Measuring the Carbon Footprint of Eden Mills, Ontario

ENVS*4012

Zhi Chen, Cameron King, Nathan McFadden, Jeffrey Ord, Ashley St Hilaire, Matthew White

April 1, 2008

University of Guelph
Faculty of Environmental Science

Eden Mills Going Carbon Neutral
Student Project Team
April 1, 2008

Dr. Paul K. Sibley
Faculty of Environmental Science
University of Guelph
50 Stone Road East, Guelph, Ontario, N1G 2W1

Dear Paul K. Sibley,

The Carbon Neutral Student Project Team takes great pleasure in submitting "Measuring the Carbon Footprint of Eden Mills, Ontario" as required for completion of ENVS*4011/12.

Within this report you will find the following sections: an executive summary that provides a brief overview of the project in its entirety; an extensive literature review; a brief introduction to the Carbon Neutral project; a concise statement of the goals and objectives; a section describing the methodology used to complete the Carbon Neutral project; a results section following the aforementioned methodology; an in depth discussion of the observed results; a thorough recommendations section; and lastly, a conclusion section.

We hope to find that the Faculty of Environmental Science is satisfied with our project's final report. If you have any questions or concerns please do not hesitate to contact us directly at: carbon.neutral2008@gmail.com.

Sincerely,

The Carbon Neutral Project Team:

Zhi Chen	Cameron King	Nathan McFadden
Jeff L. Ord	Ashley St Hilaire	Matthew White

Executive Summary

Eden Mills is a small village located within the Guelph-Eramosa township of Wellington County, Ontario. They have recently decided to launch an initiative to become the first Carbon Neutral Village in North America. This journey began as the village recognized their growing contributions to the climate change problem through increasing CO_2 emissions.

The involvement of the Carbon Neutral Student Project Team focused mainly on developing a carbon survey and calculator to determine the village Carbon Footprint which is defined as their total annual CO_2 emissions. The initial Carbon Footprint is an essential step towards Carbon Neutrality, as it determines the baseline emissions that the village must work towards lowering, through reduction intiatives and sequestration projects.

A literature review was completed in order to gain basic information on how to develop a carbon calculator, develop a survey, and present these results to participants.

With consultation from Richard Lay from Enermodal Engineering Ltd., our client Charles Simon, and survey advisors Linda Melnick and Brenda Taylor, a final carbon survey was developed. Participants were surveyed interpersonally at the Eden Mills Community Centre late in of January 2008.

Collected survey data was entered into the carbon calculator which was constructed using Microsoft Excel and CO_2 emission coefficients obtained from government sources, internet carbon calculators and available literature. The final result being the projected Carbon Footprint of 4607.9 t/yr of CO_2 for Eden Mills calculated as the total amount of CO_2 emissions from households, the Eden Mills Community Centre and Edgewood Camp.

To communicate participating households' Carbon Footprints, an appropriate media format was developed. A newsletter format was created and will be emailed or mailed to participants which will include universally accepted energy reduction recommendations. It is hoped that participants will make use of these recommendations to reduce their household Carbon Footprint thereby easing the burden of CO_2 that requires sequestration.

Table of Contents

Table of Figures and Tables

1.0. Introduction

Climate change has been a contentious political, socio-economic and environmental issue in recent years, sparking many debates on how and why it is happening and what can be done to stop it. It has been widely accepted among experts and the public today that one of the main culprits inducing global climate change has been the anthropogenic contribution of Carbon Dioxide (CO_2) to the atmosphere. However, political action to battle climate change has been less than satisfactory and with the recent withdrawal of Canada from the Kyoto Protocol, the hope of tackling this issue has become less of a reality for many Canadians.

Eden Mills, a small village on the outskirts of the township of Guelph-Eramosa has nevertheless taken a proactive stance on this issue. Recognizing that all individuals contribute in some way to climate change they have embarked on a five-year long grassroots endeavour to reduce their carbon emissions and become the first Carbon Neutral village in North America. Inspired by the actions of Ashton Hayes, the first village attempting to become Carbon Neutral in the United Kingdom (Alexander and Degg 2007), Eden Mills aims to follow their footsteps to achieve Carbon Neutrality in their community. As a grassroots program Eden Mills is proceeding without political affiliation but is open to their contributions or assistance.

The grassroots program includes a variety of steps addressing transportation, education, carbon sequestration and green power. Furthermore, determining the Carbon Footprint of the village will assist villagers in understanding their own contributions to the climate change problem. Following the actions of Ashton Hayes (Alexander and Degg 2007) a voluntary carbon survey was conducted of the households in Eden Mills.

As fourth year environmental science students from the University of Guelph we developed and administered this carbon emissions survey and associated carbon calculator. To

accomplish this we critically reviewed other carbon calculators available in North America (Zerofootprint Inc 2006; Nature Conservancy 2007) as well as the one used by Ashton Hayes (Alexander 2006) in order to assemble survey questions that are best addressed to the specific CO_2 emissions in the village of Eden Mills. Survey questions are based on calculating CO_2 emissions as well as determining the main sources of CO_2 from each household. We conducted an interpersonal trial survey of 15 households in December 2007 and conducted the full interpersonal survey in January 2008. Over the following months we inputted the surveyed data into our calculator to gain the village's Carbon Footprint. Further analysis of the collected data followed as we determined the total amount of carbon emissions per household in Eden Mills. Essentially, this will be the Carbon Footprint for Eden Mills. The survey we constructed is repeatable, as it will be performed each year to monitor changes in carbon dioxide emissions per household. Furthermore, household data will be assessed to offer general suggestions that can be used to reduce carbon emissions. The recommendations for households, along with the compiled survey results will be emailed or mailled to most residents and will be available in the early spring of 2008.

In this report, there is a detailed description of this project including a: literature review; methodology; results, discussion and recommendations. Any comments or questions concerning this proposal can be directed to the communications liaison, Ashley St Hilaire by email at carbon.neutral2008@gmail.com.

1.1. Goals and Objectives:

The goal of the project was to calculate the total Carbon Footprint for the village of Eden Mills, Ontario.

Objectives:

1) To develop and conduct a carbon survey in which the collected survey data can be used to calculate CO_2 emissions.
2) Input the survey data and calculate household and total village Carbon Footprint.
3) Create a poster that communicates to the public the methods used as well as the results of the Carbon Footprint.
4) Develop a feedback brochure, which gives survey participants their emissions results and includes general household and personal methods to reduce their Carbon Footprint.
5) Create a comprehensive report outlining the entire development of Eden Mills Carbon Footprint.

2.0. Literature Review

2.1. Climate Change

2.1.1. Carbon dioxide, Climate Change and Global Warming

Climate change is the term given to changes in weather patterns that a region experiences due to changes in temperature, precipitation and atmospheric circulation, these variables are governed by the greenhouse effect (Environment Canada 2007a, Michener *et al.* 1997). Earth's atmosphere allows short-wave radiation (visible light) to pass through, consequently heating the surface. Greenhouse gases such as water vapour, carbon dioxide and methane trap long-wave (infrared) radiation emitted by the Earth's surface due to heating, referred to as the greenhouse effect (Taylor 1991). Naturally, the greenhouse effect supports all life on earth by sustaining an average temperature of 15^{o}C; otherwise the average temperature would be -18^{o}C (Environment Canada 2007a). The magnitude of the greenhouse effect is dependent on the concentration of greenhouse gases (GHG) in the atmosphere, which can be increased by natural processes and human activities. The increase in greenhouse gases disrupts the energy balance equilibrium, which leads to rising temperatures within the atmosphere (Taylor 1991). Natural release of greenhouse gases are derived from, but not limited to, the decay of organic material, animal respiration and wastes. Anthropogenic greenhouse gases result from burning fossil fuels, industrial processing and agriculture production, which contribute most to climate change (Environment Canada 2006, Taylor 1991). Auld *et al.* (2006) indicates anthropogenic sources contributed the most to rising temperatures in the past 50 years. According to Environment Canada (2007a), water vapor represents 65 percent of total greenhouse gases while carbon dioxide represents 25 percent and other gases account for 10 percent.

The main gas causing climate change concern is carbon dioxide. However, carbon dioxide is the least efficient greenhouse gas for trapping long wave radiation; this is referred to as the Global Warming Potential. For comparison, carbon dioxide has a Global Warming Potential of 1 while methane has a Global Warming Potential of 21 (Houghton *et al*. 1996 as cited in Environment Canada 2007a). This indicates a methane molecule is 21 times more influential on climate than a carbon dioxide molecule over a period 100 years. The high atmospheric concentration of carbon dioxide (compared to other greenhouse gases) from anthropogenic sources contributes the most to the greenhouse effect (Taylor 1991). Comparing the amount of carbon dioxide and methane released in Canada in 2004, approximately 114 times more carbon dioxide was released, 593,000 kt of carbon dioxide (CO_2) compared to 5200 kt of methane (CH_4) (Environment Canada 2006). On a global scale, carbon dioxide concentrations have increased from 336 ppm in 1979 to 380 ppm in 2006 while methane increased from 1559 ppb to 1775 ppb during the same period (National Oceanic and Atmospheric Administration 2007). To further illustrate the effect of carbon dioxide, it takes 120 years for its mass to decay to 37 percent of its initial mass, compared to 10 years for methane (Rodhe 1990). The combination of high emission rates, high atmospheric concentration and long decay time for carbon dioxide have enhanced the greenhouse effect and made it the biggest contributor to climate change.

2.1.2. Impact of Climate Change

Greenhouse gases have increased to levels that scientists have concluded are changing the climate, the effects of climate change are both severe and global in nature (Auld *et al.* 2006). According to Boland *et al*. (2004) and Auld *et al.* (2006), temperatures are expected to increase more in cooler climates relative to warmer climates. In other words, temperatures in northern

latitudes are expected to increase more than southern latitudes; similarly, winters will be warmer relative to summers. In relationship to climate change, weather events such as droughts, rainstorms and tropical storms are expected to increase in frequency and intensity accompanied by severe fluctuations in temperatures (Auld *et al*. 2006). In Ontario, the temperature is expected to increase by 3^{o}C over the next 100 years while precipitation is expected to increase by 15% annually if carbon dioxide concentrations are doubled (Griefenhagen and Noland 2003, Auld *et al.* 2006). Consequently, the increase water volume and flow rates in rivers caused by increased precipitation will increase erosion leading to increased suspended sediments which results in lower water quality (Auld *et al*. 2006). With these changing atmospheric conditions human health, animal diversity, plant diversity and diseases will be impacted globally.

A number of human health related illnesses are attributed to changes to the current climatic conditions (Martens 1999, McMichael *et al.* 2006). For example, higher temperatures in urban centres are increasing the number of heat waves and smog days during summer; Toronto estimates 120 premature deaths per year (Martens 1999, OAGC 2006). Also, allergic disorders such as asthma and hay fever are expected to increase as a result of longer pollen seasons due to longer and warmer summers (McMichael *et al.* 2006). Additionally, the risk of food poisoning is greater at higher temperatures, specifically the proliferation of *Salmonella* spp, which cause Salmonellosis disease where symptoms include diarrhea, vomiting and abdominal pain (McMichael *et al.* 2006, Bentham and Langford 2001 and Barbara *et al.* 2000). Human health concerns represent a major factor for adopting climate change policies.

According to Boland *et al.* (2004), climate change will affect the occurrence of plant pathogens in the agricultural and forestry sectors. For example, the fungal pathogen *Phaeoisariopsis griseola* is known to cause angular leaf spot in beans. The United States have

reported yield losses of 50 percent due to angular leaf spot (Hagedorn and Wade 1974 as cited in Boland *et al.* 2004). In Ontario, *P. griseola* is expected to survive the milder winter as a result of higher temperatures due to climate change (Boland *et al.* 2004). Similarly, Boland *et al.* (2004) reports the Dutch elm disease and the Cucumber mosaic disease will have increased occurrences, progress and duration as a result of warmer temperatures. Lengthening the life span of pathogens in the agricultural and forestry sectors through climate change could have dire consequences on food supply and the natural environment, especially with a growing population.

The effects of climate change on the health and survival of animal and plant species are detrimental. A study by Thuiller *et al*. (2005) examined the distribution of plant species in Europe in relation to changing climatic variables, such as temperature and greenhouse gas concentrations. The study concluded that many European plant species could be threatened or extinct as a result of climate change. Under the worst-case scenario, where species cannot migrate, with an atmospheric CO_2 concentration of 800 ppm and a temperature rise of 3.6^{o}C will result in more then half of the species in the study being extinct by 2080. Under less extreme scenarios 67 percent of species are classified as low risk according to the International Union for Conservation of Nature Red List Assessment. Similarly, Thomas *et al.* (2004) reports 15 percent to 37 percent species extinction by 2050 including both animal and plant species. The consensus is that if extreme shifts in climate occur, plants and animal species may not be able to adapt to the new climate quick enough to survive (Auld *et al*. 2006).

Auld *et al*. (2006) reported on the impacts of climate change on the Great Lakes and its coastal communities, such as Toronto, Hamilton and Windsor. These communities depend on the lakes for fresh water supply, recreation and marine transport. The continual urbanization and industrialization of coastal communities will add to the impact by climate change. Since the early

1900's, communities surrounding the Great Lakes have experienced average annual air temperature increases of 0.7^{o}C. As a result of warmer air temperatures and milder winters, the amount of evaporation from the Great Lakes is expected to increase. Consequently, water levels in the Great Lakes are expected to drop by up to one meter, severely affecting the ecology of riparian zones, marine transport and fresh water supply. For example, if riparian zones dry up they will destroy wildlife habitats. Dredging to deepen channels and harbors to allow commercial transport/shipping will damage aquatic environments and increased dry periods during the summer will increase pressure on water supply. In the past, Toronto has asked residents to reduce water usage during hot and dry weather because of water shortages (City of Toronto 2005). On the other hand, regulating water levels through dam structures can mitigate low water levels, however the magnitude of regulation on the natural environment is controversial as the damages and benefits are not fully understood. In contrast, climate change is causing the sea level to rise, which has potentially detrimental effects to oceanic coastal regions (Michener *et al*. 1997, Nicholls *et al*.1999). Nicholls *et al*. (1999) predicts a rise in sea level of 38 cm from 1990 to 2080. This will result in the loss of 22 percent of coastal wetlands and the flooding of populated coastal communities will increase by five times. Climate change will decrease fresh water levels but increase sea levels; both are detrimental to natural and anthropogenic environments.

2.1.3. Carbon Neutral and Eden Mills going Carbon Neutral

The impact of climate change is severe both ecologically and anthropologically. If greenhouse gas emissions are not stabilized, the impacts of climate change will be very real. Carbon neutrality is the concept of balancing one's carbon emissions through reduction and

sequestration, ultimately achieving net zero carbon emissions (Eden Mills Millpond Conservation Association Inc, 2007). There are two courses of action that must be taken to achieve carbon neutrality. The first task is to reduce the amount of carbon emitted. This can be as simple as turning off lights, less driving or lowering the thermostat, in other words using less energy. However, the second task of carbon dioxide sequestration is more difficult because it involves mechanisms for carbon absorption with vegetation. Povellato *et al*. (2007) concluded that agriculture and forestry could effectively abate greenhouse gases at a competitive cost. Eden Mills plans to embark on an afforestation project in 2008 to complete this task.

The Canadian Federal government has created a CO_2 mitigation plan (Simpson *et al.* 2007), however significant action has yet to occur. On the other hand, the Ontario Provincial government has created its own emission targets for the coming years. According to the Government of Ontario (2007), in the short, medium and long terms, Ontario has set greenhouse gas targets at 6 percent, 15 percent and 80 percent below 1990 levels by 2014, 2020 and 2050, respectively. In 1990, Ontario's total greenhouse gas emissions were measured at 177 million tonnes. Given Ontario's current economic and population growth, it is estimated in 2020 that greenhouse gas emissions will reach 249 million tonnes. To mitigate these emission projections, Ontario has already implemented policies and initiatives to reach these goals, including (Government of Ontario, 2007):

- Coal Phase Out: Have reduced GHG emissions from coal power plants by 1/3 from 2003 to 2006.
- Renewable electricity generation: makes generating renewable energy cost-effective for businesses' to sell energy to the Ontario grid.
- Creation of the Greenbelt: protects environmentally sensitive areas from urban development. Effectively reduces urban sprawl and pollution.

- Places to Grow Act: promotes and sets targets for more environmentally sustainable urban centres.
- Ontario's new Building Code: improves energy efficiency of new housing and businesses.

The rising concerns of climate change have prompted villages such as Eden Mills and Ashton Hays to attempt carbon neutrality. Eden Mills Going Carbon Neutral project is a grassroots initiative that involves little or no political affiliation. Their project is inspired by the actions taken by the English village of Ashton Hayes to achieve Carbon Neutrality. Alexander *et al.* (2007) have outlined the steps taken by Ashton Hayes, which have been the inspiration of Eden Mills Going Carbon Neutral Project. Charnock (2007) applauds the success of the Ashton Hayes initiative and recounts how a number of other villages in both England and other countries expressed interest and request information on how they can mitigate their emissions.

2.2. Carbon Coefficients

2.2.1. Intergovernmental Panel on Climate Change (IPCC)

The IPCC was established in 1988 in order to investigate the scientific, technical and socio-economic information relevant to the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation. One of the projects that the IPCC has undertaken is a uniform methodology in determining greenhouse gas inventories. The greenhouse gas inventory is the calculation of every countries greenhouse gas emissions, including CO_2. Working closely with the Organization of Economic Cooperation and Development (OECD) and the International Energy Agency (IEA), a program was developed to

create a plan for countries to measure their total carbon emissions, as a starting point for mitigation opportunities.

The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories is the publication which outlines how to determine carbon inventories. In this document, methods for determining fuel combustion estimates were developed by forty experts from various related fields. CO_2 is one of the easiest gases to estimate combustion emissions and can be done based on their simplified tier 1 assessment. Other greenhouse gases such as N_2O, SO_2, NO_x, CO and CH_4 are more difficult to determine and require more information on how the fuel is combusted to accurately determine emissions. Measuring CO_2 emissions is a good starting point for developing a Carbon Footprint as it is easier to estimate and is the primary source of radiative forcing (60 percent pre-industrial time) and accounts for 70-90 percent of fossil fuel emissions (IPCC 1996). Radiative forcing according to the United Nations Environmental Programme (1996) "is the change in the balance between radiation coming into the atmosphere and radiation going out" therefore CO_2 accounts for 60 percent of the increase of radiation being re-emitted towards earth resulting in climate change.

The IPCC (1996) report highlights that CO_2 emissions can be estimated from energy activities via energy supplies. CO_2 emissions are also expressed in relation to the energy content of fuel; this reduces the variation of carbon and energy content by weight of fuels under the IPCC's directions. They also outline that fuel supply and fuel content give enough information to estimate CO_2, but suggest that due to changes in fuel quality, emissions factors can very from place to place and therefore local data should be used as much as possible (IPCC 1996).

2.2.2. American and Canadian CO_2 Coefficients

The U.S. has created a list of CO_2 emission coefficients based on fuel types which can be found at the Energy Information Administration (EIA 2008) website. All of their emission factors are based on the IPCC guidelines for determining carbon inventories. Canadian sources of CO_2 emission factors have been derived from numerous studies and tests conducted by Environment Canada (2007b), the US EPA (2008) and a number of other domestic and international organizations. Canadian CO_2 coefficients include CO as well as CO_2 under the assumption that any CO emissions are entirely oxidized to CO_2 in the atmosphere shortly after combustion. The emission factors used in Canada's GHG inventory are based upon the physical quantity of fuel combusted, rather than on the energy content of the fuel. This marks a significant deviation from IPCC (2006) methodology which as previously noted measure emissions in relation to energy content. According to Environment Canada (2007b) emission factors based on the physical quantity of fuel combusted provide a more accurate estimate of emissions. Fewer conversions are required to derive estimates; also because the quantity of fuel consumed is reported in physical units to Canada's statistical agency, accuracy is maintained.

The Canadian set of coefficients, however, does not supply a single factor for any biofuels. Environment Canada (2007b) explains that since CO_2-CO emissions change depending on what type of tree species biofuel is being combusted, therefore there is a unique factor for each species. The US EIA (2008) does provide a single CO_2 coefficient for biofuels on the basis of weight. Since most public purchasers of wood do not buy on a basis of weight but rather by cord (4’x4’x8’) it becomes important to know how much an average cord of wood weighs. Dewald (2005) provides the average weight of a cord of wood, booth wet and dry, for some of

the most common species of trees in North America. Using the weight of the wood burned will give a more accurate estimation of the amount of CO_2 emitted from that source.

