The Green Brewery Project

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Disclaimer

Unless otherwise explicitly stated, the views and opinions expressed herein do not necessarily represent those of the University of Michigan, the School of Natural Resources and the Environment, the Arbor Brewing Company, or any entity other than the members of the Green Brewery Project student team.

This document contains many forward-looking statements, including predictions of project costs, payback periods, performance characteristics, incentive award amounts, etc. Such statements are the results of careful analysis by the team, using the best information available at the time, and based on certain expectations and assumptions which are identified wherever possible. A variety of factors could cause the actual results to differ from predicted outcomes. Advice from qualified professionals should be sought to complement the advice contained herein.

Acknowledgements

The Green Brewery Project could not have been a success without the help of many people and organizations. First we would like to thank Matt and Rene Greff and all of the Corner Brewery Staff for allowing us to do this project and being cooperative with all of our questions and interruptions. Next we would like to thank our advisor Scott Noesen and consultant Greg Marker for helping us get started and guiding us along our journey.

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Most importantly, our extreme gratitude must go to our closest friends and family for supporting us over the past 16 months. Their behind-the-scenes work gave all of us the strength to continue working to make this project the best it could be.

Sincerely,

THE GREEN BREWERY PROJECT

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Abstract

The United States craft brewing industry has experienced a renaissance over the past thirty years, with over 1700 microbreweries and brewpubs operating in 2010.[1] Among them is the Corner Brewery, located in Ypsilanti, MI, the focus of this project. With its scope limited to on-site utilization (excluding upstream and downstream inputs), a comprehensive energy and water resources audit was undertaken in early 2010. Methods and findings are described in detail. Cooling applications used approximately 80% of total facility electricity use, with the glycol chiller for fermentation vessel cooling responsible for over 30% of total facility electricity use. Brewing and space heating together comprised approximately 80% of natural gas use, split roughly evenly between the two. Brewing and domestic hot water dominated facility water use, and followed seasonal trends. Numerous options for water and energy efficiency and renewable energy generation were explored. Over a dozen different scenarios utilizing solar power were examined. Using cost-benefit analysis, and with consideration given for ecological impacts, technical feasibility, site-dependent restrictions, and financial factors, a prioritized list of recommendations was created. Aspects of an employee, customer, and community education and engagement program are described. Finally, the Corner Brewery is situated in the context of sustainable practices in the craft brewing sector and businesses in general.

Executive Summary

Introduction

Goals and Objectives

The goal of the Green Brewery Project was to advise the owners of a Michigan microbrewery on how to best align the operation of their business more closely with their core values of environmental conservation, focusing on energy and water management. Additionally, the team aimed to spread awareness of more sustainable brewing practices throughout the craft brewing industry. Our client, the Arbor Brewing Company, operates a microbrewery-restaurant in Ypsilanti, MI called the Corner Brewery, which was the focus of this project

The team completed several key objectives to reach these goals. A resource audit mapped and measured the electricity, natural gas, and water flows throughout the facility. The results of this audit were analyzed, resulting in a prioritized list of recommended improvements to water and energy efficiency. Renewable energy generation options were explored in the context of the energy demands of the facility. Financial and environmental outcomes of all recommendations were explored to varying degrees. Finally, strategies to educate and engage employees, customers, and the community at large were articulated.

To extend the impact beyond the walls of the Corner Brewery, the team participated in two video documentaries (available online)[i,ii], an AM radio interview, an online podcast interview[iii], and presented its findings at the Brewers Association's annual Craft Brewers Conference in San Francisco in March, 2011. Social networking websites were also used to help the team reach the largest possible audience.

The Corner Brewery

The Corner Brewery is simultaneously a social space and a manufacturing plant. Located in the Historic District of Ypsilanti, it is what urban sociologist Ray Oldenberg calls a "Third Place"—a public space where one can visit with friends and neighbors, hosting regular gatherings and serving as a space for socialization outside of the home or workplace.[62] A member of the thriving

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[i] Williams, Laura. "Mastering the Challenge." Digital video recording. University of Michigan School of Natural Resources and Environment. 2010. http://www.youtube.com/user/umsnre#p/u/17/M-hyD00bczo

[ii] Nelson, Jay and Jimmy Rhoades. "Episode 308 – Green Brewery Project." Digital video recording. Out Of The Blue, University of Michigan. 2011. http://www.ootb.tv/index.html

[iii] Partan, Elsa. "Making Beer Brewing More Energy Efficient." Digital audio recording. 2010. http://www.onsetcomp.com/resources/archived-newsletters/reducing-energy-use-brewery

Michigan brewing industry, the Corner Brewery produced just over 3,000 barrels of beer (1 BBl = 31 gal) in 2010, and is in the midst of a major capacity expansion which could lead to doubling annual production by 2012. Our client is motivated to make cost-effective capital investments and process changes to ensure that the Corner Brewery grows in a more sustainable and resource-efficient way than business-as-usual.

Resource Audit

Methodology

The purpose of the resource audit was to disaggregate the water and energy budgets of the Corner Brewery into their component end-users, allowing the team to focus its efforts where the greatest gains could be realized. The audit began with an analysis of the most recent year's utility bills and a physical inspection of the facility. Dataloggers and other energy-measurement devices were used to monitor the energy usage of many individual electric devices, with data collection periods ranging from several days to several. A motor ON/OFF state datalogger was installed on the boiler blower fan in order to measure natural gas usage in brewing. Current amplifiers were used to monitor individual components of the glycol chiller and the air handler. Domestic hot water use was measured with a flow meter. Using these data sets, a model was developed to characterize and quantify the flows of energy and water throughout the facility.

Aggregate Resource Use

In 2010, the Corner Brewery used approximately 226,900 kWh of electricity, costing approximately $26,000. In the same year, 17,170 CCF of natural gas were used, at a cost of just over $18,000. The facility also used 804,100 gallons of water from a municipal source, costing nearly $8,700. Observed trends indicate that electricity use peaks in the summer to coincide with the cooling season and the peak period of beer production and on-site (i.e. at the bar) beer sales. Natural gas use peaks in the winter to coincide with the space heating season. Water use patterns appear to reflect monthly trends in beer production and on-site beer sales. A partial solid waste inventory was undertaken in this project, leading to options for solid-waste re-use and reduction.

Electricity

Approximately 80% of the electricity used by the Corner Brewery in 2010 was used for cooling applications. Of the total yearly usage, these applications included an average of 32% for the glycol chiller for wort cooling, 25% used for beer cold storage, 13% for ventilation and air conditioning, and 12% for food cold storage. Additionally, 10% of all electricity was used for lighting, 7% for compressed air and 1% was used for cooking and other applications.

The glycol chiller's compressor (excluding all other pumps and fans) was found to consume approximately 40% of the entire facility's electrical energy during the summer months. The chiller is nominally rated to provide 27 tons of cooling. However, it is currently operated at a very low partial load, averaging 1.47 tons at an average EER of 2.5 kBTU/kWh.

Natural Gas

Natural gas at the Corner Brewery was used primarily for brewing (40%) and space heating (39%). Domestic hot water used 16% of the total natural gas, and cooking used approximately 5%. The confidence in the brewing estimate is very high, while the estimates for the remaining applications is considerably lower, due to either small or incomplete datasets, or challenges associated with interpreting the available data.

Water

Surprisingly, only 37% of the water used at the Corner Brewery is used for brewing. The rest is used in the form of hot and cold water used outside of the brewhouse. The team estimates that the Corner Brewery uses over 1,000 gallons of domestic hot water per day (averaged over an entire year). For every gallon of beer produced, the entire facility uses 8.57 gallons of water. Focusing only on water used in the brewing process (including brewing equipment cleaning), the brewery uses 3.17 gallons of water for every gallon of beer produced. There are currently no efforts to reclaim, recycle, or treat wastewater.

Building Inspection

A visual and thermal inspection of the facility revealed significant infiltration and thermal insulation issues related to the windows throughout the building. The team also observed poor wall insulation, inefficient lighting, and sub-optimal use of ceiling fans. The roof appeared to be adequately insulated with a minimum estimated R-value of 24. Additional insulation could be added to yield some benefit, but would require installing a drop-ceiling, which would detract from the space's aesthetics. The floor is well-suited for hydronic radiant space heating, but would require installing a sub-floor, which could be very costly. The building's roof was found to be well-suited for deployment of solar panels.

Recommendations

Energy Efficiency

An Energy Management System, combined with systems designed to automate the process of collecting energy usage data throughout the facility, is the first step to establishing and retaining resource efficiency improvements, as well as identifying future opportunities for improvement. The same approach can be used to track and improve water efficiency. With better long-term production planning, more batches of beer could be brewed in succession in order to maximize the use of recovered heat from initial wort cooling. The brewhouse heat exchanger should be replaced with a larger model which can also be disassembled to facilitate cleaning, resulting in fewer contaminated batches. The steam distribution system should be periodically checked for leaks, and insulated with one-inch thick fiberglass which can be removed for pipe inspections. More attention should be given to regular maintenance of heating and cooling systems (steam, food cold storage, product cold storage, HVAC, etc.). In particular, heat exchange surfaces must be kept from fouling. The glycol chiller should be downsized to better match the actual chilling load at the brewery, and incorporate condenser-side heat recovery to pre-heat water and also achieve greater thermal efficiency. A related option is to install a water source heat pump to address fermentation cooling requirements at 68 degF. This solution includes heat recovery for water pre-heating, and leaves low-temperature cooling (24-44 degF) to a traditional air-source chiller—either the existing one, or a downsized replacement. This is a less-conventional approach, and should be thoroughly examined to prove technical feasibility prior to implementation.

Heat recovery systems should be installed in the brewkettle and the boiler stack, and if resources allow, in glass-washer drains. The boiler should have automatic controls to properly time its heating cycles and dynamically optimize fuel, combustion air and flue gas recirculation. The air intake for the brewhouse air compressor should be redirected to use outside air. Lights in the restaurant should be replaced with high-efficiency halogen and fluorescent lamps. Brewhouse lighting should be re-examined once all other brewhouse remodeling is complete. Windows in the restaurant should be sealed and fitted with movable, insulating shades. Ceiling fans should be used year-round to promote air circulation, with the direction of rotation reversed seasonally. Additional ceiling fans may be required for optimal summer cooling.

High-gravity brewing should be considered for low-ABV beer styles. The small grill should be replaced with a commercial oven. Strip curtains should be installed in all cold and cool storage areas, and a heat recovery wheel should be installed in the ducting to each conditioned space. The glass-door refrigerator should be replaced with an Energy Star-rated, solid-door model (if it is still required after remodeling). A radiant heat-reflective shield should be installed behind the fireplace.

Water Efficiency

Water efficiency recommendations were targeted at relatively simple, low-cost options to better measure and reduce water use. Water sub-metering, in the form of a few water meters in strategic places within the structure, will greatly help to measure water use in different zones and thus direct water conservation measures according to areas of biggest demand. Low-flow faucets and dual-flush toilets are recommended. A green “hop wall” façade should be cultivated on the south wall of the building, using roof rainwater catchment for irrigation. Other water projects, such as greywater reuse, wastewater treatment, and wastewater biogas were examined but are not recommended at this point because they are not cost-effective.

Renewable Energy Generation

The team recommends hybrid solar photovoltaic/thermal panels (PVT), which simultaneously produces electricity and hot water, as the single best option for on-site renewable energy generation. A 20 kW DC array enrolled in the DTE SolarCurrents program is expected to have a 6 year payback period, and maximize the net present value of this type of investment. Additional solar panels in excess of 20 kW DC—either solar PVT or solar photovoltaic-only (PV) panels—may be considered, with longer associated payback periods. Some of the panels should be mounted as an awning on the south wall to provide summer shading and maximize the project's visibility to customers. The hot water provided by the solar PVT panels and the other heat recovery projects previously described should allow the current boiler to be downsized. If needed, up-front costs can be reduced by switching some or all of the hybrid panels for photovoltaic-only panels, to the detriment of future returns.

Education and Marketing

There is more to establishing a "green brewery" than implementing efficiency measures and installing solar panels on the roof. A thread of sustainability must be woven throughout the business as a whole. The team recommends that the owners undertake a visioning process, staking out goals for the future and clearly defining how sustainability will be incorporated into all aspects of decision-making within the company, including management, operations, purchasing, marketing, and distribution. By incorporating sustainability education into employee training, behavioral changes will naturally lead to resource efficiency. Employees familiar with sustainability issues will be empowered to suggest positive changes that higher-level management often overlooks.

Customer engagement in sustainability is expected to increase the profitability of the company and promote the type of community and public service that the owners envision for the Corner Brewery. This can be achieved by informational signage and displays throughout the brewery, by hosting educational events with environmental themes, and also through green marketing.

Conclusion

The programs and systems described in this report should be considered first steps of many toward achieving a "green brewery." During this time of expansion, the Corner Brewery has a golden opportunity to become a leader in resource efficiency and renewable energy generation in the craft brewing sector. As a Third Place, the Corner Brewery is a nexus of ideas and imagination, making it the ideal setting to educate, inform, and inspire innovative environmental thinking. With good planning and execution, the Corner Brewery's impact can extend beyond the walls of its Ypsilanti, MI facility and promulgate sustainable practices throughout its community, and beyond.

Prioritized List of Project Recommendations

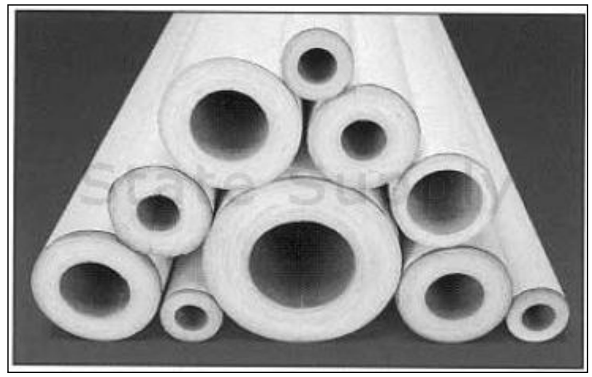
Priority	Project	IPN
1.	Energy Management System	N/A
2.	Energy monitoring system	N/A
3.	Water sub-metering	N/A
4.	Employee and Customer Education and Engagement	N/A
5.	Increase BBl per Brewing Cycle (more consecutive batches)	N/A
6.	Steam system insulation	15.4
7.	Maintenance	Varies
8.	Downsize chiller, add heat recovery	24.4
9.	(and/or) water source heat pump for simultaneous process cooling and heating	33.8
10.	Replace brewhouse heat exchanger	22.9
11.	Brewkettle heat recovery	15
12.	20 kW Solar PVT (with DTE SolarCurrents)	0.79 - 1.06
13.	Steam system leak repair (if leaks found)	Varies
14.	Improved steam process control	Varies
15.	Redirect air compressor intake to outdoors	Varies
16.	Boiler stack heat recovery	Varies
17.	High-efficiency halogen and fluorescent light retrofit	Varies
18.	Windows: seal gaps, install movable shades	Varies
19.	Optimize ceiling fan use	Varies
20.	High gravity brewing (experimental)	22.24
21.	Green façade	N/A
22.	Glass washer heat recovery	5
23.	Dual-flush and low-flow toilets (and faucets)	3.49
24.	Replace small grill with commercial oven	Varies
25.	Strip curtains in cool and cold storage areas	Varies
26.	Heat recovery wheel	Varies
27.	Replace glass-door kitchen cooler (if still required after cold storage remodeling)	0.1
28.	Radiant heat reflective shield behind fireplace	Varies

Table 1. Recommendations for immediate implementation at the Corner Brewery. For several recommendations, the investment priortiy number (IPN) does not apply or strongly depends on the specifcs of the project

Project Sheets

The following project sheets are intended to provide a quick overview of many of the key recommendations listed in the table above. Complete details are included in the full report.

Recommendation #6: Steam Pipe Insulation



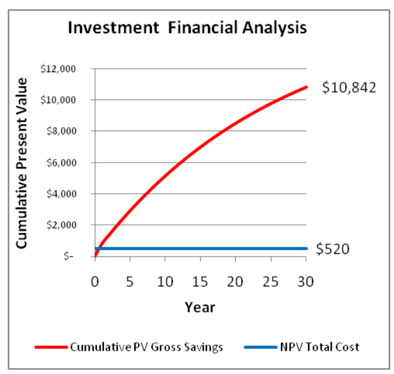
Up-Front Cost	$840.00
Payback Period	1 year
Lifetime	20 years
Net Present Value	$7,763

Investment Priority Number

$$\frac{\text{Benefits - Costs}}{\text{Costs}} = 15.40$$

Annual Project Savings

Electricity	0 kWh
Natural Gas	577 ccf
Water	0 x100 ft^3
Environmental (tons of CO_2)	3



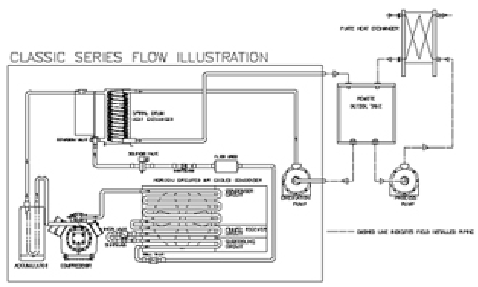
Notes

- Intangible benefits like thermal comfort in brewhouse during summer
- May need more brewhouse space heating in winter

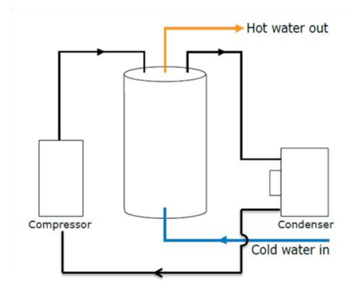
THE GREEN BREWERY PROJECT

ARBOR BREWING COMPANY CORNER BREWERY

Recommendation #8: Downsize Chiller, add Heat Recovery



Pro Refrigeration Classic 5 HP modular chiller (SEER 8)



Schematic diagram of chiller heat recovery

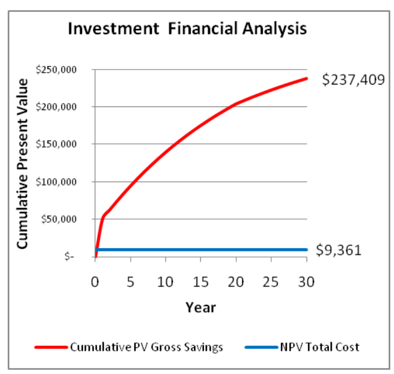
Up-Front Cost (after incentives)	$4,678
Payback Period	<1 years
Lifetime	30 years
Net Present Value	$228,048

Investment Priority Number

$\frac{\text{Benefits - Costs}}{\text{Costs}}$ =24.36

Annual Project Savings (year 1 baseline)

Electricity	0
Natural Gas	4,300 ccf
Water	-1 x100 ft^3
Environmental (tonnes of CO_2)	22



Notes

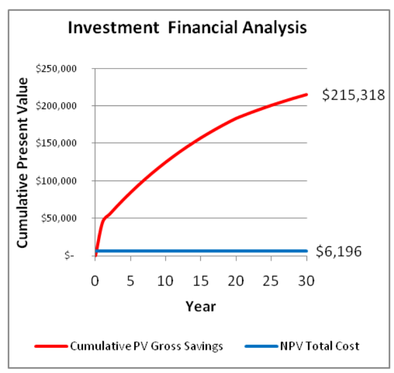
- This is a commonly implemented solution.
- Heat recovery units (e.g. Mueller and Bou-Matic brands) cost ~$2,500 but are reported to have durability issues after 5 years.
- Assumes avg EER =8, and 60% heat recovery
- May help allow boiler downsizing.

Recommendation #9: Water Source Heat Pump

Up-Front Cost (after incentives)	$5,181	Investment Priority Number
Payback Period	<1 year	Benefits - Costs / Costs = 33.75
Lifetime	30+ years	
Net Present Value	$209,122	

Annual Project Savings (year 1 baseline)

Natural Gas	4,300 CCF
Electricity	47,500 kWh
Water	0 x100 ft^3
Environmental (tonnes of CO_2)	49



Notes

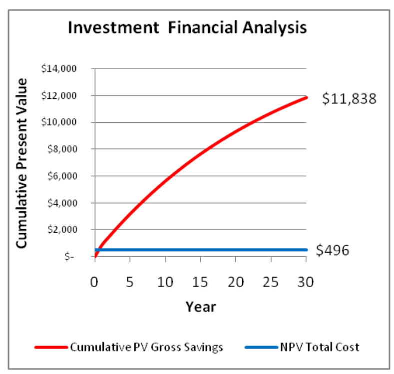
- Assumed to replace 90% total glycol chilling demand
- Could be integrated with geoexchange loop (would qualify for 10% ITC grant)
- May help allow boiler downsizing.
- Return on investment changes if downsized chiller is also placed into service.

Recommendation #10: Replace Brewhouse Heat Exchanger

Up-Front Cost (after incentives)	$5,360	Investment Priority Number
Payback Period	<1 year	$\frac{\text{Benefits - Costs}}{\text{Costs}} = 22.88$
Lifetime	30 years	
Net Present Value	$11,342	

Annual Project Savings (year 1 baseline)

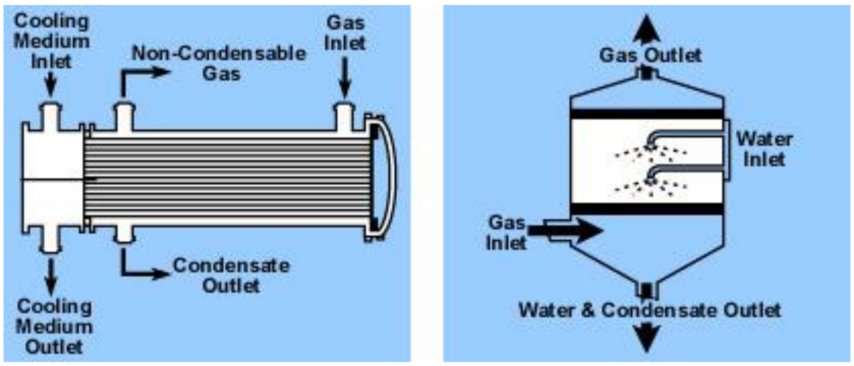
Natural Gas	4,300 CCF
Electricity	0
Water	0 x100 ft^3
Environmental (tonnes of CO_2)	22



Notes

- Assumes no increase in annual brewing output (a highly conservative assumption). Payback time halves roughly for every doubling of brewing output. Incentives increase with increase of predicted brewing output.
- May help allow boiler downsizing.

Recommendation #11: Brewkettle Heat Recovery

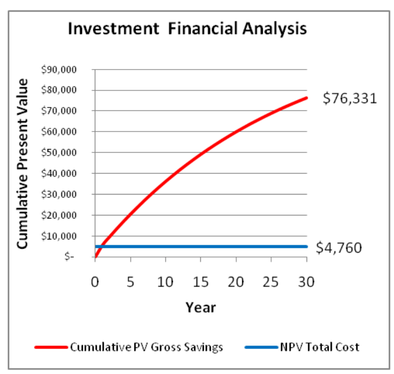


Shell and tube condenser (left) and spray condenser (right) (EPA-Course422)

Up-Front Cost (after incentives)	$5,360	Investment Priority Number
Payback Period	<1 year	Benefits - Costs / Costs = 15.04
Lifetime	30 years	
Net Present Value	$71,659	

Annual Project Savings (year 1 baseline)

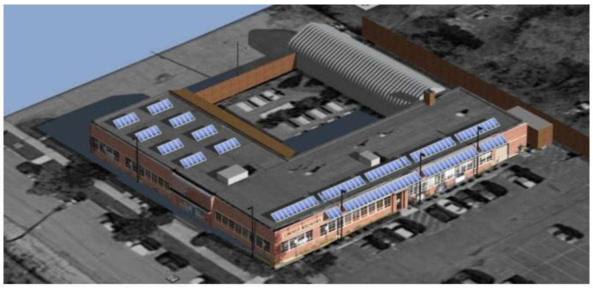
Electricity	0 kWh
Natural Gas	4,300 ccf
Water	-4 x100 ft^3
Environmental (tonnes of CO_2)	22



Notes

- Assumes no increase in annual brewing output (a highly conservative assumption). Payback time halves roughly for every doubling of brewing output. Incentives increase with increase in predicting brewing output.
- May help allow boiler downsizing.

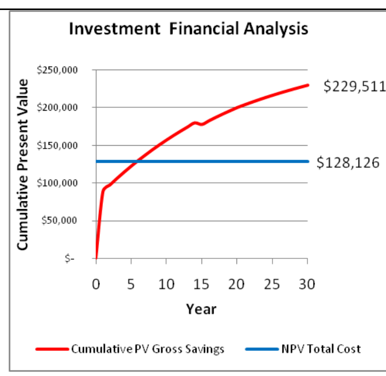
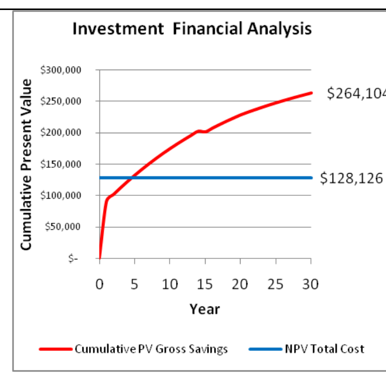
Recommendation #12: Hybrid Solar PVT with Awning



Winter Solstice – no shading **Summer – full shading**

Gross Up-Front Cost	$198,220	
Up-Front Cost (after incentives and up-front DTE REC pmt)	$114,002	Investment Priority Number
Payback Period	5-6 years	Benefits - Costs / Costs = 0.79 – 1.06
Lifetime	30+ years	
Net Present Value	$101,384 – 135,978	

Annual Project Savings (year 1 baseline)

		125 W per panel	180 W per panel (liquid cooled)
Natural Gas	4,647 CCF		
Electricity	29,822 – 42,944 kWh		
Water	0 ft^3		
Environmental (tonnes of CO_2)	47 - 56		

Notes

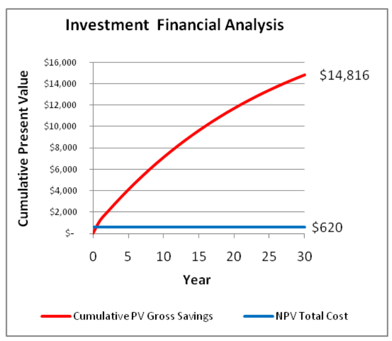
- Enroll in DTE SolarCurrents program
- See solar calculation in Appendix for complete energy and financial details
- May require structural engineering study for awning mounts (less than $2,000 for study)
- May help allow boiler downsizing.

Recommendation #20: High Gravity Brewing

Up-Front Cost	$1,000	Investment Priority Number
Payback Period	<1 year	Benefits - Costs / Costs = 22.24
Lifetime	30 years	
Net Present Value	$14,197	

Annual Project Savings (year 1 baseline)

Electricity	3,884 kWh
Natural Gas	337 ccf
Water	-1 x100 ft^3
Environmental (tonnes of CO_2)	5



Notes

- Suggested up-front cost associated with materials, time and labor to test process change
- Assumes process change for Brasserie Blonde Ale.
- May qualify for $446 in DTE incentives (pre-tax) if used toward paying for a new BT

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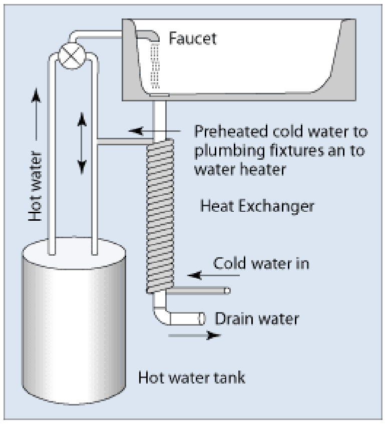
Arbor Brewing Company Corner Brewery

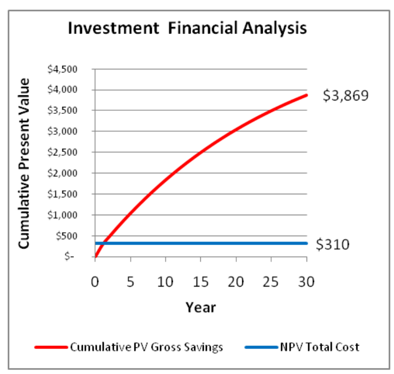
Recommendation #22: Glass Washer Heat Recovery



Up-Front Cost	$500	Investment Priority Number
Payback Period	2 years	Benefits -Costs / Costs = 11.49
Lifetime	20 years	
Net Present Value	$3,869	

Annual Project Savings

Electricity	0 kWh
Natural Gas	206 ccf
Water	0 x100 ft^3
Environmental (tons of CO_2)	1



Notes

- Assumes 80% useful heat capture and 2010 estimated glass washer use rate.

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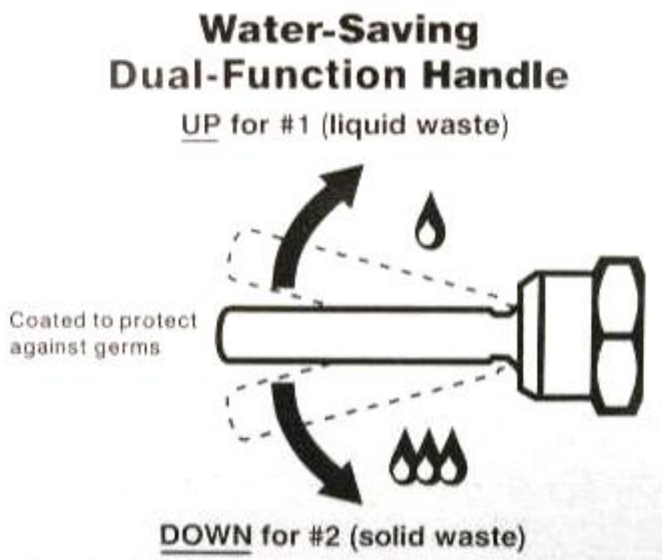
Arbor Brewing Company Corner Brewery

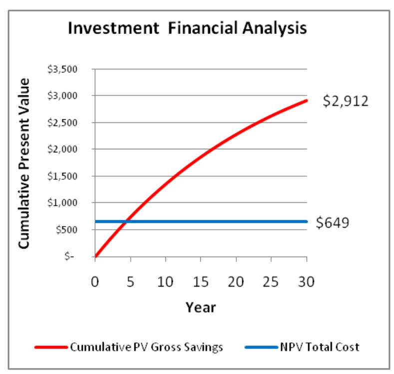
Recommendation #23: Dual-Flush Toilets



Up-Front Cost	$900.00	Investment Priority Number
Payback Period	5 years	Benefits - Costs / Costs = 3.49
Lifetime	30 years	
Net Present Value	$2,263	

Annual Project Savings

Electricity	0 kWh
Natural Gas	0 ccf
Water	20.55 x100 ft^3
Environmental (tons of CO_2)	0



Notes

- Very visible improvement has educational benefits
- Low-flow faucet aerators should also be included, but were not specifically modeled

Introduction

Background & Context

Arbor Brewing Company (ABC) consists of a brewpub and a microbrewery-restaurant: the Arbor Brewing Company Pub is located in Ann Arbor, MI; the Corner Brewery is located in Ypsilanti, MI. The Corner Brewery, which opened in 2006, is where ABC produces beer for distribution in bottles and kegs within Michigan, and is the site of interest for this project. More than just a place where beer is made and consumed, the Corner Brewery hosts numerous community events year-round, including charity fundraisers, art exhibitions, farmers' markets, and live music performances. Owners, Matt and Rene Greff, have a strong interest in environmental issues, and are deeply connected within and committed to the Ann Arbor and Ypsilanti communities. Charter members of the Washtenaw County "Waste-Knot" program, they have received numerous accolades for their progress in environmentally sustainable business practices. Still, they recognize that there is still a great deal of progress to be made.

Figure 1. View of south wall

Figure 2. A community cornerstone

Figure 3. A view of the bar and "Mug Club" mugs

Figure 4. The large, flat roof has much solar potential

The Corner Brewery & Trends in Craft Brewing

In 1994[iv], US breweries consumed 41% of all energy used by beverage manufacturing in the US. Natural gas and coal, used primarily on-site to heat boilers for steam, accounted for 60% of the total primary energy used. These energy costs alone amounted to $220 million, with electricity costs comprising 56% of the total.[2] Noting that other craft breweries in the US have successfully implemented cost-effective energy-saving measures and 'green' energy generation systems in recent years, the Greffs expressed interest in transforming their own operation. The Green Brewery Project has developed a comprehensive proposal for improving the water and energy efficiency of the brewing process, kitchen and building operations, generating energy on-site, as well as an education and outreach program to spotlight these efforts.

Figure 5. Over 93% of breweries operating in 2010 produce under 15,000 BBl per year (Brewers Association)

The Corner Brewery is representative of the thousands of small, independent breweries, which have dominated the craft brewery sector's explosive growth over the past decade.1

As scarce energy resources become scarcer and more costly, the long-term viability of this energy-intensive niche industry depends on the adoption of sustainable energy systems. Fortunately, craft beer culture is an enabling factor for reaching this goal. Typical craft beer producers and consumers are more likely to care about the quality, source, and overall impact of the product.[v] The institutional traditions of independence and innovation, which define craft breweries, make them

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[iv] Aggregate manufacturing sector energy data for more recent years does exist, but 1994 was the last year that detailed energy statistics for the brewing sector were published by the US Energy Information Administration.

[v] No hard evidence for this trend in craft beer preferences was found in published literature. However, the team's personal interactions with brewers and brewery owners over the course of this project, and especially at the 2011 Craft Brewers Association Conference strongly supported the veracity of this claim.

excellent candidates for the deployment of energy-efficient systems and sustainable on-site energy generation. As a microcosm of the industry at large, the Corner Brewery presents an opportunity to bring proven sustainable energy technology to one of America's oldest traditions.

Historic Location

The Corner Brewery in Ypsilanti is one of several locally owned microbreweries in Washtenaw County and has quickly become a landmark for local residents. It operates within the Ypsilanti Historic District and occupies a 9,190 sq. ft. building that was built in 1948. The building passed through various owners such as King-Seeley Thermos Co., which bought it in 1951, and Motor Wheel Corporation, which purchased it in 1965 and occupied it as offices for their factory across the street. When Motor Wheel was acquired in a buyout in 1996, corporate restructuring led to the factory's closure. The building changed hands a few more times until Arbor Brewing Company purchased it in January of 2006. The location of this building is a short walk from the historic Depot Town and lies just within the northern boundary of the Ypsilanti Historic District.

The Village of Ypsilanti was incorporated in 1832 and became a city in 1858. Many of the buildings in the Depot Town area were built 1850-1880.[3] There is a strong desire by the city and residents to preserve its architectural heritage. The Ypsilanti Historic Commission was formed in 1973 and granted legal authority in 1978. Consequently, many of the area's buildings have been saved and restored by business owners and residents. The Greffs share this desire to preserve the history of the area. While the Corner Brewery's building was constructed relatively recently in comparison to most of the buildings in the area, it still has to meet the same requirements regarding renovations and appearance as every other building in the Historic District.[4]

Figure 6. A street parade through Depot Town, c.1949 (Ypsilanti Historical Society Photo Archives)

The guidelines of the Ypsilanti Historic Commission play a key role in determining what types of renovations can and cannot be implemented. Due to these constraints, some worthwhile projects are quite difficult to undertake. For example, any replacement of the windows or exterior treatment must not alter the appearance of the windows. Other areas that must be considered are the roof, signs and awnings, and fences. The details of each of these areas are given in the Ypsilanti Historic District Fact Sheets in Appendix A.

The Depot Town area has attributes that make it an appealing place to live and do business. Nearby five-acre Frog Island Park on the Huron River is just north of Riverside Park, and a short walk from the Corner Brewery. It has a small amphitheater at the southern end, a soccer field and running track in the middle, and a community garden maintained by the residents at the north end. Frog Island is connected to Riverside Park via the "tridge", a three-pointed bridge at the south end of the park. Riverside Park is a 13.8-acre park on the Huron River in the center of Ypsilanti, linking downtown and Depot Town. It is the home to many popular annual events, such as the Heritage Festival, Elvis-Fest, Michigan Summer Beer Festival, and automotive events. In addition to these events it is a spacious and quiet area that residents can go to watch the river, walk their dog, or just relax.[5]

Other key features in the Depot Town area are the Huron River, the farmers market, the recycling center, and the rail line that gives it its history. A train depot still resides next to the tracks, as does a recently-renovated freight house that is slated to be a stop on a proposed light rail system. Amtrak has service on the rail line from Detroit to Chicago, but no longer stops in Ypsilanti.

Future Outlook

As far as space is concerned, the current plan for the Corner Brewery is to grow only as large as the current facility permits. Production is expected to increase with a newer, higher volume bottling line and the addition of new bright tanks. This increase in capacity is possible within the existing footprint and will have an impact on energy and resource consumption. This project took these changes into consideration.

The Corner Brewery will eventually reach its maximum production capacity. This might be relatively soon once the 2011 expansion is complete. The owners should consider another evaluation, once energy needs have stabilized, so they can continue toward the goal of sustainability. This future long-term goal is possible if the right vision and desire are present.

Problem Statement & Project Goals

Current business practices at the Corner Brewery are not fully aligned with the owner-operators' core value of environmental responsibility. There is great potential for the business to gain economic benefits from more sustainable practices. However, the owner-operators lack the time and resources to determine 1) what changes would be cost-effective while avoiding the most negative environmental impacts and 2) how to secure capital for the investments. To bridge this knowledge gap, the team has identified opportunities for improvement, performed a cost-benefit analysis of these options, and has informed the clients, staff and broader community of their findings through this report, various media outlets, and by presenting at the national Craft Brewers Conference.

The goal of this project is to help align aspects of sustainability in the business practices at the Corner Brewery with the owners' environmental values. This goal was achieved through five main objectives:

1. Conduct a Level 3 investment grade energy audit of the Corner Brewery operations that includes building systems, brewing systems, and the building envelope.
2. Working within the financial, technical and legal constraints of the Corner Brewery, develop a prioritized list of recommendations for improvements to energy efficiency.
3. Develop recommendations for onsite renewable energy generation.
4. Survey water use to consider inputs and outputs, and offer suggestions for effluent reduction and treatment.
5. Present findings at a national brewing industry conference in order to further raise awareness of cost-saving and ecologically responsible practices throughout the craft brewing industry

Brewing and Packaging Process Overview

The brewery equipment of the Corner Brewery was in large part purchased from an Arizona brewery, and consists of the following elements:

- Glycol chiller – An electric-powered split-system centrifugal chiller which provides cooling for the cold liquor tank, the fermentation vessels, and the bright tanks.
- Fermentation vessels (FV) – Stainless steel tanks which contain wort undergoing fermentation. After fermentation is complete, the liquid contained therein is called beer. Ales typically ferment at 68-70 degF.
- Bright tanks (BT) – Stainless steel tanks which contain beer undergoing final settling and clarification. This typically takes place at 28 degF.
- Cold liquor tank (CLT) – a water storage tank connected to the glycol chiller which accepts municipal source water ("city water") and can be chilled as needed.
- Hot liquor tank (HLT) – a water storage tank connected to the steam boiler which accepts city water as well as "knockout water" from the heat exchanger.
- Mash-lauter tun (MLT) – crushed and ground grain is steeped in hot water in this vessel (mashing), to extract fermentable and non-fermentable sugars. Additional hot water is added to the vessel, and the liquid contents are pumped into the brewkettle (sparging and lautering), leaving soaked grain behind in the MLT. The vessel includes a large impeller called a rake, which maintains a loose and evenly distributed grain bed.
- Brewkettle (BK) – a steam-jacketed vessel wherein wort is boiled at high temperature (218 degF).

- Heat exchanger (HX) – a single-stage counterflow heat exchanger used to pre-cool wort after boiling, and pre-heat water for the next batch to be brewed.
- Boiler – Gas-fired steam boiler (80% efficiency) which provides heat in the form of saturated steam to the hot liquor tank, the brewkettle, and the mash-lauter tun.

A single beer-brewing process run at the Corner Brewery can produce up to 21 BBl (a barrel is equal to 31 US gallons) of ready-for-sale beer (RSB). In many cases, two 21 BBl RSB batches are brewed consecutively, and combined in a single fermentation vessel (FV) to make a 42 BBl RSB double batch. Some brews are made in smaller 14 BBl batches. In some cases, these are followed by a second 14 BBl RSB batch and combined in a single FV (28 BBl RSB total).

