Building Energy Analysis
First Unitarian Universalist Congregation of Ann Arbor
4001 Ann Arbor-Saline Rd
Ann Arbor, MI

Graham Sustainability Scholars Team 2020-2021

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Completed March 31, 2021

Table of Contents

1.0 INTRODUCTION

UUAA has reached out to the Graham Sustainability Scholars team to draft a long-term carbon neutrality and sustainability plan. One focus area for this plan that the Graham team has identified is building energy consumption and efficiency. To formulate a plan for UUAA to reach net-zero carbon emissions from building energy use, we have evaluated opportunities to increase both building efficiency and renewable energy supply. The purpose of this report is to present a description of UUAA's solar generation expansion opportunity, the efficiency improvement measures we identified, and an analysis of how these two items can be leveraged for UUAA to become energy neutral.

2.0 PROBLEM STATEMENT & FINDINGS SUMMARY

UUAA would like to become carbon neutral. The first step in doing so is becoming an energy neutral building: having all energy demand satisfied by renewables. To do so, UUAA must close their current energy gap - the difference between energy used and energy produced by renewables. *The 2021 Graham team has focused on energy consumption and associated emission from electricity consumption and production. Future teams may also consider natural gas consumption, but this is outside the scope of the 2021 project.* The following table presents the electricity energy gap UUAA needs to close:

Table 1: UUAA Energy Gap

Energy Used Year Ending July 2019[1]	168,000 kWh
Energy Produced Year Ending July 2020	26,458 kWh
Energy Gap	**141,542 kWh**
$CO_{2,e}$ Emissions due to Energy Gap[2]	137 tons

UUAA needs to save and/or produce with renewables an additional 141,542 kWh per year to be energy neutral. While it is possible to completely meet current electricity demand on-site renewable generation, the cost of some energy efficiency improvements ("sure-savers") will be lower per kWh than the cost of adding panels, so we recommend that UUAA pursue both efficiency improvement measures and solar generation expansion.

[1] We took the energy used from July 2018 - July 2019 as the baseline energy consumption rather than that for the year ending July 2020 so that lower energy use that occurred as a result of the COVID-19 pandemic did not affect the energy consumption measurement.

[2] CO2,e emissions = Energy Gap (kWh)*Regional Avg. CO2,e emissions (lb/MWh) * (1 MWh/1000 kWh)
CO2,e emissions = 142,000 kWh * 1,927 lb/MWh*(1 MWh/1000 kWh)=281,342 lb=137 tons CO2,e
Regional Avg. CO2,e emissions taken from DTE website

By looking at the cost of installing more solar panels, we defined a cut-off price for implementing sure-saver technologies. If the sure-saver measure substantially decreases energy usage at a cost of $1.51/kWh or less, it should be implemented prior to more solar panels being installed. The Graham team has identified lighting and appliance use improvements that meet this criteria. Beyond lighting and appliances, UUAA should receive a building envelope audit from a recommended outside consultant and evaluate whether their recommended changes before installing more solar panels.

Overall, the Graham team recommends UUAA complete the following next-steps:

1. Implement no-cost appliance sure-savers identified by the Graham team:
    a. Unplug the copy machine when not in use.
    b. Unplug the folding machine when not in use.
    c. As long as large in-person events are not being held, consider unplugging the refrigerator in the kitchenette near the social hall (Kitchenette 119) and the large freezer box in the main kitchen (Kitchen 118).
2. Work with a building envelope consultant (possible energy audit consultants provided in Appendix C) to receive recommendations on how the building envelope can be renovated to increase energy efficiency. Once the building envelope auditors are received, evaluate which recommendations meet the cut-off criteria. The criteria is met if:

$$Price = \frac{reccomendation\ cost}{kWh\ per\ year\ saved\ by\ implementing\ recommendation} \leq \$1.51/kWh$$

    Changes meeting this criteria already identified by the Graham team are provided in a worksheet which can be further completed by UUAA found in Appendix A.
3. Once the recommendations are evaluated with this cut-off metric, UUAA will have a comprehensive list of sure-saver changes including upgrades to lighting, appliances, and the building envelope. Implement the sure-saver changes meeting the cut-off criteria as financing allows. Prioritize the changes that provide the greatest energy savings at the lowest cost. Right now, lighting upgrades should be first priority based on this metric. Record the energy savings provided by each change, and subtract this amount from the energy gap.
    a. NOTE: See lighting audit results from Electro-Matic: before implementing all lighting suggestions provided by Electro-Matic, determine why the bulbs that increase energy consumption were recommended to replace the 4 Pin 32w CFL bulbs. If they do not provide a significant other advantage, do not install these bulbs.
4. Once all the sure-savers meeting the cut-off criteria have been implemented, work with Homeland Solar to outfit the roof with solar panels that will produce enough renewable energy to close the remaining energy gap.

