UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Sustainable Heaters

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Abstract

The University of British Columbia is always making great efforts to become as sustainable as possible and lead other university campuses by example. One of UBC's goals in this effort to become increasingly sustainable is to cut back on electricity use. As a result, Kara McDougall, a manager for Sustainability Engagement, wants to investigate new and better possibilities for UBC faculty personal heating solutions. Since many of the faculty rely on their own personal heaters during cooler, winter months already, the goal is to offer a trade-in program with the best and most energy efficient heaters so that UBC can reduce its energy usage while keeping everyone happy. This report will describe the investigation into the available optimal personal heaters and provide four recommended models to the stakeholder so that an informed decision may be made on what heater is best to provide for the trade-in program. This investigation and evaluation has been completed following the Triple Bottom Line method using the economic, environmental, and social impacts to determine the most qualified heaters to recommend. The main economic impacts that were evaluated were the purchase cost, the operating cost and the energy cost savings of the heaters. The main environmental impacts that were analyzed were the energy demand and consumption, the energy efficiency settings and controllability, the materials used, and the waste created. Lastly, the social impacts that were examined were the safety, comfort, and practicality or ease of use of each heater. In conclusion, four heaters were recommended due to their good evaluations in the economic, environmental, and social aspects of the TBL method. The recommended heaters are: De'Longhi Comfort Temp Oil Filled Radiator Heater, Lifesmart Life Pro Series 1000-Watt 4-Element Infrared Electric Portable Heater with Remote, Cozy-Heater 400-Watt Wall Mounted Electric Heater with Heat Shield, and Holmes Eco Smart Energy Saving Portable Heater.

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Glossary

British thermal unit (BTU): the amount of heat or energy required to heat one pound of water by one degree Fahrenheit. The equivalent of approximately 1055 joules

Power: energy consumed per unit of time

Radiant energy: energy that is released by any object or person that is warmer than their surroundings

Kilowatt hour (kWh): unit of energy that is equivalent to one kilowatt of power consumed in an hour

Wattage: amount of power that is required to run or outputted by a device, one watt is equivalent to one joule consumed per one second

Efficiency: useful power output over total power input

Infrared: radiant heat energy given off by 700nm-1mm photons

List of Abbreviations

TBL - Triple Bottom Line

Eff - Efficiency

W - Power in watts

P - Power output

V - Potential difference in volts

I - Current in amperes

BTU - British thermal unit

kWh - Kilowatt hours

nm - Nanometer

mm - Millimeter

1. Introduction

UBC is planning to purchase and implement new personal office heaters. The main goal in this project is to increase overall sustainability. Overall sustainability of a solution may be measured by a triple bottom line (TBL) analysis. A TBL analysis focuses on three main aspects:

- Economic
- Environmental
- Social

Many different variables may be attributed to these factors to get an overall weighing on the sustainability of an item. Four different heaters will be compared in our TBL analysis. The heaters are broken into three different groups: radiant panel, convection, and oil-filled convection. In the investigative process, we will give description of our research methods and decisions. The purpose of the analysis sections is to discuss and prove the important variables to take into account for a heater, for the purpose of choosing a winner. The economic assessment will outline which heater provides the best costs savings, addressing overhead costs along with defining the efficiency of a heater. The environmental aspect will provide information about the largest contributors to energy use, choosing the heater which proves to be the most eco-friendly. Lastly, we consider social aspects including safety and ease of implementation and portability of such heaters for UBC employees. After analyzing these impacts, recommendations will be provided regarding the best proposal to replace and upgrade the current office space heaters.

2. Investigative Process

At the beginning of our investigation, it was essential for our group to completely understand the problem of our stakeholder so that we could find the best possible way to proceed. We started by reviewing the project description, which described UBC's need for personal heater recommendations, then followed up by creating a list of questions for our stakeholder. After we received clarification on all questions we had, we started our investigation by walking around campus and looking inside several offices to identify the types and sizes of areas that we would need the recommended heaters to supply heat to.

We knew that we would need to compare heaters to a standard 1500 W heater, and as heaters are essentially 100%, we decided to focus our efforts on finding heaters that would best suit the specific office types. In addition, the focus was also on units that had features such as multiple wattage settings and a thermostat to reduce the amount of power used and therefore try to reduce the amount of energy UBC needs to allocate to heating. There are also two main types of heater that we decided to look at: convection and radiant, with radiant involving both infrared and oil-filled heaters. Each type of heater has it's own strengths and weaknesses, depending on the room, the user, and the requirement. Convection heaters, which often make use of a fan, are better for spreading out the distributed heat evenly through a room, whereas radiant heaters are better for spot heating. As a result, we determined that we should recommend both a convection heater and a radiant heater so that the stakeholder can choose the best option based on the type of office that the heater will run in, as the office sizes and shapes can vary widely.