2.2.3. Fuel Efficiency

When calculating CO_2 emissions for personal transportation the most pertinent information required is personal fuel efficiency based on actual mileage and the fuel use. Using personal fuel efficiency information allows for the individual habits of each driver to be incorporated into CO_2 emissions. The personal fuel efficiency allows for the most accurate calculation of CO_2 emissions, especially because there are many different driving styles. Hedges and Moss (1996) conducted a test in a driver training course on the beneficial gains from changing driving habits and they concluded that the changes increased fuel efficiency from 14.58 miles per gallon to 14.67 miles per gallon in just 3 months. Other habits such as keeping tire pressure and driving with windows rolled up can also increase the fuel efficiency of a vehicle. If personal fuel efficiency cannot be acquired it is possible to attain general fuel efficiency from individual car manufacturing companies, yet (based on our own comparisons) these statistics have a tendency to underestimate the actual efficiency of vehicles. Also the US department of energy (2008) has a website which contains every make and model of car and contains the "new" fuel efficiency of the car in the year of its make as well as consumer sent fuel efficiency information. It is often easier to find fuel efficiency on the US department of energy website since survey respondents may not always have their fuel efficiency information available when surveyed.

2.2.4. Ontario Power Emissions Coefficients

CO_2 coefficients for Ontario power generations are available from Enermodal Engineering Ltd (Aussant, 2007). The coefficients are based on the Environment of Canada GHG Inventory (2007b) publication discussed earlier. Also it is important to note that the coefficient includes all sources of Ontario electricity generation, however, on operational levels hydro, nuclear, and biomass are not considered to produce GHG. The data used in developing the CO_2 emission coefficient are from 2004 and the coefficient is 0.222 kg/kWh. Ontario Power Generation (2000) has also released a CO_2 coefficient of 0.19 kg/kWh, which demonstrates that there is a range in the estimated emissions.

2.2.5. Public Transportation and Air Travel

Information on public transportation and air travel posed a considerable challenge. A considerable amount of research papers concerning buses contained information on particulate emissions as opposed to actual CO_2 emissions. Also each study provided different coefficients regarding emissions. For example Nigel *et al.* (1999), measured a difference in CO_2 emissions of 100 g/mi depending on whether the bus ran on diesel or natural gas. Coefficients for air travel also have many discrepancies especially since there are numerous types of planes for different flights. Depending on the distance of the flight there are a number of different sized airplanes which could be used. Generally the longer the flight the bigger the plane and the more CO_2 will be emitted. Babikian *et al.* (2002) further illuminated the difficulties with air travel by explaining that regional aircraft are 40-60% less efficient then larger narrow and wide bodied jets. Furthermore, differences in fuel efficiency rise in a large part due to changes in operation as

opposed to technology when comparing aircraft (Babikian, 2002). Another difficulty in creating coefficients for personal travel is that total emissions from the trip must be divided by the average number of passengers on the plane or bus or train. The number of passengers on a particular vessel is difficult to determine; the fact that a jumbo jet is used to fly to London does not give an indication of the number of people on the flight. Vincent (2006) determined the CO_2 emissions of public transport by using the total number of passengers over a year and dividing that by the emissions of the fleet, this method is difficult to use for a village like Eden Mills where any transport is out of town. Flights coefficients would also be difficult to determine using this method since there are so many different locations and variables to consider.

2.3. Ashton Hayes going Carbon Neutral

2.3.1. Background Information

The village of Ashton Hayes is a civil parish in the Chester District of Cheshire, England. The village has a population of 919 and is located approximately 8 miles east of Chester. In November of 2005, the Parish Council of Ashton Hayes voted to become England's first Carbon Neutral village. The idea to obtain Carbon Neutrality was proposed to the Parish Council by a village resident, Garry Charnock, after he discussed the projects feasibility with Dr. Roy Alexander, who agreed to seek support from the University of Chester (Alexander 2007). Dr. Alexander, a Geography professor at the University of Chester, undertook the task of developing a carbon survey to measure the Carbon Footprint of Ashton Hayes' (Charnock 2007). The Carbon Footprint is an assessment of the annual Carbon Dioxide emitted by villagers of Ashton Hayes. Student volunteers were recruited to help administer the survey and bolster community

support for the project. Charnock was also able to gain support from Energy Savings Trust (EST) and Energy Projects Plus (EPP), which offered free advice on energy efficiency matters (Charnock 2007). It was after Charnock had the support from both EST and EPP, and the University of Chester, that he decided to propose the idea of Carbon Neutrality to the Parish Council of Ashton Hayes. Alexander (2007) stated that the Parish Council voted to support the project on the condition that Charnock held an event that would put the proposal before village residents; this event became the formal launch of the project on January 26th, 2006. The event attracted interest from local businesses which sponsored banners, display boards, and even English sparkling wine (Alexander 2007). In his 2007 article featured in the Local Economy, Dr. Roy Alexander stated this support resulted in a high profile launch which included extensive media coverage thereby providing sponsors of the project with a great deal of exposure. According to Alexander (2007), as a conclusion to the launch meeting, members from the county, the city, and Parish Councils provided practical energy saving advice by means of an exhibition featuring stalls from both the private and public sectors. Lastly, Dr. Alexander presented an outline of planned steps, the University's five year commitment, and the information required to calculate the village's Carbon Footprint (Alexander 2007), which will be discussed in more detail in the proceeding section.

2.3.2. Ashton Hayes' Carbon Calculator/Survey

The first and most important step for Ashton Hayes' attempt at Carbon Neutrality is the development of an effective survey and carbon calculator to measure the community's Carbon Footprint. The survey, which is included in the Ashton Hayes 'Measuring your Footprint Toolkit CD' (Alexander 2007), was developed by Dr. Alexander's and his geography students and is

comprised of 31 questions divided into sections pertaining to home energy use, travel and transport energy use, and miscellaneous question regarding household habits (Alexander 2007). Responses to a portion of these questions are used in the carbon calculator to measure CO_2 emissions, and the remaining answers are compared to advice given by the Energy Savings Trust office to determine if a household's habits are "energy efficient" (Alexander 2007) (See Appendix E For Survey Questions). An important aspect of the Carbon Footprint measurement is the development of a calculator that will effectively determine CO_2 emissions to a desired degree of accuracy. Dr. Alexander decided that for the scope of the project, it would be sufficient to obtain a baseline measurement of emissions from home and travel (Jones 2007). Alexander (2007) stated that the calculator was written as a Microsoft Excel file which contains embedded macros that compute survey data into a nominal CO_2 emission. After reading the data from each survey form, the correct figures are entered into the calculator one household at a time (Alexander 2007). Once the data was entered they were able to calculate the average household emissions per household type (i.e. detached home, semi-detached home, apartment etc.) Average values were then multiplied by number of household types in the village to determine the overall Carbon Footprint of the Village. These results along with a table of recommended energy-saving actions were sent to village residents as follow-up to the Carbon survey.

Alexander (2007) noted that his calculator does not give an absolute measurement of the Carbon Footprint, but rather an estimate because it is a bespoke calculator, meaning it is based on standard average figures and conversion factors taken from sources such as DEFRA and the Energy Saving Trust rather than using actual energy consumption.

Alexander (2007) credits community participation as the key factor in successfully measuring the village's Carbon Footprint. In the next section, the role of community

participation in a grassroots project will be discussed as well as the effectiveness of community participation in the success of local initiatives.

2.3.3. Community Participation as Keys to Success

One of the key aspects that led to the initial success of the Ashton Hayes' Carbon Neutral project was the overwhelming community participation. During the surveying period 170 out of the 372 households (46% of the village) took part in the project. This large response to the survey allowed an accurate measurement of the village's Carbon Footprint.

The Ashton Hayes' Carbon Neutral Project, nevertheless, is a five year project that requires ongoing community participation. There are a number of ideas that have been presented in literature that offer mechanisms to maintain continued community support throughout the length of community projects. In a 2004 book written by Daniel Burns called: *What Works in Assessing Community Participation*, the key considerations and benchmark tools making community participation effective are discussed in great detail. Burns (2004) found that when developing a local government initiative, like in Ashton Hayes for example, it was vital to have a two way information strategy developed and implemented as a communication tool. A two way communication strategy must foster open, two way communication between the community and initiative organizers. Burns stated that by implementing a two way information strategy, clear and accessible information would reach all community members with enough time to be acted upon. Burns (2004) also postulated that in order for local initiatives to remain effective, adequate resources must be supplied to the community members and community representatives. In the case of Ashton Hayes and Eden Mills, these resources could take the form of community events, newsletters, emails, and websites that relate directly to the project.

Local Environmental Sustainability is a book written Susan Buckingham and Kate Theopold in 2003. The central concern of this book was to examine the way local government interacts with society to promote and develop environmental initiatives. According to Buckingham *et al*. (2003), failure to nurture, or acting in a contradictory way to these projects can have detrimental effects on the projects potential to contribute to environmental sustainability. As an example of this Buckingham *et al*. (2003) described a situation in one London borough where local government supported local initiatives against climate change, while simultaneously sold land to developers that directly increased the amount of traffic in the village. According to Buckingham *et al*. (2003), this type of local government behavior impedes the potential of this climate change project to contribute to environmental sustainability by increasing traffic and thus, greenhouse gas emissions. The success and sustainability of the Ashton Hayes' project will be discussed in the next section.

2.3.4. Ashton Hayes Today

It is now 2008, a little over two years since the Ashton Hayes Carbon Neutral project was launched. Dr. Alexander and the University of Chester continue their five year commitment plan and have been surveying the village annually to measure the progress being made toward their goal of Carbon Neutrality. According to the Ashton Hayes Carbon Neutral official site (Ashton Hayes Parish Council 2007), the village cut its emissions by 20% in the first year alone, which is shown as a graphical representation in Figure 1. Figure 1 shows carbon dioxide emissions in Ashton Hayes in 2006 and 2007 with respect to home energy consumption, vehicle use, and air transportation (Ashton Hayes Parish Council, 2007). As seen in Figure 1, carbon dioxide emissions saw significant decreases among all three of the aforementioned aspects. The village's

Carbon Footprint, as measured in 2006, was 4765.76 tonnes of CO_2, while the footprint measured in 2007 was 3854.93 tonnes of CO_2 (Ashton Hayes Parish Council 2007). The factors

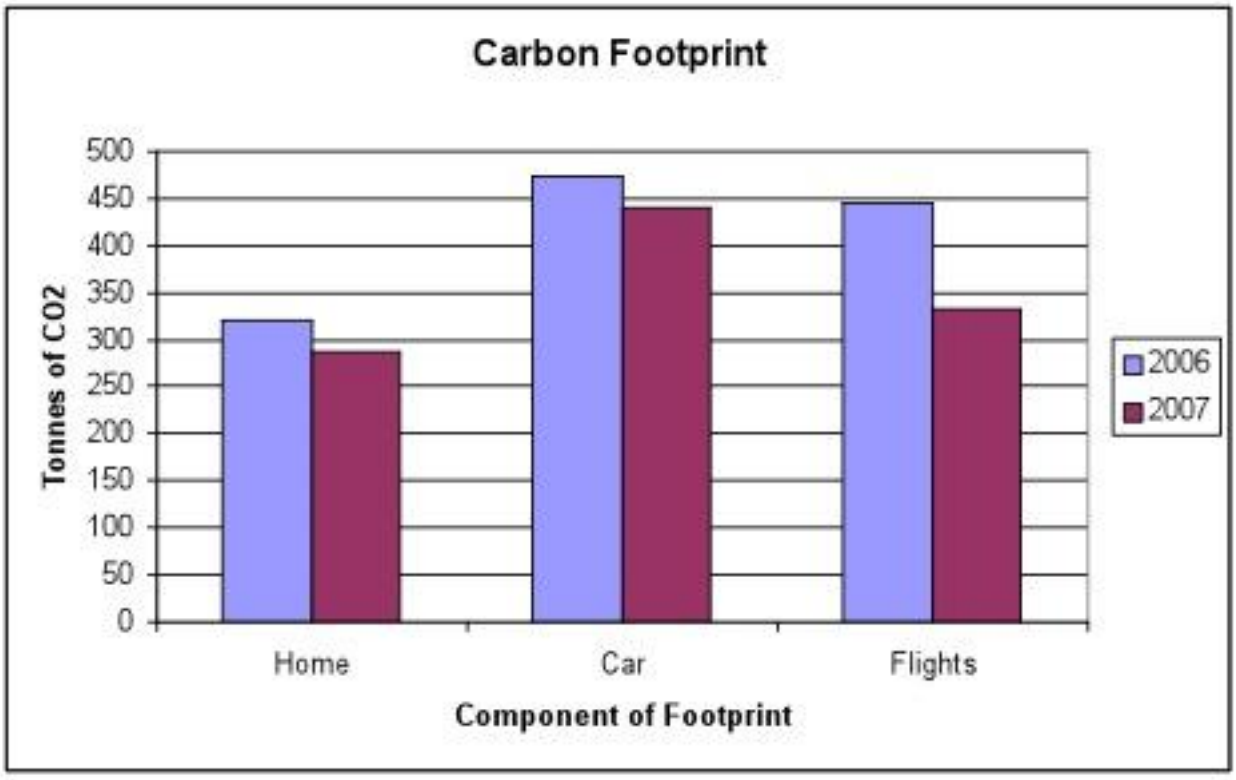


Figure 1. CO2 emissions for the village of Ashton Hayes with respect to home energy use, vehicle use and air transportation during 2006/2007 (Ashton Hayes Parish Council 2007).

leading to this success were researched by MSc Ged Edwards. During his study, Edwards surveyed the households not involved in the 2006 survey and found that 99.4% of households are engaged in environmentally-friendly behaviour (EFB) due to the community awareness made by the local initiative (Ashton Hayes Parish Council 2007). Also, 35% of villagers had become more actively involved in village life through the project. Therefore, launching a local carbon reduction project helped strengthen bonds within the community while simultaneously improving global environmental quality (Ashton Hayes Parish Council 2007). These two points demonstrate that if local initiatives have proper funding and strategy, they can promote

environmental sustainability and improve community welfare (Ashton Hayes Parish Council 2007).

2.4. Survey Design

Brace (2004, p17) truthfully remarks that " [d]esigning a survey involves many more decisions than most researchers realize." Survey design is very important for the Eden Mills Going Carbon Neutral project. It is the tool that will be used to collect villagers carbon information and more importantly, the validity of the results hinge on effective survey response. Survey design can make the difference between successful or chaotic data collection and analysis. Survey design takes many steps to complete, such as outlining the objectives, stakeholder analysis, confidentiality decisions, survey layout and language, survey mediums, survey organization and addressing information problems.

2.4.1. Pre-survey Design

When undertaking the task of collecting data from a survey, it is important to assess the stakeholders in the survey to better understand how it will be most effectively implemented. There are a number of different stakeholders in a survey, so it is important to meet the needs of everyone, without compromising the needs of any groups involved. Potentially, there can be up to five groups involved, starting with the clients. First, the clients will have specific requirements that need to be fulfilled to enable them to answer their objectives. Second, there are the interviewers whom call for a survey that is straightforward to administer. Next, the survey respondents require questions that they are willing and able to answer. Also, the data analysts

need surveys that streamline the data entry process and that are easily understandable. Finally, there is the researcher who must meet the needs of all the above groups, while still completing their objectives (Brace 2004, p8).

Another integral part of pre-survey design is an overview of objectives. This requires that the researcher has a clear understanding of what the general and specific objectives are of the client. This understanding must be met at the onset of a client-researcher relationship to ensure that the conducted research is indeed what is required (Brace 2004, p10). After reviewing the clients' objectives the researcher must translate them in to specific research objectives. This is an important in the case of Eden Mills, so that the survey will effectively address the task at hand. These research objectives will outline the survey design and lead the surveys purpose (Brace 2004, p11). Brace (2004, p12) emphasises that each research objective should not simply be turned in to a question on the survey, but should be studied to understand the information requirements. These information requirements are then craftily turned into questions.

2.4.2. Survey Design and Development

There are a large number of considerations that must be made when designing a survey; a paramount decision that must be made is survey type. Bradburn (1979, p8) outlines four (4) different types of surveys that are: face-to-face, telephone, self-administered, and random response. Also, there exists online surveys (Oishi 2003, p39), which are a type of self-administered survey. Each type has different advantages and disadvantages, so the appropriate survey must be selected for the research objectives. Survey types have different effects on responses and must be taken into consideration. To serve as an example, Bradburn (1979, p9) reveals that face-to-face interviews lead to more information distortion in responses. Oishi (2003

p6) explains that face-to-face surveys are advantageous because they allow respondents to ask questions and this can increase the accuracy of data being recorded. Self administered surveys have more privacy attached to them however, it may not retrieve the same response rates that are necessary (Bradburn 1979, p15). In the Eden Mills Going Carbon Neutral Project, a number of survey mediums may be considered to maximize the response rate.

Crafting the questions that are used in the survey is just one component of the overall success of the survey process. Sykes (1987) outlines a wide range of problems that can arise from survey questions. There are problems associated with the vocabulary level being used, difficulty with the comprehension of concepts being presented, trouble with the question technique being used, and difficulties with familiarity of issues. In some cases, questions may be asking respondents to recall things they are unable to or do not have access to. The Eden Mills survey will require individuals to compile information that they may have difficulty compiling, so this is important to keep in mind when completing the survey process. Also, "question design can influence respondents' intrinsic motivation to answer fully and accurately. For example, the wording of questions may affect the respondent's perceptions of how his/her answer will be judged or evaluated and, consequently, may influence how he/she responds (Sykes 1987, p194)." These problems must be anticipated for and should be addressed while the questions are being formulated. Many of these problems can be tackled by effective wording, as well as layout (Brace 2004, p142).

Survey layout is also very important to an effective survey because it will affect the responses that are received (Brace 2004, p141). Sykes (1987) claims that survey layout is one of the least well understood sources of error in research that is survey based. With this in mind there are many decisions that must be made regarding layout, some of which include paper orientation

and font size. Effective design can minimize the error that Sykes (1987) describes. The effective use of space is very important, yet overcrowding can have negative effects on the survey process, from responses and questions to data entry (Brace 2004, 142). The use of bold and italics can also be very useful for highlighting pertinent information and instructions (Brace 2004, p145). Routeing is an concept related to survey layout that is described in the literature (Akkerboom and Dehue 1997; Belson 1981,p389; Brace 2004, p148; Oishi 2003, p40). This is a survey design element that leads the surveyor and respondent through the questions in a logical manner that will aid the quality of the responses. This technique is well employed when questions need to be skipped if answers are dependent upon previous questions (Brace 2004, p149). Brace (2004, p149), as well as Akkerboom and Dehue (1997), warn that this technique should not be overused or misused because it has potential to become confusing.

Finally, before surveys are fully implemented, they must be tested to determine if there are going to be any unforeseen problems. Akkerboom and Dehue (1997) provide a five step survey testing procedure that researchers can implement to maximize the effectiveness of a survey. The five step procedure involves reviewing the survey with the use of incrementally larger sample test respondents. This process is used to help modify the survey until the survey reaches its final form. Belson (1981) describes a detailed question testing process that emerged from his exhaustive research on respondent response to 29 survey questions. In short, Belson's (1981) question testing method requires each question to be tested separately, where the administer reiterates the questions and probes the respondent on how they arrived at answers. The process also requires a checklist to determine how each concept in a survey question is interpreted by the respondent. It is very important that some testing and refinement of the survey

be done before full implementation of the survey to minimize errors and misunderstandings that will occur.

2.4.3. Survey Implementation

Survey implementation is the process whereby the surveys are administered to the respondents and data collection takes place. There are many considerations that must be addressed in this part of the survey process. This includes issues with sampling, advanced letters, consent, interview environment, interviewer speech and behaviour, and survey tracking.

Oishi (2003, p61) argues that "the methods chosen for finding and screening participants should maximize the chance that people with the necessary characteristics can be found and that enough eligible respondents are interviewed to provide a representative estimate of the views or experiences of the larger population." She argues that sometimes it is difficult to gain participation; large recruitment list must be established to ensure there will be sufficient data collected. Proper sampling is the first task when a survey is going to be implemented (Oishi 2003, p61).