By following the above steps, UUAA can meet the goal of being energy-neutral, eliminating CO_2 emissions due to electricity use.

3.0 DATA RESULTS AND ANALYSIS

The following section details how the building energy analysis was conducted.

3.1 Opportunity for Clean Energy Source - Solar

Based on information provided by Dave Friedrichs, founder of Homeland Solar and UUAA Implementation Team member, our team determined an estimated cost of $1.51 per kWh of solar energy[3]. This cost estimate is valid so long as a total amount of panels generating no less than roughly 100kW are installed. *As UUAA implements sure-savers and the energy gap shrinks, they should consistently work with Dave from Homeland Solar to ensure the cut off price is valid.* A visual showing the UUAA solar potential from Dave Friedrichs is provided in Appendix B.

This cost measure gives us a baseline cut off for whether or not the sure-savers described in the following section are worthwhile. If the sure-saver measure substantially decreases energy usage at a cost of $1.51/kWh or less, it should be implemented prior to more solar panels being installed. The portion of the energy gap remaining after these sure-savers are implemented should be filled by installing solar, provided UUAA can receive approval from DTE. DTE has authority to cap power generation, as Dave Friedrichs notes:

> *"Permission to add whatever amount of new solar might get UUAA to "Net Zero" would have to be cleared with DTE. Since 2008, DTE has held and holds legislated authority to CAP at one percent (1% of total power generation in DTE territory) any solar owned by others than DTE Energy itself."*

It is also worth noting that UUAA has a generation meter, because the church is part of the Solar Currents program, which should allow for easy energy generation tracking as this project is expanded.

3.2 Opportunities for Increased Efficiency (aka "Sure-Savers")

3.2.1 Lighting

A professional lighting audit was conducted on January 28, 2021 by Electro-Matic, the outcome of which is a package detailing opportunities for bulb replacement and associated corresponding levels of energy improvement. This package is attached as Appendix C.

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[3] *Estimation from Dave Friedrichs: Max additional 300 solar panels, 165,500 kWh, $250,000*
So, $250,000165.5 thousand kWh=$1.51 per kWh, define this as cut-off price

Reviewing this package shows that by implementing all of the recommended changes, UUAA can decrease energy consumption by an estimated 75,500 kWh per year. The lighting upgrades cost, on average, $0.30 per kWh, well below the cut-off price of $1.51/kWh described in Section 3.1. Thus, the Graham team recommends UUAA's first step towards energy neutrality be investing in these lighting changes. Also notable is that the payback period for the lighting changes is just three years. After three years, the money saved from decreased energy consumption will have covered the cost of the investment. The earliest any of the bulbs would have to be replaced is in roughly 8 years. Some will last as long as 17 years, so reinvestment/maintenance costs are not a big concern.

One problem with the Electro-Matic recommendations the Graham team identified is that the suggested replacement for the 4 Pin 32w CFL bulbs increase energy consumption. So, before installing these replacement bulbs UUAA should speak with Electro-Matic to understand why they recommended this change. If the bulbs increase energy consumption and provide no other advantage, they should not be installed.

3.2.2 Appliances & Office Equipment

The UUAA appliances and office equipment are responsible for the consumption of an estimated 24,700 kWh of electricity[4] when operating at maximum capacity. To view a full inventory register of the UUAA appliances and their associated energy consumption based on maximum capacity specifications, reference Appendix D.

With the following changes, the appliance and office equipment consumption can be cut to 5,800 kWh of electricity - a savings of 18,900 kWh:

Immediate opportunities to cut consumption include:

1. Unplug the copy machine when not in use.
    a. The copy machine consumes approximately 4,380 kWh of electricity per year while in sleep mode. Unplugging the device will provide UUAA with immediate energy savings.
2. Unplug the folding machine when not in use.
    a. While the Graham Team could not determine the yearly energy consumption of the folding machine while in sleep mode, the energy consumption is likely similar to that of the copy machine. Unplug this device as well to increase energy savings.

[4] Please note the appliance energy consumption was computed using appliance specifications. This likely overestimates the power consumption as the specifications assume the appliance is operating at maximum capacity at all times.

