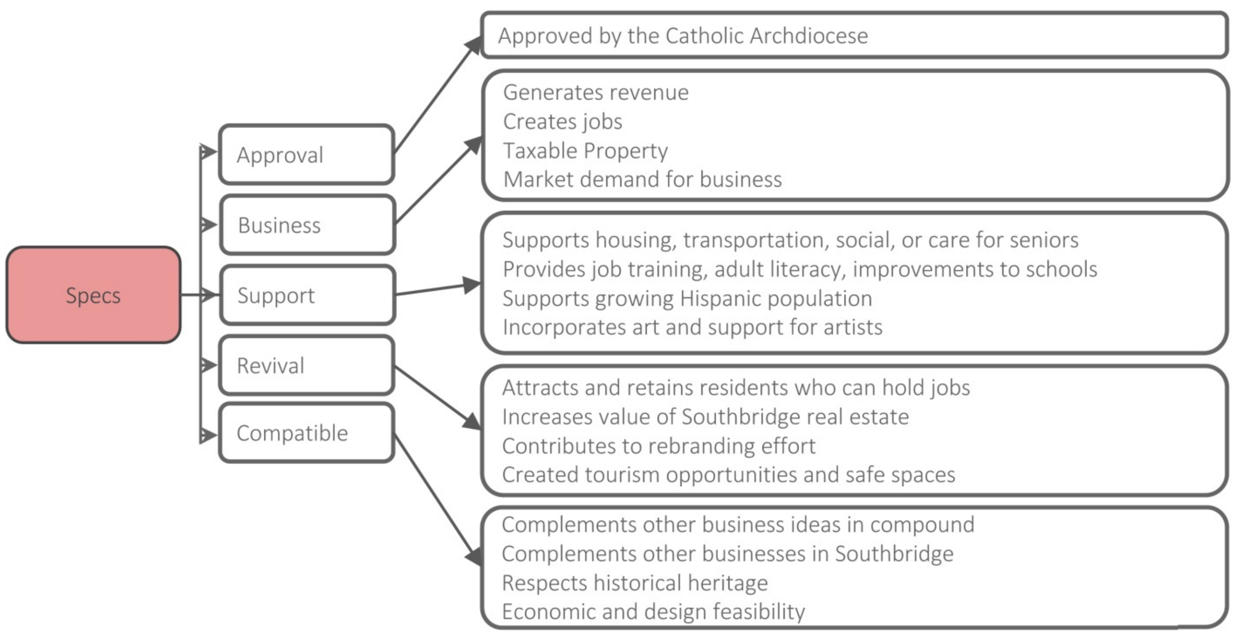


Figure 5-4. *Specifications and constraints guiding the choice of repurpose for the rectory.*

The categories were approval, business, support, revival, and compatibility. If the idea did not receive approval from Father Peter Joyce, the idea could not be considered. The category of business meant that the design should generate revenue, create jobs, make the property taxable, and align with market demand. In order to meet the specifications for the support category the design had to cater to the different communities in Southbridge. This includes support for the aging population, the growing Hispanic population, local artists, and community college students. In terms of revival, it was preferred that the design attract and retain residents who could hold jobs, increase the value of Southbridge real estate, contribute to the rebranding effort, and create tourism opportunities and safe spaces. Finally, the design had to compatible with the other ideas for the campus, complement the businesses in Southbridge, respect the historical heritage, and be feasible in terms of economics and design.

The first idea for the rectory was to convert the basement into a sport's bar, to turn the first through third floors into a bed and breakfast, and to convert the garage into a seating area for the bar patrons or a venue for live outdoor performances. This idea has the potential to easily generate revenue, attract tourists, and support the community revival effort.

The second idea was to repurpose the building into a yoga studio and health café, giving patrons the option to take classes in the studios or enjoy a healthy snack at a smoothie bar. This idea encourages locals to lead healthy lifestyles while generating revenue.

The third idea was to turn the first floor into a coffee shop where people could come to enjoy a drink and interact with other members of the community. The second and third floor would become spaces for additional seating and art studios for local artists. This repurposing would generate revenue, create safe sociable spaces, and support community members.

The class decided that the combination of basement bar and bed and breakfast (B&B) was best suited to the rectory's repurposing. Not only did the bar and B&B meet most of the desired criteria of the town (Table 5-1), it also best complemented the other ideas for the other buildings on campus.

Idea	Approval	Business	Support	Revival	Compatible/Feasible	Total
Bar/Restaurant	Yes	5	4	5	5	19
Bed and Breakfast	Yes	5	3	3	5	16
Yoga Studio	Yes	3	3	3	3	12
Healthy Snack Bar	Yes	3	3	3	4	13
Coffee Shop	Yes	5	4	3	2	14
Art Studio	Yes	2	2	2	4	10

Table 5-1. *Selection of optimal re-purposing of rectory. The bar and B&B ideas score highest.*

5.3. Re-Purposing into a Bed and Breakfast

5.3.1. Basement

The basement will be repurposed into a bar with several amenities. It will feature a kitchen/pantry housing the mechanical and electrical systems, liquor and beer storage area, a bathroom and several entertainment spaces such as a pool table, foosball equipment, dart boards and wall mounted TVs strategically placed throughout the bar. There will also be a large bar constructed with wood reclaimed from tearing down walls and the wood panels from other floors in the rectory and the campus. The uneven heights in combination with the exposed pipes and wiring will be somewhat challenging as the space undergoes its reinvention.

An alcohol-free version is also possible if the preference is to attract the local youth away from undesirable street activities.

5.3.2. First Floor

The current status of the first floor resembles the structure and flow of a residential home thanks to its past life as a rectory. The ceilings are about 9.8 feet high with doorways 7 feet high. The floor varies from old, outdated carpet to hardwood floors that could use some maintenance. Along the walls, in most rooms there lies a radiator, which served as the previous main source of heating.

This unique space lends itself well to our design plan. The first floor of the Bed & Breakfast (B&B) will serve a dual purpose in this design: one half of the space will be used as a dining area for B&B patrons, while the other half will consist of a gift shop for the brewery and a handicap-accessible guest room. The dining area will have enough seating for around 30 patrons at a time to allow for both guests of the B&B and outside customers to enjoy the comfortable atmosphere. The dining area will make use of the kitchen space that already exists in the rear to serve as the main kitchen where all meals can be prepared. On the other half of the first floor, the gift shop for the brewery requires several glass showcases or shelving displays to house all of the merchandise.

Visitors to the campus can easily flow from the factory tour of the brewery to this gift shop to purchase pint glasses, keychains, *etc*. The handicap-accessible guest room will be fully equipped with accessible restrooms and a spacious living area. Vice versa, a “Brewer-for-a-Week” program can be initiated whereby people desiring to learn the brewing craft would work in the brewery during the day and lodged in the B&B.

5.3.3. Second Floor

The purpose of the second floor is to serve as bedrooms for the Bed & Breakfast patrons. Each room on the second floor will consist of a queen-sized bed and be connected to its own bathroom. A central vision for the bedrooms that would create a sense of arrival to the town of

Southbridge is to design each room around a theme rooted in the town's unique history. Some ideas for bedroom themes include: Native American History/Heritage, Mining Town, Civil War/Union, "Eye of the Commonwealth"/Optical, Puerto Rican History, and AM Radio/Old Movies.

5.3.4. Third Floor

While most of the third floor used to serve as the rectory's storage area/attic, it also has two bedrooms with a shared restroom. The attic occupies approximately two-thirds of the available square footage of the floor and has ready access to the roof above. In its completely re-envisioned design, this space transforms into a small and cozy library where B&B patrons can feel comfortable lounging or relaxing in.

The two other rooms will retain their current purpose, *i.e.* serving as guest bedrooms. However, major renovation to the rooms is needed to reach the standards of a B&B.

5.4. Floor Plans

The external dimensions were measured and gleaned off of google maps to be 75' x 63'. The internal dimensions were estimated based on measurements and pictures we took on the first visit to the campus, but not all were noted[86].

[86] The group went back to get more accurate measurements, but the keys provided did not work, and the group was unable to get more details on the internal features.

5.4.1. Basement

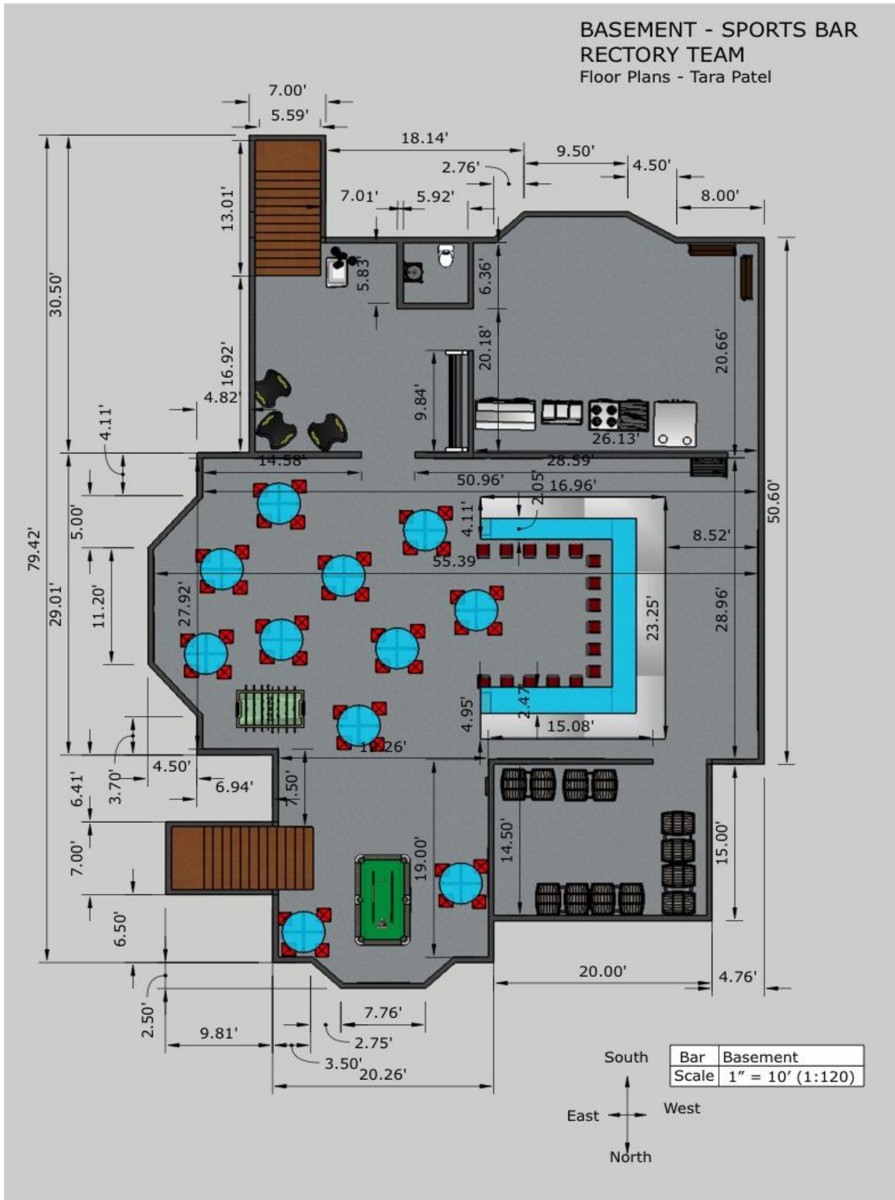


Figure 5-5. *Floor plans of the basement/bar with two exits on the east (left) and south (rear) sides. The east (left) half features the main entrance/exit, a lobby/coat area, a unisex bathroom, additional tables along with wall mounted televisions, a pool table, a foosball play table, and darts for entertainment. The west (right) side consists of the kitchen/food prep/pantry area with the mechanical/electrical equipment, the bar with seating along it, and a storage room for liquor and beer.*

5.4.2. First Floor

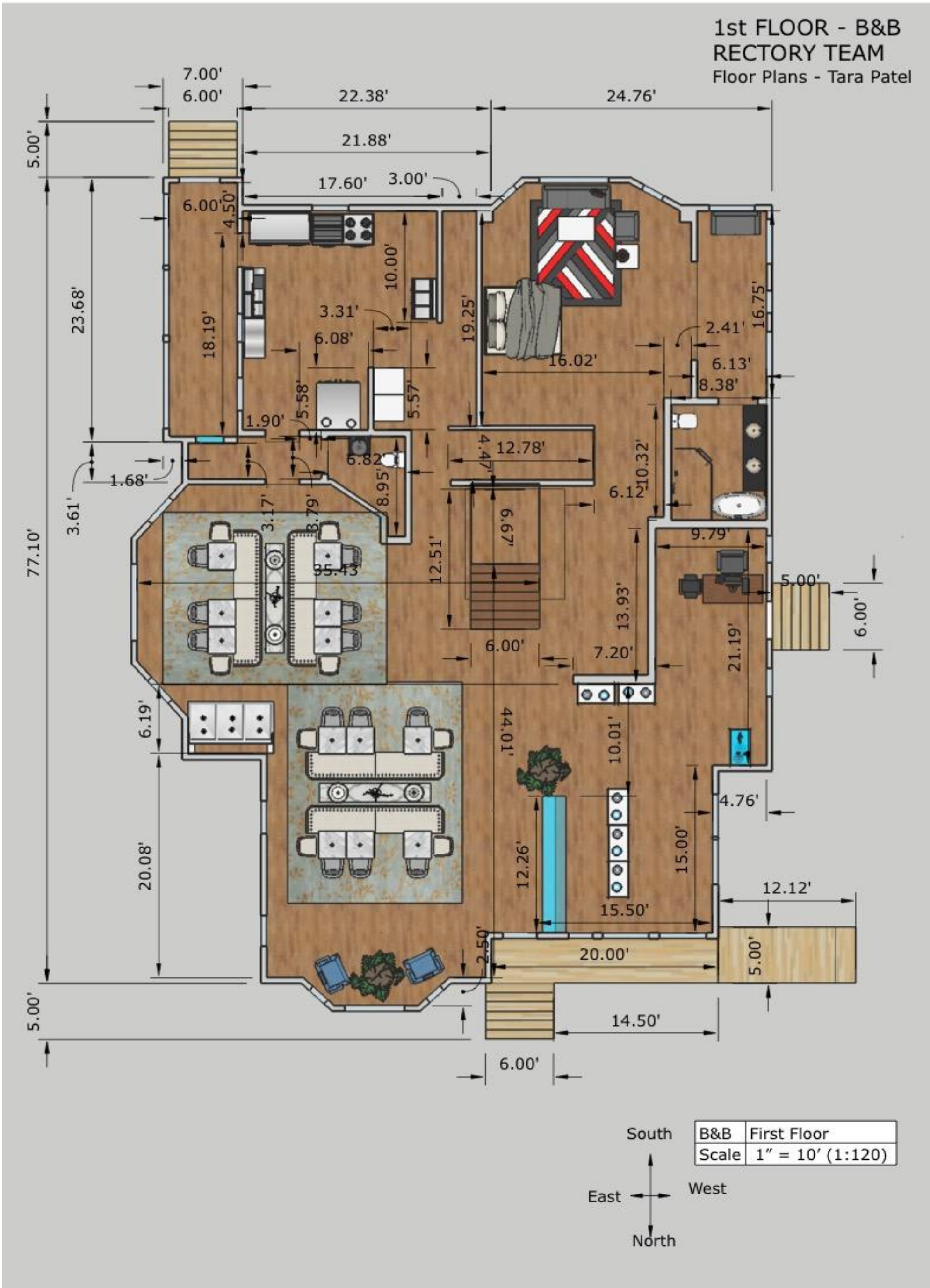


Figure 5-6. *Floor plans of the main floor with the breakfast area, kitchen and laundry on the east (left) and the reception, gift shop, office, and accessibilities bedroom on the west (right) side. There are three egress points as well as a ramp for handicap access. [Not pictured: stairs to the basement and small set of stairs to the second floor in the kitchen as well as the additional stairs to the second floor on the main staircase.]*

