UBC Social Ecological Economic Development Studies (SEEDS) Student Report

ANALYSIS OF PATIO HEATER OPTIONS FOR THE PERCH RESTAURANT

Akmal Farhan

Cody Heap

Dennis Lee

Himanshu Sharma

Ian Clelland

Jeffrey King

University of British Columbia

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EXECUTIVE SUMMARY

As colder weather settles in, some businesses that utilize the outdoors tend to suffer from the unfavorable conditions of winter. One of the many examples of such businesses is restaurants that have an outdoor seating area such as a patio. Without a method to keep patios warm during cold weather, a restaurant's available seating is reduced. Along with the inherently rainy nature of Vancouver, colder weather and the lack of a patio heating method could reduce restaurants' potential profits. As a part the upcoming AMS Student Nest, a rooftop restaurant called the Perch is planned to open in mid to late 2015. The Perch will have a large patio, and in the spirit of its LEED construction, the patio should be heated in a sustainable manner so that seating can be maximized. This report will investigate and analyze sustainable methods to heat the outdoor patio at the Perch and other patio endowed restaurants like it on the UBC campus.

Currently, propane heaters are the most common heat source to warm outdoor patios such as the one at the Perch, however they are far from optimal in terms of emissions and energy used. When examining propane heaters from economic, environmental, and social perspectives, it is immediately clear that there are many negative environmental and social impacts that could be improved upon. In order to find sustainable alternatives to propane heaters, several specific alternatives were selected and analyzed. The analysis ranged from calculating costs to researching preferences from a comfort standpoint. Along with the results from our research, the methodology used to approach this problem is discussed along with how primary and secondary sources were selected. In order to account for all the different aspects of each alternative, we utilized a Triple Bottom Line (TBL) approach to our analysis; where economic, environmental, and social factors were all considered. The heating options that we selected were based upon whether the solutions are sustainable, cost efficient, as well as stylish and discreet. Some of the limitations and guidelines that were placed upon this project include a lack of any overhead structures to hang devices off of, little protection from wind on three sides of the patio, few outlets to provide power, and the need to be able to conveniently move and store the heaters. Other aspects and consideration that were to be kept in mind included adhering to the LEED certified standard of the AMS Student Nest and a limited budget.

The parties involved with this investigation include a stakeholder from UBC Sustainability, Chiyi Tam, who provided us with all the necessary requirements of the project along with the floorplan and blueprints of the Perch, and Professor Tony Bi who would be assessing our report and providing instructive feedback that could potentially be implemented in the new Perch patio. Our team is composed of six engineering students who are focussing on different majors: two mechanical engineering students, two electrical engineering students, and two software engineering students. We each have a different perspective and background that brings a variety of opinions which benefits the decision making of this project to positively influence the outcome of our investigation. Various reports and demonstrations regarding the options that we've considered and the solution we would recommend were presented to both the stakeholder and our professor. Through collective feedback and constructive criticism, we combined the information from our research with the advice given to us.

We began our search for alternatives by shortlisting some possible alternatives to propane patio heaters. These solutions had to require no additional infrastructure while meeting the portability and heating effectiveness requirements of the stakeholders. Solutions included heated tablecloths, heated seat pads,

heating coils below tables, infrared heaters, and heated massage chairs. We narrowed down the options to infrared umbrella heaters, standing infrared heaters, and battery powered seat warmers.

The three solutions were then investigated using Triple Bottom Line (TBL) analysis techniques and compared to each other. The Triple Bottom Line analysis involved comparing economic, environmental, and social aspects of the possible heaters. Some of the aspects assessed include capital, operating, and maintenance costs, GHG emissions, typical lifespan, energy use, comfort levels, general satisfaction, and noise levels. The results of the triple bottom line comparison were gathered into a weighted decision matrix which allowed the options to be compared directly based on their respective scores.

Of the three solutions, the umbrella infrared heaters and standing infrared heaters received the highest weighted scores, followed by battery heated cushions. We found that compared to propane heaters, all three of the alternatives were substantially less expensive, less polluting, and roughly socially equivalent. The biggest advantages that the infrared options had over the battery powered heated cushion were lower initial and operating costs, and twice the life expectancy. The heated cushion outperformed the infrared heaters in energy efficiency, and had lower energy use, meaning fewer GHGs indirectly emitted through polluting electricity sources. However, compared to propane heaters, the GHGs emitted by all three alternative options were miniscule; being a small fraction of the amount emitted directly by burning propane. Since the infrared heaters produce zero noise and their heat is unaffected by wind they have a high social score. Heated seat cushions also scored well socially, but are cumbersome to charge, distribute, and replace. Based on the advantages of infrared heaters and their similarity to propane heaters, we recommend mixed use of umbrella infrared heaters and standing infrared heaters. Umbrella heaters should be used on any tables with umbrellas and standing heaters should be used where there are no umbrellas. If possible heating should be established on both sides of customers so that customers' bodies are completely covered in heat.

