UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Induction Stovetops for the New SUB

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ABSTRACT

The following report outlines a comparison between induction stovetops and conventional gas stovetops using a triple bottom line analysis approach. The purpose of this comparison was to identify the most suitable type of stovetop technology for the kitchens in the new Student Union Building. The triple bottom line analysis consists of an economic, social, and environmental assessment. Research on these three topics was gathered through websites, government documents and academic papers.

The main economic results from the analysis are that induction stoves have an increased initial capital investment, but that they have lower operating costs. In the model we developed for our research, the payback of the initial increased cost is approximately twenty three years. Although this seems like a large investment, twenty three years is not that long for a company to make a return, especially considering the life time of the new SUB. The main social result is that an induction kitchen stays at a much cooler temperature than a kitchen that operates gas stovetops. Higher temperatures in kitchens with gas stoves have been linked to high heart rates, high skin temperatures and high blood pressures for the workers. Heat stress for cooks is also a huge issue and this will be minimized with the installation of induction stoves. Increased cooking times, lower noise output, immediate heat response and ease of cleaning are also social impacts related to induction stoves. The environmental research found that running induction stoves produces approximately 13 times less greenhouse emissions than natural gas stoves. Not only does the reduction in greenhouse gases have a direct positive environmental impact, but this reduction could be a major contributor to earning LEED Platinum Plus certification, the merit that the new SUB is aiming to achieve.

In conclusion, based on the points outlined above, we believe that induction stove tops have an advantage over gas stoves and therefore our recommendation is to install induction stove tops in the kitchens of the new SUB.

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GLOSSARY

Radiant Heat Index - The Difference between ambient dry-bulb temperature and globe temperature. (C)

Ambient Dry Bulb Temperature - Refers to the ambient air temperature. It is called "Dry Bulb" because the air temperature is indicated by a thermometer not affected by the moisture of the air

Globe Temperature - Temperature depends on both convection and radiation transfer.

Heat Stress - Heat stress refers to body fatigue, due to its inability to dissipate body heat.

LIST OF ABBREVIATIONS

BTU/hr	British Thermal Unit per hour
kW	Kilowatts
CAGR	Compound Annual Growth Rate
SUB	Student Union Building
IH	Induction Heating Stove
NG	Natural Gas Stove
OHSCO	Occupational Health and Safety Council of Ontario
ICNIRP	International Commission for Non-Ionizing Radiation Protection
LEED	Leadership in Energy & Environmental Design
CO_2	Carbon Dioxide

1.0 INTRODUCTION

Induction stoves are a fairly new technology in North America and the technology itself is very different from the conventional electric or gas stoves commonly being used throughout the world today. In conventional electric or gas stoves, heat is generated either in an electric element or through the combustion process in a burner. The heat is transferred from the heat generator to a cooking vessel, which in turn is transferred through to the food. An induction type stove is different in that “the cooking vessel itself is the original generator of the cooking heat” (“Induction Cooking,” n.d.). The vessel generating heat is accomplished by the interaction of magnetic fields and the iron ferrous cookware. When electricity flows through an induction coil, which is located below the surface of the stove top (see Figure 1 below), a magnetic field is created around the coil. This magnetic field induces eddy currents to flow on the surface of the cooking vessel. As explained in the *Review of Induction Cooking* article, “the internal resistance of the pan causes heat to be dissipated following Joules effect” (Sandu et al., 2010, p. 652). The heat generated from the cooking vessel is then transferred directly to the food.

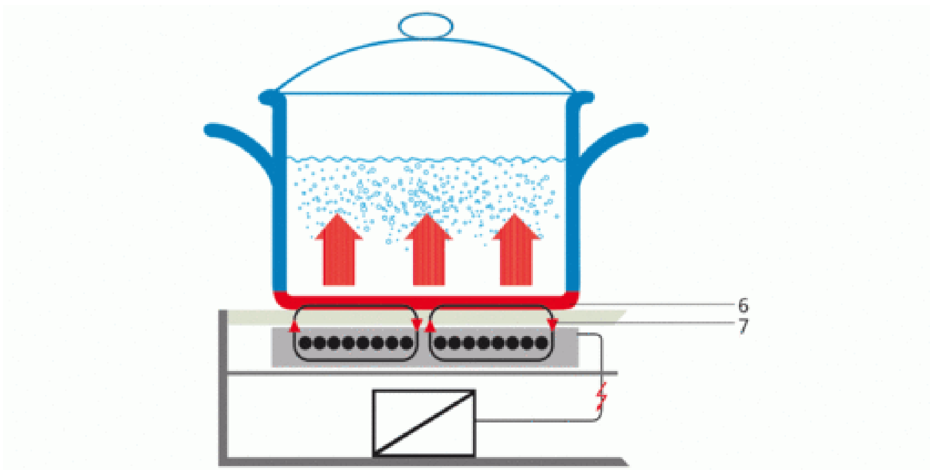

Figure 1 - General Induction Type Stove Top ("Induction Hobs," 2009)