5.4.3. Second Floor

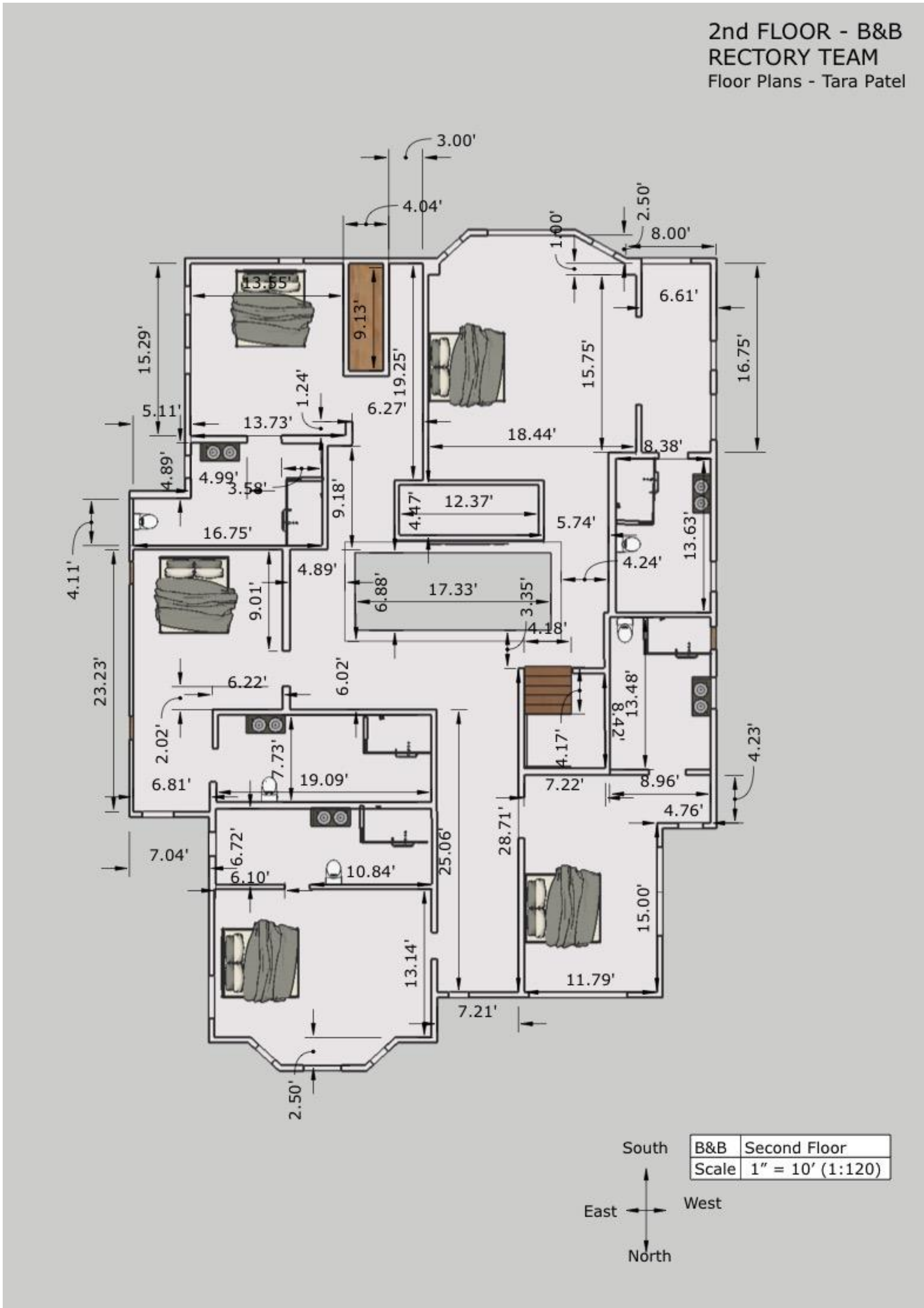


Figure 5-7. *Floor plans of the second floor with the rooms and bathrooms for the B&B. The main stairway and the additional staircase from the first floor are not shown in detail. There is a partial set of stairs to the third floor (pictured).*

5.4.4. Third Floor

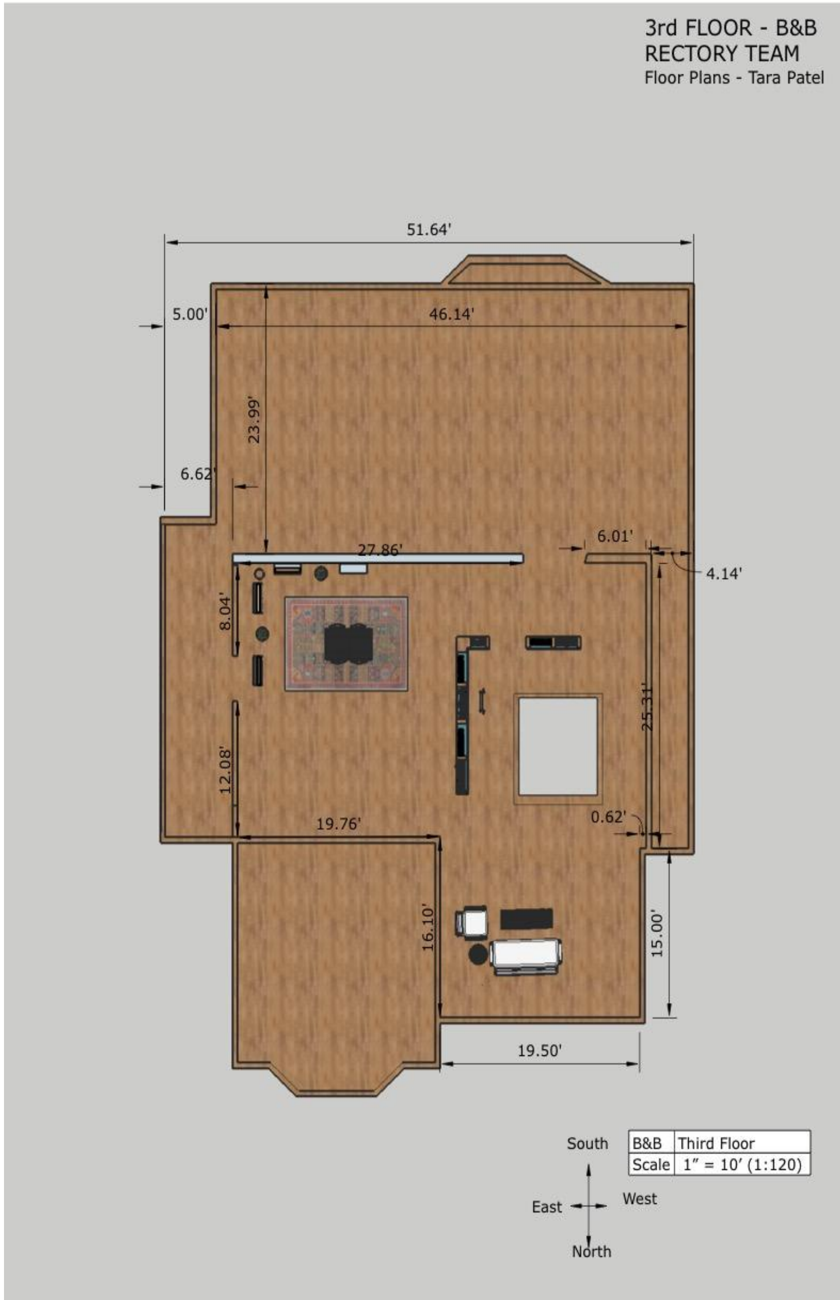


Figure 5-8. *Floor plans of the third floor with the library/lounge space for the B&B patrons in the central area. The northeast (bottom left) space remains empty due to the low roof height and can be used for storage. The area to the left of the library is also empty due to the low roof height, and there is an opening for the small window. The southern area of the space is empty except for the skylight pillar. All low-clearance peripheral areas can be for storage or HVAC equipment. [The staircases from the second floor are not pictured.]*

5.4.5. 3D Renderings

Figure 5-9. *Southeast view of rectory turned B&B, converted garage and outdoor seating.*

Figure 5-10. *West view of the B&B with garage converted into stage and outside seating.*

Figure 5-11. *Isometric view.*

Figure 5-12. *Front view (North).*

Figure 5-13. *Left view (East).*

Figure 5-14. *Right view (West).*

Figure 5-15. *Rear view (South).*

Figure 5-16. *Top view with PV panels.*

Figure 5-17. *3D view of basement .*

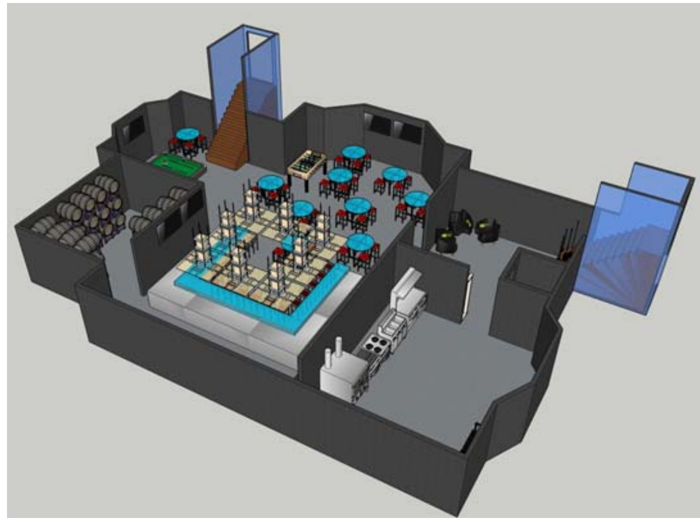


Figure 5-18. *Bar (South-West View).*

Figure 5-19. *First floor.*

Figure 5-20. *B&B (Southwest View).*

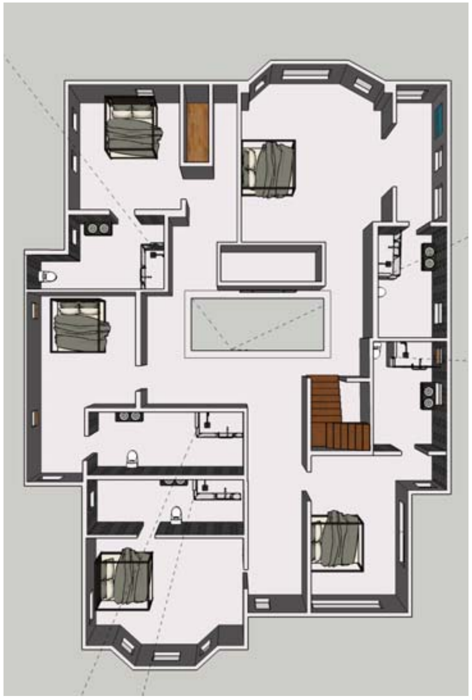


Figure 5-21. *Second floor.*

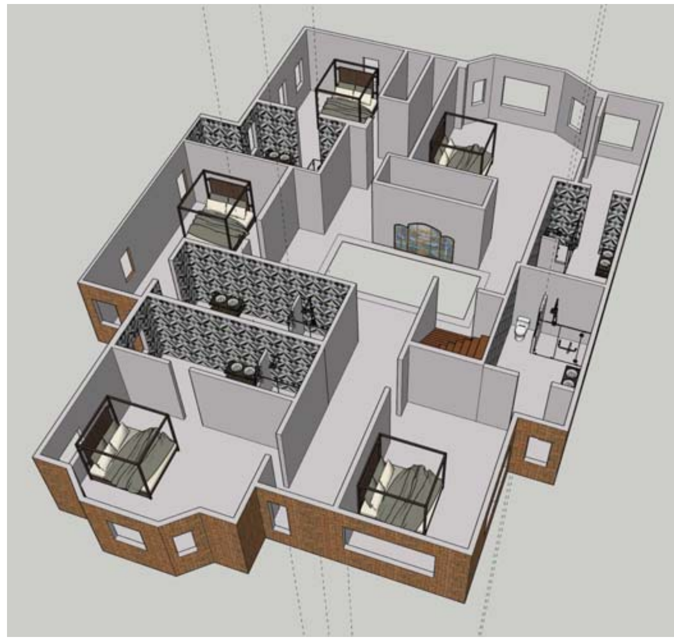


Figure 5-22. *B&B (Northwest View).*

Figure 5-23. *Third floor (Northwest View).*

5.5. Energy Analysis

5.5.1. Energy Consumption

Upon an in-depth degree-day heating and cooling analysis for Southbridge, MA we were able to deduce the times of year (according to a climatologically average year) when heating or cooling the building is necessary. Figure 5-24 displays the estimated monthly energy loads in BTUs for space heating and air conditioning. The calculations[87] are based on the assumption of a thermal envelope with 20-40-60 R-values for basement walls, exterior walls, and roof, respectively. The most energy demanding month is January with a heating demand of about 819,000 BTUs/day. In contrast, the heating load in June is a mere 323 BTUs/day. Note that in the May, June and September there is a demand for both a heating and air conditioning because variable weather during those months may lead to cold nights and warm days.

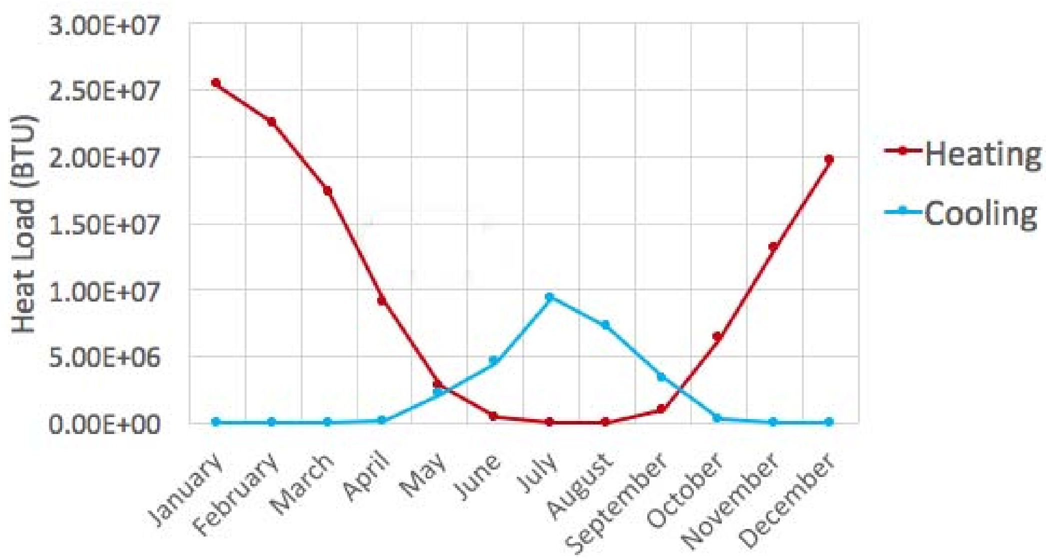


Figure 5-24. *Energy load required for both space heating & air conditioning in the Bed-and-Breakfast throughout the year.*

A search was performed on the internet to obtain pertinent estimates of the electric energy demand for dedicated spaces such as bar, hotel and mini-library. The electricity usage of the bar in the basement was modeled off of a typical bar[88], at 149 kWh/day. Electricity demand on both first and second floors was assumed to correspond to that of an average hotel in the United States, prorated to the actual number of guests[89], which amounts to 278 kWh/day. Lastly, the library that makes up the third floor was modeled as an eighth of the typical full-scale library, resulting in an energy demand of around 38 kWh/day. This brings the electric

[87] Available upon request from Prof. Cushman-Roisin at Dartmouth College
[88] 0.0364 kWh/day per square foot and 4,105 square feet.
[89] 36.1 kWh/day per guest and total of 2,808 guests per year (7.69 guests per day).

energy demand of the operations inside the building to 465 kWh/day.

5.5.2. Energy Procurement

The energy for space heating and air conditioning will be supplied by the geothermal system located in the church and serving the campus. See details in Section 2.6.2.

To meet the average electric load of 465 kWh/day, we begin by adding 50% of extra capacity to accommodate peaks and inefficiencies, raising the number to 697 kWh/day. We then ask whether this load could be provided by an array of photovoltaic (PV) panels on the southern section of the roof, which offers 453 ft^2 (= 42.1 m^2) of available surface at a 30˚ roof tilt. To optimize the capture of solar radiation over the course of the year, the tilt of the PV panels should equate the latitude (42.08˚ at Southbridge), and we thus recommend tilting the PV panels an extra 27.1˚. Because the available area is relatively small, we further recommend the installation of single-crystal silicon photovoltaic cells because of their relatively higher efficiency of 20%. According to US Government data[90], central Massachusetts receives an average of 4.6 $kWh/m^2/day$ on surfaces at latitude tilt, which means that 20% efficient cells covering 42.1 m^2 of roof would generate $(0.20)x(42.1\ m^2)x(\ 4.6\ kWh/m^2/day) = 38.7$ kWh/day, which is 5.6% of the 697 kWh/day electric load. Admittedly, this is not very much, and it is not clear whether the decision should be made to install PV panels at all. If the objective is to minimize the carbon footprint of the building, it may be more economical to purchase carbon-free electricity from the grid at a slight surcharge.

5.6. Other Analyses

5.6.1. Water

The water requirement for each aspect of the re-purposed rectory is as tabulated below (Table 5-2), yielding a total of about 430,000 gallons per year.

