UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Patio Heaters

Janyce Archutick, Nick Chappell-Moss, William Gumboc, Justin Wong

University of British Columbia

APSC 261

November 28, 2014

An Investigation into Sustainable Patio Heaters for the Perch Restaurant

Janyce Archutick

Nick Chappell-Moss

William Gumboc

Justin Wong

November 27, 2014

Image provided by Chiyi Tam

APSC 261: Technology and Society I
Instructor: Carla Paterson

EXECUTIVE SUMMARY

This report is an investigation into potential methods of supplying heat to the Perch restaurant's patio in an economical, sustainable, and socially responsible manner. The aim of our research is to reduce carbon emissions emitted through heating methods in order to meet the Leadership in Energy and Environmental Design (LEED) Gold certification for the AMS Student Nest, and achieve UBC's sustainability goals. The stakeholder for this project is Chiyi Tam, the AMS Sustainability Coordinator.

The amount of heat required must match or exceed the amount needed for 80-90 seats. Instead of calculating heat output per area, the quantity of each heater needed was calculated by taking the proximity of each heater to each customer into account. Bioethanol burners and electric infrared heaters were chosen to be suitable products to investigate for heating the patio. To ensure that the recommended mechanism was effective, each product was compared to the traditional propane patio heater. This comparison was conducted by investigating a standard model of each heater: the Endless Summer® Stainless Steel Propane Patio Heater, the Ecosmar^{+tm} Fire AB3 Bioethanol Burner, and the PARAMOUNT $^{+tm}$ Offset Pole Mounted Stainless Steel Infrared Patio Heater. By not only comparing the environmental impacts, but also the economic and social impacts in a triple bottom line assessment, the best heating choice for the Perch's patio was uncovered.

The result of the investigation was that electric infrared heaters stood to be the most environmentally friendly with no emissions coming from the actual product, and only 5t of CO_2/GWh coming from the production of electricity. The chosen model also stood to be the most cost effective with its implementation having a $3192.00 total upfront cost for eight infrared heaters and an additional $999.94/year for operating costs. In the social aspect, the electric

heaters need to be implemented carefully because of limited space, and wire tripping hazards. It is recommended that the AMS Student Perch install 8 PARAMOUNT $^{+tm}$ Offset Pole Mounted Stainless Steel Infrared Patio Heaters onto the patio of the restaurant in order to be more sustainable and extend the patio season.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

EUBIA	European Biomass Industry Association
SUB	Student Union Building
LEED	Leadership in Energy and Environmental Design
BTU	British Thermal Unit
GHG	Green house gas

GLOSSARY

Bioethanol	Ethanol derived exclusively from the fermentation of plant starches represented by C2H6O or C2H5OH (alternativefuels.about.com)
BTU	(British Thermal Unit) - is a unit of energy. It represents the amount of energy required to heat one pound of water by one degree Fahrenheit.
Smog	Various pollutants, smoke, and fog combined together
t CO_2 e/GWh	(Carbon dioxide equivalent metric tonnes per gigawatt hour) The unit Greenhouse Gasses intensities are reported in.
The Nest	The patio of the Perch Restaurant in the new Student Union Building.

1.0 INTRODUCTION

The Patio Heaters project is a sustainability initiative that investigates the alternatives to utilizing traditional propane heaters on the Perch's restaurant. The patio will be located on the top of the new Student Union Building (SUB) as part of the Perch Restaurant and will house approximately 80-90 guests. Initially, the patio was supposed to be only used during summer; however, it is now planned to be in operation during spring and fall as well, making patio heaters a requirement. Regular propane heaters are unable to be used in The Nest as it is a LEED certified building. Since LEED certification recognizes sustainable site development, water efficiency, energy efficiency, materials selection, and indoor environmental quality, using propane heaters would be contradictory to their sustainability vision. The propane heater alternatives are required to be eco-friendly, to be relatively cheap to operate, and to have a sustainable fuel source. During this sustainability investigation, available patio heater alternatives that are superior to the conventional propane patio heater will be researched by considering and focusing on the economic, environmental, and social impacts of each potential solution. Variables such as customer comfort level, ease of storage, safety, and their ability to be free standing will also be taken into account. In our conclusion, the most sustainable alternative to propane patio heaters will be identified along with its recommended implementation onto Perch restaurant's patio.