Over the past 30 years, organizations have altered the way they approach projects. Rather than just using the economics to measure a project’s success or base decisions upon, many companies have implemented a triple bottom line analysis approach. This new approach not only includes economic impacts in the assessment, but also includes a project’s social and environmental impacts as well. This report contains a triple bottom line analysis of induction stove tops versus gas stoves for the new student union building being built on The University of British Columbia's campus. Included in the report are detailed comparisons of the pros and cons for each technology, as viewed from economic, social and environmental viewpoints. To be able to properly assess the advantages and disadvantages, we had to first identify the stakeholders in this project. The stakeholders we identified were:

- kitchen staff (actual users of the equipment)
- students / staff (the individuals who are affected by the end product
- financial stakeholders

2.0 ECONOMIC ASSESSMENT

During various stages of all projects, the project designers, stakeholders, investors, etc. have to make important decisions about what technologies or systems to include or omit from a project. To make properly informed decisions, a comprehensive economic analysis of each technology or system must be performed. After the economic analysis is complete, a comparison of the results must occur so the system that offers the best economics to the project can be identified. This section of the report is a detailed economic comparison of induction stove tops versus gas stove tops. The comparison consists of an analysis of initial capital costs for the stoves themselves, initial investment costs for cookware, and operating costs.

2.1 Initial Capital Investment Costs (Stoves)

To perform an accurate analysis of the initial investments required for both induction stoves and gas stoves, one must ensure that the variables being compared between the two technologies are the same (eg. ensure we are comparing apples to apples and not apples to oranges). Using a similar approach as outlined in *Induction Cooking* (“Induction Cooking,” n.d.) the following steps in a complete analysis are required:

1. Determine what 1 BTU/hr (British Thermal Unit / hr) of gas power is equal to in kW (kilowatts) of induction power
2. Research commercial induction and gas stove prices to determine an average cost per BTU/hr and kW for both technologies
3. Estimate power requirement for the new SUB (model estimation)
4. Using the above relationships, determine an estimated initial cost for both technologies

The first step in the analysis is to establish a relationship between the different power ratings. Gas stove tops are usually rated in BTU / hr, which is a Non-SI unit of power. Induction stoves are usually rated in kW which is SI unit of power. The relationship and conversion between the two can found in the following equations:

$$1\,BTU = 1055\,Joules$$

$$1\frac{BTU}{hr} = 1055\ \frac{Joules}{hr}$$

$$1\frac{BTU}{hr} = 1055\ \frac{Joules}{hr}\ x\frac{1hr}{3600secs} \rightarrow 1\frac{BTU}{hr} = 0.293\ Watts$$

$$3413\frac{BTU}{hr} = 1000\ Watts$$

The above equations allow an accurate comparison between the SI and Non-SI power units, but equating gas power to induction power is not so simple because the "various technologies are not all equally effective at converting their energy content into cooking heat" ("Induction Cooking," n.d.). To properly convert between a certain amount of BTU/hr of gas power to the equivalent amount of kW of induction power, the calculation must include the technologies' efficiencies. Following are equations that link SI to Non-SI power units and gas to induction power through operating efficiencies.

$$\frac{BTU}{hr} = 3413\ \times\ kW\ \times\ \left(\frac{\eta induction}{\eta gas}\right)$$

This equation gives the amount of gas power in BTU/hr required to match the amount of power being supplied from an induction stove.

$$kW\ =\ 0.000293\ \times (\frac{BTU}{hr} \times \frac{\eta gas}{\eta induction})$$

This equation gives the amount of induction power in kW required to match the amount of power being supplied from a gas stove.

From our research, the average efficiency of gas stoves are in the range of 39% to 40% (Lawrence Berkeley National Laboratory, 1993, p.48) and that the average efficiency of induction stoves are around 84% (Lawrence Berkeley National Laboratory, 1993, p.49). Using these average efficiencies, the above equations can be simplified to:

$$\frac{BTU}{hr} = kW \times 7185$$

$$kW = \frac{BTU}{hr} \times \left(\frac{1}{7185}\right)$$

Having established the above relationship between gas power to induction power, the next step in the analysis is to determine average actual costs of commercial gas stoves and induction stove tops. Listed in table 1 are six randomly selected examples of commercial gas stoves with their power rating and unit cost.