Activity	Gallons/patron	Patrons/day	Gallons/day	Gallons/year
Basement Bar	2.0	50	100	36,500
B&B Restaurant	3.0	10	30	10,950
B&B Bedrooms	136	2,808/365 = 7.69	1,046	381,890
		TOTAL	1,176	429,340

Table 5-2. *Estimation of the water needs in the repurposed rectory.*

Despite the fact that the church will have a rainwater harnessing system, it is not worthy to connect the rectory building to it because much of the water consumed in the bar, restaurant,

[90] <http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/atlas/Table.html>

and showers should meet drinking standards, and it is not worth having a separate plumbing system just for the toilets. Thus, this building should plan to purchase its water from the town.

5.6.2. Materials

In the basement, the bar will need entertainment items such as a pool table, a foosball table, several plasma screens throughout the room (*e.g.* for watching New England sports games), typical bar service materials (*e.g.* glasses, napkins, plates, bar tap, bottle openers, a cash register), as well as seating and tables.

On the first floor, there will be the needs of the restaurant which will include more tables, table cloths, silverware, dishes, glasses, flowers and other decorations, and other restaurant materials. An important note is that since the restaurant operates for breakfast/brunch and the bar is predominantly night-life oriented, many of the service materials, such as plates, a cash register, and glasses could be shared between the two operations. The first floor kitchen will be equipped with an electric stove and commercial dishwasher, both of which should be Energy Star certified. Also, there will be a washing machine and dryer located in the back mainly for washing sheets and towels for B&B guests. This, too, should carry the Energy Star label.

In addition to the restaurant, the first floor houses a retail shop for the brewery, so the shop will need shelves and an additional cash register. The first floor will also be the check-in location for B&B patrons, so it will require a desktop computer. It will have one handicap-accessible room which will have the same material as needed for the bedrooms on the second floor. On the second floor, the needed materials will include bedding, toiletries, and general bedroom furniture. On the third floor, the materials will include lounge chairs and couches, bookshelves, a desktop computer, and other guest amenities conducive to a lounge area (magazine and newspaper subscriptions, *etc*.).

5.6.3. Food

Ideally, foods and drinks for the restaurant and bar ought to be sourced locally to the extent possible. Not only would this contribute to existing Southbridge businesses, but it would also support the rest of the campus. In particular, the restaurant should purchase its bread and pastries from Our Daily Bread (in repurposed convent – Section 6) and vegetables from the Garden of Eden Greenhouse (repurposed school – Section 4), while the bar could serve the beer produced in St. Benoit's Brewery (repurposed power plant – Section 3).

5.7. Environmental Benefits

In terms of environmental impact, the key impact on the environment is energy from electricity usage. We have estimated that a building with as many functions as the B&B and Sports bar consumes about 255,000 kWh/year through electric appliances, lighting, water heater and about 35,000 kWh/year for heating and cooling needs.

To meet the high energy demand of the building, the building shall harness energy from the sun. Although the building wasn't originally designed to collect and store enough sun energy via solar panel technology, we are able to make use of the available south-facing area with solar PV to generate about 25% of the total electricity demand. For the remainder of the electricity needed, we are purchasing clean electricity. It is a bold move to purchase carbon-free electricity because the cost of electricity has significantly declined over the last decade. We learned that the cost of carbon-free electricity in New England is just 2.4¢ extra per each kilowatt, and we believe it is worth pursuing for a decreased environmental impact. Additionally, by taking advantage of the geothermal system from the former church, we have reduced the heating and cooling energy demand by 40%, from 35,000 kWh/year to about 21,000 kWh/year.

Since our main concern is electricity, we are measuring environmental benefits by how much carbon dioxide emissions the renovated building accounts for. From sourcing to utilization, our building has approximately zero carbon emission from utilization thanks to the initiative of purchasing clean energy. As from sourcing, our providers of heating and cooling energy are using conventional electricity in which our contribution is 21,000 kWh/year. Therefore, the building's largest emissions are from sourcing, where unfortunately 35,605.5 lbs of carbon dioxide are emitted. In comparison to buildings with similar functions, the B&B and sports bar are emitting 91.5% less.

We acknowledge that electricity for appliances, lighting, water heating and the building's heating and cooling energy do not tell the whole story of the building's environmental impact. In fact, a lot of consumable items such as toilet paper, paper towels, cleaning supplies, *etc*. all have an impact on the environment. However, we are recommending eco-friendly appliances, namely Energy-Star certified products, to make big cuts on the building's environmental impact. In a nutshell, by taking an initiative of purchasing clean energy and generating renewable energy from the solar PV panels, the building is inherently benefiting the environment.

We believe that the repurposing of the rectory building into a bed and breakfast business with an added sports bar in the basement can fulfill the requirements of LEED-Gold certification, as shown in Appendix D.

5.8. Social Benefits

The Bed and Breakfast and Basement Bar will be staffed by a mix of full-time and part-time employees, as listed in Table 5-3 below.

Job Position	Number of People	Full Time / Part Time
Concierge/Retail/Reception	2	Full Time
Bar Manager	1	Full Time
Chef and Cooks	2	Part Time
Bartender	2	Part Time
Waiter/waitress	2	Full Time
Custodians/Maids	2	Full Time
B&B Manager	1	Full Time
Bouncer/Gatekeeper	2	Part Time
TOTAL	**14**	**8 FT + 6 PT = 11 FTEs**

Table 5-3: *Employment by the B&B and Bar.*

The fourteen jobs would be available for the residents of Southbridge and benefit the people and the town. For example, the chef/cook position is a part-time position and could take advantage of the diverse ethnicities in Southbridge by having residents create different ethnic foods on a weekly basis. In the event that alcohol is permitted within the confines of the outdoor campus, employees will need to monitor the entrances. The Sports Bar will be a safe space for residents and visitors to enjoy nightlife. The B&B will draw visitors looking for an experiential/destination feel that the campus offers such as the Greenhouse, the Bakery and other amenities like the restaurant and live entertainment in the church. The B&B design pays homage to the history of the town and will promote Southbridge's branding.

Additionally, the campus also needs to have an overarching executive board with senior managers, accountants and human resources. The campus will also need groundskeepers. The breakdown of the potential job positions is Table 5-4 below (see also Table 4-5).

Job Position	Number of People
Senior Manager	1
Accountant	1
Human Resources	1
Groundskeepers	3
TOTAL	**6**

Table 5-4: *Shared campus employment.*

5.9. Economic Considerations

The expected annual revenues are as follows:
● Bar: (50 patrons/night)x(2 drinks)x($7/drink)x(365 days/year) = $255,500
● B & B: (6 rooms)x(64% capacity)x(365 days/year)x($180/night) = $252,288
● Retail: $2,500 worth of merchandise sold at 150% markup = $6,250
yielding an estimated total of $514,038 annually of taxable revenue.

The breakdown of expected annual cost is as follows:
● Water: (431,021 gallons/year)x($1.50/1000 gallons) = $647
● Heating & Cooling: (11 cents/kWh)x(21,219 kWh/year) = $2,334
● Electricity: (13.4 cents/kWh)x(188,271 kWh/year) = $25,228
● Salaries: (11 FTEs)x(8 hours)x($16/hour)x(261 days) = $367,488
● Cost of Merchandise: $2,500 investment = $2,500
for a total of $398,197 annually.

Subtracting the costs from the revenues, we arrive at the profitability of the operations: $514,038 – $398,197 = $115,841.

In addition to the annual economic analysis, it is important to account for the installation and new materials costs associated with setting up this new business in an environmentally-friendly way. The cost of installation is estimated to be around $200,000 (Table 5-5).

Item	Estimated Cost
Appliances	$2,500
Cabinets (incl. installation)	$3,500
Countertops (incl. installation)	$4,100
Plumbing	$3,500
Flooring	$11,500
New windows (56)	$19,600
Thermal insulation	$50,000
PV cells (single crystal silicon)	$15,000
Furnishings	$90,000
TOTAL	**$199,700**

Table 5-5. *Breakdown of cost or renovations.*

With the current annual profit mentioned above, these costs will be paid off in about two years of operation.

6. The Convent Building

Student Team: Ralf H. Carestia, Kelsey E. E. Phares, Zoe A. Rivas, Sarah L. Rote, and Marie Josée Uwayezu
Teaching Assistant: Nidhi Mahambre

6.1. Description of Current Building

The convent, shown below in Figures 6-1 and 6-2, was constructed in the Colonial Revival style, in the architectural style popular around Southbridge during the period. The front of the convent faces Charlton Street and has a large open lawn. With a footprint of 3905 ft^2, it is significantly smaller than the rectory.

When it was in operation, the convent housed about eleven teaching sisters who ran the parish school. The nuns were part of the Sisters of the Assumption of Nicolet, which was the same order as the nuns who ran the Notre Dame Parish School[91]. It became vacant around 2011 when the Sacred Heart Church closed.

Figure 6-1. *Northern façade of the convent. Notable architectural features of the convent are the keys over the windows and the box cornice at the roof. (Photo by Josee Uwayezu)*

[91] Massachusetts Historical Commission. *Sacred Heart Roman Catholic Church Convent Inventory Form*. Boston, MA: Massachusetts Cultural Information System, 1989.

Figure 6-2. *The east side of the convent. (Photo by Josee Uwayezu)*

On our visit to the site in March 2017, we noted that there is significant damage to the roof (holes and leaks) that would need to be repaired in any repurpose scenario. There is visible water damage to some of the interior walls as well that would need to be repaired. The windows in the building are all single-pane and are not sealed well, and there is minimal insulation on the walls of the building. Both of these would need to be improved during the renovation.

6.2. Brainstorming, Specifications, and Selection

To determine the best way to repurpose the convent building, our team considered several criteria. The most important points were to serve the community, provide employment (including training), generate taxable revenue, and bring the community together. We explored several possibilities, including a bakery, a brewery/bottling company, a community fitness center, a daycare facility, and an art gallery.

The bakery idea was retained for the following reasons: (1) It would create employment, (2) it would offer job training opportunities under a master baker, (3) it could sell a variety of baked products that meet the food preferences of multiple ethnicities and cultures (French-Canadian, Hispanic, East Mediterranean, organic, vegan), (4) it would ideally complement the repurposes of the other buildings on the Sacred Heart Church campus (several of which would consume its baking goods – Figure 6-3), (5) the Greater Boston area provides a broad customer base, and (6) the profits would be taxable by the Town of Southbridge.

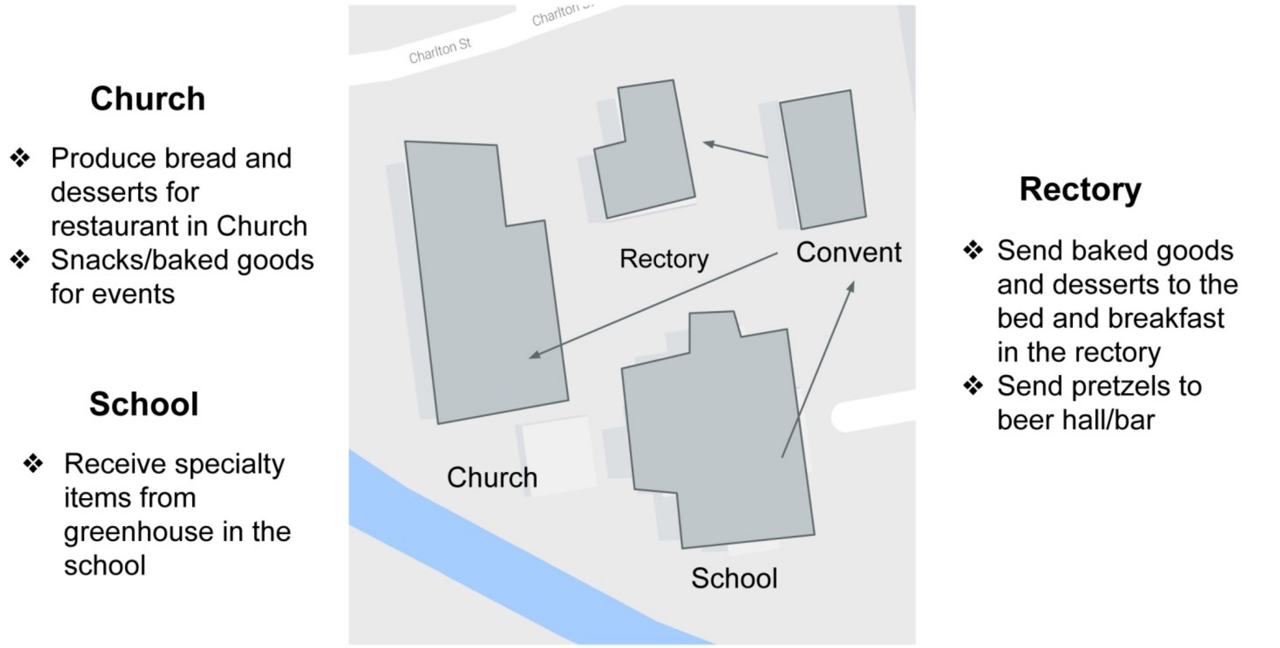


Figure 6-3. *Integration of the convent repurposed as a bakery amongst the other repurposed buildings of the campus.*

6.3. Re-Purposing into a Bakery

After considering the proposed uses of the other buildings in the complex, we decided the best new use of the convent would be a bakery. This use would coordinate well with the other businesses in the complex while bringing revenue, jobs, and training resources to the Southbridge community. As a nod to the history of the convent, we named our proposed redesign Our Daily Bread Bakery.

The Town of Southbridge and its residents are still trying to recover from the American Optical Factory closing in 1984, and a bakery would provide local residents with jobs and training. It could also offer baking classes to benefit community members looking to gain baking skills as well as draw in tourists who want an immersive experience.

The demographics of Southbridge include residents with a French Canadian background and a growing number of Hispanic residents[92]. There is also a group of educated millennials in town

[92] City-data.com: *Southbridge, MA.* <http://www.city-data.com/city/Southbridge-Massachusetts.html>

who are looking for organic foods and activities close to home. The bakery would offer a wide variety of products such as vegan breads and tortillas to appeal to Southbridge residents and local restaurants.

6.4. Floor Plans

As shown in Figures 6-4 and 6-5, the current first floor has a more open layout than the second floor, and it connects to a porch in the front of the building. The second floor has a series of small bedrooms (cells) for the nuns and one larger room serving as a chapel.

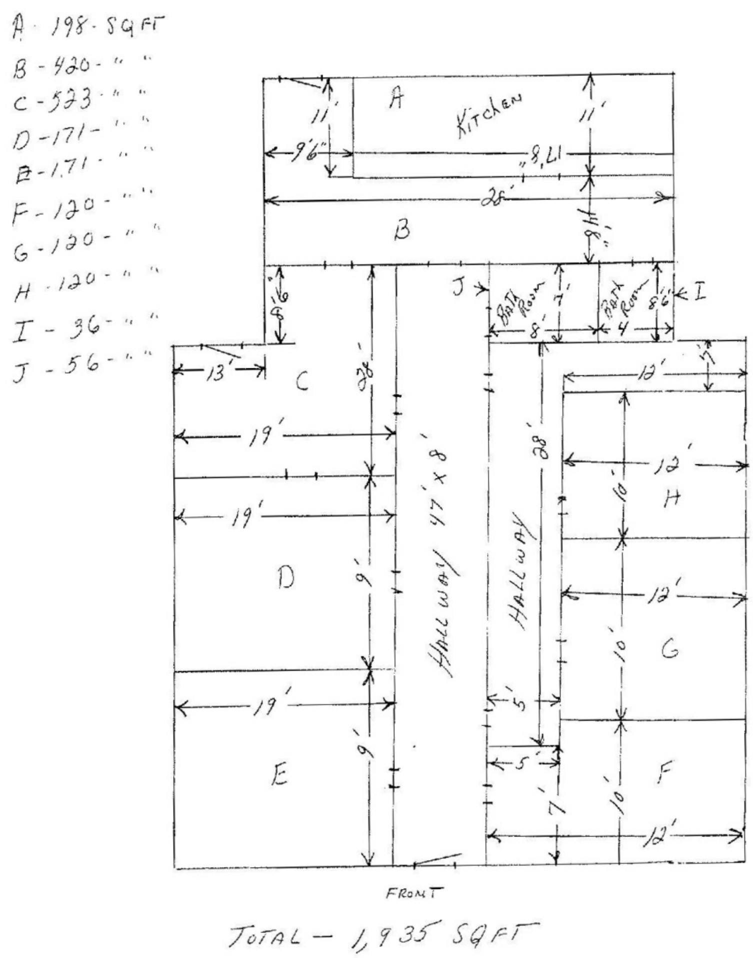


Figure 6-4. *Current first floor plans. (Courtesy of Father Peter Joyce)*

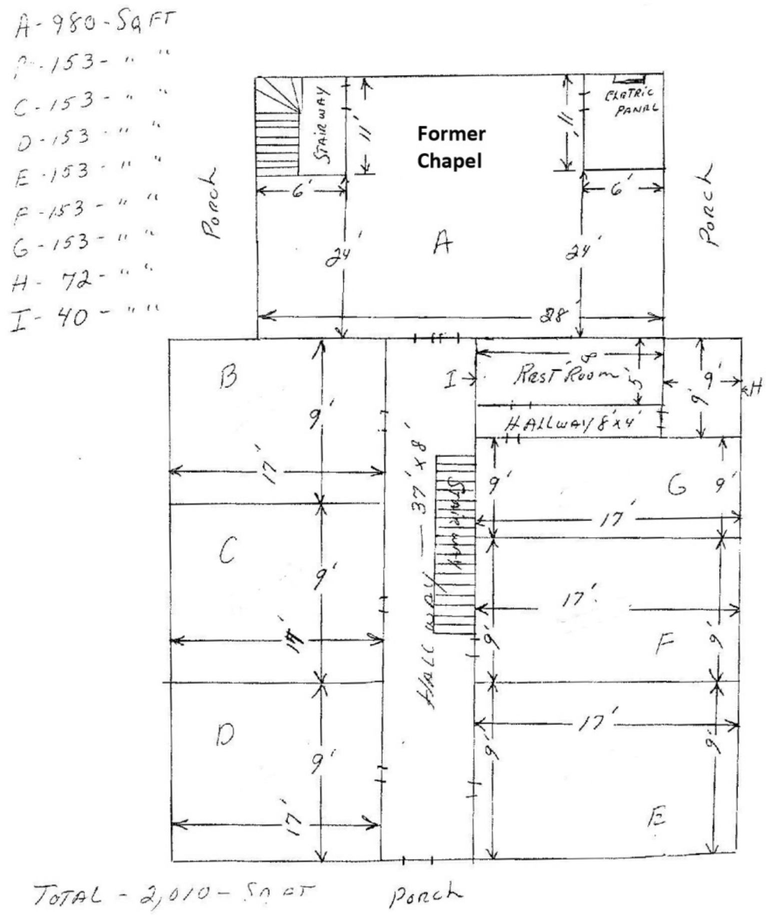


Figure 6-5. *Current second floor plans. (Courtesy of Father Peter Joyce)*

The current layout limits the building's use for food production because of the low ceilings on the first floor and the many small rooms on the second floor. The basement of the convent has approximately the same square footage as the first floor and has an open floor plan with beam supports. Ground-level windows provide daylight to the basement.