The use of advance letters, or preliminary letters, is sometimes a useful tool for the survey process. An advance letter is a letter that is sent to the respondents about the survey before the survey is administered. Often the letter would be on official letter head, which creates validity and importance of participation in the eyes of the respondent. This is a useful attribute for surveys because it can increase the response rates (Brace 2004, p153). Further, the letter can be used to secure a time and place that the survey will be administered. Also, the advance letter informs survey participants of the purpose, goals and objectives of the survey research. The advance letter can also be used to prepare the respondents for questions that they will have to

answer. Alternatively, pre-calls can be used with the same purpose of a pre-letter but are slightly less formal (Brace 2004, p155; Oishi 2003 p73). Either tool is very useful and can be implemented depending on the goals and objectives of the survey research.

Gomatam *et al*. (2005) brings attention to the increasing concern of appropriate data dissemination over time and space while still protecting confidentiality of respondents. This is a problem that must be overcome in survey research and it is often done via informed consent of the participants. Informed consent can be gained verbally or in a consent form. A consent form should be given to participants before the survey is administered and should outline what type of information will be asked of the respondent in the survey so they can make an informed decision (Oishi 2003, p76). The consent form will notify the respondent of what information will be reviled about them or if all information will remain confidential (Gomatam *et al*. 2005).

Interviewer speech and behaviour is a very important aspect of the survey process. It is important that interviewers are familiar with the survey so it can properly be administered. If the survey process is easy and smooth for the respondent, there will be better responses. This requires the interviewer to use an appropriate language level for the group that is being interviewed, if the language is too difficult to understand than there will be problems with responses (Belson, 1981, p189). Smit *et al*. (1997) concluded that suggestive behaviour and speech can have effects on responses that are positively correlated with the suggested behaviour. Similarly, feedback and probing of respondents will have some positive effect on the responses that are given because respondents will anticipate the answers that are suggested to be received (Bradburn 1979, p37). Behaviour of the interviewer can vary and set the tone and mood of the interview environment which, in some cases may be important to control. In the case of Eden

Mills the survey will take place in the Community Centre in the presence of other residents, thereby fostering a community spirit.

The interview environment can affect the outcome of the survey responses as well, such as the location of the interview as well as the setting. Interviews in households make respondents more comfortable to answer questions; where as interviews in sterile interview rooms create an unfamiliar environment that can hinder the responses given (Bradburn 1979, p132). Also interviewing with third parties present can have effects on responses. However, it has been suggested that if the respondent brings a third party to a survey interview, the responses are not affected. Similarly, if there are third parties present that the respondent does not know, there is little affect on the answers given (Bradburn 1979, p135). In the case where there are third parties present that the respondent does know, then there may be a tendency for the respondent to distort answers to questions that are of a personal nature. This is obviously dependent upon the nature of the questions being asked; highly personal information will more often be kept secret by the respondent (Bradburn 1979, p135). The Eden Mill survey will be done in a public place with other individuals in the room, so this may be taken into consideration while surveying.

Another pertinent consideration to be made in the administration of the survey is the use of a numbering system to organize interviewers and respondents. The numbers are called identifier numbers and correspond to a master list of interviewers and respondents. This type of master list is an easy way to organize individuals in the survey and keep track of the surveys themselves. This system assigns an identifier number to each respondent and their survey, each interviewer is given an identifier number that is also indicated on the survey. This process is well implemented when anonymity is important, and therefore can increase the accuracy of the

answers given (Brace 2004, p74). This system allows for the respondent to remain anonymous to the interviewer, and the data analyst while acting as a useful origination tool.

2.4.4. Information Problems

When conducting a survey there will invariably be problems with the information that is collected. These problems are then sources of error when synthesizing data to render results from the surveys. In some cases, this error could be quite large and in others it could be small, the degrees of error are a matter of circumstance. There are a number of sources of error in a survey and it is important that errors be understood and minimized during the survey process. Some of the sources of error that can arise are: question misunderstanding, non-response errors, coverage error, sampling error, "don't know" responses and incorrect answers.

Question misunderstanding is the most well understood source of error in a survey. This source of error is due to the respondents not understanding what is being asked in the question. It can relate to difficulties with understanding a concept, poor wording and complex language, or the use of vocabulary that is too advanced for the group. Measuring this error is difficult and it is suggested that in most cases it may cancel itself out. Misunderstanding can affect both positively and negatively on the response averages, thereby making the source of error moot (Belson 1980, p189). Bradburn (1979, p158) argues that the vocabularies of individuals vary greatly among similar groups of people, so it is important to keep the wording of questions simple and easy to understand thereby minimizing question misunderstanding.

Another source of error is survey non-respondents. These are classified as individuals of the population that are not included in the survey because they refuse to participate (Groves 1987, Sjostrom *et al*. 2008). This becomes a source of error when many individuals do not

participate because there is an underrepresentation of data in the survey results (Groves 1987). This underrepresentation then leads to bias in the results. However, this can be accounted for by weighting the underrepresented groups more heavily in the final results, although this requires that the surveyors know to what degree those individuals are underrepresented (Groves 1987). Sjostrom *et al*. (2008) point out that non-response rates in surveys have increased by ten percent in the last decade but this increase is thought to not increase bias in survey results. Coverage error is related to non-response error and is described as "the discrepancy between the sample survey results and the results of a full enumeration of the population under study which arises because some members of the population are not covered by the sample frame (Groves 1987)." This may be important in Eden Mills because individuals from a particular part of the village may be uninterested in participating, as a hypothetical example, the individuals that commute to Toronto daily may return home too late to participate in the survey. Coverage error is somewhat different from non-response error but can create the same bias in results. On the other hand, sampling error is a deliberate exclusion of individuals from participation in a survey, which makes errors non-random and will create some bias in the survey results. In Eden Mills there are some individuals that live outside the village border, yet still want to partake in the survey.

There is some debate about what effect "don't know" responses have on survey results (Brace 2004, Francis 1975, Groves 1987). A "don't know" is a response to a question when the respondent does not know how to answer. This is thought to be a result of complexity of the question or of respondent confusion (Brace 2004, Francis 1975). Survey analysts have difficulty managing don't know responses, but it is thought that it is an important component of a survey and should be mentioned in results, if not included (Brace 2004). Francis (1975) concluded that " low-educated, low-income, non-involved respondents with low political efficacy" will give a

higher proportion of "don't know" responses. This indicates that in a general population sample, "don't know" responses are not random and therefore create a source of bias that should be considered in survey analysis (Francis 1975).

Another major source of error is incorrect responses to questions, which has largely been unstudied (Sjostrom *et al*. 2008). This can be a result of miswriting a response, a lie, or an honest mistake, such as a respondent 'knowing' the wrong answer. Sjostrom *et al*. (2008) conducted a survey that involved asking respondents simple personal questions (i.e. the last time they visited the dentist or their social insurance number) and found that there was about a ten percent discrepancy between responses received and the correct answers. This type of error must be acknowledged when analysing survey results and formulating generalizations about a population.

Survey design and analysis is a complex process that must account for many variables throughout the process. The success of survey research is largely dependent upon the preparation and thoughtful decisions that are made by a survey researcher before and after the surveys are conducted. As it has been briefly outlined in the above sections, there are a number of considerations that must be addressed, including the outlining of the objectives, stakeholder analysis, confidentiality decisions, survey layout and language, survey mediums, survey organization and information problems. If these topics are addressed and accounted for then there is a greater chance at a successful survey, and strong results.

2.5. Effective Feedback Formation

2.5.1. Constructing a Participant Feedback Medium

One aspect of the Eden Mills Going Carbon Neutral project, is the survey participants receive feedback related to their Carbon Dioxide footprint. As the survey will be repeated annually it is very important to keep residents updated on their progress, as a town, towards their goal of Carbon Neutrality. Writing the most effective feedback medium is of paramount importance as the project solely rests on public participation, interest and by failing to provide feedback could result in less participation in following years.

Preparing this information in the form of a brochure presents some obstacles. Climate change is a topic which most have heard about *ad nauseum*. Even the jargon used to describe it may be common to most readers. The main problem within communicating climate change information is that there are only few certain facts, more probable effects and mainly unknown open questions (Smith 2000). Also the average reading grade level is Grade 8 for the general population so vocabulary and grammar may pose a limitation as well (Monroe 2007).

There are many brochures targeted on the avoidance of certain behaviors. In the medical field, many brochures are present to raise awareness and provide information. Recently, more brochures promoting awareness towards environmental issues have been produced. Environmental issues are more difficult to convey then health related brochures as they affect one's life directly, environmental issues do not always do the same. When it comes to influencing behavior an effective message is important.

The two important aspects of creating the brochure are the formation of the message and the assembly of the message. Images, text, layout and even type of paper are qualities that must be considered to maximize the influence of the brochure.

2.5.2. Message Formation

Many people feel that the environment is of great importance, but their actions do not always reflect this belief. This is not just common in small towns but all over the world. In England, it is referred to as "talking green" but failing to "act green" (Smith 2000).

According to Stutman *et al.* (1984), it is beliefs that results in behavior, therefore beliefs are to be targeted in order to create the most persuasive argument. There are certain strategies to create a persuasive argument, such as supplying the reader with new information to establish a new belief (Stutman 1984). This new belief is their motivation to change their behavior. Telling the reader how much money they will save on their bill by switching to low energy light bulbs will accomplish this change in behaviour. With the new information the belief that the old light bulbs were satisfactory has changed; motivated by monetary savings, inefficient light bulbs will be replaced.

Another method is to challenge the old beliefs that are inhibiting the new behavior (Stutman 1984). Attacking the argument of "What can I do? I am just one person" will increase the likelihood of adopting the belief that they can help. This is the belief to reinforce.

Changing the evaluation of a belief is the final persuasive technique (Stutman 1984). This means that the belief is present initially but portrayed it in a way so the reader experiences it in a different light. This would be applied to the idea of not changing behavior and waiting for someone else to step in and regulate carbon dioxide emissions. This inaction will be portrayed as

a negative belief so that action becomes the positive belief. If more people adopt this belief then more people will likely take the suggestions offered to be proactive.

When describing the effects of climate change there are two frames that the messages are in. Either a gain-framed message or a loss-framed message. Gain-frame refers to the benefits of performing a certain behavior, and loss-frame as the costs of not performing the behavior (Rothman *et al*. 1999). The problem with loss-framed messages is that any losses that may occur will not be visible to the general public. Climate change affects such a large scale that it is very difficult to look at a negative impact and attribute it solely to global warming. Without a reasonable measure of uncertainty or risk to the person exhibiting the behavior, loss-framed messages are ineffective (Rothman *et al*. 1999). Since the villagers cannot see direct effects from excess carbon dioxide emissions, a loss-framed message would not be effective. A gain-framed message is optimal for the situation because it will be more persuasive. These gains are measurable whereas the losses are not. Also if the participant perceives the behaviour to have a relatively constant outcome, gain-frame messages are more persuasive (Rothman *et al*. 1999).

Environmental issues in mainstream media are typically written with a negative tone. About one in five environmental stories have a positive tone leaving the remaining four written in a negative tone. (Hansen 1993). This negative tone towards environmental issues affects the perception of the article. Focusing on gain-framed messages which present a positive tone resulting from environmental action should be stressed as a change from current media trends.

2.5.3. Layout Formation

For the physical creation and layout in an article by Mass (1980) five major principles were developed that could be used for any good brochure. The five major principles are objective, target audience, benefit, support, tone and manner, and should all be addressed while creating the feedback brochure (Mass *et al*. 1980).

When producing the brochure, consideration must be given to every fine detail. The amount of brochures will limit the cost and quality of paper used. The material of the brochure might be made of recycled paper which could be noted somewhere on the final product. Attention to detail is paramount because spelling mistakes and an unprofessional look is unacceptable (Monroe *et al.* 2007). The orientation, layout and even font have to be selected to maximize an effective look to encourage readers to pick it up and read its contents. The colour for instance could be green; tying the colour to the purpose of the project may have an effective subliminal impact as opposed to choosing another bright colour or going with none at all. Green is linked to ideas of the environment and nature. Using proper design elements maximize the chances of our participants taking the time to read and internalize the information provided to them.

Striving to create the most effective brochure by maximizing the message and design allows the best chance for action, which is the purpose of such literature. The brochure should be worthy for a reader to put up on their fridge, so that it is readily accessible, and they should feel that it is useful. Following the above suggestions will ensure the brochure created will be effective.

3.0. Methods

3.1. Carbon Survey and Calculator Development

The development of an accurate and flexible carbon survey and calculator was the focus of our work for the Eden Mills' Carbon Neutral Project. While at first this appeared to be an easy task, it quickly became apparent that the development of such a carbon survey and calculator was quite complex. The first obstacle we faced early on was the lack of literature available on the subject. As a result there are no current guidelines for the development of carbon surveys and their associated calculators (Padgett *et al.* 2007). The majority of carbon calculators today are only available on the internet and because there are no guidelines for these calculators there are wide ranges of types, all of which generate varying estimates of a Carbon Footprint (Padgett *et al.* 2007). A Carbon Footprint is the sum of CO_2 emissions from a person or household resulting from the data inputted by an individual into the carbon survey. Answers to most survey questions are associated with a CO_2 coefficient and an algorithm that together, generates the amount of CO_2 emitted from each activity. Carbon calculators available on the internet have shown a wide variety in the nature and type of survey questions asked which has resulted in varying estimates of a Carbon Footprint. This phenomenon will be explored in a cross-calculator comparison further along in this report.

In order to develop the carbon survey and associated calculator for the village of Eden Mills we first investigated the type of carbon surveys and calculators that exist and the general questions asked by them. In using carbon surveys and calculators available on the internet we discovered that there are three types of Carbon calculators. The first type is an additive calculator that calculates CO_2 emissions from each activity and then sums them in order to produce a

cumulative Carbon Footprint. The Safe Climate Calculator is an example of this type. The second type is a subtractive calculator that begins by generating an immediate Carbon Footprint based on a national average. The nature of the carbon survey is to ask questions which either add to the Carbon Footprint or subtract from it. The Nature Conservancy uses this format. The third type is a combination that has both additive and subtractive properties but does not use a national average. The Zerofootprint calculator uses this format.

The second step in our investigation involved an examination of the type of questions asked in carbon surveys. In general we noted that carbon surveys are broken into 4 categories; household, flight travel, personal vehicle transportation and public transportation. While questions concerning flight travel, vehicle travel, and public transportation were generally similar among carbon surveys, household oriented questions showed a wide variety of types. These ranged from vague estimations of electricity, heating fuel use to specific questions on food packaging, paper use, and pet food. A full comparison of questions asked among surveys is also explored in our cross-calculator comparison later in this report.

In November 2007 after a primary inspection of carbon calculators and discussions with our client we decided to use the carbon survey format provided by Zerofootprint (2007). Initially it was thought that Zerofootprint would construct the survey for Eden Mills, but that plan fell through and our group ended up picking up that responsibility. In the case of Eden Mills it was important to use a calculator with an additive component because the aim was to calculate accurate CO_2 emissions for households. Subtractive calculators generally ask questions concerning behaviours and don't include electricity, heating fuel use or on specifics of flight travel, vehicle use, and public transportation. Therefore it wouldn't be possible to calculate an accurate Carbon Footprint using the subtractive approach.

We developed the first trial carbon survey by modifying the Zerofootprint Calculator shortly after our primary review of carbon calculators (See Appendix D). Our objective was to extract survey questions from the Zerofootprint Calculator that we felt were relevant to Eden Mills and to delineate the metrics used to calculate CO_2 emissions in order to build a custom calculator. Further, based on the fact that Eden Mills was following the Carbon Neutral initiative in Ashton Hayes we also extracted questions from the Ashton Hayes' Survey (See Appendix E). These questions revolved around behaviour so that we could identify if individuals in a household were already taking steps to reduce their Carbon Footprint. This information was also collected in order to customize survey feedback that each household was to receive following completion of their survey. Unfortunately, this trial survey was rejected by our client on the basis that it did not collect enough information to measure a household's Carbon Footprint.

For home electricity and heating fuel use we had asked in the survey (based on the Zerofootprint approach) for households to report on their average annual spending. This methodology was rejected on the basis that prices fluctuated throughout the year and that it would be more accurate and simple to report actual annual kWh and propane and heating oil use. We were also told that many residents in Eden Mills still use wood stoves and fireplaces to heat their homes and our original survey did not capture this data either. Furthermore, it was also somewhat controversial to collect electricity and energy spending in the event that surveyed individuals were not comfortable reporting such information.

Our vehicle information was also flawed in that it calculated CO_2 emissions based on vehicle manufacturer's fuel efficiency and not actual fuel efficiency calculated and reported by the vehicle user (See Appendix A). The client reasoned that the fuel efficiency claimed by the manufacturer was likely an over-estimation and that it did not account for the deterioration of a

vehicle that occurs with age, nor did it reflect driving behaviour such as maintaining correct tire pressure and keeping air filters clean (Energy Commission 2005). In addition, the original survey did not include a section based on public transportation.

At the time of receiving our clients valid complaints concerning our original survey we were only a few days away from our scheduled trial survey date in early December 2007. It was decided that the trial would still go ahead with the original survey, which gave us practice surveying community members. Also on this date a meeting to re-evaluate our survey was scheduled with our client, Charles Simon, his advisor Richard Lay of Enermodal Engineering Ltd. and the carbon survey project assistant Brenda Taylor. The outcome of the meeting was to re-create our survey with more exact metrics in order to surpass the accuracy of Zerofootprint's carbon calculator. In addition, we eliminated the questions on behaviour in order to streamline our attention on calculating the Carbon Footprint of the village. As a result, individuals surveyed are now to receive a feedback form that provides them with an account of their household Carbon Footprint and general short-term and long-term energy saving practices as opposed to household specific practices.

3.2. Development of a New Carbon Survey and Calculator

Early in January 2008 the new survey was developed based on the recommendations and requests from our client and his advisors. The new survey captures data on household energy use, flight travel, personal vehicle transportation, and public transportation (See Appendix B). CO_2 coefficients were derived from the available literature as discussed earlier in this report. Ultimately we chose the coefficients from Environment Canada's National Inventory because they justify their deviations from the IPCC methodology, and the IPCC (2006) methodology

itself recommends using local data as much as possible. Canadian coefficients include the added bonus of including CO emissions in the CO_2 coefficient. Our carbon calculator avoided the use of American coefficients but a lack of information concerning wood CO_2 emissions lead us to use the American coefficient of 3812 lbs CO_2 per short ton of wood (EIA 2008). CO_2 released varies significantly on the species of tree being combusted. Therefore, for an accurate coefficient, two assumptions were made which were validated by Richard Lay. The first assumption was that most firewood is hardwood and secondly maple, oak and birch act as good indicators of a typical wood pile. The average weight of a cord of these three species were then averaged together in order to create the cord weight for the CO_2 emission coefficient (DeWald *et al* 2005). In regards to personal transportation some surveys did not have personal fuel economy information available and in those cases we used the make, model and year of production for their car. All fuel efficiencies from makes and models were retrieved from the U.S. Department of Energy and then converted to km/L units.

We decided to use Zerofootprint's metrics for public transportation and flight travel (See Table 1). The decision to use Zerofootprints metrics for public transportation was based on the fact that they have well sourced material explaining how they logically derived the emissions for public transportation (See Appendix A). Flight travel was one section that did change although this was not at the request of our client. Unfortunately, from December 2007 to January 2008 Zerofootprint updated their calculator. Consequently their specific section on flight travel, which previously calculated emissions based on city to city destinations, was downgraded to an average estimation based on hours spent during flight travel. Nevertheless, because we were now developing a bespoke carbon survey and calculator for Eden Mills it would have been an overwhelming task to collect data for each city to city flight travel for our Excel based carbon

calculator. Therefore, we settled on using the estimated CO_2 emissions for flight travel in hours based on the metrics used by Zerofootprint although we do recognize that the accuracy of this calculation could be improved. We also decided to calculate household energy emissions solely based on electricity or other home energy sources.

Table 1. Metrics of the Carbon Calculator.