Table 1 - Commercial Gas Stove Top Power Ratings and Prices

Stove Name and Manufacturer	Model Number	Size of the Unit (BTU/hr)	Cost of Unit (US $)	Website information obtained from
Star - Max	606-HD	132,000	1157	Specs and pricing from: http://prima-restaurant-equipment.com/catalog/6-burner-star-max-gas-hot-plate-606hd-486
Star - Max	808-HD	240,000	1663	Specs and pricing from: http://www.basequipment.com/Star-Ultra-Max-808H-8-Burner-Gas-Hot-Plate-p/sta-808h.htm
American Range	ARHP-24-2	64,000	618	Specs and pricing from: http://prima-restaurant-equipment.com/catalog/american-range-heavy-duty-hot-plate-2-burners-8212-arhp-24-2-3611

American Range	ARHP-36-6	192,000	1076	Specs and pricing from: http://prima-restaurant-equipment.com/catalog/american-range-heavy-duty-hot-plate-2-burners-8212-arhp-24-2-3611
Imperial	IHPA - 6 - 36	168,000	1350	Specs and pricing from: http://www.instawares.com/heavy-duty-hot-plate.imp-ihpa636.0.7.htm?LID=NXTG&srccode=cii_9324560&cpncode=22-104281418-2
Southbend	HDO - 48	264,000	2320	Specs and pricing from: http://www.selectappliance.com/exec/ce-product/sb_hdo-48

Referring to table 1, the total power ratings for the six examples is 1,060,000 BTU/hr. The total costs of the units are $8184. Using these values, a cost ($) per (BTU/hr) of gas power is:

$$\frac{\$8184}{1060000[\frac{BTU}{hr}]} = \frac{\$7.72 \times 10^{-3}}{[\frac{BTU}{hr}]}$$

Listed in table 2 are eleven randomly selected examples of commercial induction stoves with their power rating and unit cost.

Table 2 - Commercial Induction Stovetops Power Ratings and Pricing

Manufacturer	Model Number	Size of the Unit (kW)	Cost of Unit (US $)	Website information obtained from
Eurodib	IHE3097	3	600	specs and pricing from: http://www.eurodib.com/en-US/categories/81-induction-

				cookers/products/383-induction-cooker-model-ihe3097
Garland	GIU 1.8	1.8	1420	specs from: http://www.garland-group.com/?xhtml=xhtml/gar/us/en/general/productcatalog.html&xsl=productcatalog.xsl&category=0038 Pricing from: http://theinductionsite.com/north-american-commercial.shtml
Garland	GIU 3.5	3	2377	specs from: http://www.garland-group.com/?xhtml=xhtml/gar/us/en/general/productcatalog.html&xsl=productcatalog.xsl&category=0038 Pricing from: http://theinductionsite.com/north-american-commercial.shtml
Garland	GIU 5.0	5	2980	specs from: http://www.garland-group.com/?xhtml=xhtml/gar/us/en/general/productcatalog.html&xsl=productcatalog.xsl&category=0038 Pricing from: http://theinductionsite.com/north-american-commercial.shtml
Iwatani	DI-1800	1.8	825	Specs from: http://www.iwatani.com/asp/w_product/Category.asp?CategoryID=8

				Pricing from: http://theinductionsite.com/hob-makers/iwatani-induction-hobs.shtml
Iwatani	IWA-1800	1.8	409	Specs from: http://www.iwatani.com/asp/w_product/Category.asp?CategoryID=8 Pricing from: http://theinductionsite.com/hob-makers/iwatani-induction-hobs.shtml
Iwatani	IWA-2500	2.5	650	Specs from: http://www.iwatani.com/asp/w_product/Category.asp?CategoryID=8 Pricing from: http://theinductionsite.com/hob-makers/iwatani-induction-hobs.shtml
Aervoe	ProChef -1800	1.8	612	Specs and pricing from: http://www.aervoe.com/paints_coatings/Gourmet-Specialty-Products/
Aervoe	ProcChef -3000	3	398	Specs and pricing from: http://www.aervoe.com/paints_coatings/Gourmet-Specialty-Products/
Spring	SR-181R	1.8	656	Specs from: http://www.springusa.com/productCategory.asp?category_id=3&category_name=Induction%20Systems Pricing from: http://theinductionsite.com/hob-makers/spring-induction-hobs.shtml
Spring	SR-261R	2.6	976	Specs from:

				http://www.springusa.com/productCategory.asp?category_id=3&category_name=Induction%20Systems Pricing from: http://theinductionsite.com/hob-makers/spring-induction-hobs.shtml