For a repurpose, the building's main problems are the low ceilings and crowded floor plan on the second floor, significant roof damage, and poor insulation. In order to optimize the building for food production, we propose to open the interior by removing the second floor. The challenge in doing so is the risk of compromising the structural stability of the building by depriving it of load-bearing columns and walls in the interior. After discussion with Professor Vicki May, a professional civil engineer on the engineering faculty at Dartmouth College, we found a solution that maintains the structural integrity of the building.

Due to the extensive damage, the roof needs to be completely replaced anyways. It is proposed during the roof replacement to replace the current support with a sectional steel frame (Figure 6-6) to transfer the roof load to columns on the periphery. This would ensure that the building has sufficient support for its new roof to allow the subsequent removal of the entire second floor. Being no longer accessible, the attic floor would also be removed, and this would make it easier to insulate the roof. The exterior of the roof would be reconstructed in the original style to preserve the historic character of the building. The building currently has a solid brick exterior, and the several steel columns (Figure 6-6) would be placed on the interior side of the exterior wall so as to leave the outer brick unchanged.

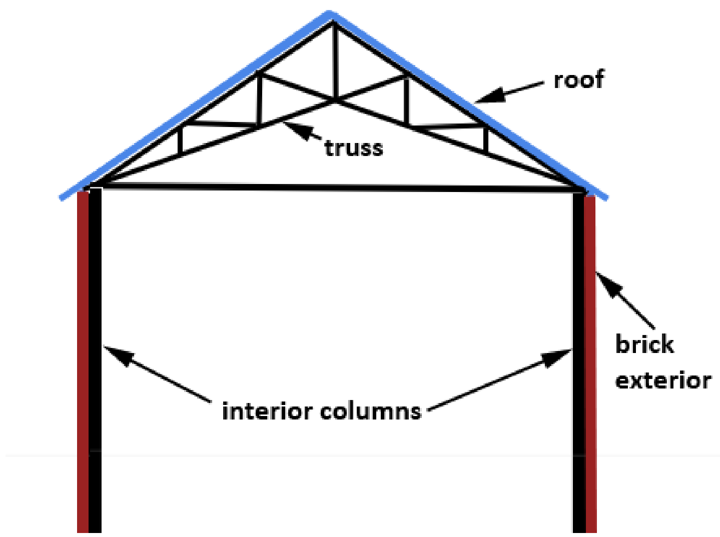


Figure 6-6. *Proposed new steel frame and roof scissor truss to support a new roof in the absence of a second floor. Black portions are steel sections, several of them placed along the length of the building.*

Opening up the space by removing the second floor has many benefits. Aesthetically, it will be conducive to a friendly café design and provide a comfortable work environment for the bakery staff. It will also be beneficial for the sustainability measures in our design. Without the second floor and attic, it will be easier and cheaper to insulate the whole building. The complete thermal envelope from the insulation will drastically cut energy usage for heating and cooling, as discussed later in the report. The large open space will also make it easier to implement proper ventilation measures in the kitchen.

Our proposed new floor plan for the basement and main floor are shown in Figures 6-7 and 6-8, respectively.

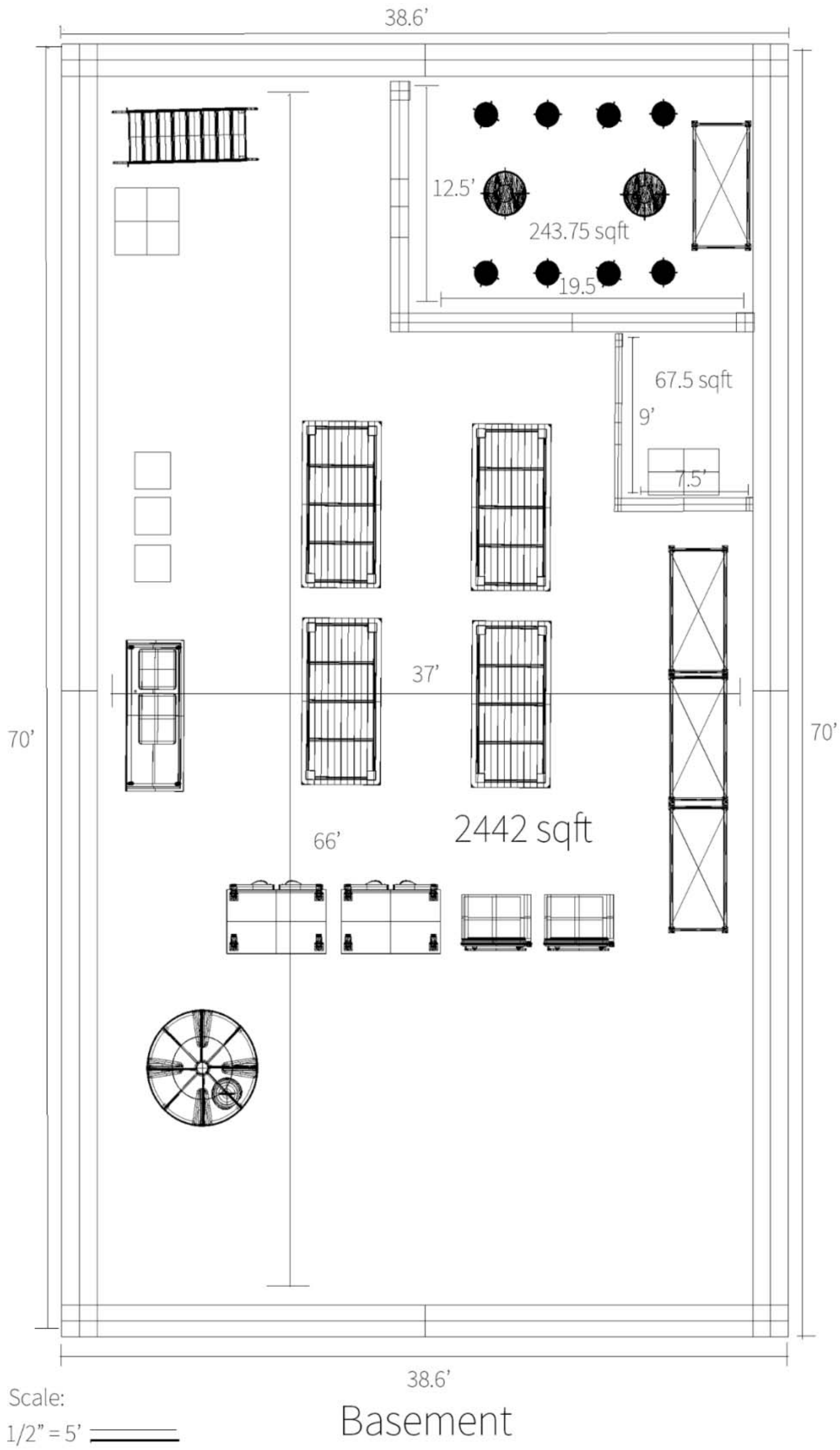


Figure 6-7. *New floor plan for the basement, serving mostly as storage, some of which refrigerated but also including a break room and an office.*

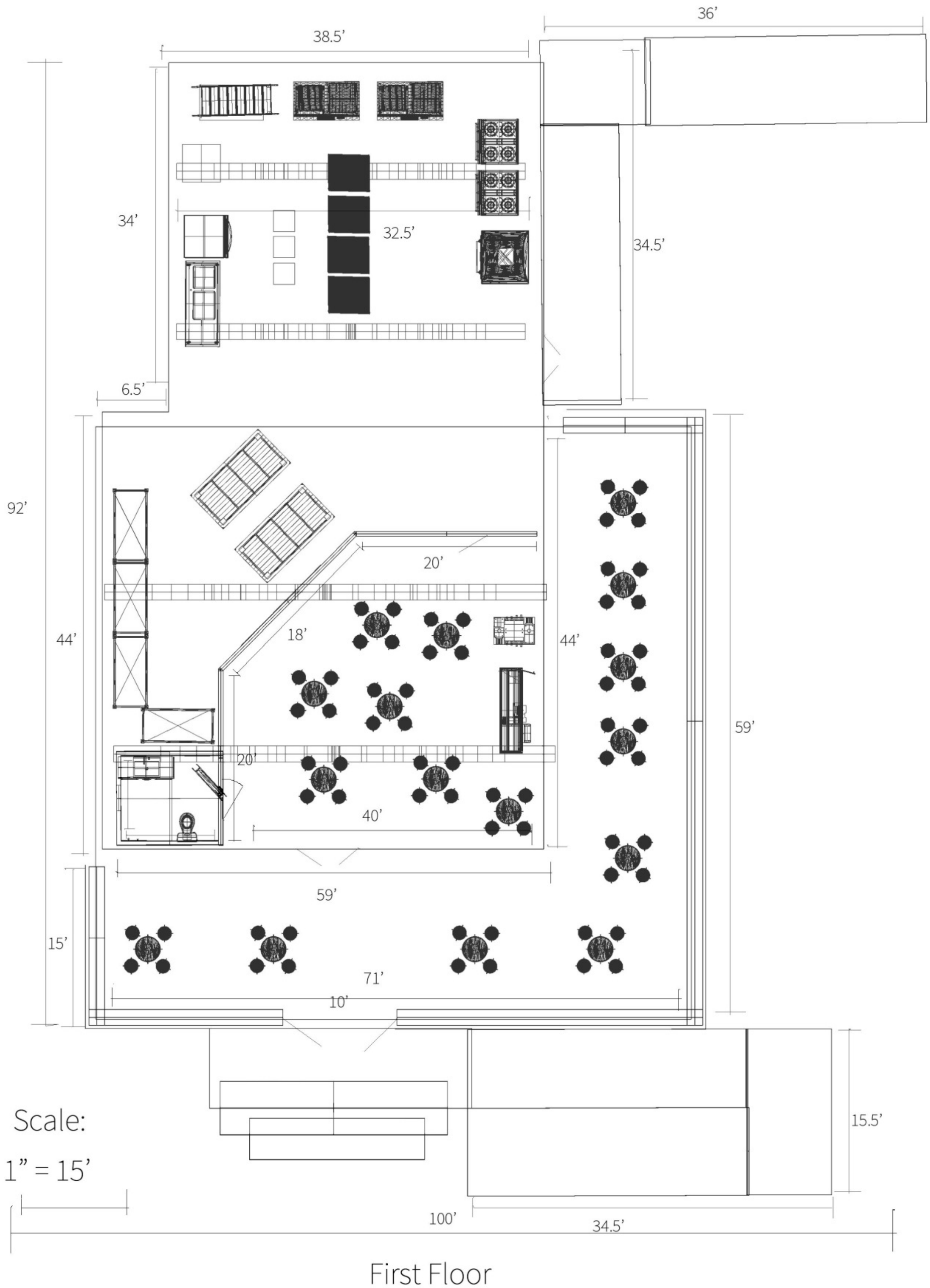


Figure 6-8. *New floor plan for first floor, with bakery and a partly separate sitting area.*

6.4.1. 3D Renderings

Figure 6-9. *3D view of the sitting area in the northwest corner of the main floor.*

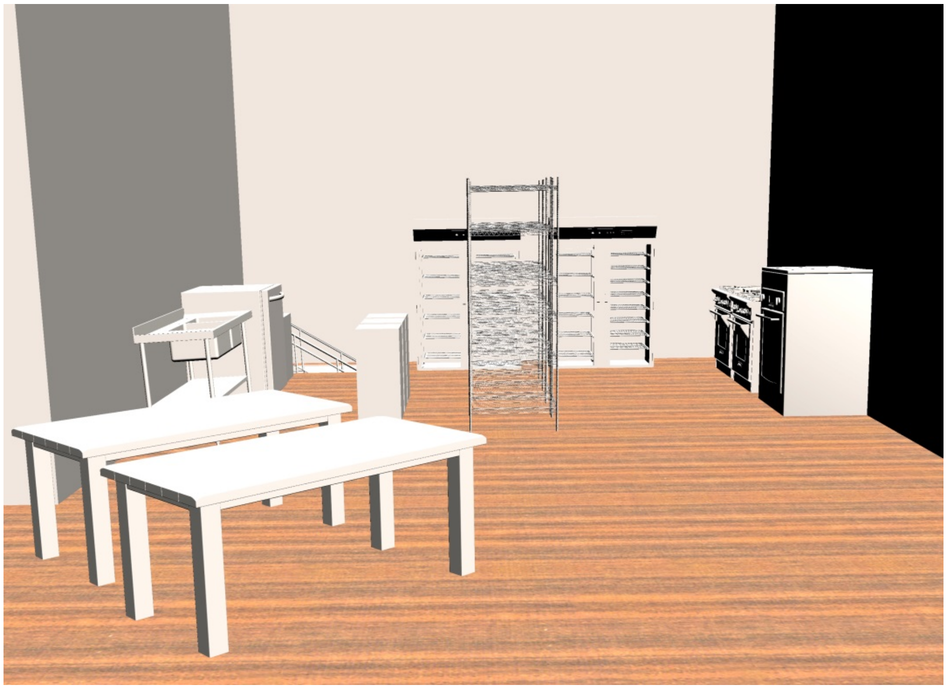


Figure 6-10. *3D view of the baking area on the south side of the main floor.*

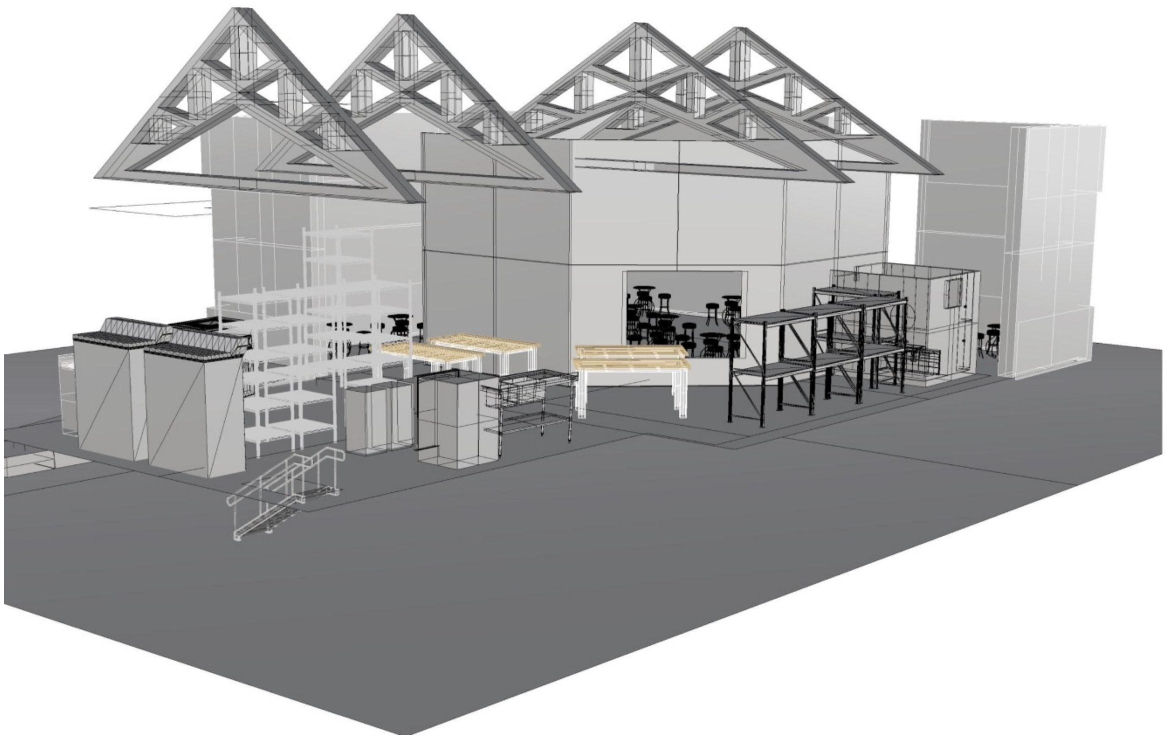


Figure 6-11. *Shaded view of the interior (main floor) from the southeast corner.*