Survey Parameters	CO2 Coefficients Used	Source
Electricity	0.222 kg CO2/kwH	Env. Canada (2007)
Heating Oil	2.83 kg CO2/L	Env. Canada (2007)
Propane	1.51 kg CO2/L	Env. Canada (2007)
Wood	2653 kg CO2/cord	EIA (2005)
Wood Pellets	17.04 kg CO2/kg wood	EIA (2005)
Short Haul Flights < 1.5hours or 0km - 567km	240kg CO2/flight	Zerofootprint (2007)
Medium Haul Flights 1.5 - 3.0 hours or 568km - 1991km	440kg CO2/flight	Zerofootprint (2007)
Long Haul Flights 3.0 - 5.0 hours or 1992km to 3117km	1230kg CO2/flight	Zerofootprint (2007)
Extended Long Haul Flights > 5.0 hours or > 3117km	2460kg CO2/flight	Zerofootprint (2007)
Vehicle gasoline consumption	2.36kg CO2/L	Env. Canada (2007)
Vehicle diesel consumption	2.73kg CO2/L	Env. Canada (2007)
Streetcar, Light Rapid Transport, Subway	9.97kg CO2/passenger/km	Zerofootprint (2007)
Public Bus (e.g.TTC, Guelph Transit Bus)	0.186kg CO2/passenger/km	Zerofootprint (2007)
Intercity Train (e.g. Via rail)	0.1033kg CO2/passenger/km	Zerofootprint (2007)
Commuter Train (e.g. Go Train)	0.1025kg CO2/passenger/km	Zerofootprint (2007)
Intercity Bus (e.g. Go Bus, Greyhound)	0.0485kg CO2/passenger/km	Zerofootprint (2007)

We did not include questions based on diet, food packing and source, waste, recycling, compost, water use, paper use, pets, recreational vehicle use, lawnmowers, or clothing because it was felt among all parties that the level of estimation in these calculations was too great and would introduce error into this survey. Although these inputs certainly contribute to an individual's Carbon Footprint, the complexity of deriving an accurate CO_2 coefficient for these actions was beyond the scope of this project. This factor demonstrates the improbable likelihood that the calculation of any Carbon Footprint is truly complete.

3.3. Administration of the Carbon Survey

The carbon survey took place on January 30th and January 31st 2008 in the Eden Mills Community Centre. Appointment times were arranged by Linda Melnick and additional time slots were made available for drop-in survey participants. The carbon survey was emailed to village residents on January 25th 2008 in order to allow participants sufficient time to collect the necessary information for the survey. On the survey day most residents arrived with their survey already completed. Participants were assigned a survey number by Linda Melnick or Brenda Taylor that corresponded with a master list of all survey participants. This was done in order to protect the confidentiality of survey responses in the event that a survey form was seen by someone other than our University of Guelph student surveyor group.

Following the assignment of a survey number, participants were instructed to discuss their completed survey with one of our student surveyors. During this process we were able to identify and clarify mistakes made in the survey in addition to collecting any missing information. This also provided the opportunity to discuss the overall project with survey participants and answer any questions they may have had. Participants who were unable to attend the survey dates forwarded their completed surveys either to Linda Melnick or directly to our student survey group at: carbon.neutral2008@gmail.com.

3.4. Carbon Survey Follow-up

Following the collection of completed carbon surveys there still remained a number of surveys that required follow-ups'. Many of the surveys retrieved by our group were missing information on either household energy use (participants were unable to collect information on

their energy use) or personal transportation (participants were unable to calculate their fuel efficiency and/or annual km driven). As a result our survey group had to retrieve this information. Surveys with missing information were identified and follow-up emails were sent via the carbon.neutral2008@gmail.com account to collect this information. Phone calls were also made in the event the participants did not provide an email address. Unfortunately, the retrieval of the missing information proved to be more difficult than initially thought and consequently reduced the number of surveys available for use in calculating the village's Carbon Footprint. These survey collection statistics were summarized in the results section.

3.5. Eden Mills Carbon Footprint Calculation

This calculation involved the use of data collected from fully completed surveys. This survey data was inputted into our carbon calculator that was developed in Excel (See CD-ROM included with this report). Once entered, the total Carbon Footprint of the participants surveyed was computed as the sum of each total Carbon Footprint per surveyed household. The mean household Carbon Footprint was then derived by dividing the total calculated Carbon Footprint by the number of successfully completed household surveys (n=61). This mean household Carbon Footprint was then multiplied by the total number of households in Eden Mills (n =163) to calculate the total household Carbon Footprint of the village. This value was added to the Carbon Footprint of the Eden Mills Community Centre and Edgewood Camp (as calculated by our survey group using annual energy use) to obtain the overall Carbon Footprint of Eden Mills.

3.6. Results and Recommendations for Eden Mills Survey Participants

Household Carbon Footprint results and the total Carbon Footprint of Eden Mills was sent via email or regular mail to participating households. These results were returned in the form of an educational brochure that describes the two Carbon Footprints and provides residents with general recommendations on how they may reduce or offset their Carbon Footprints (see Appendix C). It is hoped that residents will make use of these recommendations in order to reduce the Carbon Footprint of the village thus lessening the burden of carbon emissions to be sequestered in future tree planting operations.

3.7. Formation of a Feedback Medium

A feedback medium was developed per request from our client in order to communicate the results of each individual survey participants' footprint. Included was a brief introduction to the survey process, the topic of Carbon Neutrality in general, household results and general tips for CO_2 reduction. A brochure was created for physical delivery such as mailing or available for pick up. The brochure has more general feedback without personal information attached. Emailing a brochure to participants may not be as successful as it requires time to print and assemble. The benefit of creating a brochure is that it can be mailed or handed out to villagers who did not participate in the initial survey. This may result in their participation next year, or they might have interest in the results of their Village even if they do not participate. The entire project is not geared solely towards the survey participants nor towards alienating the non-participants. Delivery of this media may help illustrate that fact. The newsletter is a computer

friendly version and will incorporate individual feedback, and is the primary medium we will be delivering. Both forms of our feedback are included in Appendix C.

Initially the feedback was to contain individualized recommendations that the specific participant could enact to lower their CO_2 emission but eventually after consultation with Richard Lay, the carbon survey advisor, it was deemed that individual recommendations should be conducted by outside professional sources. These sources could include energy and home auditor systems that have expertise and stringent inventories developed to analyze the mitigation of CO_2 emissions. As a result, our recommendations were limited to universally accepted actions for reducing CO_2 emissions.

The newsletter contains a personal Carbon Footprint, as well as the total Carbon Footprint for the village of Eden Mills compared to various other countries of interest (Canada, U.K, US, Zimbabwe) and recommendations on how to reduce emissions. Zimbabwe was included in order for the participant to conceptualize the difference between Carbon Foortprints of developing and developed countries.

The heading for the feedback mediums utilized the Eden Mills Going Carbon Neutral logo in order to ensure recipients that the brochure is supported by the initiative. This was an important aspect because it will also give a professional appearance which will hopefully stop residents from simply disregarding it entirely. The purpose of our involvement in the project and results which ensued is clearly outlined in the introduction of the feedback form allowing readers to understand the contents of the brochure.

During the media creation we focused on the seven major principles of a successful brochure; design, objective, target audience, benefit, support, tone and manner (Mass et al., 1980). Our objective was to create a readable and enjoyable media format that included; survey

results (individual and village wide) as well as universally accepted CO_2 reduction strategies. The target audience was the entire Village of Eden Mills which had to be considered as a generalized population. The demographic population varied too much to be able to target one group specifically so the only limitation we strived for was a Grade 8 reading level (Monroe 2007). Our recommendations section allowed for the recipient to learn about the benefits from this brochure. Recommendations were used that would ultimately save our recipient money in the long run which is a tangible benefit. The tone and manner was a very positive one. We wanted to move away from constant "doom and gloom" environmental media and felt that it would benefit us in the long run. To promote change we had to present the idea that it would be feasible and beneficial to the recipient.

The colour green was used in figures and logos in order to create an environmental atmosphere. Through our research it became apparent that gain frame messages should be used in our media in order to emphasis the benefits of following each suggestion (Rothman et al., 1999). Using gain frame messages will likely increase the probability that readers will act on our recommendations; for example when a reader knows that they can save $10-$70 a year by fixing leaks in a hot water heater they are more likely to act.

We felt that it was important to stress action on behalf of the participant whether they are above or below the Village's average CO_2 footprint. This will stimulate the belief that action can be taken to reduce CO_2 emissions, regardless of how far or below the CO_2 emissions average the recipient is, reductions should still be strived for (Stutman, 1984). In the case that there are any questions, an email address was included at the end of the brochure if a reader wants to make inquiries.

4.0. Results

4.1. Participation Rate

There are 163 households in Eden Mills, Ontario. During our survey 80 households participated, which constitutes 49 percent of the households in Eden Mills. Of the 80 surveys completed during the interview process, only 61of these surveys had all the information needed and were used to determine the village's Carbon Footprint. Therefore, when calculating the Carbon Footprint of the village, the participation rate was 37 percent. Figure 2 represents participation rates of Eden Mills. Households that chose not to participate in the survey accounted for 51 percent of the total. 12 percent of the households in Eden Mills were surveyed, but had incomplete information and thus, could not be used to determine the Carbon Footprint.

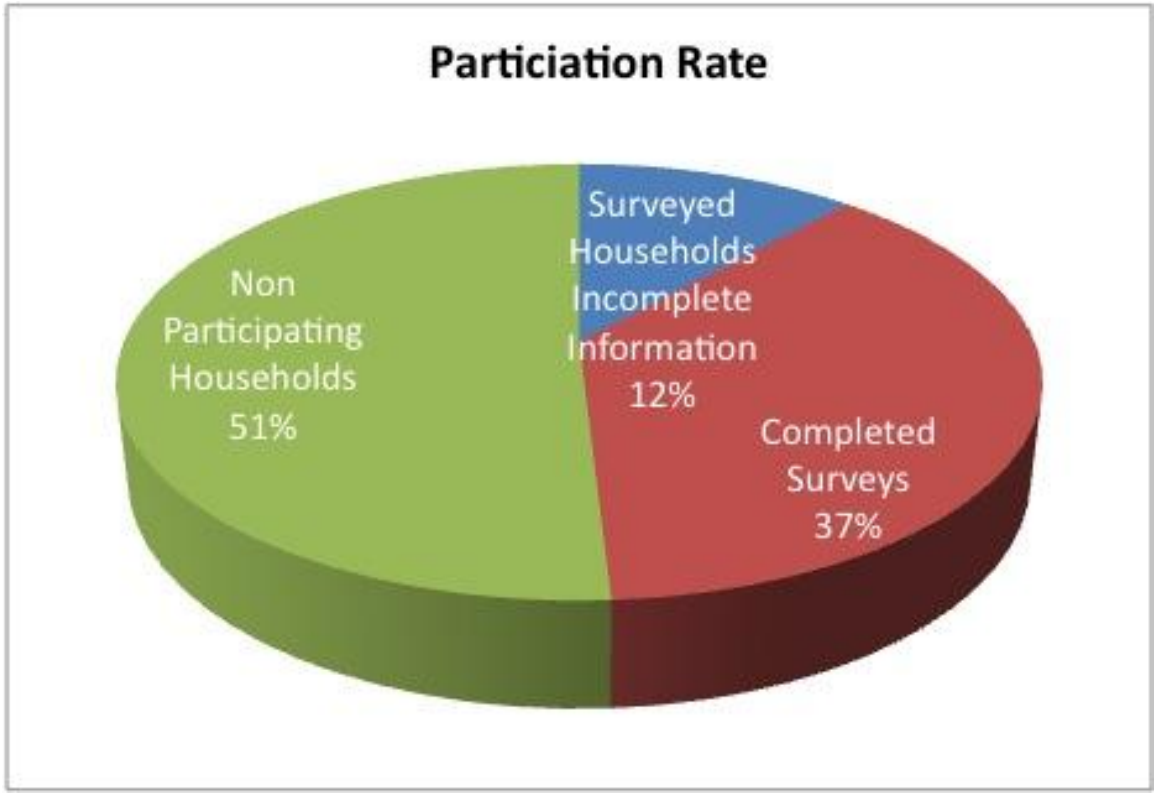


Figure 2. Eden Mills' Carbon Neutral Survey Participation Rate.

The residual 37 percent of households had complete information and were used to calculate Eden Mills' Carbon Footprint.

4.2. Emissions from Surveyed Households

The results for the individual as well as total sources of household emissions for the surveyed households are presented in Figure 3. Of the 61 surveys used for determining the Carbon Footprint, total carbon emission was calculated to be 1693.86 tonnes of CO_2. The largest contributor to total emissions is home energy consumption, which included household heating, general electric appliance use, and water heating accounted for 597.22 tonnes of CO_2. Carbon emissions contributed from personal transportation (i.e. vehicle use) was calculated to be 580.51 tonnes. Public transportation was responsible for 21.31 tonnes of CO_2, which is the smallest proportion of all sources measured. Emissions from air travel were determined to be 495.54 tonnes of CO_2.

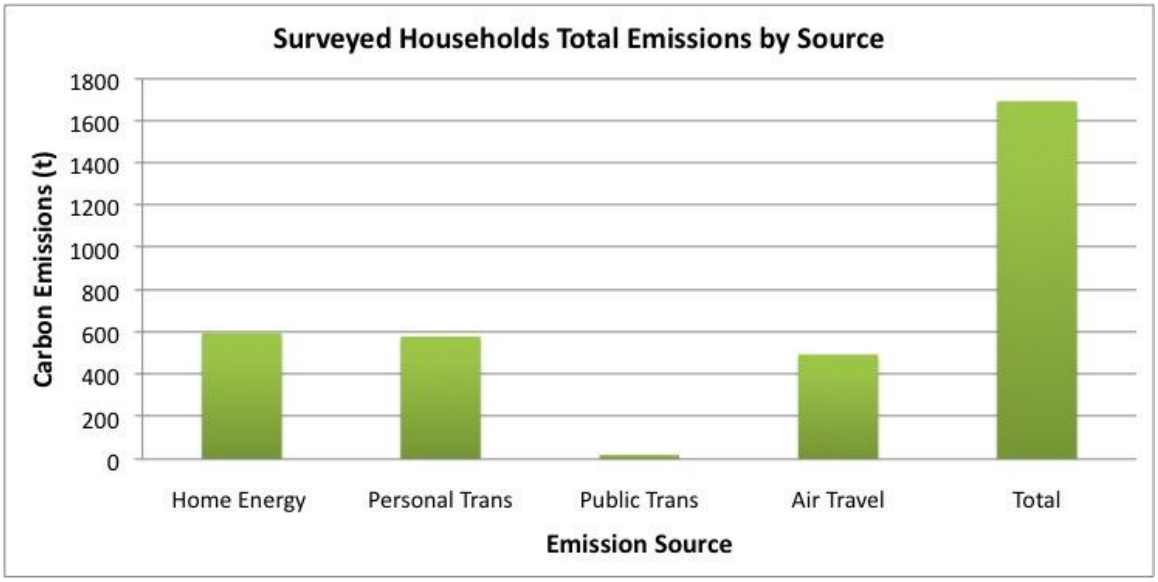


Figure 3. Carbon Footprint by emission source for surveyed households.

4.3. Projected Emissions for Eden Mills

The projected emissions were calculated from the surveyed information and represent the total emission for all households in Eden Mills. These results are displayed in Figure 4 below. The projected total emissions for the village of Eden Mills was found to be 4607.92 tonnes of CO_2. Home energy consumption for the entire village was projected to be 1595.85 tonnes of CO_2. Similarly, personal transportation, public transportation, and air travel accounted for 1551.19 tonnes, 56.95 tonnes, and 1324.14 tonnes of CO_2 respectively.

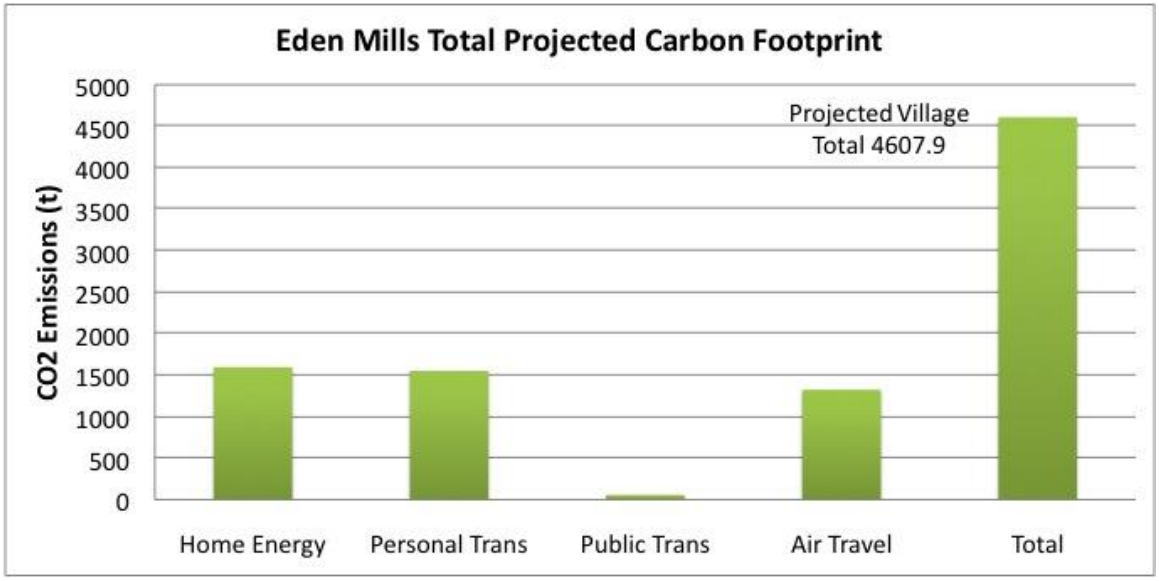


Figure 4. Carbon Footprint for Eden Mills extrapolated from survey results.

In conjunction with Figure 4, Figure 5 represents the sources of emissions and their contribution to the total projected Carbon Footprint of Eden Mills. Of the projected footprint, home energy consumption contributes 35.2% to the total, followed by personal transportation at 34.3%. The proportion of the total projected Carbon Footprint attributable to air travel is 29.2%. Lastly, public transportation was calculated to be responsible for 1.3% of the total projected Carbon Footprint of Eden Mills.

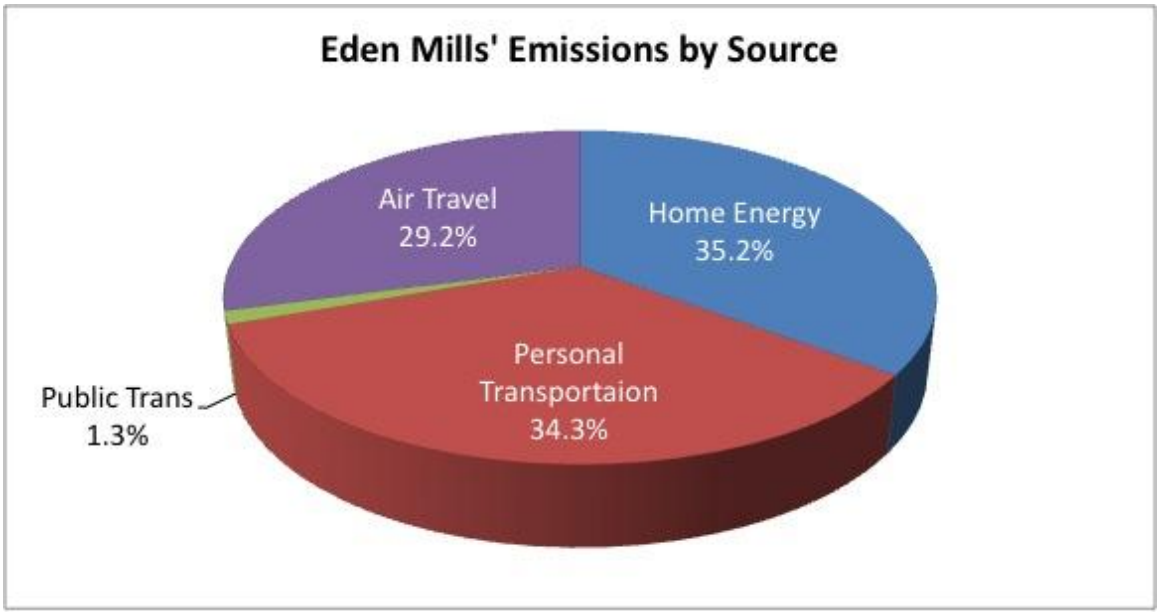


Figure 5. Percentage of Total Household Carbon Emissions by Source.

4.4. Emissions Per Capita

Total CO_2, per capita emissions were also calculated and compared to the national average as well as a number of other countries in Figure 6. The per capita emissions for Eden Mills were calculated to be 10.4 tonnes of CO_2. According to the World Bank (2004) Canada, the US, the UK and Zimbabwe had per capita emissions of 17.9, 19.9, 9.4 and 0.9 tonnes of CO_2 respectively. Carbonfootprint.com (2008) claims the per capita emissions of Canada is 9.1 tonnes of CO_2.