The final stages of our process were evaluating several heaters based on their capabilities within the three areas that the TBL method covers: economic, environmental, and social. We started with the economic and social aspects of the heaters in order to reduce the number of heaters we were evaluating to a manageable number. Then, when the number was where we wanted, we started looking at the environmental aspect as the final filter for our 4 recommended heaters. The details of our TBL evaluation of the economic, environmental, and social aspects of the heaters are in the below sections.

3. Overview of Heaters

For this investigation we have chose 3 different types of heaters: radiant panel, convection, and oil-filled convection. The two convection based heater types distribute their heat energy by warming the air close to the element and distributing it throughout the room. Oil-filled heaters store their energy in the oil, which has a high capacity for storing heat. The long term storage of the heat in the oil makes for a steadier ambient temperature over long periods of time. To understand what radiant heat is, recall feeling the warmth of the sun on your skin. Radiant energy is a form of energy that is released by any object or person that is warmer than their surroundings. Radiant panel heaters emit infrared energy in the form of heat that radiates downwards warming the floor and any objects within range of its heat distribution. Objects that are warmed by the infrared heat also release some of their own heat that can be absorbed by the air or other bodies around.

(*Figure 1:* Holmes Eco Smart Convection Heater)

(*Figure 2:* Lifesmart 1000W 4 Element Infrared Heater)

(*Figure 3:* De'Longhi Comfort Temp Oil-filled Heater)

(*Figure 4:* Cozy-Heater 400 Watt Wall Mounted)

4. Analysis of Economic Factors

The economic factors that most greatly affect the choice of a personal space heater are initial purchase price, efficiency and operating costs. The initial price can be easily compared between heaters, and heaters in the lower price range would gain a greater economic advantage over extravagant models. would provide sufficient features to satisfy a user, without being overly extravagant. Efficiency of a heater determines the power outputs costs of heaters while they are running. Overall heater use depends on variables such as room size, personal preference and temperature control, which will be discussed in the environmental section.

To analyze the efficiency of a space heater it is important to have a good understanding of how efficiency works. The efficiency of an device is a measurement of the output of desired energy form to the energy input into the system(*Equation 1*). For example, the efficiency of an electrical motor is given by the ratio of the mechanical energy to the input energy(*Equation 2*).

$$Eff = Energy\ Output\ in\ Desired\ Form\ /\ Total\ Input\ Energy \quad \text{(Equation 1)}$$

$$Eff_{motor} = Mechanical\ Energy\ /\ Total\ Input\ Energy \quad \text{(Equation 2)}$$

An electric motor will never be 100% efficient because some of the input energy is dissipated in undesired forms of energy, typically thermal and sound. However, unlike a electric motor, a heater produces almost no energy in any other form thermal, and therefore the efficiency of all electrical heaters will be very close to 100%. This near-perfect efficiency of electrical heaters can be shown by analyzing the specified input power to output power of the Holywell Ceramic Compact heater available at Best Buy. This heater produces 5118 BTU, and consumes 1500W, which corresponds to an efficiency of 99.995% which is an insignificant deviation from 100% (*Equation 3, 4*).

$$5118\ BTU\ =\ 1499.938\ W \quad (\textit{Equation 3})$$

$$Eff_{heater}\ =\ 1499.938\ W\ /\ 1500W\ *\ 100\ =\ 99.995\ \% \quad (\textit{Equation 4})$$

As seen by this efficiency calculation, there is very little room to improve an electric electric heater and this is because of the extraordinary simplicity of their operation. Essentially a heater is just a very large power resistor, so it will din teissipate energy in the form of heat when an electrical voltage is applied. The dissipation of the heat is governed by equation (*Equation 5*) which is derived from Ohm's Law.