2.0 TRADITIONAL PROPANE PATIO HEATERS

The most commonly used type of patio heater is the propane gas heater. Despite the Perch restaurant wanting to move away from these type of patio heaters, the best way to find a better solution is to compare it to the traditional way of heating a patio. This section will layout the economic, environmental, and social impacts of propane patio heaters. This is done so that there is a fair comparison made between propane heaters and the other heating solutions that are chosen, so that the best recommendation can be made. For this investigation, the Endless Summer® Stainless Steel Patio Heater will be used.

2.1 ECONOMIC ANALYSIS

When looking at the impact of the propane patio heaters the first thing that must be accounted for is the economic influence of the heater. The Endless Summer® Stainless Steel Patio Heater uses a standard 20 pound propane tank (Blue Rhino Global Sourcing, n.d), which holds 4.7 gallons of liquid propane (The Home Depot, n.d.). This patio heater burns 0.47 gallons per hour, giving it a running time of 10 hours for every 20 pound tank of liquid propane (Air & Water, 2014).

91,547 BTU's are produced per gallon of propane (Propane 101, 2011), as the patio heater uses 0.47 gallons of propane. This makes the energy imputed to the heater 43,027 BTU's per hour. Propane patio heaters output 40,000 BTU per hour (Blue Rhino Global Sourcing, n.d). The efficiency can be found by taking the output energy and dividing it by the input energy as illustrated below.

$$\frac{40{,}000}{43{,}027} \times 100 = 93.0\%$$

The calculated efficiency for this propane patio heater is 93.0%.

Each Endless Summer® stainless steel propane patio heater costs $500.00 per unit (Air & Water, 2014), not including the propane tank. An empty 20-pound (4.7 gallon) propane tank costs around $30.00 (The Home Depot, n.d.), while propane costs around $3.50 a gallon (Government of Canada, 2014). Adding all of these costs up, the up-front cost of a fully functioning unit comes to $546.45.

$$\$500.00 + \$30.00 + (\$3.50 \times 4.7gal) = \$546.45$$

Each patio heater gives off usable heat to a 10-meter radius around the patio heater itself (Blue Rhino Global Sourcing, n.d). Below is a layout of how the propane patio heaters might be configured.

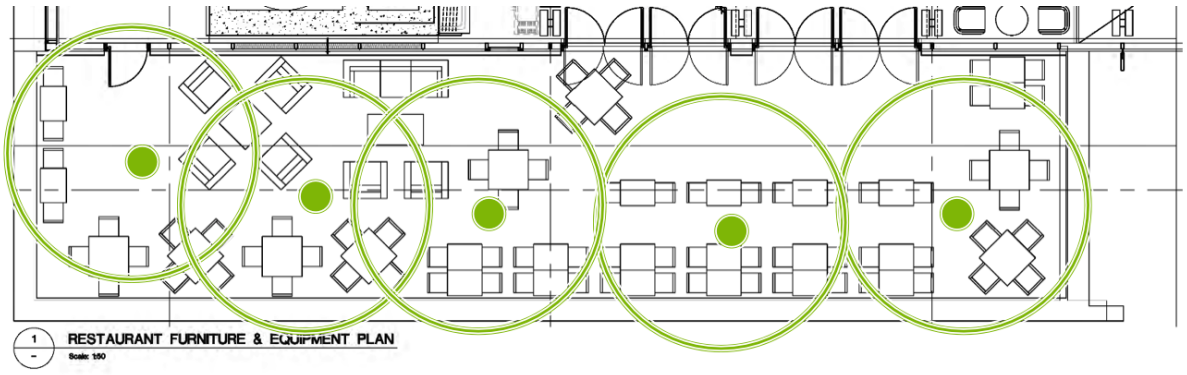

Figure 1. Potential layout for propane heaters on the Perch's patio. Solid circles indicate the location of a propane heater. The outlined circle is the area warmed by the heater.
Source: Layout provided by Chiyi Tam (2014), Graphics by Janyce Archutick (2014)