4.5. Summary Results and Statistics

A summary of the results presented in the figures above along with a summary of statistics is displayed in Table 2 below. The mean CO_2 emissions per household, with respect to home energy consumption, were calculated to be 9.79 tonnes with a standard deviation of 5.37 tonnes. Personal transportation, public transportation, and air travel had respective mean CO_2 emissions equal to 9.52 tonnes, 0.35 tonnes, and 8.12 tonnes, with standard deviations equal to 5.37 tonnes, 6.13 tonnes, and 1.32 tonnes. The mean household CO_2 emissions were 27.78 tonnes with a standard deviation of 14.89 tonnes.

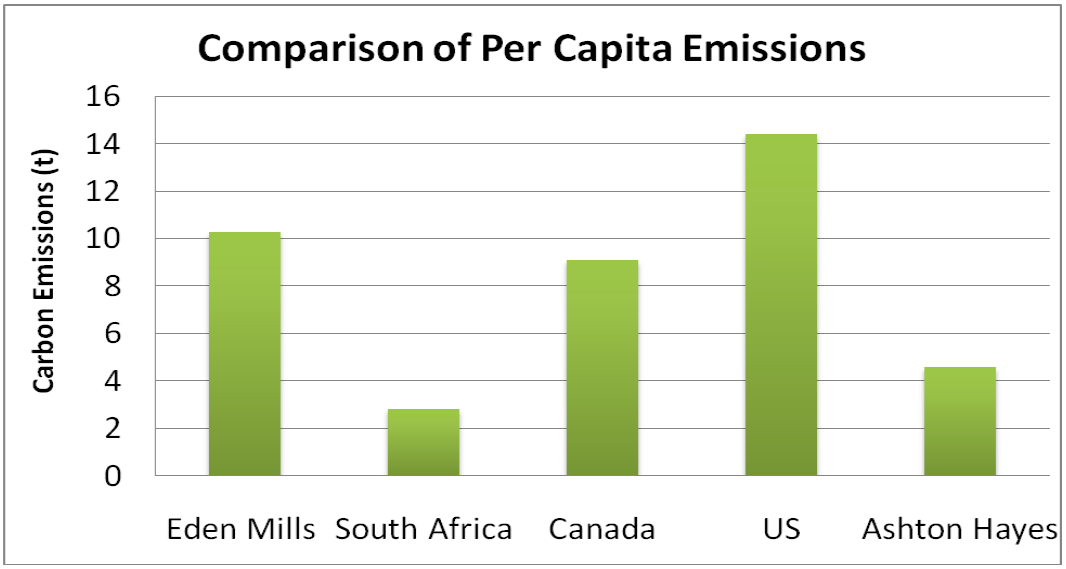


Figure 6. Comparison of per capita emissions among Eden Mills, South Africa, Canada, the US and Ashton Hayes (Ashton Hayes Parish Council, 2004, Zerofootprint 2007).

Table 2. Summary of Eden Mills' Carbon Footprint.

	Mean CO_2 Emissions (t) per household	**Total CO_2 Emissions (t) Surveyed**	**Total CO_2 Emissions (t) Projected**
n = households	**Mean +/- Standard deviation**	**n=61**	**n=163**
Home Energy	9.79 +/- 5.37	597.22	1595.85
Personal Transport	9.52 +/- 6.13	580.51	1551.19
Public Transit	0.35 +/- 1.32	21.31	56.95
Air Travel	8.12 +/- 11.48	495.54	1324.14
Total	27.78 +/- 14.89	1694.58	4607.92

5.0. Discussion

Mean CO_2 emissions presented in the results section were accompanied by large standard deviations. The large standard deviations imply a large spread of the collected data values. This was observed throughout the survey analysis, where there was a large, discernible range of CO_2 emissions from different respondents regarding home energy use. Some households would consume three or four times more energy (in kilowatt hours per year) than their neighbours. This obviously is partially dependent on the size and overall efficiency of the homes but also reflects differences in energy use habits. This wide range of data vales could also be attributed to error in calculation of energy use, which proved to be a difficult task, especially if households did not have a complete set of hydro records. Similarly, large standard deviations observed for personal transportation and air travel could be explained by varying household needs, lifestyles, and career obligations. In the case of public transportation, some of the surveyed households used

public transportation regularly while others did not. This accounted for the substantial range of observed data values.

Public transportation emissions are noticeably lower compared to the other emission sources in Eden Mills. This is due to the fact that some of the households surveyed only use public transportation once or twice a year when they travel to Toronto and considered the carbon emissions from that source negligible. Some respondents were also confused with respect to whether they should include school bus use as part of their emissions. A few reasons for the confusion was that respondents did not know the time their children spent on the school bus, or they believed that the emissions were negligible or did not consider the school bus to be public transportation. Furthermore, many households did not include public transportation in their surveys because they were unable to recall the extent of their trips. This was expected because Eden Mills does not have a public transit system and must depend upon personal transportation use (i.e. private vehicle). Perhaps Eden Mills can initiate carpooling and approach neighbouring transit systems for an extension route to the village. One suggestion by the village was to operate a bus service to and from Eden Mills to Guelph twice a day. This would allow residents who worked in Guelph to take public transportation to work.

The overall participation rate of Eden Mills in the survey was much better then expected. The original goal was to survey at least 20% of the village; surprisingly initial participation consisted of 80 households, which is approximately 49.1%. Unfortunately not all of the households had fully completed the surveys; the most frequently observed missing information was fuel efficiency, annual mileage of vehicles, and home energy use. As a result only 61 surveys had sufficient information to be included in the footprint. 49 of these surveys contained all necessary information after the initial appointment at the Community Centre. This meant that

31 households needed to be contacted in order to receive complete information; a total of 27 houses were contacted either by email or telephone (3 houses were excluded because they were involved in the preliminary survey and 1 was missed due to human error). From the 27 houses we contacted, 12 replied with the missing information needed to include them in the Carbon Footprint calculation, totaling 61 complete household surveys. The successful response rate from the email/telephone contact was 42.9 percent, the remaining 57.1 percent either did not have the information that was required, or simply did not reply at all. If the 31 unfinished surveys had been completed then there would have been a response from 49 percent of the village, indicating that interest in the project was substantial. Overall, a response rate of 37 percent was achieved, which is similar to Ashton Hayes' response rate of 40 percent and more successful than the expectations of 20 percent. Hopefully in following years survey participation will increase while the number of incomplete surveys will decrease.

There existed a number of alternative methods to derive the village Carbon Footprint from the surveyed information. The method used involved determining the mean household emissions from completed surveys (n=61) and then multiplying by the total number of households (n=163). Alternatively the household mean could have been multiplied by the number of un-surveyed households (n =102) and then added to the sum from completed surveys (n=61). However this method is inconsistent because it uses both calculated and estimated values, whereas the method used in this project assigned the same average to every household. This is consistent with Ashton Hayes whom also chose to multiply all the households by the mean emissions value. It is important however to emphasize that the calculated footprint is only an estimate of Eden Mills' true emissions level as many human activities that also contribute to CO_2 emissions could not be accounted for in the survey.

Total projected CO_2 emissions were calculated to be 4607.9 tonnes/year. Eden Mills will have to implement a number of different strategies in order achieve Carbon Neutrality. Reduction of emissions should be the first course of action as it is predominantly based on changing behaviour as opposed to physical processes. Car travel is a major issue in Eden Mills since the village itself does not contain any major commercial services. This means that most of the populace must commute not only to work but also to purchase any food, clothing, entertainment or any other services. Initiatives such as carpooling and communal food delivery are effective steps towards reducing travel emissions. Achieving large reductions in CO_2 emissions could be expensive for strategies such as buying more fuel efficient cars or renovating houses to save energy. In similar fashion, reducing flights could be very difficult for households which need to travel for work. It is not feasible to expect people to stop traveling by plane to different work related locations. Increased use of telephone meetings, or internet video communications could possibly reduce the number of trips needed. Although air travel is less frequent than other modes of transportation it is emission intensive and households in Eden Mills may not yet realize the magnitude of air travel contributions to the total footprint. It is important that each household makes an effort to reduce its emissions to help bring the village closer to Carbon Neutrality. It is not possible to become neutral strictly with emissions reduction; the village will also have to create some extensive aforestation (sequestration) and offsetting programs.

Sequestration of CO_2 emissions by aforestation is a complex science due to variations in soil type, climate, tree species, growing season and management practices. Baral and Guha (2004) estimate that in temperate regions a well managed forest with long rotation periods can sequester 2-4 tonnes of CO_2 per hectare per year (t/ha/yr). If Eden Mills were to offset all their

emissions through aforestation they would require as much as 2304 ha. It is important to note however, that there is considerable variation in sequestration rates by species and location. For example Norway spruce can sequester 0.83 t/ha/yr, douglas-fir 1.01 t/ha/yr, beech 2.26 t/ha/yr and pine oak 8 t/ha/year (Masera, 2003). The University of Guelph has already been approached by Eden Mills to develop strategies for sequestering carbon in a hybrid poplar agroforestry system which is an entire project in itself beyond the scope of our involvement.

Making comparisons of the results from Eden Mills to other national averages reveals a number of notable differences. For example, CO_2 emissions per capita in Canada as reported by the World Bank (2004) is 17.4 tonnes per capita. The calculated CO_2 emissions per capita for Eden Mills is 10.4 tonnes which is well below the value recorded by the World Bank. This large difference is a result of the method of calculation as well as the inclusion of industry and business emissions in the World Bank calculation. When computing CO_2 emissions per capita for Canada, the World Bank summed the total estimated CO_2 emissions from every source in Canada and divided it by the total population. Calculation of the Eden Mills per capita emissions did not include contributions from the workplace or industry that households were involved in, which would, to some extent, elucidate the observed difference. Zerofootprint calculated Canadian CO_2 emissions per capita to be 9.1 tonnes which is also substantially lower than the World Bank calculation. This is most likely due to the fact Zerofootprint does not include industrial emissions in their calculation. In regards to American footprints, the World Bank (2004) actually recorded smaller per capita emissions than online calculators such as the EPA's which often recorded Canadian per capita emissions in the 20 tonnes per year range. Again these differences demonstrate the difficulty in truly determining a Carbon Footprint which has serious repercussions on trying to become neutral.

There are a number of carbon emission sources that were not included in the Eden Mills calculation such as the use of propane for barbeques or recreational carbon emissions, such as boating, snowmobiling or private aircraft. It should however be noted that this is only the first step in Eden Mills attempt to become Carbon Neutral and the carbon calculator developed in this project can act as a confirmatory step. If the village successfully manages to become neutral under the derived footprint they could then expand the survey to include some of these other sources.

Overall the calculation of Eden Mills' Carbon Footprint was a success and a great learning process. Through extensive research it became apparent that there is a lack of relevant literature and guidelines which has lead to variability between Carbon Footprint calculations. The calculator created has been tailored through development to apply specifically to the village of Eden Mills. This was beneficial as it allowed more accurate results as opposed to other calculators such as Zerofootprint that are based on general attributes. Furthermore, the calculator can act as a template and accommodates the addition of future considerations (i.e. data, coefficients, emission sources).

6.0. Recommendations for Future Surveyors

1. *Send out survey in conjunction with a pre-letter to participants at least two weeks in advance of the survey schedule*

Sending out a copy of the survey with a pre-letter will allow participants the time to gather and organize the information needed to complete the survey properly. Also, the pre-letter must include instructions on how to obtain the necessary information if participants do not have this information at hand. This includes: information on how to acquire energy use in kWh, and the steps required to calculate fuel efficiency. Also, the terminology and language used in the survey should be explained in the pre-letter to reduce sources of error and increase the accuracy of results. Participants should not come to an interview with the cost of energy, as this will be unusable with respect to the carbon calculator. If participants receive the pre-letter and survey, and follow the guidelines correctly, this will decrease the amount of time spent surveying and the amount of follow-ups needed to obtain complete information. Well prepared participants will increase the amount of useable surveys, and thus, the overall efficiency of measuring the carbon footprint.

2. *Continued use of the Community Centre for conducting survey interview is crucial as well as having participants complete the survey at pre-determined appointment interval. It is also crucial to remember to bring the necessary equipment needed for proper surveying (i.e. calculators, staplers, and pens).*

The Community Centre served as a useful tool in reducing project time spent surveying. Having multiple interview stations set up at the Community Centre as opposed to going door-to-door is recommended for future surveyors. One crucial aspect of using the Community Centre for surveying is to have interviews completed at pre-determined appointment intervals. Using appointments for all participants reduced waiting time and avoided

disorganization, which would have been experienced otherwise. Also, it is important for surveyors to come to the interviews prepared with calculators, staplers, and pens, which will be needed during the survey process.

3. *To have a better understanding of what needs to be accomplished surveyors must obtain a clear outline of goals and objectives from Eden Mills. Also, make sure future surveyors outline their objectives/goals and receive feedback from Eden Mills to ensure a cooperative relationship with the client. In other words, future surveyors must be in constant collaboration with the client instead of working independently. A trial survey should also be completed as early as possible to ensure necessary changes can be made in a timely fashion.*

During our group's survey experience, there was a mass reconstruction of the survey one night before trial surveying began. This was a stressful process that could have been easily avoided had there been more collaboration between our group and the client during the survey design. Having a thorough understanding of the client's goals/objectives and obtaining feedback when designing the survey will circumvent situations akin to this in the future. Also, completing a trial survey as early as possible is important to getting confirmation from Eden Mills that the survey is sufficient, and that any changes that need to be made can be done so in a timely fashion.

4. *Future surveyors should build upon the current survey to obtain a more complete and accurate measurement of the Carbon Footprint.*

The survey developed in 2007/2008 is by no means complete for measuring the Carbon Footprint accurately. The calculator used in this survey measures baseline carbon emissions. Future surveyors should build upon the survey and calculator developed in 2007/2008 to increase the accuracy of the Carbon Footprint measurement. These added features should include things such as: carbon emissions from recreation, external fuel usage (e.g.: bbq, snow blowers and lawn mowers, etc), school busses, food and waste emission, as well as a more accurate measurement of flights and public transportation. If fuel efficiency is not provided

to surveyors during the interview process, information given to surveyors pertaining to vehicle model, make, and year should include the type of vehicle transmission to ensure accurate results. Type of vehicle transmission is an important aspect that should be built upon because it has direct effects on fuel efficiency. If needed, surveyors should also find out what kind of wood participants use in home heating because different woods have different CO_2 coefficients.

5. *Survey layout – future surveys should be more accommodating to participants. Having survey identifier numbers in conjunction with a more organized filing process will make follow-ups more efficient.*

The font used in the 2007/2008 survey was too small, questions were too cluttered, and could have benefited from more space and bigger fields for entering data. Other data field could also be eliminated altogether, such as the secondary home energy and heating field. One field for these energy use questions is sufficient. The use of identifier numbers on the survey (also on a master list of participants), along with a master list of what each survey is missing will make follow-ups much easier as well as provide a more orderly filing system.

7.0. Conclusion

The calculation of the Eden Mills Carbon Footprint involved a number of unexpected deviations from the original proposal. It was important to constantly apply new information during the development of the project in order to properly tailor the calculator to Eden Mills. Carbon calculators are complex tools and continued study is crucial to developing guidelines and decreasing variability between available calculators. The Carbon Footprint calculated is a starting tool for Eden Mills. The recommendations garnered from the experiences of this project, will provide a more accurate measurement of future footprints.

Hopefully Eden Mills will successfully achieve Carbon Neutrality and spur similar action in other communities in Canada and around the world. Global Climate Change is a very complex and daunting situation that we are facing and each household's actions create small inroads to creating a solution. Since Eden Mills could be the first village in North America to achieve Carbon Neutrality it will act as a standard for other initiatives. It is important that those involved in the initiative have the expertise and knowledge available to answer questions and provide guidance to others who are willing to reduce their emissions and protect the environment.

References

Alexander, R., Hope, M., Degg, M. 2007. Mainstreaming Sustainable Development – A Case Study. Ashton Hayes is going Carbon Neutral. *Local Economy*, 22: 62-74.

Alexander, R. 2007. [CD-ROM] Ashton Hayes Community tool kit. Ashton Hayes Parish Council.

Alexander, R. 2006. [CD-ROM] Ashton Hayes Going Carbon Neutral. Community Toolkit. Ashton Hayes Parish Council. [October 21, 2007]

Akkerboom, H. and F. Dehue. 1997. The Duch model of data collection development for official surveys. J. *of Public Opinion Research*, 9(2): 126-146.

Ashton Hayes Parish Council. 2007.Ashton Hayes Going Carbon Neutral. Goingcarbonneutral.Co.Uk. [Online] Available: http://www.goingcarbonneutral.co.uk [March 6, 2008]

Auld, H., Gray, P.A., Haley, D., Klaassen, J., Konnefat, H., Maclver, D., McNicol, D., Nimmrichter, R., Schiefer, K. and Taylor, M. 2006. *Coastal zone and climate change on the great lakes final report*. AMEC Earth & Environmental division of AMEC Americas Limited, Mississauga.

Aussant, C. 2007. *GHG emissions related to energy use in Ontario*. Endermodal Engineering Ltd.

Babikian, R., Stephen, L., Waitz, I. 2002. The historical fuel efficiency characteristics of regional aircraft from technological, operational, and cost perspectives. *Journal of air transport management*, 8: 389-400.

Baral, A. and Guha, G.S. 2004. Trees for carbon sequestration or fossil fuel substitution: the issue of cost vs. carbon benefit. *Biomass and Bioenergy*, 27(1): 41-55.

Barbara, G., Stanghellini, V., Berti-Ceroni, C., De Giorgio, R., Salvioli, B., Corradi, F., Cremon, C. and Corinaldesi, R. 2000. Role of antibiotic therapy on lon-term germ excretion in faeces and digestive symptoms after *Salmonella* infection. *Aliment Pharmacol Ther*, 14:1127-1131.

Belson, W.A. 1981. *The design and understanding of survey questions.* Gower publishing co.. England.

Bentham, G. and Langford I.H. (2001) Environmental temperatures and the incidence of food poisoning in England and Wales. *International Journal of Biometeorology*, 45:22–26.

Boland, G.J., Melzer, M.S., Hopkin, A., Higgins, V. and Nassuth, A. 2004. Climate change and plant diseases in Ontario. *Canadian Journal of Plant Pathology*, 26: 335-350.

Brace, Ian. 2004. Questionnaire design: how to plan, structure and write survey material for effective marked research. Kogan Page Ltd.. Sterling, Virginia.

Bradburn, N.M. 1979. *Improving interview method and questionnaire design*. Jolly-Bass Inc. San Francisco, California.

Buckingham, Susan, and Theopold, Kate. 2003. *Local Environmental Sustainability*. Woodhead Publishing. Cambridge, England.

Burns, Daniel. 2004. *What Works in Assessing Community Participation?* The Policy Press. Yorkshire, England.

California Energy Commission. 2005. Energy Commission says high gasoline prices may be changing driving habits. [Online] Available: http://www.energy.ca.gov/releases/2005_releases/2005-08-11_high_gasoline_prices.html [March 24, 2008]

Carbonfootprint.com. 2008. Calculate, Reduce and Offset - Welcome to Carbon Footprint. [Online] Available:http://www.carbonfootprint.com/ [March 29th 2008

Charnock, G. 2007. Grass roots village action inspires other communities to take on the challenge of climate change. *Local Economy*, 22: 75 – 79.

City of Toronto. 2005. Toronto Water asks residents to reduce water use. [Online] Available: http://wx.toronto.ca/inter/it/newsrel.nsf/0/6889ce322ab0c4828525703c00630e73?OpenDocument [March 14, 2008]

DeWald, S., Josiah, S., ErdKamp, B. 2005. Heating with Wood: Producing, Harvesting and producing firewood. Nebguide University of Nebraska Licoln. [Online] Available: http://www.ianrpubs.unl.edu/epublic/live/g1554/build/g1554.pdf [March 2, 2008]

Eden Mills Millpond Conservation Association Inc. 2007. Eden Mills is going carbon neutral. [Online] Available: http://www.goingcarbonneutral.ca/index.shtml [October 13th, 2007]

Environment Canada. 2006. National inventory report 1990-2004: greenhouse gas sources and sinks in Canada. Greenhouse Gas Division. [Online] Available: http://www.ec.gc.ca/pdb/ghg/inventory_report/2004_report/toc_e.cfm [March 05, 2008]

Environment Canada. 2007a. The science of climate change. The Green Lane. [Online] Available: http://www.ec.gc.ca/climate/overview_science-e.html [March 03, 2008].