Referring to table 2, the total power ratings from the eleven examples is 28.1 kW of induction power. The total costs of the units are $11,597. From these values, we have a cost ($) per kW of induction power to be

$$\frac{\$11903}{28.1[kW]} = \frac{\$423.6}{kW}$$

The next step in the analysis is to create an accurate model of the new SUB gas consumption. Since the actual gas consumption (BTU/hr requirement) of the new SUB is not known, the following example will be based upon usage estimations. Using the *New SUB Project 100% Schematic Design Report* as a guide, an estimation of 8 gas burner units (griddles / woks) will be used for the model. An estimated average power rating for the gas units to be installed in the new SUB will be approximately 50,000 BTU/hr. Using these estimates, the new SUB will require a total of 400,000 BTU/hr of gas power (My New Sub, 2011).

Applying the above power and cost relationships from above along with the values from the estimated consumption model, the initial capital cost for new gas stoves to supply the power requirement of the model would be

$$400{,}000\left(\frac{BTU}{hr}\right) \times \left(\frac{\$7.72 \times 10^{-3}}{\frac{BTU}{hr}}\right) = \$3{,}088$$

The initial cost of induction stoves to supply this amount of gas power is found by:

1. Converting gas power to induction power:

$$400{,}000\left(\frac{BTU}{hr}\right)\times\ 0.293\left(\frac{Watts}{\frac{BTU}{hr}}\right)\times\frac{0.399}{0.84}\ =\ 54.414\ kW$$

2. The cost of new induction stoves to supply this power would be:

$$54.414\ kW\ \times\frac{\$423.6}{kW}=\ \$23{,}050$$

Comparing the initial costs of the induction stoves to the gas stoves, the upfront cost to supply the cooking power through induction technology would be a huge capital investment compared to gas stoves.

Another possible initial investment cost to consider when comparing gas to induction stoves is the cost of new cookware. The cookware used with induction stoves must be “able to well support a magnetic field - that is to be “substantially ferrous”” (“Induction Cooking,” n.d.). This means that the pots and pans must be of an iron based material and have the ability to be affected by a magnetic field. The new SUB project will be purchasing new cookware for the kitchen regardless of which stoves they install and therefore it is important to compare the costs of the cookware to determine whether induction cookware is more expensive than traditional pots and pans. No research could be found to support the claim that induction ready cookware is more expensive than traditional pots and pans. Research shows that the cost of cookware is more dependent upon the quality of the units, rather than if they are induction ready or not.

2.2 Operating Cost Analysis

Since gas and induction technologies use different raw energy sources to generate their heating energy, both technologies will have different operating costs over the years. The following section investigates what the operating costs for each technology will be over a 25 year span, taking into account the projected costs for each raw energy source.

The first step in the analysis is to determine where the price for electricity and gas currently stand and where these prices are expected to go over the next 25 years. From our research, we found a study prepared by Stantec Consulting for The UBC Alternative Energy Sources Sub Committee that included a section on projected energy costs of natural gas and electricity for UBC. Due to the uncertainty in projecting energy costs, Stantec Consultings' energy model was developed "using a band approach in which an upper and lower band was estimated for each energy source. The midpoint of each band was then used as the most likely estimate of the cost of that energy source" (Stantec Consulting, 2010). Figure 2 is a graph from Stantec Consultings report that shows the projected energy costs of natural gas and electricity between 2013 and 2062. The projected cost of electricity in 2013 is $0.0499/kWh and with a compound annual growth rate (CAGR) of 3.066%, the cost of electricity in 2037 is projected to be $0.0988/kWh. The projected cost of natural gas in 2013 is $6.79/GJ and with a compound annual growth rate of 3.51%, the cost of natural gas in 2037 is projected to be $15.52/GJ (Stantec Consulting, 2010).