Future considerations that could stem from the implementation of the recommended solution include extending the solution to other campuses and establishments that would appreciate a more sustainable alternative to propane heaters. If the solution's implementation is successful, improvements could be looked at. Wind and rain could be reduced through the implementation of screens, and placement of heaters could be aided by additional outlets or a more convenient way for wires to run along the ground. The feasibility and the data analysis of our report will be published on the UBC sustainability website for public access and future references. Innovation towards sustainability is quickly becoming a sought over aspect of technology, and this is could serve as pioneer towards the implementation of environmental impacts with technological advances that could benefit both the society and the environment.

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GLOSSARY

Emission: When gases are released in the atmosphere.
Efficiency, Energy: Defined as the ratio of an output to input energy.
Infrared: Radiant energy that has longer wavelengths of visible light and therefore cannot be seen. It heats objects through absorption by molecules on the objects surface.
Renewable: Something that can be reused in one way or other.
Sustainable: To be able to use something up to a certain level and the rest can be saved for future.

LIST OF ABBREVIATIONS

AMS	Alma Mater Society
GHG	Green House Gases
GW-h	Giga-watt hour
LEED	Leadership in Energy and Environmental Design
MW-h	Mega-watt hour
SUB	Student Union Building
TBL	Triple Bottom Line
UBC	University of British Columbia

1 INTRODUCTION

UBC has been actively searching and implementing sustainable concepts on campus. The new Student Union Building, also known as the AMS Student Nest, will represent sustainability in construction and features offered to students and staff of UBC. The objective of this report is to investigate sustainable solutions to heating the outdoor patio of the Perch restaurant at the top of the Nest. A heating system will be implemented for the rooftop patio accommodating up to 116 occupied seats at one time. In addition to operating in summer, the Alma Mater Society (AMS) seeks to extend the usage of the patio to spring and fall through the use of patio heaters. Currently, propane heaters are the first option that businesses consider when opting for heating solutions. However, in the spirit of the new LEED certified building, the use of propane heaters does not align with sustainability. Therefore, the ultimate goal is to develop a solution, beyond propane heaters and blankets, to keep customers warm in a sustainable manner. With the goals and constraints in mind, our team aims to investigate the most energy efficient, economically rewarding and environmentally friendly method for patio heating and has conducted intensive data analysis using the triple bottom line which includes social, environmental and economic sectors to produce a firm and robust solution.

1.1 VALUE PROPOSITION

To generate a solution for the most efficient heating method, sustainable life cycle, flexible and portable, and cost-effective way (beyond propane heaters and blanket) of providing heat to customers on the new Student Union Building's Perch patio. This includes providing a data analysis to stakeholders where social research and market validation are included in the alternative solutions and recommendations.

The requirements by stakeholders and the design team are as follows.

- Cost
- Heating efficiency
- Thermal comfort
- Ease of implementation
- Emissions

1.2 CHALLENGES

Challenges faced for providing feasible recommendations to comply with the requirements set by stakeholders include the following.

- Effective range of heating - How far can the solution heat? Multiple directions? One direction?
- Portability - Can the solution be moved around? Can it be stored easily?
- Heating effectiveness - Thermal comfort is difficult to analyze analytically
- Limited power outlets
- Perch patio will not have any overhanging structure or walls to attach non-freestanding heaters on to it

2 METHODOLOGY

The team began by understanding problems of the project and the needs/requirements proposed from the stakeholder. In addition to the stakeholders' comments related to this project, we investigated the project scope further to determine additional requirements that can be imposed upon this project. By doing so, the team is able to proceed by listing out criteria within the scope of the project in order to focus on feasible solutions that are both practical and readily available for the stakeholder.

The initial plan was to conduct a survey on the types of heaters that the public would like to see implemented for the patio. However, after some discussion and consideration from the team members, a survey was decided to be ineffective in determining an alternative solution since the viability of a solution depended more on technical performance than peoples' opinions. Technical research was deemed to be the most effective way to find an alternative to propane heaters. Our technical research data is primarily from secondary sources such as newspaper articles, academic journals, peer reviewed patents, books and previous reports by UBC students on topics relating to improving sustainability at UBC. This report utilizes generalized and synthesized information from these resources to support our triple bottom line data analysis and calculations that are detailed further below. With these data, we are able to expand and simulate economical cost and determine the trajectory of the cost and life cycle of the product/solution.

