GREEN PRACTICES AND TECHNOLOGIES FOR SUSTAINABLE COMMUNITIES

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By

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Abstract

In 1987, Gro Harlem Bruntland formally introduced and popularized the concept of sustainable development. She defined it as being "development that meets the needs of the present without compromising the ability of future generations to meet their own" (World Commission on Environment and Development, 1987).

Several cities, including the City of Hamilton have adopted certain environmental practices and technologies in an endeavor to improve their level of urban sustainability and achieve Bruntland's goal of sustainable development. These practices include the support of individuals and city organizations that investigate new sustainable design alternatives for current infrastructure development. Such sustainable alternatives include the consumption of locally grown produce to avoid the detrimental effects associated with the transportation of imported foods via transport trucks, the installation of Rooftop Gardens as a viable option of 'greening' modern urban landscapes, and the construction of R-2000 Homes to reduce energy consumption rates and decrease the levels of harmful emissions that would normally be produced by conventional homes. The implications and/or benefits associated with any of the aforementioned designs were calculated using an environmental assessment tool developed by a professor at the University of British Columbia: Ecological Footprint (EF) Analysis.

The final results of this study indicated that consuming locally grown produce, installing Rooftop Gardens, and living in R-2000 homes have the potential to enhance the state of the environment by improving air quality, reducing energy consumption, reducing water consumption, improving storm water retention, or by enhancing the biodiversity of a city's landscape. However, in order to reap the benefits of any or all of the above 'green' practices or technologies and begin to establish a sustainable community, the fundamental doctrines that have influenced modern development practices, particularly those that place economic progress in front of the conservation and preservation of the environment, will need to be changed.

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"Learning is not attained by chance, it must be sought for with ardor and attended to with diligence."

Abigail Adams (1744 - 1818), 1780

"What is important is to keep learning, to enjoy challenge, and to tolerate ambiguity. In the end there are no certain answers."

Martina Horner, President of Radcliffe College

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1 Project Overview

"Only after the last tree has been cut down, only after the last river has been poisoned, only after the last fish has been caught, only then will you find that money cannot be eaten."

- Old Cree Prophecy

1.1 Introduction to Sustainability

In 1987, Gro Harlem Bruntland presented a report entitled *Our Common Future* to the United Nations World Commission on Environment and Development. It examined population patterns, food security, species, ecosystems, human resources, energy, industry, the relationship between humans and their built environment, and foremost, popularized the concept of sustainability (Agenda 21 Locale, 2002). The report defines sustainability and/or sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their [own] needs" (World Commission on Environment and Development, 1987). As well, "sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are made consistent with future as well as present needs" (World Commission on Environment and Development, 1987).

Essentially, the core ideas of sustainable development practices were to make decisions that would not impair the prospects for maintaining or improving current or future standards of living, such that society could develop according to the self-perpetuating limits of its own environment (Coomer, 1979 & Repetto, 1986). Development would be subject to a set of constraints that would yield the harvesting rates of natural resources at a level no higher than natural regeneration rates. Renewable natural resources would be "used in a manner that does not eliminate or degrade them, or otherwise diminish their usefulness for future generations," and non-renewable resources would not be exhausted in a manner that "does not unnecessarily preclude easy access to them by future generations (Goodland et al, 1987 & Pearce, 1988). In essence, the use of the environment as a "waste sink" would not exceed any natural or managed assimilation rates by the corresponding ecosystem (Pearce, 1988). Therefore, following these provisions, the establishment of sustainable practices could mean the use of environmental services over longer periods of time without the risk of severe environmental degradation.

However, current practices differ from the ideally sustainable ones, especially among higher income countries[1]. In many of these nations, urban lifestyle practices have led to the exploitation of natural resources and degradation of the environment in the pursuit of progress and development (Rees et al, 1996). These development practices have degraded forest areas, polluted the soil, water, and air, and decreased the biological diversity of the planet (Rees et al, 1996). Basically, construction of urban centers, which

[1] Higher income countries, according to the World Bank Group, are any nations, which produce an excess of $9,206 ($US Billion) or more per annum (The World Bank Group, 2003). In comparison, low-income nations have a GNI of $745 or less; lower middle-income range between $746 and $2,975; and upper middle-income range between $2,976 and $9,205 (The World Bank Group, 2003).

involves massive consumption of raw materials, disrupts the natural processes of ecological systems (Alexander, n.d.). Urban habitats contributed to the loss of forest cover, valuable farmland, and loss of natural growing conditions for oxygen-producing vegetation (Alexander, n.d.). The creation of urban habitats has also caused soil erosion, interrupted the natural flow of streams, destroyed wetlands and fish habitats, and induced the onset of eutrophication and siltation in various bodies of water (Alexander, n.d.). Urban waste pollutes water and air, and contributes to the problem of acid rain, ground-level ozone pollution, industrial and transportation smog, and the 'urban heat island effect' (Alexander, n.d.).

Essentially, the concept of urban development in 'higher income nations' is a self-destructive process that will eventually deteriorate the natural environment on which we depend, and make it difficult to harvest even the basic essentials required to support human life. In a society where the distinction between the cause and effect of detrimental actions are blurred by the complex and intricate connections that form the fibers of modern civilizations, how can modern city planners build for the future without compromising the integrity of urban ecosystems and the natural environment?

Identifying ecological impacts through environmental management research is one of the ways that city planners can make sense of urban development issues. Research in the area of environmental management has helped to clarify the boundaries that exist along the blurred line of cause and effect by helping to discern the pathway of environmentally degrading plans and actions. This may include examining processes that involve the production or transportation of food, the extraction of raw materials, or "even how cities [can] export their pollution and waste products to other regions, forcing other people to live with the consequences of [their] activities" (Alexander, n.d.). Research that currently employs the use of certain planning tools can help governments, businesses, and industries become more conscious of their actions by making it easier to detect detrimental activities that can threaten the well being of both the environment and human civilizations (Ryding, 1992).

1.2 Environmental Assessment Tools

Environmental Impact Assessment (EIA) tools are based on methodologies that are designed to support the goals of environmental protection agencies through the provision of various systematic decision and evaluation processes. "Environmental impact assessments are now generally regarded as an integral component of sound decision making...As a planning tool it has both an information gathering and decision making component which provides the decision maker with an objective basis for granting or denying approval for a proposed development" (La Forest, 1991). Essentially, these tools can help ensure that humanity only uses the "essential products and processes of nature no more quickly than they can be renewed, and that we discharge wastes no more quickly than they can be absorbed" (Rees et al, 1996). As well, these tools can provide both a visual and quantifiable estimate that people can relate to and put into context in regards to their daily lives (Rees et al, 1996).

EIA tools such as Life Cycle Analysis (LCA), Design for Environment (DFE) and Ecological Footprints (EF) were designed to aid in the prediction of potential environmental, social, economic and cultural consequences that may arise as a result of the implementation of any product, process or activity.

For instance, Life Cycle Assessment (LCA) is a process that can be adopted by industries to evaluate the environmental impacts of their products. Its purpose would be to identify and quantify the amount of energy and raw materials used in production, maintenance, operation and disposal of their product. The process also accounts for the magnitude of air emissions, water-borne effluents, and solid wastes created by the life span of their product. LCA procedures follow a five-stage analysis system that includes, resource extraction (re-manufacturing), manufacturing operation, packaging and shipping (including installations where it is applicable), product delivery, customer use, and finally, the refurbishing, recycling or disposal of the product (Allenby et al, 1996).

Design for Environment (DFE) is an abridged version of Life Cycle Analysis (LCA). This is a systematic process that incorporates the potential environmental impacts of a product into its design. This includes the product's consumption of non-renewable resources and the release of potentially toxic chemicals into the environment as a result of its production, use and disposal. The three key components that define DFE are: its consideration of the entire life-cycle of a product, its application early on in the design stage of the product realization process, and that its decision process is consistent with the values of industrial ecology. DFE uses a 5x5 matrix, where the final summation of the cell entries indicates the environmental sustainability of the product. The left column of the matrix lists the five stages of LCA: resource extraction, manufacturing and operation, product delivery, consumer use, and refurbishment or disposal. Environmental concerns, such as material choices, energy use, and residues are listed across the top. Each cell of the matrix is assigned a value between 0 and 4, where a rating of 0 indicates that the product has a significant environmental impact, and a value of 4 represents a minimal effect. Once each cell has been assigned a number, the total of each column is added together to get a number out of 100. The rating out of 100 is expressed as a percent, and represents the environmental sustainability of the product (Allenby et al, 1996).

Finally Ecological Footprinting (EF) is a comprehensive environmental accounting tool whose purpose is not to point out how 'bad' human activities are, but to remind us of humanity's dependency on nature, and to show us how much our activities can impact the natural environment. EF "accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water area required from nature to support these flows" (Rees et al, 1996).

1.2.1 Ecological Footprint Analysis

William Rees developed the concept of an Ecological Footprint (EF) over a decade ago, a professor at the University of British Columbia. Its purpose was to measure the amount of productive land and water in an ecosystem that is required to sustain a defined population's lifestyle based on the consumption and waste patterns of that population without causing degradation to the ecosystem itself. The analysis is performed using a 6x'n' matrix, whereby the summation of the cell entries, in hectares/capita (ha/cap), is the total amount of ecologically productive land required to support the defined population in a sustainable manner. The matrix columns are divided into six categories: Degraded Land, Garden, Cropland, Pasture, Forest, and Energy. Degraded

Land is the amount of land constituting the built-up environment (Rees et al, 1996). Garden and Cropland refers to the amount of land reserved for the productions of fruits, vegetables, grains and other edible products (Rees et al, 1996). Pasture Land designates the land available for dairy, meat, and wool production, while Forest Land is the amount of prime forested land in the area. Finally, Energy Land is the amount of land required to sequester carbon dioxide (CO_2) emissions produced from the consumption of fossil fuels (Rees et al, 1996). Each 'Land' column is then further subdivided into sections pertaining to the amount of land required to grow food, provide shelter (housing), support transportation networks, and produce consumer goods and services. Ideally, the concept of EF is best applied to a larger population, either a country or city, where the size of the area is sufficient enough to contain all of the aforementioned categories and sub-sections. The complexity and intricacy of an EF analysis can also vary depending on the nature of the problem being studied; for example, the transportation component due to motorized vehicles for the 'Energy Land' category can be assessed based on the total number of automobiles located in the defined population's area. A more meticulous method might be to further sub-divide the total number of automobiles into sub-categories such as cars, trucks, mini-vans, or SUV's and determine the EF for the individual groups based on their fuel consumption rates. Either method will produce a hectares/capita (ha/cap) value for the 'Energy Land' category, under the transportation section, however the result may vary. Therefore, because the calculation methods can vary, it is important to remember that the results of an EF analysis are simply an estimate and an underestimated one at best.

1.3 Initiatives to Reduce Ecological Impacts

Most industrialized countries have the scientific knowledge and technology available to them that will allow them to adopt certain practices that can ease the burden of our ecological impact. These practices would reduce the amount of non-renewable natural resources used, and improve the general energy-efficiency of the existing infrastructure. Such practices can protect renewable resources by reducing or eliminating the amount of disposal and hazardous substances, such as plastics, toxic chemicals, and CFCs that are disposed of or expelled into the environment. The resultant action of employing environmentally conscientious practices can improve air, water, and soil quality.

In Canada, several municipalities have adopted environmentally oriented programs that utilize environmentally responsible technologies in an effort to reduce waste and improve the natural state of the environment. For example, Toronto adopted the 'Blue Box' program in 1988. The program accepted glass, metals, plastic, and paper products for recycling. Due to its success, additional programs with similar objectives were introduced. Toronto now successfully supports the 'Grey Box' program, which was developed to recycle the city's paper wastes, and the 'Green Bin' program aimed at minimizing the amount of organic household wastes that find their way into landfills.

However, the use of environmental technologies are not limited to programs that are designed to reduce wastes but can also be applied to initiatives undertaken to improve the quality of the air, water and soil. As an example, 'Clean Air Hamilton', an active environmental group in City of Hamilton, focuses on improving the city's air quality by encouraging the use of emission modelling technologies to locate source pollutants that are detrimental to human health and the environment (Clean Air Hamilton, 2003). This group encourages individuals to walk, bike, use public transit and/or carpool all in an attempt to reduce the levels of air pollution that the city experiences (Green Venture, 2002).

Organizations such as 'Clean Air Hamilton' each have their own agendas and beliefs as to what can be done to create a more sustainable community; their mandates are usually based on current problems or situations that afflict their city or region. In regards to the greater City of Hamilton, air pollution has been a major concern to several groups and organizations for years. The city is geographically situated on the southwest end of Lake Ontario and is home to heavy production industries such as Stelco and Dofasco. Both companies are known producers of chemical compounds such as ammonia, benzene, lead, nickel, mercury, and sulphuric acid that are recognized by Environment Canada as being a threat to human health (Environment Canada, 2003a). Also, since Hamilton is the gateway to the Niagara Peninsula it receives much of the through traffic between southern Ontario and the United States (HAQI, 1997). The by-products of vehicular traffic are nitrogen oxides (NOx), carbon monoxides (CO), hydrocarbons (HC), ozone precursors, and volatile organic compounds (VOC), all of which present an active hazard to both human health and the environment (& USEPA, 1995 & USDOT, 1993). These pollutants can aggravate an individual's allergies, create respiratory problems, pulmonary or cardiovascular difficulties, or even induce death. Therefore, groups such as 'Clean Air Hamilton', and 'Green Venture' actively support and promote any program or initiative that "support improvements to air quality in the City of Hamilton by reducing emissions that affect human and environmental health" (Clean Air Hamilton, 2003). A brief overview of the concerns and situation surrounding air pollution in the City of Hamilton can be reviewed in Appendix A.

1.4 Introduction to Project Objective

Recycling and composting, participating with active environmental organizations, or introducing and implementing environmental protection policies, practices, legislation, and controls can be a significant beginning when attempting to improve the current state of environmental affairs (Ryding, 1992). However, there are other practices and technologies that can be implemented, both on a local and municipal level, that can further aid in the improvement of the environment. It is the intention of this project to review one 'green' practice and two 'green' technologies that can be employed by cities in an effort to become more sustainable. The first section of this report, Chapter 2, will examine the practice of consuming locally grown produce to avoid the detrimental effects associated with the transportation of imported foods via transport trucks. The third chapter will examine Rooftop Gardens as a viable option of 'greening' modern urban landscapes, while the fourth and final chapter will explore a promising 'green' technology, R-2000 Homes.

1.4.1 The Role of Ecological Footprint Analysis in this Project

The unique characteristics of the Ecological Footprint (EF) Analysis allows a person to deconstruct, calculate, and present an adequate representation of the environmental implications and/or benefits of an activity, regardless of the total EF for the particular 'defined' population being studied. An example would be the cell entry in the transportation sub-section of the 'Energy Land' category; it can be used on its own to illustrate the impact associated with vehicular movements without having to know the total EF for the 'defined' population. For this particular reason, and for the purpose of this report, EF analysis has been selected as an appropriate environmental assessment tool to interpret potential benefits or implications associated with the transportation of fresh produce, Rooftop Gardens, and R-2000 homes.

More specifically, the amount of land required to sequester carbon dioxide (CO_2) emissions produced as a result of the transportation of fresh fruits and vegetables will be calculated under the transportation sub-section of the 'Energy Land' category, while a similar calculation will be performed under the residential/building sub-section of the 'Energy Land' category for Rooftop gardens. Finally, the amount of residential land required under the 'Energy Land' category for a 'defined' population will be estimated for an average R-2000 Home.

1.4.1.1 Selecting a 'Defined Population'

Since this project's roots are well embedded with the organization 'Citizens for a Sustainable Community (CSC),' whose main objective is to help the City of Hamilton become a sustainable community, it is only logical to select Hamilton as the required 'defined' population for the Ecological Footprint (EF) Analysis.

'Citizens for a Sustainable Community' was formed after the City of Hamilton was selected by the International Council on Local Environmental Initiatives under the United Nation's Agenda 21 Programme to be one of the first communities to model sustainable living conditions. Since CSC's inception, its goals have been steady and strong, and the organization has been committed to:

- *"Promot[ing] the concept of sustainability to the residents of Hamilton and the decision-makers in business, government and education*
- *Build[ing] a network of individuals and organizations that will effectively advance the goals of sustainability throughout our community*
- *Help[ing] define and monitor indicators which measure progress toward economic, social and environmental sustainability*
- *[And] help[ing] implement demonstration projects to achieve sustainability in our community."*

(Citizens for a Sustainable Community, 2003)

1.4.2 Food and Transportation

Foodland Ontario is a subsidiary of the Ontario Ministry of Agriculture and Food that coordinates the promotion and research of agricultural practices among producers, organizations, and industry stakeholders in an attempt to ensure fresh consumer goods, such as fruits and vegetables, are available to the Ontario populace. There are approximately 3,938 vegetable growers, 3,247 fruit, nut and berry farms, as well as 2,012 greenhouse producers that can serve the citizens of Ontario with fresh produce (Statistics Canada, 2001c,d,e). Since there are usually several Ontario producers located less than one day's drive away from the majority of the markets they serve, shoppers can virtually be guaranteed fresh Ontario fruits and vegetables a little less than 24 hours after they have been hand-picked from the vine. Locally grown produce is often sweeter, and since it had the opportunity to ripen on the vine, the produce will have more vitamins, minerals, and flavour than imported vegetables (Perth District Health Unit: Health Matters, 2002). Purchasing local products supports local farmers and their families and helps to build a stronger connection by improving rural-urban links between consumers and the producers. "When you buy locally grown food, you are doing something proactive about preserving the land needed to keep our whole community food secure" (Perth District Health Unit: Health Matters, 2002).