$$P_{disspated}\ =\ V^2 R\ = V I\ =\ I^2 / R \quad (\textit{Equation 5})$$

The price of electricity, provided by BC Hydro is 5.474¢/kWh for large industrial applications. By assuming UBC receives a similar price for electricity we can analyze the cost of the running a 1500 W heater. If we assume the average employee who uses a space heater runs it for 4 hours per day, 5 days a week for 3 months each year, then the price of the electricity used is ≈ $19.70/yr. By using a 1000W infrared heater instead of a 1500W conventional electric heater the cost of electricity will be reduced to $13.14/yr, which a a 33% drop in energy cost. The wall heater presents the greatest energy savings at $5.25/year, but it should be acknowledged that the 400W wall heater might need to run more than 4 hours per day to produce similar heat, and therefore these cost saving will probably not be realized. This calculation provides a rough estimation of the electricity costs, but the large assumption (identical operation time for infrared and convection heaters) will limit the conclusions that can be drawn from this analysis. A comparison of the initial price, power consumption, and estimated price per year(using the assumptions above) is given in table 1.

Since the both oil and gas heaters are 100% efficient, it does make sense to use the true definition of efficiency as a deciding factor when choosing heater. To better compare the cost of running the heater, it will be necessary to compare how well each heater focuses the heat in a desired area, and how well the heater can be controlled to reduce wasteful heating. This analysis of features will be performed throughout the remainder of the report.

(*Table 1*: A comparison of the cost factors associated with each heater)

Heater Name	Initial Price	Power	Est. Cost / year

Eco Smart Energy Saving Portable Heater	$39.99	1500 W	$19.70
Life Pro Series 1000-Watt 4-Element Infrared Electric Portable Heater with Remote	$50.05	1000W	$13.14
Comfort Temp Oil-Filled Radiator Heater	$79.99	1500W	$19.70
Cozy-Heater 400 Watt Wall Mounted Electric Heater with Heat shield	$76.00	400W	$5.25

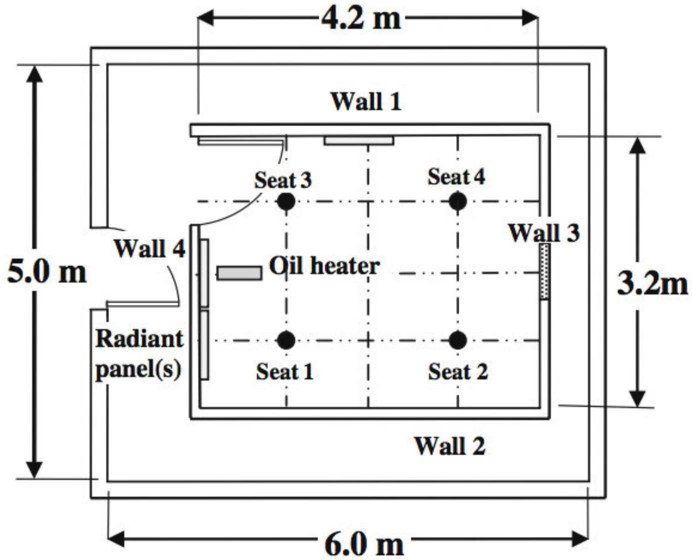
5. Analysis of Environmental Factors

The main focus of this environmental analysis of personal space heaters will highlight the types of heaters which provide the greatest perceived temperature comfort levels for the power consumption. The previous section’s inquiry into the economic aspects of personal heaters shows that all heaters have virtually 100% efficient electrical energy to heat energy transfer. Due to this fact we have concluded that the following aspects greatly contribute to heater energy consumption: personal preference, perceived temperature level, heater placement, thermal control systems, insulation, ventilation, heat distribution, room size. The latter four variables are independent of the individual heaters; however, they are arguably the most important. Increasing the air-tightness of a building from “8☐6 to 5☐6 m^3 /(h☐m^2) @ 50 Pa” would reduce heating demand by 28% (Prescott, 2008). Estimations puts heat energy loss through walls at 45%; much more of this energy could be saved by increasing wall insulation (Ruan et al., 2015). Once these other controls have been taken into account, the heater dependant variables play a large in overall energy use:

- Perceived temperature level
- Heater placement
- Thermal control systems

The main findings of our analysis concludes that there is no singular type of optimal personal heater; instead, the type of heater should be chosen for the space it will heat. Our environmental analysis recommends infrared radiant heaters for the greatest environmental benefit for the majority of rooms. Oil-filled radiators and convection electric heaters would be suitable for well insulated small offices, in which even heat distribution is a primary concern; however, in general it is shown that radiant heaters provide similar user satisfaction with less overall energy use (Ali & Morsy, 2010).