Milestones were set to ensure that the project was being managed properly and that the appropriate criteria were met at each milestone deadline. Note that the project scope is also defined within the milestones to maintain the scale of how much detail the project is to investigate for the stakeholders. To approach this problem, a variety of alternative heating methods were investigated. Such alternatives include the research of past and current innovations which have potential to be implemented in the new Student Union Building (SUB/NEST). The explored solutions consist of existing products on the market that have been used and are readily available for implementation in the new UBC SUB. The solutions suggested by each team members were further investigated by the team to identify whether they met feasibility, requirements set by stakeholders, and were technically capable of operating for a long period of time. The solutions that passed the winnowing stage were then evaluated via criteria in the Weighted Decision Matrix (WDM) which was identified via Triple Bottom Line (TBL) indicators. Scope of research during external research phase included but was not limited to:

- Feasibility - Can it work?
- Meets requirements set by stakeholder and design team
- Technical readiness - Can the solution be implemented and is it readily available?

Since TBL indicators became the evaluation criteria for each concept, it was decided that for economic indicators, a more thorough analysis would be done in terms of costs. Environmental indicators were analyzed in terms of impact to the environment. One of the challenges the team faced was quantifying social indicators quantitatively. This was due to a lack of published data, and the inherit complexity of analyzing human comfort. Human comfort was analyzed on the basis of temperature asymmetry. Since the body can only maintain a uniform temperature, a solution that offered heating on only one side of the body was less desirable than a solution that heated a large area. Qualitatively, a temperature asymmetry results in thermal discomfort.

3 CONCEPTUAL ALTERNATIVES

Analysis on each concept was done as per the requirements set by stakeholders. In addition, the heaters should be usable in the summer, spring and fall seasons, which means that product must be robust enough to withstand temperature differences and different weather conditions over the cycle of its life. The heaters also cannot be wall mounted and no structural changes are allowed to the building or the patio. This meant that portability, ease of access, and ease of repair are also priorities for the stakeholders. Referring to Figure 1, it can be seen that there is significantly limited space for the heaters. Therefore, measures such as configuring the wiring system so that customers are not at risk of tripping must be taken. Also, one of the suggestions that the stakeholder mentioned was to look for a solution like seat cushions that provides heat directly to the customer so that minimum heat is lost to the environment.

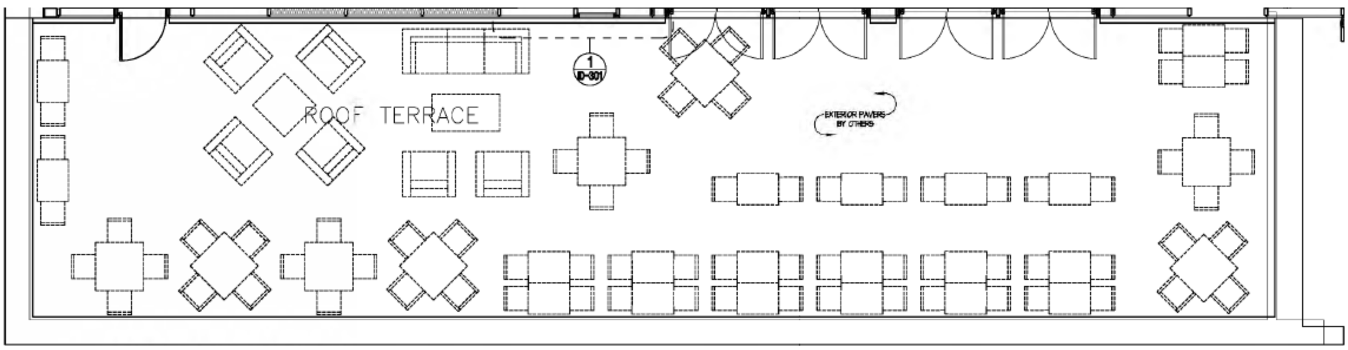

Figure 1 - Patio Space

Considering the above requirements, goals and constraints, three other alternatives to the propane heater that met the criteria of being efficient, sustainable, flexible, and cost-effective were chosen to be analysed which are:

1. Umbrella Infrared heaters
2. Standing Infrared heaters
3. Battery powered heating cushions

Through research, the team found that external factors such as temperature, humidity, and weather conditions had great impacts on the type of heating mechanism used.