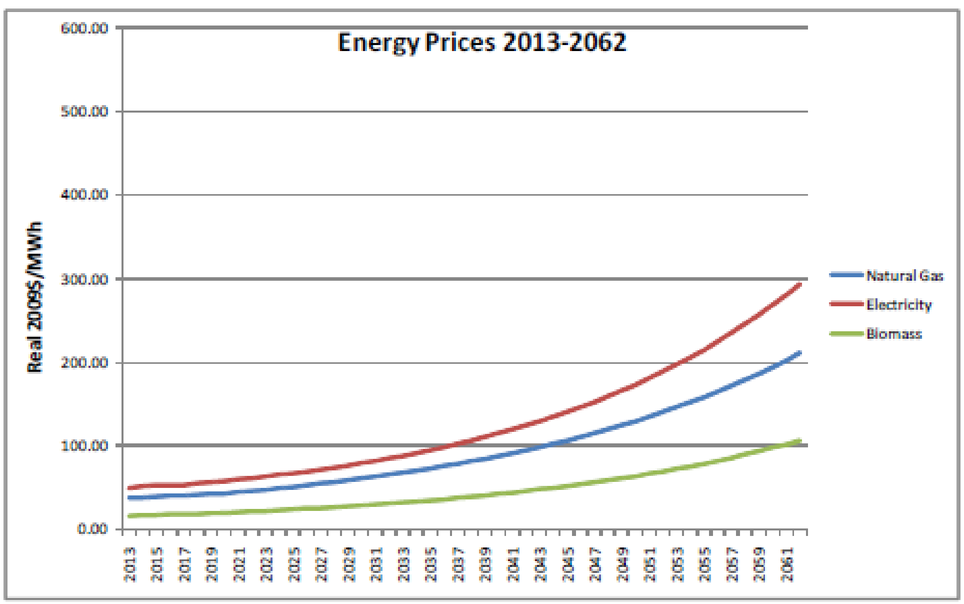

Figure 2 - Projected Energy Costs (Stantec Consulting, 2010)

Using these projected costs along with the estimated consumption values from the model used to calculate the initial capital investment, the operating costs of the stoves can be determined. Assuming the following operating conditions:

- assume the kitchen operates for 8 hrs/day
- assume the kitchen operates 5 days/week
- assume the kitchen operates 52 weeks/year
- Total hours / year = 2080 hrs/yr

Using excel to compute the yearly projected cost for electricity and the average CAGR, we can predict the operating costs of gas and induction stoves over the next 25 years.

Table 3 contains the yearly projected operating costs for the induction stoves.

Table 3- Operating Costs

Year	Operating Costs Gas	Operating Costs of Electricity	Difference in Operating Costs	Total Savings
1	5959.9904	5647.737888	312.252512	312.252512
2	6169.186063	5820.897532	348.2885314	660.5410434
3	6385.724494	5999.36625	386.3582439	1046.899287
4	6609.863424	6183.306819	426.5566044	1473.455892
5	6841.86963	6372.887006	468.9826235	1942.438515
6	7082.019254	6568.279722	513.7395319	2456.178047
7	7330.59813	6769.663178	560.9349514	3017.112998
8	7587.902124	6977.221051	610.6810727	3627.794071
9	7854.237488	7191.142649	663.0948398	4290.888911
10	8129.921224	7411.623082	718.2981421	5009.187053
11	8415.281459	7638.863446	776.4180134	5785.605066
12	8710.657839	7873.070999	837.5868393	6623.191906
13	9016.401929	8114.459356	901.9425726	7525.134478
14	9332.877636	8363.24868	969.6289565	8494.763435

15	9660.461641	8619.665884	1040.795757	9535.559192
16	9999.543845	8883.94484	1115.599005	10651.1582
17	10350.52783	9156.326589	1194.201245	11845.35944
18	10713.83136	9437.059562	1276.771798	13122.13124
19	11089.88684	9726.399809	1363.487033	14485.61827
20	11479.14187	10024.61123	1454.530643	15940.14892
21	11882.05975	10331.96581	1550.093942	17490.24286
22	12299.12005	10648.74388	1650.376168	19140.61903
23	**12730.81916**	**10975.23437**	**1755.584794**	**20896.20382**
24	13177.67091	11311.73505	1865.935861	22762.13968
25	13640.20716	11658.55285	1981.654314	24743.794
Total	232449.8015	207706.0075	-	-

The total operating costs for induction stoves over the next 25 yrs is approximately $208,000. The total operating costs for gas stoves over the next 25 yrs is approximately $232,000. The operating costs for inductions stoves are currently lower than gas stoves and are projected to be lower for years to come. Due to lower operating costs, a payback time of approximately 23 years would be required to recoup the initial investment costs required for induction stoves.

An important note is that no academic research could be found that indicates which technology has a longer operational life expectancy. The only relevant information regarding life expectancy was found in the report *Volume 2: Potential Impact of Alternative Efficiency Levels For Residential Cooking Products* prepared for the US Department of Energy that showed that conventional residential electrical and gas stoves have a similar life expectancy of approximately 19 years (Lawrence Berkeley National Laboratory, 1993, p.88). The model used in this economic assessment assumed that both gas and induction technologies have the same life expectancy.