However, since approximately 1/3 of the total Canadian population, and 1/2 of Ontario's population (Statistics Canada, 2001) live in urban areas where fertile farmland is scarce, if at all existent, many consumers rely on local markets and grocery stores for their produce, instead of nearby farms. Therefore, grocery stores and supermarkets need to obtain their products from outside sources, which in turn have their products delivered via planes, ships, trains, and transport trucks. In Canada, the preferred method of transporting both imported and locally grown produce is through the use of transport trucks. This is because our built infrastructure, which includes an extensive road network, is geared around the automobile. Trucks have a distinct advantage over other modes of transport because they can access remote locations that are not easily accessible by waterways, air, or rail.

The problem with using trucks to transport goods is that they require gasoline, or more precisely, diesel fuel to operate. Transport trailers on average consume 1.1 – 4 times[2] more fossil fuels than the typical automobile, and the longer the trip is the more fuel that will be burned. The "average distance most food travels from farm to plate is about 2,400 km. This burns up a great deal of fossil fuel, which contributes to pollution and global warming. Food that is grown and sold locally travels a much shorter distance" and therefore, less carbon emission, and greenhouse gases are emitted into the atmosphere (Perth District Health Unit: Health Matters, 2002). It is, therefore, one of the objectives of this report to examine the impact that transporting produce by truck has on the environment, and the impact will be measured using Rees and Wackernagel's Ecological Footprint Analysis.

1.4.3 Rooftop Gardens

Researchers have shown that ample vegetation is an important component in any strategy aiming to reduce a city's internal temperatures and levels of greenhouse gases

[2] Figure based on the average automobile consumption rate of 10-26.6 L / 100 km as purposed by research conducted by William Rees and Mathis Wackernagel, authors of Our Ecological Footprint, and by the United States Environmental Protection Agency who published a comparison of the fuel economy of light-duty vehicles. The average fuel consumption rates were provided by Wilson Truck lines, and ranged between 30-40 L / 100 km depending on the weight of the load.

(Liu, 2002). Canadian sources have estimated that 11 sq*ft of grass alone, can remove approximately one-half pound of unwanted air particles each year (Kurland, 2001). However, given the limited amount of space available in many North American cities, it may be unrealistic to assume that our urban centers will soon be sprouting new patches of grass as an air purification and temperature reduction method. Instead, researchers have been focusing on a potentially untapped resource: the rooftop. Rooftops are largely abundant and are forsaken spaces in many cities.

Rooftop gardens are contained, man-made, green spaces that can be located on the top levels of any existing industrial, commercial, recreational, or residential complex found within a city. They can be made to fit flat or slanted roofs, and construction generally consists of "an engineered growing medium, which may not include soil, a landscape or filter cloth to contain the roots and the growing medium, while allowing for water penetration, a specialized drainage layer, sometimes with built-in water reservoirs, the waterproofing / roofing membrane, with an integral root repellent, and the roof structure, with traditional insulation either above or below" (1999). The implementation of this unique green space can save energy, help reduce the 'urban heat island effect', minimize pollution outputs, increase air quality, improve storm water retention and create an alternative habitat for some city dwelling species. How this old, but newly resurrected, green technology can achieve these goals will be studied in the second chapter, and the benefits will be measured using an ecological footprint calculation.

1.4.4 R-2000 Homes

Finally, the last 'green' technology that will be reviewed in this report as a method of reducing human ecological impact is the R-2000 Home Program. Since its inception in 1981, the program has been dedicated to improving the energy efficiency of new houses and low-rise dwellings. The program promotes the development of technical standards for energy-efficient construction practices, use of recycled materials, low-emission building textiles, and the installation of energy-efficient appliances, all in an effort to reduce waste, provide a higher level of indoor air quality, decrease overall energy expenditures by 30% -50%, and reduce water consumption rates (Alberta R-2000, 2000 & Parekh et al, 1999 & Natural Resources Canada, 2002c). As an example, all R-2000 homes are required to have a portion of the home built using recycled materials (EnerQuality, 2002). Indoor air quality is improved through the use of building materials that are non-toxic and do not emit harmful fumes. A Heat Recovery Ventilation (HRV) system also supplies the home with fresh and filtered air, eliminating the problem of 'stale air', which can cause mould and other allergens to linger in the home, aggravating individuals with respiratory problems (Alberta R-2000, 2000 & Parekh et al, 1999). Energy is conserved through the use of energy efficient devices such as home appliances, office equipment, and lighting fixtures (EnerQuality, 2002). Similarly, water consumption is reduced through the installation of water saving appliances such as taps, showerheads and toilets (EnerQuality, 2002).

The program, aside from encouraging energy conservation, also provides the building community with a new incentive upon which to improve its trade. "R-2000 has been right in front with the best of Canadian builders producing the best of Canadian housing stock, and a trickle-down effect has resulted in improving building technology and the industry"

(Home Energy Magazine Online, 1995). New homebuyers can now see improvements in energy performances, indoor air quality, water and material conservation, as well as monetary savings from decreased utility usage. As mentioned earlier, Ecological Footprint (EF) Analysis can be used to calculate the impact certain lifestyle choices have on our environment. Similarly, it can also be used to compare and contrast these choices. Therefore the benefits of R-2000 homes will be contrasted against conventional houses built between 1970-2000 using ecological footprint as a medium of comparison.

1.4.5 Project Objective and Scope of Work

This report will review one 'green' practice and two 'green' technologies that can be implemented by cities, such as Hamilton, in an endeavor to become more sustainable and reduce the ecological impacts generated by human activities.

- The first section of this report, Chapter 2, will examine the practice of consuming locally grown produce to avoid the detrimental effects associated with the transportation of imported foods via transport trucks. Different methods of transportation including shipping by road, rail, water, and air will be reviewed, and a brief discussion will explain why transport trucks are the predominant mode for the shipment of goods in Canada. The ecological impacts associated with the utilization of transport trucks will be calculated using an Ecological Footprint Analysis.
- Chapter 3 will introduce an older, but newly applied 'green' technology in North America: Rooftop Gardens. The chapter will briefly describe the different types of Rooftop Gardens, examine their advantages and disadvantages, as well as discuss their potential benefits. Rooftop Gardens when properly installed and maintained have the potential to save energy, increase the level of urban air quality, improve storm water retention, and provide an alternative habitat for certain city dwelling species. The energy saving benefits of 'greening' rooftops will be calculated using an Ecological Footprint analysis.
- The final chapter will review the innovative 'green' technology developed by the R-2000 Home Program: The R-2000 Home. R-2000 houses, in comparison with conventionally built homes, have the potential to reduce energy use, improve indoor air quality, and create a market for recycled materials. These goals are achieved through the implementation of new technical standards for energy efficient construction and practices, the use of energy efficient appliances, and through the use of environmentally responsible building materials. The environmental benefits of an R-2000 home will also be demonstrated using an Ecological Footprint Analysis and then compared to a conventional home.

2 Food and Transportation

2.1 The Canadian Food Industry

The agriculture sector is Canada's second largest natural resource-based industry and second largest manufacturing industry (Agriculture and Agri-Foods Canada, 2002). It contributes approximately two and a quarter billion dollars annually to the Canadian economy through the sales of 794,000 tonnes of fruits and 7 million tonnes of vegetables, 20% of which remains available to the Canadian populace while the remaining 80% is exported to countries such as the United States, and various European and Asian nations (Government of Canada, 2003a,b & Industry Canada, 2003). In turn, and especially during cold winter months, approximately 65% of all fresh Canadian produce is imported from the United State, 4% from Europe, 1% from Asia; the remaining 30% is imported from various other trading nations (Industry Canada, 2003). Interestingly enough, last year 37%, or 57% of the total 65% of fresh produce shipped in from the United States, was sent to Ontario alone (Industry Canada, 2003).

The food system, while a vital economic force in Canada, includes everything from the growth process to picking and harvesting, to processing, distribution, sales, purchasing, consumption, and disposal, and usually goes unnoticed by the general population. The reason for this is because in a highly dense and populated urban area where there is little to no room left for farmland and food production, people are forced to purchase their groceries from local markets. As a result, they remain largely ignorant of the entire food process prior to their trip to the grocery store. Therefore the general populace is usually left unaware of the time and energy involved in food production and any consequences or impacts that may arise as a result of either its production or distribution.

2.2 The Canadian Greenhouse Industry

Although in Canada there are a recorded 9,829 vegetable farms, 12,158 fruit, berry, and nut growers, and 6,073 greenhouses that strive to supply Canadians with fresh produce all year long, valuable farmland is constantly being swallowed up by capitalistic investors who want to build and expand residential areas to create suburban paradises (Statistics Canada 2001c,d,e). The consequence of this action has forced the food industry to adopt innovative practices to secure their economic market share. The food sector, through technological advancements, has adopted greenhouse technologies. Most greenhouses, unlike conventional farming methods, require very little land and can be open for business all year-round to produce a variety of fruits and vegetables, they can be located in or near urban centers (Irving, 1999).

Within Ontario alone, there are over 120 greenhouse businesses registered that specialize in the production of items such as lettuce, peppers, garlic, tomatoes, asparagus, apples, and even potatoes (Findit!, 2002). The introduction of computer controlled operation systems, innovative storage techniques, and continually improving distribution methods, have allowed Canadians, along with many other developed nations, to have year round access to a wide variety of domestically grown fresh fruits and vegetables. Currently, the top greenhouse vegetables grown in Ontario are cucumbers, tomatoes, lettuce and peppers. The Canadian Produce Marketing Association periodically publishes a chart that lists which domestic produce is available on the Canadian market. *The Canadian Availability Guide,* which can be viewed in Appendix B, lists 150 of the possible 225 fruits and vegetables that are grown in Canada each year and which month they are available (Canadian Produce Marketing Association, 2003). However, it does not include the different varieties within each produce group; for instance, there are at least 15 varieties of apples available throughout the year, but only one item would be listed.

Most greenhouse fruits and vegetables are grown using what is known as hydroponics technology. Hydroponics technology is a soil-less system in which seeds and mature plants are left to propagate and grow off of a nutrient-rich water solution (Ontario Greenhouse Vegetables, 2003). The administration of the solution is controlled through a computer program that also ensures that the greenhouses maintain an appropriate internal temperature that is ideal for the particular crop. The benefit of computer regulated greenhouses using hydroponics technology is that the fruits and vegetables are protected from the potentially harmful rays of the sun, harmful bacteria from manure field run-off, and acid rain. However, a major draw back associated with modern computer-controlled greenhouses is that they can consume a considerable amount of energy for heating and fertilizing systems.

Ontario tomatoes and cucumbers also have the added benefit of "being safe, natural, vine-ripened vegetables that are virtually pesticide free" (Ontario Greenhouse Vegetables, 2003). The Greenhouse and Processing Crops Research Centre (GPCRC) in Harrow, Ontario, uses an integrated pest management system where good bugs, like spiders and ladybugs, eat bad bugs, such as aphids who consume valuable plant material.

Between 1977 and 1997 the total greenhouse area in Canada increased from 3.8 million m^2 to 12.9 million m^2 (Irving, 1999). The greenhouse industry has also marginally increased its market share from less than 2% in 1981 to 3.2% in 1996 (Irving, 1999). This demonstrates the point that the food industry, which includes greenhouse produce, is a vital economic force within Canada. In 2000, the registered vegetable growers produced close to 7 million tonnes of vegetables at an estimated worth of approximately $2 billion, while the fruit growers in Canada produced 794,000 tonnes of fruit at a recorded worth of $269 million (Government of Canada, 2003a,b). In Ontario alone, the food industry contributes a total annual worth of $29 million (WCM Consulting Inc, 2002).

Foodland Ontario, a subsidiary of the Ontario Ministry of Agriculture and Food, coordinates the promotion and research of agricultural practices among producers, organizations, and industry stakeholders who are either traditional or greenhouse farmers, to ensure that the citizens of Ontario will have access to fresh fruits and vegetables all year round. The continuous supply of fresh food is an important factor in sustaining the quality of life in Canada, especially since 1/3 of the total Canadian population, and 1/2 of Ontario's population (Statistics Canada, 2001b) live in urban areas, where fertile farmland is scarce. Therefore, in order to obtain fresh produce and packaged goods, many city dwellers are solely dependent on local markets and grocery stores, which must have their products shipped in from various locations.

It is the objective of this section to examine the different distribution methods currently used in Canada, and based on the predominant choice, discuss the potential ecological impacts associated with it. These impacts will then be measured using an Ecological Footprint (EF) Analysis. Finally, the practice of consuming locally grown produce to avoid the detrimental effects associated with the transportation of imported foods will be discussed.

2.3 Modes of Transportation

The key component in ensuring that fresh fruits and vegetables are available at local food retailers is to have an efficient and readily accessible transportation system. Canada currently employs the use of transport trucks, cargo trains, ships, and planes to transport both imported and locally grown produce around the country. However, increasing population, changing trends in the demand for food of different origins and types, and the shrinking availability of farmland due to urban intensification challenges the Canadian food production market as it strives to supply fresh products while remaining competitive on both a national and global scale.

2.3.1 Shipping by Road

Trucking is a fast-paced, dynamic business that makes up a major segment of the Canadian food economy. Approximately 75% of money spent on the transportation of goods in Canada per year is on freight transportation via trucks (Westac, 1996). Thousands of trucks and specialized equipment – such as semi-trailers, refrigerated vans, tankers and dump trailers – are utilized to carry everything from grain, dairy, fresh produce, to poultry, pork, and beef products, around the country. Trucking is the ideal transportation method for distances that are less than 500 kilometers (Westac, 1996) especially when speed, flexibility, and cost are paramount to the customers. "Modern trucking employs a range of technologies to improve their service. This includes satellite-based systems for shipment tracking, on board computers to monitor fleet operation which can keep costs in check, and paperless computer systems to expedite border crossings (from the United States) and Customs clearance" (Westac, 1996). It has also become apparent that there is a growing interest in using trucking for longer distance travel over the regular 500 km, as nearly 93% of all fresh and manufactured consumer goods are currently been shipped across United States and Canada via tractor-trailers (Leopold Centre for Sustainable Agriculture, 2001).

However, there are some concerns surrounding transport trucks; for example, trucking contributes to the deterioration of our road condition as one truck traversing one km of roadway is equivalent to several thousand automobiles, thereby significantly increasing road maintenance costs. Truck traffic also creates congestion and delays in city downtown cores and across borders. Transport trailers also consume, on average, 1.1 – 4 times more fossil fuels than the typical automobile, which increases air pollution and decreases air quality. (The figure 1.1 – 4 was based on the average automobile consumption rate of 10-26.6 L / 100 km as proposed by research conducted by William Rees and Mathis Wackernagel, authors of Our Ecological Footprint, and by the United States Environmental Protection Agency who published a comparison of the fuel economy of light-duty vehicles. The average fuel consumption rates were provided by Wilson Truck lines, and ranged between 30-40 L / 100 km depending on the weight of the load). As well, there is a public concern surrounding the issue of road safety. Too many trucks on the road can not only lead to congestion, but can also increase the number of traffic accidents and related deaths and injuries.

2.3.2 Shipping by Rail

Canada's rail industry consists of three primary companies, Canadian National (CN), Canadian Pacific Railway (CP) and Via Rail (Westac, 1996). Both CN and CP operate large freight systems that transport bulk commodities such as sulphur, potash, coal, and grain across the country and into the United States, while Via Rail is mainly a passenger service. The Canadian rail industry transports approximately 290 million tonnes of natural resources and consumer goods a year (Westac, 1996). Although one rail car can carry 110 tonnes, which is equivalent to four times the amount that the average transport truck can accommodate, most companies still prefer to ship fruits and vegetables by transport truck (Westac, 1996). This is because the fixed location of the railway tracks infringes on the industry's ability to offer door-to-door service, which is imperative when dealing with perishable items. The trucking industry on the other hand, is not limited by this factor because the built infrastructure is predominantly a road-based network that is both automobile and truck friendly.

2.3.3 Shipping by Water

Canada is home to deep harbours and natural waterways that have made commercial shipping a possibility. The St. Lawrence Seaway connects the Atlantic Ocean to the Great Lakes through a series of man-made locks, canals, docks, handling systems and port terminals. Today nearly 50 million tonnes of iron ore, coal, steel, and grain are transported along the Seaway creating more than 60,000 jobs in Canada (Westac, 1996). Vancouver, Montreal, and Halifax are the major Canadian ports that receive and send off other consumer goods such as sulphur, potash, and forest products. Like the train infrastructure, shipping by waterways is limited by location, and other means of transportation are usually necessary to move the cargo off the ships and to their destination points.

2.3.4 Shipping by Air

The transportation of consumer goods by air in Canada has dramatically increased over the last 30 years, essentially doubling every 10 years (Westac, 1996). Canada currently imports and exports approximately $60 billion worth of goods each year by air (Westac, 1996), half of which is with the United States. Air cargo is generally "postal, courier and freight forwarder cargoes"(Westac, 1996). The top nine cargo companies, which include Purolator and Loomis, control over 80% of the market, while UPS and FedEx controls 60% of the business in and around the United States (Westac, 1996). The reason this transportation sector seems to be mainly dominated by courier services is because Canadian airlines have traditionally focused on the passenger market, not the transportation of natural resources and consumer goods. However, in 1998, in an attempt to capture another portion of the market, the Canadian government passed laws that made it easier for all-cargo services to operate in Canada. However, the sector is being monitored to ensure that the Canadian airlines that supplement their revenues through cargo transportation are not comprised. Like trains, and ships, air cargo is restricted by modern infrastructure. Not every city has an airport, and depending on the characteristics of the cargo and its final destination point, it may be more feasible, economic or otherwise, to use another mode of transportation.

2.3.5 Which Mode of Transportation is Currently the Most Effective?

In Ontario, and much of Canada, improved communication and organizational technologies have allowed trucking companies to monitor where their shipment is at any time, and make their own arrangements regarding pick-ups and deliveries, virtually eliminating the producers' role from the shipping process (Westac, 1996). The trucking industry has become so efficient, that between 1990-1996, it seized another 11% of the food transportation industry (Westac, 1996). However, aside from the trucking industry's compatibility with modern transportation infrastructure, is it truly the most effective method available?