3.1 INFRARED HEATERS

Initially, infrared heaters were chosen because they can be powered by electricity. Unlike gas-fired propane heaters they do not emit any direct Greenhouse gas (GHG) or fumes and do not require any gas supply. Later on, from more investigation it was found that there they do not emit noise pollution and some manufacturers even claim them to be 90 % efficient in terms of electrical energy use (Infratech Comfort, 2014). Hence, they can take advantage of BC Hydro's electricity of which "90% [comes from] renewable energy [sources]" and is "clean" as well as "affordable" (British Columbia Ministry of Energy, 2014). Not only that, but the "heat [that infrared heaters] put out is not affected by wind or other drifty conditions" (TOP100ENERGIES, 2014).

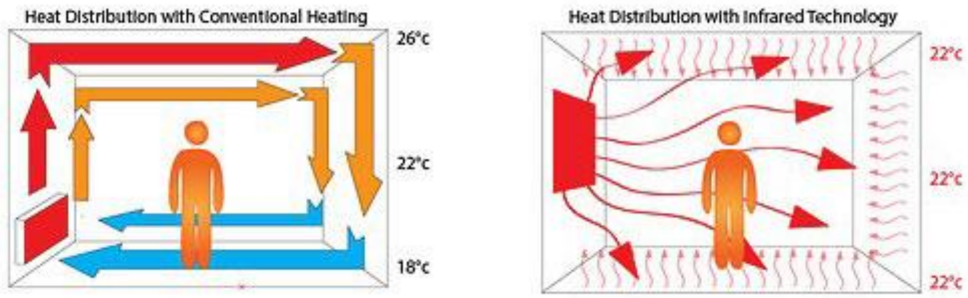

Figure 2 - Infrared Heating vs Conventional Heating
Source: Smartclima.com

The main difference between infrared heaters and conventional convection heaters is through their mechanism of heating. As seen in Figure 2, conventional heating such as propane heaters rely on convection while infrared heating works through radiation. Convective heating is influenced by the surrounding conditions such as wind, temperature, humidity, and many more. Radiated heating on the other hand, eliminates the effect of such factors. Therefore, in terms of heating, it should theoretically be a more effective and direct way to heat bodies.

One important consideration when choosing an infrared heater is the maximum distance that heat can be projected. As shown in **Error! Reference source not found.**, the three types of infrared heaters, near, medium-wave, and far tend to be used for different application. For the purpose of patio heaters, it was determined that a near or medium-wave infrared heater is to be used.

Large open space to heat; Infrequent cycling of heater (for longevity); Well out of reach of people (for safety); No risk of prolonged exposure (eyes or skin).	Near Infrared
Large open space to heat Frequent cycling of heater possible; Closer proximity to people but must be out of reach.	Medium-wave Infrared
Smaller spaces to heat; "Comfort" temperatures required; Within "touch" of people.	Far Infrared

Figure 3- Types of infrared heaters
Source: grrenenery-eu.com

The two solutions that the team would like to consider while keeping in mind the project's requirements and limitations are:

3.1.1 Infrared Umbrella Heaters

These can be mounted on various umbrella shaft sizes. Each of them can have three adjustable heating units. The benefit of being attachable to umbrella is that it can be mounted directly above the seating area and thus can distribute heat affectively/equally towards everyone seating around. If people are not seating all around the table then one or two of the three units can be turned off independently as well (JRhomeproducts, 2014).

Figure 4 - An image showing a type of infrared umbrella heater
Source: (climaonline, 2014)

3.1.2 Infrared Standing Heater

These heaters are easy to install. They come with their own stand and are portable. Their height is adjustable and they can be positioned anywhere on the floor. They do not require a wall or umbrella stand to be mounted to. They can actually be installed along the border of the patio in such a way that the heat from all the heaters is concentrated towards the seating area. In this way, the range of the infrared rays can be fully taken advantage of.

Figure 5 - An image showing a type of standing infrared heater
Source: (Infratech Comfort, 2014)

3.2 BATTERY POWERED HEATED CUSHIONS

Choosing battery powered heated cushions offers a number of advantages including increased mobility, reduced tripping hazard for staff and patrons, and an efficient means of heat transfer. Heating a large volume of air with propane heaters is inefficient because the air becomes buoyant and rises away from customers. Heated cushions use direct conduction from the heating element to the user. This limits energy consumption because minimal heat is wasted to the surrounding environment. In "Effects of heated seats in vehicles on thermal comfort during the initial warm-up period," the writers have shown through an experiment how ways of conductive heating like heated seats can increase the thermal comfort. (Hajime et al., 2012). The disadvantages of such a system include a larger investment in staff time to maintain a constant supply of charged batteries. Typically, batteries last for only 500 charges before they must be discarded.

