UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Introduction into Induction and Natural Gas Stoves:

A Triple Bottom Line Analysis for the new Student Union Building

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ABSTRACT

This report compares the attributes of induction and natural gas stoves and provides a recommendation as to which is more suitable for use in the new Student Union Building through a triple-bottom line analysis. The triple-bottom line looks at the economical, environmental, and societal impacts of these stoves. The comparisons of the two types of stoves are to be conducted based on their technological attributes for the environmental and societal impacts, while individual models from different manufacturers are compared to look at their economical impacts. The report uses peer-reviewed papers that were written by experts to provide information on the two types of stoves. Most were published in science and academic journals. The information that is presented assumes that the data from the test stoves are representative of the stoves that can be purchased for the new SUB. It is also assumed that the indicated usage and lifespan of the stoves will be similar to the stoves that will be used in the catering kitchen.

The research that is presented in this report shows that the average capital costs for induction stoves are much greater than natural gas stoves, but the variable costs for the energy are much less for induction stoves. However, the unique pricing for resources for the new SUB alters the costs of the different types of stoves. Since natural gas stoves involve combustion, emissions are present while induction stoves do not produce any. Natural gas stoves are approximately 40% energy efficient because of the significant amount of heat loss to the surroundings. Conversely, induction stoves are highly energy efficient with an efficiency of approximately 90% because heat generation takes place in the pot itself. Natural gas stoves also present a higher risk for burns from the flame as well as possible health issues due to the inhalation of the by-products of combustion. Induction stoves also provide a cooler working environment. Cleaning induction stoves is much easier because the surface is not heated and generally flat as opposed to natural gas stoves, which have burners that make it more difficult.

From analysing the economical, environmental, and social impacts of the triple-bottom line, it is recommended that the new SUB use induction stoves in the catering kitchen. The induction stoves offer safer working conditions and greater energy efficiency than natural gas.

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GLOSSARY

Btu	British thermal unit of energy [Btu]
Combustion	The process of burning.
Electromagnetic Induction	The production of voltage across a conductor moving through a magnetic field.
Ferromagnetic	The characteristic of substances that exhibit high magnetic permeability.
Flashback	The combustion that can occur within the system.
Genotoxic Effects	Known to be potentially mutagenic or carcinogenic, specifically those capable of causing genetic mutation and of contributing to the development of tumours.
Genotoxicity	The deleterious action on a cell's genetic material affecting its integrity.
Joule	Unit of energy [J].
Liftoff	The condition when the flame and burner become separated.
Primary Aeration	The amount of primary air that is put into the burner.
Specific Heating Value	The amount of heat energy that is released when a compound undergoes complete combustion.
Watt	Unit of work [1 W = 1 J/sec]

LIST OF ABREVIATIONS

CaGBC	Canada Green Building Council
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
GHG	Greenhouse Gas
GJ	Giga Joule $1GJ = 1 \times 10^9 J$
kHz	Kilo Hertz [1/sec]
J	Joule
kg	Kilogram
kWh	Kilo Watt Hours
LEED	Leadership in Energy and Environmental Design
MJ	Mega Joule $1\,MJ = 1 \times 10^6 J$
MMBtu	Million British Thermal Units
N_2O	Nitrous Oxide
NA	Not Available
NO_x	Nitrogen Oxide
ppb	Parts Per Billion
ppm	Parts Per Million
SO_2	Sulphur Dioxide
SUB	Student Union Building
TNMHC	Total Non-Methane Hydrocarbons
TSP	Total Suspended Particulate

SECTION 1.0 – INTRODUCTION

The new SUB is hoping to be an image of sustainability and provide an example that should inspire other building projects on the UBC campus and around the world. Choices must be made when designing the new SUB in order to meet UBC's sustainability goals while still maintaining the functionality of the building and the support of the staff and students. The specific choice that is being analyzed in this report is whether to use gas stoves or induction stoves. Gas stoves involve the burning of natural gas in order to generate heat and cook the food. They have been around for many years and are a time proven technology in the food industry. Induction stoves use electromagnetic waves to induce current through the cookware in order to generate heat and cook the food. They are a relatively new technology when compared to gas stoves and are still being optimized, but they provide very high efficiency. When evaluating the choice of induction stoves or gas stoves for use in the new SUB it is effective to do a triple bottom line analysis and look at the economical, environmental, and social impacts.