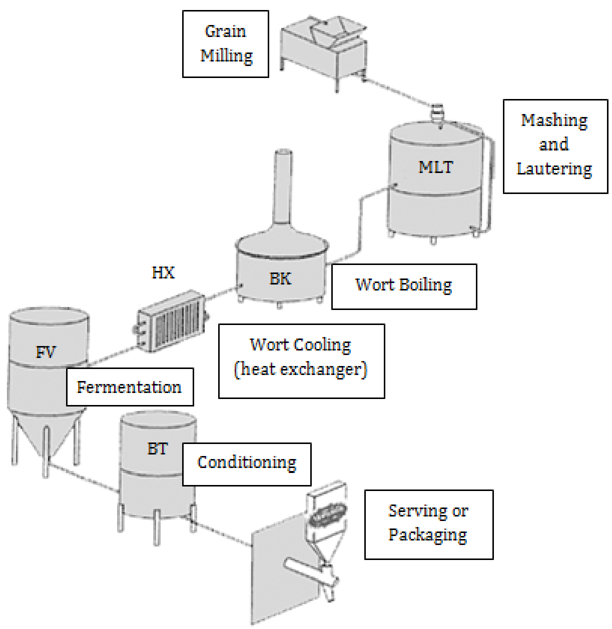

Figure 7. The brewing process at the Corner Brewery[6]

To accompany Figure 7, the following is a description of the brewing process used for a typical double-batch of 21 BBl each, for a total of 42 BBl. The afternoon of the day before brewing, the hot liquor tank (HLT) (not shown in Figure 7) is filled with approximately 1100 gallons of water. The HLT may already contain some pre-heated "knockout water" (to be explained momentarily) from the previous batch. The final volume is achieved by adding water from a municipal source ("City Water"), which enters the facility at 50 degF (typical winter) to 60 degF (typical summer). At this time, the valve connecting the boiler to the HLT is opened. This single-stage boiler (burner is fully on or fully off) produces 40 psi saturated steam at a rate of about 1 million BTU per hour (1 MMBTUH), with an 80% thermal efficiency (utilizes 12.32 CCF natural gas per hour of firing). Under this load, the boiler fires for about 3 minutes approximately every 8 minutes. The water in the HLT is heated to atmospheric boiling temperature of 212 degF over a period of several hours. At about midnight, the bar staff is responsible for switching off the connection between the boiler and the HLT. This is called "turning off the HLT." The boiler continues to fire periodically overnight in order to maintain operating pressure, for about 2 minutes approximately every 30 minutes. It should be noted here that many modern breweries have some sort of automated or timer control for their boilers.

By morning, the HLT water has cooled to approximately 210 degF. Cold water is added to the HLT to bring the final volume to maximum capacity of 1300 gallons, and the final temperature to 175 degF ("mash-in temperature").

Five BBl of this 175 degF HLT water is pumped through the CIP ("clean-in-place") pump to clean out a FV. For every one-and-a-half brew days, 5 BBl of city water will be used to clean out one of the two Bright Tanks (BT). This is because one BT cannot hold a full 42 BBl batch. In other words: half the time, only half of the contents of a FV will be moved into a BT. This mismatch will be corrected with the purchase of two new BTs, which is part of the planned 2011 expansion.

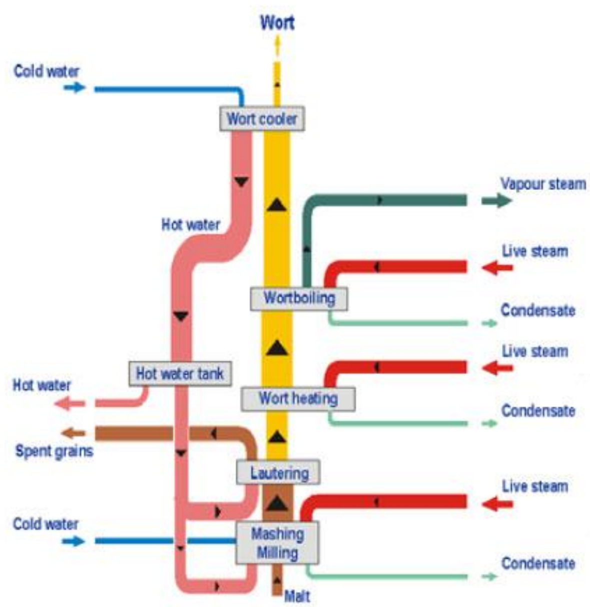

Figure 8. Heat flow diagram for the brewing process.[7]

Malted barley, specialty grains, and other ingredients are fed through the grain grinder, and conveyed into the combined Mash-Lauter Tun (MLT). Infusion mashing takes place over the next 40 minutes: with the MLT rake churning the mash, about 1 gallon of 175 degF water from the HLT is added to the MLT for every dry pound of grain contained therein. The MLT rake is then deactivated, the boiler begins to heat the HLT, and the mash is allowed to rest undisturbed for 45 minutes. The liquid in the MLT is then recirculated for 30 minutes. Approximately 1/3 of the water introduced during the mashing step is absorbed by the grain, and is lost to the brewing process.

After recirculation and once the HLT reaches 180 degF, sparging begins. In this process, hot water from the HLT is slowly added to the MLT over a period of about an hour. Simultaneously, liquid (wort) is slowly drained from the bottom to the Brewkettle (BK) until the "copperfull" volume is reached. The copperfull, or liquid volume of the BK prior to boiling, must be greater than the anticipated final batch volume in order to account for evaporation and packaging losses. For a 21 BBl batch, the copperfull volume is 25 BBl (775 gal). For a 14 BBl batch, the copperfull volume of 17 BBl is used.

The BK has two steam jackets: one encircling its lower half, and another encircling its upper half. Once the wort fluid level reaches the vertical midpoint of the BK, the lower steam jacket begins to be heated by the steam boiler. For a 14 BBl batch, only the lower jacket is ever used. If a full 21 BBl batch is being made, the upper steam jacket is also heated. Once boiling is reached, the wort is cooked at 218 degF for one hour (dissolved solids raises the boiling point of the wort). Hops and other flavoring agents (fruit, spices, etc.) are added at various times during this stage of the process.

After boiling, the wort is pumped via the brewhouse deck pump from the BK through the counterflow heat exchanger (HX), through a large-diameter hose, into an available FV. While this is happening, cold water from the Cold Liquor Tank (CLT) is simultaneously pumped through the HX, and into the HLT. The hot wort enters the HX at approximately 218 degF, and exits at approximately 70 degF. Water from the CLT enters the HX at about 55 degF, and exits at approximately 150 degF. Effective utilization of this hot water which exits the heat exchanger is a key step to efficient brewing. When only a single batch is being made, the CLT is cooled down to 45 degF. Consequently, the problem of creating more 150 degF water than required for a smaller batch is avoided. However, this practice is becoming less common at the Corner Brewery, as it is wasteful of energy.

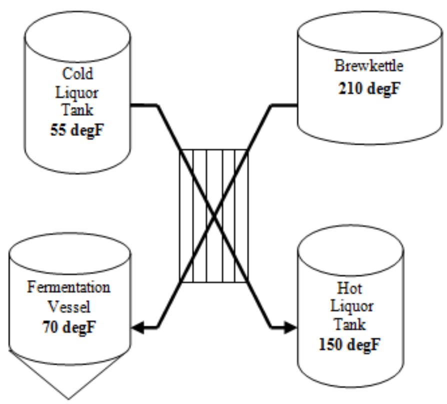

Figure 9. Heat is recovered from the hot wort after boiling, via the heat exchanger. Arrows indicate fluid flow

This 150 degF water transferred to the HLT will constitute a significant portion of the mashing water of the subsequent brew. Using the current heat exchanger, every gallon of hot wort drained from the BK and cooled to 70 degF heats 0.72 gallons of cold water from 50-60 degF to 150 degF. Therefore, the volume of this pre-heated water is equal to 0.72 of the copperfull volume of the BK (775 gal for a 21 BBl batch, and 527 gal for a 14 BBl batch).

As the cooled wort is transferred into the FV, it is blended with brewer's yeast. It is further cooled down to 68 degF, at which temperature it remains for up to 7 days. After this period of fermentation, most of the fermentable sugars have been converted into alcohol and CO_2. The beer is cooled to 45 degF, and then transferred to a bright tank (BT), where it cooled to 28 degF for clarifying. Once the solids have settled out of suspension, the beer is ready for packaging into serving tanks, bottles, kegs, or casks (for further aging).

At the time of writing, the bottling line of the Corner Brewery loses about 5.3 oz of beer per case of 24-12 oz bottles, or 1.85% of finished beer. A more sophisticated bottling line has been purchased to replace the old one, but is yet to be placed into service. No information on its resource consumption or efficiency is available at this time.

Overview of Methodology

"Energy Efficiency Opportunities in the Canadian Brewing Industry"[8] provides a step-by-step pathway to identifying and prioritizing opportunities for improvement in energy management in a brewery. This same framework applies equally well to water management, and was used as a guide for this project. The key elements are listed and/or paraphrased below, and also include additional elements developed by the team:

I. Define Scope
II. Energy and Water Audit
    a. Plan
    b. Execute
    c. Analyze Data
    d. Report Findings
III. Identifying and Prioritizing Resource Management Opportunities (RMOs)
    a. Organizational Changes
    b. Process Changes
    c. Fuel and Electricity Management and Efficiency
    d. Heat Recovery
    e. Water Efficiency and Effluent Management
IV. Evaluating and Calculating Savings and Other Impacts of RMOs
V. Selecting and Prioritizing RMO Projects
    a. Initial Scrutiny
        i. Good engineering practice
        ii. Experience of others, testimonials
        iii. Supplier information
        iv. Literature
        v. Consultants
        vi. Technical uncertainties
        vii. Performance risks
    b. Possible Synergies
        i. Interactions with existing systems
        ii. Interactions with potential projects
    c. Project Outcomes
        i. Financial
            1. First costs
            2. Lifecycle costs
            3. External financial incentives
        ii. Environmental
            1. Reduction in fossil fuel use
            2. Reduction in water use
            3. Reduction in CO2 emissions
VI. Project Costing (Feasibility Estimating)
VII. Submit Prioritized Recommendations

Resource Audit

"You can't manage what you don't measure."
- Author unknown

Introduction

Using a variety of methods and tools, an energy and water utilization profile for the Corner Brewery was constructed, with the scope confined to resources used within the boundary of the facility and on-site operations. For example, natural gas burned for heating the dining area, heating water, and boiling wort was included. Upstream fuel used for energy resource extraction and refinement, or fuel used by farmers to grow the grain was not considered. Embodied energy of packaging materials was explicitly excluded, as this has been sufficiently explored by prior work.[9,10] Downstream energy used by delivery vehicles, waste disposal efforts, transportation, agricultural and refrigeration energy used by retailers was also excluded.

According to a recent LCA study by New Belgium Brewing Co, the energy used directly by the brewery accounts for 3.9% of the life cycle energy associated with a six-pack of New Belgium Fat Tire Ale. In fact, the energy used by retailers to refrigerate the product—frequently found in inefficient display coolers with doors that are constantly opening and closing—dominates lifecycle energy use.[10] Nevertheless, this project focuses on energy used within the brewery. Our client has far greater degree of control over exactly what happens within the brewery than what happens without. They are also likely to realize the best returns on investments by focusing on their own systems. At present, no external financial incentives have been identified which encourage upstream or downstream efficiency.

To accompany an analysis of utility bills, various types of data loggers and other devices were deployed in strategic locations to measure the time-domain activity of electricity-using devices. A water flow meter was used to measure domestic hot water use, and by extension, the natural gas used to heat domestic hot water. Various approximations were used to further refine this model. Charts showing seasonal trends are shown in .

Key Assumptions

- 2010 is a representative year for energy and water use at the Corner Brewery
- Energy used by 1-3 HP motors which run less than two hours per day is negligible.
- Energy distribution losses within the building are negligible.
- Domestic hot water use varies seasonally according to intake water temperature, ambient air temperature, and on-site beer sales
- Glycol chiller efficiency changes throughout the year, but chilling output remains roughly constant.

Measurement Materials and Methods

The resource audit began as an attempt to take direct, quantitative measurements of all uses of energy and water resources at the Corner Brewery. It soon became apparent that a model for energy and water use could be constructed by taking fewer points of data. In some cases, only a single data point was required to make a reasonable estimate. Table 2 summarizes the materials and methods employed.

Device or Method	Cfg. to Measure	Used On (e.g.)	Lessons Learned
Motor ON/OFF State Data Logger **(HOBO U9-004)**	Presence or absence of oscillating electromagnetic field produced by AC motors	Air compressor Boiler fan N2 filter	Small pumps and motors do not offer consistent readings due to weak electromagnetic field
4-Channel External Data Logger **(HOBO U12-006)**	AC currents (via current amplifier clamps)	Glycol chiller Bar chiller	Glycol chiller is most electricity-intensive piece of equipment
4-Channel External Data Logger (Outdoor Model) **(HOBO U12-008)**	AC currents (via current amplifier clamps)	Air handler (compressor and fans)	Supply fan is most energy intensive out of VAC system
Temperature/Relative Humidity/2 External Channel Data Logger **(HOBO U12-013)**	Air temperature via temp probe	Air handler (heating)	Temp probe should have been placed at exhaust of furnace, not in supply air duct, to generate accurate heating cycle data
Water Flow Meter Sensor with Energy Logger (T-MINOL-130 and H22-001)	Water flow rate	Domestic hot water	Wear gloves and goggles when brazing pipe with solder paste and butane torch. Also, DHW accounts for significant use of natural gas
Ammeter or Kill-a-Watt™ and duty cycle estimates	AC or DC current	Lighting Pumps Bar and kitchen equipment, etc.	This is the best method for estimating energy use by pumps which are always or almost always running, and other equipment which follows a regular use schedule. Three-phase electric hookups are not necessarily balanced; each leg should be measured independently.

Table 2. Methods employed to conduct the energy audit.

Discussion of Results

Utility bills for 2010 are summarized in Figure 10 and Figure 11.

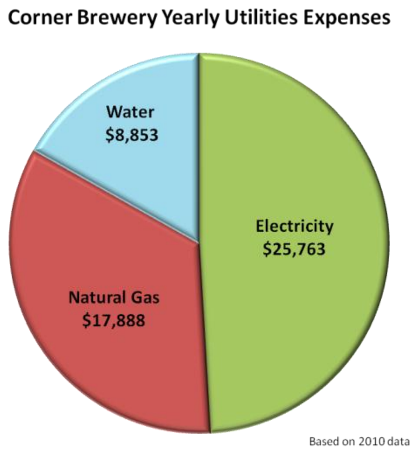

Figure 10. Electricity costs constituted the greatest utility expense in 2010. Electricity costs more than three times as much per unit energy than natural gas

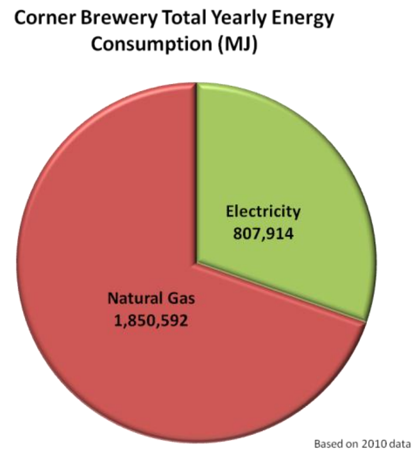

Figure 11. Joule for joule, natural gas dominates the energy use profile of the Corner Brewery

To assist in understanding the flows of energy at the Corner Brewery, consumption was broken down by application. Complex and energy-intensive systems were dissected further into component parts.

Applications: Electricity

- Wort Cooling (glycol chiller: pumps, fans, compressor)
- VAC (air handler: fans, compressor)
- Brewery cold storage
- Food cold storage
- Lighting
- Compressed Air
- Cooking
- Misc

Applications: Natural Gas

- Brewing
- Domestic hot water
- Space heating
- Cooking

Figure 12. Motor ON/OFF state dataloggers were carefully labeled prior to deployment

As previously described, the initial wort cooling takes place immediately after the boil by use of the heat exchanger. It is not represented in the list above, as it requires a minimal additional input of energy. The glycol chiller cools the wort to fermentation temperature, and then to conditioning temperature some days later. A reciprocating compressor drives the refrigeration cycle, and the chiller pump moves the glycol solution across the chiller's evaporator coils, maintaining constant flow. The process pump pushes the chilled glycol solution through heat exchange coils jacketing the FVs, BTs, and CLT. The chiller pump and the process pump share a common glycol solution reservoir, which is open to the atmosphere.

Heating, ventilation and air conditioning are achieved by a unitary rooftop air handler (Trane Packaged 12.5 ton gas/electric rooftop model YCD-150-D4-H0BB) unit using obsolete refrigerant R22. Brewery cold storage is achieved by split system direct-expansion cooling, and is slated to be entirely reconfigured in the 2011 expansion. Food cold storage is handled by several commercial coolers and chest freezers. Other devices are described in greater detail in subsequent sections. Electricity-using devices excluded from analysis include those which run for only short durations and/or have very low power requirements relative to the overall facility's demand, including the bottling and labeling lines (also due for replacement in 2011), the grain grinder and grain auger, the electric forklift trickle charger, CIP pumps, etc. The formulas used to calculate device power are shown in Appendix B.

Energy

The annual energy consumption profile for 2010 was used as the baseline for analysis. Prior years were only used for comparison purposes, as the most recent year's profile is thought to be the most representative of current operations. Figure 13 and Figure 14 show a high-level breakdown of electricity and natural gas use at the Corner Brewery, according to application.

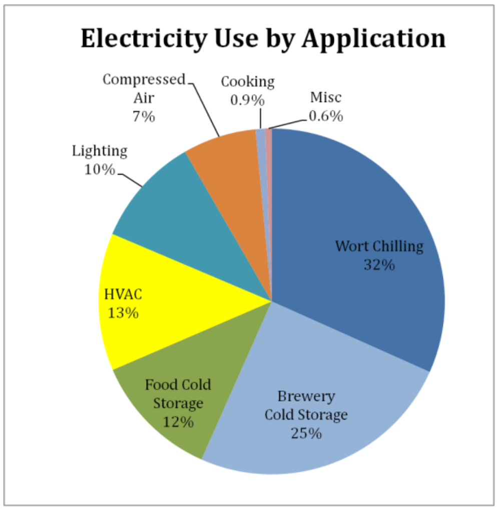

Figure 13. Electricity use is dominated by cooling applications (69% of total)

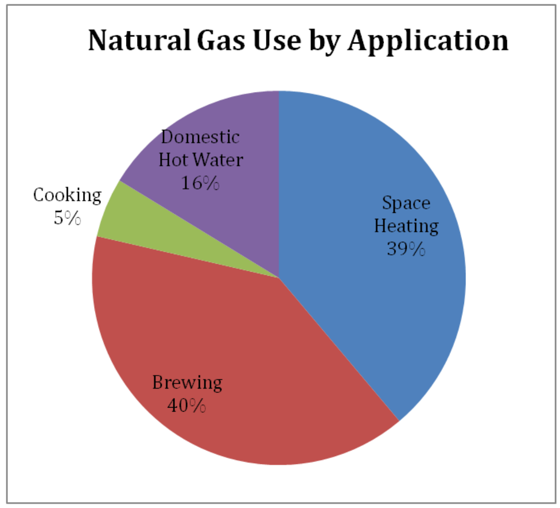

Figure 14. Space heating consumes nearly as much natural gas as brewing.

Brewing

In this report, the word "brewhouse" refers to the area of the Corner Brewery edifice in which beer is produced, as well as auxiliary systems which extend outside of the building (e.g. chiller condenser fans, etc.) In other contexts, it can refer to just the equipment of a brewery excluding the wort chiller (i.e. BK, MLT, boiler, etc.).

In 2010, the Corner Brewery produced approximately 3,024 BBl RSB (ready-for-sale beer). Electricity used for process cooling, beer cold storage, compressed air, and other minor contributors amounted to 157,227 kWh, averaging 52 kWh per BBl. The steam boiler required 6,767 CCF of natural gas, averaging 2.24 CCF per BBl. These figures represent 73% of all electricity and 39% of all natural gas consumed by Corner Brewery in 2010.

Electricity

Methodology

Electricity use in the brewhouse was measured by a combination of methods. Beer production logs recorded the number of batches brewed in a given time period. Some electricity-using devices, such as the MLT rake motor, operate for the same amount of time every batch. This is useful information, since most energy-using devices follow a uniform pattern of use for each batch brewed. Plug-in 120-volt devices, such as the carbonator pumps, were connected to the Kill-a-Watt, to directly measure power. The high levels of vibration from the nitrogen gas compressor caused the motor ON/OFF state datalogger to fall off repeatedly, despite our efforts to secure it. So, an average duty cycle was calculated based on observation of several cycles, and extrapolated for yearly energy consumption.

Figure 15. A motor ON/OFF state datalogger monitored the activity of the cold room chillers.

Figure 16. Chiller compressor current was measured over a several month period using a datalogger and current amplifier clamp.

Figure 17. Data was transferred to a laptop computer for analysis.

An ammeter was used to measure steady-state currents for several three-phase devices: the glycol chiller condenser fans, and the chiller pump, and the cold room chillers. The chiller pump was found to run 24 hours per day, and the chiller condenser fans were found to run whenever the chiller compressor was running, with the second of the two fans running about 25% as often as the first. Motor ON/OFF state dataloggers were attached to the cold room chillers to measure their activity (Figure 16. Chiller compressor current was measured over a several month period using a datalogger and current amplifier clamp.).

The glycol chiller compressor was given special treatment. A current amplifier was attached to one of the hot legs leading to the compressor's power distribution block, and left in place for several months. A configuration error led to several weeks of data loss. However, sufficient data was collected bracketing the lost period, enabling the interpolation of the missing data.

The bar tap chiller was measured in a manner similar to the glycol chiller compressor, except that the current for the entire apparatus was measured, rather than measuring the fan and compressor separately.

The electrical connections for the cold room evaporator fans were inaccessible, so estimates were made based on nameplate data. The fans run full-time, so no duty-cycle estimate was necessary.

Discussion

We begin our examination of electricity use data collected in the brewing process with the smallest considerations, and conclude with the largest considerations. Very small pumps and motors which run infrequently and/or for short periods of time were excluded from analysis. Lighting in the brewery is discussed in a separate section. The brewhouse air compressor was replaced during the study, introducing some uncertainty to its energy consumption figure. However, it is still estimated to be approximately 7% of the total electricity use in the facility.

Brewhouse Equipment	Electricity per Day Estimate	
Glycol Chiller System		213 kWh
Compressor	*139 kWh*	
Condenser Fan	*9 kWh*	
Process Pump	*38 kWh*	
Chiller Pump	*26 kWh*	
Cold Room Chiller System		168 kWh
Chiller A (cond fan + compressor)	*72 kWh*	
Chiller B (cond fan + compressor)	*80 kWh*	
Evaporator Fans	*1 kWh*	
Bar Tap Chiller		15 kWh
Compressed Air Systems		46 kWh
Air compressor	*33 kWh*	
Nitrogen Generator and Compressor	*8 kWh*	
Carbonator Pumps	*5 kWh*	
Mash Tun Rake		3 kWh
Brewhouse Total	**445 kWh**	
Facility Total	**622 kWh**	

Table 3. The glycol chiller system is responsible for 48% of the brewhouse electricity usage, and 34% of the entire facility's electricity usage

Roughly 25% of the facility's electricity usage is consumed by finished beer cooling. A 600 sqft. walk-in cooler located inside the brewhouse (Figure 18) contains finished beer in bottles, kegs, and serving tanks connected to taps at the bar. A pair of split-system direct-expansion chillers sit directly outside the building (Figure 19), and connect to twelve 3-Watt continuously running evaporator fans located inside the cooler. The 2011 expansion involves cutting the size of this cooler in half, and moving it closer to the kitchen, whereupon it will be subsequently used only for food storage and cooling the serving tanks. Finished product storage, as well as grain and other raw materials, will be relocated to a new 2,200 sqft., highly insulated stainless steel structure (see Figure 25) for which space conditioning will be assisted by groundwater heat exchange. At the time of writing, this project is scheduled to break ground by the end of April 2011.

Figure 18. Walk-in cooler showing serving tanks and keg storage.

Figure 19. Outside North wall, just East of the beer garden. From left to right are the twin glycol chiller condenser fans and the two cold room chiller units

Figure 20. Glycol chiller compressor

Electricity use in the brewing process is dominated by the glycol chiller. This system consists of a 30 HP reciprocating compressor (Figure 20), a 2 HP chiller pump, a 5 HP process pump, and a pair of twin 1 HP condenser fans (Figure 19). The Berg Chiller Group website[11] specifies the nominal "size" of this model chiller to be 27.2 tons. The actual capacity of a chiller depends on its operating conditions. The vendor's specification sheet for this unit was written Arizona design conditions, indicating a design chilling capacity of 11.5 tons of cooling in that climate. A programmable variable-frequency drive (VFD) controller later was added to the process pump, and set to reduce its operating speed from 3500 rpm to 895 rpm. This dropped the operating pressure of the process pump from 65 psi to less than 5 psi, and reduced the glycol solution flow rate from 40 gpm to 10.2 gpm.[vi] Supply and return glycol temperatures were measured, along with supply pressure. Pump affinity laws to determine total wort chilling load for the Corner Brewery, which amounted to only 1.47 tons at an average annual EER of 2.5.

Taken as a whole, this system consumed 77,677 kWh in 2010, or 34% of the facility's entire electrical energy. At its peak demand in July, this system was responsible for nearly 40% of the month's electricity bill. Chiller system specifications are in Appendix D.

Figure 21 illustrates the relatively stable energy demand from all components of the chiller system except for the compressor, which peaks in the summer months. The condenser fan's operation is tied to the compressor circuit. Figure 22 illustrates that the chiller's compressor energy demand

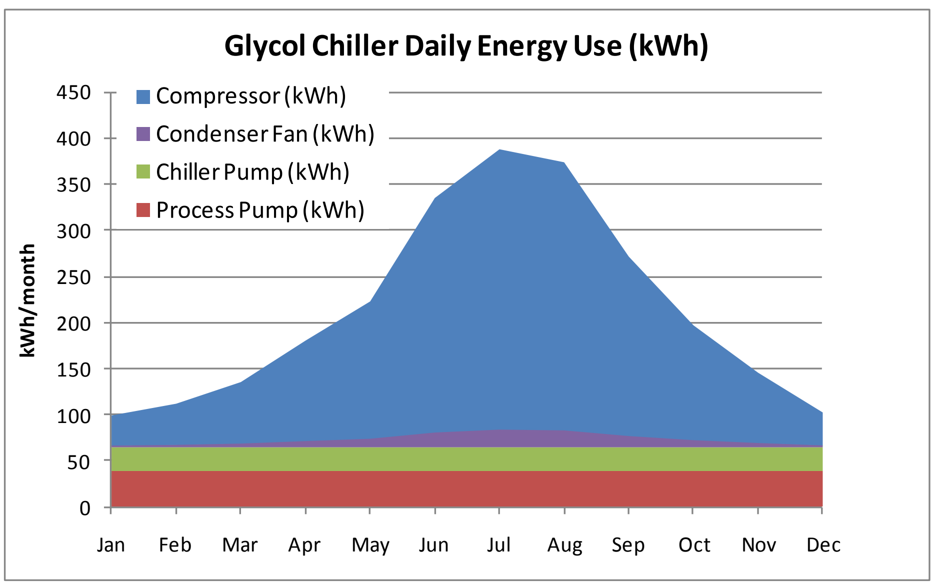

Figure 21. Glycol chiller monthly system energy consumption peaks in the summer

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[vi] Prior to installing the VFD, the process pump exceeded the pressure rating of the glycol jackets of two FVs, bursting them. Twice: a costly lesson in sizing your system to your load.

correlates to outside air temperature, and Figure 23 demonstrates that this demand is decoupled from fluctuations in monthly beer production. We concluded that the chiller cooling output (i.e. process heat rejection rate) remains nearly constant throughout the year, while the chiller device efficiency (heat rejected per unit of electrical energy input) changes. This assumption vastly simplified the assessment of the chiller's performance.

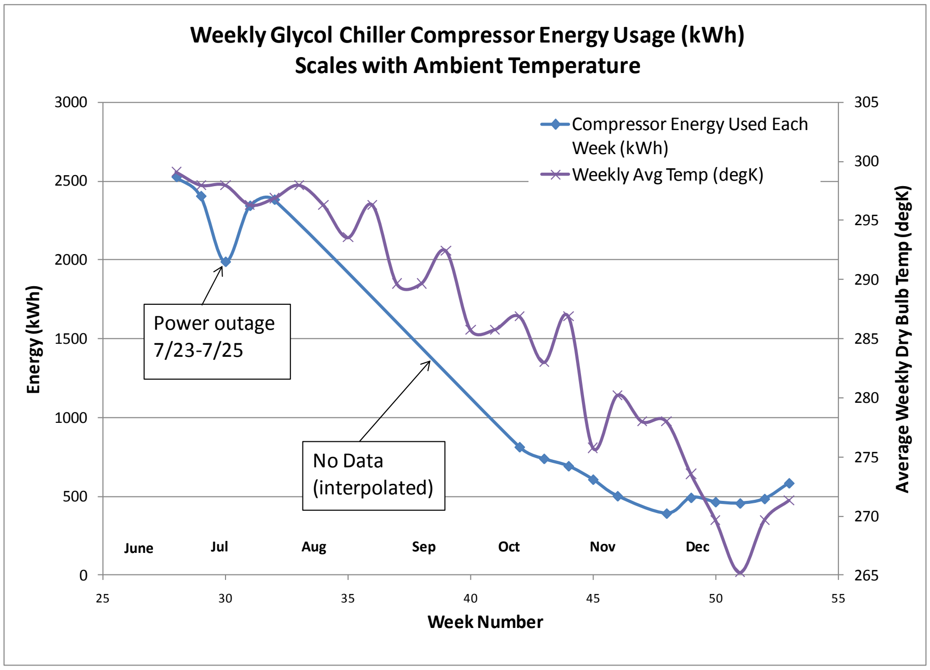

Figure 22. Compressor energy demand drops with decreasing absolute temperature (deg K)

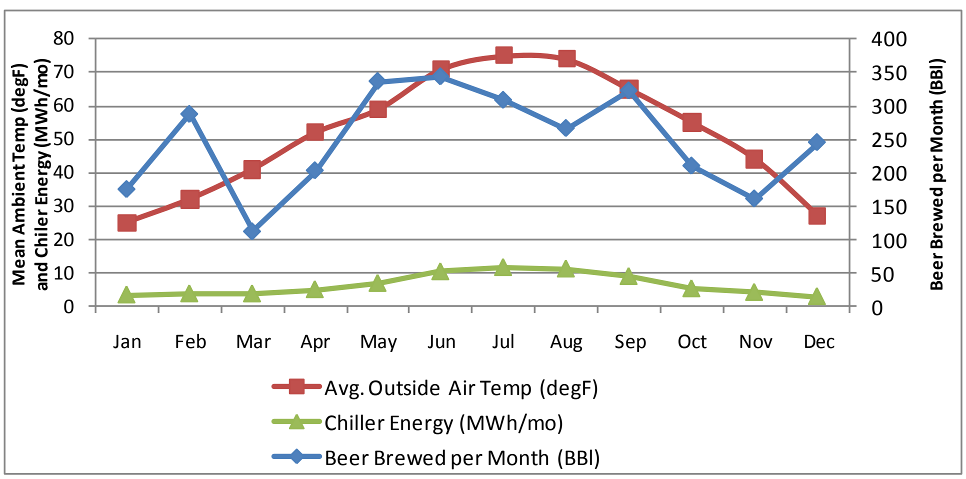

Figure 23. Glycol chiller energy consumption is sensitive to outside air temperatures, and insensitive to beer production volume.

Natural Gas

Natural Gas in Brewing (2010)	
Beer Brewed (BBl)	3,024
Natural Gas Used for Brewing (CCF)	6,838
Percent of total natural gas consumption	39%
Average CCF/BBl	2.24

Table 4. Natural gas consumption in the brewhouse in 2010.

The steam boiler is the only natural gas-using device in the brewing process at the Corner Brewery. A 30 HP tubeless upright Fulton boiler supplies 40 psi saturated steam to the HLT, the BK, and the MLT. To define terms, a brewing "batch" consists of the brewing activities related to a single mash, sparge, and boil. A brewing "cycle" consists of one or more batches in close succession (no more than 24 hours apart). All but the first batch in a cycle utilizes hot water from the previous batch. One of the complicating factors of estimating natural gas usage in the brewing process is that it can vary from cycle to cycle. When wort is cooled after boiling, it exchanges heat with incoming city water. The cooled wort continues to a FV at approximately 72 degF, and the newly heated water proceeds to the HLT at approximately 150 degF. If another batch of beer is brewed soon thereafter, a large quantity of pre-heated hot water is available. If several days pass, this hot water will have cooled, and will have to be reheated by the boiler. Therefore, the amount of gas actually used in each batch varies, depending on the amount of hot water made available from the previous brew.

Methodology

Instead of cutting into the natural gas supply line to directly measure the amount of natural gas consumed by the boiler, a motor ON/OFF state datalogger was mounted to the boiler blower fan, which operates if and only if the boiler is actively firing. This provided a very accurate activity profile of the boiler, with measurement resolution of one second. Data analysis in Microsoft Excel provided duty cycle estimates for each brewing cycle. Careful analysis of several brewing cycles allowed us to measure the amount of natural gas used for brewing cycles of varying batch sizes.

Discussion

The 80% efficient steam boiler produces 1.005 MMBTUH and consumes 12.32 CCF per hour of active firing. The motor ON/OFF datalogger was installed on 7/7/2010, and data was taken through 1/4/2011. During this time, the boiler fired for a total of 549.47 hours, consuming 6,767 CCF of natural gas. This is equivalent to an overall average duty cycle of 0.063 (hours firing divided by hours of analysis period). Using this representative duty cycle, it is possible to estimate the total amount of natural gas used for brewing for the entire year. Dividing by the volume of beer produced results in the useful metric of CCF/BBl. On average, beer production at the corner brewery consumed 2.24 CCF/BBl RSB in 2010.

Comparing the CCF/BBl of beer produced from each cycle illustrates how much energy is conserved by using the heat exchanger. A set of 13 brewing cycles were analyzed, and the results shown in graphically in Figure 24. Two representative cycles are illustrated in greater detail in Appendix G. Taking the average CCF/BBl for these 13 representative cycles yields a similar figure of 2.23 CCF/BBl, lending support to the accuracy of this estimate.

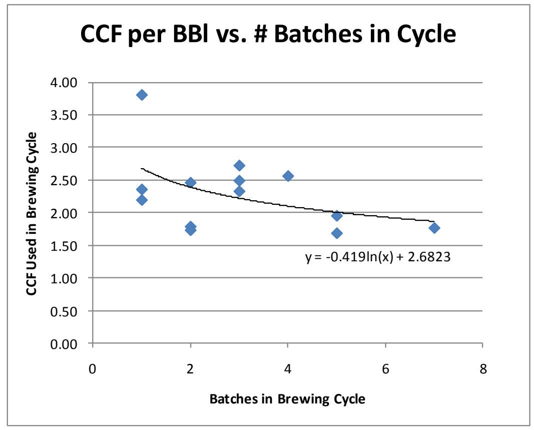

Figure 24. Heat exchanger use reduces natural gas consumption per BBl RSB.

Restaurant/Kitchen/Pub

Of the Corner Brewery's 9,118 enclosed sqft., 5,133 sqft. (56.3%) are devoted to the restaurant, kitchen and pub area (Figure 25). An outdoor kitchen occupies an additional 200 sqft.

The restaurant, kitchen and pub areas of the Corner Brewery were grouped together for the purposes of the resource audit for several reasons. They observe similar usage patterns, all utilize typical food service equipment, and have some overlap between them. The term "restaurant", unless otherwise specified, will be used for the remainder of this paper to refer to these three zones of use.

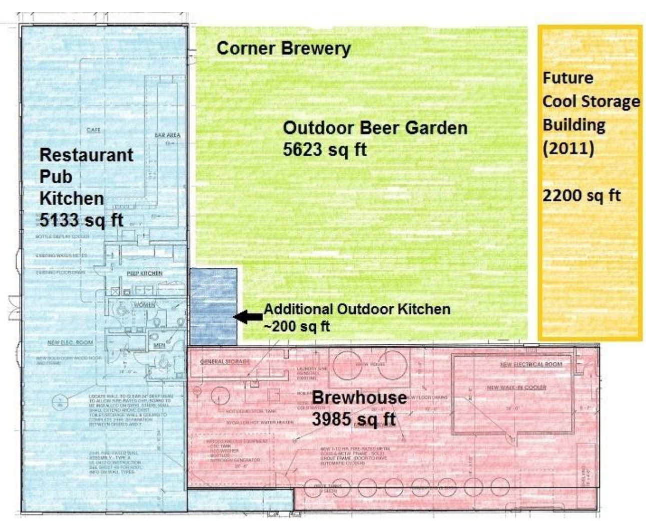

Figure 25: Corner Brewery zones

Electricity

There are dozens of electricity-consuming appliances in the restaurant, including many small appliances such as computers, cash registers, water coolers, a sound system, and a coffee machine, to name a few. These small appliances were assumed to use a minimal amount of electricity on an individual basis, and thus their usage was not estimated directly (their consumption appears in the "other" segment of the total electrical profile). Lighting is addressed separately.

The main electrical loads in the restaurant area are the food cooling and cooking equipment. Thus, the appliances that were assessed include the glass washers, refrigerators, freezers, and the electric grills (Table 5).

Restaurant Equipment	Electricity per day estimate	
Glass Washer 1	1.22	kWh
Glass Washer 2	0.05	kWh
Refrigerator 1 - beer cooler	12.70	kWh
Refrigerator 2 - bar beverage cooler	6.90	kWh
Refrigerator 3 - condiments	9.38	kWh
Refrigerator 4 - kitchen 3 door	14.49	kWh
Refrigerator 5 - kitchen 2 door	10.76	kWh
Refrigerator 6 - 3 glass door	12.60	kWh
Freezer large	8.60	kWh
Freezer small	4.30	kWh
Electric Panini grill	2.49	kWh
Electric flat-top grill	2.49	kWh
Total	**85.97**	**kWh**

Table 5: Restaurant equipment electrical usage

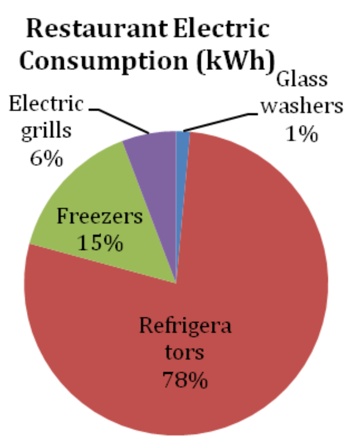

Figure 26. Restaurant electricity use by appliance

Figure 27. Refrigerator #6 sits mostly empty

Methodology

The electricity usage for five of the refrigerators was estimated by multiplying the wattage listed on their nameplates by an estimated 50%, year-round duty cycle. A duty cycle of 50% is representative of all properly-functioning refrigerators built in the past 30 years according to an ACEEE study.[12] Electricity usage for the freezers and large glass-door refrigerator that did not have nameplates was estimated using their interior dimensions and Energy Star data for conventional and high-efficiency products.[13]

The electric Panini and flat-top grills were measured with a Kill-a-Watt power meter, and were observed to have an approximate 50% duty cycle as well. They are turned on for 8.3 hours per day, according to the kitchen staff.

The glass washers have built-in counters that indicate number of cycles run. Using average number of cycles per day, the nameplate electric power usage, and their 2 minute cycle time, electric usage of the glass washers was estimated. Lacking internal heating coils, the hot water they use is provided entirely from the domestic hot water heater.

Discussion

The 85.7 kWh of electricity used daily by the kitchen equipment (averaged for 2010) was higher than expected, and accounts for 14% of total electricity consumption. The cooling equipment makes up the lion's share of the kitchen's consumption at 93%.

Natural Gas

Direct natural gas consumption in the restaurant (i.e. not for domestic hot water) is limited to the gas grills used in the outdoor kitchen area. The gas fireplace in the pub was included under the category of space heating. The primary cooking surfaces consist of 2 large grills (Figure 28) and one smaller one with a sheet metal enclosure. All are originally propane grills, retrofitted to use natural gas. The natural gas usage was not directly measured by a flow meter, so uncertainty associated with the estimates shown is high.

Figure 28. Inefficient use of heating surface

The smaller grill (not pictured) serves as a makeshift oven, with thin sheet metal for insulation. While energy-inefficient, this practice is understood to be a stop-gap measure put in place to avoid the additional costs of a fire-control hood required by a standard oven. The total cost of ownership for a kitchen retrofit to include commercial ovens was not examined in this study, but should be nonetheless considered by the client.

The glass washers sanitize glasses in the restaurant and use hot 130d degF water drawn from the domestic hot water tank located in the brewhouse, which is heated with natural gas. The sink in the kitchen also uses hot water. Lacking sub-meters, this amount was estimated, and not directly measured.