In this layout, five propane patio heaters are needed to heat the Perch's patio. By multiplying the up-front cost of an individual patio heater, the up-front cost for heating the Perch with propane heaters can be found as shown below.

$$\$546.45 \times 5 heaters = \$2{,}732.25$$

In addition to the upfront costs there are also running costs. Assuming that five heaters would be running on the patio for 1280 hours per year (see appendix 1), and that the heaters use 0.47 gallons per hour of liquid propane at $3.50 a gallon (Government of Canada, 2014), the running costs of heating the patio with propane heaters is determined.

$$1{,}280\ hrs \times \frac{0.47 gal}{hr} \times \$3.50\ gal \times 5\ heaters = \$10{,}528$$

Therefore, the capital cost of propane heaters for the patio is $2,732.25, and the cost of operation is $10,528 per year.

There is a 5-Year manufacturer's warranty on the burner and a 1-Year manufacturer's warranty on the rest of the parts (Blue Rhino Global Sourcing, n.d). Therefore, no cost should be incurred for burner malfunction of the patio heaters in the first five years and other parts for the first year. After said time period, any replacement parts that must be purchased cost as low as $6.00 (for replacement wiring) and as high as $80.00 (for replacement burners) (AZ Patio Heaters, n.d.).

2.2 ENVIRONMENTAL

The common misconception with associated with propane is that it is bad for the environment due to being a fossil fuel. When compared to other fossil fuels, propane is a much cleaner option. When propane is combusted, its output is 63.1 kilograms of CO_2 (carbon dioxide) per million BTUs (U.S. Energy Information Administration, 2014). When this number is compared to that of other fossil fuels, it can be seen that its CO_2 output is much less. The conversion below converts the kilogram output of CO_2 per million BTUs to a usable number of grams per BTU.

$$63.1\frac{kg}{mBTU} \times 1{,}000\ g/kg \div 1{,}000{,}000\ BTU/mBTU = 0.0631 g/BTU$$

It is calculated that there is 0.0631 grams of CO_2 released per BTU of energy produced. When applied to propane patio heaters, which output 40,000 BTU per hour (Blue Rhino Global Sourcing, n.d), the CO_2 output per hour is determined.

$$40{,}000\ BTU \times 0.0631\ g/BTU = 2{,}524\ g$$

For every hour that a propane patio heater is on, it is producing 2,525 grams of CO_2. For the five patio heaters that would be needed to heat the Perch's patio,

$$2{,}524\ g \times 5\ heaters = 12{,}620\ g$$

there would be an output of 12,620 grams of CO_2 for every hour of heating the patio with propane patio heaters.

Seeing as the manufacturer's warranty is 5-Years for the burners of the propane patio heater (Blue Rhino Global Sourcing, n.d), the burner replacement costs after the warranty expires would not be covered and a replacement burner would be required for the heater to be functional. Because the burner is metal, it would be disposed of in scrap metal which ends up being recycled. The environmental impact of the propane patio heaters would be influenced by the number of burners that would require replacing during the duration of service.

2.3 SOCIAL

For the Perch resturant, the social impacts of the heaters are very important, as they are trying to extend the length of the patio season by making it comfortable for people to sit on the patio in cooler weather. As the alternatives are being compared to propane patio heaters, the comfort level achieved by these heaters are the base line for the other two solutions to which it can be compared.

Propane patio heaters are not the most aesthetically pleasing heaters on the market. With a base diameter of 26.50 inches and a height of 93.00 inches (Blue Rhino Global Sourcing, n.d), the Endless Summer® stainless steel propane patio heater is quite bulky and takes up a good portion of space. Because it radiates heat in a full 360 degree circle (Air & Water, 2014), the most efficient layout is to have the heaters centrally located. This can cause the heaters to be in the way of walking lanes, creating issues for the restaurant staff. The heater is also quite heavy,

and, at 90 pounds, is not very portable (Blue Rhino Global Sourcing, n.d). Bulky heaters present difficulty in mobility as the Perch restaurant has stairs leading onto the patio, and the heaters need to be able to be put into storage (C.tam, 2014).