In a study conducted by the United States Environmental Protection Agency (USEPA), heavy duty tractor-trailers used in the transportation of most produce over long distances emit over 3 tonnes of nitrogen oxides (NOx) [3], 160,000 tonnes of particulate matter (PM) and over 80 million metric tonnes of carbon equivalent greenhouse gases (2003). In comparison, transportation by rail emits only 1.2 tonnes of NOx, 30,000 tonnes of PM and a mere 9.5 million metric tonnes of carbon equivalent greenhouse gases (USEPA, 2003). That is approximately 1/3 the amount of NOx released, 1/5 the amount of PM, and 1/8 the amount of carbon emissions produced by tractor-trailers.

Also, the longer and the more frequent vehicular traffic trips are, the greater the potential risk is of contributing to a region's air pollution problems and reduction of air quality levels. For instance, it is estimated that 33% to 50% of nitrogen oxides (NO_x), 33% to 97% of carbon monoxides (CO), 40% to 50% hydrocarbon (HC), 50% of all ozone precursors, and at least 1/4 of volatile organic compounds (VOC) are produced by motor vehicles alone (USEPA, 1995 & USDOT, 1993). These pollutants are known agitators of a variety of health and environmental problems that include asthma, bronchitis, cardiovascular disease, and pulmonary disorders in children (HAQI, 1997). Studies conducted by Environment Canada have also revealed that air pollutants such as carbon dioxide, along with sulphur dioxides, nitrogen oxides, ground level ozone and inhalable particulate matter have contributed to more than 5000 premature deaths across Canada (Environment Canada, 2002b).

From an environmental perspective, poor air quality can have a detrimental effect on food crops, fresh water resources, forests, wildlife and ecosystems. The physical effects of air pollution may also be seen on buildings and monuments, as well as on textiles, rubber, and other materials.

However, despite the apparent health and environment drawbacks associated with the by-products produced from the combustion of fossil fuels used to operate the engines of transport trucks, the trucking industry is currently the number one transport method employed in this country. Canada spends 75% of its annual transportation budget

[3] A description of nitrogen oxide, particulate matter, and carbon equivalent greenhouse gases (particularly carbon monoxide) can be found in Appendix C.

on transport trucks alone (Westac, 1996). Although some might argue that transport trucks are notorious gas-guzzlers, producers of greenhouse gas emissions, contributors to the deterioration of our road system, and a threat to the safety of motorists on highways, our built infrastructure and extensive road networks are unavoidably centered around the automobile. Therefore, trucks have the distinctive advantage over other modes of transport as they can ensure product delivery to remote locations that are not easily accessible by waterways, air, or rail, and as a result are the preferred mode used to transport goods.

2.4 Ecological Footprint Calculation Derivation for Transporting Foods via Transport Trucks

Since it has been established that the majority of produce in both Canada and the United States is shipped via transport trucks, it is interesting to discover how far any given produce actually travels prior to reaching its destination to a local grocery store or market. In a study conducted by the California Agricultural Technology Institute of California State University, the average load of fresh fruit and vegetable leaving California travels anywhere from 100 – 3,100 miles or 160.9 – 4,987.9 km before it reaches its destination (Leopold Centre for Sustainable Agriculture, 2001). This range actually conforms to the average distance of 2,400 km as suggested by Perth's District Health Unit (2002).

In a study conducted by the Leopold Center for Sustainable Agriculture at Iowa State University, several researchers collected data on fresh fruits and vegetables arriving at Chicago's food terminal market for the years of 1981, 1989, and 1998 (2000). What they determined was that the average vegetable travels approximately 2,164 km while the typical fruit traverses a slightly longer distance of 2,344 km (Leopold Centre for Sustainable Agriculture, 2001). Both Tables 1 and 2 show how far particular fruits and vegetables such as apples, peaches, pears, asparagus, beans, and tomatoes travel from their place of origin, such as California, Florida, and Iowa, to Chicago's food terminal. There is also reason to expect that similar numbers apply to cities in Southern Ontario.

Table 1: Travel Distance of U.S. Fruits to Chicago's Food

Fresh Produce Type	Distance by truck Continental US (miles)	Conversion to km (km)
Apples	1,555	2,502
Blueberries	675	1,086
Grapes (table)	2,143	3,448
Peaches	1,674	2,693
Pears	1,997	3,213
Strawberries	1,944	3,128
Watermelons	791	1,273
Average Distance Travelled:		2,344

Table 2: Travel Distance of U.S. Vegetables to Chicago's Food Terminal

Fresh Produce Type	Distance by truck Continental US (miles)	Conversion to km (km)
Asparagus	1,671	2,689
Beans	766	1,232
Broccoli	2,095	3,371
Cabbage	754	1,213
Carrots	1,774	2,854
Cauliflower	2,118	3,408
Celery	1,788	2,877
Sweet Corn	813	1,308
Cucumbers	731	1,176
Eggplant	861	1,385
Lettuce (iceberg)	2,040	3,282
Mushrooms	381	613
Onions (dry)	1,675	2,695
Peppers (bell)	1,261	2,029
Potatoes (table)	1,239	1,994
Spinach	2,086	3,356
Squash	781	1,257
Sweet Potatoes	1,093	1,759
Tomatoes	1,369	2,203
Average Distance Travelled:		2,164

Now that we know approximately how far our food travels before it reaches retail outlets, how do we calculate the environmental impacts associated with transporting our food across the country via transport trucks and trailers? One way is to use an ecological footprint (EF). The EF will represent the amount of land, or rather 'carbon sink land,' required to absorb and assimilate the carbon dioxide produced from the consumption of fossil fuel by the transport vehicles used in the transportation of our food. The EF calculated would solely represent the 'Energy Land' component of an EF that is associated with transportation. It will not include the amount of garden land, cropland, pastureland, forestland, degraded land, or any built environment used to grow, produce or transport the food. Together these components and their respective sub-sections would produce a complete EF as proposed by Rees and Wackernagel (1996). However, the size of the EF calculated in the following section will instead be a lower bound indication of the ecological demand and impact that we place on our ecosystem through the single factor of transportation.

According to William Rees and Mathis Wackernagel, the authors of Our Ecological Footprint, the manner in which to calculate an EF for transportation is to first determine the amount of energy contained in each litre of fuel consumed. For most of the calculations presented in their book, the two authors assumed that gasoline was the primary fuel source used, and it contained approximately 0.035 gigajoules of energy per litre (1996). However, since transport trucks operate on diesel fuel it was necessary to calculate how much energy diesel fuel contains. According to Shell Canada Limited, diesel fuel contains 20,000 btu/lb of energy for combustion purposes, and has a density of 52.425 lb/cubic*ft at an ambient temperature of 65 degrees Fahrenheit (Gaspari, 2003). Therefore the conversion to gigajoules per litre is as follows: 20,000 btu/lb x 52.425 lb/cubic*ft x 0.03531467 cubic*ft/L x (1.054 x 10^{-6} GJ/btu) = 0.039 GJ/L.

The next step is to determine how much fuel each transport truck utilizes. From information collected from Wilson's Truck Lines, for every 100 km a transport truck travels, it will use anywhere between 30-40 L of fuel, depending on the size and weight of its load (2003). Therefore for an average trip of 160.9 – 4,987.9 km, approximately 1500-2000 L of fuel would be consumed (Butkovic, 2003). For the purpose of this calculation 40 L/100 km (0.40 L/km) will be used as a conservative figure. It should also be noted that the transport trucks could operate on any given day of the year.

In order to account for the indirect carbon consumption value associated with auto- manufacturing and road maintenance, Rees and Wackernagel multiplied their final result by an additional 45% (1996). There should also be an indirect carbon consumption attributed to greenhouse operations and farming equipment. However, due to the lack of information pertaining to the exact amounts of energy used, the calculations in this section will remain on the conservative side and assume that the extra 45% used by Rees and Wackernagel will account for this as well. Finally, a conversion factor of 100 [GJ/ha/yr.] and the 'defined' population (cap) for the region will divide the calculation. The calculation now resembles the following format:

Equation 1:
EF [ha*yr./trip*cap] = {1.45 x 0.40 [L/km] x 0.039 [GJ/L] x Average distance travelled [km/trip]} / {100 [GJ/ha/yr.] x Population of Region [cap]}

However, this calculation is only representative of one truckload with a carrying capacity of approximately 26 tonnes (Butkovic, 2003). In order to determine a more accurate EF, the final result should be multiplied by the number of trips that a transport truck will require to deliver fresh produce to a city, such as Hamilton, in one year. According to Statistics Canada, in the year 2000, the average Canadian consumed 0.127 tonnes of fruit and 0.184 tonnes of vegetables (Agriculture and Agri-Food Canada, 2002). For a city like Hamilton, with a population of 331,121 people, this would mean that a total of 102,979 tonnes of fruits and vegetables would be consumed [(0.127 tonnes/person + 0.184 tonnes/person) x 331,121 people = 102,978 tonnes]. If each truckload can transport a maximum load of 26 tonnes per trip, then again, a city such as Hamilton would receive approximately 3961 truckloads of produce a year [102,979 tonnes/ 26 tonnes/trips = 3961 trips]. Therefore, the total EF calculation in ha/cap as previously calculated would be multiplied by a factor of 3961 trips/yr. to account for the number of trucks that transport the total amount of fresh fruits and vegetables that would be consumed by the population in one year, and divided by Hamilton's population of 331,121 people.

Equation 2:
EF [ha/cap] = {1.45 x 0.40 [L/km] x 0.039 [GJ/L] x Average distance travelled [km/trip] x 3961 trips/yr.} / {100 [GJ/ha/yr.] x 331, 121 persons in Hamilton [cap]}

2.5 Ecological Footprint Calculation for Food Transported to Hamilton

If you live in a particular city, how would you go about calculating the average ecological footprint of any fresh fruit and vegetables you consume? To begin, several assumptions would need to be made. First a person would need to decide whether or not you are going to try and calculate the EF for a fruit or vegetable that was grown yourself, or one that is grown locally and transported a minimal distance, or finally, one that is transported across the country or possibly from the United States. A fruit or vegetable that is grown in a person's garden will essentially have an EF transportation component of zero. This is because the equation in the previous sub-section focuses solely on the amount of 'carbon sink land' required to absorb and assimilate the carbon dioxide released by the consumption of fossil fuel from the trucks used to transport the produce. It does not take into account the amount of actual land required to grow the food, or the energy required to water and fertilize the plants. As noted earlier, such calculations would be necessary if we were attempting to calculate the total EF of any fruit or vegetable, but the purpose of this section is to examine only the EF component associated with the transportation of fresh produce.

Therefore, in an endeavor to calculate the transportation component of an EF for fresh fruits and vegetables shipped to a city such as Hamilton, it was necessary to determine where our produce comes from. Access to arrival data from Toronto's Food Terminal could have provided further insight into the origins of most of the produce that Toronto and its surrounding metropolitan areas enjoy. As that information was unavailable, another approach was taken.

The research complied by the Leopold Center for Sustainable Agriculture contained arrival distances of certain fresh fruits and vegetables at Chicago's food terminal market. Since Chicago is approximately 800 km southwest of Hamilton, the distance information compiled in the study, and presented in Tables 1 and 2, were used as a conservative estimate for fresh produce travelling to a southern Ontario city such as Hamilton (Yahoo! Maps Canada, 2003). Table 3 and Table 4 show the result of this EF calculation by using Equation 2.

Another way to determine the EF of fresh fruits and vegetables due to transportation would be to locate all the farms and greenhouse in Ontario that supply fresh fruits, nuts, berries and vegetables to the Canadian Market. In Ontario alone, there are approximately 3,938 vegetable growers, 3,247 fruit, nut and berry farms as well as 2,012 greenhouse producers that can serve the citizens of Ontario with fresh produce (Statistics Canada, 2001). However, trips to local grocery stores also indicated that several fruits and vegetables are imported from various Canadian provinces such as Prince Edward Island, and from American states such as California and Florida. Therefore, depending on the produce, and the time of year, our food can come from local farms and greenhouses, or those located across provincial or state borders.

Table 3: Ecological Footprint of Fruits Transported by Truck

Fresh Produce Type	Conservative Distance Estimate To Hamilton (km)	EF at 40L/100 km (ha/cap)
Apples	2,502	0.007
Blueberries	1,086	0.003
Grapes (table)	3,448	0.009
Peaches	2,693	0.007
Pears	3,213	0.009
Strawberries	3,128	0.008
Watermelons	1,273	0.003
Average:	2,344	0.007

Table 4: Ecological Footprint of Vegetables Transported by Truck

Fresh Produce Type	Conservative Distance Estimate To Hamilton (km)	EF at 40L/100 km (ha/cap)
Asparagus	2,689	0.007
Beans	1,232	0.003
Broccoli	3,371	0.009
Cabbage	1,213	0.003
Carrots	2,854	0.008
Cauliflower	3,408	0.009
Celery	2,877	0.008
Sweet Corn	1,308	0.004
Cucumbers	1,176	0.003
Eggplant	1,385	0.004
Lettuce (iceberg)	3,282	0.009
Mushrooms	613	0.002
Onions (dry)	2,695	0.007
Peppers (bell)	2,029	0.005
Potatoes (table)	1,994	0.005
Spinach	3,356	0.009
Squash	1,257	0.003
Sweet Potatoes	1,759	0.005
Tomatoes	2,203	0.006
Average:	2,164	0.006

However, due to time constraints, it was decided that it was beyond the scope of this paper to determine the exact EF transportation component for individual fruits and vegetables consumed in Hamilton based on localized information. It was possible to establish a comparison between the EF's of any given produce grown locally within the Province of Ontario, and those transported from other Provinces and States to Hamilton. The purpose of this comparison would be a means of estimate the ecological impact of a particular piece of produce, such as an apple, if it were to be shipped from a regional location or from another Province or State. The average distance any produce would have to travel, would be from the geographical center of a farming or greenhouse community located in Ontario, or from the geographical center of any other Canadian province or American state to the center of downtown Hamilton. These distances would be used in the EF calculation (Equation 2) as derived in the previous sub-section to estimate the size of the EF component associated with transportation. The distance to the center of Hamilton from the center of any given place was calculated using Yahoo! Maps Canada. It should also be noted that the distances were one-way distances because transport trucks do no often return directly to their origin of departure (Leopold Centre for Sustainable Agriculture, 2001). For example a truck leaving from California may make a delivery to Hamilton, pick up goods in Waterdown, deliver them to Toronto, then pick-up another load and deliver them before returning to California.

Table 5: Regional Growers of Fruits and Vegetables

Location	Number of Vegetable Farms	Number of Fruit, Berry, and Nut Farms	Number of Greenhouses Producing Vegetables	Distance to Hamilton from Geographical Centre (km)	EF for Hamilton at 40L/100 km (ha/cap)
Algoma District - (CD)	29	16	10	593	0.001
Brant County - (CD)	65	42	8	43	0.000
Bruce County - (CD)	87	45	8	168	0.000
Chatham-Kent Division - (CD)	327	52	9	232	0.001
Cochrane District - (CD)	14	9	10	766	0.002
Dufferin County - (CD)	32	18	4	147	0.000
Durham Regional Municipality - (CD)	122	91	13	124	0.000
Elgin County - (CD)	169	104	18	147	0.000
Essex County - (CD)	284	150	162	292	0.001
Frontenac County - (CD)	34	16	8	358	0.001
Greater Sudbury Division - (CD)	13	13	2	441	0.001
Grey County - (CD)	97	169	7	147	0.000
Haldimand-Norfolk Regional Municipality - (CD)	303	161	41	33	0.000

Location	Number of Vegetable Farms	Number of Fruit, Berry, and Nut Farms	Number of Greenhouses Producing Vegetables	Distance to Hamilton from Geographical Centre (km)	EF for Hamilton at 40L/100 km (ha/cap)
Haliburton County - (CD)	5	3	2	283	0.001
Halton Regional Municipality - (CD)	61	51	16	16	0.000
Hamilton Division - (CD)	121	118	17	0	0.000
Hastings County - (CD)	66	52	4	240	0.001
Huron County - (CD)	134	57	11	147	0.000
Kawartha Lakes Division - (CD)	64	27	8	199	0.001
Kenora District - (CD)	4	2	3	1901	0.005
Lambton County - (CD)	77	44	7	219	0.001
Lanark County - (CD)	50	22	9	391	0.001
Leeds and Grenville United Counties - (CD)	64	44	12	462	0.001
Lennox and Addington County - (CD)	30	15	3	314	0.001
Manitoulin District - (CD)	12	4	1	617	0.002
Middlesex County - (CD)	208	82	13	130	0.000
Muskoka District Municipality - (CD)	16	11	5	239	0.001
Niagara Regional Municipality - (CD)	168	943	41	70	0.000
Nipissing District - (CD)	14	10	2	372	0.001
Northumberland County - (CD)	70	65	11	185	0.000
Ottawa Division - (CD)	87	55	20	518	0.001
Oxford County - (CD)	117	69	13	82	0.000
Parry Sound District - (CD)	27	9	5	280	0.001
Peel Regional Municipality - (CD)	36	31	7	96	0.000
Perth County - (CD)	98	39	11	178	0.000
Peterborough County - (CD)	41	29	9	204	0.001
Prescott and Russell - (CD)	34	37	6	424	0.001
Prince Edward Division - (CD)	42	64	10	286	0.001
Rainy River District – (CD)	7	3	5	1779	0.004