3.0 SOCAIL ASSESSMENT

There are many social aspects to consider before installing gas or induction technologies in a commercial kitchen. When comparing kitchens with induction stoves with kitchens that have gas stove tops, the ambient temperature is lower in kitchens with induction stoves. This results in an overall lower heat stress. Heat stress is a condition that people face when experiencing prolonged exposure to a hot environment. A higher heat stress leads to a more fatigued worker, shown by measuring oxygen uptake, skin temperature, and subject awareness of heat and work load (Matsuzuki, Ayabe, 2008, p367). Other factors, such as low noise and low radiation, contribute to induction heating creating a better work environment.

3.1 Psychological Responses of People Under Heat Stress

A collaborative study between Japanese universities was published in Industrial Health magazine, and observes twelve young men as they cook in each kitchen. (Matsuzuki, Ayabe, 2008, p367). The results of the study support the argument that a lower kitchen temperature reduces the heat stress on kitchen staff. Kitchen Radiant Heat Index levels are recorded in Table 4 below for kitchens with Induction and Natural Gas stoves.

Table 4 - Radiant Heat Index, C

Height, cm	Stove Type	Before Exposure	After Exposure
90	IH	1.3	1.3
90	NG	11.2	11.8
120	IH	1.9	1.9
120	NG	5.2	6.0
150	IH	1.7	1.7
150	NG	3.0	3.5

Radiant Heat Index: The difference between ambient dry-bulb temperature and globe temperature. (C) The larger the radiant heat index, the more convection and radiation heat transfer takes place between the stove and its surroundings. The radiant heat index is about 10x higher for gas stove than induction at a height of 90cm, and considerably higher at 120 and 150cm. This is a good indication that gas stoves cause a higher level of heat stress in similar kitchens (Matsuzuki, Ayabe, 2008, p367). Based on Table 6, the physiological responses varied little before exposure to heat stress, but after exposure to heat stress they increased significantly.

Table 5 - Subject Vitals Before and After 30min of Cooking

Physiological Items	Stove Type	Before Exposure	After Exposure
Heart Rate, bpm	IH	78.6	101.0
	NG	76.6	108.8
Systolic Blood Pressure, mmHg	IH	113.8	124.3
	NG	115.9	128.0
Oxygen uptake, mL/(min*kg^2)	IH	4.3	5.4
	NG	4.6	6.5
Anebrachial Skin Temp. C	IH	34.2	36.8
	NG	34.1	39.7
Abdominal Temp. C	IH	34.2	35.2
	NG	32.4	38.4

When cooking on gas stoves it can be expected for the subject's heart rate, blood pressure, oxygen uptake, skin temperature, and abdominal temperature to be higher. Physical activity intensity was estimated using an accelerometer and found not to differ between the two heat sources (Matsuzuki, Ayabe, 2008, p367). It is important to recognize the perception of hotness, therefore data for this is listed in Table 6.

Table 6 - Subjects Perception to Hotness, at Various Temperatures During Cooking

	Stove Type	Feeling of Hottness (considrably hot survey) %	Ambient Dry Bulb Temp. C	Ambient Gobe Temp. C	Body Temp. C
Abdomen	IH	22.5	25.6	26.9	35.9
	NG	66.7	27.0	38.7	38.4
Hands	IH	50.0	25.6	27.5	37.1
	NG		26.4	32.5	39.8
Face	IH	16.7	25.7	27.4	36.6
	NG	100.0	26.3	29.7	37.0

Based on the measurements of a subject's perception to hotness (Table 6), using a gas stove under similar stove output levels leads to more people feeling hot and an overall higher temperature of the subject and environment (Matsuzuki, Ayabe, 2008, p367).

The OHSCO developed a handout outlining the risks and symptoms associated with heat stress. The article was released following an incident where a worker collapsed and died a few days later (Occupational Health and Safety Council of Ontario, 2009). Table 5 shows the difference in physiological vitals when gas and induction stoves are used. We can see that the higher heart rate, blood pressure, and oxygen intake are associated with higher temperatures. From a health perspective, induction stoves are safer than natural gas stoves for the staff that uses it. This makes induction stoves a good candidate for implementation in the new SUB.