As these heaters are run off of 20 pound standard propane tanks, they must be refilled after ten hours of use (Air & Water, 2014). This means constant removal of the tanks from the heaters and transporting them to a refueling station. This is a very time consuming consuming process that will need to be done most likely once or twice a week; a very non ideal situation.

3.0 BIOETHANOL PATIO HEATERS

As fossil fuel reserves are quickly dwindling, society has recently been looking into an alternative and renewable fuel source in the form of bioethanol. Bioethanol is made from a variety of plant products such as corn, wheat, or sugar cane. This is done by the fermentation of sugars, followed by distillation, dehydration, and sometimes denaturing (Gray, Zhao, & Emptage, 2006). This produces a product made of ethyl alcohol, isopropyl alcohol, and methyl ethyl ketone (EcoSmart Inc. 2010).To consider the effectiveness and compatibility of bioethanol burners with the Perch restaurant, it is necessary to do a triple bottom line assessment on its cost, environmental impact, and social impact. In this case, the Ecosmar^{+tm} Fire AB3 bioethanol burner is chosen for investigation.

3.1 ECONOMIC ANALYSIS

As the Ecosmar^{+tm} Fire AB3 bioethanol burner has a fuel capacity of 0.7 gallons with a fuel consumption of around 0.1 gallons / hour, it has the ability to provide heat for around 7 hours at a time calculated by the calculations below (The Fire Company Pty 2014).

$$0.7\ gallons\ \div 0.1\ gallons/hr\ =\ 7\ hours$$

Taking this into account, with a heat output of 5800 BTU/hr, this mechanism is calculated to have an efficiency of 58,000 BTUs per gallon of fuel consumed. This output is sufficient to provide heat to customers around one table (The Fire Company Pty 2014). Each unit, which includes the AB3 Burner and the Lighthouse 150 casing, comes at a capital cost of $990.00 each (AB Series 2014). For this specific heater, e-NRG Bioethanol Fuel is the

compatible ethanol product (EcoSmart Inc. 2014). At a price of $595 for 32 gallons and a restaurant usage of 1280 hours per year, the running cost of each AB3 heater comes to $1.86/hr or $2380.80/year shown in the calculation below.

$$\$595/32\ gallons * 0.1\ gallons\ /\ hr = \$1.86/hr$$

$$\$1.86/hr\ * 1280\ hr/year = \$2380.80/year$$

With the assumption of 20 tables operating at once at 1280 hours per year the capital and running cost of the heaters can be calculated.

$$capital\ cost = \$990/heater\ * 1heater/table\ * 20\ tables\ =\ \$19{,}800$$

$$running\ cost = \$2380.80/(burner * year) * 20\ burners = \$47616/year$$

Therefore, bioethanol heaters come at a $19800 capital cost, and an operating cost of $47616 per year.

3.2 ENVIRONMENTAL IMPACT

Bioethanol is a key player in reducing carbon emissions and the environmental footprint. One the main aspects that makes bioethanol stand out is its 35% oxygen composition. This allows the fuel to undergo complete combustion, reducing harmful emissions such as carbon monoxide by as much as 34% compared to standard gasoline (Mueller, 2008). In turn, this reduces the amount of smog in the atmosphere as research has shown that CO emissions are responsible for up to 20% of smog formation (Whitten & Reyes, 2004). Ford, in an investigation

of the environmental impact of bioethanol, concludes that there is a 70% reduction in CO_2 emissions compared to petrol (EUBIA 2010). Industry has also become more efficient in the production of ethanol. From 1994 to 2012, new technology has allowed production to go up by 12%, while using 36% less thermal energy and 38% less electricity (Mueller 2008). Because of this, ethanol has a positive energy balance, producing 2.3 units of useable energy per 1 unit of production energy (Mueller 2008). Finally, some suggest that the use of food products to create fuel can drive up food prices and cause a crisis. Because of this, researches propose the solution of producing fuel from wasted crops and crop residues (Kim & Dale 2004).