Location	Number of Vegetable Farms	Number of Fruit, Berry, and Nut Farms	Number of Greenhouses Producing Vegetables	Distance to Hamilton from Geographical Centre (km)	EF for Hamilton at 40L/100 km (ha/cap)
Renfrew County - (CD)	34	27	10	439	0.001
Simcoe County - (CD)	218	109	30	147	0.000
Stormont, Dundas and Glengarry Counties - (CD)	74	57	15	-	-
Sudbury District - (CD)	6	4	3	441	0.001
Thunder Bay District - (CD)	20	15	7	1425	0.004
Timiskaming District - (CD)	7	6	3	620	0.002
Waterloo Regional Municipality - (CD)	78	120	21	85	0.000
Wellington County - (CD)	94	81	17	59	0.000
York Regional Municipality - (CD)	178	14	24	73	0.000
			Average:	349	0.001

(Statistics Canada, 2001c,d,e)

Table 6: Canadian Growers of Fruits and Vegetables

Province	Distance to Hamilton from Geographical Centre (km)	EF at (40L/100 km) (ha/cap)
Alberta	3639	0.009
British Columbia	4358	0.011
Manitoba	2165	0.005
New Brunswick	1349	0.003
Newfoundland	2475	0.006
Nova Scotia	1678	0.004
Prince Edward Island	1677	0.004
Quebec	870	0.002
Saskatchewan	3135	0.008
Average Distance:	2536	
	Average EF:	0.006

Table 7: American Growers of Fruits and Vegetables

Location	Distance to Hamilton from Geographical Centre (km)	EF at (40L/100 km) (ha/cap)
Alabama	1578	0.004
Alaska	-	-
Arizona	3563	0.010
Arkansas	1768	0.005
California	4249	0.011
Colorado	2571	0.007
Connecticut	718	0.002
Delaware	868	0.002
Florida	2336	0.006
Georgia	1726	0.005
Hawaii	-	-
Idaho	3445	0.009
Illinois	1015	0.003
Indiana	828	0.002
Iowa	1292	0.003
Kansas	1968	0.005
Kentucky	982	0.003
Louisiana	2172	0.006
Maine	1035	0.003
Maryland	1056	0.003
Massachusetts	829	0.002
Michigan	665	0.002
Minnesota	1554	0.004
Mississippi	1710	0.005
Missouri	1463	0.004
Montana	2854	0.008
Nebraska	1835	0.005
Nevada	3562	0.010
New Hampshire	971	0.003
New Jersey	794	0.002
New Mexico	2827	0.008
New York	733	0.002
North Carolina	1296	0.004
North Dakota	2132	0.006
Ohio	572	0.002
Oklahoma	1996	0.005
Oregon	3938	0.011
Pennsylvania	591	0.002
Rhode Island	849	0.002

Location	Distance to Hamilton from Geographical Center (km)	EF at (40L/100 km) (ha/cap)
South Carolina	1374	0.004
South Dakota	2109	0.006
Tennessee	1236	0.003
Texas	2579	0.007
Utah	3137	0.008
Vermont	827	0.002
Virginia	1116	0.003
Washington	4046	0.011
West Virginia	712	0.002
Wisconsin	1167	0.003
Wyoming	2539	0.007
Average Distance:	1778	
	Average EF:	0.005

Table 8: Ecological Footprint of Average Summary Results

	Average Distance (km)	Average EF (40km/100L) (ha/cap)
Regional (Ontario)	231	0.001
Provincial	2536	0.006
United States of America	1778	0.005

By examining Table 8 it becomes evident that there is a significant difference between growing and shipping locally grown produce and importing it from either the United States or from other Canadian provinces. Regionally grown fruits and vegetables have a transportation component almost 5 times less than produce imported from the United States, and 6 times less than if transported from any province. The higher EF associated with inter-provincial transportation can be attributed to the fact that the average distance measured between Hamilton and the geographical center of each Province is much larger than the equivalent value for each State. Therefore, the resulting Provincial EF is also larger.

Another way to obtain a more accurate EF result, without knowing the exact amount of fresh produce shipped to each city, would be to determine the percentage of produce shipped from each farming community, Province, or State to a particular location. This figure would then be multiplied it by its corresponding EF value as previously calculated in Tables 5, 6, and 7 to produce a weighted value for each district that supplies fresh fruits and vegetables to the study area. For example, in 2002 Ontario receives 22.49% of its fresh produce from California (Industry Canada, 2003). This figure would then be multiplied by California's EF value of 0.011 ha/cap, as calculated in Table 7, to become 0.011 ha/cap x 22.49% = 0.0026 ha/cap. The benefit of this method, compared to the one demonstrated in Tables 5, 6, and 7, is that the final EF is more reflective of where fresh produce comes from, and how much of it comes from a particular place.

However, there is a drawback to this method. The Ministry of Agriculture, Agriculture and Agri-Food Canada, Industry Canada, the Canadian Food Inspection Agency, and Statistics Canada, do not keep track of inter-provincial trading, they only keep track of fresh fruits and vegetables imported from outside the country to various Provinces. Therefore, this method cannot be applied to produce travelling within the Province of Ontario or from anywhere across Canada, to the city of Hamilton. The only data currently available, that can be used for this calculation and which would best apply to the city of Hamilton, is the percentage of fresh fruits and vegetables imported from each State to the Province of Ontario. The results are shown in Table 9.

Table 9: Ecological Footprint of Fresh Produce Based on the Percentage of Imported Fruits and Vegetables from Various American States to Ontario

Location	Distance to Hamilton from Geographical Center	EF at (40L/100 km)	Percent of Produce Imported to Ontario in 2002 from Selected States[4]	EF at (40L/100 km) based on Percent Imported for 2002
	(km)	(ha/cap)	(%)	(ha/cap)
Alabama	1578	0.004	0.06	0.0000
Alaska	-	-	-	-
Arizona	3563	0.010	2.20	0.0002
Arkansas	1768	0.005	0.04	0.0000
California	4249	0.011	22.49	0.0026
Colorado	2571	0.007	0.07	0.0000
Connecticut	718	0.002	0.01	0.0000
Delaware	868	0.002	0.04	0.0000
Florida	2336	0.006	3.94	0.0002
Georgia	1726	0.005	0.58	0.0000
Hawaii	-	-	-	-
Idaho	3445	0.009	0.47	0.0000
Illinois	1015	0.003	0.34	0.0000
Indiana	828	0.002	0.07	0.0000
Iowa	1292	0.003	0.01	0.0000
Kansas	1968	0.005	0.01	0.0000
Kentucky	982	0.003	0.00	0.0000
Louisiana	2172	0.006	0.17	0.0000
Maine	1035	0.003	0.01	0.0000
Maryland	1056	0.003	0.14	0.0000

[4] Percentage figures based on information obtained from Industry Canada.

Location	Distance to Hamilton from Geographical Center	EF at (40L/100 km)	Percent of Produce Imported to Ontario in 2002 from Selected States[5]	EF at (40L/100 km) based on Percent Imported for 2002
Massachusetts	829	0.002	0.09	0.0000
Michigan	665	0.002	1.04	0.0000
Minnesota	1554	0.004	0.17	0.0000
Mississippi	1710	0.005	0.00	0.0000
Missouri	1463	0.004	0.02	0.0000
Montana	2854	0.008	0.00	0.0000
Nebraska	1835	0.005	0.01	0.0000
Nevada	3562	0.010	0.03	0.0000
New Hampshire	971	0.003	0.00	0.0000
New Jersey	794	0.002	0.58	0.0000
New Mexico	2827	0.008	0.05	0.0000
New York	733	0.002	0.21	0.0000
North Carolina	1296	0.004	0.30	0.0000
North Dakota	2132	0.006	0.02	0.0000
Ohio	572	0.002	0.10	0.0000
Oklahoma	1996	0.005	0.02	0.0000
Oregon	3938	0.011	0.47	0.0001
Pennsylvania	591	0.002	0.39	0.0000
Rhode Island	849	0.002	0.00	0.0000
South Carolina	1374	0.004	0.20	0.0000
South Dakota	2109	0.006	0.00	0.0000
Tennessee	1236	0.003	0.00	0.0000
Texas	2579	0.007	1.13	0.0001
Utah	3137	0.008	0.00	0.0000
Vermont	827	0.002	0.00	0.0000
Virginia	1116	0.003	0.20	0.0000
Washington	4046	0.011	1.17	0.0001
West Virginia	712	0.002	0.00	0.0000
Wisconsin	1167	0.003	0.16	0.0000
Wyoming	2539	0.007	0.00	0.0000
Average:	1778	0.005		
		Total:	37.01	0.0033

The final result of Table 9 is a cumulative total of 0.0033 ha/cap, which is smaller than the average total of 0.005 ha/cap for the United States, as calculated in Table 7. This

[5] Percentage figures based on information obtained from Industry Canada.

may suggest that a weighted total could be used as a more representative figure – simply because the majority of Ontario's produce imported from the United States in 2002 came from California, and that this fact is reflected in the total EF. This outcome may also indicate that depending on where the bulk on Ontario's food is grown that both the Regional and Provincial EF's, as estimated earlier, will be of lesser value.

But the interesting fact about the all EF's determined in this section, although on the low side, is that they are well within the estimated 0.12 ha/cap that Rees and Wackernagel assigned for the total transportation of goods in Canada in 1996. Several hypotheses can be stipulated for the differences.

Without having access to Rees and Wackernagel's calculations, knowing their primary source of data, or list of variables used to arrive at 0.12 ha/cap, it is impossible to duplicate their work and have a truly comparable estimate. In addition to the transportation of fresh produce, Rees and Wackernagel could have included meats, dairy, grains, and fish in their calculation, as well as all non-consumable goods – as the 0.12 ha/cap encompasses all goods, not just perishable items. These items, when totaled together with the fruits and vegetables, would constitute a significant factor of Rees and Wackernagel's 'Energy Land' value for the transportation of goods (0.12 ha/cap), suggesting that transportation of food by trucks would have a notable impact despite its small overall value in this tally. Also, Rees and Wackernagel may have included the ecological impacts of trains, ships, and airplanes in addition to those produced by transport truck in their summation, as well as the initial energy used in the construction of roadways and other transportation infrastructure. Therefore the calculations presented in this section although based on the work as published in the book Our Ecological Footprint should be viewed solely as a conservative estimate at best for the transportation of fruits and vegetables via transport trailers. However, the results of this study can be used to suggest that the transportation of non-regional fresh produce by tractor-trailers does have a significant ecological impact on the environment when compared to local production and distribution.

2.6 What can be done to reduce the Ecological Footprint of Imported Foods?

The results of this study indicated that imported fruits and vegetables have an Ecological Footprint 5-6 times larger than locally grown produce. It is believed that the production of more regionally grown fruits and vegetables can lower the ecological impacts associated with most foods as well as minimize our dependency on transport trucks used for long distance shipping. Several Ontario producers are less than one day's drive away from the majority of markets they serve, shoppers can virtually be guaranteed fresh Ontario fruits and vegetables a little less than 24 hours after they have been picked from the vine. Locally grown produce is often sweeter, and since it had the opportunity to ripen on the vine, the produce will have more flavour, vitamins, and minerals (Perth District Health Unit: Health Matters, 2002). Purchasing local products supports local farmers and their families and helps to build a stronger connection by improving rural-urban links between consumers and the producers. "When you buy locally grown food, you are doing something proactive about preserving the land needed to keep our whole community food secure" Perth District Health Unit: Health Matters, 2002). Finally, eating local produce helps to support a cleaner environment, because the "average distance most food travels from farm to plate is about 2,400 km. This burns up a great deal of fossil fuel, which contributes to pollution and global warming. Food that is grown and sold locally travels a much shorter distance" and therefore, less carbon emission, and greenhouse gases are emitted into the atmosphere (Perth District Health Unit: Health Matters, 2002).

Canada also has an extensive rail infrastructure that is potentially underused, and can be potentially adapted to haul more food products. Cargo trains, when properly maintained, can be more fuel efficient than transport trucks travelling the same distance and can carry more goods. One rail car can carry 110 tonnes of bulk goods, which in terms of load is about four times what a truck can carry (Westac, 1996). If based solely on load then the EF's calculated in Table 8 for cargo trains would be reduced by a factor of four. In terms of emissions, a cargo train operating on an equivalent amount of fossil fuel as a transport truck can reduce carbon emissions by 1/8 (USEPA, 2003). Therefore the results in Table 8 can be lessened by a factor of 8. Also, increased operation of the Canadian National Rail can help to improve Canada's rail competition in comparison with the United States, and increase profitability in that sector. Also, rail usage in lieu of trucks can reduce downtown core congestion while simultaneously lessening the detrimental impacts of tractor-trailer traffic on our roadway systems.

2.7 Conclusions

Modern infrastructure is established in such a manner that the transportation system within it caters to motorized vehicles. Convenient access to extensive road networks contributes to the fact that transport trucks are the predominant mode of transportation used by the Canadian food industry to ship products across Canada or to and from the United States. However, the trucking industry, despite its compatibility with the modern transportation substructure, has serious health and environmental implications. The vast majority of transport trucks operate on non-renewable fossil fuels, such as unleaded gasoline and diesel fuel. Aside from the consumption of these irreplaceable natural resources, the combustion of both gasoline and diesel fuels produce carbon dioxide emissions, nitrous oxides, and other volatile organic compounds that can aggravate individuals with allergies, increase respiratory problems, and exacerbate pulmonary and cardiovascular diseases.

From an environmental perspective, chemical compounds such as carbon dioxide, nitrous oxides, and volatile organic compounds contribute to air pollution and lower levels of air quality. Also the amount of productive land required to sequester the carbon emission, from motorized vehicle operation as per Rees and Wackernagel's Ecological Footprint (EF) Analysis, becomes greater as the use of cars, vans, and transport trucks increases. According to the calculations performed in this section, the transportation of food alone for a city like Hamilton requires an EF of 0.001 ha/cap, if the food is shipped solely across the province of Ontario. If the food should be transported across Canada it would have an EF of 0.006 ha/cap, and if it were imported from the United States the EF would be 0.005 ha/cap. In other words, locally grown produce has an ecological impact 5-6 times less than produce imported from outside the Province/Region being studied.

If anything, the EF values calculated in this section can be used by the average Canadian to appreciate just how much effort goes into the production of their food and how far it travels before it reaches their table. Therefore, if Canadians would like to reduce the EF solely associated with the transportation of fresh produce, minimize the amount of carbon dioxide emission emitted into the atmosphere, and improve air quality, they can adopt certain practices which includes consuming more locally grown foods.

3 Rooftop Gardening

3.1 Introduction to Rooftop Garden

"The building of cities is one of man's greatest achievements"
- Edmund Bacon (Design of Cities)

Jane Jacobs, author of The Death and Life of Great American Cities, presents a modest and refreshing systematic exploration of mid-twentieth century city planning as she unveils a dogma of delusions that have plagued past urban planners and which potentially taunt those of today. Her observations concluded that cities lack the creative vision to attract diversity and nurture lively and friendly street atmospheres. Architects, engineers, and city planners too often focus on the systematic design of traffic and roadways, subsidized housing, residential sprawl, and the intensification of dense business cores instead of trying to preserve the delicate balance between the built and natural environments (Jacobs, 1961). As a result most modern North American cities have become an eclectic collection of man-made sky-scrappers, large industrial facilities, commercial buildings, and recreation centers, which are all linked together through a sophisticated transportation network of roads, bridges, illumination posts, and traffic signals. As city cores become more built-up, more green space is paved over, and the balance between the human and natural environments becomes disrupted.

According to researchers, areas that lack sufficient green spaces are more prone to over-heating, and poor air quality. These types of cities are said to suffer from what researchers have termed the 'urban heat island effect' (Kurland, 2001). The 'urban heat island effect' is the increase in temperature of urban cities and their corresponding suburban areas, relative to the surrounding countryside. In cities where the natural landscape has been mostly paved over or built-up, solar radiation striking the hard artificial surfaces of the built environment is turned into excess heat. Studies have revealed that the temperature difference between city cores and nearby rural areas can range to an upward of 15°C (Kurland, 2001). Green spaces filled with trees, shrubs, and plant material helps to absorb and deflected solar radiation, keeping temperatures slightly lower.

These artificially induced high spring/summer temperature inversions have a direct impact on our lives. First, heat waves can exacerbate heat-related illnesses, such as headaches and nausea (Kurland, 2001 & Peck et al, 1999). And, then there is the increase in the amount of electricity people use as they turn on their air conditioners for relief from the heat. Also the use of air conditioning units can generate a handful of harmful chemical pollutants, such as ground level ozone, which can react with atmospheric particles to form haze and smog (Kurland, 2001 & Peck et al, 1999).

Therefore, what can be done to lower city temperatures, reduce energy consumption from the over use of air conditioners (AC), and minimize the production of pollutants related to the use of AC units? Researchers have shown that ample vegetation is an important component in any strategy aiming to reduce a city's internal temperatures and the production of greenhouse gases (Liu, 2002). Canadian sources have estimated that 11 sq*ft of grass alone, can remove approximately one-half pound of unwanted air particles each year (Kurland, 2001). However, given the limited amount of space available in many North American cities, it may be unrealistic to assume that our urban centers will soon be sprouting patches of grass as a new form of air purification and temperature control. Instead, researchers have been focusing on a potentially untapped resource in our cities, one that is largely abundant and forsaken: building rooftops.

Rooftops cover every building, structure, or facility in the city and are usually covered in gravel, shingles, or tar. Whether flat or slanted these empty spaces have the potential to be converted into both an economical and environmental dividend. The implementation of rooftop gardens can save energy, help reduce the 'urban heat island effect', minimize pollution outputs, augment air quality, improve storm water retention and create an alternative habitat for some city dwelling species. But what constitutes a rooftop garden?