SECTION 2.0 – ECONOMICAL

In this part of the report, the overall cost associated with using natural gas stoves and induction stoves for commercial purposes are detailed. As a part of the economical section of the triple bottom line analysis, three cost components of the stoves that had the most substantial impact on the overall pricing. First, the capital costs of induction and natural gas stove models similar design and size with the addition of all other required equipment were compared. Second, the usage costs of each type of stove and their efficiency based in a commercial environment were taken into account. Lastly, the replacement costs of a device when it reaches its end-of-life cycle were examined. By taking the summation of the three parts, the overall cost of each type of stoves was reached. Based on the more economically advantageous technology, the recommended type of stove for the new SUB was reached.

To determine the average capital cost of the different stoves, the induction and natural gas stove prices were considered after taking into account by ensuring that they were similar models and of the same size. The brands that were considered are Bosch, Electrolux, Frigidaire, Kenmore, and Whirlpool. All of them had 4 hubs. The stores from which the prices were found are Abe's of Maine Limited, The Brick, and the Hudson's Bay Company. A summary of the findings are listed on Table 1. After taking the average of the five stoves, it is found that the average difference in capital cost was about $650 for each unit. By purchasing the number of units required for the SUB, assuming 15 to 20 units, the difference grows to $10,000 to $13,000.

Table 1 - Prices of Different Induction and Natural Gas Stoves

	Induction Stoves ($)	Natural Gas Stoves ($)
Bosch 300 series	1499.99	615.00
Electrolux 30" series	2199.97	1499.97
Frigidaire 36" professional	1599.97	1299.97
Kenmore Elite 30" series	1489.88	775.99
Whirlpool Gold 30" series	1899.99	1249.99
On Average	1737.96	1088.184
10 units (~40 hubs)	17379.6	10881.84
15 units (~60 hubs)	26069.4	16322.76
20 units (~80 hubs)	34759.2	21763.68

The induction stoves cost more than natural gas stoves because they require the use of a special and a more expensive material: ferromagnetic metals. This material is used to generate the induction wave, which is the method of heating in induction stoves (Lawrence Berkeley National Laboratory, 1990, 13). In a new study, it was indicated that by implementing ferromagnetic material into the pots, the power by can be increased by 55%. However, no commercial pots have such a property so the idea was found to be not yet applicable (Koller, 2009, 159). Additional costs of buying special pots for the induction stoves are discarded because it was reported that using induction stoves with the proper coils and the correct inverter frequencies (65 turns and 50 kHz for aluminum and copper, and 15 turns and 20 kHz for iron and stainless steel), any metal vessel can be used with induction stoves (Tanaka, 1989, 641).

To find the energy usage cost by each technology, the following equation was used:

$$Energycost = \frac{Usagerate \times Time \times UsageCost}{Efficiency}$$

In another study, it was reported that the absolute efficiency property of an induction stove was as high as 84% and only 39.9% for natural gas burners (Lawrence Berkeley National Laboratory, 1990, 49 & 48). This means that induction stoves are 2.1 times more effective than natural gas stoves. From the same report, the energy consumption rate is given as 3.38 MMBtu/year for natural gas stoves (3.562 GJ/year), while induction stoves consume 206.4 kWh/year (Lawrence Berkeley National Laboratory, 1990, 129 & 49). However, these values come from residential use, which approximated that commercial use requires an additional 50 hours of weekly use (approximate 25 hours per week for residential use, and 75 hours for commercial use). Next, the rates charged to the UBC SUB in 2013 are assumed to be $6.79/GJ for natural gas and $47.99/MWh. These are assumed to be the same for the next 25 years (Tailor, Hitesh et al., 2010, 127). Table 2 shows the usage cost per year.