3.3 SOCIAL IMPACT

The Ecosmar^{+tm} Fire AB3 bioethanol burner with its Lighthouse 150 container is 18 inches tall, has a 12 inch diameter, and weighs 12 lbs (The Fire Company Pty 2014). The height prevents accidental contact with the flame, as the glass surrounding exceeds the height of the flame by a considerable margin. As well, its weight reduces the chance of vessel accidentally tipping over, creating a safe product for customers. In another aspect, the weight and general size of the mechanism allows for easy transport and storage. The burner is small enough to be placed on a table as shown in Figure 2, and can be removed to free up space when needed.

Figure 2. The Ecosmar^{+tm} Fire AB3 bioethanol burner with its Lighthouse 150 container placed on a table. ref

The Lighthouse 150 is also considered to be well designed. One customer states that it is an "elegant accessory that adds class and character to any space indoors or out" (Luongo, 2013), while another customer states that "its great for atmosphere - and it adds extra light" (Ross, 2014). He also believes that the e-NRG bioethanol fuel "is smokeless, odorless and does not spark, yet still provides enough heat to take the chill off a patio" (Ross, 2014).

4.0 ELECTRIC INFRARED PATIO HEATERS

The Perch Restaurant in the new Student Union Building has a large push to be as sustainable as possible. Infrared heating is just that. Electric infrared heaters are not affected by wind (The Home Depot, 2012). This provides a large advantage over the other heating methods which lose a large portion of their heat to the atmosphere. The infrared patio heaters achieve this because their heat is radiated so only the subject is heated (The Home Depot, 2012). As the population continues to deplete fossil fuels, electricity as a renewable energy source could be the best way to heat the Perch's patio. To consider electric infrared heating as the source of heating for the Perch's patio, we must first do a triple bottom line assessment on its cost, environmental impact, and social impact. The infrared heater thought to be best suited for this situation is the PARAMOUNT $^{+tm}$ Offset Pole Mounted Stainless Steel Infrared Patio Heater.

4.1 ECONOMIC ANALYSIS

Infrared heaters cost the least per unit and are also energy wise. The PARAMOUNT $^{+tm}$ Offset Pole Mounted Stainless Steel Infrared Patio Heater cost $399.00 per unit (The Home Depot, 2012). The infrared heater also has a rotating feature which radiates heat at a radius of 9 feet over a wide angle heating more area and eliminating the amount of heaters needed. According to the calculations we have made, we will need eight heaters. The total capital cost for equipment will then come to $3192.00.

$$8\ heaters\ \times\ \$399.00/heater = \$3192.00$$

To calculate the costs of electricity, BC Hydro's electricity prices are used (BC Hyrdo, 2014). The heaters will use around $0.09765 an hour of electricity and produce a total output of 1.5kW/hour.

$$\frac{1.5kW}{hour} \times \frac{\$0.0651}{kW} = \$0.09765/\text{hour}$$

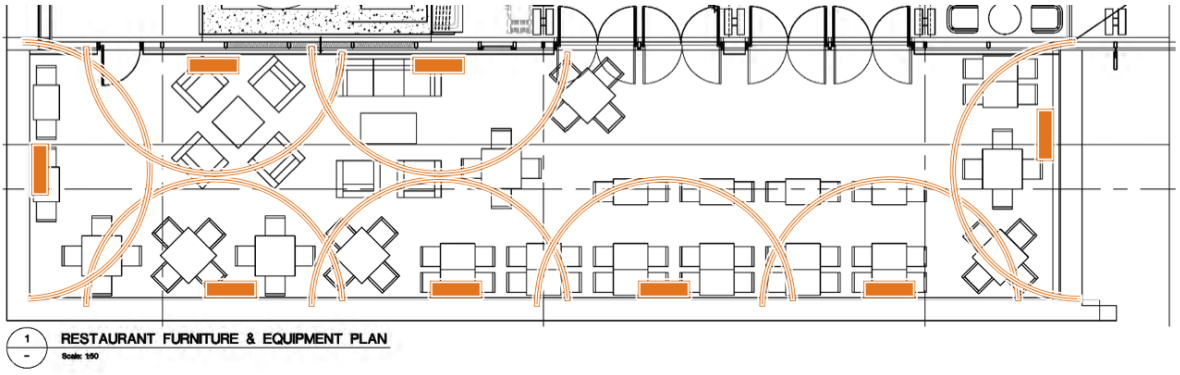

Figure 3. Potential layout for electric heaters on the Perch's patio. Solid rectangles indicate the location of the infrared heaters. The outlined semi-circle around the rectangle is area warmed by the heater.
Source: Layout provided by Chiyi Tam (2014), Graphics by Janyce Archutick (2014)