Methodology

The two identical large grills are rated at 116,000 Btu/hour, and the smaller at 68,000 Btu/hour. Based on a survey of the kitchen staff, the grills are on constantly for 8.3 hours per day and are always on their lowest setting, which was estimated at 10% power. Taking this data and the energy content of natural gas (102,000 Btu/CCF), the daily usage of natural gas was estimated.

The glass washer usage, as mentioned above, was calculated from their counters. They use 2.5 gallons of hot water per cycle. Cycles were counted over a several-week period, and then adjusted based on monthly on-premise beer sales data to estimate a daily average use for the whole year.

Restaurant hot water using appliances	Hot water usage per day
Glass Washer 1	113.4 gals
Glass Washer 2	4.6 gals
Total	**118.0 gals**

Table 6. Glass washer hot water usage

Restaurant Natural Gas equipment	NG per day estimate
Large 8 burner grill 1	0.93 ccf
Large 8 burner grill 2	0.93 ccf
Smaller grill w/ hood	0.55 ccf
Glass Washer 1	0.87 ccf
Glass Washer 2	0.04 ccf
Total	**3.32 ccf**

Table 7. Total restaurant natural gas usage. Glass washers use gas indirectly (i.e. they use hot water)

Discussion

Natural gas usage in the restaurant accounts for 7.2% of the total natural gas usage at the Corner Brewery. Our confidence in the estimate for natural gas used indirectly by the glass washers is very high. Our confidence in the estimate for the grills is much lower, since no direct measurements were actually made. A natural gas flowmeter would be required to make such a measurement, and would be a good idea for future energy use monitoring.

Lighting

Figure 29. Track lighting

Lighting at the Corner Brewery was installed after the purchase in 2006. The wiring and fixtures are all new, although some have a retro-industrial look to them. The older looking lights are hanging over the bar and mounted on the walls. All of the lights in the pub area are dimmable.

In the evening, track lights mounted to the ceiling illuminate seating arrangements on the floor of the restaurant (see Figure 29). Bar patrons receive their light from eight suspended lights that do an adequate job in being source lights without much wasted illumination (see Figure 30). Wall-mounted lights add an extra source of light to some of the booths. The primary times the lights are on are the hours from dusk to closing. It was observed that lights are often on during the day, despite ample ambient light from the extensive windows. The sections where the lights tend to be on during the day are the staff areas around the bar, kitchen, brewhouse, and the restrooms.

Figure 30. Lighting over bar

The pub has two styles of lights: overhead halogen spotlights and sconce or globe incandescent lights. Each of these types is easily dimmable and adds to the ambience of the establishment.

The brewhouse is lit by thirteen, 8ft. T-12 fluorescent fixtures that have two 59 Watt tubes each. None of these lights are dimmed and are on during a typical day nine to twelve hours. There are two banks of lights that are operated by two switches. The four exit signs are lit by fluorescents and are on 365 days per year.

A more complete analysis of the lighting can be found in Appendix E. This sheet separates the lighting into use zones, estimates usage, and gives potential payback with upgrades and bulb changes.

Natural lighting is one of the main benefits of having as many windows as the Corner Brewery. Even on a cloudy day there is generally enough light entering the establishment for customers and staff to function with minimal artificial lighting. This inherent characteristic of the building reduces daytime lighting requirements and thus reduces electrical energy usage as well.

Another advantage is the generous views of the outside that is a benefit to employees and customers. People tend to prefer a view of the outside world while working or relaxing. While some of the views look out onto an urban, built environment, the west windows have elements of nature. Though the view could use a little improvement, it is still possible to see what is going on outside of the pub. With the ample views it almost feels like an outdoor seating environment during daylight hours.

Methodology

Lighting energy use was estimated by direct observation of use patterns and installed capacity and interviewing staff.

Space Cooling and Heating

Initially, the team tried several different energy modeling software programs (eQuest, EnergyPlus, IES, RETScreen) to calculate the space heating and cooling loads for the Corner Brewery, but was confounded by the steep learning curve associated with these programs. Since time was available to take measurements over several seasons, the fan and compressor activity of the air handler was measured directly. A weather-resistant datalogger was installed in the circuit box of the air handler to measure compressor and fan currents over time. The signal to activate and deactivate the furnace firing cycle was found to be a short, transient pulse, and could not be captured by the model of datalogger used. So, instead of directly measuring the circuit, a temperature probe was placed in the supply air duct to measure gas furnace during the heating season. Visual inspection of the building envelope was aided by a thermal imaging camera and infrared thermometer readings. Direct observations were made of occupancy patterns and interior comfort levels. Examination of site plan drawings and interviews with staff provided further insight into the space heating and cooling patterns at the Corner Brewery.

Building Envelope Study

Roof/Ceiling

These two parts of the structure are actually one. When one looks up at the ceiling, the bottom of the roof is actually being seen. The corrugated metal visible is the underlayment for the layers on top. This material is estimated to be approximately 3/16" thick and is believed to be steel. On top of this material is a component that is used as insulation and to provide a surface for the watertight membrane that goes on top of it. It is shaped in such a way to provide an adequate slope for drainage. Unfortunately we were unable to make contact with the contractor who installed the roof and cannot determine its exact composition without compromising the membrane. It is likely, however, that the material is isocyanurate roof insulation board. A specification sheet for Trisotech Tapered Insulation is included in Appendix F. For every inch of material the R-value is 6. The sheets come in 4' X 8' X 4'' sections with a slope already cut in for installment. On top of this material is the watertight membrane that is laminated to either another thin piece of plywood or directly to the insulation board. It is assumed that the membrane is attached directly to the insulation board.

It was estimated that the thickness of the insulation board is 4" on the down slope edge and as high as 9" on the highest edge. For ease of calculation, the minimum of 4" was used because there is a slight natural slope in the structure and a sloped insulation material may not have been needed. All other materials have negligible R-values. Any air gaps could add up to a value of 1. These were dismissed and the roof was estimated to have a minimum total R-value of 24.

Figure 31. View of ceiling, looking upward from restaurant floor

Originally it was assumed there was substantial heat loss through the roof so an estimate for additional roof insulation was obtained from a local installer, Seal Tech Insulation. The type of insulation offered was spray foam with the trade name Icynene.[vii] This insulation has an R-value of R-19 for every three inches of foam. The bid gave an overall estimate of R-38 and also claims to keep 96% of building air from leaving the restaurant through the roof.

Other eco-friendly types of insulation were considered. Among these was Bonded Logic, which supplies a recycled blue jean material. The problem with this was the application and the constraints of a food service environment. The material needed to be fastened to the roof with minimal particle shedding. These materials generally are blown in or come in batts that are laid down on a surface. This is not possible for this location unless a drop ceiling is installed, which is unacceptable to our client for aesthetic reasons, and would require intensive lighting, ceiling fan, and ductwork reconfiguration.

Figure 32. Accumulated snow on the roof of the Corner Brewery

Figure 33. The snow has melted off this poorly insulated neighbor's roof, but remains on the overhanging eaves

Once the seasons changed and snow accumulated on the structure, snowmelt due to heat loss through the roof was examined. After observation and comparison with other structures in the area it was clear that there was roof heat loss was low, as evidenced by the presence of accumulated snow. This indicates relatively good roof insulation, but does not rule out heat loss

[vii] Not to be confused with Ice-Nine, the more stable polymorph of water than common ice (Ice I_h)

entirely. Adding insulation will help seal the envelope and cut down on heat loss especially conduction through the screws that hold down the insulation boards. However, adding insulation may not have an acceptable payback period. Figure 31 shows the view from the inside of the building. The corrugated metal and screws protruding are visible. A simple insulating rubberized coating may be sufficient to substantially reduce heat conduction through these screws.

The pictures above show the roof of the Corner Brewery and a building next door at the same time four days after six inches of snowfall. It is clear that there is a difference in the snowmelt pattern. The pattern stands out when looking at the edge of the house and see the snow that didn't melt in the overhang section. According to ASHRAE standard 90.1 the minimum R-value for zone 5 (Michigan) is R-20. A new ASHRAE 189 standard is proposed and the proposed R-value would be raised to 25.

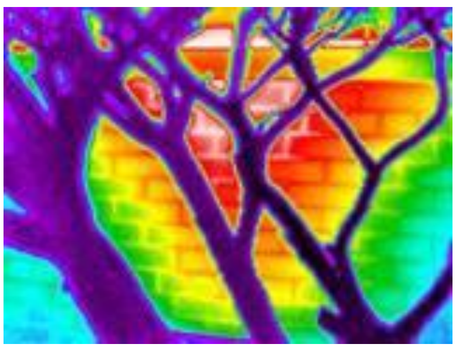

Figure 34. Thermal image of outside wall (through foliage) demonstrates heat loss from fireplace inside

Walls

Based on an inspection of the brick layout pattern and the thickness of the walls it is assumed that the walls are made of standard red brick. The thickness of the walls varies but is of a minimum of 16" thick. The R-value of red brick for every four inches is 0.80. This would make the minimum R-value for the walls 3.2 with much of the walls greater than this; up to an R-value of 4.8. This isn't anywhere near the recommended ASHRAE standard of R-20 for walls in this zone. Walls are considered the second highest source of heat loss in a colder climate at 26.9% of the total (J. Kim, personal communication, 2010). We assumed due to aesthetics that the appearance of the walls would not be changed but there are some noticeable losses through the walls. Figure 34 shows a thermal picture of the outside wall behind the fireplace, indicating significant heat loss. For aesthetic reasons, adding wall insulation is not an option for most of the building.

Windows

The windows at the Corner Brewery are the original single-paned windows from the 1940s, covering over 1900 sqft. (26% of total wall area). There is only one outside wall that doesn't have windows and that is in the brewhouse area, facing east. The windows have an industrial warehouse look that fits in well with the area.

Figure 35 and Figure 36 show the south facing windows. The thermal image was taken in March and it shows the difference in surface temperatures of the wall structure.

Figure 35. South-facing wall (camera facing East). Reserved Parking sign is visible at center of image.

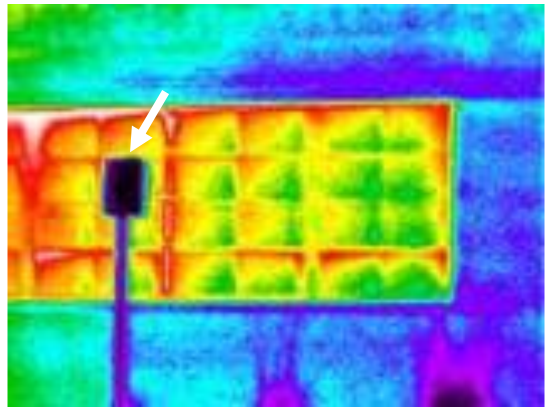

Figure 36. Thermal image of South-facing wall (camera facing North). Reserved Parking sign is the dark vertical line

The south facing exposure has full sun with a little late afternoon shade in the cooler months. There is significant solar thermal gain in the winter from these southern windows. The west windows get a substantial amount of late afternoon sun but are partially shaded by trees and shrubbery. The north windows in the pub and brewhouse have full exposure to north winds but a significant amount of day lighting is available. The east windows in the pub are shaded due to an awning for outside seating but ample daylight is allowed in.

Floor

The floor is of unknown thickness. It is an exposed cement slab that is polished and painted. It is estimated to be 8” thick in order to calculate insulation. Poured concrete has an R-value of 0.08 per inch giving an R-value of 0.64.

Air Circulation

During the winter hours, observations were taken to catalog the temperature differential between the high ceilings and a typical customer seating position. The temperature in a north booth and the temperature near the ceiling by an existing ceiling fan were noted at noon, and again after two hours. One dataset is taken with the fan off and another is with the fan on. The data collected is listed in Appendix H. The data shows a temperature drop near the ceiling of 1 degF, which isn’t that significant but this was also during the time when the pub was still heating up. During the same time the temperature at the thermostat reached its set point of 72 degF and stabilized. The booth temp rose significantly as the pub was heating up and the fan was turned on. From a personal observation there was a clear difference in comfort when the fan was running at high speed. There have been times where it was noted that the fans were on but turning at such a slow speed as to have no significant effect on air movement. There have been other visits when it was noted that the ceiling fans were not on during the winter months.

Water

Introduction

In the quest for sustainability at the Corner Brewery, it would be negligent to not examine the issue of water. Water is essential for life on this planet, for ecosystems to flourish, and for human civilizations to survive. Yet in many areas of the world, humans are consuming water faster than it is being replenished by nature. Anthropogenic climate change is affecting the earth's hydrologic cycle, exacerbating droughts in some areas and excessive rainfall and flooding in others. One shouldn't forget about the billion people worldwide that don't have access to clean drinking water. Sustainable management of water is a critical issue progressing into the 21st century.

Water use in the local context of the Corner Brewery must be examined. Situated in the Lake Erie watershed and receiving 32.8 inches of rainfall annually, Ypsilanti has an abundance of freshwater resources. The city of Ypsilanti receives its water from the Detroit Water Department through an extensive regional water supply system.

Normal Precipitation

(YPSILANTI E MICH UNIV Weather station, 1.06 miles from Ypsilanti)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Inch	1.77	1.65	2.46	3.08	3.20	3.29	2.93	3.35	3.49	2.35	2.79	2.44	32.80

Table 8 Average monthly and yearly precipitation in Ypsilanti, MI

Because there is a plentiful supply of water in Ypsilanti does not mean that water usage has no environmental impacts. Every gallon of freshwater used must be extracted, treated, and pumped to the point of use. These processes are energy and infrastructure intensive. Pumping water often accounts for a large percentage of a city's energy demands. After use on site, each gallon of wastewater must be pumped, treated, and discharged back into the environment. The cost per hundred gallons on a utility bill usually does not reflect the true economic and environmental costs of water consumption.

Brewing beer and operating a pub are water intensive endeavors. Most breweries use 4-8 gallons of water for every gallon of beer produced, with small breweries typically using even more. Even the brewery leader of sustainability, New Belgium Brewing Company, uses 3.9 gallons of water per gallon of beer.[14,15] This water ends up in the beer itself, some is evaporated during boiling, much is used in cleaning of the brewhouse equipment, and some is used in the normal building operations (kitchen, restrooms, etc.)

Overall Water Use at Corner Brewery

In 2010, the Corner Brewery used 804,100 gallons of water and paid $8,682.65 for water, sewer and associated fees, equating to about 1.08 cents per gallon. Table 9 contains monthly water usage data for 2010.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Gals	55,352	64,328	53,856	73,304	74,800	81,532	84,524	68,068	75,548	66,572	52,360	53,856	**804,100**
Total charge	$616.76	$692.05	$604.21	$767.34	$779.89	$836.37	$861.47	$746.16	$810.54	$733.28	$610.95	$623.83	**$8,682.85**

Table 9 Monthly water usage and expenditure in 2010

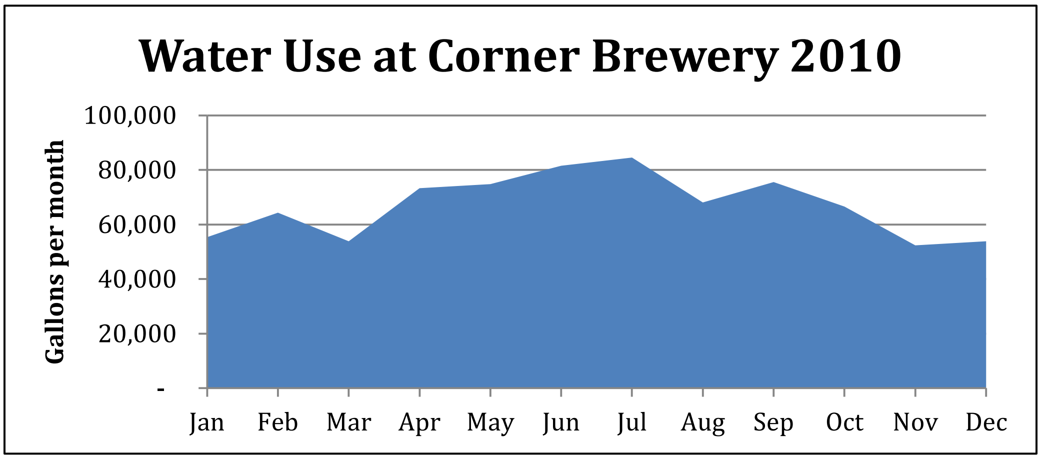

Figure 37. Graph of monthly water usage

As shown in Figure 37, monthly water usage peaks at 84,524 gallons in July, which coincides with peak brewing production, high business in the brewpub and outdoor irrigation demands. This trend is consistent in other years as well.

Water Use by Sector

Conducting the resources audit for water was less precise than that of energy. Sub-metering for water points of use is uncommon, and to install it would have been fairly costly. The team relied on knowledge of the brewing cycle, process flow measurements and usage approximations to determine where water was being used at the Corner Brewery. The team installed a submeter and datalogger on the domestic hot water tank in January, after it was found that the brewing process used a lot less of the total facility water usage than was initially assumed.

Water usage has been divided into three sectors below: brewhouse, restaurant, and building.

Brewhouse

In the Brewhouse, water is used for brewing beer, cleaning, and rinsing bottles before filling (Figures Figure 38, Figure 39, Figure 40 and Figure 41).

Figure 38 Bright tanks in the brewhouse

Figure 39 Clean In Place (CIP) cleaning pump

Figure 40 Spillage from fermenter tanks

Figure 41 Brewhouse deck pump

To quantify water used in the brewhouse without being able to measure it directly, the team used information about the brewing cycle, and gathered information from interviews with the brewers (see "Brewing and Packaging Process").

Water used in the brewing process itself accounts for quite a bit more than what actually ends up in the product. In a 21 barrel batch of ready for sale beer, approximately 12.5 barrels of water stays in the spent grain, 3.5 barrels are evaporated, and half of a barrel of finished beer is lost during packaging. About 5 barrels of cold water is used to clean each FV and BT. Two barrels of hot water from the HLT clean the MLT after each use.

Restaurant

Water is used in the kitchen for food preparation, in the bathrooms, in the water dispensers for customer drinking water, for mopping and other cleaning, and for glass washing. Based on occupancy, seasonality, and water fixture specs in the restrooms, restroom water usages are estimated below (Table 10).

Figure 42 Manual, 2.0 gpm

Figure 43 Waterless urinals in men's room

Figure 44 Standard commercial 1.6 gpf toilet

Total daily water use for the whole year	
Toilet daily water use	133.3
Urinal daily water use	0.0
Sink daily water use	67.4
Total daily restroom water use	**200.7**

Table 10 Restroom water usage (gallons per day)

Mopping, based on frequency, uses 6.0 gallons of hot water per day. Glass washing, based on average cycles per day and 2.5 gallons per cycle, consumes about 92 gallons of hot water per day. Customer drinking water, which is self served from water coolers, accounts for just 6.4 gpd.

Building

The building category encompasses the uses of water that were not fully captured by the brewhouse and restaurant categories, namely domestic hot water and water for outdoor irrigation.

Figure 45. 200,000 BTUH domestic hot water heater

The 80% efficient Lochinvar 80 gallon domestic hot water heater (model CNR200-080-DF9) shown in Figure 45 heats water that is not used in the brewing process. This water is used in the kitchen for cooking, in the whole building for cleaning floors, by the glass washing machines, and is part of the water used in the restroom sinks. The team installed a water meter on the DHW tank to measure its water use, which was found to average over 1,000 gallons per day.

Landscaping at the Corner Brewery is mostly trees and bushes, and does not require much irrigation. Flowers are grown in the beer garden in summer. In 2010, a few hops plants were grown in the beer garden as well. Based on the growing season in Ypsilanti and the watering habits of the staff, 11 gallons per day is estimated for irrigation.

Total yearly water flow through Corner Brewery

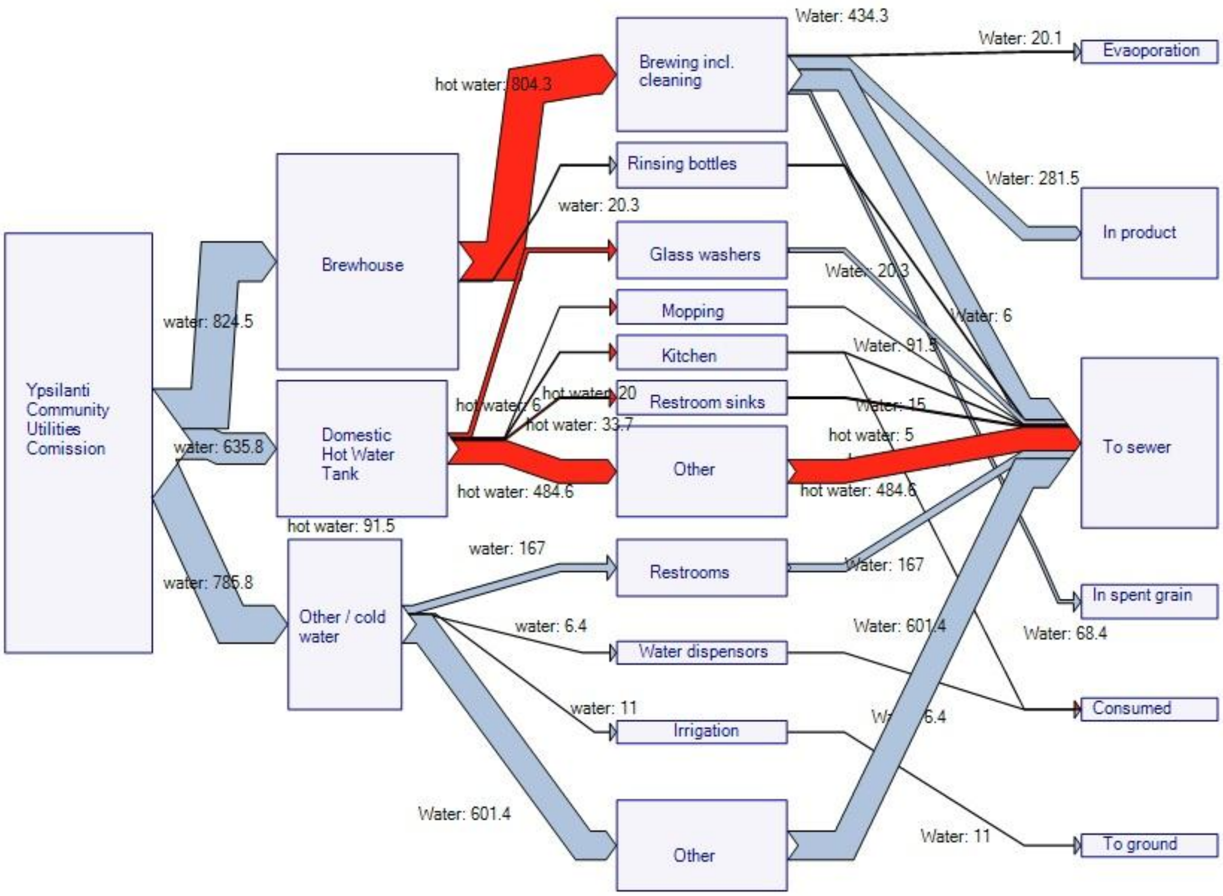

Figure 46. Water usage flow diagram. Box and arrow heights are scaled to relative water volumes within each column

Breaking total consumption down into its different uses in Figure 46, we see that the brewhouse uses only 37% of the total water consumed at the CB. A large portion of the rest of the water is heated in the DHW tank before being used. Much of this DHW water use is unaccounted for, but may be used for cleaning or dish washing.

The majority of the water leaving the Corner Brewery goes to the sewer. It's also evident from examining the water usage flow diagram that no water is reused on site.

For every gallon of beer produced, the Corner Brewery uses 8.57 gallons of water, which is on the high end of the brewing industry average, but is not unusual for a smaller brewery.[14] It should be noted that this figure represents the ratio of the volume beer produced to the gross volume of water used throughout the entire facility. A more useful metric is the ratio of the volume of beer produced to the volume of water used in the brewing process—excluding water used for toilets, glass washing, drinking, etc. Once these other uses are removed from the equation, the ratio is reduced to a mere 3.17 gallons of water per gallon of beer produced.

Consider that the current brewing setup involves a loss of 33% of mash water to spent grain, followed by an additional 12% evaporation during boiling, and a 2% loss during packaging. For now, disregard the additional losses of beer after fermentation—the yeasty dregs at the bottom of the fermentation vessel that nobody would want to drink anyway. The absolute minimum theoretical ratio under the conditions described is 1.73 gallons of water per gallon of beer.

Financial Considerations

When surveying a range of potential projects, an essential part of the decision-making process is the financial component. A business is not sustainable unless it can make a profit, regardless of how small its carbon footprint may be. Decisions based on financial alone can be achieved by the Investment Priority Number (IPN). This is a simple ratio of the total benefits in present dollars less the total costs in present dollars, all divided by the total costs in present dollars.

$$\frac{\sum \text{Benefits}_{PV} - \sum \text{Costs}_{PV}}{\sum \text{Costs}_{PV}} = \text{IPN}$$

If the IPN > 0, the investment will eventually pay for itself over a long enough time scale. Unlike an ROI calculation, IPN is normalized to the cost of the investment, enabling our client to identify the investments with the highest rate of return for the least capital investment. All else being equal, the higher the IPN, the more attractive the investment.

While a useful index, IPN does not determine the payback period of an investment. An Investment Worksheet spreadsheet was created in order to determine the yearly net impact of each potential investment on energy use, finances, and emissions. The spreadsheet considers loan financing, incentives, taxes, capital depreciation, REC payments, performance degradation over time, and multiple scenarios of energy price escalation. The payback period is calculated according to the Financed Discounted Payback Method, derived from the Discounted Payback Method, described in Appendix I.

Financial considerations should not be the only determining factor when choosing among alternatives. “Soft” benefits which come from corporate responsibility are difficult to quantify in financial terms. More to the point, no price tag can be placed on the value of conducting a business that embodies our client’s core values of environmental conservation and sustainability.

Incentives: Federal

The Federal Business Energy Investment Tax Credit (ITC) grants a tax credit worth up to 30% of the total project cost (including labor) for solar, fuel cells and small wind; 10% for geothermal, microturbines and CHP.[16] Special legislation permits the purchaser to reduce the depreciable value of this capital by only 50% (as opposed to 100%) of the value of the grant.[16]

The Commercial Building Tax Deduction, included in the Energy Policy Act of 2005, “…is limited to $1.80 per square foot of the property, with allowances for partial deductions for improvements in interior lighting, HVAC and hot water systems, and building envelope systems.”[17] By this measure, the new cool storage unit could qualify for a deduction up to $3,960, and the rest of the facility could qualify for up to a deduction up to $9,118. If improvements to the outdoor beer garden qualify, this would add an additional $10,121 deduction.

Federal Historic Preservation Tax Incentive (a tax credit) helps defray the costs incurred for energy efficient building expenditures in historic buildings. These can include lighting, HVAC and hot water systems, and building systems. The historic district tax incentive focuses on windows and can cover up to 20% of the cost.[18] A thorough reading of the application should be undertaken prior to purchasing decisions.[19]

Incentives: State

We did not discover any incentives provided by Michigan state government entities for which our client was eligible.

Incentives: Utility – Detroit Edison (DTE)

The DTE SolarCurrents program[20] offers an up-front payment of $2.40 per installed rated kilowatt DC for solar PV, and an additional $0.11 per kWh generated over the subsequent 20 years. A customer may enroll up to a maximum of 20kW DC of installed capacity in this program. In exchange, ownership rights to RECs generated from this system are transferred to DTE, helping the utility meet its state renewable portfolio standard (RPS) requirements. Solar thermal panels do not generate RECs, and are therefore ineligible for SolarCurrents. Hybrid solar PVT panels (see "Renewable Energy Generation") are eligible for SolarCurrents enrollment, though only the electricity they generate counts toward RECs.

DTE YourEnergySavings program (Commercial)[21] offers incentives for lighting and mechanical upgrades according to prescriptive and custom plans. A third plan applies to whole-building construction or remodeling. The prescriptive plan includes a long list of possible upgrades that, if approved, DTE will provide incentives for. Among the list are energy-efficient lighting, motors and drives, controls, and refrigeration. The custom incentives provide a rebate of $0.08 per kWh saved and $0.40 per CCF saved for a given energy efficiency project. The whole-building design assistance offers incentives to business owners to exceed typical building envelope and energy usage standards. It is unclear at this time which plan provides the maximum benefit to the Corner Brewery. Once energy efficiency options are chosen, a sensitivity analysis should be conducted to determine which incentive plan (or combination of plans) should be used. A dialogue with a DTE representative should accompany this analysis in order to ensure the validity of each option. Thoroughly documented and detailed engineering calculations are required for the custom plan items.

Discussion

The financial incentives provided by the Federal ITC Tax Grant and the REC payment agreement under Detroit Edison's SolarCurrents program make solar PV a very attractive option for on-site renewable energy generation. Additional "Michigan Incentive RECS" are generated from solar projects, and are described in greater detail in the "Solar Recommendations" section below.

It appears that DTE YourEnergySavings program may provide partial funding for every aspect of the 2011 expansion, as well as every energy efficiency improvement recommended in this report. Custom incentives are calculated based on projected energy savings which are for the most part reported in full in this report, enabling our client to submit an incentives claim with ample evidence to back it up.

Examples, Options, and Recommendations

Facility-Wide Energy Efficiency

Energy Management System

An energy management system (EMS) is "one of the most successful and cost-effective ways to bring about energy efficiency improvements... An EMS creates a foundation for improvement and provides guidance for managing energy throughout an organization."**Error! Bookmark not defined.** Properly implemented, an EMS can result in the reduction of 10-20% of a facility's energy consumption.[22] It is unlikely that energy conservation will be actualized as a direct result of the EMS, this recommendation is considered critical to ongoing and future energy conservation measures. It effectively transforms energy efficiency from a once-through process, to a continuing cycle of improvement and monitoring. Energy Star provides a thorough guide on how to implement an EMS.[23] A member of the staff familiar with energy use in the facility should be given the responsibility of implementing the EMS.

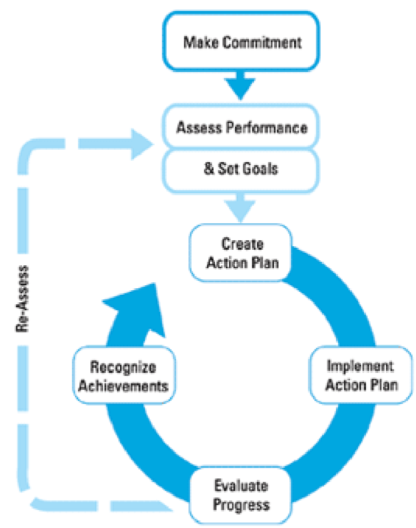

Figure 47. Energy Management System Process

Accurate instantaneous and trend performance data must be collected from energy-using equipment in order to monitor energy use and evaluate progress. Integrated systems for process automation and data collection should be considered not only to control and monitor processes at the Corner Brewery, but also to remotely monitor and control processes at the satellite brewery set to open in Bangalore, India.

At the very minimum, monitors should be installed in the most energy-intensive devices in the facility to collect instantaneous and trend data. Without this information, the overall performance of efficiency measures cannot be effectively evaluated by the EMS.

Brewing Energy Efficiency

Introduction and Overview of Current Challenges

Many technology solutions are available to reduce energy intensity in the brewing process. A 2003 study published by the Lawrence Berkeley National Laboratories and EnergyStar describes a wide range of process-specific measures and cross-cutting measures.[2] The list of measures is included in Appendix K and Appendix L, and the recommended measures chosen from this list are described in detail below.

At present, the brewing schedule of the Corner Brewery is entirely determined by demand from distributors. Consequently, strategic planning of brewing cycles to maximize efficient resource utilization is challenging. Long-term and short-term planning should be implemented in order to maximize the number of barrels of beer produced per brewing cycle, thereby maximizing the utilization of recovered hot water. Energy and cost savings from this practice can be inferred from Figure 24.

Many breweries have a “cold side” and a “hot side.” The cold side is where all the low-temperature processes take place, and houses equipment such as the CLT, the FVs, the BTs, the and the glycol chiller. The hot side is where high-temperature processes take place, and includes the boiler, the BK, the HLT, and the MLT. The amount of energy needed to maintain correct process temperatures is particularly sensitive to ambient temperatures. Unfortunately, the Corner Brewery’s entire brewhouse is located in a single large warehouse. Consequently, waste heat radiating from the air compressor, boiler, BK, and other energy-intensive systems heat the air surrounding the FVs and BTs, which rely on the glycol chiller to stay cool. The compressor motor of the glycol chiller itself produces waste heat as well, which adds to the total heat gain of the brewery. Waste heat should be recovered wherever possible or vented to the outside.

Additional heat gain in the brewery is caused by sunlight coming in through the large windows, which line the entire south face of the building. During the summer, the brewery is often uncomfortably hot for employees.

Brewing process automation and digital control is incomplete. What process automation infrastructure exists is not fully utilized. Not all components of the brewhouse are connected to the brewhouse computer, which is itself an obsolete model. For example, while the boiler seems to be connected to the control system, the system is not currently being used to control its activity.

Methodology of Options Analysis

Numerous published reports on energy conservation measures for industry in general and for brewing in specific were examined. Most options that could considerably alter the flavor or quality of the product were eliminated outright. Options which were unfeasible at the Corner Brewery's scale of operation were eliminated. Options which were incompatible with site constraints were eliminated. Consultation with our client, brewing experts, and energy efficiency experts narrowed the field of options.

Recommendations for Brewing Energy Efficiency

Brewkettle Heat Recovery with Vapor Condensers or Heat Exchangers

Heat recovery from wort boiling is commonly achieved using either spray condensers or simple heat exchangers.[25] Sierra Nevada Brewing Company of Chico, CA; Soo Brewing Company of Sault Sainte Marie, MI; and Original Gravity Brewing Company of Milan, MI all utilize spray condenser heat recovery systems. Atwater Block Brewing Company of Detroit, MI uses a simple heat exchanger for wort boiling heat recovery (M. O'Brien, personal communication. March 2011). It is reported that up to 60% of the energy required for wort boiling can be recovered.[25] Using 2010 data for the Corner Brewery, this represents a savings of up to 4,103 CCF, or up to 24% of the facility's total natural gas consumption that year. Both heat recovery options should be seriously explored at the Corner Brewery.

High Gravity Brewing

In brewing, "gravity" refers to the specific gravity of the wort prior to fermentation, which is directly proportional to the starting concentration of sugars. Starting with higher gravity results in a beer with higher alcohol concentration and a more intense flavor profile. Many breweries brew at higher gravity, and then dilute the end product with water to reach the final desired "low-gravity" flavor profile and alchol concentrations. While this so-called high-gravity brewing tends to be looked down upon in the craft brewing industry, claims of energy savings between 18% and 30% have been reported.[24,25]

In 2010, the Corner Brewery produced approximately 600 BBl of Brasserie Blonde Ale, their most popular low-gravity "session beer." This represents 20% of the total brewery output for that year. By beginning with higher gravity, and diluting with water to reach the final low-gravity desired, the Corner Brewery could theoretically save 3.6% to 6% of natural gas used for brewing and electricity used for process cooling. No additional investment would be required to enact this recommendation on a trial basis, to determine if there are any adverse effects on flavor, material utilization, foam stability, etc.[26] This process could be used with other low gravity styles as well.

Wort Cooling – Additional Heat Recovery (Upgrade Heat Exchanger)

Multiple-stage heat exchangers can recover up to 10.54 kWh thermal energy (36 kBTU) per BBl of wort cooled.[27] An experiment measuring the inlet and outlet temperatures of the single-stage heat exchanger at the Corner Brewery determined that only 5.57 kWh thermal energy (19 kBTU) per BBl of wort cooled was in fact recovered. If the full improvement to 10.54 kWh thermal were realized, this would represent a yearly savings of 630 ccf of natural gas at 80% fuel efficiency, using 2010 brewing figures. The payback period would depend entirely on the cost of the heat exchanger and the brewery production volume. A final advantage of replacing the current heat exchanger is switching to a model which can be fully dismantled for thorough cleaning, which is expected to reduce the likelihood of contamination, and result in a net improvement in quality

Improved Steam Process Control

Flue gas monitors can actively analyze the combustion exhaust from the steam boiler. An automatic controller can use this information to maintain optimal flame temperature and fuel to air ratio. It can also detect problems such as air infiltration, excessive CO generation, or smoke content, all of which cause or indicate inefficient combustion. Miller Brewing Company in Milkwaukee, WI switched from pneumatic to electronic boiler controls, and saved 2.1 kBTU per BBl.**Error! Bookmark not defined.**

Boiler Flue Gas Heat Recovery

Boiler intake air, boiler feed water, domestic hot water, and even hot water for brewing can be pre-heated using a waste heat economizer. One rule of thumb states that one percent of fuel use is saved for every 20-25 degC reduction in flue gas temperature.[28] So long as the flue gas temperature does not drop below the dew point of acids in the flue gas, corrosion effects are not a concern. Regardless of downsizing or upgrades to the steam boiler, this option should be pursued.

Steam System Leak Repair and Insulation

Regular inspection and maintenance of steam pipes can save 3% of energy costs, and avoid the probability of having to repair small leaks. A small leak can release up to 1 kg of steam per hour without being detectable by the naked ear or eye.**Error! Bookmark not defined.** Insulation, especially over joints, fittings, and valves, should be removable for regular inspection.

Currently the cast iron pipes that carry steam in the brewhouse are not insulated whatsoever. These pipes range from 3/4” to 3” in diameter, total 213 linear feet, and carry steam from the boiler to the hot liquor tank, the mash tun and the brew kettle and return condensate back to the boiler. Insulation of these pipes would greatly reduce heat loss to the brewhouse air and significantly reduce natural gas use by the boiler. According to the EPA Energy Star program, improved insulation of steam pipes in a brewery is a great example of low-hanging fruit, observing a typical payback period of less than two years.[2]

Figure 48. Uninsulated steam pipes are a big energy loser **Figure 49. Inexpensive fiberglass pipe insulation**

The amount of heat energy that escapes from these pipes is considerable, as shown in Table 11. Energy savings from steam pipe insulation. When brewing on a summer day, the temperature in the brewhouse climbs drastically, making the space quite uncomfortable. On a winter day, this escaped heat is actually somewhat beneficial for space heating purposes, keeping the ambient temperature of the brewhouse more comfortable than it would otherwise be. This is not an efficient way to heat the space. It forces the glycol chiller to work harder, and extends the time required for brewing.

Using standard thermodynamics and heat transfer equations, the amount of heat lost by the steam and condensate return pipes was quantified. An alternate case was considered using 1" fiberglass insulation and the simulation was run again. Results are summarized in Table 11. See Appendix M for detailed calculations.

Total length of steam pipe (m)	Uninsulated energy loss (kWh thermal)	Insulated energy loss (kWh thermal)	Annual insulation energy savings (kWh thermal)	Annual natural gas savings (ccf)
66.5353	10095	1973	8122	577

Table 11. Energy savings from steam pipe insulation

In order to come up with a simple payback period, a cost estimate for the necessary insulation was acquired from State Supply in Minneapolis, MN (Table 12).

Insulation subtotal	Shipping	Installation estimate	Total installed cost of insulation
$ 494.56	$ 195.44	$ 150.00	$ 840.00

Table 12. Cost of insulation

Payback Period	
Annual natural gas savings (ccf)	577.01
Annual Cost savings of NG	$605.86
Cost of insulation	$840.00
Simple payback period	**1.39 years**

Table 13. Simple payback period

The simple payback period was then calculated, based on the annual energy savings of the proposed insulation, the total installed cost of the insulation, and the 2010 price of natural gas ($1.05/CCF) (Table 13).

The simple payback period was found to be a relatively quick 1.39 years, but this is a conservative estimate. In reality, two factors will lead to an even shorter payback period. First, the Corner Brewery plans on expanding their production significantly in the coming years. More brewing means more heat loss from the bare pipes. Secondly, the price of natural gas is steadily rising, which will also lead to a faster return on investment. Finally, financing and utility incentives have not yet been accounted for.

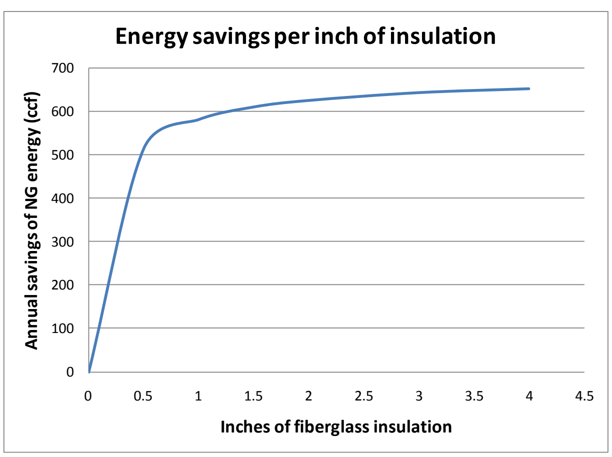

Figure 50. Diminishing returns of increased insulation thickness

Figure 50 shows that 1 inch of insulation is right at the sweet. In the case of the Corner Brewery's steam pipes, it shows that drastic savings are achieved for the first 0.5 to 1 inches of insulation, but beyond that, little is gained.