3.2 What is a Rooftop Garden?

A rooftop garden, or green roof, is a contained, man-made, green space that can be located on the top levels of any industrial, commercial, recreational, or residential complex. Adding layers of protective waterproofing/roofing membranes, a growing medium, and various plant materials on top of a traditional roofing system, generally creates rooftop gardens. According to the Institute for Research in Construction (IRC), in partnership with the Canadian Mortgage Housing Corporation (CMHC), a successful rooftop garden consists of, from the top down, selected zone specific plants, which are often selected for particular applications, "an engineered growing medium, which may or may not include soil, a landscape or filter cloth to contain the roots and the growing medium, while allowing for water penetration, a specialized drainage layer, sometimes with built-in water reservoirs, the waterproofing / roofing membrane, with an integral root repellent" all on top of a well insulated roof structure (1999). Rooftop gardens are generally associated with being above street level, but could easily be at, or below street grade (CMHC, 1999).

There are essentially two basic types of green roof systems – extensive and intensive, both of which will be examined below.

3.2.1 Extensive and Intensive Rooftop Gardens

The two types of rooftop gardens – extensive and intensive differ mainly by their cost, depth of growing medium and the selection of plant material. Extensive green roof systems are generally characterized by a thin layer of soil, low weight, low capital cost, little to no irrigation, minimal maintenance and which can produce a stressful or harsh growing environment for certain plant species (CMHC, 1999 & Peck et al, 1999). Intensive green roof systems have a deeper depth of growing material, greater weight, higher start up costs, an operative irrigation system that induces higher maintenance requirements, but, provides a more favourable growing condition for vegetation (CMHC, 1999 & Peck et al, 1999). However in order for both systems to be successfully implemented, they require:

- Plants specifically chosen for the growing conditions on the roof
- An engineered growing medium, which may or may not include soil

- A filter or landscape cloth to contain the growing medium and root systems, but which will allow for water penetration
- A specialized drainage layer, which depending on circumstances, will contain built-in water reservoirs, a waterproofing / roofing membrane with an integral root repellent
- An adequate roofing system that will support either of the two green roofs, and finally
- Climate, location, budget, and structural capacity of the building, the availability of material, and the clients' need and ability to maintain the gardens will dictate the type of roof system used
  (CMHC, 1999).

The differences in costs, growth medium depth, and weight, between an extensive and intensive garden will be examined in the table below, and followed by their distinct advantages and disadvantages.

Table 10: Comparison of Extensive and Intensive Rooftop Garden Systems

Description	Extensive Roof Systems	Intensive Roof Systems
Green Roof System Cost (Includes curbing drainage layer, filter cloth, growing medium and plants).	\$66.00 - \$142.00 / m² * (\$6.00 - \$13.00 /sq*ft)	\$214.00 - \$2,470.00 / m² (\$20.00 - \$230.00 /sq*ft)
Depth of Growing Medium	Varies between 5-15 cm (2-6")	Varies between 20–60 cm (8-24")
Weight of Growing Medium	Ranges between 72.6-169.4 kg / m² (16-35 lbs./sq*ft)	Ranges between 290 - 967.7 kg/m² (60-200 lbs./sq*ft)
Types of Growing Mediums	Mineral-based mixture of sand, gravel, crushed brick, leca, peat, and organic matter	Soil based
Microclimate	Desert-like	Varies depending on location
Plant Type	Due to the shallowness of the growing medium and plants must be low and hardy, typically alpine, dryland, or indigenous	Due to the increased soil depth, the plant selection can be more diverse and can include trees and shrubs

* Note: Prices do not include consultation fees for design and specifications, project administration, site review, cost of re-roofing with a root-repelling membrane, the inclusion of an irrigation system, placement guardrail or fences, labour, and maintenance costs. The total cost, including these options, is an upward range of: for an extensive garden \$232.00 - \$452 /m² (\$22.25 - \$42.00 / sq*ft); and for an intensive garden \$498.00 - \$3,019.50 /m² (\$61.25 - \$309.00 / sq*ft (Peck et al, 1999).

Description	Extensive Roof Systems	Intensive Roof Systems
Maintenance	Low maintenance. Two visits per year to weed, prune back invasive species, and for safety and membrane inspections	Continual maintenance. Watering demand is ongoing, and sometimes may require an irrigation system. Structural and horticultural consultations are recommended
Advantages	• Does not require an irrigation system • Suitable for large areas • Suitable for roofs with 0° - 30° (slope) • Minimal technical expertise required • Often suitable for retrofit projects • Can leave vegetation to grow spontaneously • More natural look to gardens • Easier to obtain planning approvals • Lightweight • Lower start up costs	• Better at simulating wildlife garden found on the ground • More visually attractive • Often accessible, therefore, gardens can be used to grow food, as an open space, or it can be used for recreational purposes • More energy efficient • Better storm water retention capability • Longer membrane life
Disadvantages	• Less energy efficient • Less capable to retain storm water • Limited plant selection • Usually inaccessible, therefore not good for growing food, used as green space, or for recreational purposes. •	• Irrigation system recommended • Greater weight loading on roof • Higher capital & maintenance costs • More complex systems and expertise require to install, operate, and maintain

(CMHC, 1999 & Peck et al, 1999).

3.3 History of Rooftop Gardens

The greening of rooftops is not a new phenomenon; in fact the concept has been standard construction practice in many Scandinavian, and African countries for hundreds, if not thousands, of years. The first known rooftop garden dates back to the ancient Babylonians and the legendary hanging gardens of Babylon. Rooftop gardens can even be traced back to the Roman Empire as the storekeepers of Pompeii grew vines along their balconies (CMHC, 1999). However, the practice of greening rooftops was mainly attributed to their excellent insulating properties.

In the colder regions of Iceland, Norway, Greenland and probably Sweden, Viking colonists layered their walls and roofs with turf to protect against the snow, wind, and rain, and this helped the buildings retain their internal heat (CMHC, 1999). Canadian examples of this innovative technology can be seen in Newfoundland and Nova Scotia (CMHC, 1999 & Peck et al, 1999). In the warmer African nation of Tanzania, rooftop gardens provide shade, keeping the buildings cool as the plant material absorbed and/or deflected solar radiation.

The 16th and 17th century saw the emergence of hanging gardens in Spain, India Mexico, and Russia, while France adopted the technique in the 18th century for aesthetic purposes (CMHC, 1999). Essentially, until the 20th century, North American architects, engineers, and planners mainly viewed rooftop gardens as a vernacular building property of Scandinavian, African, and European nations (Peck et al, 1999).

However, the 1960's brought rise to a new movement that saw people concerned about the degradation of our air quality and the rapid decline of green space in urban centers (Peck et al, 1999). Re-examination of works completed by both Le Corbusier and Frank Lloyd Wright, who had previously introduced green roof technologies into their designs, alerted North Americans to the advantageous properties of rooftop gardens. "Le Corbusier encouraged rooftops as another location for urban green space, and Wright used green roofs as a tool to integrate his buildings more closely with the landscape" (Peck et al, 1999). Their innovative designs which included 'La Maison de Diable' in 1913, and Wright's vertical gardens at the Midway Gardens of 1913 in Chicago renewed interest in rooftop gardens as a feasible 'green' solution to the decay of urban air quality and loss of green space (Frank Lloyd Wright Preservation Trust, 2003 & Peck et al, 1999).

In comparison with many European cities, many North American metropolitan areas are still behind in forging ahead with this 'green' revolution. In Germany, for example, the green-roof market increased by an annual average of 15-20% between 1989 and 1996 (Peck et al, 1999). In 1989 there was approximately one million square meters of 'green' rooftops, where as by 1996 the area of 'greened' rooftops had expanded to ten million square meters (Peck et al, 1999). Canada, on the other hand, only has a handful of experimental test sites, some of which include the University of Toronto's Vertical Garden, Vancouver's Public Library, and the Mountain Equipment Co-op green roof (CMHC, 1999). So, what is preventing further progress in Canada?

The governments, of the 75 European municipalities that currently support the construction of rooftop gardens, provide incentives, such as grants or have legislation requiring all new industrial buildings to be fitted with rooftop gardens (CMHC, 1999 & Peck et al, 1999). The German government, for example, currently offers a monetary incentive of 35-40 Deutsch Marks/m^2 of roof greened. Canada currently offers no incentives or does not have any legislation in regards to the implementation of green roof technology. "Both Canada and the United States are at least ten years behind Europe in investing in green roof infrastructure as a viable option for solving many quality of life challenges facing our cities" (Peck et al, 1999).

There is still hope for change. A key component in bringing about this permutation to our urban landscape is through public education, accessible examples, and local research on technical performance. Canadian landscape architect Cornelia Hahn Oberlander, architects Doug Pollard and Charles Simon, and engineers Greg Allen and Mario Kani, are some of the people who have helped to establish some of the first rooftop gardens in this country. They include the Boyne River Education Centre in Southern Ontario and Robson Square in Vancouver. Also, volunteer groups advocating rooftop gardens such as 'Rooftop Gardens Resource Group' and 'Green Roofs for Healthy Cities', help to promote the industry (Peck et al, 1999). They can provide valuable information through research and studies to citizens, businesses, and government officials who otherwise may not be aware of the benefits associated with rooftop gardens, and who may one day play a pertinent role in establishing the use of green technologies in our cities.

Also partnerships between the National Research Council's Institute for Research in Construction (IRC), Environment Canada, and the Canadian Mortgage Housing Corporation (CMCH) can aid in the establishment of new technologies. These technologies can include root-repelling agents, protective or drainage membranes, lightweight growing mediums, and the determination of which plants are most suitable for rooftop gardens. Research programs can further conclude the best course of action that will make rooftop gardening more compatible with our pre-existing city structures and spearhead us into a new century that reaps the full benefits of rooftop gardens.

3.4 Benefits

As mentioned earlier, rooftop gardens can reduce energy consumption, minimize the impact of the 'urban heat island effect', and decrease the expulsion of chemical pollutant generated from cooling apparatus by filtering out particulate matter from the air. This action increases the quality of urban air. Also, rooftop gardens can retain and cleanse storm water improving a city's storm water retention, and rooftop gardens can create alternative habitats for some city dwelling species (CMHC, 1999 & Peck et al, 1999).

3.4.1 Energy Savings

Rooftop gardens reduce energy consumption through their unique insulating properties. "A 20 cm (8") layer of growing medium and a thick layer of plants has a combined insulating value of RSI 0.14 (R20)[6]" (Peck et al, 1999). Studies have also revealed that a growing medium with a depth of 30 cm (12") will not experience temperatures below 0° C (32° F), when outside temperatures fall below -20°C (Peck et al, 1999). Therefore, appropriately fitted rooftop gardens can keep a building warmer in winter and cooler in the summer.

During the winter months, green roofs minimize the amount of heat that escapes through the roof and thereby decreases the amount of energy required to heat the building (Kuhn, 2000 & Peck et al, 1999). In the spring and summer, plant matter provides shade for the building, and absorbs or deflects solar radiation through the process of evapotranspiration, reducing any net heat gain. "This in turn helps to cool the surrounding

[6] For a definition of a RSI value, please refer to section 4.2.2.

area, as well as decreasing the amount of energy required to cool the building" – of which, both methods reduce your energy consumption and subsequently your bill payments (Kuhn, 2000 & Peck et al, 1999). However, the extent of your energy savings will depend on the size of the garden and building, the location, the type of plant materials used, and the depth of the growing medium (Peck et al, 1999). As an example, if the building is a one or two story complex, where the roof consists of a large portion of the building envelope, and has sufficient coverage of plant material, then the energy savings due to cooling in the summer months can be as high as 25% (Peck et al, 1999).

3.4.2 Urban Heat Island Effect

As mentioned earlier, the 'urban heat island effect' is a "macro-climate caused by the difference in temperatures between a city and the surrounding country side" (CMHC, 1999). This means that urban centers can experience temperatures 8°-15° C higher than the corresponding rural areas (CMHC, 1999 & Peck et al, 1999). This happens when the amount of paved or built-up environment significantly exceeds the amount of green space, instead of being absorbed or deflected, the solar radiation is converted into heat when it strikes the concrete, stone, and asphalt surfaces of a city's infrastructure. Green roofs can absorb the solar radiation, thereby deflecting the heat and keeping the surrounding areas cooler.

3.4.3 Reduction of Pollutant Expulsion

Another benefit of rooftop gardens is their ability to keep buildings cooler via their insulating properties and by providing ample shade during warm summer months. This basically reduces the need to use air conditioning technology. The operation of air conditioning (AC) units to relieve heat waves is the first step in a vicious catalyst cycle of energy consumption that is followed by the expulsion of harmful greenhouse gases and/or other chemical pollutants into the atmosphere (Kurland, 2001). Some AC units produce ground level ozone as a by-product, which can react with various atmospheric particles, such as nitrogen oxides to form haze and smog (Kurland, 2001). Both smog and haze can act as heat traps and actually increase city temperatures, defeating the initial purpose of trying to cool down the room, or building (Kurland, 2001 & Peck et al, 1999). Since people want to escape the sticky and uncomfortable warmth created by smog and haze they often turn on their AC units. This action consequently consumes more energy and expels more chemicals, creating more smog and haze, thus establishing an inescapable loop of power consumption and pollution generation. Rooftop gardens can minimize the impact of this loop, by providing shade to their respective building and helping to maintain cooler internal temperatures.

3.4.4 Increased Air Quality

Urban centers, with their concrete, stone, glass and asphalt surfaces, have a tendency to generate dust and dirt particles that can become suspended in the air. Therefore, another benefit of rooftop gardens is the ability of plants to naturally filter out airborne particulate matter that passes over them (CMHC, 1999 & Peck et al, 1999 &

Kuhn, 2002). These particles become trapped on the plant's outer surfaces which are later washed away by rain and trickles down onto the growing medium below (Peck et al, 1999). Studies revealed that urban streets with planted trees experience a reduction of 10-15% fewer dust particles than similar streets without trees (Peck et al, 1999).

Also, areas with 2,000 m^2 of unmowed grass (100 m^2 of leaf surface per m^2) are estimated to remove 4,000 kg of dirt particles from the air per year (2 kg/m^2) (CMHC, 1999 & Peck et al, 1999). These figures also hold true for rooftops covered in unmowed grass (CMHC, 1999 & Peck et al, 1999). In addition to removing dirt and dust particles, plants also absorb gaseous pollutants such as carbon dioxide (CO_2). This pollutant is sequestered through a plant's leaves by the process of photosynthesis and then converted into humus during the autumn and winters months when the leaves have fallen to the ground (CMHC, 1999 & Peck et al, 1999).

From an environmental perspective, by increasing the city's biomass, through the addition of rooftop gardens, the oxygen levels in the air can be increased while "the amount of CO_2 produced by cars and other fuel burning technologies" is decreased (Kuhn, 2000). This, in combination with the removal of dirt, dust and other gaseous pollutants, helps to clean and purify the air. Cleaner air directly benefits people with respiratory difficulties such as asthma and bronchitis, and reduced levels of air pollution can minimize smog and haze and help preserve urban infrastructure that is susceptible to damage by air pollution (CMHC, 1999).

3.4.5 Improved Storm Water Retention

If properly installed and maintained, green roofs can be designed for storm water retention, which can help eliminate combined sewage overflows, reduce storm water discharges, and provide municipalities with indirect financial incentives. However, the rate at which a rooftop garden can retain water is determined "by saturated infiltration capacity, thickness of the growing media, field capacity, porosity, under-drainage layer water retention and flow, and relief drain spacing" (Peck et al, 1999). Basically plant material absorbs and stores water every time it rains, which means that your rooftop garden is retaining water that would otherwise be discharged into a combined sewage system or storm water system.

Studies have shown that a heavily vegetated rooftop garden with a 20-40 cm (8-16") of thick growing medium can retain anywhere between 10-15 cm (5-6") of water (Peck et al, 1999). A storm-water retention study conducted for the City of Portland, Oregon, discovered that if half of the buildings in the downtown area, approximately 219 acres, had rooftop gardens, then 66 million gallons of water could be retained per year (Peck et al, 1999). This would mean that the overflow of the combined sewage system would be reduced by 17 million gallons, and storm water discharges would diminish by 11-15% (Peck et al, 1999). Therefore, if both the combined and storm water systems are taking in less quantities of water per annum, then the possibility exists that maintenance costs will also reduce, financially benefiting the city.

Rooftop gardens not only decrease the load on the city's sewage/storm water systems (Kuhn, 2002) but can also reduce the amount of water pollution that finds its way into our rivers and lakes. As water runoff makes its way along many of the impermeable surfaces in the city, it can collect a variety of particulate matter, pesticides, oil, grease, heavy metals, rubber, and garbage (CMHC, 1999). In cities like Toronto, storm water runoff is the number one cause of water pollution in lakes, local creeks, and rivers (CMHC, 1999). Thus, if excess water is retained by plant material then less chance exists that non-airborne pollutants will contaminate it.

3.4.6 Habitat Creation

The establishment of green roofs should never be considered a justification to destroy natural habitat at grade, but can be an acceptable remediation for areas without habitats for some city dwelling species. Several European communities have developed two types of green roof habitats that can be implemented as part of a larger encompassing system of wildlife corridors in urban areas. The first type of rooftop garden is a "stepping stone" habitat. It connects naturally isolated habitat pockets with each other. However, "it is important to remember that this connection can be by air only (nesting and migrating birds, insects, airborne seeds)" (Peck et al, 1999). The second type is an "island" habitat because it remains isolated from other habitats. Essentially this type of habitat would contain selected plant varieties whose seeds do not propagate or spread by air or over short distances (Peck et al, 1999). Since most green roofs are generally inaccessible, the gardens are also less likely to be disturbed which can create a safer environment for certain insects (Peck et al, 1999). However, these 'safe' bug havens can also attract birds. Insects, as well as any berries or fruits produced by certain plants, which can be grown in these types of gardens, are an integral part of a healthy bird diet (CMHC, 1999). Therefore, these green roofs actually create a micro-ecosystem equipped with bottom and top feeders, which are necessary to maintain an orderly balance in the food chain.