With our assumption of 1280 hours (see appendix 1) of operating time per year and utilizing eight infrared heaters, the running cost comes to $999.94 per year.

$$\frac{\$0.09765}{hour} \times \frac{1280\ hour}{year} \times 8\ heaters = \$999.94/\text{year}$$

Electric infrared heaters provide economic benefits that outweigh their competition's as they run on minimal costs and have a low per unit price.

4.2 ENVIRONMENTAL IMPACT

Infrared electric patio heaters have thermal efficiency of over 90% (Jobling-Hey, 2012). Needing a very low amount of maintenance and cleaning, infrared heaters virtually eliminate the need for harmful chemicals saving the environment from exposure to waste (Jobling-Hey, 2012). The electricity used to run the heaters is also very environmentally friendly, with hydro being one of the most sustainable sources of energy. In 2013, BC Hydro's hydro facilities produced a total of 5 t CO_2 e/GWh (BC Hydro, 2013). Comparing this to the 569 t CO_2 e/GWh (carbon dioxide equivalent metric tonnes per gigawatt hour) produced by the BC Hydro fossil fuel electricity generation, the hydro facilities produce 113.8 times less GHG's (BC Hydro, 2013). This being said, the infrared heaters also have a very low upstream environmental impact. The PARAMOUNT $^{+tm}$ Offset Pole Mounted Stainless Steel Infrared Patio Heater's bulb lasts 5000 hours of use which means each bulb would have to be replaced approximately every four years using the 1280 hours per year assumption (The Home Depot, 2012).

$$5000\ hours\ \times \frac{1\ year}{1280\ hours} = 3.90625\ \text{years} \simeq 4\ years$$

Overall, the electric infrared patio heaters have a small environmental impact making them a clean choice.

4.3 SOCIAL IMPACT

The PARAMOUNT +tm Offset Pole Mounted Stainless Steel Infrared Patio Heater stands tall at a height of 93.7 inches, a width of 31.5 inches, and a weight of 49 Lbs (The Home Depot, 2012). This allows the heater to be easily transported. The height provides a large distance for anyone from the elements, keeping the public safe from burns. There also is a protective sheet over the element to protect the public from any incidents (Air & Water, 2014). The infrared heater also has a very modern look, which can easily blend in with any placement. Since the heater is electric, the layout of the cords will need to be dealt with. The cords could be run under the tables and out of the way of walkers, along the parameter of the patio. This will eliminate any tripping hazards caused by cords. The minimal maintenance is a benefit for everyone. It reduces stress for employees by reducing work and keeps the heaters available regularly for the public to enjoy. Infrared heaters also heat silently, which means the environment of the patio will not be disrupted by any awkward noises (Air & Water, 2014). Since the heat is not affected by wind, the patron receives all of the heat in a consistent and comfortable manner (Air & Water, 2014).

5.0 CONCLUSION

This report on sustainable alternatives to propane patio heaters has focused on bioethanol heaters and infrared heaters to determine the best choice for the patio. The recommended heater was chosen based off of each one's economic, environmental and social impacts.

On the economical side, propane patio heaters allow 10 hours of heat per tank of propane, which costs approximately $10,528 to run per year with 5 propane heaters heating our target space. Bioethanol burners would provide 7 hours of heat per refill, costing $19,800 for the initial capital cost and an additional $47,616 per year for operating expenses. Infrared heaters utilize electricity, making them very convenient in terms of usage. Furthermore, it was calculated that 8 infrared heaters would be required to warm the patio having an annual operating cost of $999.94. In addition, patio heaters are unaffected by the wind, which makes them an ideal choice for a rooftop patio. Looking at the economic impacts of each of the heating choices, we see that using infrared heaters are advantageous compared to using bioethanol or propane heaters.