Another social factor to consider when comparing the two technologies is the ease of cleaning the equipment. Induction stoves are much easier to clean when compared to gas stoves. The glass or ceramic flat top makes it easy to wipe up spills between cooking. The top of the stove does not become hot enough to bind the food to the top, unlike with a natural gas stove, where food can instantly cook or carbonize to the enamel surface or to the metallic frames

("Induction Cooking," n.d.) **.** As a result, less cleaning solution will be used and there will be a reduction in the clean-up time – both factors benefitting the staff.

Natural gas stoves are popular among kitchens due to the instant heat and immediate response to varying output levels. Induction stoves provide the same benefit of instant response to varying heat levels. Induction stoves provide constant and even heating (Energy Efficient Homes, 2011)**.** Another advantage to induction stove tops is that, when turning the stove off, the stove top does not remain hot like a gas stove. This has significant safety impacts due to a decreased risk of getting burned when cleaning spills during or after cooking ("Induction Cooking," n.d.).

3.2 Electromagnetic Radiation

As previously mentioned, induction stoves emit low amounts of electromagnetic radiation, which counters the general consensus people have about their electromagnetic radiation emission. As shown in Figure 3 (Induction Hobs, 2009), electromagnetic radiation from induction stoves follows the inverse square law. The magnitude of the magnetic field decreases with 1/distance^2.

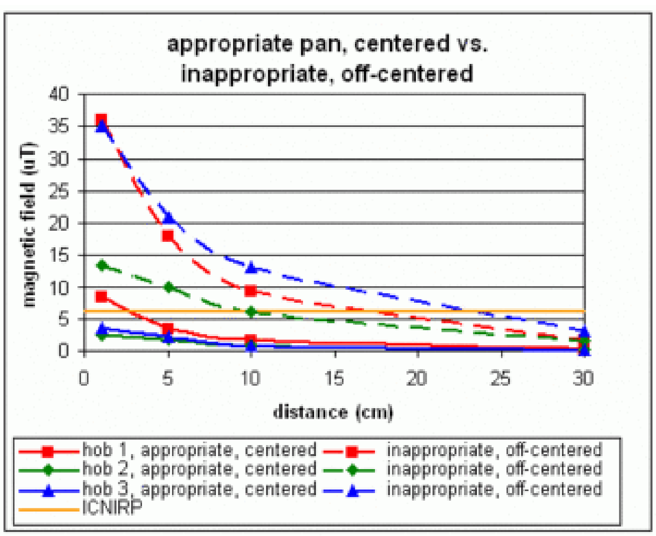

Figure 3 - Electromagnetic Radiation Measured at Distances from Stovetop

The ICNIRP recommends that all induction stovetops remain below a value of 6.25 microtesla (μT) (Induction Hobs, 2009). Using inappropriate cookware and off-centered pans result in the largest radiation levels. However in this worst case scenario, radiation levels die within about 20cm. Given that proper cookware will be used, the risk associated with radiation from stoves is very low.

3.3 Effect on implanted electronic devices

The effect of induction stoves on pacemakers is not considered a risk according to (Frank, R., & Souques, M, 2003). This is given that the stove is operating between the normal 50-60 Hz, and the pacemaker is set to the medically correct settings. It is still recommended that people dependent upon pacemakers, speak to their doctor before working near a stove ("Induction Cooking," n.d.). The unipolar cardiac pacemaker is an example of an implanted device that can be affected by induction hobs. People with unipolar pacemakers are warned not to touch pans for extended periods and should not use metal spoons for cooking. However, it is not likely that the implanted device will be affected adversely if the induction stove is used correctly (Irnich, W., & Bernstein, A. D, 2005).

4.0 ENVIRONMENTAL ASSESSMENT

The final aspect of the triple bottom line analysis is the environmental assessment. Many companies neglect taking into account environmental effects and consider only factors that impact their bottom line. However, the ideology of "going green" is becoming increasingly more popular with clients and stakeholders striving to achieve LEED certification. The new SUB is striving for LEED certification and striving even further to become LEED Platinum Plus certified. To achieve this high status, every aspect of the project must be analyzed thoroughly from an environmental standpoint. This section will compare the environmental impacts of induction stovetops to those of conventional gas stoves. This comparison consists of greenhouse gas emissions, energy transportation and dissipation, and transportation of each stove.

One of the most devastating effects on the environment is the production of greenhouse gases, mainly carbon dioxide (CO2). The increasing level of CO2 in the environment is known to be one of the leading contributors to global warming. It is suspected that global warming may cause increases in storm activities and melting of ice caps, which will cause flooding of the inhabited continents and other environmental problems (Environmental problems - The Greenhouse Effect, n.d).