3.4.7 Additional Benefits

Aside from helping to reduce energy consumption, minimizing the impact of the 'urban heat island effect', decreasing the amount of pollutants generated from air conditioning units, increasing air quality, retaining storm water runoff, and creating alternative habitats, what else are rooftop gardens good for? Green Roofs can also be converted into fruitful vegetable gardens that can produce enough food to feed a family, or simply provide an alternative outdoor space in the heart of the city without having to buy extra property (Kuhn, 2002). Rooftop gardens can be used as a tool to educate both children and the general population about the environment (Kuhn, 2002). Toronto Hydro Energy Services, the Toronto Catholic School Board, and Green Roofs for Healthy Cities are currently attempting to install outdoor rooftop classrooms in some schools to increase public awareness of the benefits of rooftop gardens as well as providing additional green space for students (Peck et al, 1999).

The establishment of a functional green roof will not only provide more space to occupants, and enhance a building's aesthetic appearance, but it can also increase the marketable value of the building itself (Kuhn, 2002 & Peck, 1999). The installation of green roofs can also "help gain planning approval for projects from local building officials, community members, and rate payers associations" (Peck et al, 1999).

The implementation of rooftop gardens can create jobs for designers, consultants, landscapers, and contractors and help enhance the following manufacturers and suppliers of:

- Roof membranes
- Root repellants
- Drainage layers
- Landscaping cloth
- Curbs
- Irrigation systems
- Engineering growing mediums, such as light-weight soils and amendments

(CMHC, 1999).

Finally, "green roofs have been proven to protect the roofing membrane against ultra-violet (UV) radiation, extreme temperature fluctuations, and puncture or physical damage from recreation or maintenance" (CMHC, 1999). Flat roofs without rooftop gardens are 50% more likely to incur damage over a 5 year period then those that have been equipped with green roof technology (CMHC, 1999). Therefore, the life span of a roof and the roofing membrane will increase, and reduce the economic costs associated with general repairs and/or replacement (Peck et al, 1999).

3.5 Calculating Benefits

Calculating the energy savings on your hydro and electrical bills is one method of determining one of the more visible benefits of rooftop gardens. Rooftop gardens can help keep a building cooler during the summer and warmer during the winter, minimizing the amount of energy required to heat or cool the structure. Currently, the Institute for Research in Construction (IRC), a division of the National Research Council (NRC), is working on developing a model "that will more accurately predict the energy efficiency gains of various green roof systems on different building types" so as to establish the exact extent of energy benefits that can be reaped from rooftop gardens (Peck et al, 1999).

A less apparent benefit can be in the form of a reduction in the levels of carbon dioxide found in the atmosphere. Studies have shown that a single mature beech tree between the age of 80-100 years old, with a crown diameter of 15 m, and a leaf surface area of approximately 600 m^2, will use 24 kg of carbon dioxide, 96 kg of water, and 25.5 kJ of heat energy to create close to 170 kg of oxygen and 16 kg of glucose each hour (CMHC, 1999). This means that if a city's bio-mass is increased through the planting of more trees, plants, and grass or by installing a green roof, then the levels of carbon dioxide produced by vehicles, industry, and mechanical systems native to any city, can be reduced providing a higher level of air quality for city dwellers (CMHC, 1999)

One method of converting the abstract reduction of carbon dioxide emissions in the atmosphere into a tangible calculation can be achieved using an Ecological Footprint (EF) Analysis. According to Rees and Wackernagel, for every 1.8 metric tonnes of carbon dioxide produced each year, an addition of 1.0 ha of forested land needs to be made in the 'Energy Land' category (1996). Note that 'Energy Land', is the amount of land required to sequester carbon dioxide emissions produced from fossil fuel consumption (Rees et al, 1996). If data pertaining to carbon emissions is not explicitly available, it can be calculated from the amount of fossil fuel consumed.

If we use the rooftop garden adorning Chicago's City Hall and its proposed expansion program as an example, the amount of carbon dioxide it will be able to sequester in one year, and its subsequent EF for the 'Energy Land' component is as follows: according to Weston Design Consultants, the existing rooftop garden and the proposal to green all available roof space, can reduce the City of Chicago's energy consumption by 720 MW (Kurland, 2001). This arguably translates into an approximate saving of 2.21×10^7 GJ of energy, as per the following calculation: 720 MW = 720×10^3 kW, and 720×10^3 kW x 8760 h [per year] = 6.31×10^9 kWh, and 1 kWh = 3.60×10^{-3} GJ then 6.31×10^9 kWh x 3.60×10^{-3} = 2.21×10^7 GJ (Serway, 1996). As specified by Rees and Wackernagel, the average land-for-energy conversion ratio for sequestering the CO_2 released by fossil fuel consumption is 100 (GJ/ha/yr.) (1996). Therefore, since the population of the city of Chicago was 2,896,016 persons in 2000, the EF calculation now becomes 2.21×10^7 GJ/year / (100 (GJ/ha/yr.) x 2,896,016 cap) = 0.076 ha/cap (Infoplease.com, 2003 & Rees et al, 1996).

To put this number into perspective, the 'Energy Land' component for Canada in 1991 was 2.34 ha/cap. The implementation of a rooftop garden program that can cover all available rooftops of a city, saving 720 MW of energy, can decrease the EF by approximately 0.076 ha/cap (Rees et al, 1996).

However, the interesting fact about this type of EF calculation for a rooftop garden, aside from providing an estimate by which the Energy Land component can be reduced, is that the actual surface area of the garden can be subtracted from the 'Degraded Land' component of the Total EF. This is because the 'Degraded Land' component represents the amount of land that is built-up and can no longer be used as productive land. However, rooftop gardens provide a viable alternative by which the built-up environment can be transformed into a thriving and productive environment that is capable of growing food, and purifying the air by sequestering carbon dioxide emissions. As such it becomes clear that a simple EF calculations understates the benefits that rooftop gardens would accrue to an urban community.

3.6 Design Guidelines for Rooftop Gardens

The design and construction of a green roof project can be relatively straight forward, provided that the garden has been designed as site specific. The designer will need to take into consideration not only the structural capacity of the building, but will also need to consider the end purpose of the garden as required by the building's owner, and any other end user.

3.6.1 Design Considerations

Some of the design considerations will include:

1. Location
- Height of building
- City, Province, Country
2. Climate of Area
- Horticultural growing zone
- Selection of plants that will grow due to climatic condition on the roof

3. Building code requirements are met
- For example in Toronto, recent changes in the Ontario Building Code require that a "general snow load of only 107 kg/m^2 (22 lbs./sq*ft down from 40 lb. in earlier editions) must be accommodated on the roof, with capacity for higher snow loading required only in specific areas on the roof which are subject to drifting and build-up. This leaves 88 kg/m^2 (18 lbs./sq*ft) for a green roof installation, on buildings designed in accordance with earlier code requirements. This additional reserve strength is enough for a simple extensive system (Peck et al, 1999)

4. Additional Loading
- Wet soil weighs approximately 1,597 kg/m^3 (100 lbs/ft^3) (Peck et al, 1999)
- Most rooftops in Ontario, Canada are designed for a live and snow load of only 195 kg/m^2 (40 lbs./sq*ft) (Peck et al, 1999)

5. Cost
- "If a green roof is part of the initial design of the building, the additional loading can be accommodated easily and for a relatively minor cost. However, if a green roof is installed on an existing building, the design will be limited to the carrying capacity of the existing roof, unless the owner is prepared to upgrade the structure" which can be costly (Peck et al, 1999)

6. Structural Integrity of the building
   - Structural loading requirements
   - Location of supporting beams and columns
   - Structural stability of railings or guarding posts
   - Location of electrical outlets
   - Location of water pipes
   - Current condition of the roof – does it need to be repaired?
   - Exit requirements
     - types and number of exits allowed or required by law
     - distance between exits
     - travel distance to exits (in case of fire)
     - sizes of exits
     - possible requirements for fire alarms, exit lights, emergency lighting
   - Effect on overall building height
   - Fire rating of structural members
7. Purpose of Garden
   - Recreational
   - Food production
   - Additional green space
   - Aesthetics (no access to garden)
8. The type of rooftop garden needed
   - Extensive
   - Intensive
9. Occupancy and the size of the garden
   - Occupant load i.e. the number of people allowed in the garden at one time
10. Handicapped accessibility

11. Barrier Free Design, either as a Code requirement or as a Client/User requirement
12. Requirements for enclosures such as guards, railings, parapets, walls around rooftops, terraces, and balconies
13. Future Consideration
    - Possible modification of window washing anchors on the roof
    - Possible upgrading of washroom and service requirements
    - Possible upgrading of drainage and water-proofing requirements

(Adapted from Urban Agricultural Notes: Rooftop Gardens, 1999).

3.7 Example of Rooftop Gardens

In theory, any rooftop has the potential to be converted into a garden paradise. Whether flat, slanted, or curved, most roofs can support a layer of sod or native wildflowers (Urban Agricultural Notes: Rooftop Gardens, 1999). However, if the addition of a soil or engineered medium is not possible, then there are several plant species that can grow in gravel (Urban Agricultural Notes: Rooftop Gardens, 1999). Several examples of buildings retro-fitted to support rooftop gardens include government offices, public libraries, industrial or commercial facilities, hospitals and other health care facilities.

Chicago's City Hall is one of the few buildings in the United States that is currently experimenting with green roof technology (City of Chicago, 2001). The 20, 300 sq*ft garden consists of "20,000 plants of more than 150 varieties including 100 shrubs, 40 vines, and 2 trees water" (City of Chicago, 2001). An ASHRAE simulation of the city's green roof indicated that for every one degree (F) decrease in ambient air temperature, there was a 1.2% drop in cooling energy use during warm weather conditions (Peck et al, 1999). The significance is that less ground level ozone, nitrous oxide, and smog would be produced from current coal fired utilities that are currently in place, and could lead to a higher level of urban air quality (Peck et al, 1999).

The 2400 m^2 rooftop garden in Vancouver sits on top of a 7-storey public library, and although the implementation was a success, any quantifiable results in air quality and energy consumption reduction have yet to be recorded (CMHC, 1999).

In Belgium, Ecover Inc. a manufacturer of biodegradable laundry products established a two-acre green roof consisting of native grasses and wildflowers on top of their industrial buildings (Peck et al, 1999). The purpose of the project may have been to provide amenity space for employees, keep the factories cooler, or to simply improve the aesthetic appearance of the facility, but the green roofs now acts as a secondary filter. Once the factory has treated the effluent, it passes through the garden, which subsequently removes any nutrients missed by the water treatment process (Peck et al, 1999).

As for hospitals being suitable candidates for rooftop gardens, a head injury recovery centre in Northern Toronto is currently planning to install a green roof based on the observation that horticultural therapy can speed recovery rates and reduce the amount of drugs prescribed to patients (Peck et al, 1999).

3.8 General Construction Techniques

General construction practice, after successfully designing the green roof to the building specification, is to apply a waterproof membrane, or vapour control membrane. The membrane should be designed to hold water and prevent sand, soil, and vegetation debris from coming in direct contact with the roof which, could cause considerable damage to the structure (Urban Agricultural Notes, 1999). In most causes, the membrane is not shock resistant, therefore point-loading from shovels and shoe heels should be avoided (Urban Agricultural Notes, 1999). The second step is to install an insulation board for thermal control, followed by a protective slab of concrete as a support panel for the root-repellant/waterproof membrane (GreenTeck, 2002 & Green Roofs for Healthy Cities, 2002).

The next step is to install a drainage layer with an appropriate medium based on design criteria, which can be an engineered medium, gravel, or sand. A filtering blanket or membrane tops off the drainage layer, and should prevent any large clumps of soil, rock or vegetation from percolating down to the roof level (GreenTeck, 2002 & Green Roofs for Healthy Cities, 2002). After all this, the growing medium then can be applied, but again, it should be stressed that a structural engineer should confirm that the roof structure can accommodate the additional weight, because "one cubic foot of wet earth weighs around 100 pounds" (Kuhn, 2002). However, remember that the growing medium does not necessarily need to consist of just soil. You can also add compost to enrich the soil, vermiculite to lighten the soil and create air pockets, and mulch to help reduce the weight (Kuhn, 2002). Also, depending on the type of garden, be it extensive or intensive, and the purpose of the garden, not all of the planting beds will have to be a maximum of 60 cm (24") deep, nor will they likely be uniformly distributed over the whole roof surface. "Heavy planters can be placed strategically over bearing walls or columns. Grasses do not need more than three inches of growing medium, and some plants will grow in gravel" (Kuhn, 2002). Therefore, there are options available to reduce the weight of the growing medium, and reduce garden bearing loads on roof structures. Finally, the last phase in any successful rooftop garden is the planting.

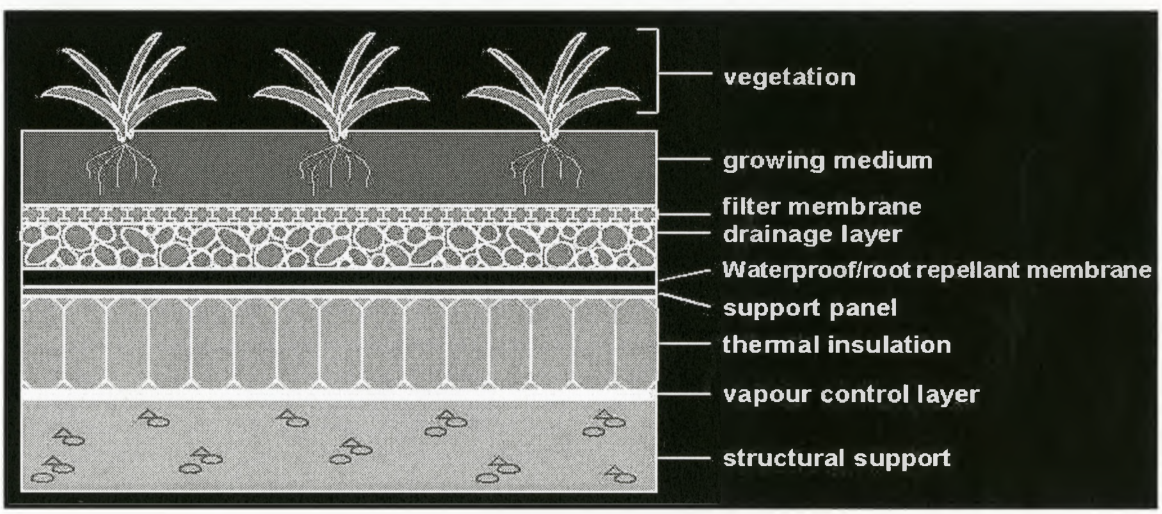

Figure 1: Typical Cross Section of a Rooftop Garden
(Courtesy of the National Research Council, Institute for Research in Construction)

3.9 Plants

Gardening on a roof is quite different from nurturing a garden at grade. The ability of a garden to adapt and flourish is dependent on certain key factors. These factors include the building location, how high it is, what the wind intensity is, the amount of rainfall the area receives, the amount of sunlight or shade the roof is subject to, and what the soil depth, and root size will be (Kuhn, 2002 & Peck et al, 1999). Also, knowing where the plants were previously grown and if the growing conditions were similar to those on the rooftop will help ensure the success of the garden (Peck et al, 1999). But when do you plant, and which plants are most suitable for extensive and intensive gardens?

The most ideal time to start up a rooftop garden, like any grade level garden, is in the spring. However, according to Steven Peck and Monica Kuhn, in the paper they prepared for the Canadian Mortgage Housing Corporation, if you plant in high summer, extra watering my be required to get the plants through the heat before they become established (1999). "Fall planting will depend on the availability of suitable plant stock and time enough to allow for the plants to get established before the cold weather sets in" (Peck et al, 1999). It is also possible to plant certain species during the winter months, when the plants are dormant, although one runs the risk of the plant going into shock and not establishing itself. As for which type of plant can grow and where, the key is simply location.

"Typically, extensive green roofs rely on a mixture of grasses, mosses, sedums, sempervivums, festucas, irises, and wildflowers - plants that are native to drylands, tundras, alvars, and alpine slopes" (Peck et al, 1999). The selection of plant material for an intensive green roof, is fairly limitless, provided that the green roofs are equipped with an irrigation system, shading devices, and have appropriate growing medium depths (Peck et al, 1999). It is imperative to know what the climatic conditions of the area are, and which horticultural zones the region is in, to best determine which plants will do well.

The Canadian Plant Hardiness Zones, as defined by Agriculture and Agri-Food Canada, is a map that outlines eight different climatic conditions in Canada where various types of trees, shrubs, vines, perennials, and annuals will most likely survive (2003). The first North America Hardiness Zone map was released by the United States Department of Agriculture in 1960, and was based only on minimum winter temperatures. "In 1967, Agriculture Canada scientists created a plant hardiness map using Canadian plant survival data and a wider range of climatic variables, including minimum winter temperatures, length of the frost-free period, summer rainfall, maximum temperatures, snow cover, January rainfall and maximum wind speed" (Agriculture and Agri-Food Canada, 2003).

Table 2 is a brief list, adapted from the Canadian Mortgage Housing Corporation report entitled *Greenbacks From Green Roof: Forging a New Industry in Canada*, of plants that will do well on extensive rooftop gardens (1999). Due to the harsher conditions associated with extensive green roof projects only certain plant matter is suitable, where as for intensive gardens, as long a there is a proper irrigation system installed almost any plant can thrive and flourish. A complete list of which vines, shrubs, and perennials can do well in an extensive garden can be found in the Canadian Mortgage Housing Corporation Report. Plants that will thrive in an intensive garden are simply limited by the horticultural hardiness zone of the area. A full listing of available plant material for any Canadian horticultural hardiness zone can be obtained from Human Resources Canada at the URL address http://g4.glfc.cfs.nrcan.gc.ca/ph_listspp.pl.

Since the focus of this project has been on Hamilton the following table reflects a brief list of vines, shrubs, and perennials, suitable for growing conditions in that geographical area, which according to a map of Canada has a horticultural hardiness zone of 6 (Agriculture and Agri-Food Canada, 2003). The Canadian Mortgage Housing Corporation has also recognized the plants recorded in Table 10, as being well suited for extensive rooftop gardening (1999).