Table 2 - Energy Costs per Year

	Induction	Natural Gas
Efficiency (%)	84.00	40.00
Assumed Hour Usage per Week (hours)	75.00	75.00
Energy Consumption per Hour	0.159 KW	0.00274 GJ
2013 Energy Charged to UBC	$ 47.99 / MWh	$ 6.79 /GJ
Usage Cost per Year	$33.02	$167.15

The longevity of the stoves are unknown because articles were either non-existent or out of reach. Therefore, it was assumed that both stove types last for 15 years, which is a similar assumption made in a study by an office in Switzerland (Jungbluth, 2009, 19). Figure 3 shows that one replacement cost is added to our estimation every 15 years.

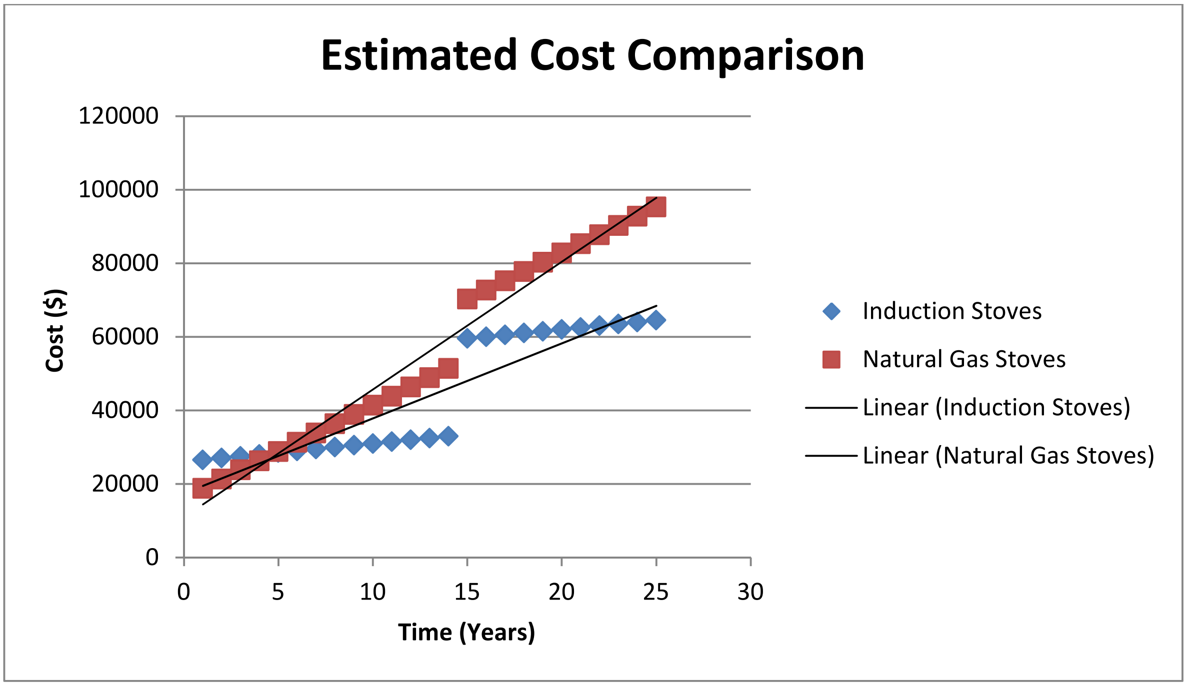

Figure 3 - Cost Projections of Using Induction and Natural Gas Stoves

In Figure 3, note that natural gas stoves have a lower initial cost. At approximately 5 years, the usage costs make the natural gas stoves more expensive to operate. Even at 15 years into the life of the new SUB, the induction stoves will cost about $10,000 less than natural gas stoves. It was also reported by the organizers of the new SUB that electricity will be provided by UBC, while the new SUB pays a standard fixed rate for the natural gas, regardless of the amount used. By taking the usage costs out of the equation, an updated version of the plot is generated. In Figure 4, the cost of induction stoves is approximately $20,000 greater by the end of the 25th year.