The environmental variables do not heavily rely on the individual brands of heaters, but rather the types of heaters. This investigative shall compare and contrast: convection electric heaters, infrared heaters, and oil-filled radiators. Our main contributor the for the argument of the environmental benefits of different heaters is from the Ali & Morsy comparative study between radiant panel and portable convective heaters. This study tested a highly insulated and air-tight controlled test room shown below in Figure 1.



(*Figure 5:* Ali & Morsy's environmentally controlled test room)

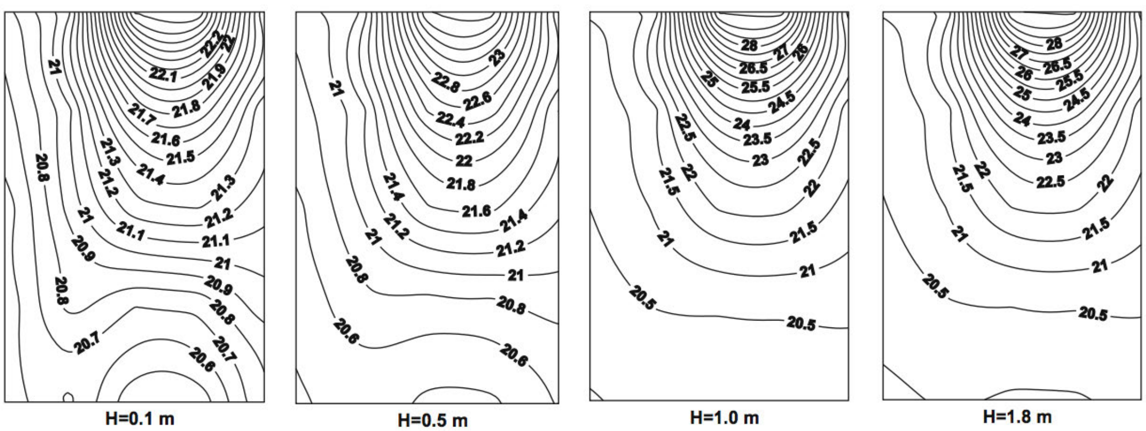
We will provide a brief description of Ali & Morsy's experiment, along summarized descriptions of the findings. Controlling for the outdoor temperature outside of the building, 14 people ages 21-23 were queried on their temperature comfort status sitting in the different seats in the room for the two different types of heaters. The subjective temperature ranking scale ranged from -3 (cold) to 3 (hot). Findings were tested for outdoor temperatures of 0, 5, and 10 degrees celsius. See Figure 2 below for the findings of temperature, subjective vote, and power consumption at an outdoor temperature of 10 degrees celsius.

Temperature °C	One Radiant Panel	Two Radiant Panels		Oil Heater
		Position (1)	Position (2)	
Room Air				
After 5 min	19.5	24.6	21.4	22.9
After 2 h	23.3	28.3	26.4	27.4
Walls average				
After 5 min	17.9	23.5	20.0	22.9
After 2 h	22.3	27.1	24.3	27.4
Ceiling				
After 5 min	18.1	24.1	20.7	23.8
After 2 h	23.0	28.1	25.5	28.7
Floor				
After 5 min	22.7	24.7	21.6	23.7
After 2 hrs.	23.0	25.6	23.7	25.1
Door				
After 5 min	15.0	18.8	16.6	18.6
After 2 h	17.5	20.6	19.5	21.0
Window				
After 5 min	13.9	17.0	15.3	16.3
After 2 h	15.9	18.5	17.2	18.2
Sensation vote				
After entry	−1	0	0	0
After 2 h	0.33	1.50	0.25	0.25
Average excluding at entry	0.19	1.13	0.38	0.19
Power consumption (W)	290	580	580	670