3. As long as large in-person events are not being held, consider unplugging the refrigerator in the kitchenette near the social hall (Kitchenette 119) and the large freezer box in the main kitchen (Kitchen 118).
    a. These units consume 2,800 and 1,700 kWh per year, respectively. If they are being used at least biweekly for events during "normal" operation, they should be left plugged in. However, as long as they remain empty as large, in-person events are not occurring at UUAA, the energy consumption could be cut by unplugging the appliances.

Based on preliminary readings with a multimeter, the Graham team does not recommend upgrading any of the UUAA appliances at this time. We found that the fridges were operating at only ¼ of maximum capacity (the energy consumption amount determined with appliance specifications). Based on review of the cost of more energy efficient fridges, we determined that the fridges operating at the reduced capacity will not provide energy savings at a cost below the cut-off price. Energy efficiency improvements for microwaves, ovens, and the dishwasher also do not meet the criteria of being below the cut-off price.

3.3.3 Building Envelope

Conducting an audit of the building envelope requires expertise not possessed by the scholars team, yet remains an important step in energy efficiency improvements. We recommend making this audit a top priority, as several of the windows currently contribute to thermal leakage. The IPL-EPA EnergyStar Workbook for Congregations offers guidance for the energy audit process on pages 56-61, which may be valuable for implementation team members preparing for this audit. Appendix E lists two companies able to audit the building envelope, and provides quotes and other relevant information where applicable.

3.3.4 Utility Switches (Fans and Lights)

Congregants sometimes leave the fan turned on in empty restrooms, which wastes energy. UUAA may be able to deter this action by connecting the restroom fan and light switches to one combined switch, or by setting both on a motion sensor or timer. An alternative approach may be to post signage discouraging the behavior with an explanation of its negative impacts for the carbon neutrality approach. We recommend signage be installed first, and if changes are not observed UUAA may install motion sensor or timer switches.

3.3.5 HVAC Operation Schedule

The Graham team does not have any changes to recommend for the HVAC operation schedule. Currently, UUAA has a well maintained, energy efficient HVAC system that is only in operation

when the building is in use. The system is divided into multiple zones, and Ed Lynn, UUAA's lead administrator, turns the system on and off based on whether or not the areas will be occupied.

In the future, a geothermal system may be considered to reduce HVAC system use. This consideration would necessitate evaluation outside of the scope of this project, but we strongly recommend that future teams or members of the UUAA Implementation Team investigate this option, as the building's current HVAC system relies on natural gas, a carbon-based energy source with associated greenhouse gas emissions.

4.0 CONCLUSION AND RECOMMENDATIONS

The Graham team has completed the analysis of building electrical energy consumption to the best of our ability. We identified the energy gap UUAA needs to close – 142,000 kWh per year – and investigated possible sure-savers as well as the opportunity to install more solar panels to generate renewable energy.

By looking at the cost of installing more solar panels, we defined a cut-off price for implementing sure-saver technologies. If the sure-saver measure substantially decreases energy usage at a cost of $1.51/kWh or less, it should be implemented prior to more solar panels being installed. The Graham team has identified lighting and appliance upgrades that meet this criteria. Additionally, UUAA should receive a building envelope audit from a recommended outside consultant and evaluate whether their recommended changes meet this criteria. UUAA should work to implement these recommendations if their cost is below the cut-off price of $1.51/kWh.

Overall, the Graham team recommends UUAA complete the following next-steps:

1. Implement no-cost appliance sure-savers identified by the Graham team:
    a. Unplug the copy machine when not in use.
    b. Unplug the folding machine when not in use.
    c. As long as large in-person events are not being held, consider unplugging the refrigerator in the kitchenette near the social hall (Kitchenette 119) and the large freezer box in the main kitchen (Kitchen 118).
2. Work with a building envelope consultant (possible energy audit consultants provided in Appendix C) to receive recommendations on how the building envelope can be renovated to increase energy efficiency. Once the building envelope auditors are received, evaluate which recommendations meet the cut-off criteria. The criteria is met if:
    i. $Price = \frac{reccomendation\ cost}{kWh\ per\ year\ saved\ by\ implementing\ recommendation} \leq \$1.51/kWh$

    Changes meeting this criteria already identified by the Graham team are provided in a worksheet which can be further completed by UUAA found in Appendix A.