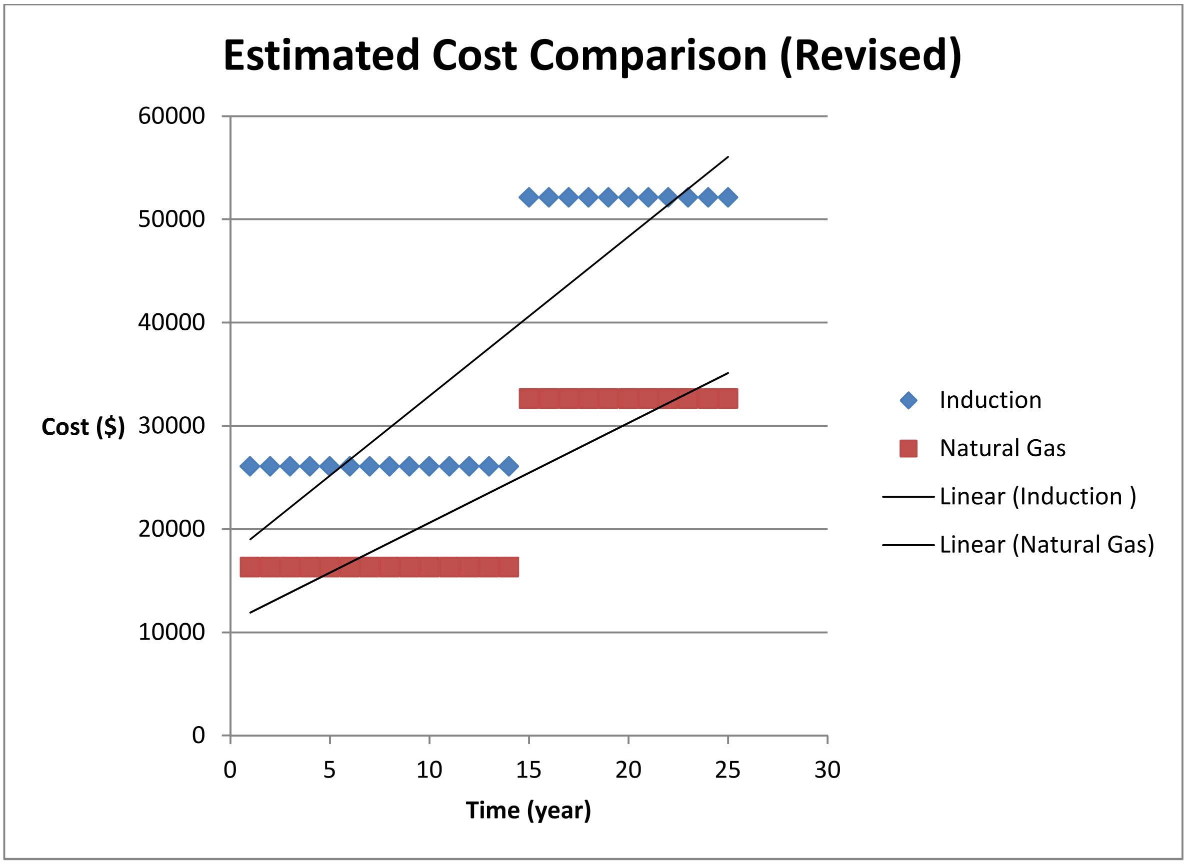

Figure 4 - Cost Projections of Using Induction and Natural Gas Stoves Neglecting Usage Costs

Normally, induction stoves offer greater cost savings. However, the unique pricing for the new SUB means that newer projections in Figure 3 better represent the economical cost of the two types of stoves. From the latest cost projections, the natural gas stoves offer lower costs to the new SUB.

SECTION 3.0 – ENVIRONMENTAL

There are many emissions from the natural gas combustion process that are released to the environment. Table 5 provides some examples of the by-products of the combustion process.