The Green Brewery Project strongly recommends insulating the steam pipes at the Corner Brewery, not only for energy savings and financial reasons, but also because the thermal comfort in the brewhouse that will be strongly enhanced by this improvement.

Improve Operations and Maintenance

High returns can be realized with relatively low investment costs associated with improving the operation and maintenance of cooling systems. "Such improvements can include shutting doors, setting correct heat pressure, maintining correct levels of refrigerant. Energy saving can also be achieved by cleaning the condensers and evaporators. Scale on condensers increases power input and decreases regrigeration output. Three millimeters of scale can increase power input by 30% and reduce output by 20%."**Error! Bookmark not defined.** Looking beyond the brewhouse, numerous examples of fouled heat exchange surfaces were observed throughout the facility, most notably in food and beverage refrigeration equipment in the kitchen area.

Heat Recovery Wheel

A regenerative heat recovery wheel is a "revolving disc filled with an air-permeable medium including a desiccant. When the air passes through the medium, heat energy and moisture are transferred to the medium. As the medium rotates into the opposing air stream, the warmed, moist medium transfers the heat and moisture to the opposite-flowing air stream. Therefore, a heat wheel can either: reduce entry of warm, moist outside air into the space, or recover heat and moisture that would have been simply exhausted for the space. There has been a renewed interest in heat wheels since molecular sieve coatings have been used that ensure minimal contaminant transfer."[29,30] There is ample opportunity for this technology to be utilized in all conditioned spaces, including the finished product storage space. The very high space heating demand for the restaurant could make this a very attractive option to reduce space heating costs in the winter. Though it is a common enough solution, an HVAC professional should be consulted to properly design the system to meet the needs of the facility.

Install Strip Curtains on Doors to Cold Storage

Strip curtains are overlapping flexible plastic strips which can reduce heat loss from heated or refrigerated spaces.[31,32] The Energy Independence and Security Act of 2007 Section 312 states that all new walk-in coolers and freezers manufactured and installed in the United States with a floor area of less than 3,000 square feet must include flexible PVC strip doors or spring-hinged doors.[33] With a strip curtain in place, air infiltration can be reduced by up to 75% when the door is open.[34] If forklift access to the space is required, the curtain should be mounted on a track, allowing it to be temporarily moved aside.

Special Topic: Process Cooling Efficiency and Heat Recovery

As previously stated, the glycol chiller is the top consumer of electricity at the Corner Brewery. The glycol chiller currently operates at an evaporator temperature range of 24-28 degF. Yet, most of the process cooling demand arises from the need to maintain FVs at 68 degF during fermentation. The beer is cooled to 45 degF prior to transfer to bright tanks. Only after it is transferred to bright tanks and further cooled to 28 degF is the chiller's low-temperature cooling capability is required. At present, a nominal 27-ton chiller is being part-loaded to provide only 1.47 tons of cooling at all three temperature ranges. We believe that the improper matching of loads and operating points to the equipment is responsible for significant losses in efficiency. We present several options to address these problems.

Option 1: Purchase Lower-Capacity Glycol Chiller with Heat Recovery

It is well understood that chillers do not operate efficiently under such low part load conditions as observed at the Corner Brewery. It was observed that the nominally 27-ton chiller is only providing 1.47 tons of cooling throughout the year. To achieve this, the process supply pump operating rpm had to be reduced to about 25% of its design speed. The oversized and obsolete (R22) primary chiller could be replaced with a smaller, more efficient model which also uses a less environmentally-hazardous refrigerant (e.g. R-410a).

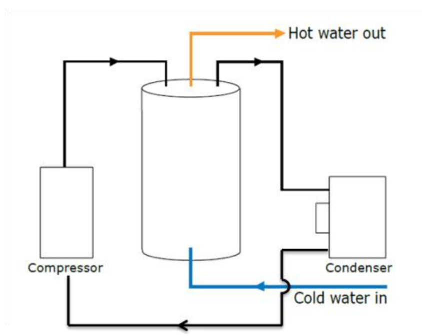

Figure 51. Schematic diagram of chiller heat recovery

Heat recovery units used in the dairy industry such as the Mueller Model DHS Fre-Heater® or the BouMatic Therma-Stor®[35] recover up to 60-65% of waste heat from milk cooling operations (see Figure 51). Such a unit could be integrated with a downsized chiller.

Pro Refrigeration[36] Inc. has been identified as a vendor with particular expertise in brewery process cooling, as well as innovative heat recovery as described in the previous paragraph. Considerable insight was gained from an email exchange with the CEO, Jim VanderGiessen Jr.:

Some of the reasons [heat recovery units] are not more common are due to the Therma-Stor and Fre-Heater Systems [not] holding up over the long haul and the high cost to install and replace. I've also seen many of these units added in the field and due to incorrect installation (undersized piping, location of units, etc), the "cost" in efficiency loss is much higher than if the customer had used traditional hot water heating units. [viii]

Mr. VanderGiessen, Jr added that his company is working on a chiller system which incorporates the heat recovery capabilities of the Fre-Heater® or Therma-Stor®, but as built-in components, and features enhanced durability.

Option 1 Analysis: Downsized Chiller with Heat Recovery at Corner Brewery

No specific energy or economic analysis could be performed on this option due to the lack of performance data for a downsized chiller at the time of writing. However, it is the most "conventional" approach to solving this problem, and should be explored with the assistance of an experienced vendor.

[viii] If this option is pursued, a vendor with extensive experience installing these systems should be used in order to avoid common installation errors.

Option 2: Water Source Heat Pump (WSHP) for Process Cooling

A heat pump is a machine which uses work (electricity or fuel) to drive a refrigeration cycle, which is used to transfer heat from a low temperature reservoir to a high temperature reservoir. One of the benefits of a heat pump is that it can take a waste heat stream and raise it to a higher temperature at which point the heat is useful. The reservoir may be any medium, but is most commonly water or air. A refrigerator is an example of an air-to-air heat pump. A WSHP (also called high-lift water-cooled chiller) uses water (or other thermal liquids) as thermal reservoirs. The WSHP used in geothermal heating and cooling is sometimes called a ground-source heat pump, since one of final thermal reservoirs is earth.

The US Department of Energy has recommended the use of heat pumps for a variety of applications in industry, including food and beverage, chemical, wood, and textiles.[37] Although work energy is required to drive a heat pump, they can reduce the use of purchased steam or fuel. The temperature difference between the waste heat and the output heat stream (called "lift") determines the amount of mechanical work required to drive a heat pump.

Functioning as a heat extraction device at the evaporator, and as a heat supplying device at the condenser, heat pumps can be integrated into environments which simultaneously require heating and cooling.[38]

Chris Nutt of AirTech Equipment, Inc.[39] supplied performance characteristics for such a WSHP, shown in Appendix N. Using these numbers it was possible to compare the energy that would be consumed using a WSHP to offset a given percentage of the year's chilling demand, and the corresponding fuel use reduced by utilizing the WSHP's condenser heat. This was compared to the base case, which uses a 30 HP reciprocating compressor chiller as described in Appendix N.

Option 2 Analysis: WSHP at Corner Brewery

The efficiency improvements realized by a WSHP are due to its higher operating temperature compared to type of chiller currently used. A downsized chiller would be more efficient than the current one due to proper load-matching, but would still operate at a much lower temperature than is required for much of the cooling demands of the Corner Brewery (i.e. fermentation at 68 degF).

The glycol chiller load for 2010 was, on average, 1.47 tons (5.18 kWh thermal). Its efficiency varied seasonally with ambient air temperature, as shown in Figure 23. Including all pumping and fan energy used, its average system EER was 2.5 (BTU rejected per Wh electricity input). The WSHP specified will have an average EER of 9, assuming an average incoming city water temperature of 55 degF.

To remain on the conservative side, our model (summarized in Table 14) assumes that the WSHP will require an additional 1.0 kW of electricity in order to run dedicated process pumps, and that only 80% of the recovered heat will be usable in the form of hot water.

Four scenarios are considered. The Base Case describes business as usual, using the current chiller. Three Alternative Cases predict the outcomes if a WSHP were used to provide 50%, 75%, or 90% of the cooling demand currently handled by the current chiller. The more cooling unloaded by the current chiller to the new WSHP, the more savings are realized.

	Annual Electricity Used (kWh)	Annual Change in Natural Gas Used (CCF)	Annual MT CO2 Released	Annual Equivalent Car-Years	Cost of Electricity Used Less Cost of Natural Gas Saved
Base Case (Existing Chiller Only)	77,677	0	56.72	10.91	$ 9,321
Alt Case 1: 50% WSHP	54,418	-1,307	32.62	6.27	$ 5,157
Alt Case 2: 75% WSHP	39,284	-1,961	18.01	3.46	$ 2,655
Alt Case 3: 90% WSHP	30,203	-2,353	9.25	1.78	$ 1,154

Table 14. Considerable savings could be achieved relative to business as usual with a WSHP providing high-temp cooling

Process Cooling Efficiency and Heat Recovery Conclusion

The Corner Brewery requires a large amount of hot water for both its brewing and restaurant operations. With the planned increase in beer production, this demand will only grow. The planned purchase of two additional bright tanks will increase its demand for cooling. With sufficient thermal storage to accommodate times of low production, a WSHP, a heat recovery unit, or a downsized chiller with integrated heat recovery could pre-heat (to 120-130 degF) a significant portion of this hot water, potentially allowing the brewery to downsize its steam boiler, and/or eliminate its domestic hot water heater. Combined with other heat recovery projects and solar thermal panels, the fossil fuel use for water heating at the Corner Brewery could potentially be reduced to almost nil.

Further savings in space heating and cooling could be achieved by installing radiant water coils in the rooftop air handler unit and cool storage spaces, which would allow excess cold and/or hot water to be used for space heating and cooling.

By utilizing the highly efficient simultaneous heating and cooling capabilities of a WSHP or appropriately-sized chiller with heat recovery, a tremendous amount of energy, money, and emissions could be saved. A careful system-wide study should be undertaken in partnership with equipment vendors, and will ideally include a pinch analysis to optimize system-wide energy performance.

Non-brewing Energy Efficiency

Restaurant

Some of the cooling equipment in the kitchen and restaurant is old and inefficient. In particular, refrigerator #6 (Figure 27), is old and has glass doors. Refrigerators with glass doors consume 56% more electricity than those with solid doors.[40]

In 2011, a new walk-in cold storage space will be constructed. Frequently-accessed food items should be stored in refrigerators separately from this long-term cold storage area in order to reduce the heat gain from the door opening and closing. Therefore, this refrigerator, if still needed after the expansion, should be replaced with a solid-door Energy Star rated model.

Most of the potential improvements in kitchen natural gas usage could be achieved through behavior change. Kitchen managers should assess whether or not grills need to running constantly throughout the day, on all burners, and whenever possible, they should be turned down or off. Options for more efficient cooking equipment should be explored.

Lighting

Because the lights in the pub are dimmable, the options for upgrades are more limited. Dimmable CFLs are available but are more expensive and the dimming switch needs to be changed to accommodate the lower outputs.

Recommendations eligible for the DTE Your Energy Savings (prescriptive) program are indicated by the "DTEPP" acronym. Refer to the "Financial Considerations" section for details. Refer to Appendix O for information on high efficiency halogen lamps and suggestions for LED exit lights.

- Replace the globe fixtures over the bar with low wattage CFLs. A 13W bulb has a similar feel as the 75W incandescent bulbs that are set dimmed at about 50%. This would cut the usage from ~30W (a bulb dimmed at 50% is 40% of wattage) to 13W. These new CFLs would need to be set at 100% due to the limitations of the non-dimmable bulb. DTEPP.
- Replace wall-mounted fixtures with lower watt bulbs. These could also be replaced with CFLs but if the dimming switch is not replaced they would have to be left at 100%. This may affect the ambience of the establishment. A suggestion is to make sure they are off during daylight hours because they add very little lighting to the pub area.
- Replace the track-mounted lights with GE Halogen PAR38s that are also dimmable. These 48 Watt halogen lights have a longer life, similar lumens, and are 27 Watts less than the existing

bulb. They also are very likely to match the current aesthetics and desired ambience of the restaurant. See Appendix O for Halogen light specifications.

- The brewhouse lighting could be upgraded to more efficient T-8 fixtures but we suggest that this is done after the latest adjustments to the work area are done. DTEPP.
- Replace the exit signs with LED exit signs. DTEPP (see Appendix O).
- Replace the light in the bar refrigerator with an LED light bar to reduce the unnecessary load within the cooled area.
- Install occupancy sensors in the restrooms.

Building Envelope: Windows

The windows provide excellent daylight for the facility but have a big disadvantage: their weak insulating properties. In colder climates windows are the largest source of heat loss, at 30.4% of total loss of the building.**Error! Bookmark not defined.** Due to their expanse and age, these single-pane windows lose a lot of heat energy during the winter and gain heat during summer. It isn't uncommon to see customers keeping their coats and hats on in the winter to cut down on the chill. The windows have visible signs of aging and deterioration, including gaps and cracks around the edges, which allow air movement in and out.

Options

One option is to replace all the aging single-pane windows with new double-pane windows. However, there are a few technicalities that make this slightly more difficult than it would seem. Among these are the Ypsilanti Historic District requirements, which require new windows to appear nearly identical to the original windows. Even if double-pane windows identical in appearance were installed, there may be additional complications related to the age of the existing windows. Possible lead or asbestos abatement issues would drive up the labor and disposal costs. Ideally the glass would be recycled along with the metal frames, but again this drives up costs due to the extra labor needed to separate the materials. One final issue to consider, from an industrial ecology perspective, is the energy embodied in the existing windows. They have already been manufactured and there is little energy needed to maintain them in their current state.

Figure 52. South-facing window detail shows sunlight passing through gap between sash and frame

A second option is to do a limited replacement: choose the windows that would provide for the most gain in employee and customer comfort while reducing the air infiltration and heat transfer.

This option would reduce the windows replaced by about a third because the brewhouse windows do not affect customer comfort. Focusing solely on those windows that are directly adjacent to the customer seating areas could reduce the windows needing replacement even more. This would limit the replacements to those windows on the north and west walls.

A third option is to leave the existing windows in place and do some periodic maintenance on them. There are windows that need to be caulked and sealed better. Figure 52 is representative of the deteriorating condition of most windows at the Corner Brewery. A gap between the window sash and the frame is perceivable by the sunlight passing through. Items like this could be sealed with inexpensive caulk. A couple of tubes of caulk to match the windows would help in reducing air infiltration and drafts. This is a low-cost option with minimal man-hours needed.

Figure 53. Inside view of shutter system. The small gaps that are visible are closed when the shade is pulled down tight, blocking all sunlight.

A fourth option is to install window-shading devices, like the ones seen below. This type of shade runs along a track installed along the window frame, outside of the window. When fully closed, the shade creates a very tight seal, blocking all sunlight and greatly reducing airflow. The core of the shade is filled with foam, which provides some insulating properties as well. When open, the shades are hardly noticeable, allowing full sunlight to enter the window. They can also be pulled partly down, if the user only wants some shade. The shades serve the purposes of storm windows and curtains, and are attractive and user friendly as well. They can be operated manually or with an installed electric motor. The cost of installing these shades is orders of magnitude cheaper than upgrading the windows (see Appendix P).

A fifth option is to do a mix of the previous recommendations to maximize on the solar gain in the winter and day lighting benefits year-round. Install shades on the north and east windows that are controllable by the staff or customers and install new windows on the west and south walls in the pub where there would be minimal customer interaction. The brewhouse windows would be left alone as a cost saving measure due to their minimal interaction with customers. Also, there are plans to change the configuration and some of the non-street facing windows may be removed to allow for a new garage door.

It is first recommended to do some maintenance on the windows and catalog the condition of them. The next step would be to pinpoint the windows whose replacement would achieve the greatest impact with customers and staff. If replacing the windows is cost prohibitive then look into other ways to tighten the envelope, especially in the nighttime winter hours, such as blinds or shades.

Building Envelope: Roof/Ceiling/Floor

For aesthetic reasons, and to comply with historic district guidelines we do not recommend any major insulation upgrades. Small steps can be taken to decrease air infiltration, which is the third largest source of heat loss at 18.7%.**Error! Bookmark not defined.**

The ceiling/roof insulation appears to be adequate. Adding insulation to the ceiling would benefit the structure but would also change the appearance. In addition the pub would have to be closed and the vendor said there might be slight off gassing for a few days. If the job were scheduled during other maintenance periods it wouldn't be an issue.

A suggestion for the area behind the fireplace is to install a radiant heat reflective shield. It could be hidden behind the fireplace with minimal viewing to the customers this method would reflect 95% of the radiant heat back into the facility. A specification sheet for Arma-Foil is in Appendix Q. A roll that covers 500 sq. ft. costs $70.00.

A radiant floor heating system could be installed using recovered heat from the brewing process and incorporating solar thermal heating systems. The existing floor is an excellent subfloor for such a system. However, installing subfloor would lower the effective height of all permanent furniture in the facility, such as the bar and booths, and would significantly alter the feel of the space.

Air Circulation

We recommend utilizing fans during all seasons for air circulation. Reversing the directionality of the fans according to the seasons should be considered. Fans should blow down in the summer to create a cooling, "wind-chill" effect, and should blow up in the winter at a high enough speed to disturb the temperature gradient. However, the number of fans may be insufficient to achieve these desired effects. With the existing configuration of the three fans, only one is near the majority of the customer seating, and just a few tables would feel direct air movement. Additional fans may be necessary to obtain the above-mentioned "wind-chill" effect in the summer. With the limited number of fans in the restaurant and their uni-directional configuration, using them in the summer would move the warm air down to the customers and thermostat, thus forcing the air conditioner to run more often. Further temperature observations should be considered in the summer months to optimize usage.

Water Efficiency

Introduction

Because of the rate structures of the various utilities at the Corner Brewery (electricity, natural gas, water), there is much less incentive to conserve water than to conserve energy. Water is relatively cheap, and water disposal (sewer) fees are likewise inexpensive. Thus water saving measures at the Corner Brewery typically do not predict high rates of return because the water they are saving is inexpensive to begin with. Water does account for 17% of total utility bills, however, which is not inconsiderable.

As shown in our analysis of wastewater treatment (see "Wastewater Treatment" section), wastewater treatment options such as greywater systems, wastewater biogas, and aerobic digesters, are not economically viable at this point. Thus we are limiting our water efficiency recommendations to small price tag projects that will reduce the water demand at the Corner Brewery, rather than provide methods of water reuse or wastewater treatment, with the notable exception being the green façade.

Water efficiency recommendations

Green Façade

The orientation of the Corner Brewery makes it an ideal location for an innovative and eco-friendly green façade. A green façade incorporates multiple functions including day lighting, shading, ventilation, and formal expression. Conventional building façade designs have only a single function, to protect the interior space from the elements. With the long-term objective of creating a sustainable brewery in mind the installation of a hop-wall and solar awnings on the premises are proposed. This exterior south facing wall will serve multiple functions. These are: shading in the summer to lower the cooling demands of the facility while still allowing for the ample winter solar gain, a small portion of on-site hop growth to supplement the hops shipped in, and the incorporation of a rainwater catchment system that should provide for most of the normal watering needs of the hops.

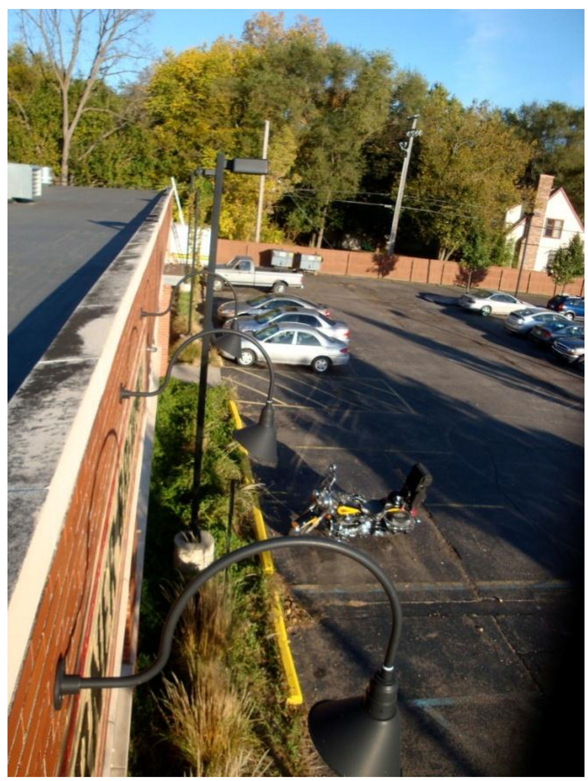

Figure 54. The south wall offers plenty of space to anchor a green façade

According to research published at the International IBPSA Conference in Glasgow, Scotland,

> *"In cold climate, represented by Detroit, Michigan, the most prominent source of heat gain is solar radiation at 42.5%, followed by conduction through windows (7.4%), infiltration (2.5%). Conduction heat gain through walls (2.1%), doors (1.0%) and roof (0.8%) are insignificant. This indicates that in Michigan shading is essential for reducing the cooling energy consumption, while envelope insulation is less beneficial in summer."* **Error! Bookmark not defined.**

Figure 54 shows the lack of summertime shading and the space available for a hop wall and solar awnings. Without blocking the view and obstructing the doorways there is about 80ft. of length to establish a hop wall. Each hop hill should be about 2ft. apart so there is room for 40 hills with each having four to six vines. These hills would be watered by a rainwater catchment system from the roof and stored on site using only gravity. In the typical four month growing season in Ypsilanti and with the roof size taken into consideration about 67,000 gallons of water could be harvested and distributed using on-site storage and a drip irrigation system. However, water from bottle rinsing, and even glass washing could be recovered and pumped into this tank, provided that no toxic chemicals are used. The water storage tank could be buried underground if desired.

Figure 55. The hop wall offers superb shading in the sumemr, while providing a key ingredient used for small batches

Figure 56. Rainwater catchment would provide much of the required irrigation under typical weather conditions.

The pay-off in hop production would be small in comparison with the overall usage of the Corner Brewery. The hops grown on site should easily provide for the small "Rat Pad" brews and any need for fresh hops during the summer and fall. One of the main benefits of this proposal would be the secondary function and location of the hops: shading in the summer while still allowing for sun in the winter. Another benefit would be driving home the sustainability message by providing for some of the inputs of the facility on site and potentially inspiring other local brewery hop walls. The green façade could easily be combined with a solar panel awning recommended below. See Appendix R for additional green façade information.

Sub-metering

We recommend installing several water meters within the building. Sub-meters will allow accurate measurements of water usage at various locations in the building, which will allow for more informed decision-making with respect to what further water efficiency projects to undertake. For instance, if it turns out that much more water usage than expected is occurring in the restrooms, then the fixtures should be checked for leaks, and also perhaps considered for replacement. An additional benefit to sub meters is that building users, namely employees, will subconsciously be encouraged to conserve water when they know that their usage is being monitored.

We recommend sub meters in the following places:

- Each restroom
- The main line leading to the kitchen and restaurant
- All points of use within the brewhouse
- Domestic hot water tank (already installed by the GBP)

Dual flush toilets

Replacing the toilets in the restrooms with low flow, dual-flush, WaterSense labeled toilets is recommended. WaterSense is the EPA's water efficiency labeling program, akin to the more well known EnergyStar. According to the EPA, an efficient toilet can save over 4,000 gallons per year in a residential setting.[41] Toilets in a commercial setting such as the Corner Brewery are used much more frequently, thus the potential for savings is even greater. The men's restroom toilet is less important because it is used less frequently than the women's room toilets, but should nonetheless be replaced for consistency.

Aside from saving water, installing efficient toilets in the restrooms is a very visible way for the Corner Brewery to show guests that they are making a strong environmental effort.

Low-flow faucets

WaterSense labeled faucets reduce flow by 30%.[42] According to our water estimations, installing WaterSense faucets in both restrooms can reduce water use by over 7,000 gallons annually.

Renewable Energy Generation

After considering the list of feasible options, including solar energy, small wind energy, and biogas energy (see “Anaerobic Digestion for Biogas” under “Other Topics for Consideration” below), the single most attractive option was found to be solar energy. Solar energy generation falls into two basic categories: solar photovoltaic (PV) and solar thermal. The solar PV technology of interest in this study uses silicon-based flat panels which receive incoming sunlight, and convert it into DC electricity. Additional equipment is used to convert the DC power into AC, and also tie the system into the electric grid. Solar thermal technology uses flat panels or arrays of evacuated tubes to collect sunlight in order to heat a thermal fluid such as glycol-water solution. Using a heat exchanger, this heat is extracted, and typically transferred to water. This water can be used for brewing, domestic hot water, or even space heating.

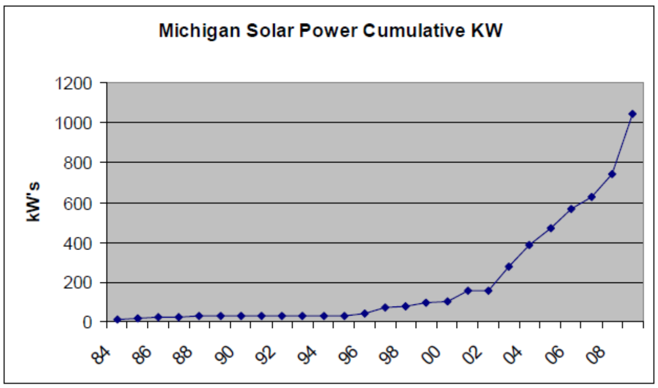

Figure 57. Solar power generation in MI has grown rapidly over the past decade.[43]

On the basis of useful energy collected per square meter of collector surface, solar thermal is several times more efficient than solar PV. However, the financial incentives available to solar PV users in Michigan are considerably greater than those available to solar thermal users.

Ypsilanti, MI is situated in a relatively sunny part of the country, and experiences greater yearly solar insolation than Germany, one of the world leaders in solar power generation.[44] The cold climate actually improves the efficiency of solar PV panels, and evacuated tube solar thermal collectors perform well even in cold temperatures, thanks to the insulation provided by the vacuum-sealed tubes. Climate data for Ypsilanti, MI can be found in Appendix R.

Solar PV

Sierra Nevada Brewing Co. in Chico, CA installed in 2008 a 1.4 MW (AC) solar array, then one of the largest privately owned solar PV installations in the United States. At the time it supplied over one-third of the brewery’s electrical energy needs.[45] The brewery relied heavily on incentives provided by the utility company PG&E.[46]

Solar Thermal

Microbreweries throughout the United States have made successful use of evacuated tube and flat panel solar thermal collectors to meet their demand for hot water. Central Waters Brewing Company in Amherst, WI installed 24 flat-panel solar thermal collectors to support their operation, relying on Federal and Wisconsin state grants.[47] In 2009, Upland Brewing Co. in Bloomington, IN used Federal tax grants and a $24,000 Indiana state grant to help pay for ten Apricus AP-30 solar collectors. This system produces approximately 1,670 therms, or 49,000 kWh (thermal) per year, eliminating about 75% of the brewery's natural gas.[48] The Lucky Labrador Brewing Company of Portland, OR uses solar thermal energy for water heating, generating about 1,000 therms, or 29,000 kWh (thermal).[49] Financial incentives played significant enabling roles in this project as well.

All three breweries leveraged their use of solar power for marketing, with beer names like "Shine On," "Helios Pale Ale" and "Solar Flare Ale."[50,51,49]

Hybrid Solar PV-Thermal (PVT)

PowerPanel, a Detroit solar panel manufacturer, has begun producing combination solar PV and solar thermal panels. These panels effectively function as liquid-cooled solar PV panels, which produce hot water as a waste product. The liquid cooling has been shown to boost efficiency up to 18%.[52] Furthermore, these panels are capable of functioning even after being covered in snow: a brief recirculation of hot water through the collector is sufficient to melt accumulated snow and ice, restoring PV functionality. This same company also offers an extremely low-cost thermal storage solution. The solar PVT panels alone cost almost double ($5.20 per Watt DC vs. $2.74 per Watt DC) that of a leading solar PV model (Evergreen 210W), but deliver considerable value from the hot water they provide.

Methodology of Analysis

The major challenge of this analysis was to find a way to easily compare the energy-generation performance of different solar options. Off-the-shelf software packages such as HOMER and RETscreen did not provide the ease of use or customizability a true "apples-to-apples" comparison of solar options required. In order to easily compare different system configurations (number of panels, panel tilt angle, panel manufacturer, etc.), a solar performance model was created using Microsoft Excel.

There are numerous variables to consider when modeling the performance of a solar panel system. First, monthly average solar insolation and ambient temperature data was collected using NREL databases[53] and the online solar insolation calculator PVWatts.[54] Next, the performance characteristics of several different panel models were collected from both manufacturer specifications, and information published online by the Solar Ratings and Certification Corporation.[55] Up-front project costs were divided into per-panel costs and fixed costs from several different vendors. Per-panel costs include the cost of each individual panel, labor, engineering, and inverter costs (approximately $1 per watt). Fixed costs include the cost of a monitoring system, a pumping station, and the cost of boiler replacement (less the salvage value of the existing boiler). The cost of thermal storage is set to scale automatically to provide 10 liters (13.21 gal) of water per square meter, with the option to select from a list of different storage products.

Provided that the panels do not shade each other, the annual energy savings achieved by the solar PV or solar thermal system scales linearly with the number of panels. As previously described, most costs associated with a solar project also scale linearly. Consequently, this model calculates a payback period which is, to a close approximation, independent of system size, for a large range of system sizes. This is particularly true for solar PV-only installations, which are modeled using per-panel costs only (i.e. no additional fixed costs).

Solar at the Corner Brewery

Criteria for Decision

- Total installed capacity must not exceed annual projected electricity or thermal demand
- Panels must be located on facility roof space without interfering with exhaust stacks or other rooftop equipment
- Panels must be set back at least six feet from edges of roof, in compliance with OSHA requirement for roof equipment
- Project should maximize utilization of state, local, and Federal incentives
- Project should minimize payback period
- Project should maximize energy savings and CO_2 reduction

Key Assumptions and Model Parameters

Financing	100% project first costs		Initial Electricity Price	$0.12 /kWh
Loan Term	15 years		Elec. Cost Escalation	3%
Loan Interest	4.75%		Initial Natural Gas Price	$1.05 /CCF
Discount Rate	7%		Nat. Gas Cost Escalation	3%
Marginal Tax Bracket	35%		Year 1 Capital Depreciation Tax Deduction	100%[56]

All variables for the solar design spreadsheet are described in Appendix T.

A ruling in late March 2011 by the Ypsilanti Historic District Commission (HDC) granted the Corner Brewery permission to install solar panels on the roof and also overhanging the south façade in the manner of awnings, despite their visibility to the street. Therefore, visibility is no longer a factor limiting the number of panels.

Any solar project should take full advantage of the DTE SolarCurrents program. The most "conservative" solar PV option is to install a 20kW array of panels on the roof, which would maximize the allowable capacity under the DTE SolarCurrents program. A less conservative option would be to install a total capacity in excess of 20 kW, and sell the RECs generated from the remaining capacity on the open market. A thorough economic analysis of such a decision is beyond the scope of this project, and should be discussed with a financial advisor familiar with such investments. However, two REC price scenarios for each general project design are explored this model.

A sufficiently large solar thermal project—especially in combination with other heat recovery measures—may offset enough hot water demand to permit Corner Brewery to downsize its 30 HP steam boiler to a smaller, more efficient model, saving floor space and energy costs. However, solar thermal panels do not generate RECs, and therefore are ineligible for enrollment in SolarCurrents.

The hybrid solar PVT solution provides a unique solution, in that it is able to fully leverage the benefits of the DTE program, as well as provide heated water to the facility. A 160-panel installation (20kW) is predicted to generate almost 30,000 kWh of electricity and almost 125,000 kWh thermal (4262 therms) annually. Including extra costs for thermal storage and other balance-of-system components, the payback period for such a project is predicted to be eight years, and the 30 year net present value of the investment is estimated to be $95,245. Thanks to Federal and utility incentives, nearly 2/3 of the total investment cost will be recovered in the first year. The project will offset approximately 50 metric tonnes of CO_2 per year, or remove the equivalent of ten typical passenger vehicles from the road each year. A boiler replacement project should be considered separately, on its own merits, after all hot water projects have been fully explored.

The above figures are based on a calculation which assumes 125 W DC output per panel. If the efficiency improvements from liquid cooling are taken into account, the installation's electricity output could be as high as 43,000 kWh annually (19% of 2010 electricity use). This would also have a significant impact on REC payments collected, earning an additional $1,540 from REC sales each year (before taxes), and reducing the payback period to seven years.

Solar Recommendations

Solar power should be utilized to generate electricity and/or hot water. The solar panel system should, regardless of other concerns, be rated to provide at least 20kW DC, maximizing enrollment in the DTE SolarCurrents program. Solar thermal (only) projects are not recommended, as they do not generate RECs.

A portion of the panels should form an awning on the south wall in order to provide shading during the summer. These panels should be either PV only or hybrid PVT. To determine the optimal mix of panels, brewkettle, glass washing, wort cooling (via brewhouse heat exchanger), and fermentation (via water source heat pump or other options) heat recovery should first be specified. If a demand for more hot remains after these improvements have been made, the remainder should be provided by hybrid solar PVT panels. Once hot water demand is met, any remaining solar PV capacity (up to a maximum of 20 kW) should be met by PV-only panels.

Future hot water demands should take into consideration the expected changes in annual beer production volume. Results of solar project simulations under various scenarios are summarized in Appendix R.

There may be hidden benefits to a project with electricity-generating capacity in excess of 20 kW. To understand these benefits, it is necessary to understand a little more about RECs. One REC is earned for every 1000 kWh (=1 MWh) of renewable energy generated. Additional "bonus" Michigan Incentive RECs may also be earned, as defined by Michigan's Renewable Energy Standard (2008 PA 295).[57] In summary:

"Incentive" Renewable Energy Credits: The Act provides for a variety of incentive RECs that are in addition to the base REC earned for every MWh of electricity produced from renewable energy resources.

- Two additional RECs for solar generated electricity.
- 1/5 REC for on-peak production.
- 1/10 REC for systems constructed in Michigan [for first 3 years of service]
- 1/10 REC for systems constructed using Michigan labor [for first 3 years of service][58]

These Michigan Incentive RECs are treated exactly like any other REC, except that they may not be sold to entities outside of Michigan (J. Baldwin, personal communication, April 2011). It should be noted that solar panels generate nearly 100% of their electricity during "on-peak" hours of 11 AM to 7 PM. This effectively means that every MWh generated from a solar panel built in Michigan, 3.4 RECs could be earned during the first three years. Every year after that, each MWh would generate 3.2 RECs.

So, if these RECs could be sold on the market for, say, $100 each[ix], they would be worth:

1 MWh * 3.4 RECs per MWh * $100 per REC = $340

As previously explained under "Financial Considerations" SolarCurrents program compensates the customer for RECs based not on the total number of *RECs generated*, but the total amount of *renewable energy generated*. That is, the ownership of all RECs generated from a solar project enrolled in SolarCurrents are transferred directly to DTE as part of the program agreement, in exchange for a flat rate of $0.11 per kWh generated.

In 1 MWh * 1000 kWh per MWh * $0.11 per kWH = $110.

So, additional capacity beyond the 20 kW enrolled in SolarCurrents will also generate RECs and bonus Michigan Incentive RECS—and the Corner Brewery retains ownership of them. RECs may be retained for up to three years before expiring, so they could be banked for a future time

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[ix] This figure is not meant to be representative of a typical price; the market REC price may considerably less or considerably more.

when REC prices are higher. The uncertainty involved in the future REC market reduces the confidence in predictions involving REC sales. Herein lies the benefit of the SolarCurrents program: while it may not provide the best value for RECs under the most optimistic REC price scenario, it 1) provides for an up-front payment and 2) does not depend on the market price of RECs.

Simulations summarized in Appendix U attempt to predict the outcomes of various solar projects.

Employee Education and Customer Engagement

Education & Engagement Framework

1. Conduct workshops for benefit of brewery owners, staff and community members. Present recommendations to bring about enduring improvements to sustainability.
    a. Visioning session for Owners
        i. Importance of Owner Support
        ii. Goals of CB: brewing, community, learning, net-through puts in 10-15 years.
        iii. Key Take-Aways for Employees & Customers
        iv. Share vision with other stakeholders
    b. "Pre-Tests" for Employees
        i. Sustainability & Environmental Knowledge of Issues
        ii. Evaluation & Management of Improvement Projects
        iii. Sustainability Behavior at Work/Home
    c. Employee Education Plan
        i. BREW: Building Responsible Engagement in the World
        ii. Staff Meetings & Continued Improvement
        iii. Outings
        iv. Potential for Reward/Incentive Options
    d. Customer Engagement Plan
        i. Environmental Events
        ii. Environmental Signage/Displays
        iii. Interactive Environmental Learning Station/Area (Beer Garden)

Visioning for Sustainability

Creating an engaged organization is not only about education to your employees and customers, it's about tying sustainability to the company's mission, goals and performance evaluation processes.[59] Before educating Corner Brewery stakeholders on sustainability, they must first be aware of the Brewery's mission and goals. This aspect is something that could be created and implemented for the Arbor Brewing Company as a whole. For instance, on the Corner Brewery website, the History page is blank.[60] It might be decided that the mission and goals of the Corner Brewery are the same as for the Brewpub, in which case, the website could to be re-designed and awareness about the Brewing Company's values will be easier to implement given only one set for both locations.

An important tool in both business management and in sustainability planning is *visioning*. Pioneer American environmental scientist Donella Meadows writes of the importance of visioning in her 1994 essay, “Envisioning a Sustainable World” and how it is the step most often left out of policy discussions. Visioning is not a rational process, but is informed by rationale. Values are used to create the vision and rational tools are used to shape it into something responsible that acknowledges the physical constraints of the world.[61] One important tool for making a responsible vision is sharing it with people and incorporating their visions.[61]

To create a responsible vision for the Corner Brewery, a two-step process is proposed. The first step is a visioning session for only the owners, Matt and Rene Greff. One of the most important factors for motivating employees to be involved with environmental and sustainability initiatives in the company is support and/or mandates from company CEOs, or in the case of the Corner Brewery, owners.[59] It is important to first capture their vision as a framework to then bring to Corner Brewery employees and other key stakeholders. A vision starts out as what the owners want for the Corner Brewery, or the Arbor Brewing Company as a whole. All of the information gathered, models and implementation plans are only steps towards the ultimate vision. After the owners have created their vision and written out statements of that vision, the second step is to share their vision with employees and/or other stakeholders. This should be done in a welcoming and comfortable atmosphere, as open visioning is something that people often feel embarrassed about. This second visioning session would also be a good time for review and evaluation of current operations. Steps for sharing and discussing what is working and what could be improved at the Brewery should be held. Then goals reflecting this discussion should be created, all in reference to the original vision statement(s). By giving employees ownership in the creation of the vision and goals, they will be more likely to work to achieve them and share them with other employees and customers. The owners may find it appropriate to invite other key stakeholders to the visioning session as well, such as long-time Mug Club members or Groundbreakers Club Members. The importance of these stakeholders in the future of the Corner Brewery is expressed in the following section.

The Corner Brewery as a Third Place & Implications for the Future

The Corner Brewery has a special connection to the local community because of the partnership formed during its renovation in 2006, and continuing support of local organizations and activities. Involving them in the visioning process could strengthen this relationship. What this relationship has done is establish the Corner Brewery as a Third Place. Urban sociologist Ray Oldenburg defines a Third Place as a public space where one can visit with friends and neighbors, hosting regular gatherings and social outlets outside of the home or workplace.[62] Third Places are vital in a community, creating an area where people can meet and mingle, learn and engage, and discuss relevant issues in a friendly establishment. A Third Place can be many things, but are often small, locally owned bars, coffee shops, eateries, etc. within a neighborhood. These places are often patronized by regular customers who become part of the social fabric of the establishment. It is argued that the Third place establishments are characterized by personalization, permeability to aid in coherence, seating and shelter from the elements.[63]

In the Ypsilanti and Ann Arbor area, with its abundance of breweries, bars and restaurants, there has been a clear availability and use of Third Places. In an age of energy insecurity, it is important to recognize the need for these establishments and how they can be maintained. Although brewing beer is energy and resource intensive, "eating and drinking are activities commonly associated with relaxation, and people frequently combine eating and drinking with socializing. This combination of food and social activity supported by outdoor seating makes people stay longer, making it a very important characteristic to support social life on the street."[63] In a study of Third Places, a Main Street area in Cambridge, Massachusetts consisted of 120 businesses, with 17 considered a Third Place by the community. Of these, 13 were coffee shops, bars, restaurants or ice-cream shops. All four bars in the area were identified as Third Places.[63]

Because young students currently dominate the Ann Arbor and Ypsilanti areas, the importance of the Third Place is even more critical to older patrons. These establishments hold significance to elderly consumers because they are more prone to social or emotional loneliness due to stressful events like retirement and loss of loved ones.[64] They obtain social support through third places, where they are able to forge new social relationships and networks,[65] and reinforce existing ones. In an era of transition, where people will be undergoing a number of emotional stressors, it is important that these refuges are maintained. They serve a valuable service to the community and allow people to educate each other and share concerns.