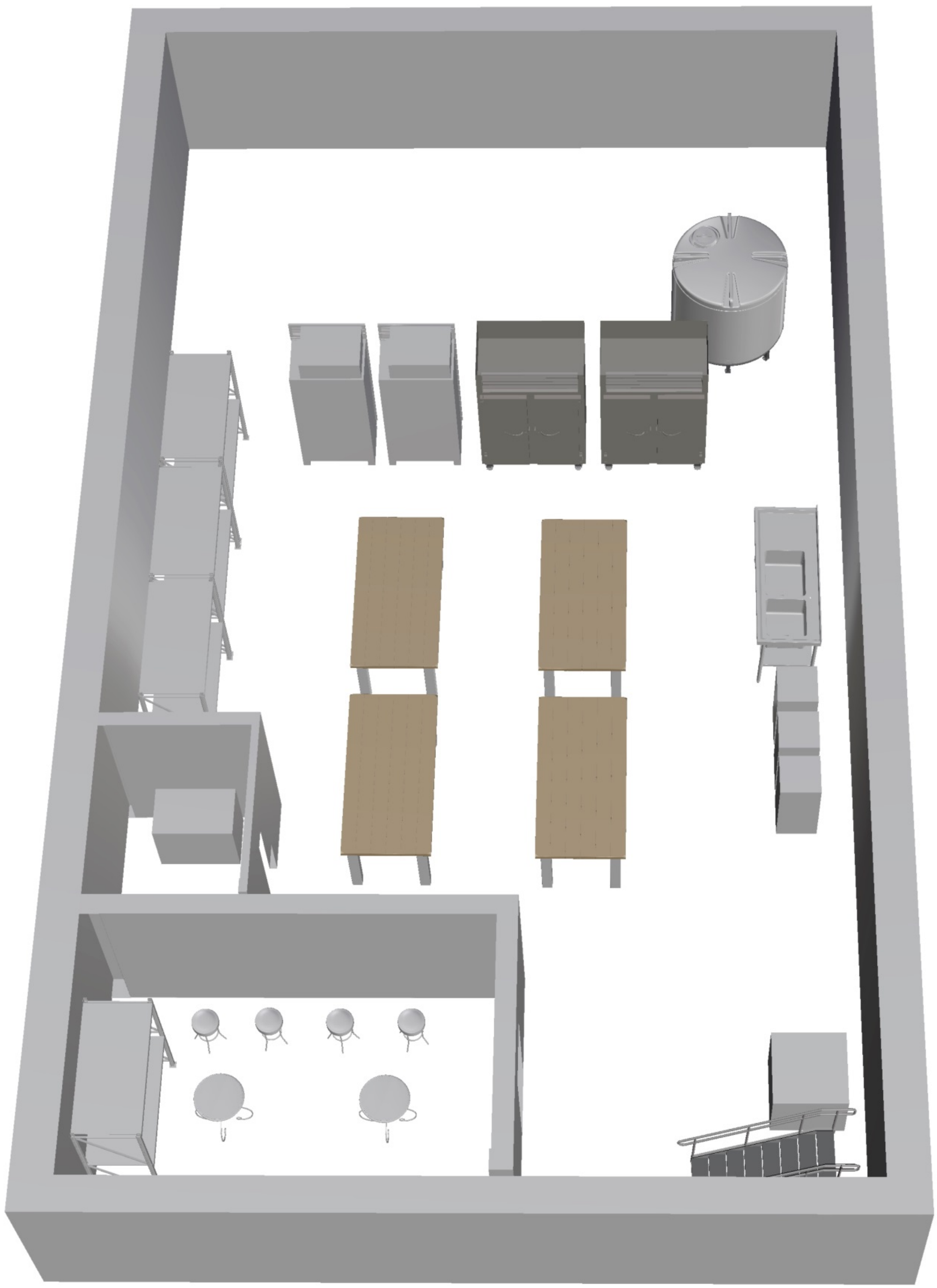


Figure 6-12. *3D view of the basement. The employee break room is shown in the bottom left (southwest) and the office is adjacent to it on the left (west) side.*

6.5. Energy Analysis

6.5.1. Energy Consumption

The primary energy demands in a bakery come from equipment, lighting, and HVAC (heating, ventilation, air conditioning)[93]. The total energy demand for the proposed bakery is estimated at 80,387 kWh per year (Table 6-1).

Category	kWh/yr
Equipment	62,921
Lighting	13,760
Ventilation	3,478
Cooling/Heating	228
Total	**80,387**

Table 6-1. *Energy demand in the bakery by category.*

The section below breaks down the energy demand into those main categories and shows how almost half of the demand can be met using solar energy.

Energy demand from equipment

According to our calculations, the largest use of energy comes from the equipment needed to operate the bakery. The equipment consists of ovens, refrigerators, freezers, dishwashers, hot water pumps, a dumbwaiter, and a greywater treatment system. There are other electric appliances in a bakery, like mixers, but these run infrequently enough that they contribute little to the total energy demand.

A significant amount of energy can be saved by carefully selecting efficient appliances. The goal is to select equipment that would be precise and reliable, while still being as efficient as possible. The Food Source Technology Center[94] is a valuable resource for selecting and optimizing the equipment. We used the life-cycle cost calculator on their website to estimate annual energy consumption for each appliance, and then used that information in our selection process (Table 6-2).

[93] Food Service Technology Center (2017). *Life Cycle & Energy Cost Calculators.* fishnick.com/saveenergy/tools/calculators/
[94] Idem

Item	Model	kWh/yr
Ovens	Baker's Pride BCO-E	50,900
Dishwasher	Hobart LXeR	1,485
Fridges and Freezer	Atosa MBF series	4,683
Dumbwaiter	Ryoden RT-100	550
Greywater system	Nexus NEXtreater	5,000
Hot water pumps	generic	303
	Total	**62,921**

Table 6-2. *Equipment energy use by appliance.*

The following sections include information about the selected appliances.

Oven: Bakers Pride BCO-E

We chose the Bakers Pride BCO-E model for the two ovens[95]. This model has a high-efficiency convection fan, which is very important for an energy-efficient oven. More details regarding the ovens and their annual energy consumption will be discussed in the section titled "Heating and cooling."

Fridge/Freezer: Atosa MBF series

Atosa manufactures high-efficiency cooling products and is rated highly by the FSTC for achieving low energy demand in commercial kitchens[96]. Using the life-cycle cost analysis tool, the total energy demand for a freezer and two fridges came to 4,683 kWh per year. These appliances must run continuously throughout the year, creating a high energy demand. Another important consideration is the type of coolant used in the fridge or freezer. The Atosa MBF series uses Refrigerant R134a[97], which is one of the most inert refrigerants available and has very low ozone depletion properties.

Dishwasher: Hobart LXeR

For a small-scale bakery, the ideal dishwasher is small and can do many loads per hour. The Hobart LXeR dishwasher fits this description and also has an energy recovery system where

95 Bakers Pride. (2014). *Cyclone series electric convection ovens.* http://www.bakerspride.com/products-cyclone-e.asp
96 Atosa Catering Equipment. (2017). *MBF5807 bottom-mount (2) two door refrigerator.* http://atosausa.com/?product=dual-door-mbf8507
97 Idem

steam heat is used to preheat the incoming cold water[98]. There are two options for commercial dishwashers: low temperature units that use chemicals to sanitize dishes, and high temperature units that use hot water to sanitize. From a sustainability perspective, each style has drawbacks: chemicals to dispose, or high energy demands. We chose the hot water style of dishwasher because we can sustainably heat water using a unique heat recycling feature (discussed in "Heating and Cooling" section). Using the life cycle cost calculator, the annual energy demand for the dishwasher is 1,485 kWh[99].

Energy demand from lighting

Lighting is the second largest energy use in the bakery. In preliminary calculations, we estimated the total annual consumption to be around 20,000 kWh per year, but we were able to reduce this number by optimizing the lighting. The recommended lighting level for a commercial cooking area is 50 ft-candles, but this amount of light is not needed for the entire building. Energy can be conserved by providing that amount of light only to localized cooking spots, with lower luminance level of 15 ft-candles for the rest of the space. Additionally, ambient light sensing technology can be used to reduce the lighting load depending on the levels of natural light detected in a room[100]. With the removal of the second floor, natural light will be in abundance.

Based on an efficient LED lighting model that consumes only 2.11 W/ft^2, the energy demand falls to 8.44 kW at the maximum load[101]. Using light sensing technology, the maximum load would only be required between 6:00AM and 8:00 AM for morning food preparation. From 8:00 AM to 5:00 PM during daylight hours, an estimated 20% of max load would be used on average. While the bakery is closed for the night, from 5:00 PM to 6:00 AM, the lights would run at 5% for theft protection. Given these loads, the total annual consumption would be 13,700 kWh. This is a 45% savings in energy compared to a standard lighting setup using inefficient lights to provide 50 ft-candles to the entire space and no ambient light sensing.

Energy demand from ventilation

We originally estimated the energy demand for ventilation using a single point exhaust system at around 8,000 kWh per year. The total annual consumption was significantly reduced by switching to a Heat Recovery Ventilation system with around 80% heat retention. The total building volume is around 58,000 cubic feet. With a desired air exchange every 90 minutes it was determined that 664 cubic feet needed to be exchanged every minute. Based on these

---

98 Hobart Corp. (2017). *LXeR and LXePR advansys hot and cold.* https://cdn2.webdamdb.com/md_dezp5gnPHlWS.jpg.pdf?v=1
99 Food Service Technology Center. (2017). *Life Cycle & Energy Cost Calculators.* fishnick.com/saveenergy/tools/calculators/
100 ETAP Lighting. *Lighting - light line systems - individual*. http://www.etaplighting.com/level2.aspx?seq=79&seqpicture=2650&name=Individual&LangType=1033
101 Idem

specifications, a unit from Zehnder called the ComfoAir was selected[102]. The ComfoAir demands 700 Watts when running at max exchange. Because the building would be otherwise evacuated during the night, the unit would only have to run at full exchange rate from 6 AM to 5 PM. During the night it could run at 50% the full exchange rate. For this it would demand 140 Watts. These numbers when used for all 365 days a year produce a total annual energy demand of 3,400 kWh, a 135% improvement over the exhaust style ventilation.

Heating and cooling

In order to improve energy efficiency through reduced heat loss and infiltration, we opted for R6 windows, R40 walls, and a R60 roof. We decided to use triple-pane argon windows with a 5.99 R-value to reduce the amount of heat gain in the summer and heat loss in the fall and winter. Though expensive, these windows are worth their cost over the long run because windows are the greatest sources of heat loss and infiltration. To achieve a minimum of R40 in the walls, we plan to use a combination of 10 inches of spray-fill cellulose (R36 for 10 inches) and 1 inch of Polyiso foam (R7.62 per inch)[103]. For the roof, we suggest using 4 inches of spray-fill fiberglass (R4.2 per inch) and 6 inches of Polyiso foam (7.62 per inch) for a total R-value of 62 (Figure 6-13). The spray-fill fiberglass in particular was selected because it is easier to apply to the sloped roof interior than loose-fill insulation, and a spray fill would fill cavities between the roof's support beams to create a flat layer underneath the rigid foam board.

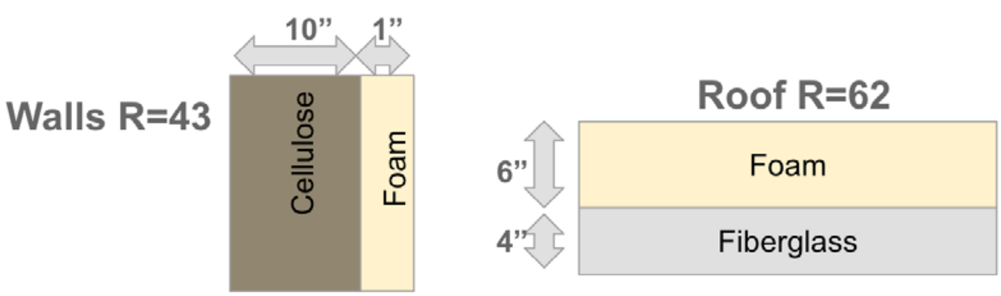


Figure 6-13. *Illustration of proposed insulation, providing an R-value of 43 in the walls and 62 for the roof.*

After renovation and insulation upgrades, the building will require 8,327 BTU/^{o}F.day for heating. During the winter, the degree-days in Southbridge are around 6,237 ^{o}F·days[104], so total heating energy need for the bakery is approximately 52,216,164 BTUs per year.

Based on feedback from bakeries of a similar scale, two 10.5 kW Bakers Pride BCO-E ovens

[102] Zehnder (2015). *Heat & Energy Recovery Ventilation Units.* http://zehnderamerica.com/products/heat-and-energy-recovery-ventilation-units/

[103] Wilson, A. *Getting to know spider insulation.* 25 July 2013. http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/getting-know-spider-insulation

[104] Citydata.com (2017). *Southbridge, MA.* http://www.city-data.com/city/Southbridge-Massachusetts.html

would be required. Therefore, a total of 21 kW (71,655 BTUs) of heat are being generated when the ovens are running at full capacity. The ovens would run approximately 8 hours a day, 303 days a year, producing 173,691,720 BTUs. This is more than double the energy required to heat the building. For this reason, we developed a mechanism to catch some of the waste heat to provide hot water to the building. In the proposed system, the two ovens sit close to each another such that the heat along the common wall is shared. As shown in Figure 6-14 below, the device is a "cage" of water coils around the two ovens.

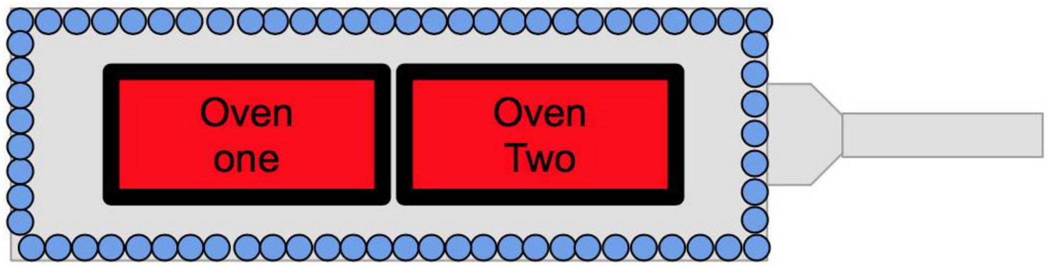


Figure 6-14. *Sketch of the proposed oven waste heat capture system*.

The black lines represent the oven walls of the original ovens around which there is a cage of water pipes several inches away. The air buffer is important because without the water pipes would cool the ovens, forcing them to consume more energy to maintain temperature. Around the water pipes there is an insulating box to trap the heat and maximize heat absorption into the water. The vent to the right would only be used during the summer months to vent any rejected heat to the outdoors.

Assuming a 50% energy capture rate, the water would absorb 86 million of the 173 million BTUs produced by the oven annually. The total hot-water consumption of the bakery is estimated at 73,100 gallons per year as discussed in a later section. Given the heat capacity of water, 39,644,369 BTUs would be needed annually to meet the bakery's demand.

The remaining heat, which is rejected due to the capture rate of 50%, would go towards heating the building itself. Of the 86 million BTUs available, only 75% of that heat would be available during the winter months when it is needed. There would still be 64.5 million BTUs available to heat the building–more than the required 52 million. This heat would be efficiently moved throughout the building using the HRV ventilation system[105].