The environmental considerations of patio heaters include the type of fuel that it burns, the associated environmental impact of burning that fuel, and how that fuel is generated. Bioethanol heaters use bioethanol fuel to produce heat. As bioethanol is renewable source made from the fermenting plant by-products, which makes it eco-friendly. Although burning bioethanol still releases CO2 into the atmosphere, it produces much less than burning alternative types of fuel. Propane heaters burn propane to create heat through combustion. Burning propane is less eco-friendly and produces approximately 34% more CO2 than burning bioethanol. Furthermore, propane is a derivative of natural gas and petroleum, and is a non-renewable energy source. Infrared heaters simply require electricity. Using electricity does not release carbon

dioxide into the atmosphere and electricity is considered a renewable energy source due to hydroelectric installations. Once again, infrared heaters appear to be the most eco-friendly.

Social impacts of patio heaters are related to the context of the patio heater application. A focus is placed on the appearance of the heater, the comfort associated with using the specific heater, and its ease of use. Infrared heaters look sophisticated and provide a new look compared to the typical propane heater. Moreover, they are not affected by drafts, ensuring that the customer is heated as required. Infrared heaters are tall enough so that individuals will not find them a nuisance and they can simply be unplugged to be stored in a different area. Bioethanol heaters are the most visually attractive patio heater alternative as they provide the customer with the ambiance of an open flame; however, this also means there is a chance of being burnt by the flame and a potential fire hazard. Bioethanol heaters would take up space on the tables of guests and their efficiency would also depend on how strong the wind draft is that specific day. On the other hand, they are very easy to store due to their compact design. Propane heaters have an expected look and provide warmth when it is not too windy outside. Despite this, they are heavy and hard to move. Propane and bioethanol heaters also require to be refueled once the fuel is burnt off, whereas infrared heaters simply need be plugged in.

Considering the performance of infrared heaters in the categories that we have investigate, we recommend the use of infrared patio heaters for the Perch Restaurant’s patio. Infrared heaters would allow the patio to be used year-round and for the patio’s occupants to be comfortable year-round. Moreover, infrared heaters are by far the most environmental in terms of GHG emissions, economical in terms of cost, and socially responsible in terms of ease of usage and appearance. Implementing infrared heaters on the Perch's patio would be a very eco-friendly decision and would raise the bar for patios all over to be more modern and sustainable.

REFERENCES

AB Series. (2014, July 7). In EcoSmar+. Retrieved November 17, 2014, from http://www.ecosmartfire.com/bioethanol-fireplace-products/ethanol-burners/available-models/ab-series

Air & Water. (2014). Endless Summer ES-233000 Patio Heater. Retrieved November 26, 2014, from http://www.air-n-water.com/product/es-233000.html#resp-tabs2

Air & Water. (2014). Infrared Heaters: 10 Amazing Benefits. Retrieved November 26, 2014, from http://www.air-n-water.com/infrared-heaters-benefits.htm

AZ Patio Heaters. (n.d.). Tall Patio Heater Parts [brochure]. Retrieved November 26, 2014, from https://azpatioheaters.com/home.php?cat=2

BC Hydro. (2013). *Greenhouse Gas Intensities*. Retrieved November 26, 2014, from http://www.bchydro.com/content/dam/BCHydro/customerportal/documents/corporate/environment-sustainability/environmental-reports/ghg-intensities-2004-2013.pdf

Blue Rhino Global Sourcing. (n.d.). *Outdoor LP Gas Patio Heater* [Owner's Manual]. Retrieved November 25, 2014, from http://bluerhino.com/BlueRhino/media/MainMedia/PDFs/Products/PatioHeater/ES4000COMM-OM-100_EF.pdf

Business Rates Prices. (2014, April 1). In *BC Hydro*. Retrieved November 17, 2014, from https://www.bchydro.com/accounts-billing/customer-service-business/business-rates-overview/business-rates-prices.html