Three features: food and drink, accessibility and a welcoming atmosphere, maintain the Corner Brewery's patronage. In the event of a disruption to reliable or affordable energy, the Corner Brewery's focus will change, forcing it to redefine its role and purpose. The Corner Brewery, since it's renovation in 2006, has been closely connected to the local community. The renovation was partially financed and completed by a network of community members, with additional startup funds provided by membership in the "Groundbreakers Club", with the membership fee largely refunded in the form of a house account. The Corner Brewery has opened up its space to many community organizations and events over the years including indoor farmers' markets, political groups, and even weddings. Matt and Rene Greff truly make an effort to support the local community and contribute space and services when they can. Their already strong connection will become even more important in the event of far-reaching energy supply disruptions; community members will need a comfortable and familiar place to gather and find solutions.

Learning and knowledge-based events are much less common at the Corner Brewery currently. This is where their potential to help the community in the energy descent truly lies. Brewing beer is a time-honored skill that can likely translate to other fermentation processes. Brewing and fermentation will be valuable skills into the energy descent by making it possible to preserve foods and create important items such as vinegar. The Corner Brewery would benefit from sustaining their business, as well as sharing their knowledge with the community, by leading workshops and sharing their knowledge about brewing, distilling, and fermenting. These can be energy and resource intensive processes, so it would also seem logical for the Corner Brewery to be a "hub" for these activities in the community. A centralized location for these activities can help take advantage of potential "economies of scale" if many residents are all working on similar projects.

Large scale brewing will become financially unfeasible after a widespread energy interuption due to resource constraints, even for as small of a brewing operation as the Corner Brewery. But, by having the connection with the community already established, the Corner Brewery can ensure its success through this transition by sharing their space and knowledge with the community. Other potential Third Places will be needed in the area, however. An establishment can aid the community through the energy descent by being open and welcoming, easily accessible and having some food and drink available. New attributes businesses might have to work more to achieve will be hosting and sponsoring community events and fostering the sharing of important skills and knowledge, including knowledge inherent in their business.

Employee Environmental and Sustainability Education: Introduction and Benefits

Once a clear vision for the future is developed and employee buy-in of the company's mission is obtained, then move on to environmental and sustainability education. Enthusiasm for sustainability issues is gaining more and more momentum, so it is likely that employees are already interested in these topics. However, it is important to clearly establish their competency in environmental and sustainability issues, especially in reference to the improvements that will be taking place at the Corner Brewery.

Before any open conversations are held, it might be useful to hand out a brief "pre-test" to employees. The results will guide conversations and prevent any unnecessary basic information or, on the other hand, too advanced subjects from being discussed at the wrong time.

It is important for employees to have a basic understanding of environmental issues for a number of reasons. Employees are running the day-to-day operations of the brewery. Once employees have fundamental knowledge of general environmental topics, those topics can then be applied to brewery operations and improvements. Employee behavior can undermine the effectiveness of improvements if not properly educated. However, employees can also be crucial in finding new opportunities and innovations for increased sustainability due to their close relationship with brewery performance and functions.[66] This improves the profitability of the brewery by having less waste, water and energy usage. Employees in customer-oriented positions need to be aware of the sustainability initiatives underway at the Corner Brewery. This enables employees to put those efforts in proper context for patrons, reinforcing the Brewery's role as a sustainability leader, and strengthening relationships with customers interested in sustainability issues.[66] As employees begin to learn about the environmental and sustainability impacts of their workplace, there is also potential for greater impact through the transfer of behaviors to the home environment. Employees will likely take the environmental and sustainability knowledge and behaviors learned at the brewery to their home and continue to improve the environmental impact of the whole community.

Employee Environmental and Sustainability Education: Continued Learning

Continuing an education plan with employees requires more than just a starting survey; a long-term program can have positive results for the Corner Brewery. One issue the Corner Brewery struggles with is the quick turnover of employees. Most lower-level managers and employees aren't working at the Corner Brewery with a long-term position in mind (R. Greff, personal communication, February 5, 2010). This is a detriment to company profits because recruiting and training employees is very costly.[66] Environmental and sustainability education is becoming an increasingly important factor in attracting and *retaining* employees.[66] That is why an ongoing program is recommended for the Corner Brewery.

Concordia College in Moorehead, Minnesota originally coined the acronym "B.R.E.W." (Building Responsible Engagement in the World) as a theme for their core curriculum.[67] Due to the relevance of the acronym and topic it includes, this acronym is proposed as the slogan for the Corner Brewery's education and engagement program.

There are many organizational models for employee education programs, from online collaboration sites to employee-to-employee teaching.[59] Because the Corner Brewery has a small enough staff that already meet with managers on a regular basis, this time could also be used to facilitate environmental and sustainability education. Regular meetings could have a portion focusing on environmental initiatives and continued monitoring of current practices in order to improve operational efficiency, develop new products, services, technologies and processes that reduce material, water and energy waste as well as those minimizing the use of harmful materials. By continuing to frame sustainability initiatives around brewery success and improvement, employees can see actual results from their efforts.

As the environmental and education program develops it could be useful to plan larger educational events or outings, potentially partnering with external organizations such as the local Clean Energy Coalition. The final component of the employee sustainability and environmental education program is to include creative aspects that will keep employees involved. Some ways of doing this are by creating employee-led “green” teams, awards and recognition and even performance incentives.[59] For example, Hewlett-Packard, provided a brown-bag informational luncheon for employees about installing solar panels on their homes and then offered incentives to employees who use solar energy.[59] Stoneyfield links a portion of employee compensation to the achievement of annual environmental goals.[59] These are just a couple ideas to keep employees invested in the environmental and sustainability education program.

Customer Engagement

As stated earlier in the section about the Corner Brewery’s role as a Third Place, the relationship with community members is vital to the success of the business. The Corner Brewery is embarking on a lot of changes, large and small, and it is important to involve the customer base during this transformation so as not to risk losing their support. A three-part program is recommended to keep the valued customers involved and informed about the improvements happening at the Corner Brewery, as well as furthering their understanding of environmental and sustainability topics.

The first component of the recommended engagement program is open, environmental education events. These could be co-sponsored by other local organizations, most likely with environmental expertise, again such as the Clean Energy Coalition and Waste Knot Washtenaw County. These events would be an opportunity for community members to come learn about environmental issues in a setting they already trust and are familiar with. Events such as these are also an opportunity to gain new customers and bring in profits.

Displays and signage around the brewery are the second elements of the engagement plan. As renovations take place around the Corner Brewery, signage describing the change and expected benefits from the project should be displayed throughout the building. Customers’ beloved Corner Brewery will be undergoing changes that will make it look a lot different than what they’re used to, so these signs help them adjust to the change and take part in the pride that comes from being a sustainable business. Another way to incorporate learning into the Brewery experience is to have a Rolodex-style card display featuring environmental trivia or facts, especially those with a local focus, at every booth. This implicitly promotes the environmental goals of the Corner Brewery in a way that is fun for customers.

Figure 58. A kiosk in the restaurant could educate customers about the solar panels at work on the roof

The last pieces of customer engagement are interactive learning stations or areas. These are similar to the second component of signage, except that learning stations go a step further and get the participant up, moving, and learning by doing something hands-on. A recommendation for this part of engagement is a guided "walking tour" around the Brewery. This would consist of a page of information, highlighting certain improvements around the Brewery that customers could walk around to while waiting for their food to be ready. Another recommendation is to create a learning area out in the beer garden. An outside area could be used to teach customers how to compost, grow their own herbs for cooking, use a rainwater catchment system, or a number of other sustainability projects.

Employee education and customer engagement go hand-in-hand. Both are necessary to fully incorporate a vision of sustainability for the Corner Brewery. As the education and engagement programs are being implemented, some measurements may be important to track the progress. Data can be gathered from routine surveys of prospective, new and established employees, asking specific questions about environmental and sustainability education and engagement. Correlations can then be established between those responses and outcomes such as satisfaction rates and acceptance of job offers.[66] Employee engagement results can be correlated to environmental results. A measure of education (hours in training, for example) can be correlated with results related to operational efficiency improvements.[66] Customer surveys can determine the extent to which their satisfaction is influenced by the environmental knowledge of employees.[66] Finally, outside community members and stakeholders can be surveyed to determine what extent of their perceptions of the Corner Brewery are influenced by employee and customer engagement in environmental and sustainability activities.[66] A final recommendation for customer and employee engagement is the installation of a real-time environmental dashboard. Lucid Design Group Building Dashboard and Microsoft Dynamics are both options for systems that give feedback to the resource users (customers and employees) at the brewery. The awareness of resource use and how it affects usage would also be an interesting metric.

“Green” Marketing

What is Green Marketing?

Conventional marketing uses two main concepts: marketing strategy and marketing mix. The marketing strategy is a continuous loop of demand measurement, segmentation, targeting and positioning which are used in sequence to find competitive advantages.[68] The marketing mix includes tactical marketing tools a company can use to influence the demand for their products.[68] Four components make up the marketing mix: product, price, place and promotion.[68]

Figure 59. A sample mockup of a proposed product to highlight the new solar power project at the Corner Brewery, "Perihelion Pale Ale.”[x]

Green marketing, on the other hand, has been around since the 1970s when the awareness of environmental problems began to gain popular momentum.[68] American naturalist and botanist Peattie defines green marketing as “the holistic management process responsible for identifying, anticipating and satisfying the requirements of customers and society, in a profitable and sustainable way”[68] Green marketing must integrate transformative change that creates value for individuals and society, as well as for the natural environment.[69] Most traditional marketers focus on not producing societal harm and meeting human needs, where as green marketing actually enhances the quality of life for humans while *improving* the natural environment.[69]

There are three levels of green marketing. First is strategic greening where substantial, fundamental change in the corporate philosophy is taken. Next is quasi-strategic greening, which includes substantial change in business practices. Last is tactical greening when there is a shift in functional activities, such as promotional campaigns.[68] Examples of marketing activities at each of the three levels can be found in Table 15.

[x] Stylized sun image adapted from original art: ©Stacy Reed, www.shedreamsindigital.net

	Tactical Greening	*Quasi-strategic Greening*	*Strategic Greening*
Targeting	Ads mentioning green features are run in green-focused media.	A firm develops a green brand in addition to its other brands.	A firm launches a new SBU aimed at the green market.
Green Design/NPD	A firm switches from one raw material supplier to another with more eco friendly processes.	Life-cycle analysis is incorporated into the NPD process to minimize eco harm.	Fuji Xerox develops its Green Wrap paper to be more eco-friendly from the ground up.
Green Positioning	A mining company runs a PR campaign to highlight its green aspects and practices.	BP Amoco redesigns its logo to a sun-based emblem to reflect its view of a hydrogen/solar-based future for the energy industry.	The Body Shop pursues environmental and social change improvements and encourages its customers to do so as well.
Green Pricing	Cost savings due to existing energy-efficiency features are highlighted for a product.	A water company shifts its pricing policy from a flat monthly rate to a per-unit-of-water-used basis.	A company rents its products rather than selling them; customers now pay only for use of the products.
Greening Logistics	A firm changes to a more concentrated detergent, which reduces package size and weight and lowers shipping costs.	Packaging minimization is incorporated as part of a firm's manufacturing review process.	A reverse logistics system is put into place by Fuji Xerox to reprocess and remanufacture photocopiers.
Marketing Waste	A firm improves the efficiency of its manufacturing process, which lowers its waste output.	Telstra (a phone company) has internal processes so that old telephone directories (waste) are collected and turned into cat litter products by other companies.	A Queensland sugarcane facility is rebuilt to be cogeneration-based, using sugarcane waste to power the operation.
Green Promotion	An oil company runs a PR campaign to highlight its green practices in order to counter an oil spill getting bad press coverage.	A company sets a policy that realistic product eco-benefits should always be mentioned in promotional materials.	As part of its philosophy, the Body Shop co-promotes one or more social/eco campaigns each year with in-shop and promotional materials.
Green Alliances	A company funds a competition (one-off basis) run by an environmental group to heighten community awareness on storm water quality issues.	Southcorp (a wine producer) forms a long-term alliance with the Australian Conservation Foundation to help combat land-salinity issues.	A company invites a representative of an environmental group to join its board of directors.

Table 15. Green Marketing Activities at the Three Levels[68]

Green marketing must be integrated across all organizational areas and activities to be successful and achieve long-term benefits.[70] By taking an "environpreneurial" approach, firms see change as an opportunity to develop innovative, need-satisfying products and technologies that result in a competitive advantage. Green positioning ensures that all activities and behaviors of the company thoroughly incorporate environmental values into decision-making processes. Caution should be taken because firms that self-promote as environmentally responsible are held to a higher standard. Any deviation from eco-values—whether real or perceived—can result in extensive negative publicity and a loss in consumer confidence. [71]

Characteristics of Green Consumers

During the 1980s and 1990s, green marketing research focused mainly on the size of the green market and the profile of the green consumer.[68] In 1993, the Roper Organization's Green Gauge Study found three environmentally active consumer groups and two inactive groups which differed in demographics, attitudes and behaviors. “True-blue greens” were the most environmentally active, having changed many behavior patterns. “Green-back greens” have committed financially and philosophically, but have not changed their behavior patterns. “Sprouts” are just starting to change their behaviors. “Grousers” think companies should be solving environmental problems instead of consumers. Finally, “Basic browns” are apathetic and think their individual actions are not able to effect change.[71]

Many variables have been used to identify the green consumer. When segmenting the market for green products and services, or any market, five criteria are used: segment size, segment accessibility, ease of identification, strategic/operational effectiveness and segment stability. The size and accessibility of the green market have been proven.[72,73] Demographic profiling is the most used and researched method for identifying the green consumer. The typical profile given for green consumers are young, middle to high income, educated, urban women.[72] However, the effectiveness of this profile is waning. The stability of the green consumer segment has been shown to be quite variable when using demographic profiling. This is most likely due to the evolution of the environmental movement and the green consumer since the 1970s.

A demographics-only model lacks the explanatory power of psychographic variables. A psychographics-only model or a mixed model (incorporating a range of demographics and psychographics) should be preferred to traditional demographic profiling methods. Psychographic variables provide stronger and more useful profiles of green consumers.[72, 73] Ecologically conscious consumer behavior was most correlated with perceived consumer effectiveness. Consumers want to know *how* choosing green products are helping the environment, claiming to be “green” is no longer enough. Altruism was the second most important predictor of ecologically conscious consumer behavior. This suggests that firms should also show how other people are better off as a result of choosing their green products. Liberalism was the third most important predictor for green consumer behavior. This characteristic is still useful for profiling, while not as important as the first two predictors, and suggests that choosing spokespeople with similar liberal views would improve the perceived argument strength.[72] Finally, environmental concern is shown to be an important foundation for environmentally friendly behavior. However, even if someone is concerned about the environment, she is unlikely to behave proactively unless she feels individuals can be effective in fighting environmental problems.[72]

People are be more likely to behave in environmentally friendly ways if they

1. Are aware of various environmental problems, and the consequences of their behaviors
2. Believe that their individual efforts help solve problems
3. Care about solving problems
4. Are willing to reallocate their own time, money, and attention in order to make their behaviors more environmentally friendly.[71]

Tactics for Successful Green Marketing

Production and consumption patterns need to be changed in order to achieve sustainable development.[68] This will not be achieved by targeting green consumers alone, as can be seen in Figure 60. It has been argued that "green" may not be a fixed characteristic of a consumer and that the context in which the purchase is made is of more importance in determining whether or not people will choose the green alternative. The targeted consumer group should be broadened from targeting green consumers with green products to a larger consumer base and including green properties as just one aspect of an appealing product. This will require a different and larger set of marketing tools and creates a more active role for businesses in the path towards greener production and consumption.[68]

Marketing efforts should help consumers evaluate the environmental consequences of product choices.[71] Messages should show how positive environmental consequences are achieved when certain brands or products are purchased. Another marketing technique would be to create a sense of personal or moral obligation to take care of the environment. Celebrities or opinion leaders could also be used to endorse environmentally friendly behaviors and appeal to consumers' feelings of guilt for non-compliance or enhanced self-esteem for shared environmental concern.[71]

THE MARKETING STRATEGY	DEMAND MEASUREMENT	SEGMENTATION	TARGETING	POSITIONING		COMPETITIVE ADVANTAGE
Focus in green marketing:	Market size	The green consumer		Ecolabel (product)	⇨	Doubtful
Other means in conventional marketing:	Market needs and wants	All consumers		Place, price, promotion	⇨	Possible

Figure 60 Traditional green marketing will not bring widespread business success.[68]

Emphasizing the delicate balance of nature and how consumers can still consume, but in a more ecologically friendly fashion will probably be successful considering consumption in the U.S. has never been so high.[74] Educating the consumer on environmental issues will also be important in encouraging ecologically conscious decision making in the consumer marketplace.[74] A survey found that many consumers have low objective knowledge of environmental issues, even among environmentally concerned consumers. This means that many may not have the essential knowledge to make sound ecological decisions.[74] Companies selling products made wholly or partially from recycled materials should stress that as responsible consumers and citizens, we need to get more out of the "precious natural resources" that go into the products we use.[74] Selling products that can be refilled, reused or require a returnable deposit for the container can also benefit from this approach.[74]

To encourage recycled, reused or efficiently packaged products, marketers can explain the disastrous effects of our “throw-away” consumer culture.[74] Another approach is to stress that a product is comparable in price, quality and convenience to competitors with the added benefit of ecological compatibility. [73,74]

New processes may be developed to satisfy consumer needs. Consumers may not even have to buy goods if they can purchase the use of need-satisfying services instead. The greening of logistics in a company can be done in many ways. Packaging can be modified to reduce the amount of raw material used, which reduces weight and shipping costs as well. Reverse logistics entails moving packaging and “used” goods from the consumer back up the distribution channel to the firm. Reverse logistics is an opportunity to generate more corporate revenue by reprocessing parts back into production for example. Waste products may be used as inputs into other production processes or as completely new products being sent to both other firms or on-site.[70] The steps included in reverse logistics can be found in Figure 61. Marketing the waste from production is another way to add value, though isn’t very radical as the creation of waste in the first place isn’t being reduced.

Recognition	Monitor goods so that they flow through the reverse logistics process.
Recovery	Collect goods for reprocessing.
Review	Test materials to evaluate whether they meet appropriate reprocessing standards or can be disassembled for parts or disposal.
Renewal	Remanufacture the product to its *original* standards or claim appropriate parts for reuse.
Removal	Dispose of materials that cannot be remanufactured and market the remanufactured goods to new or existing customers.
Reengineering	Evaluate existing goods for better design.

Source: Giuntini and Andel (1995)

Figure 61: The Six Rs of Facilitating Reverse Logistics[70]

Other Topics for Consideration

The topics discussed in this section represent various opportunities for improving operational sustainability which have not yet been addressed. Some may not carry high financial returns, but carry intangible or difficult-to-quantify benefits, and speak directly to the overarching vision of sustainable brewing. Other ideas are simply not cost-effective at this time due to various economic and operational scale conditions, but should be revisited in the future.

Geothermal Heating and Cooling

Geothermal, or ground-source heating and cooling is a well-established technology used in many parts of the world as an alternative to fossil fuel heating and direct-expansion cooling. Closed-loop geothermal heating and cooling uses a network of tall vertical pipes buried in the ground, called a geoexchange field. A thermal exchange fluid such as an ethylene glycol or propylene glycol solution is pumped. During the summer cooling season, a heat pump draws heat from the space to be cooled, and transfers it to the thermal fluid. The thermal fluid is then pumped through the network of buried pipes. During its transit, heat flows out of the fluid and into the surrounding earth. At the end of its circuit, the thermal fluid returns to the heat pump, cooled, and ready to receive another allocation of heat to be dispersed. Variants of geothermal heating and cooling systems include the practice of burying the pipes in shallow, wide trenches in a "slinky loop configuration," or placing the pipes in a lake instead of underground. Open-loop systems differ only in that groundwater or lake water is directly as the thermal exchange medium.

The term "geothermal" is somewhat confusing, as it can also refer to the utilization of high-pressure steam from very deep boreholes. This steam can be used for electricity generation, or direct use for heating. Klamath Basin Brewing Company uses steam from a municipal deep geothermal project for heating.[75] The availability of this high-temperature resource is dependent on geography, and is not an option in Ypsilanti, MI.

Geothermal Heating and Cooling at the Corner Brewery

The Midwest United States is well-suited to direct use geothermal heating and cooling systems. According to the Energy Information Administration, Michigan received the tenth most shipments of geothermal heat pumps by tons of capacity. Ohio, Illinois, Indiana, and Michigan combined received over 22% all shipped capacity that year.[76]

The first phase of the Corner Brewery's expansion is already slated to include a form of geothermal heating and cooling which does not use a heat pump, but rather relies on direct heat exchange with groundwater via a plate heat exchanger and radiant heating and cooling system. This system could not be thoroughly studied due to the proprietary nature of the technology.

Conclusions

The second phase of the expansion could potentially include a geothermal component for space heating and cooling as well as process heating and cooling. However, the up-front costs of such a system tend to be very high, costing tens of thousands of dollars for the borehole field alone. Soil characteristics strongly influence the performance and overall cost of such systems, making it difficult to predict in the absence of costly test-well drilling. The test well that will be constructed in preparation for the groundwater cooling system attached to the outdoor cool storage facility should provide useful insight into soil conditions.

An efficient heating and cooling solution is proposed elsewhere in this report (see "Special Topic: Process Cooling Efficiency and Heat Recovery") which achieves many of the advantages of ground-source heating and cooling without the need for a geoexchange field.

Grain Sacks

The Corner Brewery doesn't have a recycling option for one of its main waste streams, grain sacks. With their current production they discard approximately 4,000 grain sacks per year. This number is expected to rise to about 12,000 per year if expansion plans continue with a tripling of output. With this increase in grain sack throughput it is more likely that a recycling center will find this item to be used as an input for the recycling stream. One of the main tenets of industrial ecology is that waste is potentially an input to another process. Essentially, any by-products or refuse wouldn't be considered waste anymore. Each item would have a use within some other input stream—just like a natural ecosystem. This kind of thinking helps to close the loop in the supply chains and reduce the need for the end use of a product ending up in a landfill. While recycling is an option that is desirable and preferred it isn't the only option available while vendors are sought that would accept grain sacks.

Figure 62. Prototype grain sack growler cozy

Figure 63. Prototype grain sack laptop sleeve

Grain Sacks as Products

The structure of a grain sack is strong in order to hold 25kg of product. This makes it an ideal material to create items of a different shape that also need strength. Three ideas that the Team created prototypes for are growler cozies, knapsacks, and laptop sleeves. Each product uses one grain sack with very little, if any waste and requires only the new inputs of thread and some type of string to cinch the top. The estimated sale price for these products would be $7.00 to $15.00. While it is expected that neither of these products would be produced in enough quantities to completely use all of the grain sacks, they would eliminate some of the waste stream and be an eye-catching addition to the marketing and education campaign of a "green" brewery by highlighting the "waste as input" tenant of industrial ecology.

Substitution

The Corner Brewery uses plastic trash bags for waste disposal. This item has to be manufactured and shipped to the point of use site. There is an opportunity to completely substitute the purchase of these trash bags and use the grain sacks as trash bags. This could be done by using the whole sack if it is desired or by cutting out the plastic liner that is inside the grain sack. This has been done on a trial basis at one of the project members' home. There have been no complaints from those involved and it removed the need to purchase trash bags.

With figures given by the staff at the Corner Brewery it is estimated that the facility buys one case of trash bags per week. Each case has 100 bags and costs $29.08. The total annual use is estimated at 52 cases and costs $1,512.16. This is not an insignificant amount. With a little employee assistance and change in behavior it is possible to completely remove an item from the input stream of the Corner Brewery by substituting it for an item that is currently discarded.

Reuse

A final suggestion would be to contact the vendors and see if they could reuse the grain sacks. This would be an ideal outcome by drastically reducing the need for these bags to be manufactured and create a reverse supply chain that would help fill trucks as the return to the warehouse.

Greywater System

Greywater reuse follows the same principles that make wild rivers clean…even though they drain many square miles of dirt, worms, and feces. Beneficial bacteria break down nasties into water-soluble plant food, and the plants eat it, leaving pure water.

- Art Ludwig, "Create an Oasis with Greywater"

Greywater is water used at a site that can readily be recycled and used again for secondary purposes. A greywater system is thus a means of on-site water reuse. Greywater systems are most commonly associated in the residential setting, as shown in Figure 64.

In a residential system, water from toilets is called blackwater, and is not recycled. Water from all other sources in the home (sinks, showers, washing machines) is considered greywater and has separate plumbing infrastructure and is sent to a holding tank. Greywater systems vary widely in their complexity as far as water treatment. In the simplest systems, as long as only biodegradable chemicals are used in the home, the water can be reused directly to water the lawn or garden, or even indoors for secondary uses like toilet flushing or clothes washing.

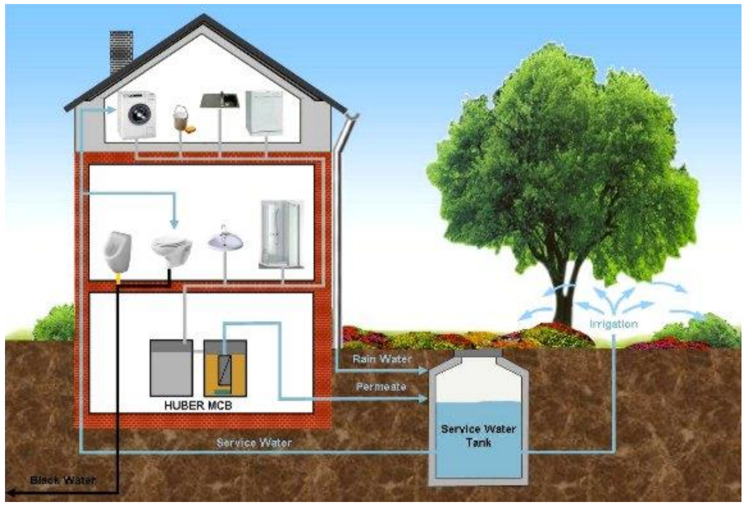


Figure 64: A typical residential greywater system

Greywater systems are not only used in residential settings, however. Industry is also coming around to the idea of water reuse because of economics, regulation, and public perception. [77]

Why should water be purified and pumped for miles to use it for flushing toilets and watering gardens? Greywater reuse makes ecological sense. The concept is simple to understand and very cost effective, *if* it is implemented from the onset. If greywater is considered as a retrofit to an existing operation, then a more careful analysis must be undertaken.

Possible complications for a greywater retrofit are numerous. Access to the necessary plumbing may be difficult (i.e. it may be under the floor or within the walls). There may be no good space for installing a holding tank or other treatment equipment. Pumps may be necessary if a gravity-fed system is unfeasible.

Water Reuse at the Corner Brewery

There are a number of factors that go into deciding whether installing a water reuse system makes sense.

- Is there a resource limitation? Or is water abundant?
- Is there a large enough demand for recycled greywater at the Corner Brewery?
- What kind of environmental regulations does the company face with regards to water?
- What are the economics of the water situation? What is the cost of water? What is the cost of sending water to the sewer?

- How does public perception play a role in water reuse?

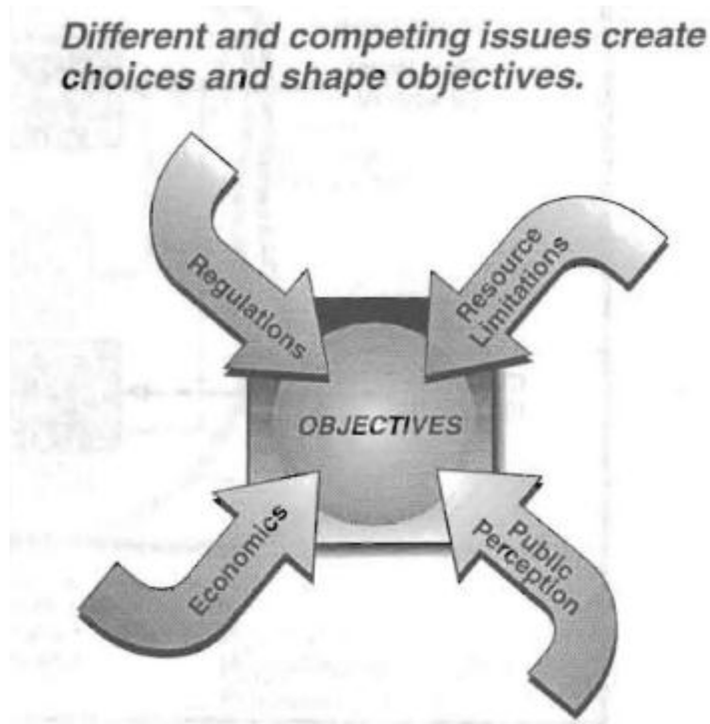


Figure 65. Decision-making issues. Image from AIChe[78]

In the case of the Corner Brewery, the answer to most of these questions leans away from implementing a water reuse system. The resource, regulatory and economic drivers that drive many companies to explore water reuse are simply not in play Corner Brewery. Water, as discussed in the Resources Audit section, is abundant in Ypsilanti and relatively inexpensive. The Corner Brewery is a small operation and faces no special penalties with respect to its wastewater, and the cost to send water to the sewer is likewise inexpensive.

The one factor that could be considered as a driver is public perception and company image. Undertaking a water reuse system at the brewery would be viewed favorably by the public and media. However this alone does not provide sufficient influence to undertake a water reuse project at this time.

The Green Brewery Project recommends that if two or more of these drivers come into play in the future, then the Corner Brewery should consider a greywater system.

Anaerobic Digestion for Biogas

Using anaerobic digestion to produce biogas as a source of energy is a beautifully simple, closed-loop, sustainable technology that should be considered in any brewery, or for that matter, in any industrial setting that produces organic wastes.

The idea behind anaerobic digestion is simple. The first thing needed is organic feedstock material, which can be waste products such as food scraps, manure, agricultural residues, or in the case of a brewery, spent grains or wastewater. Organic material is broken down by specialized bacteria in the absence of oxygen. The product of this digestion is biogas, which contains mostly methane, the primary constituent and energetic component of natural gas. Basically anaerobic digestion turns waste into energy. It doesn't get much greener than that.

Waste → Energy

Wastewater is the most common feedstock used in breweries, because brewery effluent has very high levels of biological oxygen demand, solids, and organic carbon. Spent grains are not commonly used because their fibrous material is difficult to digest anaerobically.

For a brewery, the process serves two primary purposes:

1) Produce a renewable source of energy, and
2) Treats the brewery's wastewater, which minimizes environmental pollution and in many cases saves the brewery money.

Wastewater treatment plants around the US are aware of the high levels of organic contaminants found in brewery effluent, and often charge large breweries heftily for treating their wastewater. So by treating their own water onsite, breweries can achieve significant cost savings.

Many breweries have proven the efficacy of anaerobic digestion for biogas. New Belgium Brewery in Fort Collins, Colorado installed a $5 million wastewater treatment plant to treat up to 80,000 gallons of wastewater per day, and produces 85% methane biogas which is stored for later use. During peak electricity demand during the day, the biogas is fired in a 290 kW combined heat and power generator. This generator typically runs for 10-15 hours per day and achieves a 50-60% reduction in electrical demand during peak hours. It accounts for 9% of total brewery electrical production throughout the year. The waste heat is used to maintain a desirable 37°C in the digester.[79]

Abita Brewing Company in Abita Springs, Louisiana, installed a similar system in 2008. Instead of running a generator, the 85,000 BBl per year brewery uses its biogas directly in its boiler to displace natural gas. The biogas must be first treated to remove moisture and sulfur content, but after that it burns just like natural gas. The Abita system cost $1.5 million dollars.[80]

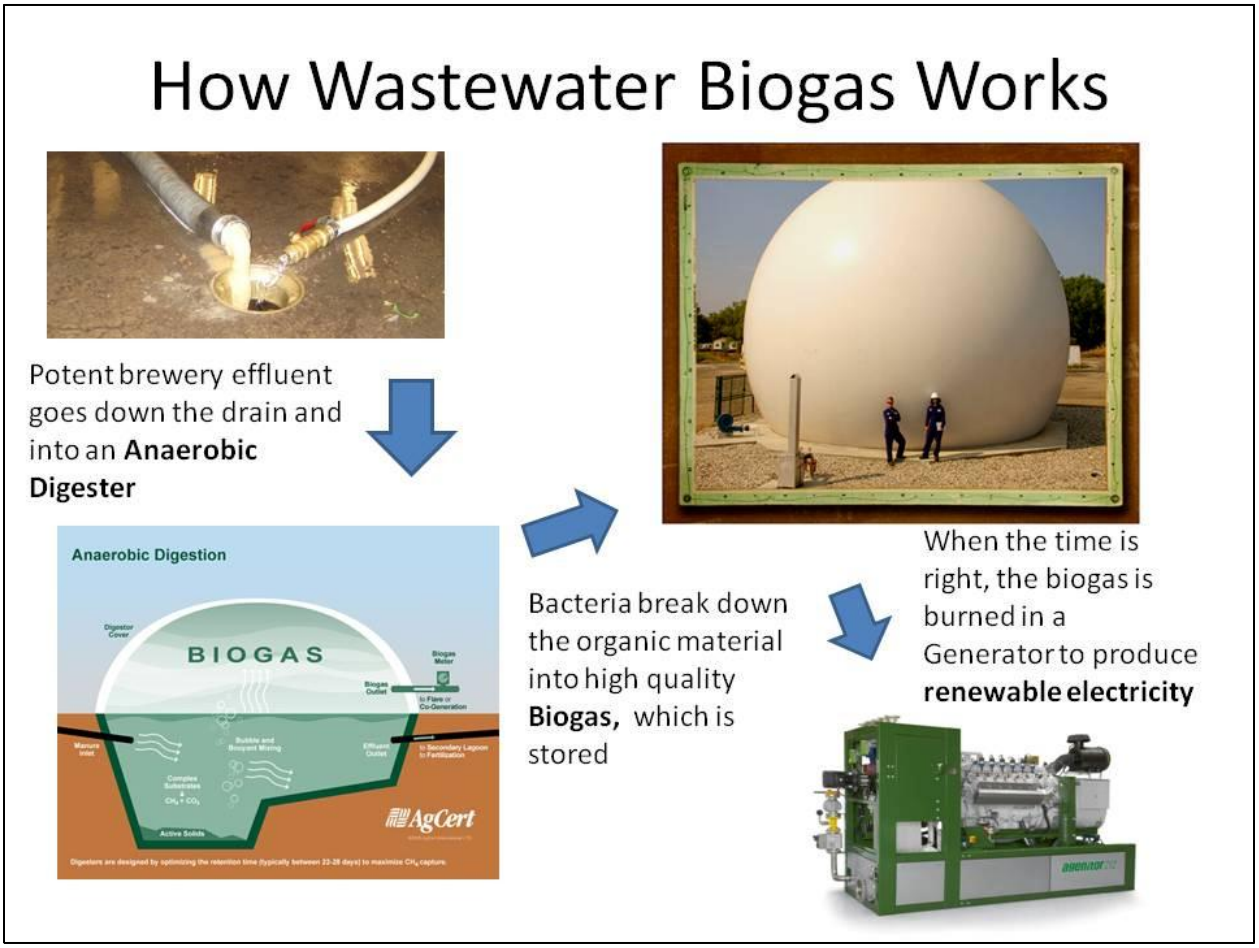


Figure 66. Wastewater biogas is a closed-loop energy carrier

A number of other breweries and distilleries, including big names like Sierra Nevada Brewing Company and Stone Brewing Company also tout successful anaerobic digester projects. Like New Belgium, these breweries pursued a wastewater biogas and treatment program in response to abrupt increases in effluent disposal costs. Bacardi Limited has a biogas system at several production sites, but also has the advantage of a very large scale. The question that remains is at what scale does the technology become economical?

Small-scale biogas is catching on rapidly in the developing world, particularly in Central America[81]. However, most small-scale biogas projects use denser feedstock like manure. There simply hasn't been enough research done on small-scale brewery wastewater biogas.

In the context of the Corner Brewery

To assess the feasibility of anaerobic digestion for biogas production at the Corner Brewery, one must consider a couple of key differences between the Corner Brewery's situation and that of the larger breweries mentioned above.

Key Differences

1. *The Corner Brewery has little financial incentive to treat its wastewater*. The larger breweries face infrastructure investment fees and hefty charges from municipal wastewater treatment plants for their high volume, high strength wastewater. This creates a strong financial incentive to treat wastewater on site, which rapidly speeds up payback times for biogas systems. The Corner Brewery is a small operation and sees no such incentive.
2. *The Corner Brewery does not currently face an electrical demand charge.* A biogas system has an advantage in that the generator can run whenever it is needed. Most operations use biogas to offset their electrical use during peak demand, which occurs in the early afternoon, because many electric utilities charge higher rates during peak times, creating a strong financial incentive to use homegrown energy during that time. Because the Corner Brewery's utility, DTE Energy, does not currently employ a demand charge, the Corner Brewery does not see this incentive.

That said, it is certainly a possibility that should the Corner Brewery grow significantly, it may face the above costs in the future. So it is worth investigating the ballpark feasibility of a wastewater biogas system at the Corner Brewery.

Feasibility at the Corner Brewery

Disclaimer: The following cost calculations and cost benefit analysis are rough approximations. Because the exact quantity of brewing wastewater is unknown, and the brewhouse effluent has not been tested, a more thorough assessment is unjustified. A ballpark feasibility study has been done in order to decide whether more investigation into the subject is warranted.

Energy Production

Based on the results of the resource audit, the Corner Brewery produces 562 gallons of brewing wastewater per day. Assuming typical biological oxygen demand and nutrient levels in the wastewater, it can be estimated that 0.88 liters of biogas would be produced for every liter of wastewater treated[82]. Assuming moderate 80% methane content in the biogas, the energy content of the biogas would be 58.4 MJ/day. If this gas were treated to remove water and sulfur and combusted in a 40% efficient natural gas generator, then a modest 6.5 kWh of electricity could be produced daily, or 2,370 kWh/year.

Cost of Anaerobic Digester (AD) and Generator

A true cost estimate for a complex, custom system like this would be very complicated. Instead, a known cost of a larger system will be scaled down to fit the needs of the Corner Brewery.

The anaerobic digester system at the Abita Brewing Company cost $1.5 million dollars in 2008. The Corner Brewery is approximately 3.5% of the size of Abita, based on annual barrels of beer produced. So assuming the system could be scaled down in size and cost proportionally, an AD system with biogas storage at the Corner Brewery is estimated at $60,000, rounded up somewhat to account for economies of scale. A Generac 17kW air-cooled natural gas generator will be used for this model, with a list price of $5,000[83]. This gives a total system cost of $65,000.

Scenario 1: Utility rates stay constant

Under the first scenario, the model assumes that utility rates stay constant at today's prices. Currently the Corner Brewery pays approximately $0.11 per kWh and $3.00 per 1,000 gallons of wastewater treated. A renewable energy credit (REC) value of $0.11 is assumed for the renewable energy generated from the biogas. Under this scenario, the system saves a modest $521.48 per year.

Scenario 2: WWTP raises sewer charge to $46 per 1000 gallons

Under the second scenario, the municipal wastewater treatment plant increases their charges from $3 to $46 per 1,000 gallons treated. This is precisely what happened to Stone Brewery in San Diego, CA in 2005[84], leading them to construct their wastewater biogas project. This could happen because the treatment plant is approaching daily capacity and needs to start charging large users for improvements to their system.

Everything else in this scenario is the same as in scenario one, except that the anaerobic digester system is assumed to eliminate the fee increase, so annual savings from the system are greatly increased. The savings from the avoided wastewater fee increase are $9,345.85 per year.