During the last century, production of energy has been the leading cause of increased CO_2 levels in the atmosphere. According to a study done at the University of Sydney Australia, entitled "Life Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia", the production of natural gas into energy emits 642 grams of CO_2 per Kilo Watt hour (g CO_2/kWhr). The same study showed that the production of hydroelectric energy produces only 15 g CO_2/kWhr (Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia, 2006, p.8). The only supplier of electricity in the Lower Mainland is BC Hydro. Their energy is comprised of 86.3% from hydroelectric dams and 13.7% from natural gas fuelled thermo plants (BC Hydro - Our Facilities, 2010). Combining these facts with the model used in the economics section of this paper, the total amount of CO_2 -emissions can be calculated.

Natural Gas Stovetops: Using the conversion equations from the economics section, it can be found that natural gas stoves use 243776 kWhr/yr. The equation is shown below:

$$400{,}000\left(\frac{BTU}{hr}\right) \times 0.293\left(\frac{\frac{Watts}{BTU}}{hr}\right) \times 2080\left(\frac{hr}{yr}\right) = 243776.0\ kWhr/yr$$

Recalling that 642 g of CO_2/ kWhr is produced from converting natural gas into energy, we can calculate the total CO_2 emissions produced while a natural gas stove is on:

$$243776.0\left(\frac{kWhr}{yr}\right) \times 0.642\left(\frac{kgCO_2}{kWhr}\right) = 156504.0\left(\frac{kgCO_2}{yr}\right) = 17.86\ kgCO_2/hr$$

Induction Stovetops: Referring to the conversion equations in the economics section of the report, induction power is found to be 113181.7 kWhr/yr. The equation is shown below:

$$400{,}000\left(\frac{BTU}{hr}\right) \times 0.293\left(\frac{\frac{Watts}{BTU}}{hr}\right) \times \frac{0.399}{0.84} \times 2080\left(\frac{hr}{yr}\right) = 113181.7\ kWhr/yr$$

The electricity that is supplied to the new SUB is 86.3% hydroelectricity and 13.7% natural gas electricity. Knowing that 15 g of CO_2/ kWhr is produced from hydroelectricity and that 642 g of CO_2/kWhr is produced from converting natural gas into energy, we can determine the total amount of CO_2 produced from induction stovetops. The calculations are shown below:

$$\left(113181\left(\frac{kWhr}{yr}\right) \times 0.015\left(\frac{kgCO_2}{kWhr}\right) \times 0.863\right) + \left(113181\left(\frac{kWhr}{yr}\right) \times 0.64\left(\frac{kgCO_2}{kWhr}\right) \times 0.137\right) = 11420\left(\frac{kgCO_2}{yr}\right) = 1.3\ kgCO_2/hr$$

From this it is seen that using induction stovetops produces 13 times less CO2 emissions than that of gas stovetops. Over the life time of these stovetops, this is an incredible amount of savings.

The above calculations are assuming 100% efficiency throughout the transmission and distribution of electricity and natural gas; however, this is not the case. The *U.S Energy Information Administration – Independent statistics and Analysis* claims that in 2007 the national level losses from transportation, transmission and distribution of electricity were 6.5% (FAQ, 2007). Although the amount of gas leaks through pipelines, compressors, joints and other parts of the system are related to the distance travelled, it was found to be on average 1.4% (Natural Gas Transmission - Leaks of Natural Gas, n.d). Therefore, they are more energy losses in the transportation of the power source for induction stoves then for gas stoves. However, it only differs by 5.1% and considering that induction stoves at 40% more efficient then gas, this loss in energy is almost negligible.

5.0 CONCLUSION AND RECCOMENDATION

The use of Induction Stoves was considered for use in the UBC Student Union Building. Induction stoves were compared to natural gas stoves from an economic, social, and environmental standpoint. Economically induction stoves have higher start-up costs, however looking at energy price projections, we found that induction stoves would be cheaper than natural gas over a 25 year comparison. The payback time is approximately 23 years for a natural gas stove. Induction stoves are more efficient and therefore give off less waste heat. This higher efficiency translates to lower kitchen temperatures and lower heat stress experienced by workers. Induction stoves do not present a radiation threat to the user. Radiation levels were found to be low, and at frequencies which die out quickly. Pacemakers also have not proven to malfunction, when used near induction stoves. Environmentally induction stoves have been found to give off 13 times less carbon dioxide emissions than natural gas. This is a large asset to the LEED Platinum certification.

Weighing the information found both for and against induction stoves, we recommend that induction stoves be used in the new SUB. We feel that the large upfront costs are offset by the environmental and social benefits.

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