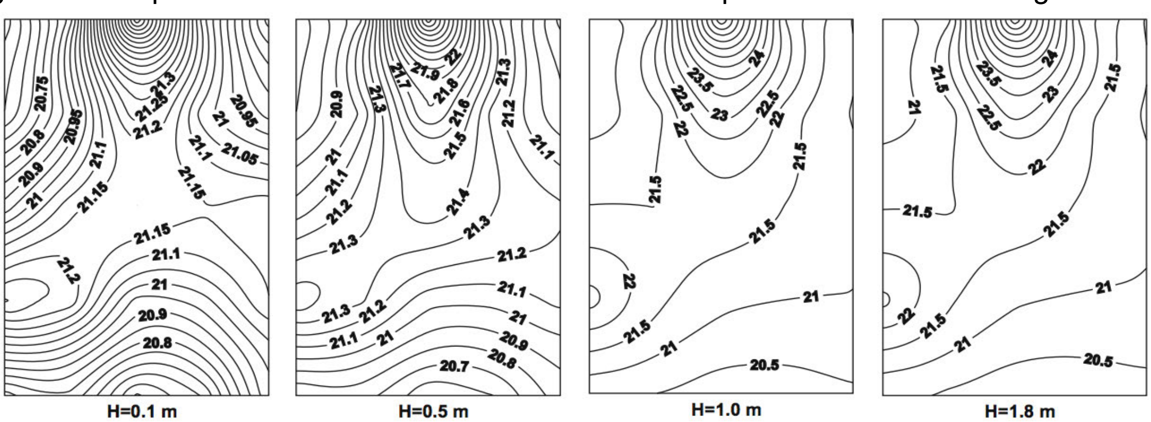
(*Table 2:* Temperature, subjective vote, and power consumption at outdoor temperature of 10°C)

This study concluded that a single radiant heater of power 270W provided a slightly greater comfort sensation than that of a standard convection oil based heater of 670W, with energy savings of roughly 56%. The findings of this study reflect that the placement of radiant heaters is largely effectual towards the heat dispersion throughout the room, as well as comfort levels. The trend of heat dispersion throughout the room diminishes at the lower outdoor temperatures of 0 and 5 degrees celsius. Overall, the ambient temperature of the room is lesser for the radiant heaters; however, this is expected due to the lower power output. Despite the less even temperatures, and lower overall temperatures, users ranked their satisfaction levels slightly greater than standard heaters for both heater positions 1 and 2. The evidence indicates that overall, the radiant panel heaters provide up to 39% improved energy savings at virtually the same outdoor temperature as standard heaters (Ali & Morsy, 2010).

Analytic results from the Ali & Morsy study reveal that for a radiantly heated room, the indoor thermal distribution is largely reliant on the heaters placement in regards to the windows. It was concluded that placement of one panel heater facing the window on the opposite wall, and one close to the window on the wall adjacent to the window. This placement provides even heat spread throughout "90% of the room area at different heights from the room floor"(Ali & Morsy, 2010).



(*Figure 2:* Temperature distribution of two radiant heaters placed on the wall facing a window)



(*Figure 3:* Temperature distribution of one radiant heaters placed on the wall facing a window, and one place close to the window on the wall adjacent)

6. Analysis of Social Factors

The social factors that govern a decision when using the triple bottom line method are often difficult to measure as they take into account the people whom are affected by the outcome and the way people react can be hard to quantify. In this investigation, researching optimal personal heaters for UBC faculty, the social aspect of the TBL analysis is paramount because if the faculty members are not happy with the heater provided, then they will not use them and the results of this investigation will essentially be useless to UBC. Therefore, the challenge faced is how to convince faculty to trade-in their current office heaters and the solution is mostly found through social aspects as many people look towards personal comfort rather than saving the university money. In order to find the most attractive features in heater, a small survey was taken, asking the ten participants what they valued most in their heaters, the results are shown in Table 3, with the rankings from 1 - 5 and the average score of each feature.

Rank	Feature	Average Ranking
1	Comfort	2.21
2	Safety	2.31
3	Ease of Use	2.56
4	Price	3.54
5	Appearance	3.94

Table 3: Ranking of most desirable heater qualities

During our analysis of the social impact, guided by the survey results, we looked at three main factors: safety, comfort, and practicality or ease of use. The first area, which is often the most important in any decision or research, is the issue of safety. Heaters are mainly dangerous due to their ability to start fires since they achieve very high temperatures in order to heat a room. Therefore, the features we looked for, with regards to safety, were an automatic shutoff if heater tips over or if it overheats and a full encasement, preferably made of fire retardant material, of the heat source to prevent burns. The next factor that affected our research was comfort, which is integral to finding a desirable heater for the end user. In this case, we focused our efforts on finding heaters which could provide a comfortable heat level in a room and not over or under heat the room while also keeping noise to a minimum. For the last social impact factor, practicality and ease of use was considered because, like the first two, it was rated in the top 3 most desirable qualities in a heater. The evaluation of this factor was completed by looking at the control system of the heater, as the user should be able to operate the heater without difficulty. The four heaters that follow are all ETL listed, or 1-UL listed which means they all meet certain standards set out and , in no particular order, all meet the desired factors and features set as our goal (Intertek, n.d.).