C. Tam, personal communication, (2014, September 30)

EcoSmart Inc. (2010). Material Safety Data Sheet. Retrieved November 17, 2014, from http://www.e-nrg.com/media/pdf/e-NRG_MSDS_090610_F.pdf

EUBIA (2010) Bioethanol Production and Use. *European Renewable Energy Council*. Retrieved November 17, 2014, from http://www.erec.org/fileadmin/erec_docs/Projcet_Documents/RESTMAC/Brochure5_Bioethanol_low_res.pdf

Government of Canada. (2014, November 25). *Average Retail Fuel Prices in Vancouver*. Retrieved November 26, 2014, from http://www2.nrcan.gc.ca/eneene/sources/pripri/prices_byfuel_e.cfm?LocationID=2#Glance

Gray, K., Zhao, L., & Emptage, M. (2006). Bioethanol. *Current Opinion in Chemical Biology, 10,* 141-146. DOI:10.1016/j.cbpa.2006.02.035

Jobling-Hey, A. (2012, September 7). How to stretch out your patio season using energy efficient heaters. In *Bizenergy*. Retrieved November 17, 2014, from http://www.bizenergy.ca/how-tos/how-to-stretch-out-your-patio-season-using-energy-efficient-heaters/

Kim, S., & Dale, B. (2004) Global potential bioethanol production from wasted crops and crop residues. *Biomass and Bioenergy, 26,* 361-375. DOI:10.1016/j.biombioe.2003.08.002

Luongo, M. (2013) EcoSmart Fire Lighthouse 150 Review and Unboxing. Total Home Supply

Your Total DIY Source. Retrieved Nov, 2014, from http://blog.totalhomesupply.com/2013/10/21/ecosmart-fire-lighthouse-150-review-unboxing/

Mueller, S (2008). National Dry Mill Corn Ethanol Survey. University of Illinois-Chicago, May 4, 2010 -DOI: 10.1007/s10529-010-0296-7

Paramount Offset Pole Mounted Stainless Infrared Patio Heater. (2012, November 18). In *Home Depot*. Retrieved November 17, 2014, from http://www.homedepot.ca/product/offset-pole-mounted-stainless-steel-infrared-patio-heater/916673

Propane 101. (2011). About Propane – Characteristics, Properties and Combustion. Retrieved from http://www.propane101.com/aboutpropane.htm

Renewable Fuels Association (2014) Ethanol Facts Environment. Retrieved No, 2014, from http://www.ethanolrfa.org/pages/ethanol-facts-environment

Ross, M. (2014) The Heat is On. *The Florida Times Union.* Retrieved Nov, 2014, from http://jacksonville.com/community/clay/2014-11-13/story/heat

The Fire Company Pty. Ltd (2014). Bioethanol Burners, Retrieved November 17, 2014, from http://www.ecosmartfire.com/products/download_file?file=http://www.ecosmartfire.com/media/products/Model%20Specs%202013/EFB/EFB%20AB3/EcoSmart-AB3-model-spec_V0214.pdf

The Home Depot. (n.d.). Bernzomatic 20lb Empty Propane Tank [brochure], Retrieved November 26, 2014, from http://www.homedepot.com/p/Bernzomatic-20-lb-Empty-Propane-Tank-309791/202034840

U.S. Energy Information Administration. (2014, February 14). *Carbon Dioxide Emissions Coefficients.* Retrieved November 26, 2014, from http://www.eia.gov/environment/emissions/co2_vol_mass.cfm Whitten, G., Reyes, S. (2004). Air Quality and Ethanol in Gasoline. Retrieved November 22, 2014, from http://www.greenfuels.org/uploads/documents/22_nec-whitten.pdf

APPENDIX A

Assuming that the patio will need to be heated for 16 weeks out of the year and that the restaurant is open for 80 hours during each of these weeks, this number can be converted into hours that the patio heater will be open each year.

$$16\ weeks/year\ *\ 80\ hrs/week\ =\ 1280\ hrs/year$$

This also assumes that the patio heaters are on for the entire 80 hours that the restaurant is open for business during the spring and fall.