Table 5 - Comparison of some GHG and Other Pollutants Emitted By Induction and Natural Gas Stoves

Examples of Pollutants	Induction Stoves	Natural Gas Stoves
CO_2	No	Yes
CO	No	Yes
CH_4	No	Yes
NO_x	No	Yes
N_2O	No	Yes
SO_2	No	Yes
TNMHC	No	Yes
TSP	No	Yes

(Zhang, 2000, 7)

If insufficient oxygen is supplied, then incomplete combustion occurs and leads to increased CO emissions and soot formation (Ko, 2003, 3). Liftoff, flashback, and inadequate heat input can also occur (Ko, 2003, 3). NO_2 is also released to the atmosphere and can have severe health effects, which are discussed in more detail in Section 4.0 (Basu, 1999, 1).

The study by Ko and Lin showed that one can optimize burning by decreasing the gas pressure to a suitable value, by enlarging the primary aeration to a favourable level, by selecting a proper thermal input, and by adjusting the optimized heating height for natural gas with a specific heating value (Ko, 2003, 12). This shows that each stove must be individually adjusted to the specific fuel used to attain maximum efficiency, which can vary from region-to-region. Doing this would increase the time and costs required to install the stoves.

Tables 6 and 7 show the emission factors of natural gas. The data was obtained from using (a) a gas stove with an infrared head without flue and (b) a traditional gas stove without flue. The same fuel with the same heating value was also used. The efficiency of the infrared stove was reported to be 60.92% and 53.69% for the traditional stove (Zhang, 2000, 10).

Table 6 - Natural Gas Emission Factors for Different Stoves (average grams of compound per kg of fuel)

	CO_2	CO	CH_4	Carbon in TNMHC	TSP	NO_X	SO_2
Infrared	3.44 E+03	NA	3.91 E-02	1.67 E-01	2.03 E-01	5.77 E-01	NA
Traditional	3.44 E+03	2.63 E-01	NA	8.97 E-02	1.13 E-01	2.89 E+00	1.49 E-03

(Zhang, 2000, 9)

Table 7 - Natural Gas Emission Factors for Different Stoves (average grams of compound per 1 MJ of delivered energy)

	CO_2	CO	CH_4	Carbon in TNMHC	TSP	NO_X	SO_2
Infrared	1.10 E+02	NA	1.24 E-03	5.35 E-03	6.49 E-03	1.85 E-02	NA
Traditional	1.25 E+03	9.51 E-03	NA	3.29 E-03	4.09 E-03	1.05 E-01	5.37 E-05

(Zhang, 2000, 10)

The data in Tables 6 and 7 clearly shows that CO_2 is by far the largest by-product of the natural gas combustion process. Some of the emission factors were either not detected or the background level in the air was greater than the concentration in the flue gas (noted in the tables as NA). These tables are expressed in the Figures 8 and 9 as bar graphs. Figure 8 shows all of the emission factors while Figure 9 excludes the CO_2 data to display the other compounds more clearly.