Table 11: List of Plants Suitable for Extensive Gardens in Zones 6

Latin Name (Sub-species)	Common Name	Height (cm)	Soil Type	Wildlife Notes
Vines				
Clematis (C.m. rubens) (C. vitalba)	Clematis (Old Man's Beard)	1000	Various (Prefers Alkaline Soils)	Provides seeds, nectar, and nesting materials for birds
Lonicera (L. henryi)	Honeysuckle	600	Rich	Provides seeds, nectar, nesting materials, and nesting location for birds
Hedra (H. helix)	Ivy	3000	Moist, Rich	Provides nectar and pollen for bees, a good nesting location for robins and wrens, and hibernation for butterflies
Campsis (C. radicans) (C. Tagliabuana)	Trumpet Vine	1200	Rich, Well drained	
Wisteria	Wisteria	1800	Moist, Rich, Loam	Provides nectar and pollen for bees, and a nesting location for birds
Shrubs				
Cotoneaster	Cotoneaster	3000 – 6000	Various	Provides berries for birds, a nesting location for birds, and nectar and pollen for bees
Euonymous	Euonymous	5000	Various	
Rosa	Climbing Rose	5000	Most	Provides nectar and pollen for bees
Rubus	Common Garden Raspberry		Most, but prefers acidic soil	Provides berries for birds, and nectar and pollen for bees and butterflies
Weigela	Weigela	1500 – 2700		Attracts hummingbirds

Latin Name (Sub-species)	Common Name	Height (cm)	Soil Type	Wildlife Notes
Perennials				
(Flowering)				
Alyssum (A. saxatile)	Golden Alyssum	10	Well-drained	Provides nectar for bees and butterflies
Cerastium (C. tormentosum)	Snow-in-Summer	10-20	Well-drained	
Sedum (S. album) (S. acre) (S. reflexum) (S. seanguiare)	 (White Stonecrop) (Biting Stonecrop) (Relexed Stonecrop) (Tasteless Stonecrop)	 (5-10) (2-10) (5-10) (5)	Poor, Well-drained, acidic or alkaline	Attracts bees
(Grasses)				
Agrostis (A. capillaris)	Common Bent	10-70	Poor, Acidic, Dry, Sandy to Clay	
Festuca (F. ovina)	Sheep's Fescue	5-60	Well-Drained, Poor, Acidic or Alkaline	
Poa (P. annua)	Annual Meadow-Grass	5-30	Most	
(Herbs)				
Allium (A. schoenoprasum)	Chives	20-30	Loamy, Neutral to Alkaline	Attracts bees
Lavendula (L. augustifolia)	Lavender	50	Well-drained, Alkaline	Provides nectar for bees and butterflies
Thyme (T. serpyllum) (T. drucei)	 (Wild Thyme) (Common Thyme)	 20 20	Poor, Well-drained, Alkaline	Provides nectar for bees and butterflies

(Adapted from a list released by the Canadian Mortgage Housing Corporation in *Greenbacks From Green Roof: Forging a New Industry in Canada, 1999*)

3.10 Conclusions

Components of the built urban infrastructure, particularly the rooftops of commercial facilities, recreational centers, and residential buildings can provide a city with both economical and environmental benefits if they are converted into rooftop gardens. Rooftop gardens are contained man-made, green spaces. They are characterized by their unique layering system that consist of a protective waterproofing or roofing membrane, a layer of growing medium, and various types of vegetation. The insulating property of these gardens prevents heat from escaping through the roof, the result of which keeps the building warmer during the winter. Contrarily, since the plant material can absorb solar radiation, the garden also averts excess heat from entering the facility and keeps the building cooler during the summer. Both of these features can translate into financial savings for the building owners because the cost of heating and cooling the building will decrease.

The environmental benefits of rooftop gardens are inherently found in their ability to increase air quality by filtering out particulate matter, improve storm water retention, and provide an alternative habitat for some birds, butterflies, and other city dwelling organisms (CMHC, 1999). Also, the Ecological Footprint (EF) Analysis performed in this chapter revealed that if all available rooftops in a city the size of Chicago were to be covered with gardens, the city could save 720 MW of energy and lower it's EF 'Energy Land' component by 0.076 ha/cap. However, it should be mentioned, that although 0.076 ha/cap may seem small in comparison to the total 2.34 ha/cap of the 'Energy Land' category, as suggested by Rees and Wackernagel in their book, the saving of 0.076 ha/cap it is still greater than the amount of land the authors set aside for the operation and maintenance of housing, at 0.06 ha/cap (Rees et al, 1996). The calculated EF is also larger than most of the EF's assigned to the general services as listed in the 'Energy Land' column of Rees and Wackernagel's EF Analysis for the average Canadian (Rees et al, 1996). Also, a reduction of 0.076 ha/cap of land is approximately equal to the total amount of land, 0.08 ha/cap that is degraded due to the construction of residential units. In addition the EF calculated in this chapter does not capture any benefits pertaining to water purification, augmentation in air quality, or the possible benefits related to storm water retention. Therefore, once put into perspective, the implementation of rooftop gardens can help reduce the overall EF of a city.

Essentially, rooftop gardens can be viewed as a viable solution in transforming the built-up environment into one that is thriving and productive. An environment that is capable of providing areas to grow food, purifying the air by sequestering carbon dioxide emissions, and supplementing the minimal amount of green spaces that may exist in downtown urban cores.

4 R-2000 Homes

4.1 Introduction to the R-2000 Home Program

Since the inception of the R-2000 Home Program in 1981, over 9000 R-2000 homes have been built and certified in Canada (Natural Resources Canada, 2002c). The program's objective was to improve the energy efficiency of new houses and low-rise dwellings through the development and promotion of technical standards for energy-efficient construction practices, the use of recycled materials, low-emission building textiles, and energy-efficient appliances (Parekh et al, 1999 & Natural Resources Canada, 2002c). The program, aside from encouraging energy conservation, also provided the building community with a new incentive upon which to improve their trade. "R-2000 has been right in front with the best of Canadian builders producing the best of Canadian housing stock, and a trickle-down effect has resulted in improving building technology and the industry" (Home Energy Magazine Online, 1995). New home-buyers can now see improvements in energy performance, indoor air quality, water and material conservation, as well as monetary savings from decreased utility usage.

However, the financial savings incurred from owning and living in an R-2000 home may take a while to show up in the homeowner's pocket book. On the whole, most R-2000 homes can cost $4-$5 /sq*ft more than a conventional home depending on the size and location (Alberta R-2000, 2000). Nevertheless most R-2000 home buyers can look forward to cash rebates or special mortgage rates from a few utilities and lending institutions in Canada who support the construction of R-2000 homes, and this may help offset the initial purchasing costs (Home Energy Magazine Online, 1995).

Aside from cost and the promise of energy conservation through energy-efficient technologies, what sets an R-2000 home apart from conventional residential units? R-2000 homes are built according to a set of stringent and rigorous performance standards (Alberta R-2000, 2000). These standards, which were developed in a joint effort by Natural Resources Canada (NRCan), the Canadian Home Builders Association (CHBA), and over 700 active licensed R-2000 builders, ensure that all mechanical, electrical, or structural components comply with a higher level of energy efficiency beyond that of what current building codes require (Home Energy Magazine Online, 1995 & Natural Resources Canada, 2002a). This, for the most part, warrants a higher quality of material used in the home's construction, whether it is recycled or a new low-emission/non-toxic material (Natural Resources Canada, 2002a). R-2000 homes will have improved thermal characteristics, a higher level of air quality due to reduced off-gassing, and a refined ventilation system, as well as experience a reduction in both water and energy consumption (Alberta R-2000, 2000). Essentially, the resultant household is a fully functional home, with all the comfort and amenities of a conventional dwelling.

4.2 Characteristics of an R-2000 House

Some of the more distinguishable characteristics of an R-2000 home are its use of recycled materials, thermal efficiency, high levels of indoor air quality, a superior building envelope, responsible material use, an improved ventilation system, frequent air exchange rates, and most importantly, energy efficiency.

4.2.1 Responsible Material Use

As a part of the R-2000 Home Program, certified builders are asked to carefully select products and materials that are environmentally responsible (Canadian Home Builders Association, 2003). Environmentally responsible products can be used in a manner as to help conserve our natural resources; for example, the use of water-based paints and finishes, instead of oil-based ones, can reduce the amount of toxic wastes and solvents from being emitted into the air or released into our water supply (Canadian Home Builders Association, 2003). Also, engineered wood products made from the fibre of certain tree species which are not suitable for lumber production – thereby decreasing the demand of prized timber, can be used in floor systems or as support beams (Natural Resources Canada, 2002a). In terms of using recycled materials home insulation can be made from engineered wood, truss joints, or even paper products (Alberta R-2000, 2000 & Home Energy Magazine Online, 1995). Other environmentally responsible products and materials include those used in dry-walling, roofing, carpeting and even in the mixing of concrete (Alberta R-2000, 2000 & Natural Resources Canada, 2002a).

In addition to reducing waste and energy consumption, the use of selected recycled materials and energy efficient products has created a marketable niche for 'waste' materials that might have otherwise found their way into a local landfill.

4.2.2 Thermal Characteristics

Anil Parekh and John Gusdorf conducted a study for Natural Resources Canada comparing the energy efficiency and indoor air quality of recently constructed conventional homes to R-2000 homes built in Canada between 1990 and 1996 (1999). The houses were randomly selected from each geographical location within Canada, and represented the majority housing type constructed in the area (Parekh et al, 1999). A total of 226 residential units were tested: 163 were conventional homes, and 63 were homes built in accordance with R-2000 standards (Parekh et al, 1999).

Among their published conclusions, R-2000 homes appeared to be more airtight, more energy efficient, have a higher level of indoor air quality, and used less space heating energy than conventional homes (Parekh et al, 1999). Parekh and Gusdorf were also able to deduce that these benefits were in part due to the higher level of thermal characteristics inherent in R-2000 homes (1999). As Table 12 demonstrates, R-2000 homes generally have a higher RSI value than most conventional homes.

An RSI (R-) value is a number that indicates the ability of a material to resist heat flow. The higher the RSI (R-) value or number is, the better the quality of the insulating material (SaskPower, 2003). However, it should be noted that insulators should be measured out using the RSI (R-) value system and not by thickness. "For instance, two materials rated RSI 1.93 (R-11) have precisely the same insulating ability while 50 mm (two inches) of each may not. Take fiberglass and brick as an example. To achieve RSI 5.28 (R-30) with fiberglass batts requires 216 mm (8.5"), while it would take 1524 mm (60") of brick" (SaskPower, 2003).

As a result of these improved levels of thermal insulation, R-2000 homes will experience a more even distribution of heat loss. This means that the occurrences of hot or cold spots in the home would be reduced, creating uniform indoor temperatures, thus making the home more efficient to heat or cool (Alberta R-2000, 2000).

Table 12: Comparison of Thermal Characteristics

Home Characteristic	Conventional Homes Mean (RSI)	R-2000 Homes Mean (RSI)
Ceiling Insulation	5.84	7.26
Main Floor Wall Insulation	2.85	3.58
Basement Wall Insulation	2.00	2.84
Windows	0.37	0.43

(Parekh et al, 1999)

4.2.3 Indoor Air Quality

Homes built in accordance with R-2000 standards can experience a higher level of indoor air quality compared to conventional houses because the level of air quality in the home can be controlled (Alberta R-2000, 2000). This can be achieved in several ways. The first is to construct a building envelope that seals out harmful substances. The second is to ensure that the building materials used are non-toxic and do not emitted harmful fumes. A third method is to have a ventilation system that properly balances air supply throughout the house and finally, air quality can be controlled via air tightness and air exchange rates (Alberta R-2000, 2000 & Parekh et al, 1999).

4.2.4 Building Envelope

A properly sealed building envelope will help increase air quality levels by reducing the amount of pollutants that can flow into the house (Alberta R-2000, 2000). In combination with a well functioning ventilation and air exchange filtration system, a R-2000 building envelope can keep allergens such as dust and pollen out, while helping to eliminate the growth of mould (Alberta R-2000, 2000). This is of particular importance to individuals who suffer from asthma, chronic bronchitis, or other allergies that are triggered by these substances (Alberta R-2000, 2000).

4.2.5 Material Use

The careful selection of finished materials, which includes any material that has been pre-stained or pre-treated with non-toxic products prior to installation, can significantly reduce the amount of off-gassing that occurs during the construction and completion of an R-2000 home. Often in R-2000 homes, it is customary to pick paints, varnishes, and carpeting that emit minimal amounts of volatile organic compounds (VOC's), formaldehyde, or other chemicals that can be detrimental to human health (Alberta R-2000, 2000 & Home Energy Magazine Online, 1995).

Volatile organic compounds (VOC's) are "a class of compounds that contains at least one carbon atom," are volatile, and generally exist in the atmosphere as a gas (HAQI, 1997). VOC's react with nitrogen oxides (NOx) in the presence of sunlight to form ground level ozone (O_3), which when inhaled can cause inflammation of the respiratory airways, causing an individual to cough and wheeze, as well as aggravating any existing cardiovascular and lung conditions. (Environment Canada, 2002a). In the average residential environments over 50 types of VOC's can be found (Alberta R-2000, 2000 & Parekh et al, 1999). However, determining the exact amount of each individual VOC can be costly, so most studies such as the one performed by Parekh and Gusdorf, aim to calculate the culmination of all VOC's in a home. This total amount of VOC's or Total Volatile Organic Compounds (TVOC) was compared between conventional homes and R-2000 homes. Parekh and Gusdorf concluded that the average level of TVOC in an R-2000 house was about 33% lower than that of a conventionally built home (Alberta R-2000, & Parekh et al, 1999). An average R-2000 home experiences a TVOC level of 388 $\mu g/m^3$ while a conventional home contains an average of 571 $\mu g/m^3$ (Parekh et al, 1999). However, both homes experience tolerable levels of TVOC emission, because most people will not experience some type of discomfort until TVOC levels reach 3,000 $\mu g/m^3$ (Parekh et al, 1999).

Another chemical pollutant that can be off-gassed from some materials is formaldehyde. Generally, formaldehyde levels in R-2000 homes are 50% less than those measured in conventional homes (Alberta R-2000, 2000). According to Health Canada Indoor Air Quality Guidelines, formaldehyde level should be below 0.05 ppm, but action to reduce this degree of concentration should not be taken until formaldehyde levels exceeds 0.1 ppm (Parekh et al, 1999). This is because monitoring data has shown that formaldehyde levels can steadily decrease over a two year time period, at which point it can settle down to a constant value below the acceptable 0.05 ppm (Parekh et al, 1999). However, with regards to the average formaldehyde levels in the home, Parekh and Gusdorf determined that in a conventional home the mean range of formaldehyde was about 0.053 ppm while in an R-2000 home is was approximately half of that, at 0.027 ppm (1999).

4.2.6 Ventilation Systems

An important aspect in maintaining high indoor air quality is to ensure that the air supply throughout the home is fresh, filtrated, and exchanged at a controllable rate. In most cases this can be achieved with the installation of a heat recovery ventilator (HRV) unit. This system, which is integrated with the furnace and air ducts, operates by reclaiming the warmer air leaving the home, filtering it, and then mixing it with the cooler fresh air entering the building (Alberta R-2000, 2000). However, in order for the HRV units to be R-2000 certifiable, they must be designed and installed by a certified Heating, Refrigeration, and Air Conditioning Institute (HRAI) technician (Alberta R-2000, 2000).

According to Parekh and Gusdorf, all 63 of the R-2000 homes examined in their study were outfitted with HRV systems, which could explain why most of the R-2000 homes out-performed conventional homes in air quality levels (1999). However, 34% of the conventional houses studied did have a HRV system, and hopefully this number will increase as the benefits of this type of ventilation system become more apparent (Parekh et al, 1999).

4.2.7 Air Exchange

The remaining conventional homes investigated by Parekh and Gusdorf that were without a heat recovery ventilator (HRV) mainly relied on natural forms of air exchange; it is likely that these homes will experience indoor air quality problems (Alberta R-2000, 2000 & Parekh et al, 1999). This is because natural forms of air exchange, via open windows or doors, allow allergens, mould, and harmful chemical pollutants to enter the indoor air supply, and without proper ventilation, these substances can remain airborne with the home causing lower levels of air quality. The acceptable rate of air exchange for most homes is 0.35 air changes per hour (ac/hr); anything lower would likely result in indoor air quality problems (Parekh et al, 1999). The results of Parekh and Gusdorf's monitored data indicated that approximately 90% of new conventional houses experienced an air exchange rate less than the prescribed 0.35 ac/hr (1999). This meant that these homes required the use of a mechanical ventilation system, with a capacity of about 40 to 65 L/s to successful circulate the air (Parekh et al, 1999). However, in contrast, all of the R-2000 homes were equipped with an HRV system, so their air exchange well succeeded the average 0.35 ac/hr (Parekh et al, 1999).

4.2.8 Energy Efficiency

One of the foremost characteristics of an R-2000 home is its distinguishing promise of energy efficiency. Both construction and adornment of R-2000 homes takes full advantage of the most innovative and up-to-date technologies to maximize a home's use of energy. This is accomplished in various ways. One way is through the installation of highly efficient windows. When windows are strategically positioned as to maximize passive solar energy, they not only bathe the home's interior with light, essentially reducing the amount of energy required to light the home, but the sunlight can also help heat the home during cooler winter months (EnerQuality, 2002). In contrast, the positioning of roof overhangs during warmer summer months can reduce the amount of direct sunlight entering the home and minimize summer cooling requirements (EnerQuality, 2002). Other features inherent in R-2000 homes are state-of-the-art air barriers to ensure air tightness, and a high level of insulation; both contribute to the elimination of drafts and cold spots which keep heat in during winter months and out in the summer (EnerQuality, 2002). Finally, all R-2000 homes are outfitted with energy efficient lighting fixtures, appliances, and home office equipment that can reduce daily energy requirements (EnerQuality, 2002).