Environment Canada. 2007b. National Inventory Report, 1990-2005: Greenhouse gasses sinks and sources in Canada. [Online] Available: http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/tdm-toc_eng.cfm [March 3, 2008]

EIA. Voluntary Reporting of Greenhouse Gases Program Fuel and Energy Source Codes and Emission Coefficients. Energy Information Administration Official Energy Statistics from the US government. [Online] Available: http://eia.doe.gov/oiaf/1605/coefficients.html [date accessed March 2, 2008]

Francis, Joe, D. Lawrence Busch. 1975. What we now know about "I don't knows". *The Public Opinion Quarterly*, 39(2): 207-218.

GHG Protocol. 2008. Green House Gas Protocol initiative the foundation for sound and sustainable climate strategies. [Online] Available: http://www.ghgprotocol.org/ [March 12, 2008]

Government of Ontario. 2007. Go green Ontario's action plan on climate change. Go Green Ontario. [Online] Available: http://www.gogreenontario.ca/docs/actionplanonclimatechange.pdf [March 05, 2008]

Griefenhagen, S., and Noland, T.L. 2003. A synopsis of known and potential diseases and parasites associated with climate change. *Forest Research Information Paper No. 154*. Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste Marie.

Groves, R.M. 1987. Research on survey data quality. *The Public Opinion Quarterly*, 51(2): 156-172.

Hansen, A. 1993. *The Mass Media and Environmental Issues*. Leicester University Press. Leicester, London, England.

Hedges, P., Moss, D. 1996. Costing the effectiveness of training: case study 1 - improving Parcelforce driver performance. *Industrial and Commercial Training* 28: 14-18.
IPCC. 1996. The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual (Volume 3). [Online] Available: http://www.ipccnggip.iges.or.jp/public/gl/guidelin/ch1ref1.pdf [March 2, 2008]

Jones, Andrew, and Ennis, N. 2007. Bringing the Environment into Economic Development. *Local Economy*, 22: 1-5.

Martens, P. 1999. How will climate change affect human health? *American Scientist*, 87(6): 534-541.

Masera, O., Garaz-Caligaris, J.F., Kanninen, M., Karjalainen, J., Liki, J., Nabuurs, G.J., Pussinen, A., de Jong, B.H.J., Mohren, G.M.J. 2003. Modeling Carbon Sequestration in aforestation, agroforestry, and forest management projects: CO2 Fix V.2 approach. *Ecological Modeling*, 164 177-199

Mass, J. 1980. Better Brochures for the Money. *The Cornell H.R.A. Quarterly*, 20(4): 21-34.

McMichael, A.J., Woodruff, R.E. and Hales, S. 2006. Climate change and human health: present and future risks. *Lancet*, 367: 859-869.

Michener, W.K., Blood, E.R., Bildstein, K.L., Brinson, M.M. and Gardner, L. 1997. Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands. *Ecological Applications,* 7(3): 770-801.

Monroe, M. and Ludovica, W. 2007. *Enhancing Natural Resource Programs: Designing Effective Brochures*. University of Florida IFAS Extension. pp.1-14.

National Oceanic & Atmospheric Administration. 2007. The NOAA annual greenhouse gas index (AGGI). [Online] Available: http://www.esrl.noaa.gov/gmd/aggi/ [March 03, 2008]

Nature Conservancy, The. 2007. [Online] Carbon footprint calculator. Available: http://www.nature.org/initiatives/climatechange/calculator/ [October 22, 2007]

Nicholls, R.J., Hoozemans, F.M.J. and Marchand, M. 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. *Global Environmental Change*, 9: S69-S87.

Nigel, C., Gautam, M., Rapp, B., Lyons, D. 1999. Diesel and CNG Transit Bus Emissions Characterization By Two Chassis Dynamometer Laboratories: Results And Issues. SAE International, Warrendale, PA (US). [Online] Available: http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=771073 [March 21,2008]

Office of the Auditor General of Canada (OAGC). 2006. Report of the Commissioner of the Environment and Sustainable Development (RESD). [Online] Available: http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c20060902ce.html#ch2hd3a [Oct 27, 2007]

Ontario Power Generation. 2000. Ontario Power Generation Greenhouse Gas Action Plan 2000. [Online] Available: https://ozone.scholarsportal.info/bitstream/1873/6481/1/10299371.pdf [April 21, 2008]

Oishi, S.M. 2003. *How to conduct in-person interviews for surveys*. Sage Publications. Thousand Oaks, California.

Povellato, A., Basello, F., and Giupponi, C. 2007. Cost-effectiveness of greenhouse gases mitigation measures in the European agro-forestry sector: a Literature Survey. *Environmental Science and Policy,* 10: 474-490.

Rodhe, H. 1990. A comparison of the contribution of various gases to the greenhouse effect. *Science, New Series*, 248(4960): 1217-1219.

Rothman, A., Martino, S., Bedell, B., Detweiler, J., Salovey, P. 1999. The Systematic Influence of Gain-and Loss-Framed Messages on Interest in and Use of Different Types of Health Behavior. *Personality and Social Psychology Bulletin*, 25: 1355-1369.

Safe Climate. Calculator. [Online] Available: http://www.safeclimate.net/calculator/ [March 30 2008]

Simpson, J., Jaccard, M. and Rivers, N. 2007. *Hot Air: fixing Canada's climate change challenge.* Toronto, ON: McClelland & Steward Ltd.

Singer, E., Mathiowetez N.A., Couper, M.P. 1993. The impact of privacy and confidentiality concerns on survey participation: the case of the 1990 U.S.census. *The Public Opinion Quarterly*, 57(4): 465-482.

Sjostrom, O., Holst, D., Lind., S.O. 2008. Validity of a questionnaire survey: the role of non-response and incorrect answers. *Acta Odontologica Scandinavica*, 57(5): 242-246.

Smit, J.H., Dijkstra, W., van der Zouwen, J. 1997. Suggestive Interviewer Behavior in Surveys: An Experimental Study. *Journal of Official Statistics*, 13(1): 19-28.

Smith, J. 2000. *The Daily Globe: Environmental change, the public and the media*. Earthscan Publications Ltd: London, England.

Skyes, W., Williams, J.M. 1987. Evaluation survey questions. *J. of Official Statistics*, 3(2): 1991-2007.

Stutman, R. and Newell, S. 1984. Beliefs versus Values: Salient Beliefs in Designing a Persuasive Message. *The Western Journal of Speech Communication*, 48: 362-372.

Taylor, F.W. 1991. The greenhouse effect and climate change. *Reports on Progress in Physics*, 54:881-918.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumount, L.J., Collingham, Y.C., Erasmus, B.F.N., Ferreira de Siqueira, M., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. and Williams, P.E. 2004. Extinction risk from climate change. *Nature*, 427: 145-148.

Thuiller, W., Lavorel, S., Araujo, M.B., Sykes, M.T. and Prentice, I.C. 2005. Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences*, 102(23): 8245-8250.

United Nations Environmental Programme. 1996. Radiative Forcing – Climate Change. [Online] Available: http://www.grida.no/climate/vital/04.htm [March 14th, 2008]

U.S. department of Energy. Find and Compare Cars. [Online] Available: http://www.fueleconomy.gov/feg/noframes/7903.shtml [March 2, 2008]

Vincent, W., Jerram, L. 2006. The Potential for Bus Rapid Transit to Reduce Transportation-Related CO_2 Emissions. Breakthrough technologies institute. [Online] Available: http://www.gobrt.org/BTI_BRT_CO2_Journal_2006.pdf [March 21, 2008]

The World Bank Group. 2008. World Environment Indicators. [Online]Available:http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/

EXTDATASTA/0,,contentMDK:21055263~pagePK:64168445~piPK:64168309~theSitePK:2875751,00.html [March 14th 2008]

Zerofootprint Inc. 2006. [Online] Zerofootprint: Carbon Calculator. Available: http://www.zerofootprintoffsets.com/calculator.aspx [October 22, 2007]

Zerofootprint. [Online] Zerofootprint calculator in partnership with the University of Guelph. [Online] Available: http://www.zerofootprint.net/about/calculators [March 12,2008]

Zerofootprint. My Calculator. [Online] Availble: http://Toronto.zerofootprint.net/profile/sign_in [March 30, 2008]

Appendix A:

A Comparison of the Eden Mills' Carbon Calculator to Canadian Internet Carbon Calculators

Introduction

A cross – carbon calculator comparison of Canadian additive calculators (see Methodology section for description) was completed following the execution of the carbon survey in Eden Mills. In retrospect, it would have been useful to complete this analysis prior to the development of the Eden Mills carbon survey and calculator however due to time constraints we were unable to do so. Nevertheless, the cross-calculator comparison may prove helpful for the development of future carbon surveys to be administered in Eden Mills in addition to improving the understanding of carbon calculators.

Canadian carbon calculators available on the internet and the Eden Mills' carbon calculator were analyzed using similar methods employed by Padgett et al. (2007) in their comparison of America carbon calculators (See Table 1).

Table 1. Canadian carbon calculators examined.

Carbon Footprint Ltd.	http://www.carbonfootprint.com/
Carbon Footprint Offsetters	http://www.offsetco2.ca/calculate.htm
Climate Care	http://www.climatecare.org
Safe Climate	http://www.safeclimate.net
The Carbon Farmer Inc	http://www.thecarbonfarmer.ca/
Tree Canada	http://www.tcf-fca.ca/calculator/
Zerofootprint	http://www.zerofootprint.net/about/calculators
Eden Mills' Calculator	See Accompanying CD-Rom

Carbon calculators were compared to the Eden Mills' calculator based on the survey questions posed and the coefficients used in the calculation of home energy, personal vehicle transportation, public transportation and flight travel emissions. Carbon Footprints were also compared by inputting identical data into each carbon calculator. Mean and standard deviation summary statistics accompanied each comparison. Overall, available carbon calculators showed a large variance among questions posed in the carbon survey, coefficients used, and Carbon Footprints generated. Furthermore, references and survey methodology were only included in some carbon surveys and the amount of detail included again varied noticeably. This demonstrated the overall lack of guidelines available in the development of carbon calculators and the need for uniform CO_2 coefficients.

Household Emissions

Household carbon survey questions, coefficients and Carbon footprints were compared among carbon calculators. Although, many calculators included the option of natural gas and kerosene these parameters were not examined as they had not been included in the Eden Mills' carbon survey. Electricity consumption was measured in annual kWh consumed by all carbon calculators except for Zerofootprint which collected information on average monthly electricity bills and converted this to annual kWh consumed. Safe Climate, The Carbon Farmer Inc., Carbon Footprint Offsetters and Tree Canada also requested information on province of resident in order to calculate CO_2 emissions based on CO_2 coefficients specific to each province. For the purposes of comparing calculators to the Eden Mills calculator Ontario was chosen as the province of residence for all carbon calculators. In Table 2 it was demonstrated that the CO_2 coefficients for kWh varied among carbon calculators, however the Eden Mills CO_2 coefficient did fall within one standard deviation of the mean CO_2 coefficient calculated.

Table 2. CO_2 emissions related to home electricity consumption of examined carbon calculators.

	Electricity Conversion (kg CO_2/kWh)	CO_2 emitted for 4000 kWh (kg/year)	Electricity Conversion (lb CO_2/kWh)	CO_2 emitted for 4000 kWh (lb/year)
Carbon Footprint Ltd.	0.430	1720.000	0.948	3792.600
Carbon Footprint Offsetters	0.300	1200.000	0.662	2646.000
Climate Care	0.530	2120.000	1.169	4674.600
Safe Climate	0.294	1176.000	0.648	2593.080
The Carbon Farmer Inc	0.170	680.000	0.375	1499.400
Tree Canada	0.304	1216.000	0.670	2681.280
Zerofootprint				
Eden Mills' Calculator	0.222	888.000	0.490	1958.040
Mean	**0.321**	**1285.714**	**0.709**	**2835.000**
Median	**0.300**	**1200.000**	**0.662**	**2646.000**
Standard Deviation	**0.122**	**488.867**	**0.269**	**1077.952**
Max	**0.530**	**2120.000**	**1.169**	**4674.600**
Min	**0.170**	**680.000**	**0.375**	**1499.400**

Table 3. CO_2 emissions related to heating oil consumption of examined carbon calculators.

	Heating Oil Conversion (kg $C0_2$/L)	CO_2 emitted for 4000 L (kg/year)	Heating Oil Conversion (lb $C0_2$/gal)	CO_2 emitted for 4000 gal (lb/year)
Carbon Footprint Ltd.	2.674	10696.000	22.334	89335.909
Carbon Footprint Offsetters	2.830	11320.000	23.637	94547.727
Climate Care	2.690	10760.000	22.468	89870.455
Safe Climate	3.117	12468.000	26.034	104136.136
The Carbon Farmer Inc				
Tree Canada	2.830	11320.000	23.637	94547.727
Zerofootprint				
Eden Mills' Calculator	2.830	11320.000	23.637	94547.727
Mean	**2.829**	**11314.000**	**23.624**	**94497.614**
Median	**2.830**	**11320.000**	**23.637**	**94547.727**
Standard Deviation	**0.159**	**635.714**	**1.327**	**5309.660**
Max	**3.117**	**12468.000**	**26.034**	**104136.136**
Min	**2.674**	**10696.000**	**22.334**	**89335.909**

In comparison to the variance demonstrated among American CO_2 coefficients for kWh in the by Padgett et al. (2007), the variance among CO_2 coefficients used by Canadian carbon calculators proved to be less by 0.082lbs of CO_2/gal [0.351-0.269 = 0.082lbs of CO_2/gal].

Household CO_2 emissions from heating oil were measured in annual litres consumed by all carbon calculators except for The Carbon Farmer Inc. who neglected this emission's factor all together (See Table 3). Zerofootprint did include heating oil in their survey however they asked for the annual amount of dollars spent on heating oil converting this to annual litres consumed. The CO_2 coefficient for heating oil also varied among carbon calculators, however the coefficient used in the Eden Mill's Calculator was close to the mean CO_2 coefficient falling within one standard deviation from it. Compared to the variance demonstrated among American carbon calculator CO_2 coefficients for heating oil in the study by Padgett et al. (2007), the variance among CO_2 coefficients employed by Canadian carbon calculators proved to be less by 0.673 lbs of CO_2/gal [2.00 – 1.327 = 0.673 lbs of CO_2/gal].

Household CO_2 emissions for propane were also measured in annual litres consumed by all carbon calculators except for Climate Care (See Table 4). Again, Zerofootprint did include propane in their survey however they requested the annual amount of dollars spent on propane converting this to annual litres consumed. In contrast to the previous CO_2 coefficients for household energy use the CO_2 coefficients for propane did not vary as greatly among carbon calculators, and the CO_2 coefficients employed in the Eden Mill's calculator was close to the mean CO_2 coefficient falling within one standard deviation from it. Compared to the variance demonstrated in the study by Padgett et al. (2007) among propane CO_2 coefficients used in American carbon calculators the variance among CO_2 coefficients used by Canadian carbon calculators proved to be less by 24.903lbs of CO_2/gal [25.0-0.097=24.903 lbs of CO_2/gal] .

Table 4. CO_2 emissions related to propane consumption of examined carbon calculators.

	Propane Conversion (kg $C0_2$/L)	CO_2 emitted for 4000 L (kg/year)	Propane Conversion (lb $C0_2$/gal)	CO_2 emitted for 4000 gal (lb/year)
Carbon Footprint Ltd.	1.530	6120.000	12.779	51115.909
Carbon Footprint Offsetters	1.530	6120.000	12.779	51115.909
Climate Care				
Safe Climate	1.518	6072.000	12.679	50715.000
The Carbon Farmer Inc	1.520	6080.000	12.695	50781.818
Tree Canada	1.500	6000.000	12.528	50113.636
Zerofootprint				
Eden Mills' Calculator	1.510	6040.000	12.612	50447.727
Mean	**1.518**	**6072.000**	**12.679**	**50715.000**
Median	**1.519**	**6000.000**	**12.687**	**50113.636**
Standard Deviation	**0.012**	**46.648**	**0.097**	**389.614**
Max	**1.530**	**6120.000**	**12.779**	**51115.909**
Min	**1.500**	**6000.000**	**12.528**	**50113.636**

The variety and type of survey questions posed on household energy consumption was also investigated in our analysis of Canadian carbon calculators. As can be seen from Table 5 some calculators went into great depth in calculating household CO_2 emissions asking specific questions on diet, clothing, waste and recycling, green composting, food packaging, water usage, and newspaper and magazines.

Table 5. Summary and comparison of carbon survey designs for household energy consumption.

	Sources and References	Province of Residence	Household Occupancy	Housing Type	100% of green power usage	Electricity in kWh	Propane in L	Heating oil in L	Wood in Cords
Carbon Footprint Ltd.	x (vague)		x			x	x	x	
Carbon Footprint Offsetters		x				x	x	x	
Climate Care	x (vague)					x		x	
Safe Climate	x (thorough)	x			x	x	x	x	
The Carbon Farmer Inc		x				x	x		
Tree Canada	x (vague)	x				x	x	x	x
Zerofootprint	x (thorough)		x	x	x				
Eden Mills' Calculator	X (thorough)		x			x	x	x	x

	Wood Pellets in kg	Diet Emissions	Clothing Emissions	Waste and Recycling	Green Compost	Food Packaging	Water Usage	Newspaper and Magazines	
Carbon Footprint Ltd.		x	x	x		x			
Carbon Footprint Offsetters									
Climate Care									
Safe Climate									
The Carbon Farmer Inc									
Tree Canada									
Zerofootprint		x		x	x	x	x	x	
Eden Mills' Calculator									

Personal Vehicle Emissions

Personal vehicle carbon survey questions, CO_2 coefficients and Carbon Footprints were compared among carbon calculators. Carbon emissions produced from gasoline fuelled vehicles are summarized in Table 6 and diesel fuelled vehicles in Table 7. All carbon calculators were able to calculate emissions using fuel economy (L/100km) or fuel efficiency (L/km), and annual km driven except for Tree Canada which requests annual fuel consumption and Zerofootprint which bases the emissions calculation on the annual km driven by the type of vehicle size (small, medium, large, SUV/Truck, or Hybrid). As seen in Table 7, Carbon Footprint Ltd., Safe Climate and Zerofootprint did not include a calculation of CO_2 emissions from diesel fuelled vehicles. It was demonstrated that the CO_2 coefficients for gasoline did vary slightly among carbon

calculators; however, the Eden Mills CO_2 coefficient was close to the mean falling within one standard deviation from it.

Table 6. CO_2 emissions related to gasoline fuelled personal vehicles.

	Vehicle Use Conversion (kg CO_2/L)	CO_2 emitted for 30,000km driven at 11.9km/L (Kg CO_2/year)	Vehicle Use Conversion (lb CO_2/gal)	CO_2 emitted for 18,642miles driven at 8.4MPG (lb CO_2/year)
Carbon Footprint Ltd.	2.315	5835.000	19.336	42869.591
Carbon Footprint Offsetters	2.729	6880.000	22.793	50536.118
Climate Care	2.321	5850.000	19.386	42980.700
Safe Climate	2.328	5868.000	19.444	43110.327
The Carbon Farmer Inc	2.360	5950.000	19.711	43702.909
Tree Canada	2.247	5664.000	18.768	41610.355
Zerofootprint				
Eden Mills' Calculator	2.360	5949.000	19.711	43702.909
Mean	**2.380**	**5999.429**	**19.878**	**44073.273**
Median	**2.328**	**5868.000**	**19.444**	**43110.327**
Standard Deviation	**0.158**	**399.905**	**1.324**	**2934.806**
Max	**2.729**	**6880.000**	**22.793**	**50536.118**
Min	**2.247**	**5664.000**	**18.768**	**41610.355**

Table 7. CO_2 emissions related to diesel fuelled personal vehicles.