A comparison of heated cushions and the aforementioned conceptual alternatives with standard propane heaters is explained using a Triple Bottom Line analysis as explained in the subsequent section.

Figure 6 - Seat Heated Cushion
Source: VentureHeatedClothing and Amazon

4 TRIPLE BOTTOM LINE ANALYSIS

Triple Bottom Line is an accounting framework developed to analyze social, environmental, and economical measures (Elkington, 1999). The process of Triple Bottom Line analysis is intended to advance the goal of sustainability in business practices. Typical propane heaters are simple to maintain, relatively inexpensive and perform well in a freestanding format. However, propane heaters do not consume a renewable energy and occasionally produce offensive propane odors. Therefore, in the spirit of the new LEED certified building and AMS branding, propane heaters are not an ideal option. For the purposes of benchmarking, propane heaters and a number of alternative concepts were analyzed during the Triple Bottom Line analysis. Refer to Appendix A for tabulated results.

4.1 SOCIAL INDICATORS

Ideally, social considerations incorporate fair and favorable business practices associated with labour and the local community. For example, this involves not contracting companies associated with any means of labour exploitation. Workers are paid fair wages and are provided safe and adequate work environments. Social considerations also include identifying negative impacts on producers, consumers and users. Specifically, in relation to patio heating options, the following social considerations were analyzed and assigned metrics.

- Thermal comfort of users
- Satisfaction of users
- Non-use of exploited labour practices
- Operational noise level of heating concepts

4.2 ENVIRONMENTAL INDICATORS

Environmental aspects focus on reducing impacts to the environment by employing sustainable business practices. Environmentally conscious businesses minimize consumption of energy and produce limited manufacturing waste. The purpose of not using propane heaters is to minimize consumption of non-renewable fossil fuels. Concepts were benchmarked against propane heaters using the following indexes (refer to Figure 7, Figure 8 and Figure 9 for a pictorial comparison of results).

- Amount of GHG produced
- Anticipated lifespan
- Expected total energy consumption
- Energy conversion efficiency

As can be seen from Figure 7, the standing infrared heaters and umbrella-mounted heaters had equal lifespans. After 5000 hours of use, the carbon filament lamps reach the end of their expected lifespan (Natural Resources Canada, 2005). This expected life span for the infrared heaters corresponded with typical manufacturer specifications and for the purposes of heating the patio we translated this to approximately two years of use at under an estimated 3000 hours of use per year. Typical manufacturer specifications for propane heaters correlated to two years of use and above. The least favorable concept in terms of expected lifespan was the heated cushions. Typical heated cushions utilize lithium-ion batteries whose manufacturers specify a lifespan of only 500 charge cycles. Since the batteries last only 1.5 to 5 hours per charge batteries were estimated to last under a year.

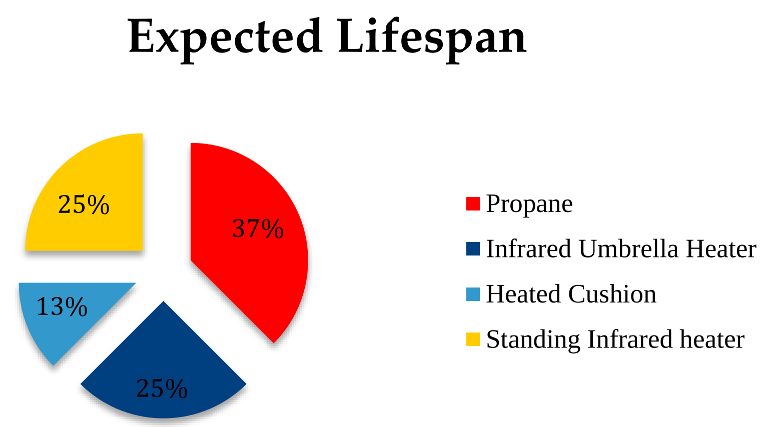

Figure 7 - Expected lifespan of patio heating concepts.

Annual energy consumption was compared for all four concepts. Scoring high in the category was determined to be negative. Energy consumption was measured in MW-h per year. Propane heaters were found to consume an estimated 209 MW-h of energy per year compared to 105, 50, and 2 MW-h for standing infrared, infrared umbrella, and heated cushion heaters respectively. In terms of the modes of heat transfer the results make intuitive sense. The propane heater heats the air around the patrons which becomes a buoyant plume rising into the atmosphere. The infrared devices use radiation to direct heat to the surface of patrons. Heated cushions consume the least amount of energy because the heat is conducted directly to the patrons with minimal wastage. Again, energy consumption was based on manufacturer's specifications for the various concepts running for just under 3000 hours per year.