To calculate the energy demands of cooling the building, several assumptions were made. The oven box does an effective job of rejecting excess heat to the outdoors when the vent is open

[105] Zehnder. (2015). *Heat & Energy Recovery Ventilation Units.* http://zehnderamerica.com/products/heat-and-energy-recovery-ventilation-units/

during the summer months. The proofer's heat generation is negligible. Furthermore, the basement is subsurface and is predicted to remain cool on its own. This area on average has 708 cooling degree days which when multiplied by the heat capacity of the building (8,372 BTUs/degree per day) comes to a required 7,418548 BTUs worth of cooling. This cooling is to be provided by the church geothermal system, and with a very high coefficient of performance a very low demand for total cooling energy has been achieved at 228 kWh.

6.5.2. Energy Procurement: Solar Energy?

The roof of the convent building has large east and west facing aspects whereas the north and south facing sections are much smaller (Figure 6-15). To utilize the roof area, we considered both solar hot water heating and photovoltaic electric power generation. Since the hot-water need can be met using waste heat from the ovens (discussed in the previous section), we decided to use the roof for photovoltaic cells. The total usable roof area is approximately 2,780 square feet.

When calculating the total annual solar production of the panels, we made several assumptions. To provide a small safety buffer for the final calculated number, we estimated that the entire roof faced either east or west. The cells were modeled as standard efficiency cells with the ability to recover 15% of the sun's energy. The roof angle was estimated to be 30 degrees, and system losses were taken at 30%. The system loss percentage was made large to account for snow during winter and the large number of cloudy days in the region[106]. Based on these assumptions, the total annual energy production came to 30,531 kWh. As detailed in the previous sections and Table 6-3, the total annual energy demand is 80,387 kWh per year. Offsetting with solar energy, the bakery will draw only 49,856 kWh from the grid annually.

Figure 6-15. *Aerial view of the convent roof. (Image from Google Earth)*

[106] Citydata.com. (2017). *Southbridge, MA.* http://www.city-data.com/city/Southbridge-Massachusetts.html

Category	kWh/yr
Ventilation	3,478
Equipment	62,921
Lighting	13,760
Heating and Cooling	228
TOTAL	**80,387**

Table 6-3. *Energy use by category.*

6.6. Water Analysis

As a food service establishment, water use in the bakery is an important factor. According to the US EPA[107], the average restaurant's water use is more than half for kitchen/dishwashing followed by about ⅓ for domestic/restroom (Figure 6-16). Therefore, it is most effective for us to target these two large categories for improvements in water efficiency.

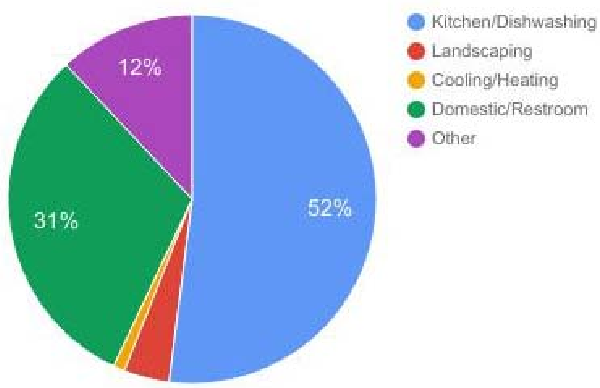


Figure 6-16. *End use of water in restaurants. (Source: US EPA)*

	Gallons per day	Gallons per year
Dishwashing	86.2	26,119
Food preparation	125	37,875
Cleaning	30	9,090
Toilet * Using greywater	90	27,270

[107] U.S. Environmental Protection Agency (2017). *Types of facilities - restaurants - end uses of water in restaurants.* https://www.epa.gov/watersense/types-facilities

Others	30	15,150
TOTAL * Minus greywater	**290**	**89,385**

Table 6-4. *Water use by category.*

By choosing a water efficient dishwasher carrying the Energy Star label, the daily use in the kitchen/dishwashing category can drop significantly. Based on the Hobart LXeR-2 automatic dishwasher and a volume of 10 dish racks per day, water use can be as low as 6.2 gallons per day[108]. With a low-flow aerator for the kitchen faucet/hose, an additional estimated 80 gallons of water per day are used. The food preparation water use includes water that is used as an ingredient, but this value is likely an overestimate given that the exact menu of the bakery is unknown. These water uses are summarized in Table 6-4 above.

To reduce water demand further, low-flow toilets with approximately 1.28 gallons per flush should replace any existing ones. Accounting for use by 15 employees and about 20% of the estimated 200 customers, the daily toilet water demand is estimated at 90 gallons.

6.6.1. Greywater System

To reduce the water use in the domestic/restroom category, the bakery will install a greywater system to reuse water from the kitchen sinks to flush the toilets. Greywater consists of water that has been previously used (such as a sink, clothes washer, or shower but excluding toilets) but is still clean enough to be reused with minimal treatment. Common greywater applications include toilets and outdoor irrigation[109]. Kitchen sink water, however, is not as common of a source for greywater since food particles and high grease content affect its reusability. Since the bakery will not have as many greasy dishes as a typical restaurant, we anticipate its water to be compatible as long as some initial filtration is in place. The kitchen sink water use – the greywater supply – is slightly less than the predicted demand, so it will be supplemented with a small amount of municipal water. Again, low-flow aerators on the handwashing sink in the bathroom will help conserve water. The NEXtreater system can treat and reuse approximately 200 gallons a day, which is the capacity of its storage tank[110]. It also comes with remote monitoring technology to track use and assist with upkeep.

[108] Hobart Corp. (2017). *LXeR and LXePR advansys hot and cold.* https://cdn2.webdamdb.com/md_dezp5gnPHlWS.jpg.pdf?v=1
[109] Greywater Action. *Manufactured greywater systems.* https://greywateraction.org/contentmanufactured-greywater-systems/
[110] Nexus eWater (2017). *Home drainwater treatment device cleans soapy drain water for recycling*. http://cdn2.hubspot.net/hub/409087/file-1201734735-pdf/pdf/NEXtreater.pdf?t=1495586194567

6.6.2. Distribution and Baseline Comparison

Water used in the kitchen should meet drinking standards, and for this reason the only source would be from the local municipal water distribution. By estimating and calculating water need for most equipment and dividing the need in five different categories: dishwashing, food preparation, cleaning, toilet and others, the total water demand is roughly 90,000 gallons per year (Table 6-4). There is an option of collecting rain water, but it is hardly justified for the bakery, to avoid redundancy with the other buildings that are collecting rainwater either because of their large roof (church) or high needs (school turned into greenhouse).

For further assessment, we compared our water usage to a local bakery in Hanover, Umpleby's Cafe, which uses 0.128 gal/ft^2 per day[111] whereas our estimation is 0.059 gal/ft^2 per day.

6.7. Environmental Benefits

The proposed bakery uses many energy and water efficient measures which make it feasible to obtain LEED Gold certification. The bakery redesign will preserve the historic architecture of the building while sustainably meeting the community's needs.

The sustainability features in the redesign will have a measurable impact on the building's energy and water use. The energy-saving HVAC measures in the bakery made it about 22% more efficient than if it used a traditional HVAC system[112] (a savings of over 75 million BTU/year). The biggest savings come from reducing the heat load of the building by recycling waste heat generated from the ovens.

We compared our proposed bakery's annual water usage to the water usage of a similar-scale bakery[113] in Hanover, NH, and saw a savings of 10,908 gallons per year. The annual water use of the proposed bakery amounts to about 1.45 gallons per person or 0.41 gallons per loaf of bread. The biggest savings are from reusing greywater within the building, as well as choosing efficient appliances.

The bakery would draw about 34,790 BTU per square foot per year from the grid, so about 62% of the energy would come from non-renewable sources. The other 38% of the energy would

[111] Umpleby, C. (12 May 2017). *Meeting with Charles Umpleby, owner of Umpleby's Bakery & Cafe in Hanover, NH.*
[112] Zehnder (2015). *Heat & energy recovery ventilation units.* http://zehnderamerica.com/products/heat-and-energy-recovery-ventilation-units/
[113] Umpleby, C. (12 May 2017). *Meeting with Charles Umpleby, owner of Umpleby's Bakery & Cafe in Hanover, NH.*

come from the photovoltaic cells on the roof, a renewable source. The CO_2 footprint for the energy drawn from the grid is approximately 30,200 kg of CO_2 per year[114].

6.7.1. LEED-Gold Certification

The proposed bakery can feasibly obtain a LEED Gold certification[115] with a score of 62 points. The minimum score to achieve Gold is 60. The detailed point calculation is provided in Appendix E, but a few select categories are worth being highlighted here.

The category with the highest points is energy. Efficient appliances, lighting and HVAC help reduce energy consumption, and removing the need for space heating (via oven heat recovery) saved a significant amount. The next significant category is water efficiency, and significant savings were generated by the selected water-efficient dishwasher as well as the greywater system. The existing building's designation as a historic site also factored into the LEED certification.

6.8. Social Benefits

A crucial part of the redesign project is that the new use benefits the community. The café in the bakery would be a friendly social space for Southbridge residents, and the bakery would donate baked goods to local food-based charities. In addition, we envision a teaching space where Southbridge residents could learn useful baking skills in community classes. This teaching space could also bring in revenue from tourists who would visit Southbridge to become "bakers for a day" in connection with the proposed bed & breakfast for the rectory building. Lastly, one of the goals of the town of Southbridge is to encourage businesses that provide job training. Our bakery would employ approximately 14 people (6 full time, 8 part time) and would provide training to work in the foodservice industry and gain specialized baking skills.

---

[114] Cushman-Roisin, Benoit (2017). *Useful Numbers for Environmental Studies and Meaningful Comparisons*. http://engineering.dartmouth.edu/~d30345d/books/Numbers/Chap4-Pollutants.pdf

[115] U.S. Green Building Council. (2016). *Checklist: LEED v4 for building design and construction*. http://www.usgbc.org/resources/leed-v4-building-design-and-construction-checklist

6.9. Economic Considerations

6.9.1. Estimated Cost of Retrofit

One of the first steps to having an energy efficient building is to ensure that it has a good thermal envelope. As mentioned previously (Section 6.5.1), our goal is to have R40 insulation for the walls and R60 insulation for the roof. The windows should be replaced with triple-pane, argon-filled windows. In total, there are 19 basement windows and 53 standard windows in the bakery. Based on construction costs[116] in Springfield, MA, replacing 10 3x5 double-hung windows costs $14,939. We assume an additional cost factor for the triple-pane, argon-filled windows, and since the awning windows for the basement are smaller than 3x5 we assume a reduced cost factor. The total window replacement cost for the bakery is ultimately estimated to be $119,000.

For wall insulation, a combination of 10-inch thick spray-fill cellulose and 1-inch thick Polyiso foam board is chosen to achieve a combined R43 value[117]. Based on the building floor plans, the total estimated wall area is 4,956 ft^2. At a cost of $0.24 per board ft (square feet x inch thickness), the cellulose insulation costs $11,900. At a cost of $0.39 per ft^2 for 1-in thick Polyiso foam board, the foam insulation costs $1,900.

For roof insulation, a combination of 4-in thickness spray-fill fiberglass and 6-in thickness Polyiso foam board is chosen to achieve a combined R-value of 62. With an estimated roof angle of 30°, there is approximately 3,338 ft^2 of roof area to be insulated. At a cost of $0.28 per board foot, the spray-fill fiberglass costs $3,700. Combining a 4-in layer and a 2-in layer of Polyiso foam board at $1.74 per ft^2, the foam board costs a total of $6,200.

Table 6-5 recapitulates and sums up the various costs associated with the improved thermal envelope.

Insulation Type	Unit price	Cost
Windows - triple pane argon	N/A	$119,000
Wall insulation: Polyiso foam	$0.39/ sq ft	$1,900

[116] Hanley Woods Media Inc. "Remodeling 2017 cost vs. value report." *Cost Vs. Value.* 2017.
[117] Wilson, A. (25 July 2013). *Getting to know spider insulation.* http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/getting-know-spider-insulation

Wall insulation: spray-fill cellulose	$0.24/ board ft	$11,900
Roof insulation: spray fiberglass	$0.28/ board ft	$3,700
Roof insulation: Polyiso foam	$1.74/ sq ft	$6,200
TOTAL		**$142,700**

Table 6-5. *Cost of thermal insulation including window replacement.*

Table 6-6 adds the costs of the various pieces of equipment necessary for running the bakery operations, yielding a total of $50,000.

Equipment	Cost	Equipment	Cost
Baker's Pride BCO-E oven (x2)	$7,000	Toto Eco Drake low-flow toilet (x2)	$1,022
Hobart LXeR dishwasher	$7,200	Pan racks (x10)	$1,500
Atosa MBF8503 freezer	$2,600	Proofer	$6,000
Atosa MBF8507 fridge	$2,050	Kitchen sink	$500
Ryoden RT-100 dumbwaiter	$7,000	Other	$9,128
NEXtreater greywater system	$6,000		
		TOTAL	**$50,000**

Table 6-6. *Cost of major appliances and equipment.*

Before it can be insulated, the current leaky roof must be entirely replaced and reshingled, and support beams must be added before the second floor is removed; the estimated construction cost is around $100,000. We plan to add a wraparound porch for the bakery's seating area, as shown in the proposed design plans, and the estimated construction cost for the porch is $20,000. The proposed solar array will cost $20,000, and the cafe furniture will cost around $15,000. This brings the total renovation costs to a first total of $347,700. To account for other construction and incidental costs not detailed here, an extra cost factor of 1.5 is included for a grand total of $521,550 (Table 6-7).

Item	Cost
Roof replacement and support beams	$100,000
Insulation and window replacement	$142,700
Equipment	$50,000

Porch construction	$20,000
Furniture	$15,000
Solar Panels	$20,000
PRELIMINARY TOTAL	$347,700
ADJUSTED TOTAL (x 1.5)	**$521,550**

Table 6-7. *Summary of renovation costs.*

6.9.2. Estimated Annual Revenues and Costs

Energy and water cost:

The bakery's annual energy demand from the grid is approximately 49,856 kWh, once the supply from the onsite solar panels is subtracted (see Section 6.5). Based on a local energy price[118] of 7.38 ¢ per kWh, the electricity cost is about $3,680 per year.

The bakery's annual water use is projected at 89,385 gallons per year (Section 6.6). In addition, the heat recovery system will be used to provide hot water to the Garden of Eden greenhouse, the former school building, totaling 87,034 gallons per year. The combined water demand is therefore 160,118 gallons per year, or 21,405 cubic feet. At current Southbridge municipal water and sewer prices[119], the annual water cost is about $1,912.

Production and employment:

The projected sales for the bakery include revenue from approximately 200 walk-in customers per day as well as wholesale deliveries to restaurants and grocery stores in the surrounding area. The anticipated output of 700 loaves of bread per day[120] will include 400 loaves to walk-in customers at a price of $4 each and 300 loaves via delivery at a price of $3 each. Combined, the daily revenue is $2,500. The bakery will be open 6 days a week, and accounting for holidays there will be 303 operational days per year. As a result, the bakery's yearly revenue is projected to be $757,500. In the foodservice industry[121], revenue can be approximately divided into thirds: ⅓ food costs, ⅓ wages and operating costs, and ⅓ profit. Therefore, the bakery is projected to make $252,700 per year in profit.

[118] Electricity Local (2017). *Southbridge, MA electricity statistics*. http://www.electricitylocal.com/states/massachusetts/southbridge/

[119] San Angelo, R. (30 June 2016). *Town of Southbridge water fees and charges*. http://www.ci.southbridge.ma.us/sites/southbridgema/files/file/file/2016-17_water_sewer_rates_0.pdf

[120] Reference for Business. (2017). *Bread bakery business plan.* http://www.referenceforbusiness.com/business-plans/Business-Plans-Volume-05/Bread-Bakery-Business-Plan.html

[121] Locsin, Aurelio. *The average profit margin for a restaurant.* http://smallbusiness.chron.com/average-profit-margin-restaurant-13477.html

The bakery is expected to employ 14 people total, with 6 full-time and 8 part-time. A master baker will supervise both full and part-time bakers. There will be a manager, assistant manager, custodial staff, cafe waiter staff, a delivery driver, and a supervisor for the instructional classes.

7. Grounds and Outdoor Features

Student Team: Christian N. Kwisanga, and Kelsey E. E. Phares
Teaching Assistant: Danielle Castley

7.1. Description of Current Grounds

Currently, the 4-acre Sacred Heart Church campus is mostly paved with driveways and parking areas (Figure 7-1), except for some lawn and mature trees on the north side, facing Charlton Street (Figure 7-2). There is no connection with the Quinebaug River in the rear, and the place is hardly inviting.