3. Once the recommendations are evaluated with this cut-off metric, UUAA will have a comprehensive list of sure-saver changes including upgrades to lighting, appliances, and the building envelope. Implement the sure-saver changes meeting the cut-off criteria as financing allows. Prioritize the changes that provide the greatest energy savings at the lowest cost. Right now lighting upgrades should be first priority based on this metric. Record the energy savings provided by each change, and subtract this amount from the energy gap.
    a. NOTE: Before implementing all lighting suggestions provided by Electro-Matic, determine why the bulbs that increase energy consumption were recommended to replace the 4 Pin 32w CFL bulbs. If they do not provide a significant other advantage, do not install these bulbs.
4. Once all the sure-savers meeting the cut-off criteria have been implemented, work with Homeland Solar to outfit the roof with solar panels that will produce enough renewable energy to close the remaining energy gap.

By following the above steps, UUAA can meet the goal of being energy-neutral, eliminating CO_2 emissions due to electricity use. To become fully carbon neutral, UUAA must still address natural gas consumption used for heating, but this investigation was out of the scope of the Graham project.

The Graham team appreciates you involving us in the carbon-neutrality project, and we hope that our recommendations will be helpful moving forward. Please don't hesitate to reach out to us with any questions or concerns. You can contact the team members responsible for the building and energy analysis, Morgan McBain and Zoe Bultman, by email at mmcbain@umich.edu and bultmanz@umich.edu, respectively.

5.0 REFERENCES

United States of America, Environmental Protection Agency. (2019). *ENERGY STAR® Action Workbook for Congregations*. IPL-EPA.

Appendices

Appendix A: Recommendation Tracking Table

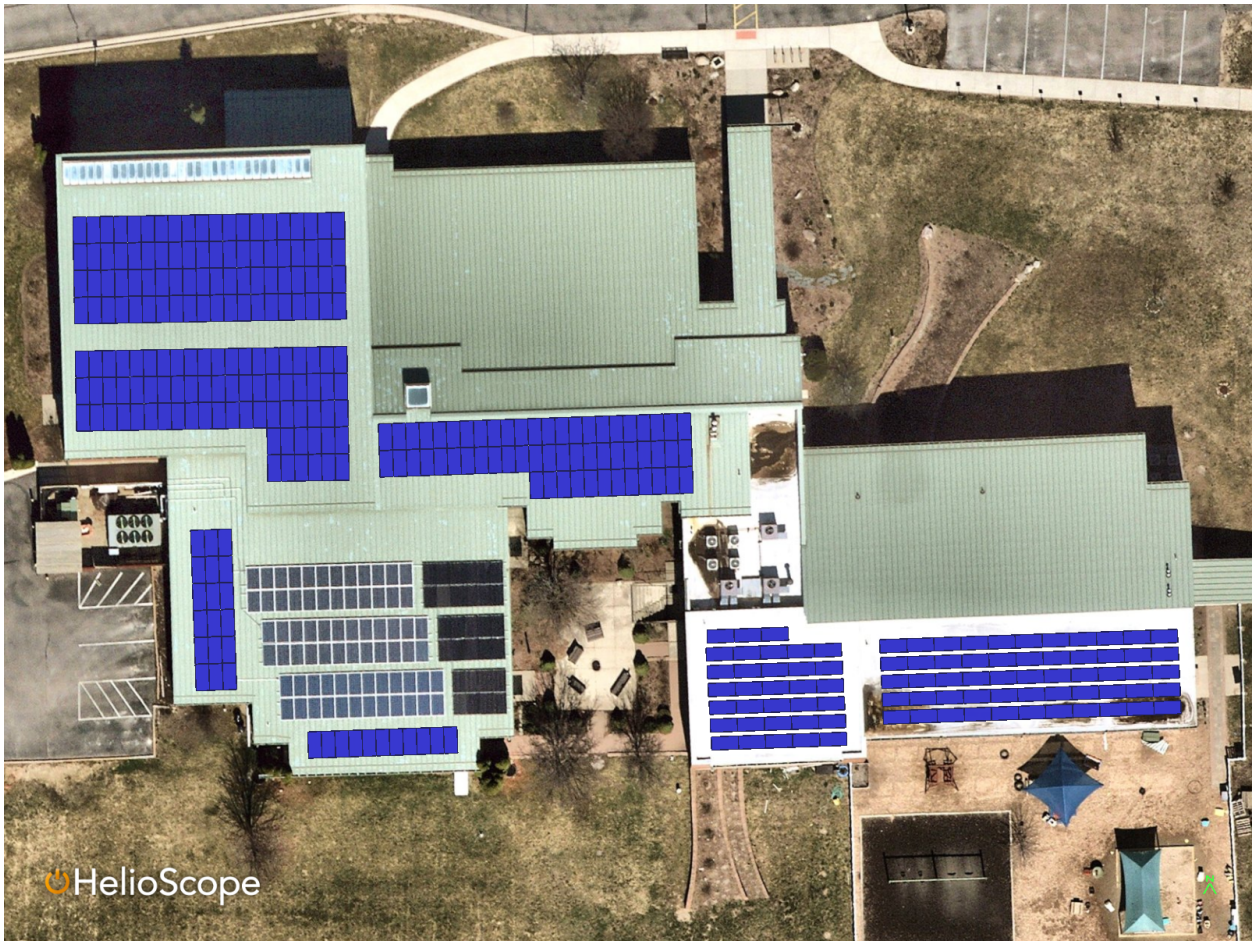
The Graham team recommendations are shown in the table below. UUAA can continue to complete this table to identify the cost of efficiency improvements and prioritize investments moving forward.