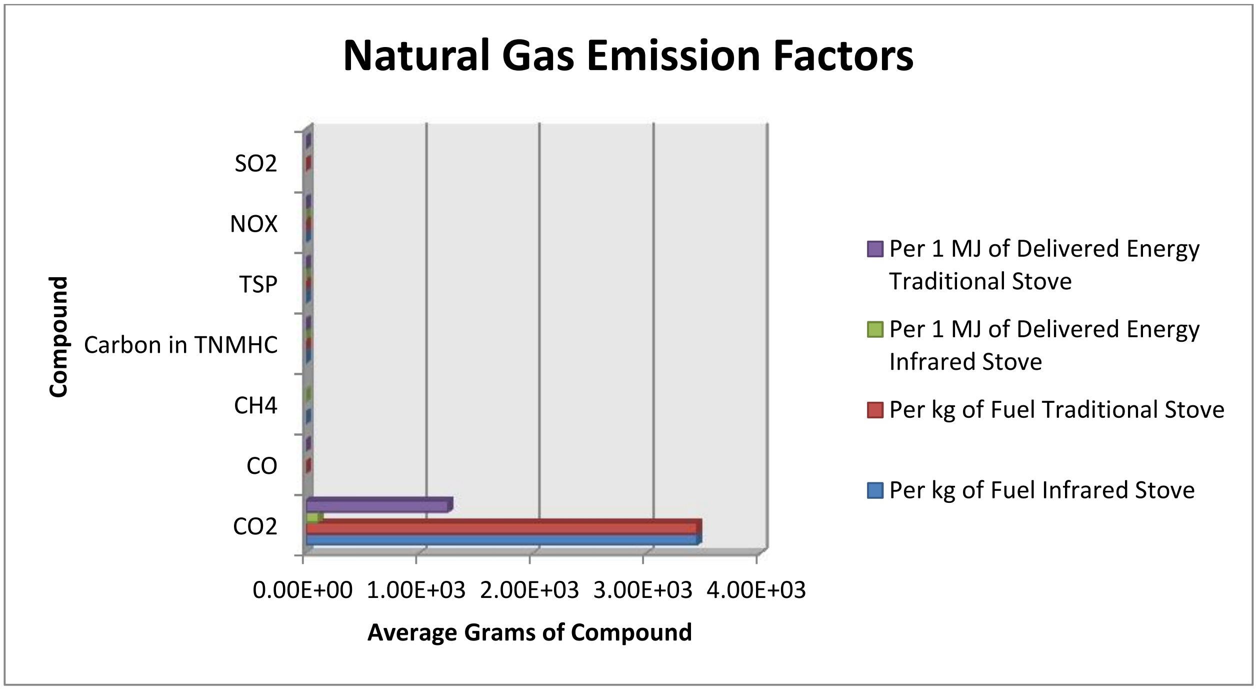

Figure 8 - Natural Gas Emission Factors
(Zhang, 2000, 9)