Figure 7-1. *Typical sights on the Sacred Heart Church campus with paved driveways and parking areas.*

Figure 7-2. *Lawns and mature trees between rectory and convent.*

Without well-planned landscaping, the set of repurposed buildings, no matter how much their indoor functions might be complementary, would remain unconnected to each other. Since the goal of the campus is to bring various communities together through different activities, choices for pathways, plantings, seating, and parking should all contribute to an overall theme of community, sustainability, and beauty. The goal is to create a communal center out of multiple buildings, *i.e*. a true campus. The grounds should become a courtyard.

In addition, the outdoor spaces can strive to incorporate environmental components that reduce rainwater runoff and promote connection with nature and among people.

7.2. Alcohol Perimeter

First and foremost, in order to have a campus with outdoor activities that include alcohol, a perimeter needs to be established surrounding the campus and courtyard within which people can congregate outside with their alcohol and listen to live music courtesy of the converted garage. Referring to Figure 7-3, a shrub barrier is suggested to connect the rectory and church's north-facing walls, as well as the church's south wall with the brewery's east-facing wall. The other two red lines on Figure 7-3 that work to enclose the campus and create a central courtyard should be archways that allow guests that enter the campus an entry and exit point.

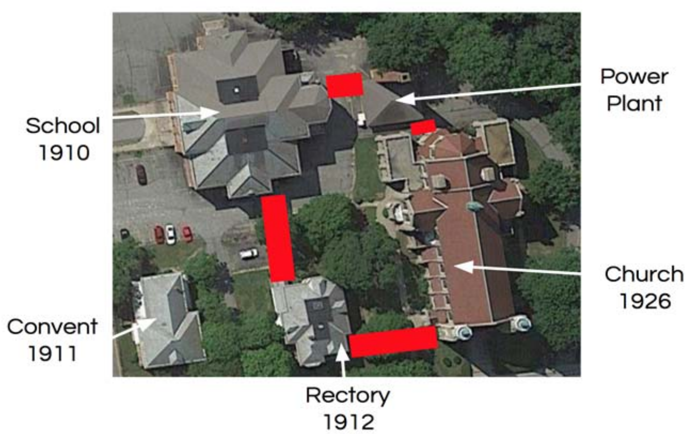


Figure 7-3. *Location of proposed perimeter enclosure for outdoor alcohol consumption.*

The entry point to the south that grants guests access to the campus after parking in the lot would work as a station where a part-time security guard could hand out wristbands during outside events during which alcohol is served. The second archway to the east would allow guests to visit the bakery during their campus visits, acting as a gate in and out of the campus with wristband checks. During evenings and nights with no outdoor activities, the archways would merely be unmanned and serve as aesthetic entry points to the campus.

This central campus concept would require removing the pavement of the central parking lot to create a grass lawn contoured with landscaped walkways and overhead twinkle lights. This would give the vibe of a beer garden, as patrons buy local beer, stay in a historical-themed B&B, and eat campus grown produce in the restaurant.

7.3. Some Ideas that Combine Utility with Aesthetics

The beautiful glass and stained glass features around the complex can be continued in the landscaping plan through the use of glass fragments in the concrete used for pathways, on sculptures and figures around the open areas, and on covered seating areas. To reduce the need for major year-round landscaping, the landscape should include plants that can either survive throughout New England winters like evergreen trees or lose foliage each fall and return to life in the spring without added fertilizer. In order to reduce watering of plants and grass, native plants should be chosen because they are adapted to the amount of rain that the area receives. In addition, for plants that need a small amount of additional watering, a water collection amphitheater could be constructed on the grounds to collect excess water in an underground cistern during times of rain that can be used to water plants during drier times.

7.3.1. Water collection amphitheater

Because of the rainy nature of New England, an excavated rainwater collection amphitheater (Figure 7-4) could be constructed in the central area of campus to collect rainwater that might otherwise flood the campus, potentially drowning plants and covering sidewalks. During dry times, the amphitheater would be a great place for visitors to relax and talk, for small performances to occur, and for visitors to the brewery/bar to drink their beverages. A potential addition would be a draining tank underneath the amphitheater to reduce the amount of standing water after a rain (or when snow is melting); this rainwater can be captured and used to water the landscape when necessary. A water collection amphitheater/cistern also protects the environment from pollutants emitted from the surrounding buildings that would otherwise drain into the groundwater or river.

Figure 7-4. *Example of a water collection amphitheater, which serves the dual purpose of impounding water after rainstorms and outdoor performance arena in dry periods[122].*

7.3.2. Transportation, Parking, and Solar Car Covers

Due to the high traffic nature of the restaurant, bed and breakfast, and brewery, parking is a necessity on site. When renovations are underway, we suggest regrading and repaving the parking lot so that there is a slight slope into a drain that can collect potentially toxic runoff from cars that would otherwise pool underneath vehicles or run off into the river. In between parking levels there should be green medians that can also absorb rainwater and sidewalks so that pedestrians are not required to walk in the parking lot to enter the campus. Also, in order to make the campus more sustainable, the parking lot and several of the buildings will feature decorative bike racks so that visitors are encouraged to ride their bikes to the campus during low traffic times.

Figure 7-5. *Examples of solar car covers, which would provide shade in summer and protection from snow in winter[123].*

[122] http://indohoy.com/selasar-sunaryo-art-space-an-artsy-place-to-hang-out-in-bandung-west-java/
[123] https://www.r-e-a.net/upload/rea-bre_solar-carpark-guide-v2_bre114153_lowres.pdf
https://solarthermalmagazine.com/wp-content/uploads/2015/04/Solarcity-JS-Beam-carport-parking-structure.jpg

Since parking lots are generally unattractive areas that don't serve a purpose beyond parking vehicles, the complex could install solar car park covers (Figure 7-5). The solar car covers could be positioned at the optimal angle for solar energy collection that could be used to power outdoor lighting around the campus, as well as any buildings that may need it. A car park of a similar size at the Harvey Hadden Sports Village in Nottingham, England has 40 parking bays, each with 67kWp capacity, and produces 50,000 kWh per annum[124].

Though not an enormous amount of generated energy, the solar power could help push the entire complex into a higher LEED certification level and produce power for the complex. The solar covered car park could also have a few solar car hook ups and be a draw for people in future years driving through Southbridge in electric cars and need to charge, as well as a benefit for people who would appreciate non-direct sunlight on their cars in the summer, and protection from snow in the winter.

7.3.3. Covered Trellises

To protect pedestrians from the elements while also able to enjoy the warm summer days and snowy winter evenings, the complex could invest in covered trellises with seating (Figure 7-6).

Figure 7-6. *Examples of outdoor covered furniture and trellis that can serve as seating places along paths[125].*

[124] C Jackson and G Hartnell. BRE (2016) *Solar Car Parks: A Guide for Owners and Developers.* https://www.r-e-a.net/upload/rea-bre_solar-carpark-guide-v2_bre114153_lowres.pdf
[125] Mflandscapeanddesign.com and ubifence.com

Over the summer, the trellises can have wisteria growing in them to provide shade from the sun and produce beautiful smells to fill the entire campus. In the winter, temporary backings can be placed behind the open back to protect from the wind and cold. Ultimately, the idea is for visitors to the complex to be able to enjoy the renovations and nature of New England while naturally protected from the elements while giving the campus an enchanting feeling, especially if stained glass is built into the semi-open sides of the trellises.

7.3.4. Stained Glass Walkways

Finally, to complete the enchanting, semi-religious theme of the grounds, we suggest emulating the style of Spanish architect Antonio Gaudi, whose love of stained glass permeated most of his works across Barcelona and Spain. Crushed glass could be mixed into the concrete (Figure 7-7) used to make the sidewalks throughout the campus and in the green space in the car park. Stained glass and colored ceramic tiles could also be used to create mosaic patterns in the walkways to make them more interesting and make people more likely to take a walk around the campus where they might find a new venue to visit and more items to purchase.

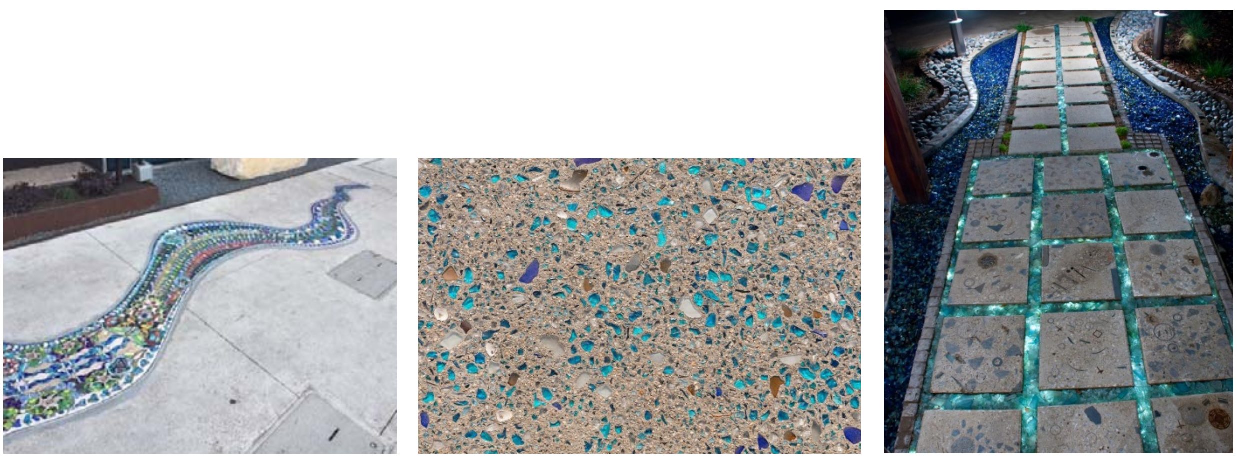


Figure 7-7. *Examples of stained glass walkways[126].*

7.4. Re-Purposing of the Rectory Garage

The rectory grounds also contain a detached two-car garage. Its current primary purpose is for storage (Figure 7-8).

[126] www.bloglovin.com/blogs/we-built-this-city-3458982/beautiful-stained-glass-sidewalk-inlay-at-5516964463
Fineartamerica.com and Greenstrides.com

Figure 7-8. *The garage behind the rectory in its current state.*

For the garage space to be converted into an outdoor entertainment center, two adjoining walls will be knocked down with a post left in the corner. This will open up the space for live entertainment to project their sound all around. A few conventional updates will be installed to meet sound and power requirements of typical live performances.

The external dimensions of both the garage were measured, approximating 2,025 ft^2 of floor space with 40' x 40' x 16' of usable space.

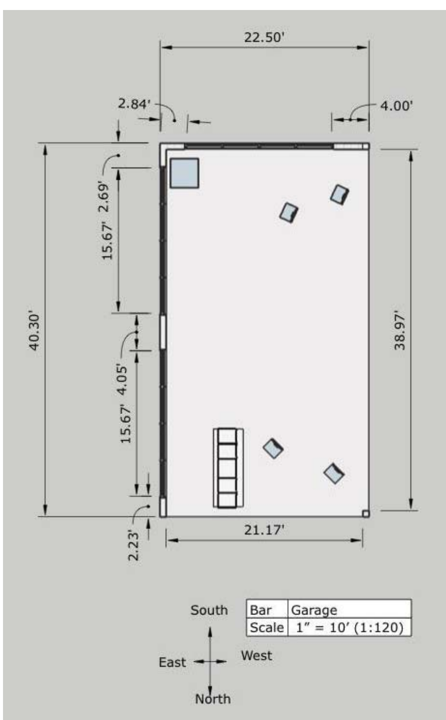


Figure 7-9. *Floor plans of repurposed garage.*

Figure 7-10. *Garage conversion into outdoor entertainment.*

7.5. Connection with Other Side of River

The Sacred Heart Church campus is bordered on its southern side by the Quinebaug River. At present, with the entrance to the campus on Charlton Street on the northern side, the river side gives the impression of a back yard. It is further curtained off the campus by a row of trees (Figure 7-11).

Figure 7-11. *A view of the river in late winter.*

Yet, a river holds much aesthetic potential, and moreover the main part of the Downtown Opportunity Area identified in Southbridge's 2016 Economic Development Plan (Figure 1-4) lies immediately across the river. Thus, it seems imperative to capitalize on the river and to create a connection across it to the rest of the downtown area. In addition, the repurposing of the school as an indoor farm calls for parking with solar shades (Section 4.6.2, Figure 4-14).

It is suggested that the row of trees along both banks be replaced by low bushes and/or a pretty wooden fence (for safety reason), and that a pedestrian bridge or two be constructed to connect with the major parking areas on the opposite side. An effort should also be made to landscape the rear of the buildings along the river to create the impression that the river side is as much as a front entrance as the street side.

Appendix A: LEED-Gold Points for the Church Building

Summary:

Category	Points Available	Points Sought
Innovation in Operations (IO) Find innovative ways to enhance your home's efficiency, comfort and durability.	6	2
Regional Priority (RP) Select property that is close to work, school, shopping, access to mass transit, etc.	4	0
Sustainable Sites (SS) Protect natural habitat, minimize the effect of storm runoff and water usage on site, etc. through non-destructive construction practices and site development.	26	7
Water Efficiency (WE) Reduce water usage in your home and find creative ways to reuse it, inside and out.	14	12
Energy & Atmosphere (EA) Cut the energy usage of your home and resulting environmental pollution, mainly through improvements to the building envelope and heating and cooling system design.	35	31
Materials & Resources (MR) Sustainable purchasing and solid waste management	10	8
Indoor Environmental Quality (EQ) Minimize the creation of and exposure to pollutants and maximize fresh air indoors through energy efficient means.	15	6
	110	**66**

LEED-Gold is attained by garnering more than 60 points.

Water Efficiency	**Points Available**	**Points Sought**	**Strategy**
Prerequisite: Minimum indoor plumbing and fixture and fitting efficiency	Required	0	Do so
Credit 1 Water performance measurement	1 to 2	2	Submetering of indoor plumbing and domestic hot water
Credit 2 Additional indoor plumbing fixture and fitting efficiency	1 to 5	5	Must reduce potable water use by 30% from baseline calculated in prerequisite
Credit 3 Water efficient landscaping	1 to 5	5	Reduce potable water use from irrigation by 100% by catching water on roof
Credit 4.1 Cooling tower water management - chemical management	1	0	Not doing water cooling tower
Credit 4.2 Cooling tower water management – non-potable water source use	1	0	Not doing water cooling tower
	14	**12**	
Energy and Atmosphere	**Points Available**	**Points Sought**	**Strategy**
Prerequisite 1 Energy efficiency best management practices	Required	0	Do so
Prerequisite 2 Minimum energy efficiency performance	Required	0	Do so
Prerequisite 3 Fundamental refrigerant management	Required	0	Do so
Credit 1 Optimize energy efficiency performance	1-18	15	Be in 39th percentile level above the national median (for similar buildings)

Credit 2.1 Existing building commissioning, investigation and analysis	2	2	Do a breakdown of energy use in building to ASHRAE standards
Credit 2.2 Existing building commissioning – Implementation	2	2	Implement findings of energy analysis
Credit 2.3 Existing building commissioning – Ongoing commissioning	2	2	Continue to implement plan
Credit 3.1 Performance measurement – Building automation system	1	1	Install a system that monitors and controls all energy use in the building
Credit 3.2 Performance measurement – System Level Metering	1-2	2	Install metering system (continuous and data logged) for 2/3 of the major energy systems
Credit 4 On-site and off-site renewable energy	1-6	6	Of the total energy used 12% must be from onsite renewable energy
Credit 5 Enhanced refrigerant management	1	0	Do not use refrigerants in HVAC system or use refrigerant that eliminate emissions relating to climate change
Credit 6 Emissions reduction reporting	1	1	Identify, track and report emissions reductions using a 3rd party
	35	**31**	
Sustainable Sites	**Points Available**	**Points Sought**	**Strategy**
Credit 1 LEED Certification design and construction	4	0	Show that the building has previously been certified under LEED new construction and major renovations
Credit 2 Building exterior and hardscape management plan	1	1	Reduce harmful chemical use, energy waste, water waste, air pollution, solid waste and or chemical runoff

Credit 3 Integrated pest management, erosion control, and landscape management plan	1	1	Same as credit 2 however mostly aimed towards outdoor pest management, erosion and sediment control etc.
Credit 4 Alternative commuting transportation	3-15	3	Points calculated by percentage reduction in conventional commuting trips (Pg. 23) 10% gives us 3 points
Credit 5 Site development - protect or restore open habitat	1	1	Native or adaptive vegetation covering 25% of site excluding footprint
Credit 6 Stormwater quality control	1	1	Greater than 15% of precip must infiltrate be collected and renewed or evapotranspiration
Credit 7.1 Heat island reduction - non roof	1	0	50% of site hardscape should be shaded
Credit 7.2 Heat island reduction - roof	1	0	Use roofing materials with SRI
Credit 8 Light pollution reduction	1	0	Interior lighting should all be automatically controlled and monitored
	26	**7**	
Materials and Resources	**Points Available**	**Points Sought**	**Strategy**
Prerequisite 1 Sustainable purchasing policy	Required	0	
Prerequisite 2 Solid waste management policy	Required	0	
Credit 1 Sustainable purchasing - ongoing consumables	1	1	Paper, toner cartridges, binders batteries and desk accessories should contain 10% post-consumer material, 50% rapidly renewable materials, 50% of materials harvested and processed within 500 miles, batteries are rechargeable