Scenario 1 Payback		
Cost of system	$ 65,000	initial investment
Savings	$521.48	per year
Simple payback period	**125**	**years**

Table 16. Scenario 1 simple payback period

Scenario 2 Payback		
Cost of system	$ 65,000	initial investment
Savings	$9,345.85	per year
Simple payback period	**7.0**	**years**

Table 17. Scenario 2 simple payback period

As shown in the tables above, the simple payback period changes drastically with the increased fee to treat wastewater. The project goes from a defunct 125 year payback to an attractive 7 year payback overnight.

Conclusions

The Green Brewery Project suggests that under the current conditions, it is not economically feasible to pursue an anaerobic digester and biogas production at the Corner Brewery.

However, should the Corner Brewery grow to a size such that the Yspsilanti Community Utilities Authority chooses to impose substantial wastewater treatment fees, the Green Brewery Project suggests that Corner Brewery do an extensive analysis to determine whether a biogas project could work for them.

Wastewater Treatment

Many industrial operations must treat their wastewater on-site before discharging it either into the environment or into a municipal sewer system. The Corner Brewery is lucky to be small enough that it is not required to do that. The Ypsilanti Community Utilities Authority treats all of their wastewater for a very small fee.

As discussed earlier in the anaerobic digestion and greywater sections, the necessary drivers to warrant exploring water treatment at the Corner Brewery are simply not present. From an economic standpoint, this is very fortunate because many breweries are forced to spend countless dollars and worker-hours on treating wastewater.

However, should circumstances change in the future, the Green Brewery Project recommends that the Corner Brewery explore the following options:

Anaerobic Digestion involves collecting wastewater into an airtight containment, and treating it with specialized bacteria. Biogas capture for energy production is an option. See Anaerobic Digestion section for more information.

Aerobic Digestion is wastewater treatment in the presence of oxygen. It is generally done in outdoor pools or tanks exposed to the air. It is a cheaper option than anaerobic digestion but does not allow for biogas capture. New Belgium Brewery uses aerobic digestion after anaerobic digestion in order to further treat its effluent.

Greywater Systems involve capturing wastewater from all sources except toilets, treating it mechanically or chemically, and reusing on site. See greywater section for more information.

Living Machines© are a type of greywater system that uses plants and beneficial microorganisms to treat the wastewater on-site, in often beautiful and elaborate constructed wetlands, and yield clean, recycled water for secondary uses. See Appendix V for a thorough discussion of this technology.

Leveraging the Learning

The Green Brewery Project focused on improving the sustainability of the Corner Brewery in Ypsilanti, Michigan. However, as the project progressed, opportunities arose to make an impact beyond the client brewery. Through the project, community members and brewing industry stakeholders worldwide were given the opportunity to learn about resource efficiency and principles of sustainability in brewing. The two main ways this was achieved were through Facebook.com and the Brewers Association Craft Brewers Conference. Other outreach and publicity also occurred from various interviews and videos done about the Project online, on television and the radio.

Brewers Association Craft Brewers Conference

Figure 67. Over 200 craft brewing industry professionals attended our presentation

The Brewer's Association, based in Boulder, CO has the purpose of "promoting and protecting small and independent American brewers, their craft beers and the community of brewing enthusiasts."[85] The Brewers Association invited the Green Brewery Project to present our findings in a seminar at its annual conference, the Craft Brewers Conference. The 2011 Craft Brewers Conference hosted over 4,000 attendees from all over the North America and featured 50 different seminars.[86] The Green Brewery Project's presentation was even highlighted on the Brewers Association website as one of the "Four Must-See CBC Seminars" and was the featured seminar in the Sustainability track.[87] The Green Brewery Project's seminar session attracted over 200 attendees. The presentation was well received, with a highly participatory question-and-answer session. In addition, about 20 people approached the Team members after the session and throughout the day, asking for even more information about the Project for guidance at their breweries. Project team members are still actively engaged in correspondence with these individuals at the time of writing. The Craft Brewers Conference was the most important and effective way of reaching out to other breweries for this Project.

Social Networking

In April 2010, the Green Brewery Project was formally launched as a Masters Project, after having successfully submitted the Project Proposal to the School of Natural Resources and Environment. Because of the Corner Brewery's close connection with their customers and wider community, the Project Team decided a good way to keep these stakeholders informed was with the readily accessible social networking sites: Twitter.com and Facebook.com.

Figure 68. Our Facebook page connected us with brewers and brewery owners interested in sustainability, worldwide

Twitter.com ended up being much less worthwhile, with only one "follower" of the Green Brewery Project Page. However, the Facebook.com/greenbreweryproject site gained much more popularity. As of April 2, 2011 there were a total of 136 supporters of the Green Brewery Project Facebook page. Several brewing professionals interested in learning about sustainability efforts for their breweries learned about the Project through this page and contacted the team for more information. It is expected that as the Corner Brewery continues its sustainability improvements, the followers of the Green Brewery Project will increase. As the project draws to a close, followers of the Green Brewery Project will be directed to follow the Corner Brewery page, which will feature announcements and information concerning the sustainability measures which are ultimately implemented.

Other Publicity

In addition to the Craft Brewers Conference and online social networking sites, the Green Brewery Project has been able to spread the word about sustainability in breweries using other means as well. On April 22, 2010, the Green Brewery Project was officially introduced to the Corner Brewery community at an Earth Day release party for an organic beer. Coupon books were also available for purchase, with proceeds benefitting the project team. The coupon books were the idea of the owner Rene Greff. These coupons books were available for purchase for $50 between April and September, and contained over $350 worth of savings to be redeemed at the Corner Brewery in Ypsilanti and the Arbor Brewing Company in Ann Arbor. The coupon books spread awareness about the Green Brewery Project and gave purchasers more information about how to stay involved with the Team's progress. Eleven books were ultimately sold to benefit the Green Brewery Project.

The next community outreach event the Green Brewery Project did was on May 29, 2011. An interview of three of the team members and information about the Project was given on 1290am WLBY during the "Local Lifestyle" segment. This important event was the first time information was available about the project to a greater audience than just those affiliated with the Corner Brewery.

Then on June 16, 2010, two team members conducted an online podcast interview for Onset Computer Corporation. Onset sponsored the team by donating dataloggers necessary for research. This interview focused on how the dataloggers were benefitting the Project and brought awareness of the Project to professionals in many different industries. One of the team members is working on an instructional video on the use of these dataloggers in the brewhouse setting. This video will be made freely available on the Onset website for use by its customers.

A couple other publicity spots came from the help of the School of Natural Resources. First was a short article about the Project in the Spring/Summer 2010 edition of *Stewards*, a magazine for the alumni and friends of the School of Natural Resources and Environment.[88] The second opportunity was having the Project highlighted in a video promoting the Masters Project option at SNRE.[89] This video is available on Youtube.com, and publicizes the work the Green Brewery Project was doing as well as the importance of sustainability to the owners.

The final piece of publicity the Green Brewery Project will conduct is the airing of episode 308 of "Out of the Blue", a documentary series the University of Michigan produces for broadcast on the Big Ten Network. Video for this show has been taken a few times throughout the project term and will be the most comprehensive about details of the project. The show is set to air on April 29, 2011 and will also be available online.

By promoting the Green Brewery Project through various methods, including a national conference, online social networking and radio and video interviews, a broader audience could be made aware of sustainability issues, especially for breweries. This elevated the impact of the Green Brewery Project from one local brewery, to many other breweries and interest groups around the world.

Future Research

Life Cycle Considerations

While costly and prone to subjectivity in interpretation, life cycle assessment (LCA) is recognized as one of the most powerful tools available for measuring a product's ecological impact, and for identifying opportunities for improvement. New Belgium Brewing Company publishes an annual update to an LCA of their most popular beer, Fat Tire Amber Ale.[10] Their efforts identified the primary contributors to their product's carbon footprint to be derived from agricultural and packaging inputs upstream, and retailer refrigeration downstream. The Corner Brewery may opt to undertake a similar study in order to identify upstream and downstream contributors to its overall ecological footprint. The beginnings of such a study are laid out below.

Supply Chain Considerations

Hops are used extensively in the brewing operation. According to Corner Brewery owner, Matt Greff, the brewery consumed 3,440 pounds of hops in a recent twelve-month span. This works out to approximately 1.43 pounds of hops per barrel of beer produced. The bulk of the hops originate from a company called HopUnion in Washington state. This company grows some of its hops but receives most of them from their international supplier network. HopUnion ships by truck to Mid-Country Malt Supply in South Holland, IL. These hops are finally shipped by truck to Ypsilanti, MI.

The growing of hops can and does happen in Michigan. Unfortunately, there is not a vendor who can dry, process, and pelletize the hops in this area. This process of treating the hop cone allows for storage and capturing of the necessary oils and flavors. Without it, the hops could not be used or warehoused properly and would make an inferior product.

Malted barley is the primary grain ingredient used at the Corner Brewery. Their current annual production of beer is 2,400 barrels/yr. They utilize 203,000 lbs of grain which equates to almost 85 pounds of grain per barrel. Grain is also purchased from HopUnion, as well as a local Ypsilanti vendor. These suppliers purchase the grain from producers in England, Ontario Canada, and Wisconsin. The method of transportation locally is by truck while the method from England is by ship. With this existing supply chain, once it is bagged, the grain travels 4,067 miles from England, 687 miles from western Ontario, and 263 miles from Wisconsin.

Barley can also be grown locally but the missing link is a malting company. There are no malting companies in Michigan. Malting is the process of soaking the grain enough so it starts to germinate and then quickly removing the moisture to halt the germination process. This modifies starches so they can be used in the brewing process. Another factor is the wide variance in malts. The drying process can be modified so that the grain provides different flavors – with some of the desirable malted barley coming only from Europe.

As pointed out, the distance that the hops and grain travel is not conducive to a lower energy world. Without these supply chains in the volumes needed, the brewing process would come to a standstill for both the Corner Brewery and the many other local micro-breweries unless a less energy intensive supply chain is developed or a local hop processing or malting industry is created. It is clear that the Corner Brewery's status quo is not sustainable in the face of uncertain energy supplies. However, by embracing their role as a Third Place, by providing accessibility, food and drink and education, and lowering or substituting their energy use they will be able to transform into a gathering place for our low-consumption future. The importance of their role in the community and taking into consideration the social and environmental impacts will be important for the visioning process.

Conclusions

The Question of Sustainability

Ask anyone what sustainability means and they will give you an answer that fits their worldview. Each answer is likely to be a little different. Within our own team we had lively debates trying to do just that, asking "What is the definition of sustainability?" The Corner Brewery owners and staff need to ask themselves the same hard questions. Not doing so opens the door to accusations of "green-washing" or attempting to just boost their profit margin. This self-critiquing of their own vision allows them to respond to these potential allegations with clear and concise answers. The Corner Brewery and the craft-brewing sector have a tremendous opportunity to lead and set the example for a new business paradigm into the twenty-first century. Here are a few topics to help with the thought process and the establishment of a culture of sustainability.

Growth vs. Limits

Can growth continue forever without consequences or a correction? Does the craft brewery sector want to sponsor unlimited expansion of their product or do they want to be known as a group that lives within its means? There are real limits to growth and every system has a carrying capacity. This sector surely can't grow forever without consequences. The Corner Brewery could be a leader in recognizing this.

Efficiency and Consumption

Is the goal of operational efficiency to maximize potential output, or to minimize water and fossil fuel inputs? Will these gains help to ensure a healthy profit margin, or contribute to unrestrained (and unsustainable) growth? The capping of potential sales while maintaining a profitable business could re-enforce the Corner Brewery's image as a "green brewery" by modeling restraint.

Towards the Local

One aspect of sustainability is of living within the naturally occurring regenerative process. This thinking means taking a good hard look at the businesses inputs and outputs. Could the Corner Brewery survive if its supply chain was disrupted? What happens when the hops and barley are no longer delivered? How can a local, seasonal, regenerative supply chain be implemented? Imagine being the leader in implementing a new Michigan based supplier network that uses local renewable energy, grains, hops, and has the resiliency to function regardless of what happens to supply inputs outside of their region.

Implementation and the Future

The implementation of the programs and systems described in this report should be considered a first step of many toward achieving a "Green Brewery." During this time of expansion, coupled with the availability of extraordinary financial incentives, the Corner Brewery has a golden opportunity to become a leader in resource efficiency and renewable energy generation in the craft brewing sector. As a Third Place, the Corner Brewery is a nexus of ideas and imagination, making it the ideal setting to educate, inform, and inspire innovative environmental thinking. With good planning and execution, the Corner Brewery's impact can extend beyond the walls of its Ypsilanti, MI facility and promulgate sustainable practices throughout its community, and beyond.

Appendix A. Ypsilanti Historic District Fact Sheets

YPSILANTI HISTORIC DISTRICT **FACT SHEET**	**YPSILANTI HISTORIC DISTRICT**

This is one of a series of Fact Sheets provided by the Historic District Commission

WHAT IS HISTORIC PRESERVATION?

Historic preservation is the planned and guided protection, rehabilitation, maintenance and reuse of our architectural resources.

As recently as 1960, private efforts at preservation were limited to the rescue of an occasional mansion or monument, the federal government was busily engaged in urban renewal programs which leveled the older parts of many communities, few states had effective preservation programs, and local governments which made preservation an official part of their planning process were few and far between.

Enormous changes in attitude toward preservation have come in more recent years as a result of growing concern for our dwindling resources (including buildings themselves), the escalating costs of new construction, a revived interest in the nation's history, and a new appreciation of the aesthetic and economic value of historic architecture.

Preservation is no longer the sentimental saving of a beautiful old building – it is now a broad concept involving building codes, land use planning, tax law, open space planning, downtown revitalization – a vital tool for the conservation of neighborhoods and cities. Private involvement in preservation is extensive: thousands of people of ordinary means are engaged in the restoration of historic buildings, federal laws and tax benefits now encourage preservation, the states pursue active programs and offer assistance to local communities, and hundreds of cities have adopted preservation as official policy by establishing historic districts.

YPSILANTI

With the designation in 1973 of the Ypsilanti Historic District and the passage in 1978 of an ordinance to protect the District, the City of Ypsilanti recognized its wealth of historic architecture and committed itself to the conservation and careful development of the District for the benefit of the entire community. In so doing, it joined a rapidly growing number of U.S. cities in choosing preservation as one way to deal with an all too familiar array of urban problems.

The Ypsilanti Historic District enjoys the honor of being on both the State and National Registers of Historic Places, the highest possible recognition of the merit of its historic architecture.

WHAT IS A HISTORIC DISTRICT?

A historic district is an area of a community with a high concentration of historically and architecturally significant structures worthy of preservation. It is <u>not</u> an architectural museum in which no old building is ever torn down and no new building ever built. It must always be a growing, functioning part of the total community. Ideally, it is protected by a historic district ordinance and administered by a historic district commission.

Communities across the country have established historic districts in order to maintain the unique character of the district, encourage the recycling and continued productive use of fine old buildings, encourage new construction of a compatible nature, prevent the visual and financially harmful effects of neglected property, provide guidance for property owners, stabilize property values, protect investment and encourage new vitality.

These goals are realized through the implementation an ordinance whose provisions serve to guide the decisions of the Historic District Commission.

WHAT IS THE HISTORIC DISTRICT COMMISSION?

The Historic District Commission consists of seven citizens appointed by the Mayor with the concurrence of City Council.

A historic district commission has many duties, but just one basic responsibility – to protect and develop the area so that it can continue to be an asset to the community.

It is, therefore, in the power of a historic district commission to guide exterior alterations and new construction in order to preserve and enhance those features which warranted the designation of the area as a historic district.

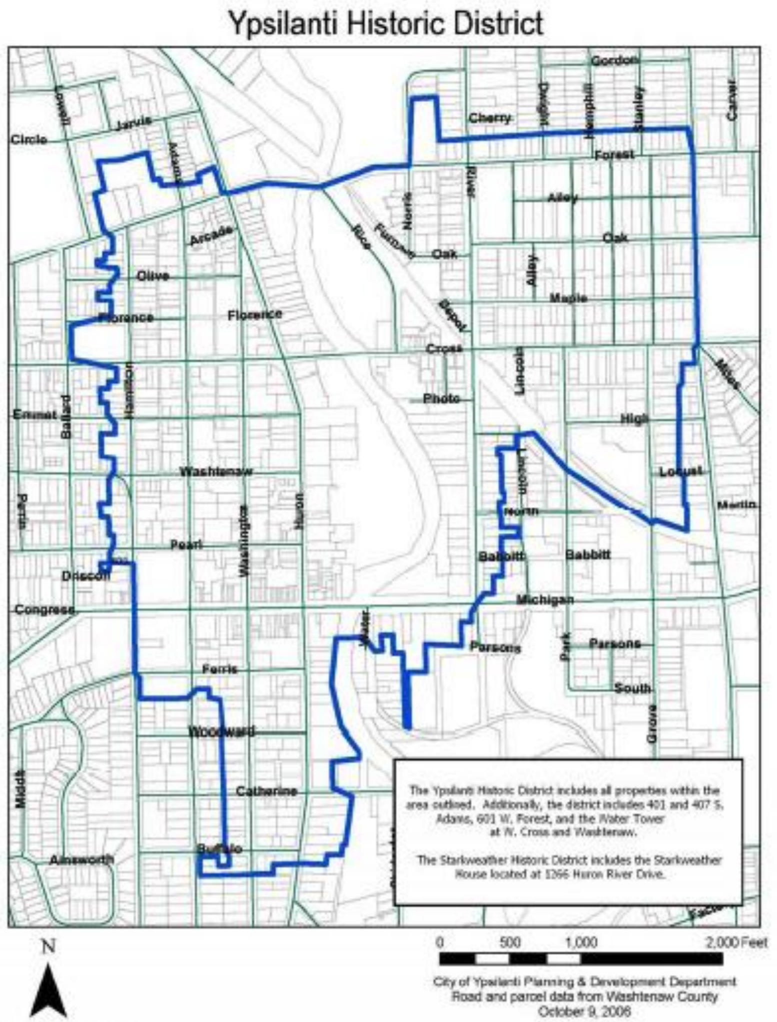
A city administrative agency, the commission reviews and acts upon all applications for building permits in the District for work which will affect a structure's exterior appearance, including, but not limited to, alteration, addition, repair, demolition and moving, as well as fences, signs, painting, etc.

The commission is guided in its decisions by the provisions and guidelines of the historic district ordinance and by the U.S. Secretary of the Interior Standards for Rehabilitation.

Copies of the ordinance are available at City Hall or online at the City's website www.cityofypsilanti.com.

2008 HDC – fact sheet, Ypsilanti Historic District

IS MY PROPERTY LOCATED IN THE HISTORIC DISTRICT?



HOW DO I GET A PERMIT?

1. If your property is in the Historic District and you need to do any work which will affect the property's exterior appearance, you must apply for a building permit at the Building Department on the third floor of City Hall, and submit your plans (include samples of materials and colors, and as much information as possible) and a completed work permit application for Historic District Commission approval. Once your properly prepared application has been submitted, you will be charged an application fee. This is in addition to the fee charged when the building permit is issued.

2008 HDC – fact sheet, Ypsilanti Historic District
The Historic District Commission reserves all rights to amend or update this Fact Sheet at any time.

2. Your application will be forwarded for review to the Historic District Commission and you will be told on what date it will be reviewed. The Commission meets on the 2nd and 4th Tuesdays of each month in City Council Chambers. The deadline for permit applications is noon of the preceding Wednesday.

3. It is advisable for you and/or your contractor/architect to meet with the Commission to discuss your permit application, any possible changes, and to answer questions. Lack of information and/or unanswered questions will prevent the Commission from taking action and, therefore, delay your project.

4. Following Commission action, your application is returned to the Building Department. If it has been approved by both the Commission and the Building Official, you can pay your permit fee at the Building Department and pick up your permit. You must then begin work within six months of the approval date. If your application has been denied (rare), you may meet with the Commission as soon and as often as you wish in order to work out a plan which can be approved.

You are encouraged to discuss your needs and ideas with the Commission well before you plan to start work and before you spend time and money on architectural drawings, blueprints, materials, etc., so that a satisfactory plan can be decided upon and delays avoided – this is called a "study item" on the agenda. The Commission is able to offer you a great deal of assistance and can often help you achieve what you need in an appropriate and sometimes less expensive way.

INFORMATION TO ACCOMPANY APPLICATION

Please be clear and complete. Furnish manufacturer's specifications, catalog illustrations and samples whenever possible.

SCOPE OF WORK: Give written description of proposed work. Will it involve repair, addition, alteration, new construction, sign, fence, demolition, moving, painting, etc.?

ALTERATION OF EXISTING STRUCTURE: Furnish detailed set of working drawings, including plan view of each floor, elevations of all exterior views, and specifications detailing kinds of materials, colors and textures of surfaces.

REPAIR OF EXISTING STRUCTURE: State conditions which necessitate repair. Specify type of existing materials which require repair, such as asphalt shingle roof, wood shingle roof, metal roof. Give species of wood involved in repair, such as cedar siding, tongue and groove clear fir porch flooring, pine railing or column, etc. State whether gutters, downspouts, decorative trim, or other material exists in the area of repair. Specify whether the repair will change any condition which presently exists.

ADDITION: Show plot plan (copy of mortgage survey) and relationship of the addition to existing structure, property lines and neighboring structures. Provide all drawings in scale. Give specifications of construction as required for new construction.

FENCES: Show plot plan (copy of mortgage survey) and relationship of the fence to existing structure, property lines and neighboring structures.

DEMOLITION: Refer to Historic District Ordinance for relevant provisions and state your proposal accordingly.

MOVING STRUCTURES: Refer to Historic District Ordinance for relevant provisions and state your proposal accordingly.

SIGN: Provide elevation drawing and section drawing, in scale of proposed sign, and indicate its relationship to the building or site. Indicate proposed materials. Provide sample of colors and lettering. Include details of any proposed lighting of the sign.

AWNING: Provide elevation drawing and section drawing, in scale of proposed awning and indicate placement on building. Indicate proposed materials. Provide sample of colors and any lettering.

PAINTING: Provide color chips. Indicate portions of building on which each color will be used.

QUESTIONS? Call Planning and Development Department at 483-9646 or the Building Department at 482-1025.

2008 HDC – fact sheet, Ypsilanti Historic District
The Historic District Commission reserves all rights to amend or update this Fact Sheet at any time.

YPSILANTI HISTORIC DISTRICT **FACT SHEET**	**ALTERNATIVE ENERGY SYSTEMS**

This is one of a series of Fact Sheets provided by the Historic District Commission to assist property owners and building contractors in planning appropriate rehabilitation of structures within the Historic District.

The Historic District Commission requires that a building be maintained in its original form whenever possible. The character and historic value of a building both change whenever alterations are made and every effort shall be made to maintain the historical integrity of a building.

Your application for a Historic District Work Permit, submitted to the Building Department, will be forwarded to the Historic District Commission for review and must be approved by the Commission before work can begin. A Building Permit will likely also be required.

Historic District Work Permit applications may be obtained from the Building Department in the basement of City Hall, in the Planning and Development Department on the 4th floor of City Hall, or on the City website, www.cityofypsilanti.com.

THE FOLLOWING APPLIES TO ALL PROPERTIES IN THE HISTORIC DISTRICT

The term "alternative energy" covers a range of technologies; for example, the National Renewable Energy Laboratory conducts research into biomass, geothermal, wind, and solar power. But, practically speaking, at present (2007) the only alternative energy systems technically feasible for most properties within historic districts are solar collectors to provide heat and electrical power; therefore any specific examples given in this fact sheet will refer to solar power systems. However, the general principles of review set out here apply equally to all types of alternative energy installations.

Because modern mechanical systems were not part of the original form of structures in the historic district, and the range of potential configurations is wide, it is not possible to provide a "cookbook" type fact sheet for alternative energy installations. The purpose of the fact sheet, instead, is to summarize the general standards against which any proposal must be reviewed.

RULES THAT GOVERN HDC REVIEW

Ypsilanti's Historical Preservation ordinance guides the decisions made by the HDC and also requires the HDC to apply the Standards for Rehabilitation established by the U.S. Secretary of the Interior when reviewing any work proposed in the district.

The Secretary's Standards define "rehabilitation" as the "process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values." In other words, both the Ypsilanti ordinance and the Secretary of the Interior Standards recognize that the long-term preservation of historic properties depends in part on the ability to adapt them to changing circumstances.

But, both sets of rules also require that any alteration be appropriate. The function of the Standards for Rehabilitation is to provide guidelines by which to determine what types and methods of repair and alteration are appropriate and permissible, and what are inappropriate.

HOW THE SECRETARY OF INTERIOR STANDARDS APPLY

Standard 2. "The historic character of a property will be retained and preserved. The removal of historic materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided."

The Standards refer to "character-defining features" of a property: examples include doors, windows, porches, transoms, and the like. Both the materials and the arrangement of these features define a property's historic character, which must not be obscured, radically changed, damaged, or destroyed in making a property more energy efficient.

Example: A business owner whose building faces south wants to install an array of solar panels. Because any significant alteration to the primary facade would obscure character-defining features, the HDC could not approve installation of the south-facing wall, and the owner would have to propose an alternative location for the solar array – e.g., on the roof.

***Standard 5.** "Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved."*

Example: A homeowner proposes to install solar panels on a stucco wall. HDC would be required to review the effect of the installation on the stucco finish. If the likely consequence would be to cause the finish to deteriorate, the HDC would have to deny the application.

***Standard 9.** "New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and it environment."*

Alterations to the exterior must not be so intrusive that they destroy the integrity of the building's character by their very presence. Repairs or alterations must not damage or destroy historic materials directly or indirectly.

Example: A business owner proposes to install a solar array on the rear wall of a building. Although the proposed installation would not obscure or damage character-defining features, and no historic material would be destroyed, it is not clear what effect the weight of the new equipment would have on the structural integrity of the wall. The HDC might then require the owner to obtain a professional structural analysis of existing physical conditions to demonstrate that the installation will do no long-term damage to the building.

Example: A homeowner proposed to install a row of solar panels on the south-facing rear roof of her house. The panels would be fixed at a 60-degree angle from the horizontal, while the roof lies at a 45-degree angle. Because the HDC must consider the effect of the proposed work on the massing of the house – that is, the outline of the building – the Commission might require that the panels be fixed at the same angle as the surface on which they are installed, even if that were not the optimal angle.

***Standard 10.** "New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired."*

The HDC must consider not only the details of installation of a system, but also how it will be uninstalled and what effect that would have on the physical integrity of the structure. The method of eventual removal and repair of any resulting damage to the structure shall be clearly identified in any work permit application

ADDITIONAL CONSIDERATIONS

Installation – attachment

The proposed method and materials for attachment shall be clearly identified in any work permit application.

Cost versus benefit

Energy conservation measures (additional insulation, weather stripping, caulking, new or repaired storm windows, etc.) are the most cost-effective methods of cutting energy costs for any property, historic or otherwise.

Although the HDC has no role to play in how an individual property owner calculates the cost versus the potential benefit of installing an alternative energy system, the HDC will consider whether the applicant has taken all available measures to achieve maximum energy efficiency.

And, because the justification for altering a historic property requires that the alteration be necessary to "[make] possible an efficient contemporary use", the presumption must be that if a property owner has not already taken all available energy conservation measures, the proposed alteration is not necessary.

OTHER INFORMATION

The Secretary of the Interior Standards for Rehabilitation are online at www.nps.gov/history

The HDC review criteria are online at www.cityofypsilanti.com/boards

Further information: e-mail hdc@cityofypsilanti.com or call the Planning & Development Department at 734-483-9646

2007 HDC – fact sheet, alternative energy systems

YPSILANTI HISTORIC DISTRICT **FACT SHEET**	**ROOF WORK**

This is one in a series of Fact Sheets provided by the Historic District Commission for the purpose of assisting property owners and building contractors in planning appropriate treatment of structures located within the Historic District.

The Historic District Commission requires that a building be maintained in its original form whenever possible. The character and historic value of a building both change whenever alterations are made and every effort shall be made to maintain the historical integrity of a building.

Your application for a Historic District Work Permit, submitted to the Building Department, will be forwarded to the Historic District Commission for review and must be approved by the Commission before work can begin. A Building Permit will likely also be required.

Historic District Work Permit applications may be obtained from the Building Department in the basement of City Hall, in the Planning and Development Department on the 4th floor of City Hall, or on the City website, www.cityofypsilanti.com.

The following Historic District Commission requirements apply to all roofing jobs, new or replacement:

Decorative or unusual features of the roof and trim at the eaves must be retained. Roof deck must overhang sufficiently to accommodate all trim or molding.

Shingles must match shingles on any adjoining roof in color and material. Shingles must be a flat color – no 'sparkles'. Colors not approved are white, pale green, pale blue and pink.

Drip edge must be used. It is generally available in white, brown and black. Color must closely match either the roof shingles or the trim of the building. Matching the roof shingles is recommended.

Other metal work (vents and flashing) must be in a color, either factory-finished or painted on the job. Mill finish (raw metal) will not be approved.

Flashing must be inserted under siding (clapboard, shingles, etc.), or in the mortar joints of masonry buildings where the roof meets these surfaces. Aluminum for flashing is available in a number of colors. Colors must closely match the adjacent surface (roof shingles, chimney brick, etc.) Mill finish (raw metal) will not be approved.

Roof venting shall, whenever possible, be accomplished through the use of ridge and soffit vents. If additional vents, such as cans, must be used to meet code requirements, they must be flat low profile, in locations as inconspicuous as possible (i.e., not visible from the street) and in a color to match the roof shingles.

Gutter systems
If gutters are to be hung by straps, the straps must be placed under the roof shingles. Downspouts must be installed where they will be as inconspicuous as possible.

2007 HDC – fact sheet, roof work
The Historic District Commission reserves all rights to amend or update this Fact Sheet at any time.

YPSILANTI HISTORIC DISTRICT FACT SHEET	SIGNS and AWNINGS

This is one in a series of Fact Sheets provided by the Historic District Commission to assist property owners and building contractors in planning appropriate treatment of structures within the Historic District.

The Historic District Commission requires that a building be maintained in its original form whenever possible. The character and historic value of a building both change whenever alterations are made and every effort shall be made to maintain the historical integrity of a building.

Your Historic District Work Permit application, submitted to the Building Department, will be forwarded to the Historic District Commission for review and must be approved by the Commission before work can begin.

Historic District Work Permit applications may be obtained from the Building Department in the basement of City Hall, in the Planning and Development Department on the 4tf floor of City Hall, or on the City website, www.cityofypsilanti.com.

SIGNS

General Guidelines:

In general, signs should not be designed as a permanent feature, as the life of a given building normally exceeds the life of any business located in that building.

Installation Methods:

Signs must always be installed without causing undue damage to the fabric of the building.

All installation devices (screws, nails, bolts, anchors, etc.) shall be corrosion-resistant and of a material that will not react adversely with adjacent materials. In most instances, stainless steel will be the metal of choice.

Signs may be attached to wood surfaces with nails or screws.

Signs that must be affixed to a brick or stone wall shall be attached with installation devices located at the mortar joints wherever possible.

Standoffs shall be used when installing a panel sign to a building in order to provide air circulation between the sign and the surface of the building.

Holes created to allow the insertion of installation devices shall be caulked with an exterior grade, high performance sealant to prevent water from entering the structure and causing damage to the fabric of the building.

Back-lit Signs:

Back-lit signs are strongly discouraged within the Historic District. When a back-lit sign is approved, the letters only may emit light, the background shall be opaque.

Wall Signs:

Signs which are attached to the façade of a building, such as just above storefront windows, are normally constructed of wood or MDO (medium density overlay). Signs shall be weatherproof and thus not constructed of any materials which cannot withstand the elements. Signs of this "board" type shall have trim around all edges to protect the sign from water damage.

Neon Signs:

Pre-existing neon signs may be restored. The use of new neon signs must be appropriate to the character of the building.

Billboards:

Roof billboards will not be approved.

AWNINGS

Styles:

Varying styles of awnings may be used within the Historic District. The style and type that is acceptable for a particular location depends on the style of the building on which it will be installed.

Owners should consider matching the profile of awnings on adjacent structures.

Materials for Awnings:

Awnings with the Historic District shall NOT be translucent.

Awnings may be constructed of many different materials. Canvas awnings are preferred but vinyl, acrylic and other materials may be considered.

Lights under awnings may be approved provided light does not show through the awning.

Metal, fiberglass and unpainted aluminum awnings are generally not in keeping with the style of buildings within the Historic District and are not likely to be approved.

Lettering for Awnings:

Awnings should not, in general, serve as the primary sign for a business.

If an awning is intended to serve as a sign, lettering may be added to the valance only. Any other proposed uses of lettering will be examined on a case-by-case basis.

Revised August 2009 HDC – fact sheet, signs & awnings
The Historic District Commission reserves all rights to amend or update this Fact Sheet at any time.

YPSILANTI HISTORIC DISTRICT FACT SHEET	WINDOWS

This is one is a series of Fact Sheets provided by the Historic District Commission to assist property owners and building contractors in planning appropriate treatment of structures within the Historic District.

The Historic District Commission requires that a building be maintained in its original form whenever possible. The character and historic value of a building both change whenever alterations are made and every effort shall be made to maintain the historical integrity of a building.

Your application for a Historic District Work Permit, submitted to the Building Department, will be forwarded to the Historic District Commission for review and must be approved by the Commission before work can begin.

Historic District Work Permit applications may be obtained from the Building Department in the basement of City Hall, in the Planning and Development Department on the 4th floor of City Hall, or on the City website, www.cityofypsilanti.com.

REPAIR:

Although old windows often need repair or leak cold air, it is always preferable and more appropriate to repair the windows than to replace them. Replacement windows will save some energy, therefore some money, but it will take a long time to break even.

Window repair often results in considerable cost savings while at the same time preserving original architectural materials. Epoxy wood-consolidating materials and polyurethane glues make it possible to repair even badly deteriorated wood windows.

- Remove the sash and lay it on a flat surface.
- Examine the exterior window frame, especially the sill, for rot or other deterioration.
- Dig out and replace bad sections with new wood or epoxy repair material. The epoxy works like auto body filler. Mix it up and pack it tightly into any depression or hollow in the wood. When hardened, it can be sanded, primed and painted.
- Then remove paint or varnish on both interior and exterior of the sash, re-glue where necessary, replace cracked glass and loose or missing glazing putty.
- Sand, apply a coat of linseed oil, prime with old-based primer, and paint the sash with latex paint.
- Replace sash cord if windows are counterweighted.
- Return sash to window.
- Nail stops back into place.

NEW WINDOW OPENINGS:

Newly created window openings transform a building's character, often threatening historic integrity, and are not generally allowed.

SCREEN/STORM WINDOWS:

- Any new screen/storm must have its horizontal members in the same place as those of the window it is covering.
- Metal combination screen/storms are permitted, although wood screens and storms are encouraged for better appearance and more efficient energy conservation.
- If a metal-framed screen/storm is installed, it must fit within the exterior trim and rest upon the blind stop. The metal frame must be either painted or factory-finished, not mill (raw metal) finish.
- Recaulking and weatherstripping are required and will improve the thermal efficiency.

SHUTTERS:

Shutters are permitted as a way to close off an unnecessary window. They must be properly hinged, fit within the window frame and painted.

REPLACEMENT WINDOWS:

In some cases, replacement windows are approved by the Historic District Commission. In all cases, the Commission will require an installation which does not reduce the glass area of any window.

Wood replacement windows are preferred. Wood windows clad in vinyl or aluminum may be approved in some cases. Solid vinyl windows will not be approved.

The new window shall be the same configuration as the window it is replacing; for example, three panes over one, one over one, etc. Panes of glass in the replacement must match the size and shape of the original. The exterior trim installed after replacement must match the original.

In cases of replacement windows where the glass is not physically divided into panes by muntins, the Commission will require that muntins be permanently adhered to the exterior of the window, in order to accurately replicate the appearance of the original windows.

Glass must be clear, not smoked or tinted.

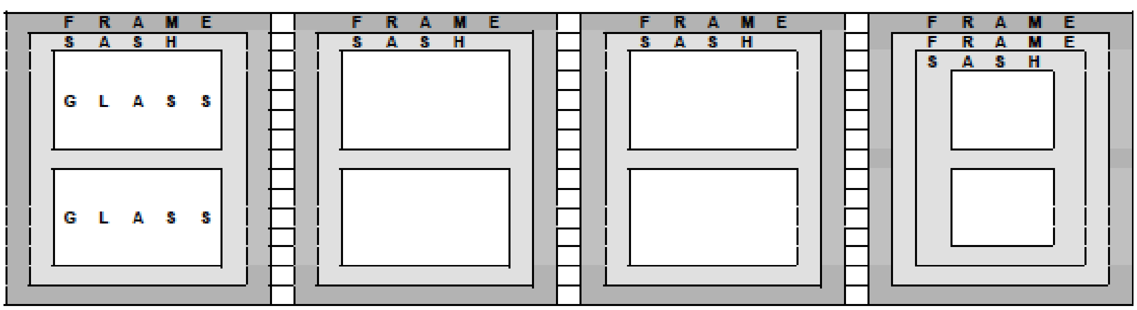
There are two kinds of replacement windows:

1. **SASH KITS**, which consist of sash only. *(The sash is the part of the window that holds the glass and moves up and down within the frame.)*
2. **FULL-FRAME REPLACEMENTS**, which consist of sash and frame.

SASH KITS are installed by removing the old sash, leaving the old frame in place, and inserting the new sash in the old frame. Thus the glass area is not reduced (see illustration #2). This installation is appropriate and can be approved.

FULL-FRAME REPLACEMENTS are installed in one of two ways:

1. The old sash and the old frame are removed. The replacement window is inserted in the rough opening. Thus, the glass area is not reduced (see illustration #3). This installation is appropriate and can be approved.
2. The old sash is removed, but the old frame is left in place. The replacement window (sash and frame) is inserted in the old frame. This results in two frames, the old frame and the replacement frame. Thus, the glass area is reduced (see illustration #4). This installation is not appropriate and will not be approved.



#1 ORIGINAL WINDOW	**#2 SASH KIT installed in OLD FRAME**	**#3 FULL-FRAME REPLACEMENT installed in ROUGH OPENING**	**#4 FULL-FRAME REPLACEMENT installed in OLD FRAME**
Original frame and sash intact.	Old frame is retained, old sash is removed, new sash kit is inserted in old frame.	Old frame is removed, old sash is removed, full-frame replacement is inserted in rough opening.	Old sash is removed, old frame is retained, full-frame replacement is inserted in old frame.
	Result - no reduction in glass area.	**Result - no reduction in glass area.**	**Result – two frames and reduction in glass area.**
	YES	**YES**	**NO**

2007 HDC – fact sheet, windows The Historic District Commission reserves all rights to amend or update this Fact Sheet at any time.

Appendix B. Seasonal Trends in Energy and Water Use

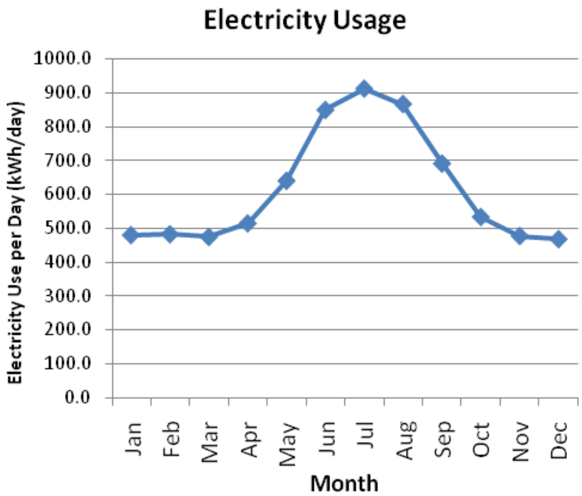


Figure 69. Annual electricity usage peaks in the summer

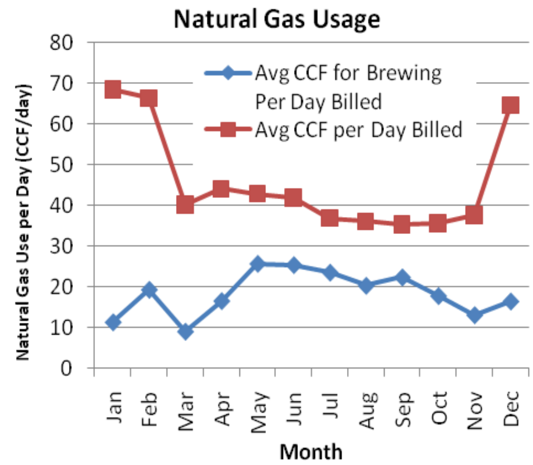


Figure 70. A smaller-than expected fraction of total facility natural gas usage goes toward brewing

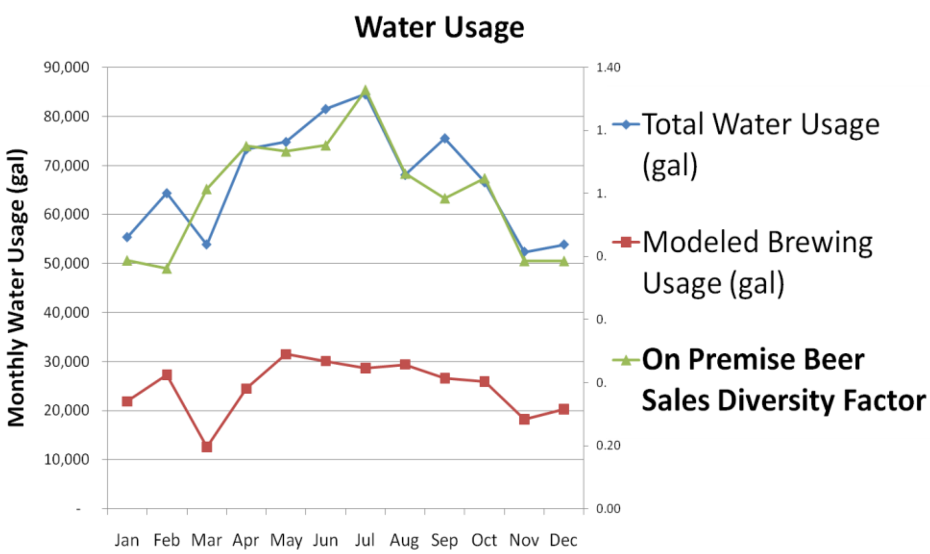


Figure 71. On premise beer sales diversity factor is a number from 0 to 1 representing the relative proportion of annual beer sales which take place in a given month. Peaks in water usage appear to coincide with peaks in on premise beer sales, suggesting that significant quantities of water are used for glass washing at the bar.