Please note: As the energy gap decreases, UUAA should continuously work with Homeland Solar to ensure the cost of solar does not increase dramatically based on the need for few solar panels.

Starting energy gap = 142,000 kWh

Action	Energy Savings (kWh)	Cost ($)	Price per kWh = $\frac{Cost}{Energy\ Savings}$ ($/kWh)	Price per kWh < cost of solar ($1.51/kWh)	New, reduced energy gap with <u>just</u> this action (kWh)
Upgrade to LED lighting	75,000	$24,200	$0.30	Yes	67,000
Unplug copy machine	4,000	$0	$0	Yes	138,000
Unplug social hall kitchenette fridge	2,800 (based on max capacity specs)	$0	$0	Yes	139,200
Unplug box freezer	1,700 (based on max capacity specs)	$0	$0	Yest	140,300

Appendix B: Rooftop Solar Potential



Source: Dave Friedrichs, Homeland Solar

Appendix C: Electro-Matic Lighting Audit Recommendations

Audit results from Electro-Matic are provided in the Table on the following page. For easier viewing we recommend viewing the Excel file Electro-Matic delivered to UUAA.

ELECTRO-MATIC Visual

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Project Room by Room Report: First Unitarian Church Ann Arbor

Area Information			Lighting																			
			Existing Fixture					Proposed Fixture														
Area	Space	Burn Hrs /per year	Type	Qty	Watts	Total Watts	KWH Use	Type	% Usage after Occ. Sensor	Adj. Burn Hrs /per year	Qty	Watts	Total Watts	KWH Use	KWH Savings	Heat Penalty	Install Cost	Unit Cost	Product Total	Line Total	Rebate	ROI
Interior	Classrooms/Meeting Rooms	3,000.00	4FT T8 Florecent	723.00	32.00	23,136.00	69,408.00	L48T8/840/10G-ID DE	100%	3,000.00	723.00	10.00	7,230.00	21,690.00	47,718.00	689.70	10,845.00	7.00	$5,061.00	$15,906.00	$1,879.00	2.7
Interior	Classrooms/Meeting Rooms	3,000.00	100w E11 Halogen Lamp (see pics)	84.00	100.00	8,400.00	25,200.00	EA-E11-9.5W-001-309F-D	100%	3,000.00	84.00	9.50	798.00	2,394.00	22,806.00	329.63	1,260.00	27.00	$2,268.00	$3,528.00	$588.00	1.2
Interior	Classrooms/Meeting Rooms	3,000.00	4 Pin 32w CFL (see pics)	84.00	32.00	2,688.00	8,064.00	GC-57881	100%	3,000.00	84.00	45.00	3,780.00	11,340.00	-3,276.00	-47.35	1,260.00	54.00	$4,536.00	$5,796.00	$588.00	-14.5
Interior	Classrooms/Meeting Rooms	3,000.00	75w A-Type Bulbs	17.00	75.00	1,275.00	3,825.00	GC-98146	100%	3,000.00	17.00	15.00	255.00	765.00	3,060.00	44.23	255.00	9.00	$153.00	$408.00	$119.00	0.9
Interior	Classrooms/Meeting Rooms	3,000.00	4FT T12 Lamps	58.00	40.00	2,320.00	6,960.00	L48T8/840/10G-ID DE	100%	3,000.00	58.00	10.00	580.00	1,740.00	5,220.00	75.45	870.00	7.00	$406.00	$1,276.00	$273.00	1.7
																			$0.00		$0.00	
			Totals	966.00	279.00	37,819.00	113,457.00				966.00	89.50	12,643.00	37,929.00	75,528.00	1,091.66	14,490.00		$12,424.00	$26,914.00	$3,447.00	2.8
				Qty	Watts	Total Watts	KWH Use				Qty	Watts	Total Watts	KWH Use	KWH Savings	Heat Penalty	Install Cost	Unit Cost	Product Total	Line Total	Rebate	ROI