Credit 2.1 Sustainable purchasing – Electric powered equipment	1	1	40% of equipment should be electric powered
Credit 2.2 Sustainable purchasing - Furniture	1	0	Sustainable purchases of at least 40% of furniture
Credit 3 Sustainable purchasing - Facility alterations and additions	1	1	Base building element purchases contain 70% of material salvaged onsite
Credit 4 Sustainable purchasing – Reduced mercury in lamps	1	1	Low-mercury content lamps or LED lights
Credit 5 Sustainable purchasing - Food	1	0	25% of total food and beverages should be labelled sustainable or produced within 100 miles
Credit 6 Solid waste management – Waste stream audit	1	1	Audit consumables waste stream and set baseline for improvements
Credit 7 Solid waste management – Ongoing consumables	1	1	Reuse, recycle or compost 50% of the ongoing consumables
Credit 8 Solid waste management – Durable goods	1	1	Reuse or recycle 75% of the durable goods (office equipment, appliances etc.)
Credit 9 Solid waste management – Facility alterations and additions	1	1	Divert 70% of waste by alterations and additions from disposal to landfills and incineration facilities (redirect to manufacturing process etc.)
	10	**8**	
Indoor Environmental Quality	**Points Available**	**Points Sought**	**Strategy**
Prerequisite 1 - minimum indoor air quality performance	Required	0	
Prerequisite 2 - environmental tobacco smoke control	Required	0	
Prerequisite 3 - green cleaning policy	Required	0	

Credit 1.1 Indoor air quality best management practices - Indoor air quality management plan	1	0	IAQ management plan based on EPA guidelines
Credit 1.2 Indoor air quality best management practices - outdoor air delivery monitoring	1	0	Install monitoring systems that provide feedback on ventilation system performance
Credit 1.3 Indoor air quality best management practices - Increased ventilation	1	0	Increase outdoor air ventilation rates for all air-handling units serving occupied spaces by at least 30% above min ASHRAE requirement
Credit 1.4 Indoor air quality best management practices - reduce particulates in air distribution	1	0	Filtration media with min efficiency reporting value of 13 or greater
Credit 1.5 Indoor air quality best management practices - indoor air quality management for facility additions and alterations	1	0	IAQ management plan for construction and occupancy phases
Credit 2.1 Occupant comfort - Occupant survey	1	1	Comfort survey and complaint system about thermal comfort, acoustic, IAQ, lighting levels, building cleanliness from at least 30% of occupants.
Credit 2.2 Controllability of systems - Lighting	1	1	For at least 50% of building have adjustable lighting controls
Credit 2.3 Occupant comfort - Thermal comfort monitoring	1	1	Have continuous tracking and optimization of systems that regulate indoor comfort and conditions (air T, humidity, air speed, radiant T)
Credit 2.4 Daylight and views	1	0	Demonstrate that 50% or more of regularly occupied spaces achieve daylight illuminance levels of a minimum of 25 fc and maximum of 500 fc.

Credit 3.1 - Green cleaning - high performance cleaning program	1	1	Appropriate staffing plan, training in hazards and use of equipment and products, use sustainable materials in all aspects of cleaning
Credit 3.2 - Green cleaning - custodial effectiveness assessment	1	0	Conduct an audit in accordance with APPA custodial staffing guidelines
Credit 3.3 - Green cleaning - purchasing of sustainable cleaning products and materials	1	1	30% of total annual products purchased are Green Seal
Credit 3.4 - Green cleaning - sustainable cleaning equipment	1	0	Janitorial equipment should reduce building contaminants eg. certified vacuum cleaners, battery powered equipment uses environmentally preferable gel batteries
Credit 3.5 - Green cleaning - indoor chemical and pollutant source control	1	0	Install grilles, grates, or mats at least 10ft long in primary direction of travel to capture dirt and particulates entering the building at all public entry points
Credit 3.6 - Green cleaning - indoor integrated pest management	1	1	Develop, implement and maintain an integrated pest management plan to manage indoor pests and protect human health
	15	**6**	

Innovation in Operations	Points Available	Points Sought	Strategy
Credit 1 Innovation in operations	1 to 4	0	Achieve significant, measurable environmental performance using an operations, maintenance or system upgrade strategy not addressed in LEED 2009
Credit 2 LEED accredited professional	1	1	1 principal participant of the project team shall be a LEED accredited professional
Credit 3 Documenting sustainable building cost impacts	1	1	Document building operating costs and financial impacts of all aspects of the building on an ongoing basis

	3 to 6	**2**	
Regional Priority	**Points Available**	**Points Sought**	**Strategy**
Credit 1 Regional priority	1 to 4	0	
	1 to 4	**0**	

Appendix B: Energy Calculations for the School Building

B.1. Electricity Supply with Photovoltaics

Area of S roof	170.6	m^2		Area of solar carport	4000	m^2
Solar panel W/ft^2	10	W/ft2		Solar panel W/m^2	148	W/m^2
	148	W/m^2			148	W/m^2
	0.148	kW/m^2			0.148	kW/m^2
Efficiency	0.5			Efficiency	0.5	
Sun days in MA	4.5	kWh/m^2/day		Sun days in MA	4.5	kWh/m^2/day
kWh supplied	56.8	kWh/day		kWh supplied	1,332	kWh/day
	20736	kWh/year			486,180	kWh/year
TOTAL kWh supplied	**506,916**	**kWh/year**				

Electrical supply	506,916	kWh
Electrical demand (kWh)	617,375	kWh
Demand met	82.11%	

B.2. Heat Load Pre-Renovations

Month	Heating Degree Days	Conduction Heat Loss (BTU/month)	Infiltration Heat Loss (BTU/month)	SHGF (BTU/month)	Net Monthly Flux (BTU/month)
April	605.9	104639737.9	177320270.4	38020183.2	-243939825.1
May	309.4	53433792.53	90547766.4	38254351.56	-105727207.4
June	91.3	15767631.73	26719492.8	40482102.24	-2005022.293
July	28.2	4870177.6	8252899.2	45026591.92	31903515.12
August	13.6	2348738.133	3980121.6	51079125.96	44750266.23
September	123.6	21345884.8	36172281.6	46201008.96	-11317157.44
October	436.8	75435942.4	127832140.8	47150045.75	-156118037.5
November	686.3	118524925.1	200849812.8	32942167.2	-286432570.7
December	1091.4	188486235.2	319404758.4	25978997.06	-481911996.5
January	1087.3	187778159.7	318204868.8	35336154.41	-470646874.1
February	920.6	158988847.5	269419113.6	38440719.21	-389967241.9
March	1090	188244453.3	318995040	42437540.97	-464801952.4

B.3. Heat Load Post-Renovations

Month	Heating Degree Days	Conduction Heat Loss (BTU/month)	Infiltration Heat Loss (BTU/month)	SHGF (BTU/month)	Net Monthly Flux (BTU/month)
April	605.9	20402994.44	88130820.96	38020183.2	-70513632.2
May	309.4	10418693.65	45003591.36	38254351.56	-17167933.44
June	91.3	3074423.82	13279986.72	40482102.24	24127691.7
July	28.2	949602.9763	4101814.08	45026591.92	39975174.87
August	13.6	457964.5559	1978179.84	51079125.96	48642981.57
September	123.6	4162089.641	17978163.84	46201008.96	24060755.48
October	436.8	14708743.97	63534481.92	47150045.75	-31093180.15
November	686.3	23110373.14	99825354.72	32942167.2	-89993560.66
December	1091.4	36751655.61	158748932.2	25978997.06	-169521590.7
January	1087.3	36613592.77	158152569.1	35336154.41	-159430007.5
February	920.6	31000159.57	133905320.6	38440719.21	-126464761
March	1090	36704512.2	158545296	42437540.97	-152812267.2

B.4. Cooling Energy Load post-renovations

Month	Cooling Degree Days	Conduction Heat Gain (BTU/month)	Infiltration Heat Gain (BTU/month)	SHGF (BTU/month)	Net Monthly Flux
April	22.8	767764.1085	3316360.32	38020183.2	42104307.63
May	56	1885736.407	8145446.4	38254351.56	48285534.37
June	108.4	3650246.902	15767256.96	40482102.24	59899606.1
July	239.6	8068257.912	34850874.24	45026591.92	87945724.08
August	223.5	7526108.695	32509058.4	51079125.96	91114293.06
September	81.4	2741052.563	11839988.16	46201008.96	60782049.68
October	7.4	249186.5966	1076362.56	47150045.75	48475594.9
November	0.1	3367.386441	14545.44	32942167.2	32960080.03
December	0	0	0	25978997.06	25978997.06
January	0	0	0	35336154.41	35336154.41
February	0.4	13469.54576	58181.76	38440719.21	38512370.51
March	0	0	0	42437540.97	42437540.97

Adding the eight months of projected heat deficit from B.3 and the four months of projected cooling energy needs from B.4, we find the total annual space heating and cooling for the structure will require just over 2.1 billion BTUs or approximately 84,000 BTUs per square foot. This demand is designed for and met the geothermal and heat pump system of church building.

Appendix C: Calculations of Water Needs for Greenhouse Operations

The primary water needs in greenhouse operations stem from (1) hydroponics, (2) mushroom cultivation, (3) aquaponics, and (4) conventional domestic needs.

C.1. Hydroponics

Freight Farms[1] estimates 1.56-3.124 gallons of water needed per 100 ft^2 per day (for 5 ft tall towers) → 3 gallons per 100 ft^2 per day (conservative estimate) → 3 x 365 x 5344/100 = 58,522.28 gallons per year.

A regular greenhouse's water intensity[2] is 0.3 gallons per ft^2 per day. We would use: 0.3 x 365 x 5344 = 585,222.75 gallons per year → 1 - 58,522.28/585,222.75 = 0.9, a 90% improvement!

C.2. Mushroom Cultivation

The main water needs here are to pasteurize the substrate and to mist the substrate to induce fruiting and maintain the required humidity. One gallon of water is needed to pasteurize 5 lbs of substrate[3]. A 5-pound bag produces 0.3 lbs of produce → 1/0.3 = 3.33 gallon per lb → 3.33 x 2,825 = 226,000 gallons per year for pasteurization. Assuming overall need of 1 gallon for misting/washing per 5 lbs of produce → 2,825/5 = 13,560 gallons per year for misting. Overall annual need for the oyster mushrooms we are producing: 226,000+13,560 = 239,560 gallons per year.

C.3. Aquaponics

Since fish water cycles through the hydroponic towers and gets purified in the process, we estimate that the water in the fish tanks would have to be completely replaced only once a year. Therefore, the annual water demand of the fish tanks equals the volume of the tanks, 80,505 gallons per year.

C.4. Conventional Domestic Needs

1 https://www.freightfarms.com/features
2 https://ag.umass.edu/greenhouse-floriculture/fact-sheets/sizing-greenhouse-water-system
3 https://www.chelseagreen.com/blogs/indoor-oyster-mushrooms-small-spaces/

The typical water use of a commercial building, including ventilation, sanitation, kitchen, and all other uses come out to 20-35 gallons per day per employee[4]. Since we are planning to have very water efficient appliances, we worked with 20 gallons per day per employee. We will have 17 full time employees, 9 part-time, and 12 shared across campus. Since we are providing the administrative space for all campus-shared employees, the water demand by employee was weighted in the following manner: Full time employee 100%, part time employee 50%, shared employee 75%. It was assumed that employees would on average be in the building 5 days a week for 50 weeks of the year. Thus, the annual domestic water use is estimated at:
20 x (1.00 x 17 + 0.50 x 9 + 0.75 x 12) x 5 x 50 = 152,500 gallons per year.

C.5. Rainwater Supply

Area of roof							
	Southern face	170.6	Collecting on entire roof				
	Northern	170.6		Area available:	910		
	Eastern	284.4					
	Western	284.4					
	Total	910					
Rainfall in MA		Inch	Meters	80% efficient catchment		Water collected	
	Jan	4.09	0.103886	0.0831088		75.629008	
	Feb	3.58	0.090932	0.0727456		66.198496	
	March	4.61	0.117094	0.0936752		85.244432	
	April	4.72	0.119888	0.0959104		87.278464	
	May	3.94	0.100076	0.0800608		72.855328	
	June	4.49	0.114046	0.0912368		83.025488	
	July	4.53	0.115062	0.0920496		83.765136	
	August	4.03	0.102362	0.0818896		74.519536	
	Sept	4.09	0.103886	0.0831088		75.629008	
	Oct	4.92	0.124968	0.0999744		90.976704	
	Nov	4.72	0.119888	0.0959104		87.278464	
	Dec	4.41	0.112014	0.0896112		81.546192	
	Total	52.13	1.324102	1.0592816		963.946256	m^3
						963946.256	Liters

[4] https://engineering.dartmouth.edu/~d30345d/courses/engs44/water.pdf

Appendix D: LEED-Gold Points for the Rectory Building

1. Sustainable Sites		
Credit	**Strategy**	**Points**
Alternative Transportation	Transportation surveys, bike racks, walkability	5
Rainwater Management	Water from roof and pavement diverted to rain garden	3
Heat Island Reduction	Provide shade over paved areas	2
Site Management	Site manager responsible for meeting criteria	1
Site Improvement Plan	5 year strategy to improve hydrology, vegetation, soil	1
	Total	**12**

2. Water Efficiency		
Credit	**Strategy**	**Points**
Outdoor Water Use Reduction	Reduce current water consumption by 40% by using rainwater to water lawn	2
Indoor Water Use Reduction	Retrofits on indoor plumbing structures (showerheads, toilets, faucets) must meet code, water-efficient appliances	5

Water Metering	Monitor water consumption	2
	Total	**9**

3. Energy & Atmosphere		
Credit	**Justification**	**Points**
Existing Building Commissioning	Energy audit, apply requirements to energy systems	4
Ongoing Commissioning	Develop plan to monitor building performance	3
Optimize Energy Performance	Perform 28% better than national average due to energy reduction with geothermal and solar panels.	4
Advanced Energy Metering	Permanent meter to record energy consumption data	2
Demand Response	Permanent load shifting system	2
Renewable Energy & Carbon Offsets	Using renewable energy	5
	Total	**20**

4. Materials & Resources	
Credit	**Points**
Purchasing - Ongoing Consumables and Electric-Powered Equipment	1

Purchasing - Lamps	1
Purchasing - Facility Maintenance and Renovation	1
Solid Waste Management - Facility Maintenance and Renovation	1
Solid Waste Management - Ongoing	1
Total	**5**

5. Indoor Environmental Quality	
Credit	**Points**
Indoor Air Quality Management Program	1
Enhanced Indoor Air Quality Strategies	1
Thermal Comfort & Indoor Lighting	2
Daylight and Quality Views	4
Green Cleaning - Custodial Effectiveness Assessment & Equipment	2
Integrated Pest Management	2
Occupant Comfort Survey	1
Total	**13**

Total LEED Credits	
Credit	**Points**
1. Sustainable Sites	12
2. Water Efficiency	9
3. Energy & Atmosphere	20
4. Materials & Resources	5
5. Indoor Environmental Quality	13
6. Regional Priority	4
Total	**63**

Certification Level	Points
LEED Certified	40-49
LEED Silver	50-59
LEED Gold	**60-79**
LEED Platinum	80+

Appendix E: LEED-Gold Points for the Convent Building

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Y	?	N			
1			Credit	Integrative Process	1
7	**1**	**2**		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
1			Credit	Sensitive Land Protection	1
1			Credit	High Priority Site	2
4			Credit	Surrounding Density and Diverse Uses	5
	1		Credit	Access to Quality Transit	5
1			Credit	Bicycle Facilities	1
		1	Credit	Reduced Parking Footprint	1
		1	Credit	Green Vehicles	1
5	**0**	**5**		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
1			Credit	Site Assessment	1
		2	Credit	Site Development - Protect or Restore Habitat	2
1			Credit	Open Space	1
3			Credit	Rainwater Management	3
		2	Credit	Heat Island Reduction	2
		1	Credit	Light Pollution Reduction	1
9	**0**	**2**		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
2			Credit	Outdoor Water Use Reduction	2
6			Credit	Indoor Water Use Reduction	6
		2	Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1
14	**3**	**5**		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
	3		Credit	Enhanced Commissioning	6
10			Credit	Optimize Energy Performance	18
1			Credit	Advanced Energy Metering	1
		2	Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
		1	Credit	Enhanced Refrigerant Management	1
		2	Credit	Green Power and Carbon Offsets	2