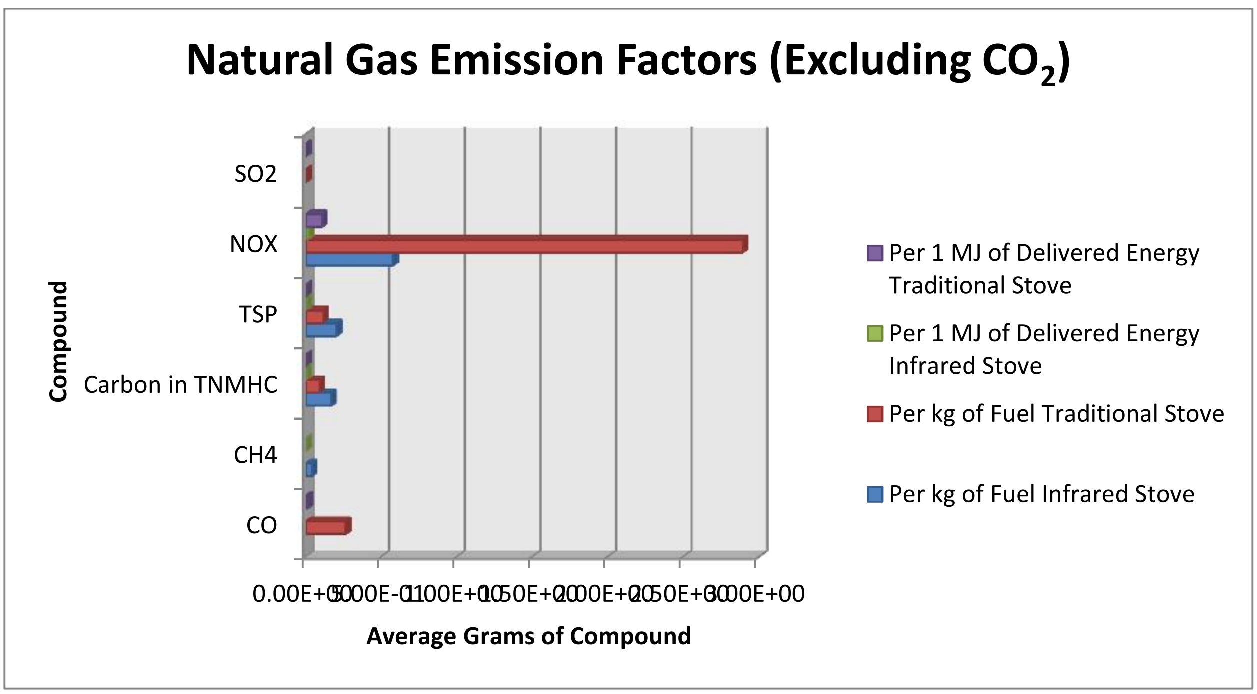

Figure 9 - Natural Gas Emission Factors, excluding CO_2
(Zhang, 2000, 9)

The heating characteristic of induction stoves is that the pot itself generates heat through electromagnetic induction. This means that the heating efficiency can be as high as 90% (Matsuzuki, 2008). On the other hand, the heating efficiency of a gas stove may be up to 40% because a lot of heat is lost to heating the surrounding air (Matsuzuki, 2008).

Looking at induction stoves, the power supply can be turned off when not in use because restarting is so quick (Zinn, 1988, 8). Whereas with natural gas stoves, energy must be supplied continuously to maintain temperature during delays and to avoid long start-ups (Zinn, 1988, 8). This means that when natural gas stoves are not in use in a commercial kitchen, they must stay lit and continue to release pollutants to the environment. Conversely, induction stoves can stay on and not release any pollutants or be turned off and back on with a very short amount of time to start it back up again.

Another consideration is in regards to the resources that each stove requires. The induction stoves will only require electricity and a plug to connect them to the building. Reports say that the electricity supplied to the new SUB will come from hot water run-off from the stream plant on campus. Conversely, the natural gas stoves require piping and other infrastructure to supply the natural gas. Since natural gas cannot be produced locally, the gas must come from farther regions where it is produced, such as Northern British Columbia or Alberta. This means that it could be transported through piping or by trucks, causing harm to the environment through deforestation and/or pollution.

From an environmental point of view, induction stoves have a significantly smaller impact than natural gas stoves because the relative amount of pollution that the latter produces is much greater throughout its operational life. For this reason, it is recommended that the new SUB's catering kitchen use induction stoves.

SECTION 4.0 – SOCIETAL

A lot of people believe that in order to design 'green' buildings you must also sacrifice human comfort; that you must essentially go back to a more basic way of living. However many people are unwilling to do this and you cannot sell the idea of sustainable buildings if people do not support them. That is why the social aspect is very important and why it is incorporated in the triple bottom line assessment. It is especially important in this case because the SUB's primary role is social space for the students to eat, get together at the bar, see a movie and so on. When looking at the social impact of choosing induction stoves or gas stoves for use in the new SUB kitchens it will affect the customers and staff by affecting their safety, working environment and cooking process.

Gas stoves involve the burning of natural gas in order to create heat energy to cook food. A by-product of this combustion is NO_2. According to the World Health Organization short-term exposure (i.e. 6–7 hours) to NO_2 at levels of about 150 to 500 ppm may lead to fatal pulmonary oedema, laryngospasm, bronchoconstriction or respiratory arrest (Basu; 1999, 173). Lower concentrations of NO_2 may also cause acute pulmonary oedema, bronchitis or pneumonia (Basu, 1999, 173). Other potential health effects of NO_2 are: reduced efficacy of lung defences could lead to increased incidence and severity of respiratory infections, airway injuries could lead to respiratory symptoms and reduced lung function and worsening of the clinical status of persons with chronic respiratory conditions (Basu, 1999, 174). These are very serious issues because peak concentrations may reach 200 to 400 ppb in the kitchen during the use of a gas stove (Basu, 1999, 173). Incomplete combustion, due to insufficient oxygen, leads to increased CO emissions which can be very dangerous in a closed kitchen because exposures of 100 ppm or greater can be dangerous to human health (Ko, 2003, 3001). Associated with the use of a gas stove is the presence of an open flame, which presents the risk of burns, one of the most common safety concerns in the food industry.