	Vehicle Use Conversion (kg CO_2/L)	CO_2 emitted for 30,000km driven at 11.9km/L (Kg CO_2/year)	Vehicle Use Conversion (lb CO_2/gal)	CO_2 emitted for 18642miles driven at 8.4MPG (lb CO_2/year)
Carbon Footprint Ltd.				
Carbon Footprint Offsetters	3.070	7740.000	25.641	56905.764
Climate Care	2.630	6630.000	21.966	48749.889
Safe Climate				
The Carbon Farmer Inc	2.730	6880.000	22.802	50603.497
Tree Canada	1.949	4914.000	16.279	36126.819
Zerofootprint				
Eden Mills' Calculator	2.730	6882.000	22.802	50603.497
Mean	**2.622**	**6609.200**	**21.898**	**87591.955**
Median	**2.730**	**6880.000**	**22.802**	**91206.818**
Standard Deviation	**0.411**	**1036.894**	**3.436**	**13744.753**
Max	**3.070**	**7740.000**	**25.641**	**102565.909**
Min	**1.949**	**4914.000**	**16.279**	**65114.318**

Compared to the variance observed by Padgett et al. (2007) for CO_2 coefficients for gasoline, there was a greater variance of 0.154 lbs CO_2/gal [1.17-1.324 = - 0.154 lbs CO_2/gal of gasoline] observed among CO_2 coefficients used by Canadian carbon calculators. We were unable to do a comparison of CO_2 coefficients for diesel fuel as this parameter was not included in the study by Padgett et al., (2007).

Table 8. Summary and comparison of carbon survey designs for personal vehicle transportation.

	Vehicle make and model	Fuel Efficiency or Economy	Annual fuel usage	Based on vehicle size	Annual km driven	Emissions for gasoline
Carbon Footprint Ltd.	X	X			X	X
Carbon Footprint Offsetters		X	X		X	X
Climate Care		X			X	X
Safe Climate		X		X	X	X
The Carbon Farmer Inc		X	X		X	X
Tree Canada			X			X
Zerofootprint				X	X	
Eden Mills' Calculator	X	X	X		X	X
	Emissions for diesel	**Unlimited cars**	**Emissions motorbikes**	**Emissions boats**	**Emissions Scooters**	
Carbon Footprint Ltd.	X		X			
Carbon Footprint Offsetters	X					
Climate Care	X	X				
Safe Climate						
The Carbon Farmer Inc	X					
Tree Canada	X		X			
Zerofootprint			X	X	X	
Eden Mills' Calculator	X	X				

Public Transportation

Public Transportation carbon survey questions, CO_2 coefficients and Carbon Footprints were also compared among Canadian carbon calculators. Calculators in this category differed in their calculation of emissions from public transit using either city to city, km driven or hours spent in

transit (See Table 9). In order to standardize this category so that a comparison was possible the Zerofootprint methodology for transit emissions was used.

Table 9. Summary and comparison of carbon survey designs for public transportation.

	Public Bus Transportation	Subway or LRT Transportation	Inter-city Train	Inter-city Buses	Commuter trains
Carbon Footprint Ltd.	x	x	x	x	
Carbon Footprint Offsetters					
Climate Care					
Safe Climate					
The Carbon Farmer Inc	x	x	x	x	
Tree Canada	x	x		x	
Zerofootprint	x	x	x	x	x
Eden Mills' Calculator	x	x	x	x	x
	City to city travel	Travel in kms	Travel in hours	Option of Round Trip	
Carbon Footprint Ltd.		x			
Carbon Footprint Offsetters					
Climate Care					
Safe Climate					
The Carbon Farmer Inc		x			
Tree Canada	x	x		x	
Zerofootprint			x		
Eden Mills' Calculator			x	x	

As stated on their website they calculated emissions for street car, subway, LRT, and public bus using the following formula: Streetcar/Subway/LRT/Public Bus Emission Factor x 32.5km/h x Hours Traveled. Therefore 3 hours of travel equated to 97.5km and this was used as the basis for comparison. Although Tree Canada did use a city to city question to calculate emissions for public transit they also included the option of inputting the kilometres travelled which we took advantage of in order to complete our comparison. For public transportation by intercity bus

(Greyhound buses, Go Buses) and intercity train (Via Rail) we also used the Zerofootprint methodology for transit emissions which is as follows: Intercity Train/Intercity Bus Emission Factor x 100km/h x Hours Traveled. Therefore 3 hours of travel equated to 300km travelled. It was not possible to compare emissions from Intercity Trains (Go Train) as this category was only included in the Zerofootprint and Eden Mills' carbon calculator.

Table 10. CO_2 emissions and Coefficients for Streetcar, Light Rapid Transit, and Subway.

	CO_2 emitted for 97.5km or 3hours (kg CO_2/year)	CO_2 Coefficient (kg CO_2/hr)	CO_2 Coefficient (kg CO_2/hr)
Carbon Footprint Ltd.	6	0.062	2.000
Carbon Footprint Offsetters			
Climate Care			
Safe Climate			
The Carbon Farmer Inc	10	0.103	3.333
Tree Canada			
Zerofootprint	10	0.103	3.333
Eden Mills' Calculator	10	0.103	3.333
Mean	**9**	**0.092**	**3.000**
Median	**10**	**0.103**	**3.333**
Standard Deviation	**2**	**0.021**	**0.667**
Max	**10**	**0.103**	**3.333**
Min	**6**	**0.062**	**2.000**

Table 11. CO_2 emissions and Coefficients Public Buses.

	CO_2 emitted for 97.5km or 3hours (kg CO_2/year)	CO_2 Coefficient (kg CO_2/hr)	CO_2 Coefficient (kg CO_2/hr)
Carbon Footprint Ltd.	9	0.092	3.000
Carbon Footprint Offsetters	30		
Climate Care			
Safe Climate			
The Carbon Farmer Inc	20	0.205	6.667
Tree Canada	14.16		
Zerofootprint	17.5	0.179	5.833
Eden Mills' Calculator	17.5	0.179	5.833
Mean	**18.0267**	**0.164**	**5.333**
Median	**17.5**	**0.179**	**5.833**
Standard Deviation	**6.989**	**0.049**	**1.604**
Max	**30**	**0.205**	**6.667**
Min	**9**	**0.092**	**3.000**

Table 12. CO_2 emissions and Coefficients for Intercity Trains (Via Rail).

	CO_2 emitted for 300km or 3hours (kg CO_2/year)	CO_2 Coefficient (kg CO_2/hr)	CO_2 Coefficient (kg CO_2/hr)
Carbon Footprint Ltd.	18.000	0.060	6.000
Carbon Footprint Offsetters	30.000	0.100	10.000
Climate Care			
Safe Climate			
The Carbon Farmer Inc	40.000	0.133	13.333
Tree Canada	30.990	0.103	10.330
Zerofootprint	30.833	0.103	10.278
Eden Mills' Calculator	30.833	0.103	10.278
Mean	**30.109**	**0.100**	**10.036**
Median	**30.833**	**0.103**	**10.278**
Standard Deviation	**7.018**	**0.023**	**2.339**
Max	**40.000**	**0.133**	**13.333**
Min	**18.000**	**0.060**	**6.000**

Table 13. CO_2 emissions and Coefficients for Intercity Buses (Greyhound Buses, Go Buses).

	CO_2 emitted for 300km or 3hours (kg CO_2/year)	CO_2 Coefficient (kg CO_2/hr)	CO_2 Coefficient (kg CO_2/hr)
Carbon Footprint Ltd.			
Carbon Footprint Offsetters	20.000	0.067	6.667
Climate Care			
Safe Climate			
The Carbon Farmer Inc	20.000	0.067	6.667
Tree Canada	16.950	0.057	5.650
Zerofootprint	15.000	0.050	5.000
Eden Mills' Calculator	15.000	0.050	5.000
Mean	**17.390**	**0.058**	**5.797**
Median	**17.170**	**0.057**	**5.723**
Standard Deviation	**2.512**	**0.008**	**0.837**
Max	**20.000**	**0.067**	**6.667**
Min	**15.000**	**0.050**	**5.000**

Among all categories for public transportation a range of variances for CO_2 coefficients were demonstrated however in all cases the coefficients used by Eden Mills fell within one

standard deviation of the mean. A comparison to the study Padgett et al. (2007) carbon calculator analysis could not be performed as they did not include the category of public transportation.

Flight Travel

Flight Travel carbon survey questions, CO_2 coefficients and Carbon Footprints were also compared among Canadian carbon calculators. Calculators in this category differed in their calculation of emissions from flight travel using either city to city, km flown or hours spent in flight travel (See Table 14).

Table 14. Summary and comparison of carbon survey designs for flight travel.

	City to city flight travel	Distance of flight travel	For hours of flight travel	Option for round trip	Number of passengers	Unlimited number of flights
Carbon Footprint Ltd.	x			x		
Carbon Footprint Offsetters						
Climate Care	x			x	x	x
Safe Climate		x				
The Carbon Farmer Inc		x				x
Tree Canada	x	x		x		
Zerofootprint			x			x

The Eden Mills' flight travel coefficients (which were based on the Zerofootprint flight calculations) were related to the hours spent in flight travel i.e. short haul (< 1.5hours), medium haul (1.5 – 3.0 hours), long haul (3.0 – 5.0 hours), and extended haul (> 5.0 hours). However, only the Eden Mills' carbon calculator and the Zerofootprint used this methodology to calculate CO_2 emissions. All other calculators investigated employed either city to city travel or distance of flight travel to calculate CO_2 emissions. In order to standardize and compare the calculators a series of five direct flights for each category of hourly travel were determined using flight destinations for Air Canada and West Jet (See Table 14). Each travel destination was then inputted into the 'city to city flight travel' carbon calculators and the mean CO_2 coefficient was

determined which corresponded to the Eden Mills' carbon calculator hourly flight categories. The distance for each city to city destination was also determined, and these distances were inputted into the 'distance of air travel' carbon calculators and the mean CO_2 coefficient was determined which corresponded to the Eden Mills' carbon calculator flight categories.

Table 14. City to city flight travel destinations and distances associated with hourly flight travel categories used by the Eden Mills' carbon calculator.

Short Haul Flights (< 1.0 Hrs)	Medium Haul (1.5 – 3.0hrs)	Long Haul (3.0 – 5.0 hrs)	Extended Haul (>5.0 hrs)
Toronto to Montreal 505Km	Toronto to Halifax 1283 km	Toronto to Edmonton 2687km	Toronto to Los Angeles, USA 3471
Toronto to Detroit 315km	Vancouver to Los Angeles 1729 km	Toronto to Havana, Cuba 2297km	Vancouver to Honolulu 4348km
Toronto to New York 567km	Vancouver to Las Vegas 1583km	Toronto to Las Vegas 3117km	Toronto to Paris, Fra 6009
Toronto to Buffalo 109km	Toronto to Fort Lauderdale 1991km	Montreal to Calgary 3002km	Toronto to London, Eng 5720km
Vancouver to Seattle 186km	Toronto to Washington DC 584km	Toronto to Punta Cana, DR 2944km	Toronto to Jeruselem, Isr 9328km

Table 15. Summary of flight coefficients derived for short haul flight (< 1.5 hrs or 0 – 567km).

	Flight Conversion kg CO_2/flight	Flight Conversion lb CO_2/flight
Carbon Footprint Ltd.	145.8	321.489
Carbon Footprint Offsetters	37.2	82.026
Climate Care		
Safe Climate	62.8	138.474
The Carbon Farmer Inc	50	110.25
Tree Canada	45.718	100.80819
Zerofootprint	240	529.2
Eden Mills' Calculator	240	529.2
Mean	**117.3597143**	**258.77817**
Median	**62.8**	**138.474**
Standard Deviation	**91.25270568**	**201.212216**
Max	**240**	**529.2**
Min	**37.2**	**82.026**

Table 16. Summary of flight coefficients derived for medium haul flight (1.5 -3.0hrs or 568km - 1991km).

	Flight Conversion kg CO_2/flight	Flight Conversion lb CO_2/flight
Carbon Footprint Ltd.	295.4	651.357
Carbon Footprint Offsetters	154.8	341.334
Climate Care		
Safe Climate	259.2	571.536
The Carbon Farmer Inc	174	383.67
Tree Canada	194.926	429.81183
Zerofootprint	440	970.2
Eden Mills' Calculator	440	970.2
Mean	**279.7608571**	**616.87269**
Median	**259.2**	**571.536**
Standard Deviation	**119.7344459**	**264.0144531**
Max	**440**	**970.2**
Min	**154.8**	**341.334**

Table 17. Summary of flight coefficients derived for long haul flight (3.0 – 5.0hrs or 1992 – 3117 km).

	Flight Conversion kg CO_2/flight	Flight Conversion lb CO_2/flight
Carbon Footprint Ltd.	387.6	854.658
Carbon Footprint Offsetters	450	992.25
Climate Care		
Safe Climate	504	1111.32
The Carbon Farmer Inc	308	679.14
Tree Canada	381.796	841.86018
Zerofootprint	1230	2712.15
Eden Mills' Calculator	1230	2712.15
Mean	**641.628**	**1414.78974**
Median	**450**	**992.25**
Standard Deviation	**406.4842172**	**896.2976989**
Max	**1230**	**2712.15**
Min	**308**	**679.14**

Table 18. Summary of flight coefficients derived for extended haul flight (> 5.0hrs or > 3117 km).

	Flight Conversion kg CO_2/flight	Flight Conversion kg CO_2/flight
Carbon Footprint Ltd.	579.75	1278.34875
Carbon Footprint Offsetters	648	1428.84
Climate Care		0
Safe Climate	1039.2	2291.436
The Carbon Farmer Inc	642	1415.61
Tree Canada	869.434	1917.10197
Zerofootprint	2460	5424.3
Eden Mills' Calculator	2460	5424.3
Mean	**1242.626286**	**2397.49209**
Median	**869.434**	**1672.970985**
Standard Deviation	**846.403133**	**1980.908315**
Max	**2460**	**5424.3**
Min	**579.75**	**0**

Among all categories investigated for the carbon calculators the CO_2 coefficients for flight travel showed the greatest variance (See Tables 15, 16, 17, 18). The CO_2 coefficients used in the Eden Mill's carbon calculator and the Zerofootprint carbon calculator were demonstrated to be the outlier values in all categories for flight travel and were never within one standard deviation of the mean CO_2 coefficient. A comparison to the CO_2 coefficients derived for flight travel by Padgett et al. (2007) could not be made as their CO_2 coefficients were calculated in lbs CO_2/mile.

Discussion and Conclusion

Overall a range of variances for CO_2 coefficients used for household energy, personal transportation, public transportation and flight travel were observed among all Canadian carbon calculators investigated. The variances for CO_2 coefficients for household energy and personal transportation were relatively small indicating that some uniformity for CO_2 coefficients exists in this category. However, had the coefficients for other categories of household emissions such as

waste and recycling, water usage, diet, food packaging etc. been investigated, it is likely that a wide range of CO_2 coefficients would have been observed. This is due to the complex nature of such questions and the number of assumptions that are taken into account by the carbon calculator creator in order to produce a corresponding CO_2 coefficient. As a result these additional categories for household energy consumption would introduce further error and inaccuracy into the carbon survey. This mentality was likely the reason that these categories were not included in the majority of carbon calculators examined.

In terms of the methods used to generate the household CO_2 emissions all calculators requested actual kWh and heating fuel consumed except for the Zerofootprint carbon calculator. Zerofootprint uses dollars spent on electricity and heating fuel and coverts it to kWh using the average cost of 1kWh in that year. However, because energy prices have been fluctuating recently using this methodology would introduce additional error into the carbon survey. This was likely the reason that this methodology was not used by other carbon calculators examined. It's difficult to understand why Zerofootprint uses this methodology because it's just as simple for the survey participant to report annual kWh usage and heating fuel usage by looking at bills or calling energy providers so it's unclear what the benefits are of requesting dollar amounts spent on household energy.

CO_2 coefficients for personal vehicle transportation were also related to fuel efficiency or fuel economy and annual km driven by most carbon calculators examined. This method of calculation generates the total annual fuel used which is then multiplied by the fuel CO_2 coefficients to generate the carbon emissions from this activity. Tree Canada was one calculator that did not use this methodology but requested only annual fuel usage. It's unlikely however that many participants would be able to accurately estimate their annual fuel use although it can

also be argued that participants would also have difficulty reporting the actual fuel efficiency of their vehicle. The Carbon Footprint Ltd. and the Eden Mills carbon calculators give the participant the option to input actual fuel efficiency or to input vehicle make and model thereby using the manufacturer's fuel efficiency. However, the manufacturer's fuel efficiency may be optimistic and would not reflect actual driving habits which reduce or increase the fuel efficiency of the vehicle. Nevertheless, both methods are more accurate than the method employed by Zerofootprint which uses the average fuel efficiency for vehicle size or type.

Public transportation showed increased variance among CO_2 coefficients reflecting the complexity of such calculation. This category requires a number of assumptions to be made on behalf of the carbon calculator creator such as the average number of passengers per flight, the average fuel efficiency of a public bus and the average speed travelled in order to produce a corresponding CO_2 coefficient. Calculators which use distance travelled on public transportation assume the participant is aware of this information; however, it's not likely that they'd be able to accurately estimate this in all four categories of public transportation. An improvement to this survey process would be to include categories for city to city travel such as Tree Canada did or use hourly travel such as Zerofootprint or the Eden Mills calculator which is easier to estimate and reflects the time spent stuck in traffic which can not be accounted for in the calculators that use distance travelled on public transit.

Flight travel showed the most discrepancies among CO_2 coefficients of the carbon calculators examined. This is again due to the inherent complexity of generating the carbon emissions from this activity and the assumptions made in this process such as the size and type of plane, the plane fuel type, the number of passengers on the plane, and the plane fuel efficiency. The most accurate method of calculating flight emissions would be to use city to city

travel thereby generating an estimate of the flight distance travelled. This method was employed by the majority of carbon calculators in this study. Safe Climate and the Carbon Farmer Inc. require that survey participants input only the distance travelled by air plane, although it's doubtful that participants would be able to correctly make this estimation. The other option would be to employ the method used in the Eden Mills' and Zerofootprint carbon calculators which uses an estimate of the CO_2 emitted from the approximate time spent in flight travel. Although this employs more average values and assumptions it would be easier for a participants to estimate this value rather than distance travelled. However, the calculator comparison involved in this study demonstrated that the CO_2 coefficients employed by the Eden Mills' and Zerofootprint calculators were much larger than all other carbon calculators. Although, Zerofootprint (which was the basis for the Eden Mills' flight travel coefficients) has referenced the GHG Protocol as the source they used to generate this CO_2 coefficient their website is password protected for paying clients so this information could not be accessed by this study.

This study observed the wide variety and accuracy of Canadian carbon calculators that are currently available on the internet. A clear objective for developing or employing a carbon calculator is therefore essential. If the goal is to produce an accurate Carbon Footprint then it's important to choose a carbon calculator that uses CO_2 coefficients derived from primary literature and employs a carbon survey that uses minimal assumptions. However, if the goal is to encourage the public to understand their general carbon impact on the world then the priority would be to employ a public friendly calculator at the sacrifice of some accuracy. In the case of the Eden Mills' calculator accuracy and public participation were priorities therefore a balance of the two aspects had to be achieved. Nevertheless, a uniform method of calculating accurate carbon emissions from all human activities is essential to streamline carbon calculators.

However this study has clearly demonstrated the complexity and magnitude of effort that would be required to accomplish this task.

References

Carbon Footprint. [Online] Carbon Footprint Calculator. Available: http://www.carbonfootprint.com/calculator.aspx [March 30 2008]

Carbon Footprint Offsetters. [Online] Carbon Footprint Calculator. Available: http://www.offsetco2.ca/calculate.htm [March 30 2008]

Climate Care. [Online] Flights Calculator. Available: http://www.climatecare.org/calculators/flight/ [March 30 2008]

Climate Care. [Online] House Calculator. Available: http://www.climatecare.org/calculators/house/ [March 30 2008]

Climate Care. [Online] Car Calculator. Available: http://www.climatecare.org/calculators/car/ [March 30 2008]

Padgett, J.P., Steinemann, A.C., Clarke, J.H., Vandenbergh, M.P. 2007. A comparison of carbon calculators. *Environemtnal Impact Assessment Review.* [In press].