Product Cost		**$12,424.00**
Tax		**$745.44**
Installation Estimate		**$14,490.00**
Total Product & Install Cost		**$27,659.44**
Minus DTE Estimated Rebate		**$3,447.00**
Net Cost		**$24,212.44**
Estimated Monthly Savings	**$**	**755.28**
Estimated Annual Savings	**$**	**9,063.36**
Estimated ROI		**2.67**

Michigan Saves 0% Interest Program		
Monthly Payment (36 months at 0% In	**$**	**833.00**
Monthly Energy Savings	**$**	**755.28**
Cash Flow Positive	**$**	**(77.72)**

Appendix D: Appliance Inventory

Appliance	Model	Serial #	Location	Voltage (V)	Current (A)	Power (W)	Operation time (hrs/day)	kWh per year	Notes
Formax folding machine (active)	FD342 Document folder	A111134	Copy room 147	120	2.5	-	negligable (folding 500 pamphlets takes about 2 minutes)	negligable - except sleep mode consumption	would be good to know sleep mode energy consumption - can assume similar or worse than copy machine?
Copy Machine	Bizhub C654e	-	Copy room 147	-	-	0.5 sleep mode, 2100 max	24 sleep, negligable active	4380	unplug machine!!
Fridge	CTX21DA BLRWW	TT616742	Kitchenette 141	115	7	805	24	2351	
Microwave	JVM1440 WA001	ZT941373 S	Kitchenette 141	-	-	1580	0.5	288	
Fridge	KTRS25K GWH00	ECH2001 335	Kitchenette 119	115	8.3	954.5	24	2787	
Microwave	JVM1440 WA001	ZT941400 S	Kitchenette 119	-	-	1580	0.25	144	
Electric Oven	JVP24W0 K4WW	GM27755 8Q	Kitchenette 119	-	-	8800	0.25	803	
Dishwasher	GDF520P SD1SS	HA859032 B	Big Kitchen 118	120	7.1	852	2	622	used each day by daycare
Fridge	FFTR1821 TW0	HA859032 B	Big Kitchen 118	115	6	690	24	2015	rarely full, only for events
Freezer	FFFH20F2 QWC	WB74748 858	Big Kitchen 118	115	5	575	24	1679	try to confirm cycles three times; barely used,only for events

Stove (GE)	JBP24WOK4WW	GM277556Q	Upper Wing Kitchen	120	-	1120	0.25	102	
Microwave (GE)	JVM1540DMIWW	DM908337U	Upper Wing Kitchen	120	-	1500	0.5	274	
Fridge (GE)	GTEI6DTHMRWW	RH705500	Upper Wing Kitchen	127	6.5	825.5	24	2410	
Fridge (GE)	GTEI6DTHMRWW	RH705459	Breezeway to Kitchen	127	6.5	825.5	24	2410	daily use, full capacity
Fridge	TX2IVC	10217247	Breezeway to Kitchen	115	7.74	890.1	24	2599	daily use, full capacity
Mini Fridge (Sunbeam)	REFSBI7B	T47B190133658	Harper Room	115	0.8	92	24	269	
Mini Fridge (Fridgidare)	FFP545L3QM	AK73900701	Potter Nursery	115	1.45	166.75	24	487	
Mircorwave (oster)	OGZF1301	T2F2017110100636	Marley Room	120	-	1100	0.5	201	daily use
Mini-fridge (Kenmore)	25594683010	EEV233287	Marley Room	115	1.45	166.75	24	487	daily use
Mini-fridge (GE)	GMR06AAPBB	09944AF00125	Anthony Room	115	-	-	24	360	daily use
								24668.197	
for refrigerator = Power(W)*24hr/day*365day/year*(1/3)[cycle time]/1000									
for freezer = divide by 3, same as fridge									
for others = Power(W)*operation time(hrs/day)*365days/1000									

Appendix E: Potential Building Envelope Energy Auditors

Company	Quote	Notes
Evergreen Energy Savers	$575	Audit includes blow test, infrared analysis & attic to basement envelope analysis Contact: (734) 358-3909
Pro Energy Consultants	$2,720	See pdf in zip file for full details