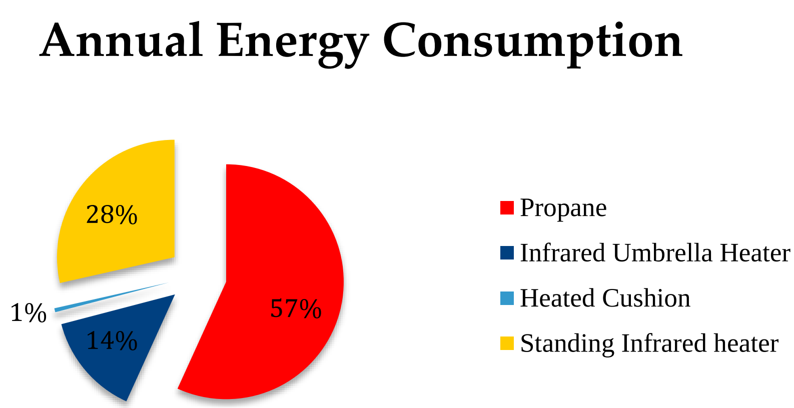

Figure 8 - Annual energy consumption estimates.

Annual greenhouse gas emissions were predicted and compared as shown in below in Figure 9. Unsurprisingly, propane heaters produced the most GHGs. Propane calculations were based on a GHG emission of 62.7 kg of CO_2 per million BTU (Antes, 2007). Typical propane patio heaters were found to be between 25,000 and 45,000 BTU and the analysis was based on a 35,000 BTU heater. Electrical calculations were based on 5 kg of CO_2 produced per GW-h of energy (BC Hydro, 2013), therefore this assumption would not apply to regions who do not generate power from hydropower. BC Hydro trades power with local regions based on demand but for the purposes of this report it was assumed all electrical energy would be generated by hydropower in British Columbia.

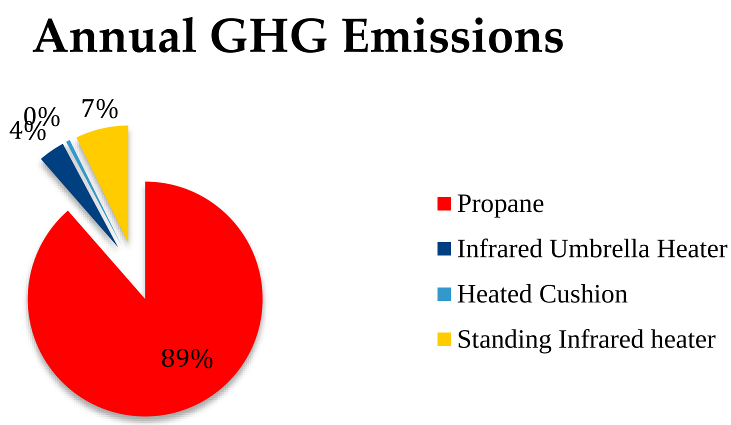

Figure 9 - Predicted annual greenhouse gas estimates.

4.3 ECONOMIC INDICATORS

Economic values consider the value created by the company not only for itself but also for the surrounding community and society in general. Since it was difficult to apply a metric to the value produced by the surrounding general populace, for the purposes of this analysis only fiscal aspects were considered as outlined below (refer to Figure 10 and Figure 11 for a pictorial comparison of results).

- Initial equipment investment
- Annual running cost
- Annual maintenance prediction
- End of lifecycle disposal cost
- End of lifecycle cost/credit

Initial investment calculations were based on local retail supplier research. Although heaters could potentially be sourced more economically from alternative suppliers, this is expected to be a valid assumption because prices should only scale relatively. Number of expected units also had significance on the total initial investment. Supplier specifications were used to estimate total required units for each concept. For example, typical propane heaters have a heating range of approximately three meters. An estimated 180 m^2 of patio space required heating resulting in approximately seven propane patio heaters being required. The total cost for the propane heaters was estimated to be slightly under \$2,800. Similar estimations were made for the electrical concepts. Predicted initial costs were \$10,400, \$4,800, and \$1,800 for heated cushion, standing infrared, and infrared umbrella heaters respectively. High initial investment in not necessarily a negative attribute when considering long term running costs.