Appendix C. Power and Thermal Energy Formulas

Electricity

The power for multiple-phase electric systems is calculated according to the following formula:

$$P = \sqrt{\Phi} * P_f * V * I$$

Where
P is power in Watts
F is the number of phases
P_f is the power factor
V is the voltage in Volts
I is the current in Amps

Where P_f could not be directly measured, it was assumed to be equal to 0.8. Where motor currents could not be measured, the rule of thumb was applied: [90]

$$P = 0.55 * \text{HP}$$

The heating value of 1 CCF of natural gas is assumed to be 102,000 BTU/CCF. Natural gas-burning devices at the Corner Brewery are 80-85% efficient.

Natural Gas

The rate of natural gas consumption is found by the following formula:

$$\text{CCF per hour} = \frac{\text{Rated Thermal Output (BTUH)}}{102{,}000 * \eta}$$

Where η is the thermal efficiency of the device. The value of 0.8 was used for most cases at the Corner Brewery

Appendix D. Glycol Chiller System Specifications

QUOTATION

PRICE-SCHONSTROM INCORPORATED
P.O. Box 249
35 Elm Street
Walkerton, Ontario
N0G 2V0
fax 519-881-3573
Attention: ***Mr. David Hellerud***

Date: 29 May 1996
Quote No: 0496-A-300
Page 1 of 5

Thank you for allowing BERG CHILLING SYSTEMS INC. to submit a proposal for your Arizona brewery cooling requirements.

The system presented in this proposal has been sized based on your request for 11½ tons of cooling at 23 °F leaving fluid temperature.

ONE (1) BERG AIR-COOLED PORTABLE CHILLER WITH REMOTE OUTDOOR CONDENSER, MODEL PA-30-2P-R, *as described below and capable of supplying the specified cooling capacity at 23 °F leaving fluid temperature and 109 °F ambient air temperature (124 °F condensing)*

SPECIFICATIONS:

Chilling Capacity . . . . 11.5 tons
Chilling Pump . . . . 2 hp
Flow & Pressure . . . . 30 USGPM @ 35 psi
Process Pump *. . . . . 5 hp*
Flow & Pressure *. . . . . 40 USGPM @ 66 psi*

PRICE . . . .
LESS OEM DISCOUNT 10% . . . .
NET PRICE . . . .

AIR COOLED UNITS - LARGE RANGE

Model		PA-30
Compressor	nom. H.P.	30
Cooling Capacity [1]	tons	27.2
Evaporator Flow [2]	USGPM	65.2
Heating Capacity	MBH	431
Fan (Twin Blower)	H.P.	1
Fan Air Flow (@ 1.2 E.S.P)	CFM	18000
Pump @ 40 PSI (Higher Pressure Available)	H.P.	3
Process Connections	Inches	2 1/2
Holding Tank Capacity	US Gallons	159
Unit Dimensions (LxWxH)	Inches	97x44x101
Operating Weight	lbs	3190
Normal Run Amps	575/3/60	61.8
(Nameplate Amps)	460/3/60	77.3
	230/3/60	154.6

Company: Berg Chilling Systems Inc.
Project:
by: E.PIKK

PUMP-FLO rev: 4.27
File: PS009A2.UFS
Date: 07/17/96

CURVE: 40.000.216 PUMP DATA SHEET Catalog: SCOT60HZ v. 1.03

TYPE - SPEED: Endsuct-Encl - 3500
PUMP Size: .50-6.5-2.0x1.5
Speed: 3500 rpm
Imp dia: 6 in

FLUID DOWFROST 30% tmp: 23 °F
SG: 1.039
vsc: 8.623 cpois
vapor: 0.061 psi
atm: 14.7 psi

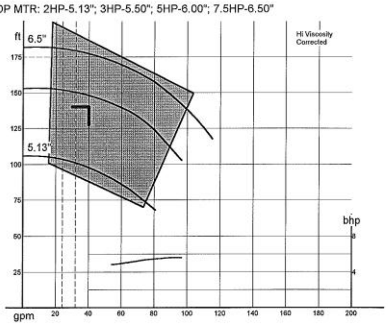
Maximum tmp: 300 °F
pres: 175 psi
Minimum flow: - % of BEP
Suction size: 2 in
Discharge size: 1.5 in

AVAILABLE HEAD NPSHa: - ft
PIPING Pressure: - psi
Suction elev: - ft
size: - in
Discharge size: - in

STD IMP-ODP MTR: 2HP-5.13"; 3HP-5.50"; 5HP-6.00"; 7.5HP-6.50"

DESIGN CONDITIONS
FLOW: 40 gpm
TDH: 145.2 ft
EFF: 31 %
POWER: 4.914 bhp
NPSHr: 5.32 ft ***

DESIGN NOTES
BEP: 48%eff @ 77.979
MAX: 5.556 bhp @ 96.734
SHUTOFF: 153 ft
MIN FLOW: - gpm
SPECIFIC Speed: 820
Suction: 5050



PERFORMANCE EVALUATION

	FLOW gpm	SPEED rpm	TDH ft	PUMP %eff	POWER bhp	NPSHr ft	MOTOR %eff	POWER kWh	HRS/YR	COST
120%	48	3500	143.6	37	4.887	5.98				
100%	40	3500	145.2	31	4.914	5.32				
80%	32	3500	146.7	25	4.928	4.65				
60%	24	3500	148.3	19	4.915	3.99				
40%	16	3500	149.9	12	5.243	3.33				

Company: Berg Chilling Systems Inc.
Project:
by: E.PIKK

PUMP-FLO rev: 4.27
File: PS009A1.UFS
Date: 07/17/96

CURVE: 40.000.132 PUMP DATA SHEET Catalog: SCOT60HZ v. 1.03

TYPE - SPEED: Endsuct-Encl - 3500
PUMP Size: .16-5.5-2.0x1.5
Speed: 3500 rpm
Imp dia: 5 in

FLUID DOWFROST 30% tmp: 23 °F
SG: 1.039
vsc: 8.623 cpois
vapor: 0.061 psi
atm: 14.7 psi

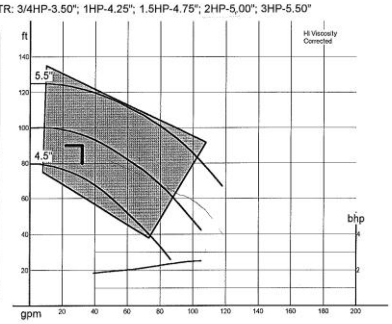
Maximum tmp: 300 °F
pres: 175 psi
Minimum flow: - % of BEP
Suction size: 2 in
Discharge size: 1.5 in

AVAILABLE HEAD NPSHa: - ft
PIPING Pressure: - psi
Suction elev: - ft
size: - in
Discharge size: - in

STD IMP-ODP MTR: 3/4HP-3.50"; 1HP-4.25"; 1.5HP-4.75"; 2HP-5,00"; 3HP-5.50"

DESIGN CONDITIONS
FLOW: 32 gpm
TDH: 94.71 ft
EFF: 43 %
POWER: 1.849 bhp
NPSHr: 1.81 ft ***

DESIGN NOTES
BEP: 65%eff @ 68.744
MAX: 2.547 bhp @ 105.08
SHUTOFF: 100.1 ft
MIN FLOW: - gpm
SPECIFIC Speed: 1120
Suction: 6100



PERFORMANCE EVALUATION

	FLOW gpm	SPEED rpm	TDH ft	PUMP %eff	POWER bhp	NPSHr ft	MOTOR %eff	POWER kWh	HRS/YR	COST
120%	38.4	3500	93.65	51	1.85	1.98				
100%	32	3500	94.71	43	1.849	1.81				
80%	25.6	3500	95.78	34	1.892	1.65				
60%	19.2	3500	96.85	26	1.876	1.49				
40%	12.8	3500	97.92	17	1.934	1.33				

(source: facsimile from Berg Chiller Group)

Actual Use Conditions		
Propylene Glycol 50%		
Cp	0.85	BTU/lb degF
SG	1.018	
Density	8.4956	lb/gal
Leaving T (degF)	24	degF
Return T (degF)	28	degF
Process Pump		
Pressure	28	psi
Current	2.4	amps (@895 rpm)
Power	1.6	kW
Flowrate	10.2	GPM
Chiller Pump		
Pressure	60	psi
Power	1.1	kW
Heat Rejection	17,678	BTUH rejected
	1.47	tons cooling average

Month	**Start Date**	**End Date**	**Avg T degF**	**Avg T degK**	**Monthly Total (kWh)**
Jan	12/23/2009	1/27/2010	25	269	3,478
Feb	1/27/2010	3/2/2010	32	273	3,811
Mar	3/2/2010	3/30/2010	41	278	3,793
Apr	3/30/2010	4/27/2010	52	284	5,049
May	4/27/2010	5/28/2010	59	288	6,903
Jun	5/28/2010	6/28/2010	71	295	10,370
Jul	6/28/2010	7/28/2010	75	297	11,617
Aug	7/28/2010	8/27/2010	74	296	11,195
Sep	8/27/2010	9/29/2010	65	291	8,948
Oct	9/29/2010	10/26/2010	55	286	5,315
Nov	10/26/2010	11/24/2010	44	280	4,223
Dec	11/24/2010	12/23/2010	27	270	2,976
					77,677
					^Total

*Electricity billing period dates were used to allow a direct comparison to monthly electric bill.

Appendix E. Lighting Retrofit

Current Lighting Configuration and Costs

Zone	Number of lights	Existing Wattage	Dimmed factor	Total wattage per zone	Avg. hours p/day	kwh p/day	kwh p/yr	Cost p/yr
Bar globe	8	100	0.4	320	14	4	1,626	$ 179
Bar spotlight	20	75	0.4	600	14	8	3,049	$ 335
Wall sconce	9	100	0.5	450	6	3	980	$ 108
North seating	40	75	0.4	1200	12	14	5,227	$ 575
South seating	30	75	0.4	900	12	11	3,920	$ 431
Brewhouse	26	59	1	1534	15	23	8,353	$ 919
Parking	10		1			-	undet	undet
Kitchen	6	28	1	168	14	2	854	$ 94
Bathrooms	8	28	1	224	14	3	1,138	$ 125
						Total kwh p/day	Total kwh p/yr	Total cost p/yr
						69.3	25147.9	$ 2,766

Alternative Lighting Configuration and Costs

Zone	Number of lights	Recommended wattage	New factor	Total wattage per zone	Avg. hours p/day	kwh p/day	kwh p/yr	Cost p/yr
Bar globe	8	13	1	104	14	1	529	$ 61
Bar spotlight	20	45	0.4	360	14	5	1,830	$ 210
Wall sconce	9	75	0.5	337.5	6	2	735	$ 85
North seating	40	45	0.4	720	12	9	3,136	$ 361
South seating	30	45	0.4	540	12	6	2,352	$ 271
Brewhouse	26	28	1	728	15	11	3,964	$ 456
Parking	10		1	0		-	undet	undet
Kitchen	6	28	1	168	14	2	854	$ 98
Bathrooms	8	28	1	224	14	3	1,138	$ 131
						New total kwh p/day	New total kwh p/yr	New total cost p/yr
						40.0	14537.8	$ 1,672

Lighting Cost-Benefit Analysis

Zone		Cost per upgrade	Savings per/year	Simple payback in years
Bar globe	8	$ 9	$ 118	0.08
Bar spotlight	20	$ 149	$ 125	1.19
Wall sconce	9	NA		
North seating	40	$ 298	$ 214	1.39
South seating	30	$ 224	$ 161	1.39
Brewhouse	26	$ 2,543	$ 463	5.49
Parking	10	NA		
Kitchen	6	NA		
Bathrooms	8	NA		

Appendix F. Roof Insulation Specification Sheet

Trisotech™ Tapered Insulation

Isocyanurate Roof Insulation Board

Composition: Trisotech™ Tapered Insulation consists of a rigid, closed cell polyisocyanurate foam core laminated on both sides to a black, fiber reinforced, non-asphaltic facer. The board panels are sloped for improved drainage of water.

Basic Uses: Trisotech Tapered Insulation is used to provide positive drainage of water from rooftop areas. Trisotech Polyisocyanurate boards provide high thermal insulation and are compatible under most roof membrane systems. Trisotech Tapered Insulation Systems include layout drawings to support the design and construction team in providing the best drainage based on the actual conditions of the roof. Tapered Trisotech is recommended for use in combination with a wood fiber overlay board in hot and cold applied BUR and MB roof systems. Meets ASTM C 1289-01, Type II, Class 1, Grade 2.

Limitations:

- Not intended for use under ponding conditions. Positive drainage is required.
- Not to be exposed to solvents, oils or other contaminants harmful to polyisocyanurate foam insulation.
- Insulation stops are required on roofs with slopes of 2:12 (2") or greater.
- Not for use directly under hot applied roof membranes. A wood fiber overlay board is required prior to the application of a hot applied roof membrane.
- Not for use in direct contact with lightweight insulating concrete or recently poured gypsum decks.
- For adhered systems where a cover board is not specified, multiple layers of Trisotech must be used when the total insulation thickness is 2.5" or greater.
- For adhered single ply systems when a cover board is not specified, the maximum thickness for the top layer of Trisotech is 2.0".

Product Advantages	
Features	**Benefits**
Factory Tapered Insulation	• Provides positive drainage • Custom layout for rooftops • Conforms to existing conditions
Closed cell foam	• High thermal "R-Value" • Low thermal conductivity • Non-rotting, non-absorbent core • Lightweight, rigid board, easy to handle
Thick fiber facer	• Suitable for adhering to substrates in hot or cold applied adhesives • Protects foam core
FM Approved	• Manufactured under a FM quality assurance inspection program • Fire/wind protection
UL Approved	• Manufactured under UL quality assurance inspection program • UL classified fire protection

Sizes: Trisotech Tapered Insulation is available in truckload quantities in 4' x 4' (1220mm x 1220mm) or 4' x 8' (1220mm x 2440mm) board panels and packaged on dunnage. Thicknesses range from 1" (25mm) to 4" (101mm). System tapers typically range from 1/8" to 1/2". Contact your Tremco Representative for a full list of available thicknesses.

When Trisotech Tapered Insulation is specified for application in FAS-n-FREE Adhesive or hot bitumen, the recommended board size is 4' x 4'. Board sizes of 4' x 8' are only acceptable when mechanical attachment of insulation is specified.

GENERAL APPLICATION DATA:

Roof replacement usually involves more complexities than new construction roofing. Often encountered are situations such as rusted/deteriorated decks, rotted wood components, rooftop equipment which cannot be moved or shut down, and numerous other conditions.

The following application information is designed to serve as a general guide. Your local Tremco Representative will prepare detailed specifications based on the condition of your roof.

Structural Decks: Must be properly designed and structurally sound.

Drainage: Ponding conditions are unacceptable and will adversely affect the performance of any roofing system. If positive drainage does not exist, water removal from the roof surface must be facilitated by lowering drains, and/or installing additional drains, tapered insulation, or Tremco approved cellular concrete system.

Insulation Storage: Insulation must be dry and kept dry. When stored outdoors, stack insulation on pallets at least 4 inches (100mm) above ground level. Upon receipt of insulation on the job site, remove the factory plastic packaging. Cover the top and sides of the insulation with waterproof tarpaulin (not polyethylene) and secure. Do not stack more than two pallets high.

TREMCO

Roofing & Weatherproofing Peace of Mind™

Appendix G. Representative Multiple-Batch Brewing Cycle

<table>
<tr>
<td>Cycle 1:

Days since previous brew: 6
Batches: Brown x1 (12 BBl), IPA x2 (39 BBl total), Blonde x2 (40 BBl total)

Total BBl: 91

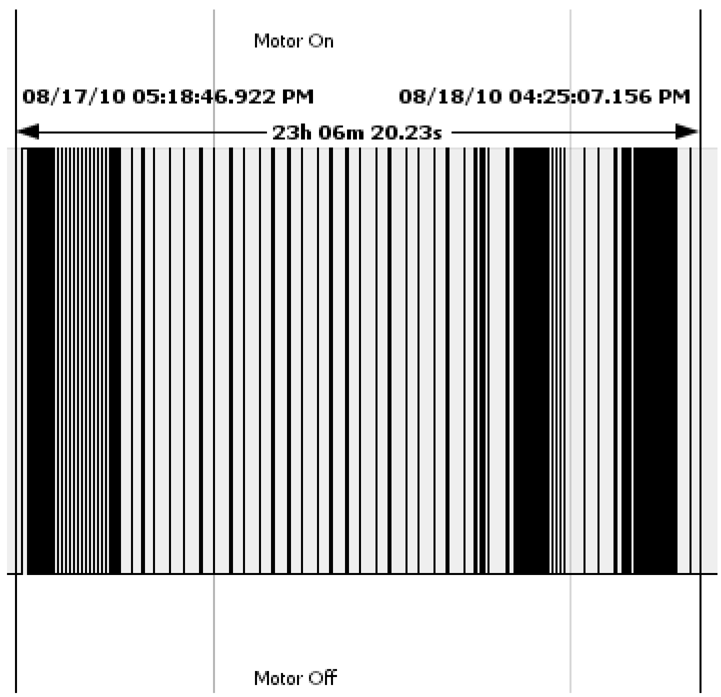
CCF Used: 150.6

CCF/BBl = 1.64</td>
<td>
</td>
</tr>
<tr>
<td>Cycle 2:

Days since previous brew: 4
Batches: Brown x1 (12 BBl total)

Total BBl: 12

CCF Used: 39.4

CCF/BBl = 3.28</td>
<td>
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Appendix H. Temperature Observations

	Temperature observations on February 11th, 2011		
Location		Temperature at 1200 hours	Temperature at 1400 hours
Outside air temperature for Ypsilanti, MI		21.3'F	28.6'F
North booth temperature		60.8'F	69'F
Temperature near ceiling and 15ft from booth		78.8'F	77.8'F
Thermostat actual temperature		68'F	72'F
Givens: Thermostat was set at 72'F; Ceiling fan was turned on at 1330 hours			

Appendix I. Financed Discounted Payback Method

The Financed Discounted Payback method is a modification of the Discounted Payback Method for calculating the payback period of an investment. It takes into consideration factors related to capital depreciation and loan financing.

Financed Discounted Payback Method

$$\sum_{n=1}^{N_{\min}} \frac{\left(B_{S,n} - C_{S,n}\right)}{\left(1+d\right)^n} + \sum_{n=1}^{N_D} \frac{\left(B_{T,n}\right)}{\left(1+d\right)^n} + \sum_{n=1}^{N_L} \frac{\left(B_{L,n} - C_{L,n}\right)}{\left(1+d\right)^n} = I_0$$

where

$B_{S,n}$ is the benefit of the system in period n

$B_{T,n}$ is the tax savings from capital depreciation in period n

$C_{S,n}$ is the cost of the system in period n

$C_{L,n}$ is the loan payment in period n

d is the discount rate

$N_{\min}$ is the discounted payback period

N_D is the book depreciation period of the capitalized investment

N_L is the loan term

I_0 is the initial investment cost

The first term represents the sum of present values of all financial benefits (including REC payments) less operation and maintenance costs, for each year from year one to the payback year.

The second term represents the sum of present values of net tax savings for each year from year one to the book depreciation year of the capital.

The third term represents the sum of present values of tax savings due to loan interest payments less loan payments to creditor.

Appendix J. Partial Solid Waste Inventory

The scope of this project did not include a full evaluation of the material throughputs at the Corner Brewery. However, a preliminary inventory of solid wastes is included in . This list is included for future evaluation by the Brewery in order to minimize negative environmental impacts and unnecessary production and waste.

Corner Brewery Solid Waste Inventory		
Area	**Use**	**Waste Created**
Brewhouse	Brewing	Spent Grain & Yeast Grain Sacks Waste Water Cleaning chemicals
	Shipping & Packaging	Label Wrappers Boxes Broken bottles Cardboard
Office	Computer/Printer	Paper Empty Ink Cartridges
	Files	Paper Writing Utensils
Bar	Transactions	Receipt Papers
	Drinks	Waste Water Used Bottles Paper Coasters Menus
	Cleaning	Waste Water Cleaning chemicals
Kitchen	Meals	Food Waste Cardboard Basket liners Napkins
	Cleaning	Waste Water Cleaning chemicals
Bathrooms	Toilets	Waste Water Toilet Paper
	Sinks	Waste Water Soaps Paper towels
	Cleaning	Waste Water Garbage Bags
General Interior	Lighting	Light Bulbs
	Publicity, incl. merchandise	Chalk Paper Textile Waste Posters
Exterior	Parking Lot	Light Bulbs Runoff Water
	Beer Garden	Light Bulbs

Table 18: Solid waste inventory

Appendix K. Process-Specific Energy Efficiency Measures

Process -Specific Energy Efficiency Measures**Error! Bookmark not defined.**	Typical Payback	Implement?
Mashing and Lauter Tun		
Capture of waste heat energy	3+	No
Use of compression filter (mashing)	1-3	No
Wort Boiling and cooling		
Heat recovery with vapor condensers	3+	Yes
Thermal vapor recompression	1-3	No
Mechanical vapor recompression	3+	No
Steinecker Merlin system	1-3	No
High gravity brewing	1-3	Yes
Low pressure wort boiling	1-3	No
Wot stripping	1-3	No
Wort cooling-additional heat recovery	3+	Yes
Fermentation		
Immobilized yeast fermenter	1-3	No
Heat recovery	1-3	Yes*
New CO2 recovery systems	1-3	No

Processing		
Microfiltration for clarification or sterilization	3+	No
Membranes for production of alcohol-free beer	3+	No
Heat recovery-pasteurization	3+	No
Flash pasteurization	3+	No
Packaging		
Heat recovery washing	3+	No
Cleaning efficiency improvements	3+	No

* Implemented as part of Water-to-Water Heat Pump project

Appendix L. Cross-Cutting and Utilities Energy Efficiency Measures

Cross-cutting and utilities energy efficiency measures for brewing industry**Error! Bookmark not defined.**		
Boilers and Steam distribution	Typical Payback	Implement (Yes/No/Current Practice)
Maintenance	0-2	CP
Improved process control	0-2	Yes
Flue gas heat recovery	2+	Yes
Blowdown steam recovery	2+	No
Steam trap maintenance	0-2	CP
Automatic steam trap monitoring	0-2	No
Leak repair	0-2	Yes
Condensate return	0-2	CP
Improved insulation of steam pipes	0-2	Yes
Process integration	0-2	Yes*
Motors and Motor Systems		
Variable speed drives	0-2	CP
Downsizing of motors, pumps, compressors	0-2	No

High-efficiency motors, pumps, compressors	0-2	Yes
Refrigeration and cooling		
Better matching of cooling capacity and loads	2+	Yes*
Improved operation of ammonia cooling system	2+	No
Improve operations and maintenance	0-2	Yes
System modifications and improved design	2+	No
Insulation of cooling lines	0-2	CP
Energy Management Systems	N/A	Yes
Redirect Air Comprssor Intake to Use Outside Air	Unk.	Yes
Install strip curtains in cold storage units	Unk.	Yes
Heat recovery wheel	Unk.	Yes

* Implemented as part of Water-to-Water Heat Pump project

Appendix M. Pipe Insulation Calculations Spreadsheet[91]

Steam Pipe Insulation Calculations

Baseline Year	2010		Air Temp	75 degF	24 degC
BBl Brewed	3024		Steam Temp	274 degF	134 degC
Cycles	107		Pressure	45 psi	310.3 kPa
Batches	157	(28 and 42 BBl brews each count as two batches)	Enthalpy (h_g)	1172.2 BTU/lb	2726.4 kJ/kg
NG Price	1.05				

Insulation				
Type	Fiberglass			
Thermal Conductivity k_s (W/m2C)	0.0414	0.0332 min	0.0894 max	0.0414 typical
Thickness	1 in	0.0254 m		
R-value (thickness/k)	0.614 per Kelvin m2			

1 (btu in) / (h ft^2 F) = 0.1442279 W/(m K)

Steel Pipes	
Type	Sched 40
Thermal Conductivity k_w (W/m2C)	43

Annual Savings	
CCF Nat Gas	577.01
$	$ 605.86
Simple Payback Period	1.39 years

Cost estimate from State Supply - 1" thick fiberglass insulation

item	size	feet	length of pipe insulation	sections needed	cost per section	cost
insulation	3"	23.5	3	8	$8.67	$69.36
insulation	1 1/2"	116.5	3	39	$6.57	$256.23
insulation	3/4"	78.3	3	27	$5.25	$141.75
tape	3" x 150'					$27.22
					subtotal	$494.56
					shipping	$195.44
					Total	**$690.00**

Installation	
Number of worker-hours	10
Hourly Rate	$15
Installation cost	$150
Total installed cost	**$840.00**

Note sizing convention when selecting insulation

Pipe size (ID)	Insulation ID
3"	3-1/2"
1 1/2"	1-5/8"
3/4"	1"

Brewhouse Steam/Condensate Return Pipes - measurements refer to "easily insulatable" bare pipe (not counting valves, steam traps, etc.)

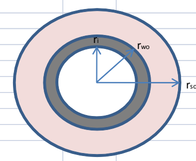
Pipe internal diameter	Main Supply Line (in)	Main Return Line (in)	HLT Supply (in)	HLT Return (in)	MT Supply (in)	MT Return (in)	BK Supply (in)	BK Return (in)	Mystery Tanks (in)	Totals in inches	Totals in feet	Totals in meters
3" pipe	282	0	0	0	0	0	0	0	0	282.0	23.5	7.1628
1 1/2" pipe	0	714	114	0	294	0	120	96	60	1398.0	116.5	35.5092
3/4" pipe	0	0	27.5	215	105	332	95	165	0	939.5	78.3	23.8633
Duty Cycle	0.2930	0.2930	0.2930	0.2930	0.0313	0.0313	0.0179	0.0179			218.3	66.5353
	0.2930	0.2930	0.2930	0.2930	0.0313	0.0313	0.0179	0.0179				
Hours In Use per Yr*	2568	2568	2568	2568	275	275	157	157				

* Based on 2010 brewing schedule and boiler fan on/off data logs

Radii

Pipe internal diameter	r_i (m)	r_{wo} (m)	r_{so} (m)
3" pipe	0.0390	0.0445	0.0699
1 1/2" pipe	0.0204	0.0241	0.0495
3/4" pipe	0.0104	0.0133	0.0387

Heat Transfer Cons	Min	Max	Value	Notes
hi_steam	5000	100000	50000	Condensing water vapor
hi_cond_return	50	10000	5000	Water forced convection
h_o	5	25	10	Air natural convection
ΔT			110	degC



Other Physical Constants and Parameters

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return
h_i (from HX Const table above)	50000	5000	50000	5000	50000	5000	50000	5000
Length (m)								
3" pipe	7.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 1/2" pipe	0.00	18.14	2.90	0.00	7.47	0.00	3.05	2.44
3/4" pipe	0.00	0.00	0.70	5.46	2.67	8.43	2.41	4.19
Inner Area (m2)								
3" pipe	1.755	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1 1/2" pipe	0.000	2.330	0.372	0.000	0.959	0.000	0.392	0.313
3/4" pipe	0.000	0.000	0.046	0.357	0.175	0.552	0.158	0.274

$$\frac{1}{U_i} = \frac{1}{h_i} + \frac{r_i \ln\left({r_{wo}}/{r_i} \right)}{k_w} + \frac{r_i}{h_o r_{wo}}$$

$$\frac{1}{U_{i'}} = \frac{1}{h_i} + \frac{r_i \ln\left({r_{wo}}/{r_i} \right)}{k_w} + \frac{r_i \ln\left({r_{so}}/{r_{wo}} \right)}{k_s} + \frac{r_i}{h_o r_{so}}$$

U_i is overall heat transfer rate based on inner surface area

$U_{i'}$ is overall heat transfer rate based on inner surface area (with insulation)

h_i and h_o are inside and outside convective heat transfer coefficients

r_i and r_{wo} are inner and outer radii of pipe

r_{so} is outer radius of insulation

k_w and k_s are thermal conductivity of wall material and insulation

Uninsulated Heat Flux Rate U_i (W/m2C)

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return
3" pipe	11.38	11.36	11.38	11.36	11.38	11.36	11.38	11.36
1 1/2" pipe	11.79	11.76	11.79	11.76	11.79	11.76	11.79	11.76
3/4" pipe	12.79	12.76	12.79	12.76	12.79	12.76	12.79	12.76

Insulated Heat Flux Rate U_i' (W/m2C)

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return
3" pipe	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
1 1/2" pipe	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27
3/4" pipe	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89

Uninsulated Heat Loss (W) $Q = U_i A \Delta T$

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return	Total heat loss
3" pipe	2208	0	0	0	0	0	0	0	2208
1 1/2" pipe	0	3030	485	0	1250	0	510	407	5683
3/4" pipe	0	0	65	504	247	779	223	387	2204
Total	2208	3030	549	504	1497	779	734	794	10095

Insulated Heat Loss (W) $Q = U_i A \Delta T$

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return	Total heat loss
3" pipe	378	0	0	0	0	0	0	0	378
1 1/2" pipe	0	585	93	0	241	0	98	79	1097
3/4" pipe	0	0	15	114	56	176	50	87	498
Total	378	585	108	114	297	176	149	166	1973

Annual Energy Loss (kWh_th)

Descrip	Main Supply Line	Main Return Line	HLT Supply	HLT Return	MT Supply	MT Return	BK Supply	BK Return	Total heat loss
Uninsulated	5671	7781	1411	1295	411	214	115	125	17022
Insulated	970	1503	277	293	82	48	23	26	3222
Difference	-4700.4	-6278.0	-1133.4	-1002.0	-329.8	-165.5	-91.8	-98.6	20244
CCF Saved (80% eff)	196.5	262.5	47.4	41.9	13.8	6.9	3.8	4.1	
Total CCF Saved	**577.01**								

Appendix N. Sample WSHP Specification

Mfg	FHP Manufacturing		
Model	WW420		
Refrigerant	R-410a		
			Chiller Performance
Condenser	110	43	Condenser Entering Fluid Temp ({F}{C})
	120	49	Leaving Fluid Temp ({F}{C})
	80	5.0	Flow Rate ({GPM}{liter per sec})
	11	32.9	Pressure Drop ({FOH}{kPa})
	0		% Propylene Glycol
	32	0	Freeze Point ({F}{C})
Evaporator	55	13	Evaporator Entering Fluid Temp ({F}{C})
	45	7	Leaving Fluid Temp ({F}{C})
	58	3.7	Flow Rate ({GPM}{liter per sec})
	7.6	22.7	Pressure Drop ({FOH}{kPa})
	0		% Propylene Glycol
	32	0	Freeze Point ({F}{C})
	290,510	85.1	Chiller Capacity ({BTUH}{kW_th})
	9.0	2.6	EER ({BTUH/W}{ COP (W/W) })
	400,234	117.3	Heat Rejection ({BTUH}{kW_th})

Spec sheet supplied by Chris Nutt of AirTech Equipment, 3/8/2011

Appendix O. Halogen and LED Exit Light Specifications

GE
Lighting

HIR™ Plus Halogen PAR38s

You Can Get Less Than a One Year Payback Just By Changing A Light Bulb!

Product Overview

- With increased demand for energy saving lighting alternatives, GE - the inventor of HIR technology - has developed another breakthrough ecomagination product within the Halogen product family.

GE Advantage

- Although several companies offer PAR38 IR lamps, GE's HIR® Plus lamps will lead the industry in efficiency (LPW).

Product features & benefits

- Huge Cost of Light Savings
  ... Less than a one year payback in most cases
- Long 4,200 hour life
- Up to over 2X longer life than Standard PAR38s
- Up to 55% more efficient than Standard PAR38s
- Industry most efficient Halogen PAR38 lamps (LPW)

HIR™ Plus

PC	Description	Lumens	CBCP
90512	45PAR/HIR+/SP10	870	14100
90513	45PAR/HIR+/FL25	870	3500
90515	48PAR/HIR+/SP10	970	15500
90519	48PAR/HIR+/FL25	970	3800
76143	53PARHIR+XL/FL25	1500	3700
76142	53PARHIR+XL/SP10	1500	15000
71446	55PAR/HIR+/SP10	1120	17500
71598	55PAR/HIR+/FL25	1120	4100
90601	67PAR/HIR+/SP10	1500	22000
90602	67PAR/HIR+/FL25	1500	5000
90520	60PAR/HIR+/SP10	1260	19000
90529	60PAR/HIR+/FL25	1260	4700
90605	83PAR/HIR+/SP10	2030	30000
90606	83PAR/HIR+/FL25	2030	7000
NEW 62232	75PARHIR+8KSP10T	1500	22000
62231	75PARHIR+8KFL25T	1500	5000

GE Halogen PAR38

Good			Better			Best		
Standard Halogen			**HIR™**			**HIR™ Plus**		
						Industry Leading LPWs		
Life = 2500 - 3000 Hours			Life = 3000 Hours			Life = 4200 Hours		
Watts	Lumens	LPW	Watts	Lumens	LPW	Watts	Lumens	LPW
120	1900	15.8	100	2030	20.3	83	2030	24.5
100	1500	15.0	80	1500	18.8	67	1500	22.4
90	1310	14.6	70	1260	18.0	60	1260	21.0
						55	1120	20.4
75	1050	14.0	60	1050	17.5	48	970	20.2
60	800	13.3	50	800	16.0	45	870	19.3

imagination at work

GE HIR™ Plus Halogen PAR38s

How Much Can Be Saved By Using HIR™ Plus?

	Good	Better	Best
	STANDARD	HIR™	HIR™ Plus
Lamp Description	75PAR/H	60PAR/HIR	48PAR/HIR+
Lamp Life @120V	2500	3000	**4200**
Wattage	**75**	**60**	**48**
Lumens	1050	1050	970
LPW	**14.0**	**17.5**	**20.2**
Estimated Price Premium per lamp vs. STD		$3.50	$7.25
Lamp Cost Example (prices vary)	$6.00	$9.50	$13.25
Annual Cost Per Socket			
Annual Lamp Cost (Price * Annual Op Hours / Lamp Life)	$10.80	$14.26	$14.19
Labor (Labor Rate * Annual Op Hours / Lamp Life)	$3.60	$3.00	$2.14
Electricity (Electric Rate * Lamp Wattage * Annual Op Hours)	$33.75	$27.00	$21.60
HVAC Savings		$0.74	$1.34
Total Annual Operating Cost	$48.15	$43.52	$36.60
Annual Savings Per Socket vs. STD		**$4.63**	**$11.55**
Cost Of Light Savings vs. STD		**10%**	**24%**
Simple Payback in Years		**0.8**	**0.6**
Return On Investment		**130%**	**160%**
ecomagination℠			
Annual Kwh's	338	270	216
KwH's Reduction		(68)	(122)
KwH's Reduction %		-20.0%	-36.0%
Carbon Dioxide: CO_2 Reduction (lbs.)		(94)	(169)

Assumptions:
Annual Operating Hours = 4,500, Labor Rate = $2.00
Average Electric Rate = $0.10 kwh
HVAC Savings = 1/3 watt for every 1 watt saved times the HVAC Coefficient .33 (from ASHRAE guidelines)
Simple Payback calculation = (Lamp Price Premium / Annual Savings)

For additional product and application information, please consult GE's Website: www.gelighting.com

Information provided is subject to change without notice. Please verify all details with GE. All values are design or typical values when measured under laboratory conditions, and GE makes no warranty or guarantee, express or implied, that such performance will be obtained under end-use conditions.

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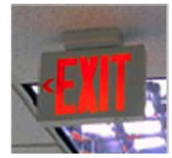
SAVE ENERGY, MONEY AND PREVENT POLLUTION WITH LIGHT-EMITTING DIODE (LED) EXIT SIGNS



Illuminated exit signs are an important and legally required safety feature in your facility. In the case of an emergency such as a fire, their operation is critical in protecting the well being of your congregation's members. By design, exit signs operate 24 hours per day, and can consume large amounts of energy to operate. Many exit signs in today's buildings use older, incandescent and fluorescent/compact fluorescent lighting (CFL) technology. To make matters worse, many older exit signs require frequent maintenance due to the short life span of the lamps that light them. For example, many older exit signs consume over 350 kilowatt-hours (kWh) and cost $28 each annually to operate.

ADVANCED LIGHTING TECHNOLOGY TO THE RESCUE

The high-energy usage and maintenance of many exit signs is completely unnecessary due to advances in lighting technology. Solid-state light-emitting diodes (LED) are those small colored lights that have been used extensively in consumer electronics for decades. However recent advances in the technology have allowed exit sign manufacturers to develop signs that harness the advantages of this technology at competitive costs. In addition, exit signs are easy to install, if you can install a light switch or electrical receptacle you can install an exit sign.

LED Exit Sign Advantages

- **Ultra-Low Energy Usage:** ENERGY STAR® labeled LED exit signs use approximately 44 kWh of electricity annually to operate. Low energy use not only means less pollution but also lower electricity bills as a LED exit sign usually costs less than $4 annually to operate.
- **Low Maintenance**: To be ENERGY STAR labeled, a LED exit sign must be guaranteed to last at least 5 years, however, many manufacturers state that their lamps will maintain National Fire Protection Association compliant levels of luminance for 10 to 25 years.

Exit Sign Energy Use by the Numbers				
Exit Sign Lighting Technology	**Annual Energy Use**	**Annual Energy Cost**	**Lamp Service Life**	**Annual Carbon Dioxide (CO_2) Pollution**
LED	44 kWh	$4	10+ Years	72 pounds
Fluorescent/CFL	140 kWh	$11	10.8 months	230 pounds
Incandescent	350 kWh	$28	2.8 months	574 pounds

- **Safety:** LED exit signs are usually brighter than comparable incandescent or fluorescent signs, and have greater contrast with their background due to the monochromatic nature of the light that LEDs emit.

EXIT SIGN FEATURES

- **Color:** Exit signs come in two colors, green or red. Choosing what color is right for your facility is dependent on several factors, including aesthetics and local regulations. Check with your local building codes office or fire officials before purchasing any exit sign.
- **Battery Back-up:** To ensure a powered exit sign remains lit during an emergency if the building's electrical system is interrupted, many exit signs come with a battery back-up or offer this feature as an option. Some localities may require that a battery back-up be installed with any exit sign so consult your local building codes office or fire officials before purchasing.