Option 1: De’Longhi Comfort Temp Oil-Filled Radiator Heater

The De’Longhi heater excels when it is analyzed while looking at the social factors safety, comfort, ease and of use. This heater has a built in automatic shutoff in case in falls over or starts to overheat, a rust-resistant, robust, fully enclosed metal construction to prevent burns to users or damage to the heater itself, and also the diathermic oil used is permanently sealed inside. An extra feature for anytime it gets very cold is an anti freeze setting, where if the temperature drops below 44 degrees fahrenheit, the heater turns on. In addition to the safety features, this model also provides a virtually silent operation while heating, and has multiple power settings, or a thermostat to help keep the heat at a comfortable level. The control system of the heater consists one adjustable thermostat, three heat settings controlled with two switches, and one more button for an energy saving option. This unit is also ETL listed (Home Depot, n.d. [2]).

Option 2: Lifesmart Life Pro Series 1000-Watt 4-Element Electric Portable Heater

The Lifesmart model is a heater that fully satisfies the social factors that are looked at in this evaluation. The safety features include both an automatic shutoff for overheating and a tip over switch. Furthermore, the casing is made of fire retardant material and full encloses the heating elements to prevent burns or other contact that could be a fire hazard. The comfort features include a thermostat to keep constant temperatures and not over or under heat the space, and a quiet, if not silent, operating noise. Lastly, for ease of use, this model comes with a remote to control power, thermostat, and timer, and the thermostat is on an easy to understand digital screen. This unit is also ETL listed (Home Depot, n.d. [5]).

Option 3: Cozy-Heater 400-Watt Wall Mounted Electric Heater with Heat Shield

The Cozy-Heater option provides solid features that also meet the desired social factor requirements. The safety features integrated on this heater involve high impact strength casing material and a fully enclosed heating element to prevent burning. The automatic shutoff due to overheating is also included but, as this model mounts to the wall, there is no tip over switch. Comfort features include quiet operation and as it is only a 400 W heater, it will most likely not overheat the desired area. The practicality or ease of use factor is satisfied simply with this model as the user just mounts it on a wall, turns it on and it runs, using natural air movement to help spread heat. This unit is ETL listed (Cozy-Heaters, n.d. [6]).

Option 4: Holmes Eco Smart Energy Saving Portable Heater

The Holmes Eco Smart model is a slim, robust, and efficient heater that is well qualified in all three areas, safety, comfort, and ease of use. The safety features involve an automatic shut off if overheated, a manual reset for the user if needed, a cool-to-touch plastic casing that prevents burns, and a tip over shut off switch. The two heat settings for varying amount of heat and the thermostat to keep temperatures constant both are solid comfort features that are augmented by the quiet operation of the unit. Lastly, the unit is very easy to use, with a digital thermostat reading and LCD digital controls provided so the user has an easier time of reading the display. This unit is 1-UL listed (Home Depot, n.d. [4])

7. Conclusions and Recommendations

Through the process of investigating sustainable heaters, it became apparent that there would not be one heater that was best for all situations. By a TBL analysis it was determined that radiant heaters are optimal for heating individual work areas in rooms where it is inefficient to heat the air in the room. This could be caused by the size of the room, or the lack of insulation present. It is also important to recognise that infrared heaters produce very localized heat, and therefore each person in an office will require their own individual heater, which will reduce the overall efficiency. The recommended convection heaters are well suited for heating offices containing more than one person. This is due to the fact that both these heaters will warm the air in the room providing evenly dispersed warmth for each employee. Deciding which convection heater should be chosen depends on the size of the room, and the desired heating rate because the larger 1500W convection heater will produce much more heat than the small 400W wall mounted heater. Due to the large heat capacity of a oil heater, it is not particularly ideal for office heating. This heater will be slow at getting up to temperature when the employee arrives in the office and when the employee leaves the office at the end of the day, the large amount of energy stored in the heat capacity of the oil will be radiated into an empty room. The advantage of an oil heater is that the slow steady heating provides a high level of comfort and reduces the likelihood of overheating. High heat capacity oil heaters are better suited to an environment that is continuously occupied, such as in a home. The triple bottom line approach has lead us to believe that the infrared heater(*Option 2 above)*, radiant panel heater (*Option 3 above),* and the conventional heater (Option 4 above) are sustainable choices for office heating and the decision between these heaters should be made on the particular scenario of use.

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