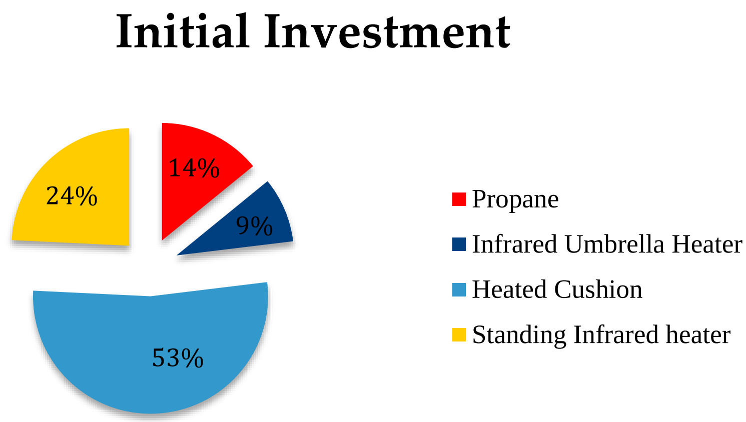

Figure 10 - Initial financial investment for patio heating concepts.

Annual running costs were also analyzed. In most cases, running cost was a function of energy input. However, in the case of the heated cushions, the high rate of battery replacement was a significant contributor to running cost. As stated previously, each battery lasts only 500 charges before being considered waste. Typical replacement batteries were found to cost approximately $45 and are expected to last under one year of operation. Electrical running costs were based on a value of 11.27 cents per kilowatt-hour (BC Hydro, 2014). Propane running costs were based on a value of $0.56 typical of Vancouver. For propane, standing infrared and infrared umbrella heaters running costs were estimated to be approximately $20,000, $11,800 and $5,900 respectively. For the heated cushion the estimated running cost was $9,500 per year with $9,300 of that being annual battery replacement costs.

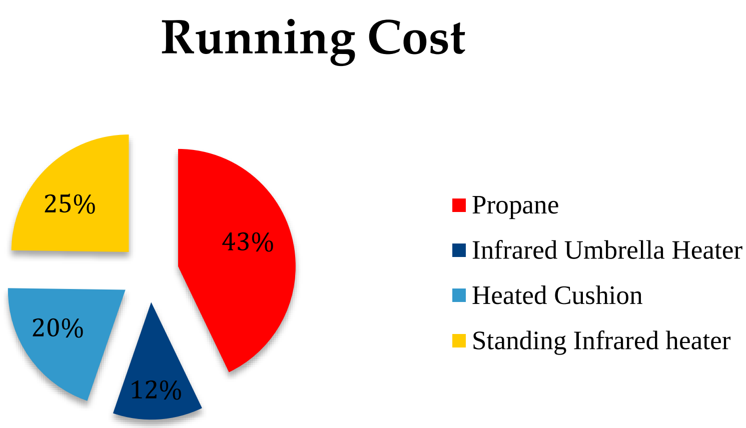

Figure 11 - Projected annual running costs.

5 CONCLUSION AND RECOMMENDATIONS

Upon collecting data on all of the possible winnowed patio heater solutions, inter-comparisons were made and scores were compiled into a weighted decision matrix based on triple bottom line indicators. Of the three narrowed solutions, standing infrared heaters received the highest triple bottom line score, followed closely by umbrella infrared heaters, and finally by battery powered heated cushions. Propane heaters, which were included in the comparisons as a benchmark of an industry standard solution, received the lowest score among the options investigated. The results of our triple bottom line analysis show that although propane heaters comprise the majority of patio heaters used in industry, they are the most expensive to run, the most polluting, the least efficient, and the loudest of the surveyed solutions. The only advantageous aspects of propane patio heaters are in their relatively low initial cost and their slight lead in general satisfaction over the infrared options. Compared to propane, all three of the proposed solutions were less expensive, more comfortable, and polluted substantially less. The clear findings of our Triple Bottom Line analysis are that standing infrared heaters, followed closely by umbrella infrared heaters, are the preferred solution(s) to a sustainable patio heater.

In practice, the heating on patio at the Perch would likely be implemented using a combination of standing and umbrella infrared heaters. Both options have similar energy requirements, pollution levels, and comfort ratings. The two options are separated primarily by their configurations and cost. Standing infrared heaters would need to be used around tables that don't have umbrella stands and umbrella heaters could be used at any tables with umbrella stands. In practice, this would allow less than one heater per table due to overlapping radii. Varying configurations could also lead to lower capital or operating costs than estimated in our triple bottom line analysis. Our recommendation is to use both standing and umbrella infrared heaters where appropriate. The heaters are easy to operate, relatively inexpensive, used in industry, relatively portable, and will allow the Perch to operate its patio into the late night, spring, autumn, and possibly winter.

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APPENDICES

Appendix A: Triple Bottom Line Benchmarking
Appendix B: Calculation sample for economic, environment and social indicators

APPENDIX A

Triple Bottom Line Benchmarking

TRIPLE BOTTOM LINE BENCHMARKING

Figure 12. A table showing Triple Bottom Line accounting for patio heating concepts.