Appendix P. Window Shading Devices Cost

Cost of roll down shades for north, west and south facing windows in restaurant area of Corner Brewery

Manual							
# of windows	Length (in)	Length (ft)	Height (in)	Height (ft)	L + H	Cost per window = (L + H) * $7	Total cost = (L + H)*$7 * # windows
7	48	4.00	66	5.50	9.50	$66.50	$465.50
15	95	7.92	66	5.50	13.42	$93.92	$1,408.75
2	66	5.50	66	5.50	11.00	$77.00	$154.00
						Total:	$2,028.25

Motorized							
# of windows	Length (in)	Length (ft)	Height (in)	Height (ft)	L + H	Cost per window = (L + H) * $10	Total cost = (L + H)*$10 * # windows
7	48	4.00	66	5.50	9.50	$95.00	$665.00
15	95	7.92	66	5.50	13.42	$134.17	$2,012.50
2	66	5.50	66	5.50	11.00	$110.00	$220.00
						Total:	$2,897.50

- Cost estimate supplied by Hans Stahl of Bio-Green Technologies

Appendix Q. Radiant Barrier Specification

Saving money through energy efficient solutions

Call 972.283.0163

ARMA FOIL™ - Data Sheet

Applications

- Under Roof Decking
- Stapled up in Attics
- Fire Walls
- House Wrap
- Floors and Crawl Spaces
- Metal Buildings
- Industrial Applications

Specifications

- Standard Size: 16", 24" and 48" wide by 125 or 250 ft long
- Double Sided Radiant Barrier
- ENERGY STAR® Qualified
- Contains metalized film with polyethylene reinforcement
- Emissivity: 0.05 (ASTM C1371-04a)
- Reflectivity: 95% (ASTM C1371-04a)
- Class A / Class 1 Fire Rating (ASTM E84-10)
- Flame Spread: 0 (ASTM E84-10)
- Smoke Development: 5 (ASTM E84-10)
- Clean and Non-Toxic
- Corrosivity: 100% Humidity, PASS (ASTM D3310-00)
- Mold and Mildew: No Growth (ASTM C1338)
- Water Vapor Permeability: 6.3 perms (ASTM E96-05)
- Thickness: 5 mil
- Weight: 29.95 lbs / 1000sf roll
- Shear/Tear Strength (Length): 13.23 lb of force (ASTM D2261)
- Shear/Tear Strength (Width): 13.98 lb of force (ASTM D2261)

Code Approvals

- Meets EPA standards for sheet radiant barriers
- Meets California Insulation Standards

Seal and Insulate with ENERGY STAR
LEARN MORE AT energystar.gov

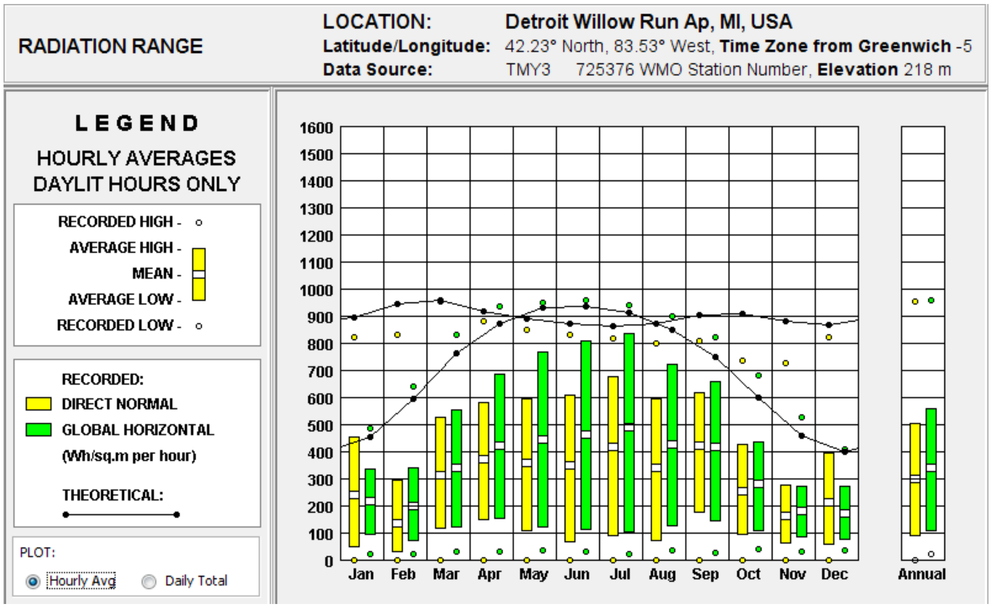
web: www.energyefficientsolutions.com
email: sales@energyefficientsolutions.com

Energy Efficient Solutions, LLC
1126 S Cedar Ridge Drive #106 ~ Duncanville, TX 75137
phone: 972.283.0163

This technology could be used to conserve fireplace heat, as well as provide additional insulation in the brewhouse.

Appendix R.   Green Façade

Appendix S. Solar Insolation and Design Considerations for Ypsilanti, MI[xi]



Direct Normal Irradiance is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.[xii]

Global Horizontal Irradiance is the total amount of shortwave radiation received from above by a horizontal surface. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF).[xii]

Tilt angle is the angle from horizontal of the roof inclination of the PV array (0° = horizontal, 90° = vertical). The common practice is to set a tilt angle equal to the array's latitude. This normally maximizes annual energy production. Increasing the tilt angle favors energy production in the winter, and decreasing the tilt angle favors energy production in the summer.

According to data collected from the PVWatts solar calculator, the optimal tilt angle for Ypsilanti, MI is **32 degrees**, not the more typical tilt equal to latitude (42 degrees). This is likely due to greater cloud cover during the winter months.[54]

[xi] Source: Climate Consultant 5, Weather data file: USA_MI_Detroit-Willow.Run.AP.725376_TMY3.epw

[xii] "Glossary of Technical Renewable Energy Terminology" http://www.3tier.com/en/support/glossary/

Appendix T. Solar Performance Calculator Variables and Constitutive Equations

Variable Type	Resource Variables	Solar Thermal (only) Variables	Solar PV (only) Variables	Financial Variables
Independent	Monthly insolation levels Collector tilt angle Number of panels	Manifold temperature Inlet water temp Exit water temp Loss coefficients Transversal IAM performance adjustment factor Boiler efficiency Cost of boiler replacement Cost of thermal storage	STC DC power rating Derating factors Efficiency degradation rate	Costs per panel (incl. balance of system costs per panel) Fixed costs per complete installation Grid electricity cost and escalation rate Natural gas cost and escalation rate REC payment structure Capital depreciation Loan term and interest rate Discount rate Marginal tax bracket
Dependent	Incident sunlight collected Diffuse sunlight collected	Collector thermal efficiency Thermal output rate	Energy generation rate Energy generated Power conversion and transmission losses	REC payments Subsidy payments Tax advantages and liabilities Energy cost savings Payback period

For solar PV, the DC output per panel scales roughly linearly with solar radiation levels

$$E_{DC} = STC * G$$

E_{DC} is daily DC electrical energy generated (kWh/day)

G is the daily average solar radiation (kWh/m2/day)

Evacuated tube solar thermal collectors obey the following efficiency law[xiii]:

$$\eta(x) = K\eta_0 - a_1 * x - a_2 * G * x^2$$

$$x = \frac{T_m - T_a}{G}$$

$$T_m = \frac{T_{inlet} + T_{exit}}{2}$$

$\eta(x)$ = Collector efficiency

K = Transversal IAM performance adjustment

η_0 = Conversion factor

a_1 = Loss coefficient 1 (W/m^{2}K)

a_2 = Loss coefficient 2 (W/m^{2}K^2)

G = Insolation level (W/m^2)

xiii "Performance Basics, Collector Efficiency." http://www.apricus.com/html/solar_collector_efficiency.htm Accessed 4/4/11

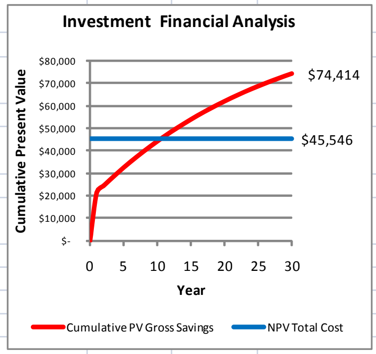
Appendix U. Solar Scenarios

System	Model	Qty	Solar Currents	$/REC Market Value*	Yr 1 Energy Offset	First Cost	30 Year NPV	Payback Period (yrs)	IPN
Solar Thermal	Apricus AP-30	20	n/a	n/a	3151 ccf	$70,463	$28,868	11	0.63
19.92 kW Solar PV	**Thistle 240W**	**83**	**Yes**	**n/a**	**29,495 kWh**	**$112,923**	**$50,166**	**4**	**0.69**
19.92 kW Solar PV	Thistle 240W	83	No	$10	29,495 kWh	$112,923	$10,898	21	0.15
19.92 kW Solar PV	Thistle 240W	83	No	$100	29,495 kWh	$112,923	$69,873	7	0.96
19.95 kW Solar PV	**Evergreen 210W**	**95**	**Yes**	**n/a**	**29,748 kWh**	**$123,728**	**$46,390**	**5**	**0.58**
19.95 kW Solar PV	Evergreen 210W	95	No	$10	29,748 kWh	$123,728	$6,972	24	0.09
19.95 kW Solar PV	Evergreen 210W	95	No	$100	29,748 kWh	$123,728	$66,453	7	0. 83
20 kW Solar PVT	**PowerPanel 125 W**	**160**	**Yes**	**n/a**	**29,822 kWh 4,647 ccf**	**$198,220**	**$101,834**	**6**	**0.79**
20 kW Solar PVT	PowerPanel 125 W	160	No	$10	29,822 kWh 4,647 ccf	$198,220	$61,959	12	0.48
20 kW Solar PVT	PowerPanel 125 W	160	No	$100	29,822 kWh 4,647 ccf	$198,220	$122,411	7	0.96
20 kW Solar PVT (18% eff)**	**PowerPanel 125 W**	**160**	**Yes**	**n/a**	**42,944 kWh 4,467 ccf**	**$198,220**	**$135,978**	**5**	**1.06**
20 kW Solar PVT (18% eff)**	PowerPanel 125 W	160	No	$10	42,944 kWh 4,467 ccf	$198,220	$90,852	9	0.71
20 kW Solar PVT (18% eff)**	PowerPanel 125 W	160	No	$100	42,944 kWh 4,467 ccf	$198,220	$177,902	5	1.39

* Pre-tax value per REC for regular RECs and MI Incentive RECs.
** This simulation accounts for PV efficiency improvements realized from water cooling effect

The scenarios which do not include the SolarCurrents program are intended as examples of two possible outcomes for each system, based on the average REC price for the lifetime of the project. A second set of simulations were conducted for the Solar PVT projects, which

Project Name	20 Panel Solar Thermal (20x Apricus AP-30)						**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30		**Analysis At-A-Glance**			**Investment Priority Number**		
			NPV of Investment	$ 28,868		0.63	Benefits - Costs / Costs	
Project Costs			NPV Costs	$ 45,546				
$ 70,463	Initial Investment (incl sales tax)		Payback Time	11 years				
$ 176	Annual O&M*		NPV at Payback Time	$ 46,417				
Financing				*Year 1*	*Lifetime*			
100%	% Financing		Gross PV Savings	$ 45,546	$ 74,414			
15	Loan Term (yrs)		MT CO2 Offset	17	514			
4.75%	Interest Rate		Car-Years Offset	3	99			
$ 70,463.00	Loan Principal							
0.095	CRF(i,n) per yr		**Select Price Escalation Scenario**		**Annual Real Rate Selected**			
$ 6,674.34	Annual Loan Payment		Electricity	Nominal	3%			
			Natural Gas	Nominal	3%			
Financial Variables			Water	Nominal	3%			
7%	Discount Rate							
35%	Marginal Tax Bracket			**Resource Costs**				
6%	State Sales Tax				*Baseline Price*	*New Price*		
				Elec (per kWh)	$ 0.12	$ 0.12		
Capital Depreciation				Natural Gas (per CCF)	$ 1.05	$ 1.05		
100%	Tax Depreciation in Year 1			Water (per 100 ft^2)	$ 1.00	$ 1.00		
25	Book Depreciaton Period (yrs)							
Panel Mfg Info				**Annual Projected Savings**				
0	Michigan Labor? (1 or 0)				Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
0	Michigan Mfg? (1 or 0)			Elec (kWh/yr)	0	0.00%	0	0
				Natural Gas (CCF/yr)	3151	0.00%	0	3151
				Water (100 ft2/yr)	0	0.00%	0	0



Other Initial Funding and Grants (non-REC)		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 19,871
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 19,871

		Note State of Use Controller Switch					
REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*	**Resource Real Cost Escalation Rate Scenarios**			
Up-Front REC Payment	$ -	$ -	0		*Cheap*	*Nominal*	*Expensive*
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0	Elec	1%	3%	5%
Years of Annual DTE REC Pmts	20			Natural Gas	1%	3%	5%
				Water	1%	3%	5%
REC Market Value	0	$ -	0				
MI REC Market Value	0	$ -	0				

		Emissions Factors		
Carbon Taxes		1 kWh from Grid	730.2E-6	metric ton CO2
$ -	Carbon Tax Rate (per metric ton CO2)	1 CCF Nat Gas	5.4E-3	metric ton CO2
17	Year 1 Carbon Offset (MT CO2)	1 Car-Year*	5.2	MTCO2e per average passenger car year
$ -	Year 1 Carbon Tax Savings	*Source	http://www.epa.gov/oms/climate/420f05004.htm	
Notes		**Other Variables**		
Includes O&M costs of .25% gross up-front costs		0	kW DC Solar	
Includes inverter replacement after 15 years at $1 per Watt DC		93.8%	Overall DC to AC conversion efficiency	

Project Name	19.92 kW Solar PV (83x Thistle 240) - Enrolled in SolarCurrents				**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30					

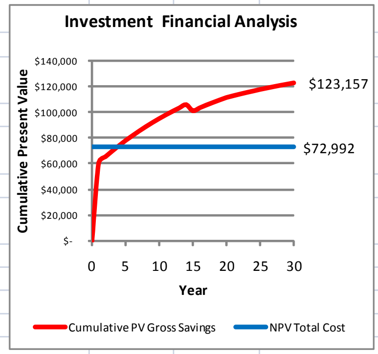
Investment Priority Number

0.69	Benefits - Costs / Costs

Analysis At-A-Glance

NPV of Investment	$ 50,166
NPV Costs	$ 72,992
Payback Time	4 years
NPV at Payback Time	$ 74,298

	Year 1	*Lifetime*
Gross PV Savings	$ 72,992	$ 123,157
MT CO2 Offset	21	598
Car-Years Offset	4	115



Project Costs

$ 112,923	Initial Investment (incl sales tax)
$ 282	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 112,923.00	Loan Principal
0.095	CRF(i,n) per yr
$ 10,696.19	Annual Loan Payment

Select Price Escalation Scenario		**Annual Real Rate Selected**
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	*New Price*
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

0	Michigan Labor? (1 or 0)
0	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29495	0.50%	0	29495
Natural Gas (CCF/yr)	0	0.00%	0	0
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 31,844
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 31,844

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 47,808	$ 28,207	1
Annual DTE REC Pmt per kWh	$ 0.110	$ 0.065	1
Years of Annual DTE REC Pmts	20		
REC Market Value	100	$ -	0
MI REC Market Value	100	$ -	0

Resource Real Cost Escalation Rate Scenarios	*Cheap*	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
21	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

19.92	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

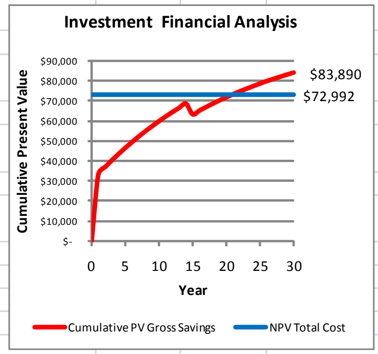
Project Name	19.92 kW Solar PV (83x Thistle 240) - NOT Enrolled in SolarCurrents ($10 per REC)	**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

	Year 1	Lifetime
NPV of Investment	$ 10,898	
NPV Costs	$ 72,992	
Payback Time	21 years	
NPV at Payback Time	$ 73,115	
Gross PV Savings	$ 72,992	$ 83,890
MT CO2 Offset	21	598
Car-Years Offset	4	115

Investment Priority Number

0.15	Benefits - Costs / Costs



Project Costs

$ 112,923	Initial Investment (incl sales tax)
$ 282	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 112,923.00	Loan Principal
0.095	CRF(i,n) per yr
$ 10,696.19	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

0	Michigan Labor? (1 or 0)
0	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29495	0.50%	0	29495
Natural Gas (CCF/yr)	0	0.00%	0	0
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 31,844
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 31,844

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 47,808	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	10	$ 6	1
MI REC Market Value	10	$ 6	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
21	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

19.92	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	19.92 kW Solar PV (83x Thistle 240) - NOT Enrolled in SolarCurrents ($100 per REC)	v. 1.02	4/11/2011

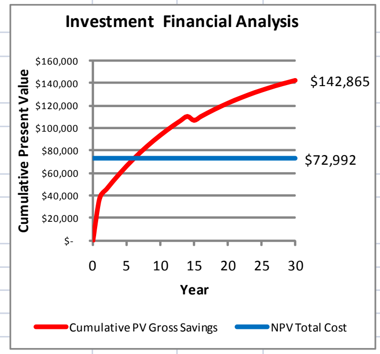
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

	Year 1	Lifetime
NPV of Investment	$ 69,873	
NPV Costs	$ 72,992	
Payback Time	7 years	
NPV at Payback Time	$ 78,625	
Gross PV Savings	$ 72,992	$ 142,865
MT CO2 Offset	21	598
Car-Years Offset	4	115

Investment Priority Number

0.96	(Benefits - Costs) / Costs



Project Costs

$ 112,923	Initial Investment (incl sales tax)
$ 282	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 112,923.00	Loan Principal
0.095	CRF(i,n) per yr
$ 10,696.19	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

0	Michigan Labor? (1 or 0)
0	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29495	0.50%	0	29495
Natural Gas (CCF/yr)	0	0.00%	0	0
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 31,844
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 31,844

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 47,808	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	100	$ 59	1
MI REC Market Value	100	$ 59	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
21	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

19.92	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	19.95 kW Solar PV (95x Evergreen 210) - Enrolled in SolarCurrents			**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30				

Investment Priority Number

0.58	Benefits - Costs / Costs

Analysis At-A-Glance

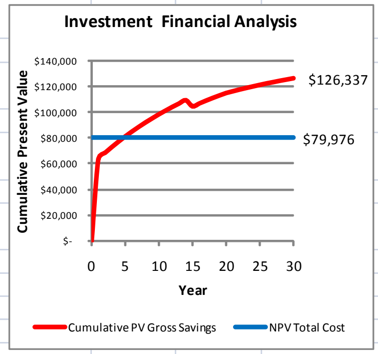
	Year 1	Lifetime
NPV of Investment	$ 46,361	
NPV Costs	$ 79,976	
Payback Time	5 years	
NPV at Payback Time	$ 81,218	
Gross PV Savings	$ 79,976	$ 126,337
MT CO2 Offset	22	603
Car-Years Offset	4	116

Project Costs

$ 123,728	Initial Investment (incl sales tax)
$ 309	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 123,728.00	Loan Principal
0.095	CRF(i,n) per yr
$ 11,719.66	Annual Loan Payment



Select Price Escalation Scenario		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

0	Michigan Labor? (1 or 0)
0	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29748	0.50%	0	29748
Natural Gas (CCF/yr)	0	0.00%	0	0
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 34,891
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 34,891

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 47,808	$ 28,207	1
Annual DTE REC Pmt per kWh	$ 0.110	$ 0.065	1
Years of Annual DTE REC Pmts	20		
REC Market Value	0	$ -	0
MI REC Market Value	0	$ -	0

Resource Real Cost Escalation Rate Scenarios	*Cheap*	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
22	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

19.92	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	19.95 kW Solar PV (95x Evergreen 210) - NOT Enrolled in SolarCurrents ($10 per REC)	v. 1.02	4/11/2011

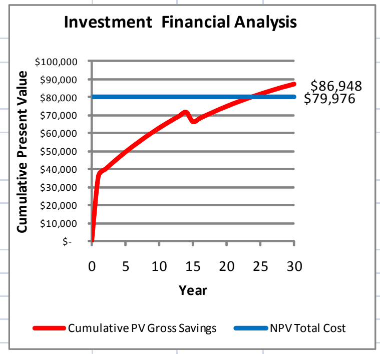
Project Lifetime (max 30 yrs)	30			
Project Costs				
$ 123,728	Initial Investment (incl sales tax)			
$ 309	Annual O&M*			
Financing				
100%	% Financing			
15	Loan Term (yrs)			
4.75%	Interest Rate			
$ 123,728.00	Loan Principal			
0.095	CRF(i,n) per yr			
$ 11,719.66	Annual Loan Payment			
Financial Variables				
7%	Discount Rate			
35%	Marginal Tax Bracket			
6%	State Sales Tax			
Capital Depreciation				
100%	Tax Depreciation in Year 1			
25	Book Depreciaton Period (yrs)			
Panel Mfg Info				
0	Michigan Labor? (1 or 0)			
0	Michigan Mfg? (1 or 0)			

Analysis At-A-Glance

	Year 1	Lifetime
NPV of Investment	$ 6,972	
NPV Costs	$ 79,976	
Payback Time	24 years	
NPV at Payback Time	$ 80,216	
Gross PV Savings	$ 79,976	$ 86,948
MT CO2 Offset	22	603
Car-Years Offset	4	116

Investment Priority Number

0.09	Benefits - Costs / Costs



Select Price Escalation Scenario		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29748	0.50%	0	29748
Natural Gas (CCF/yr)	0	0.00%	0	0
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 34,891
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 34,891

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 47,880	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	10	$ 6	1
MI REC Market Value	10	$ 6	1

Resource Real Cost Escalation Rate Scenarios	*Cheap*	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
22	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

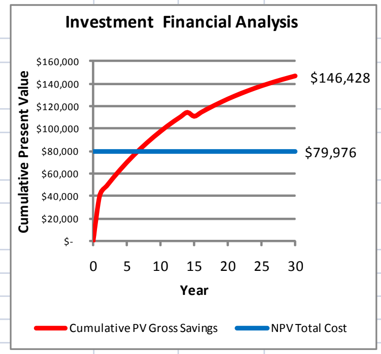
Other Variables

19.95	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	19.95 kW Solar PV (95x Evergreen 210) - NOT Enrolled in SolarCurrents ($100 per REC)	v. 1.02	4/11/2011

Project Lifetime (max 30 yrs)	30	**Analysis At-A-Glance**			
		NPV of Investment	$ 66,453		
Project Costs		NPV Costs	$ 79,976		
$ 123,728	Initial Investment (incl sales tax)	Payback Time	7 years		
$ 309	Annual O&M*	NPV at Payback Time	$ 81,759		
Financing			*Year 1*	*Lifetime*	
100%	% Financing	Gross PV Savings	$ 79,976	$ 146,428	
15	Loan Term (yrs)	MT CO2 Offset	22	603	
4.75%	Interest Rate	Car-Years Offset	4	116	
$ 123,728.00	Loan Principal				
0.095	CRF(i,n) per yr	**Select Price Escalation Scenario**		**Annual Real Rate Selected**	
$ 11,719.66	Annual Loan Payment	Electricity	Nominal	3%	
		Natural Gas	Nominal	3%	
Financial Variables		Water	Nominal	3%	
7%	Discount Rate				
35%	Marginal Tax Bracket	**Resource Costs**			
6%	State Sales Tax		*Baseline Price*	*New Price*	
		Elec (per kWh)	$ 0.12	$ 0.12	
Capital Depreciation		Natural Gas (per CCF)	$ 1.05	$ 1.05	
100%	Tax Depreciation in Year 1	Water (per 100 ft^2)	$ 1.00	$ 1.00	
25	Book Depreciaton Period (yrs)				

Investment Priority Number		
0.83	Benefits - Costs	Costs



Panel Mfg Info		**Annual Projected Savings**					
			Initial Offset	Offset Degradation Rate	Extra Used	Net Offset	
0	Michigan Labor? (1 or 0)	Elec (kWh/yr)	29748	0.50%	0	29748	
0	Michigan Mfg? (1 or 0)	Natural Gas (CCF/yr)	0	0.00%	0	0	
		Water (100 ft2/yr)	0	0.00%	0	0	

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 34,891
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 34,891

		Note State of Use Controller Switch					
REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*	**Resource Real Cost Escalation Rate Scenarios**			
Up-Front REC Payment	$ 47,880	$ -	0		*Cheap*	*Nominal*	*Expensive*
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0	Elec	1%	3%	5%
Years of Annual DTE REC Pmts	20			Natural Gas	1%	3%	5%
				Water	1%	3%	5%
REC Market Value	100	$ 59	1				
MI REC Market Value	100	$ 59	1				

		Emissions Factors		
Carbon Taxes		1 kWh from Grid	730.2E-6	metric ton CO2
$ -	Carbon Tax Rate (per metric ton CO2)	1 CCF Nat Gas	5.4E-3	metric ton CO2
22	Year 1 Carbon Offset (MT CO2)	1 Car-Year*	5.2	MTCO2e per average passenger car year
$ -	Year 1 Carbon Tax Savings	*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes	**Other Variables**	
Includes O&M costs of .25% gross up-front costs	19.95	kW DC Solar
Includes inverter replacement after 15 years at $1 per Watt DC	93.8%	Overall DC to AC conversion efficiency

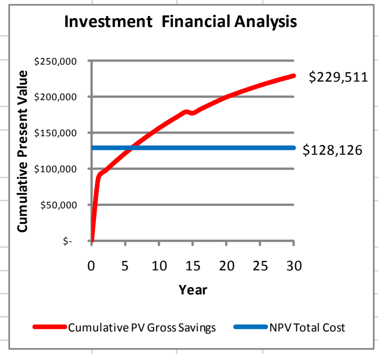
Project Name	20 kW Solar PVT (160x PowerPanel 125) - Enrolled in SolarCurrents	**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

NPV of Investment	$ 101,384	
NPV Costs	$ 128,126	
Payback Time	6 years	
NPV at Payback Time	$ 129,611	
	Year 1	*Lifetime*
Gross PV Savings	$ 128,126	$ 229,511
MT CO2 Offset	47	1364
Car-Years Offset	9	262

Investment Priority Number

0.79	(Benefits - Costs) / Costs



Project Costs

$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	*New Price*
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29822	0.50%	0	29822
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ 28,320	1
Annual DTE REC Pmt per kWh	$ 0.110	$ 0.065	1
Years of Annual DTE REC Pmts	20		
REC Market Value	0	$ -	0
MI REC Market Value	0	$ -	0

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
47	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	20 kW Solar PVT (160x PowerPanel 125) - NOT Enrolled in SolarCurrents ($10 per REC)	**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

	Year 1	Lifetime
NPV of Investment	$ 61,959	
NPV Costs	$ 128,126	
Payback Time	12 years	
NPV at Payback Time	$ 131,657	
Gross PV Savings	$ 128,126	$ 190,086
MT CO2 Offset	47	1364
Car-Years Offset	9	262

Investment Priority Number

0.48	(Benefits - Costs) / Costs

Project Costs

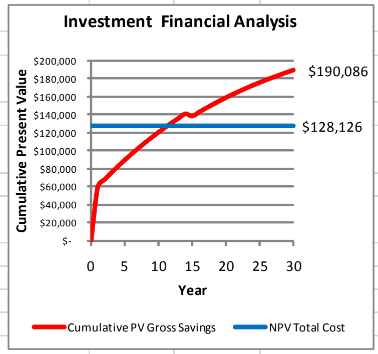
$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%



Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29822	0.50%	0	29822
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	10	$ 6	1
MI REC Market Value	10	$ 6	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
47	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	20 kW Solar PVT (160x PowerPanel 125) - NOT Enrolled in SolarCurrents ($100 per REC)	v. 1.02	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

NPV of Investment	$ 122,411	
NPV Costs	$ 128,126	
Payback Time	7 years	
NPV at Payback Time	$ 130,842	
	Year 1	*Lifetime*
Gross PV Savings	$ 128,126	$ 250,537
MT CO2 Offset	47	1364
Car-Years Offset	9	262

Investment Priority Number

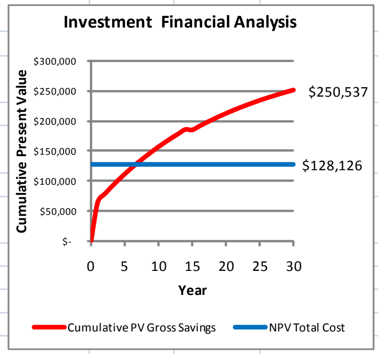
0.96	Benefits - Costs / Costs

Project Costs

$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment



Select Price Escalation Scenario		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	*New Price*
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	29822	0.50%	0	29822
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	100	$ 59	1
MI REC Market Value	100	$ 59	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
47	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Project Name	20 kW Solar PVT (160x PowerPanel 125) - Enrolled in SolarCurrents + 18% Eff	v. 1.02	4/11/2011

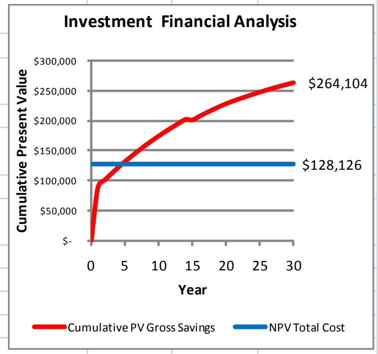
Project Lifetime (max 30 yrs)	30

Analysis At-A-Glance

NPV of Investment	$ 135,978	
NPV Costs	$ 128,126	
Payback Time	5 years	
NPV at Payback Time	$ 132,417	
	Year 1	*Lifetime*
Gross PV Savings	$ 128,126	$ 264,104
MT CO2 Offset	56	1630
Car-Years Offset	11	313

Investment Priority Number

1.06	Benefits - Costs / Costs



Project Costs

$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	*New Price*
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	42944	0.50%	0	42944
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ 28,320	1
Annual DTE REC Pmt per kWh	$ 0.110	$ 0.065	1
Years of Annual DTE REC Pmts	20		
REC Market Value	0	$ -	0
MI REC Market Value	0	$ -	0

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
56	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

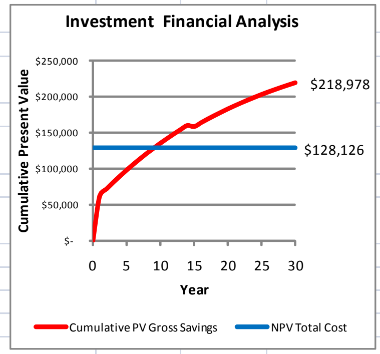
Project Name	20 kW Solar PVT (160x PowerPanel 125) - NOT Enrolled in SolarCurrents + 18% Eff ($10 per REC)	v. 1.02	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

	Year 1	Lifetime
NPV of Investment	$ 90,852	
NPV Costs	$ 128,126	
Payback Time	9 years	
NPV at Payback Time	$ 128,399	
Gross PV Savings	$ 128,126	$ 218,978
MT CO2 Offset	56	1630
Car-Years Offset	11	313

Investment Priority Number

0.71	(Benefits - Costs) / Costs



Project Costs

$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	New Price
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	42944	0.50%	0	42944
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives- Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives- Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	10	$ 6	1
MI REC Market Value	10	$ 6	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
56	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
1 CCF Nat Gas	5.4E-3	metric ton CO2
1 Car-Year*	5.2	MTCO2e per average passenger car year
*Source	http://www.epa.gov/oms/climate/420f05004.htm	

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

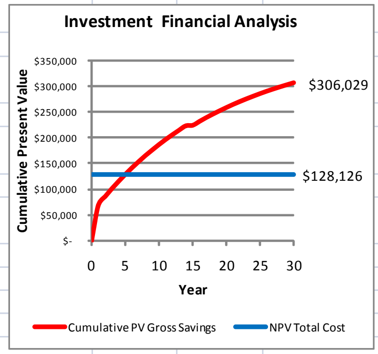
Project Name	20 kW Solar PVT (160x PowerPanel 125) - NOT Enrolled in SolarCurrents + 18% Eff ($100 per REC)	**v. 1.02**	4/11/2011
Project Lifetime (max 30 yrs)	30		

Analysis At-A-Glance

NPV of Investment	$ 177,902	
NPV Costs	$ 128,126	
Payback Time	5 years	
NPV at Payback Time	$ 128,772	
	Year 1	*Lifetime*
Gross PV Savings	$ 128,126	$ 306,029
MT CO2 Offset	56	1630
Car-Years Offset	11	313

Investment Priority Number

1.39	Benefits - Costs / Costs



Project Costs

$ 198,220	Initial Investment (incl sales tax)
$ 496	Annual O&M*

Financing

100%	% Financing
15	Loan Term (yrs)
4.75%	Interest Rate
$ 198,220.00	Loan Principal
0.095	CRF(i,n) per yr
$ 18,775.62	Annual Loan Payment

Select Price Escalation Scenario

		Annual Real Rate Selected
Electricity	Nominal	3%
Natural Gas	Nominal	3%
Water	Nominal	3%

Financial Variables

7%	Discount Rate
35%	Marginal Tax Bracket
6%	State Sales Tax

Resource Costs

	Baseline Price	*New Price*
Elec (per kWh)	$ 0.12	$ 0.12
Natural Gas (per CCF)	$ 1.05	$ 1.05
Water (per 100 ft^2)	$ 1.00	$ 1.00

Capital Depreciation

100%	Tax Depreciation in Year 1
25	Book Depreciaton Period (yrs)

Panel Mfg Info

1	Michigan Labor? (1 or 0)
1	Michigan Mfg? (1 or 0)

Annual Projected Savings

	Initial Offset	Offset Degradation Rate	Extra Used	Net Offset
Elec (kWh/yr)	42944	0.50%	0	42944
Natural Gas (CCF/yr)	4647	0.00%	0	4647
Water (100 ft2/yr)	0	0.00%	0	0

Other Initial Funding and Grants (non-REC)

		Subtotal
30%	Fed ITC Tax Grant (as % of Initial Investment before sales tax)	$ 55,898
0%	State Incentives (as % of Initial Investment before sales tax)	$ -
0%	Utility Incentives (as % of Initial Investment before sales tax)	$ -
0	DTE Custom Incentives - Elec ($ 0.08 per kWh) (enter 1 if used, leave blank if not used)	$ -
0	DTE Custom Incentives - Gas ($ 0.40 per CCF) (enter 1 if used, leave blank if not used)	$ -
$ -	Other Funding (after applicable taxes)	$ -
	Incentives Grand Total	$ 55,898

Note State of Use Controller Switch

REC Payments	*Before Tax*	*After Tax*	*Use? 1 or 0*
Up-Front REC Payment	$ 48,000	$ -	0
Annual DTE REC Pmt per kWh	$ 0.110	$ -	0
Years of Annual DTE REC Pmts	20		
REC Market Value	100	$ 59	1
MI REC Market Value	100	$ 59	1

Resource Real Cost Escalation Rate Scenarios

	Cheap	*Nominal*	*Expensive*
Elec	1%	3%	5%
Natural Gas	1%	3%	5%
Water	1%	3%	5%

Emissions Factors

1 kWh from Grid	730.2E-6	metric ton CO2
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Carbon Taxes

$ -	Carbon Tax Rate (per metric ton CO2)
56	Year 1 Carbon Offset (MT CO2)
$ -	Year 1 Carbon Tax Savings

Notes

Includes O&M costs of .25% gross up-front costs

Includes inverter replacement after 15 years at $1 per Watt DC

Other Variables

20	kW DC Solar
93.8%	Overall DC to AC conversion efficiency

Appendix V. Living Machine Technology

Living Machines Overview & Potential

Living Machines is a patented technology of eco-machines that was developed by Dr. John Todd in 1981. Worrell Water Technologies now owns the rights to Dr. Todd's machine, though there are other companies that design similar machines not using the copyrighted name. 23 Machines have been commissioned by Worrel Technologies since 1994 ranging from capacities to treat 2,400 up to 200,000 gallons per day (Project List). The majority of these systems are used for the treatment of sewage. However, two of these come from food production: Cedar Grove Cheese in Wisconsin and EFFEM Mogi Miri in Brazil. The Cedar Grove Living Machine was constructed in 1999 and has the capacity of 6,500 gallons per day. Their washwater comes from cleaning milk trucks, tanks and cheese making equipment. This includes the pasteurizer, cheese vats and cream separator. This water contains soaps and chlorinated, acidic and caustic cleaners, and some cheese particles, milk and whey (Environmental Policy). The Cedar Grove Living Machine restores the water to a pure enough state for surface discharge.

Effem Produtos Alimenticios is a large producer of sauces, canned pet food and dry pet food located in Mogi Mirim, Brazil, near Sao Paulo (Ramjohn 186). Though Worrell Water's database states their wastewater source as coming from "confectionary production". The Effem Living Machine was created in two phases (Ramjohn 186). The first phase was designed to treat up to 75,000 gallons per day. The second phase increased the capacity of the system to 170,000 gallons per day. This water is also treated for surface discharge.

After selling the patent to Living Machines, Dr. Todd created his own business called "John Todd Ecological Design" that constructs Eco-Machine wastewater treatment systems. Of the 15 clients listed for John Todd Ecological Design, three come from food & beverage companies. One is for Tyson Foods, Inc. that is a larger restorer unit in a retention pond that can treat up to 9 million gallons (Industrial Waste Treatment). Another is for Coca Cola and the final Eco-Machine is for Ethel M Chocolates in Henderson, Nevada. The Chocolates Eco-Machine treats up to 32,000 gallons per day (Ethel M Chocolates Case Study). The wastewater sent to the Eco-Machine comes from cleaning process equipment, utensils and floors, as well as that used in boilers and cooling cowers (Ethel M Chocolates Case Study).

According to John Lohr, a 40,000 gallon per day living machine with a greenhouse can have capital costs around $428,875 with average annual operation costs at $50,400 (Lohr p. 838).

A Comparison of Living Machines with Conventional Technologies

	Living Machines	Conventional Technologies
Energy		
Primary Sources	The Sun	Fossil fuels, nuclear power
Secondary Sources	Radiant energy	Internal biogenesis of gases
		Combustion and electricity
Control	Electricity, wind, and solar electric	Electrical, chemical, and mechanical
Capture of External Energy	Intrinsic to design	Rare
Internal Storage	Heat, nutrients, gases	Batteries
Efficiency	Low biological transfer efficiency in subsystems, high overall aggregate efficiency	High in best technologies, low, when total infrastructure is calculated
Flexibility	Inflexible with regards to sun- light, flexible with adjunct energy sources	Inflexible
Pulses	Tolerant and adapted	Usually intolerant, tolerant in specific instances
Design	Parts are living population	Hardware-based
	Structurally simple	Structurally complex
	Complex living circuit	Circuit complexity often reduced
	Passive, few moving parts	Multiple moving parts
	Dependent entirely upon environmental energy and internal storage systems	Energy-intensive
	Long life spans.. centuries	Short life spans... decades
	Materials replacement	Total replacement
	Internal recycling intrinsic	Recycling usually not present
		Pollution control devices used
	Living Machines	Conventional Technologies
	Ecology is scientific basis for design	Genetics is scientific basis for biotechnology
		Chemistry is basis for process engineering
		Physics for mechanical engineering
Materials	Transparent climatic envelopes	Steel and concrete
	Flexible lightweight containment materials	Reliance on motors
	Electrical and wind-powered air compressors/pumps	Structurally massive
Biotic Design	Photosynthetically based ecosystem	Independent of sunlight
	Linked sub-ecosystems	Unconnected to other life forms

	Components are living populations	Only biotechnologies use biotic design
	Self design	No self design
	Multiple seedings to establish	
	Internal structures	
	Pulse driven	
	Directed food chains: end points are products including fuels, food, waste purification, living materials, climate regulation	
Control	Primarily internal throughout complex living circuits	Electrical, chemical, and mechanical controls applied to system
	Threshhold number of organisms for sustained control	External orchestration and internal regulation
	All phylogenetic levels from bacteria to vertebrates act as control mechanisms	
	Disease is controlled internally through competition, predation, and antibiotic production	Through application of medicines
	Feedstock both internal and external	Feedstocks external
	Modest use of electrical and gaseous control inputs orchestrated with environmental sensors and computer controls	Sophisticated control engineering
Pollution	Pollution, if occurs, is an indication of incomplete design	Pollution intrinsically a by product; capture technologies need to be added
	Positive environmental impact	Negative or neutral environmental impact
Management and Repair	Training in biology and chemistry essential	Specialists needed to maintain systems
	Empathy with systems may be a critical factor	Empathy less essential
Costs	Capital costs competitive with conventional systems	The standard
	Fuel and energy costs low	Fuel and energy costs high
	Labor costs probably analogous - still to be determined	The standard
	Lower pollution control cost	The standard
	Operation costs lower because of reduced chemical and energy input	The standard
	Potential reduction of social costs, in part because of potential transferability to less industrialized regions and countries	Social costs can be high

Table from Todd and Todd, *Steering Business Toward Sustainability*. United Nations University Press. New York: 1995

Living Machines Resources

Project List

http://www.worrellwater.com/images/uploads/resources/Project_List.pdf

Environmental Policy

http://my.execpc.com/~cgcheese/EnvironmentalPolicy.html

Ethel M Chocolates Case Study

http://toddecological.com/files/case-studies/mars.pdf

Industrial Waste Treatment

http://toddecological.com/PDFs/100623.casestudy.tyson.pdf

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