Safe Climate. [Online] Calculator. Available: http://www.safeclimate.net/calculator/ [March 30 2008]

The Carbon Farmer Inc. [Online] Carbon Calculator. Available: http://www.thecarbonfarmer.ca/carbon-calculator.php [March 30 2008]

Tree Canada. [Online] Homeowner's and Traveller's CO_2 Emissions Offset Calculator. Available: http://www.tcf-fca.ca/calculator/ [March 30 2008]

Zerofootprint. [Online] My Calculator. Available: http://toronto.zerofootprint.net/profile/sign_in [March 30 2008]

Appendix B:

Final Survey for Eden Mills Going Carbon Neutral

Eden Mills and Area C02 Footprint Survey

SURVEY #
(assigned at registration)

GENERAL BUILDING

1. How many people occupy your household/building? 1 2 3 4 5 6 7 8 9 10 Other____
(circle appropriate number)

2. What is the gross floor floor area of your household/building __________ sq.ft or ___________ sq.m

3. How do you heat your household/building?
(check one or more of the choices)

Electrical	Oil	Propane	Wood	Pellets	Other

4. How do you heat your domestic hot water?
(check one or more of the choices)

Electrical	Oil	Propane	Other

Please indicate other: __________

5. Do you own ________ or rent ________ your hot water heater?
If you own it, how many years old is your hot water heater? ________yrs.

6. What year was your home/building built? _________
If you have renovated or added an addition to your household/building indicate year construction was completed ________
and gross floor area added________

BUILDING ENERGY USE

Please indicate the specific amount of each energy type that you currently use in your home. Also note, if you use a secondary source of heat, in addition to your main heating type please include both.

Energy Type	Measured In	Primary	Secondary	Secondary
Electrical	kWh/yr			
Heating Oil	L/yr			
Propane	L/yr			
Wood	bush cords/yr			
Pellets	kg/bag/yr			
Other				

TRANSPORTATION

Vehicle Information	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
Fuel Efficiency				
km/yr driven				
Type of Fuel				
Information below is not required if fuel efficiency above, calculated using a) or b) has been recorded				
Make of Vehicle				
Model of Vehicle				
Year of Vehicle				

To calculate:
a) record annual km travelled/litres of fuel consumed

b) Step 1 - Fill-up your vehicle
Step 2 -Record the the number of km's travelled before you need to fill up again.
Step 3 - record total litres of second fill-up
Step 4 - km's travelled/litres of 2nd fill-up
= fuel efficiency

Public Transportation (indicate in hours how much time each person in the household/building uses public transportation)

Method of Transportation (In hours/month)	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Total
Streetcar, Light Rapid Transport, Subway							
Public Bus (e.g.TTC, Guelph Transit Bus)							
Commuter Train (e.g. Via rail)							
Intercity Train (e.g. Go Train)							
Intercity Bus (e.g. Go Bus, Greyhound)							

Air Travel (indicate the number of short,medium, long or extended haul flights taken by each person in the household during a one year time period)

Number of Flights/yr	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Total
Short Haul (<1.5 hrs)							
Medium Haul (1.5 - 3 hrs)							
Long Haul (3- 5 hrs)							
Extended Haul (>5hrs)							

GENERAL

Is there anything else you feel we should know about your household/building?

Appendix C: Results Newsletter and Brochure

1. Newsletter

Eden Mills Quest for Carbon Neutrality

Eden Mills Survey Results and Carbon Dioxide Reduction

|introduction|

One of the few communities that has recognized their contributions to Climate Change is the Village of Eden Mills, and has initiated this project to obtain Carbon Neutrality.

The student surveyors from the University of Guelph carried out a survey to calculate the amount of CO_2 emissions from the villagers. The emission sources included in the surveys were vehicle travel, air transportation, home electrical and heating sources, as well as public transportation. The survey was completed in late January of 2008.

as an essential step towards gaining the overall Carbon Footprint of the village and serving as a baseline for future year's reference. Through overwhelming support participation rates measured 50% of households. In comparison, Villages' such as Ashton Hayes had 40% participation.

Gaining the high participation level is important because it increases the accuracy of the Carbon Footprint calculation. The Carbon Footprint is then used as a benchmark for carbon reduction and sequestration efforts by the villagers.

|results|

After inputting the data from the surveys and computing the individual household carbon emissions, the surveyors were able to extrapolate a projected Carbon Footprint for the entire village. The villages' projected Carbon Footprint is 4607.92 tonnes of CO_2 emissions per year. The average villager emits 10.4 tonnes of CO2; this average can be compared to other Countries as seen below in Figure 1.

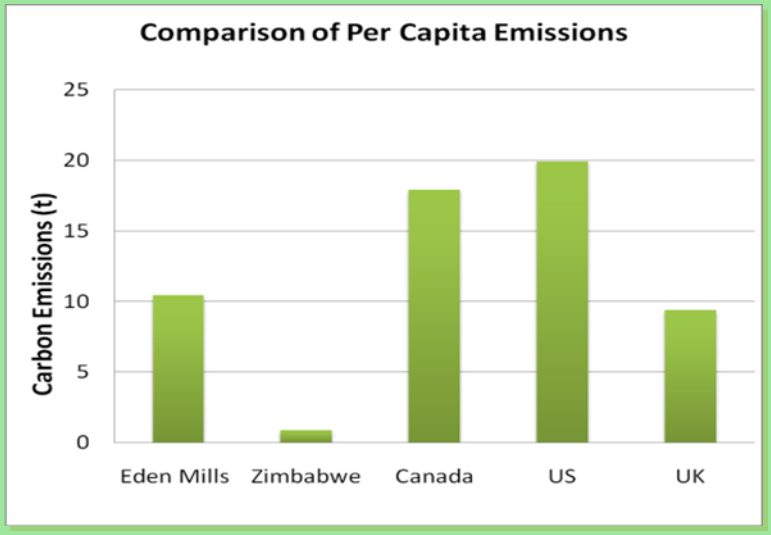


Fig 1. Comparison of Per Capita Emissions

Below in Figure 2 is a breakdown of the average CO_2 emission sources for the households in Eden Mills.

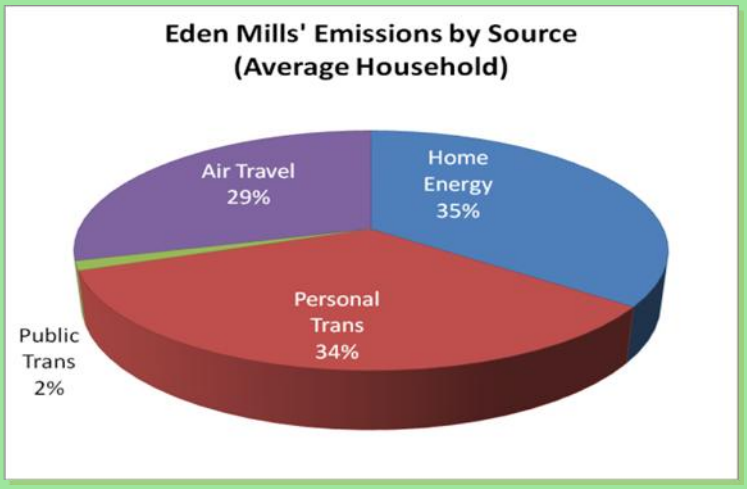


Fig 2. Emissions by Source

Below in Figure 3 is the total projected Carbon Footprint of Eden Mills, as well as the breakdown of individual sources.

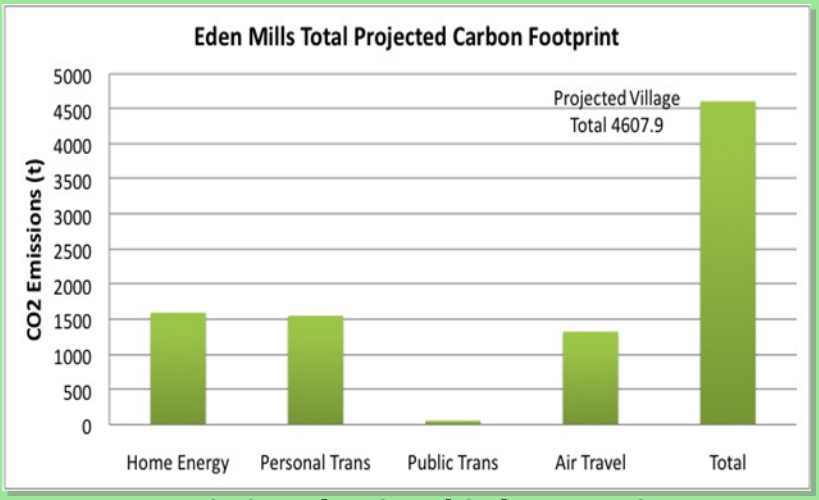


Fig. 3 Total Projected Carbon Footprint

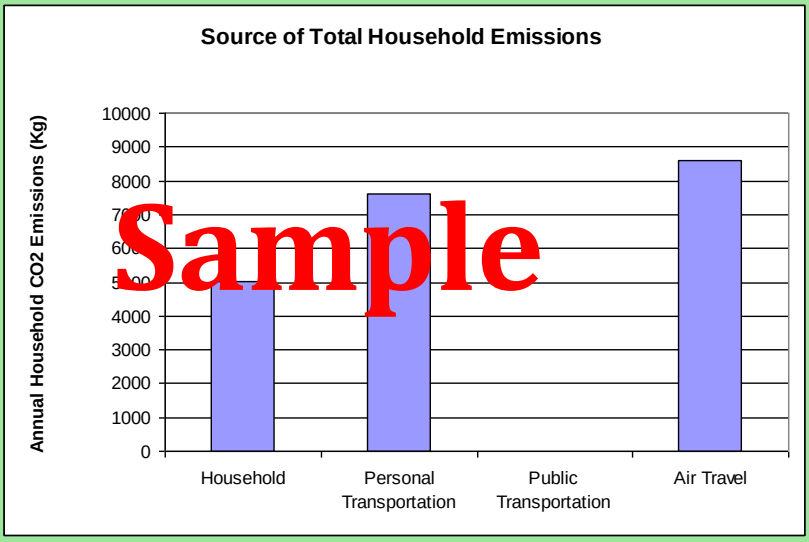
|your household results|

Your household Carbon Footprint is XXXX Tonnes of CO_2 per year

If you are below the average congratulations! There is still more you can do, finding certain areas in which you can easily reduce CO_2 emissions is a great starting point.

If you are above the average, don't worry! There are many suggestions in this newsletter that are intended to help you reduce your CO_2 footprint.

This graph shows your household Carbon Footprint and the overall Carbon Footprint of Eden Mills.



|tips for household CO_2 reduction|

The following tips are available for Eden Mills Residents to adopt in their daily habit:

- Use energy efficient light bulbs. they are 75% more efficient then incandescent bulbs
- Turn off electronics and lights when not in use
- Subscribe to green power, Bullfrog power is available in your area and is completely carbon neutral (bullfrogpower.com)
- In Winter, turn down the thermostat 1^{o} C during the day, and 2^{o} C at night or when not home
- In Summer, turn up the thermostat 2^{o} C during the day
- Bike, walk or take public transportation
- For electric water heaters through fixing leaks and insulation one can save 20-1400 kwH/year which results in 10-70$ annual savings
- Hang washing on the line
- Buy energy efficient appliances, ex. 'EnergyStar' label on new appliances you buy-energy efficient washing machine uses a 1/3 less power
- Drive smaller, more efficient cars, reducing your carbon output
- Increase the efficiency of your home by putting more insulation in your attic, or replacing your windows
- Pay to offset your carbon emissions, these organizations will sequester CO_2 for you:
    - offsetco2.ca
    - carbonzero.ca
    - offsetters.ca
- Get informed and get involved—learn how to reduce more and help with community projects!
- For electric water heaters through fixing leaks and insulation one can save 20-1400 kwH/year which results in 10-70$ annual savings

---

Thanks for your participation, and good luck on your quest towards Carbon Neutrality!

University of Guelph Surveyors

Email @ carbon.neutral2008@gmail.com

2. Brochure

|tips for household CO_2 reduction|

- Use energy efficient light bulbs. they are 75% more efficient then incandescent bulbs
- Turn off electronics and lights when not in use
- Subscribe to green power, Bullfrog power is available in your area and is completely carbon neutral (bullfrogpower.com)
- In Winter, turn down the thermostat 1^{o} C during the day, and 2^{o} C at night or when not home
- In Summer, turn up the thermostat 2^{o} C during the day
- Bike, walk or take public transportation
- Hang washing on the line
- Buy energy efficient appliances, ex. 'EnergyStar' label on new appliances you buy-energy efficient washing machine uses a 1/3 less power
- Drive smaller, more efficient cars, reducing your carbon output
- Increase the efficiency of your home by putting more insulation in your attic, or replacing your windows
- Pay to offset your carbon emissions, these organizations will sequester CO_2 for you:
    - offsetco2.ca
    - carbonzero.ca
    - offsetters.ca
- Get informed and get involved—learn how to reduce more and help with community projects!
- For electric water heaters through fixing leaks and insulation one can save 20-1400 kwH/year which results in $10-$70 annual savings

---

Thanks for your participation, and

good luck!

University of Guelph Surveyors

Email @

carbon.neutral2008@gmail.com

Eden Mills Quest for

Carbon Neutrality

Results of the Eden Mills Household Surveys and Simple CO_2 Reduction Strategies

|introduction|

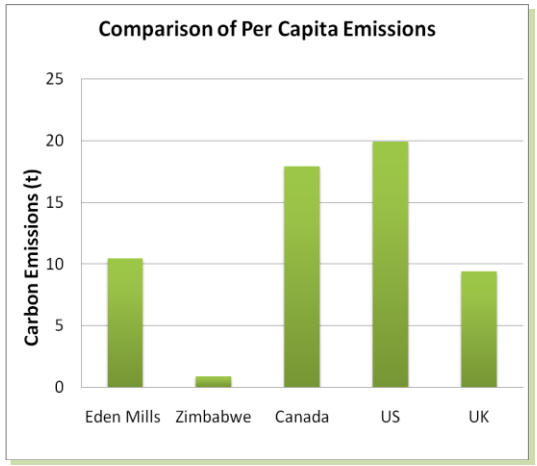
One of the few communities that has recognized their contributions to Climate Change is the Village of Eden Mills, and has initiated this project to obtain Carbon Neutrality.

The student surveyors from the University of Guelph carried out a survey to calculate the amount of CO_2 emissions from the villagers. The emission sources included in the surveys were vehicle travel, air transportation, home electrical and heating sources, as well as public transportation. The survey was completed in late January of 2008 as an essential step towards gaining the overall Carbon Footprint of the village and serving as a baseline for future year's reference. Through overwhelming support participation rates measured 50% of households. In comparison, Villages' such as Ashton Hayes had 40% participation.

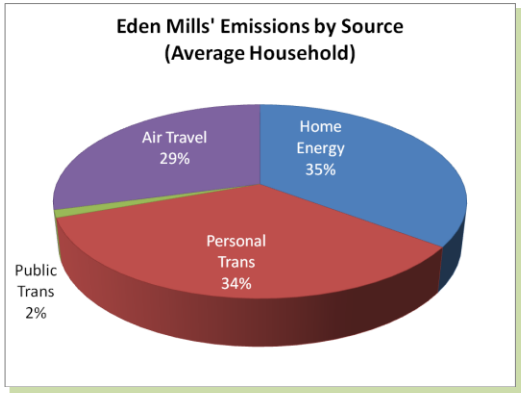
Gaining the high participation level is important because it increases the accuracy of the Carbon Footprint calculation. The Carbon Footprint is then used as a benchmark for carbon reduction and sequestration efforts by the villagers.

|results|

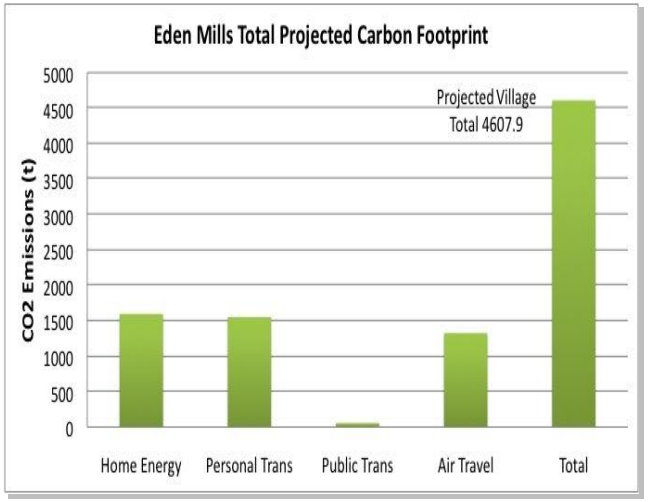
After inputting the data from the surveys and computing the individual household carbon emissions, the surveyors were able to extrapolate a projected Carbon Footprint for the entire village. The villages' projected Carbon Footprint is 4607.92 tonnes of CO_2 emissions per year. The average villager emits 10.4 tonnes of CO2; this average can be compared to other Countries as seen below.



On the adjacent panel is a breakdown of the average CO_2 emission sources for the households in Eden Mills.



Below is the total projected Carbon Footprint of Eden Mills, as well as the breakdown of individual sources.



Appendix D: Eden Mills' Trial Carbon Survey

Going Carbon Neutral!
Household Survey Questions:

Personal Info:

Name:

Address:

Number of people living at residence:

Type of Dwelling:

Email:

Home Energy:

1. **What is your main heating system?**
   - Central heating(boiler / radiators)
   - Electric storage heaters
   - Room heaters or fires
   - Other (please specify)

2. **What is your main fuel for heating?**
   - Main gas
   - Electricity
   - Solid fuel
   - Bottled gas
   - Oil
   - Wood

3. **What heating controls do you have?**
   - Room thermostat
   - Programmer (timer)
   - Thermostatic radiator valves
   - Storage heater dials
   - None

4. **How is your hot water provided?**
   - From main heating system
   - Electric instantaneous
   - Electric immersion
   - Gas instantaneous
   - Back boiler
   - Combi boiler
   - Range
   - Other (please specify)

5. **What is your insulation like?**
   - Double Glazed Windows
   - Insulated Doors
   - Loft Insulation
   - Hot Water Tank Insulation
   - All-walls insulated
   - Partial wall insulation

6. **How many lightbulbs are in your house? How many of these are low-energy?_____**

7. **Do you use Energystar appliances? (Nature conservancy)**
   - Yes
   - No

8. **Do you unplug your electronics and equipment when not in use? (Nature Conservancy)**
   - Yes
   - No

9. **Are you on a Green Energy Tariff? Ex. Bullfrog.**
   - Yes
   - No

10. **Do you include meat: (Nature Conservancy)**
    - At most meals
    - Most days, but not every meal
    - Rarely
    - Never

11. **Do you regularly check the air filter in your car? Tire pressure? (Nature Conservancy)**
    - Yes
    - No

12. What kind of car do you drive? (Zerofootprint)

Year:	Year:
Make:	Make:
Model:	Model:

How far do you drive each year (km)?

Car 1: _____

Car 2: _____

University of Chester

Appendix E: Ashton Hayes' Trial Survey

going carbon neutral Ashton Hayes

Ashton Hayes Carbon Calculator 2006

1 What type of property is your home? — **Home**

Detached	1
Semi-detached	6
Mid-terrace	11
End-terrace	6

2 What is your main heating fuel? — **Fuel**

Mains gas	1
Electricity	2
Solid fuel	4
Bottled gas	1
Oil	3
Wood	4

3 How much loft insulation do you have? — **Loft:**

No loft/access	1
None	1
1 inch/25mm	1
2 inches/50mm	2
3 inches/75mm	2
4 inches/100mm	2
5 inches/125mm	3
6 inches/150mm	3
8 inches/200mm	4
10 inches/250mm	4
Don't know	1

4 How much of the property has insulated walls? **Wall:** ☐

None	1
Partial	3
Full	5

5 How much of the property is double / secondary glazed?

None	1
Some (25%)	2
About half	3
Most (75%)	4
All	5

Glaze: ☐

6 How many cars are there in your household? **Cars** ☐

_____

For each car: **1** ☐ **2** ☐

7 What size engine does the car have?

Small (up to 1.4 litres)	1
Medium (1.4 - 2 litres)	2
Large (over 2 litres)	3
Sports utility vehicle	4

3 ☐

8 What fuel does the car use? ☐ ☐

Petrol	1
Diesel	2
Autogas No data	0

Biofuel	No data	0

9 What is the approximate annual mileage for the car?

Up to 2,500 miles	1
2,500 - 4,999 miles	2
5,000 - 7,499 miles	3
7,500 - 9,999 miles	4
10, 000 - 12,499 miles	5
Over 12,500 miles	6

10 How many short haul (UK, Europe and Mediterranean) return flights have been taken by the household in the past year?

11 How many long haul (rest of the world) return flights have been taken by the household in the past year?

_____

Your total Carbon footprint is 0 **tonnes per year**