Induction stoves on the other hand induce current through the metal of the pot causing the pot to heat up and cook the food (Sadhu, 2010, 650). This keeps the surface of the stove cool, avoiding any risk of burns. As well since there is no burning of gas, there are no adverse chemicals present. Although induction cookers are not very common in commercial kitchens across North America, they are popular in Japan and Europe (Miyakoshi, 2007, 529). The biological health effects due to presence of the magnetic fields in induction cookers remain unclear. One study has shown that there are no genotoxic effects in cells exposed to magnetic fields generated in an induction cooker (Miyakoshi, 2007, 535). The magnetic density in these tests was 80 times that found in any induction cooker (Miyakoshi, 2007, 535). From the research done induction cookers are much safer than gas stoves because there is less risk of burns and no harmful chemicals produced when cooking.

The working environment for a typical person in the food industry can be very tough; they work long irregular hours, most of this time is spent standing, and working in a very hot environments. This alone causes a high risk of musculoskeletal disease and dermatitis (Matsuzuki, 2008, 360). In a study done to directly compare the working environments using an induction or gas stoves it was found that both provided different comfort levels for the staff. After exposure to heat stress (i.e. stove operation) environmental values in front of the induction stove did not change, whereas the ambient dry-bulb temperature, globe temperature, radiant heat index and wet-bulb globe temperature significantly increased in front of the gas stove (Matsuzuki, 2008, 363). The workers all felt significantly hotter in major areas over their body when working in front of the gas stove rather than the induction stove (Matsuzuki, 2008, 363).

When comparing induction stoves to gas stoves, it is clear that induction stoves provide better maintenance of the thermal environment in the kitchen. This suggests a better work environment in kitchens with induction stoves. One of the major unpleasant consequences of working in a commercial kitchen with gas stoves is the work environment being very hot and uncomfortable. Therefore it is safe to assume that a cooler working environment in the kitchen would result in a more pleasant working experience for the staff.

Gas stove tops have been a major part of commercial kitchens for many years, and although the thought of induction stoves presents a more energy efficient process to cook the food we can understand why some chefs might be hesitant to make the switch. That is why we must analyze the effect of using induction stoves instead of gas stoves on the cooking process. The gas stove top is a time proven technology, and anyone who has worked in the food industry has experience using gas stove tops. Whereas inductions stoves have been criticized because they were in need of special magnetic cookware, but modern induction cook tops can use almost any metal cookware (Miyakoshi, 2007, 529). Also induction stoves were originally criticized for uneven cooking, but recent studies support that newer induction stoves have fixed this problem with alternative coil design and magnetic field distribution (Meng, 2009, 5).

Constant output power, quick response and flexible temp control makes cooking for the staff easy as they have full control of the temperature (Sadhu, 2010, 650). Whereas using gas stoves can result with uneven temperature for cooking because of combustion. Induction stoves also provide an advantage for maintenance as they're designed to be flat. On gas stoves the heat from the burning gas causes food to get cooked onto the stove and may be hard to clean off, but because the surface of the induction stove stays cool it makes it easy for the surface to be cleaned and can be done right after the cookware is removed.

SECTION 5.0 – CONCLUSION AND RECOMMENDATIONS

After looking into all three aspects of the triple bottom line analysis, it was found that the induction stove offers a superior solution for use in the new SUB. Economically, natural gas stoves offer reduced costs relative to induction stoves, however the costs for natural gas can fluctuate since energy is limited. From the environmental point of view, induction stoves were clearly the best option. They produce in far less pollution that could be harmful to users and the surrounding environment. From the social aspect, induction stoves allow the cooks to operate the stoves with better control of the temperature and easier cleaning. Using induction stove technology allows the new SUB to maintain and possibly enhance health and safety standards, be energy efficient, reduce its impact on the environment, and help the building achieve its goal of LEED Platinum Certification under the CaGBC for New Construction.

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