			Gas	Electric		
		Metric	*Propane*	*Infrared Umbrella Heater*	*Heated Cushion*	*Standing Infrared heater*
Profit	*Initial Investment*	$CAD	$2,793	$1,776	$10,434	$4,800
	Running Cost	$CAD/year	$20,472	$5,915	$9,531	$11,831
	Maintenance Estimate	$CAD/year	$250	$100	$100	$100
	Disposal Cost	$CAD	$50	$50	$50	$50
	Recycling Credit	$CAD	$35	$5	$0	$600
Planet	*GHG Emission*	kg-CO2/year	6399	262	39	525
	Typical Lifespan	year(s)	3	2	1	2
	Energy Use	MWh/year	209	52	2	105
	Conversion Efficiency	%	0.81	0.87	0.9	0.87
People	*Thermal Comfort*	Y/N	N	Y	Y	Y
	General Satisfaction	%	0.75	0.70	0.90	0.70
	Potential Health Impacts	Y/N	Y	N	N	N
	Sustainable Labour	Y/N	N/A	N/A	N/A	N/A
	Approximate Noise Level	dB	40	0	0	0

TRIPLE BOTTOM LINE BENCHMARKING

Figure 13. A table showing Triple Bottom Line accounting for patio heating concepts non-dimensionalized with relative weighting.

		Gas	**Electric**		
		Propane	*Infrared Umbrella Heater*	*Cushion*	*Standing Infrared Heater*
Profit	*Initial Investment*	0.35	0.39	0.00	0.26
	Running Cost	0.00	0.43	0.32	0.25
	Maintenance Estimate	0.00	0.33	0.33	0.33
	Disposal Cost	0.00	0.00	0.00	0.00
	Recycling Credit	0.05	0.01	0.00	0.94
Planet	*GHG Emission*	0.00	0.33	0.35	0.32
	Typical Lifespan	0.38	0.25	0.13	0.25
	Energy Use	0.00	0.34	0.44	0.22
	Conversion Efficiency	0.23	0.25	0.26	0.25
People	*Thermal Comfort*	1.00	0.00	0.00	0.00
	General Satisfaction	0.25	0.23	0.30	0.23
	Potential Health Impacts	0.00	1.00	1.00	1.00
	Sustainable Labour	0.00	0.00	0.00	0.00
	Approximate Noise Level	0.00	0.33	0.33	0.33

Score	2.3	3.9	3.5	4.4
Rank	4	2	3	1

APPENDIX B

Sample calculation for standing infrared heater (http://www.costco.ca/EnerG%2b-Freestanding-Infrared-Heater.product.100130491.html)

Assumptions	Metric	Reference/Source
Days of operation per year.	180	UBC SEEDS Program: Project Proposal Form. Winter and some of Fall / Spring
Weekday Hours	62.5	
Weekend Hours	18.5	
Week Hours	81	
Heating Use	0.4	% of time heater is used during operational hours (ie. rain, dusk to closing, etc.)
Yearly Operational Hours	2916	UBC SEEDS Program: Project Proposal Form. Proposed operational hours.
Recycling Credit of Materials ($/lb)		
Steel	0.075	
Aluminum	0.5	http://scrapmetalpricesandauctions.com/canada/
Disposal Cost @ Vancouver Landfill ($/Ton)		
Construction Waste	50	
Electricity Variables		
Cost (kWh) Electricity	$0.11	
CO2-e/GWh (tones of GHG/GWH)	5	http://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/environmental-reports/ghg-intensities-2004-2013.pdf
Thermal comfort is defined by maintaining the skin surface at body temperature (34 Degrees C). Calculation was done to see whether T_ambient (temperatureof surrounding) can match the skin termperature.		

Voltage = 120 V

Energy = 1.5 kW or 5100 BTU

Power required for each unit $= \frac{Energy * Yearly\ operational\ hours}{1000} = 4.374\ MWh/year$

Operational cost of each unit = 4374kWh * $0.11/kWh = $492.95 / kWh

Power required for 24 units (since, we require 1 heater per 4 seats) = 4.374 *24 = 104.976 MWh/year

Operational cost of 24 units = $492.95 * 24 = $11830.80 / kWh

Life $= \frac{Expected\ Life}{Yearly\ Operational\ hours} = \frac{5000}{2916} \approx$ 2 years

Cost of 24 units = $199.99 * 24 = $4799.76

Weight of each unit = 22.7 kg

Metal composition in it = 0.5

Recycling credit for all units = $25 * 24 = $600

Maintenance estimate = $100