4.3 Benefits

R-2000 homes are gaining recognition in Canada as being a "Better Built Home" because their unique energy efficient design can offer a wide variety of benefits over traditionally constructed homes (EnerQuality, 2002). These benefits can manifest themselves in the form of an economic reimbursement, an environmentally responsible practice, or through observed improvements in the health of the users; for example, since home energy costs are on the rise as demonstrated in Table 13, purchasing an R-2000 home with energy saving features can help reduce the amount of energy required to operate the household by 30% - 50% (Alberta R-2000, 2000). This reduction in energy consumption translates into a monetary dividend for the homeowner on a monthly basis (Alberta R-2000, 2000). However, the actual dollar savings incurred by the homeowner will vary from household to household. It will be dependant on the homes main fuel source, current energy costs, the number of people living in the home, and on the owner's and/or their family's lifestyle habits (Natural Resources Canada, 2002a).

Table 13: Typcial Home Heating Costs

Year	Cost per GJ
1996	$1.31
1997	$1.78
1998	$1.96
1999	$2.61
2000	$3.40

(Alberta R-2000, 2000)

Another advantage to owning an R-2000 home is that it has been designed with environmentally responsible technology that can help to conserve energy and water. R-2000 homes are retro-fitted with energy efficiency devices such as light fixtures, appliances, and office equipment which not only use less energy, but produce on average fewer greenhouse gases during daily operation compared to those found in a conventional home (Natural Resources Canada, 2002c). This reduction in greenhouse gas production helps to minimize the impact on global climate change and lessens the amount of detrimental chemicals that find their way into our atmosphere (Natural Resources Canada, 2002c). Also since every R-2000 home is outfitted with a number of water-conserving fixtures such as toilets, faucets and showerheads, water consumption is diminished (Natural Resources Canada, (c) 2002). Home Energy Magazine Online published an article that stated that "the installation of water saving toilets [13.25 L/flush (3.50 gal/flush) or less], low-flow showerheads [less than 9.8 l L/minute (2.6 gal/minute) at 80 psi], and faucets [less than 8.3 L/minute (2.2 gal/minute) at 60 psi]" can reduce water consumption by up to 35% (1995). Therefore, the practice of using water-conserving technology not only means you use less water, but the local water purification plant will also have less water and sewage to treat and purify (Natural Resources Canada, 2002c). In addition to energy and water conservation, energy efficiency technology cuts back on the homeowner's monthly energy and utility costs (Natural Resources Canada, 2002c).

The installation of mechanical heat recovery ventilation (HRV) systems in an R-2000 helps to circulate air through the home, improving indoor air quality. The benefit of fresh filtered air being brought into the house while stale air is continuously exhausted reduces the amount of allergy-aggravating pollutants from irritating people with allergies, asthma, chronic bronchitis, or other respiratory problems (Alberta R-2000, 2000 & EnerQuality, 2002). HRV's help to reduce exposure to outdoor dust and pollen while removing indoor air pollutants such as radon, carbon monoxide, formaldehyde, and other particulate matter. Fresh airflow can prevent stale air pockets and can control the growth of moulds that can make certain people ill (Alberta R-2000, 2000 & EnerQuality, 2002).

Therefore R-2000 homes can save energy and money, reduce water and energy consumption, and provide a healthier indoor environment for people who suffer from respiratory complications.

4.4 R-2000 vs. Conventional Homes

In an attempt to compare the energy efficiency and air quality levels of R-2000 homes to conventionally built homes, the Institute for Research in Construction (IRC), a department of the National Research Council (NRC), has built three test houses on their Ottawa Campus. The first two houses, built using state-of-the-art construction techniques as per R-2000 specifications, are identical in size, type, and base construction and include similar housing systems, and control and communications technologies (IRC, 1997). They are 2,000 sq*ft, and 2-storeys with a full basement (Natural Resources Canada, 2002a). Both houses are "fully computer-controlled, with instruments and electronic links for remote control and data acquisition" (IRC, 1997). The first house is the control unit, while the second acts as a laboratory, "where features can be altered or added allowing the relatively quick assessment of new components and systems" (IRC, 1997). Finally, the third house, which is similar to the first two minus a different floor surface area, acts as a showplace for the Canadian Housing System, while displaying certain housing components (IRC, 1997). All three dwelling units are also representative of single detached homes (SDH).

In order to perform the experiments it was necessary to establish a set of base criteria from which to compare all other results. Therefore certain assumptions were made. The testing facility in Ottawa assumed that the homes were occupied by 2 adults and 2 children (one teenager and one baby), received enough electricity (about 24 kWh/day) to operate lighting fixtures, kitchen appliances and entertainment equipment, used natural gas for space heating and domestic hot water, and maintained an internal temperature of 21 C on the main floor and 19°C in the basement (Natural Resources Canada, 2002a). Also, the homes had no air-conditioning and had windows distributed in all cardinal directions to optimize solar gains (Natural Resources Canada, 2002a). Based on these assumptions, typical carbon dioxide (CO_2) emissions for the average single detached home (SDH) were calculated along with energy consumption for both R-2000 homes and conventional homes built over the last three decades. The results are shown in Tables 14 and 15.

Essentially, conventional houses emitted anywhere from 43% - 67% more CO_2 than the average R-2000 home and consumed 32%-66% more energy than the average R-2000 home constructed after the year 2000 (Natural Resources Canada, 2002b).

Table 14: Typical CO_2 Emissions for SDH

Home Type	CO_2 Emitted tonnes/yr./SDH	Difference Between Conventional And R-2000 Homes tonnes/yr./SDH	Percent Difference Between Conventional And R-2000 Homes (%)
Conventional Home – 1970	13	8.7	67%
Conventional Home – 1980	11	6.7	61%
Conventional Home – 1994	7.5	3.2	43%
R-2000	4.3	-	-

(Adapted from Natural Resources Canada, 2002b based on the test Houses Located in Ottawa)

Table 15: Typical Energy Consumption for SDH (Natural Gas)

Home Type	Natural Gas Consumption (GJ/yr.)	Difference Between Conventional And R-2000 Homes (GJ/yr.)	Percent Difference Between Conventional And R-2000 Homes (%)
Built in 1950	250	165	66%
Built in 1970	212	127	60%
Built in 1989	145	60	41%
Current Conventional New Home	125	40	32%
R-2000 Built in 1990	95	10	11%
Current R-2000 Built in 2000	85	-	-

(Adapted from Natural Resources Canada, 2002a based on the test Houses Located in Ottawa)

4.5 Calculating Benefits using Ecological Footprints

As mentioned in previous chapters, Ecological Footprint (EF) Analysis can be used to calculate the impact certain lifestyle choices have on our environment. Similarly, it can also be used to compare and contrast these choices. In regard to newly built conventional homes and R-2000 homes, an EF can be calculated to compare the amount of productive land required to act as a 'carbon sink' to sequester the amount carbon dioxide (CO_2) generated by each type of residential unit.

According to Rees and Wackernagel for every 1.8 metric tonnes of CO_2 produced each year, one hectare of forested land will be required to assimilate the carbon emissions produced (1996). Therefore 0.56 hectares of forested land are required each year to sequester one tonne of CO_2 (1/1.8 (tonne-CO_2/ha/yr. = 0.56 ha*yr./tonne-CO_2). By using the latter value 0.56 ha*yr./tonne-CO_2, and the data as recorded by the Natural Resource Council for the average amount of CO_2 emitted per year per single detached home (SDH), presented earlier in Table 14, we can estimate what the 'Energy Land' EF component would be for an SDH unit for a particular city such as Hamilton. The calculation will take into account the amount of CO_2 emitted each year per dwelling unit, multiplied by Rees and Wackernagel figure of 0.56 ha*yr./tonne-CO_2, multiplied by the number of residential units, then divided by the population of Hamilton. The final calculation will resemble the following format:

Equation 3:
EF [ha/cap] = {CO_2 Emissions (tonnes/yr./SDH) x 0.56 (ha*yr./tonnes-CO_2) x The number of SDH}[7] / {331, 121 persons in Hamilton [cap]}.

Table 16: Ecological Footprint Comparison

Home Type	CO_2 Emitted (tonnes/yr./SDH)	Population of Hamilton [Old City] (Census Year) (cap)	Number of Single Detached Homes[8] (SDH)	Ecological Footprint (ha/cap)
Conventional Home – 1970	13	309,173 (1971)	53,810	1.26
Conventional Home – 1980	11	306,434 (1981)	55,055	1.10
Conventional Home – 1994	7.5	322,352 (1996)	66,955	0.87
R-2000	4.3	331,121 (2001)	69,555	0.50

The results of Table 16 indicate that R-2000 models emit significantly less carbon emissions, over 40% less than homes built almost a decade ago. It is interesting to note that although the population has increased over the years, improvements in housing construction and energy efficiency devices has lead to a decrease in the amount of CO_2 generated by each household. In effect, this means that the amount of productive land required to assimilate all the carbon dioxide emissions produced by these types of homes will also be smaller.

4.6 Retro-fitting Conventional Homes to R-2000 Standards

The Government of Canada in accordance with the *Government of Canada Action Plan 2000 on Climate Change*, as per the Kyoto Protocol, recently introduced the *EnerGuide for Houses Program.* Under the program's initiatives, Canada's housing sector will reduce greenhouse gas emissions and energy consumption rates by 20% from existing low-rise housing development (Natural Resources Canada, 2003). The program

[7] The reason the number of Single Detached Homes (SDH) is being used for this calculation is in relation to the fact that the results used from studies conducted at the NRC campus in Ottawa are based on SDH.
[8] Numbers obtained from the Long-term Planning Department, City of Hamilton. (Paolo, 2003).

will "foster the development of energy efficiency expertise in the housing industry in Canada and provide Canadian homeowners with reliable energy efficiency information to help them make informed choices when retrofitting/renovating their homes" (Natural Resources Canada, 2003). In an endeavor to promote the program's objectives, the Government of Canada announced the introduction of a grant program that will hopefully encourage homeowners, "particularly those who have older homes that are in need of energy efficiency upgrades, to retrofit their homes to make them more energy efficient and reduce greenhouse gas emissions that contribute to climate change" (Natural Resources Canada, 2003).

Essentially retrofitting a conventional home requires purchasing equipment and material that is certifiable as per the R-2000 standard. The upgrades will usually include, but are not limited to:

- Installation of a high-energy furnace
- Installation of high-efficiency windows, appliance, and office equipment
- Installation of a Heat Recovery Ventilation (HRV) system
- Installation of Roof-Overhangs over west facing windows
- Installation of water conserving fixtures, such as faucets, and toilets
- Appropriate weather stripping around windows and doors
- Sufficient insulation in walls, roofs, and floors
- An inspection of the building envelope for suitable air tightness and exchange rates

(Natural Resources Canada, 2003)

The cost of retro-fitting will undoubtedly vary from area to area as prices can differ from company to company; therefore it is always a wise decision to do some research and shop around at certified dealers prior to having any re-construction done. However, for a general idea of how much it will cost, the Alberta Government assessed that on average, the cost to retrofit a 1700 – 2500 sq*ft house can range between $4-$5 per sq* ft (Alberta R-2000, 2000).

4.7 Conclusions

The development and introduction of the R-2000 Home Program in 1981 raised the bar on new home construction and pushed the boundaries for creating environmentally responsible residences and communities (EnerQuality, 2002 & IRC, 1997). The initial purpose of the program was to improve the energy efficiency of new houses and low-rise dwellings by 30% -50% (Alberta R-2000, 2000). However, the scope of the program has expanded to include standards that would ensure that all new R-2000 homes will be built using recycled materials, provided a higher level of indoor air quality for the homeowner, and decrease the overall rate of water consumption. Indoor air quality would be improved through the use of building materials that are non-toxic and do not emit harmful fumes, and by having a building envelope that seals out harmful substances. A Heat Recovery Ventilation (HRV) system would supply the home with fresh and filtered air eliminating the problem of 'stale air' that could cause mould and other allergens to linger in the home and aggravate individuals with respiratory problems (Alberta R-2000, 2000 & Parekh et al, 1999). Using energy efficient devices would conserve energy, and installing water saving devices would reduce water consumption. (EnerQuality, 2002).

The Ecological Footprint (EF) Analysis revealed that R-2000 homes had an EF of 0.50 ha/cap, which is 40% smaller than a conventionally dwelling built almost 10 years before it. The significance is that R-2000 homes emit less carbon dioxide and as a result would require less land per capita to naturally assimilate the emissions, making the R-2000 home a more environmentally responsible choice.

Through experimentation, research, and the introduction of new innovative technologies, organizations such as the National Research Council of Canada (NRC) will continue to develop and modify new and existing energy efficient technologies that will hopefully transform the Canadian housing industry and help the country take it's first steps towards building a successful and sustainable community.

5 Conclusions

"Urbanization...represents an unprecedented human ecological transformation... People now live and work far from the land and biophysical processes that actually support them. Cities [which are considered to be "the engines of economic growth, the centers of culture, the well-springs of new knowledge, and the repositories of cumulative learning,"] require ever greater quantities of food, material commodities, and energy – all often shipped great distances – to sustain the increasingly consumer lifestyles of their inhabitants. High-income cities in particular impose greater burdens on the global commons to assimilate their metabolic wastes. Indeed, through commercial trade and natural flows, modern cities draw on resources and dump their garbage all over the world."

- William Rees

For the first time in history it is possible that the vast majority of humankind will be living in cities where economic markets will determine the allocation and transformation of natural resources and where the immediate environment will not be a natural one, but a 'built environment' (Rees, 1999). This means it will be an environment that consists of large buildings, roads, paved sidewalks, industrial facilities, electrical generation stations, schools, homes, and minimal green space. Although these green spaces might be appropriate for recreational use they are limited in their ability to act as 'carbon sinks' to assimilate wastes or be large enough to produce enough food to support the city's population. If current trends continue along the path of rapid urban sprawl, and city planners neglect to account for the important role that the natural ecosystems plays in maintaining the integrity and productivity of the both the built and natural environment, then it is possible that the ecological impacts could reach a level that will no longer allow cities the capability of supporting human life. However, as an intelligent race, our past or even current actions do not have to set precedence by which to limit human growth. We have the ability to recognize our mistakes and evolve, to progress in a manner that is less injurious to the planet that supports us. One way is through the potential adoption of Gro Harlem Bruntland's ideology of sustainable development.

Sustainable development is a process that would oversee a change in the exploitation of resources so that harvesting rates of raw materials would be at a level no higher than natural regeneration rates. Renewable natural resources would be used in an appropriate manner to ensure its longevity, and non-renewable resources would not be exhausted in a manner so as to "preclude easy access to them by future generations" (Goodland et al, 1987 & Pearce, 1988). The use of the environment as a "waste sink" would not exceed any natural or managed assimilation rates by the corresponding ecosystem, and therefore, secure that the needs of the present are met without compromising the ability of future generations to meet their own (Pearce, 1988).

Organizations across the world, including Hamilton's own 'Citizens for a Sustainable Community,' have banded together to help fund and support research projects in the area of sustainable development in hopes of achieving Bruntland's goals. It was incentives from groups like 'Citizens for a Sustainable Community,' that instigated the investigation into the ecological consequences of routine infrastructure operations that included the transportation of fresh produce by transport trucks. Also, interest was expressed in the benefits associated with Rooftop Gardens and the R-2000 Home Program. The implications and/or benefits associated with either the transportation of goods, green roofs in urban centers, and the construction of R-2000 residential units have been illustrated using an appropriate environmental assessment tool: Ecological Footprints.

Ecological Footprint (EF) Analysis allowed for the environmental impacts of the aforementioned activities to be expressed in an easily physical and identifiable manifestation: land area. The results indicated that for a city, such as Hamilton, which uses transport trucks to ship fresh produce to their city would have an ecological impact that varied from 0.001 ha/cap – 0.006 ha/cap. The value 0.001 ha/cap is applicable for produce grown in Ontario, 0.006 ha/cap is for fruits and vegetables grown in other Canadian Provinces and 0.005 ha/cap is for produce shipped in from the United States. Although these values are low in comparison to the 0.12 ha/cap that Rees and Wackernagel assigned for the transportation of food in their 1996 study, the results proved to be significant in their own right. The EF values calculated highlighted the fact that locally grown produce can have an ecological impact 5-6 times less than comparable produce that is imported from outside the region.

In regard to rooftop gardens, the EF analysis indicated that a city could reduce the environmental impact associated with energy generation by 0.076 ha/cap if all available rooftops in the city were green roofs. There is no doubt that this figure would increase if the EF were to also include any benefits associated with a positive augmentation in both the quality of the air and water supply.

The results of the R-2000 Home Program study suggested that the average single detached R-2000 residential unit could decrease its EF, due to carbon emission, by 40%. This figure is noteworthy when considering the impact a 40% reduction in carbon emission per household would have on the environment, particularly on air quality, in an area such as Hamilton that is already exposed to a variety of pollutants from industry and traffic.

However, like any model the Ecological Footprint (EF) Analysis used in this report, has its own set of limitations. EF estimates the minimum amount of land area per capita that is required to provide the basic material and energy flows as required by modern economies to sustain human life, but neglects to include an equivalent fresh water land area. Also, EF calculations are not representative of all possible inter-actions between man and the environment, only those that are quantifiable and specified by Rees and Wackernagel. EF Analysis does not consider any effects of pollution other than that of carbon dioxide on the environment nor is it able to measure the impact pollution has on human health. Essentially, the EF calculation is a simplistic indicator used to illustrate humanity's dependency and reliance on natural resources, and to demonstrate how different types of lifestyle choices can impact our ecological surroundings.

The final results of this study indicated 'green' practices and/or technologies can play a crucial role in helping to achieve urban sustainability. The practice of consuming locally grown produce, installing of rooftop gardens, and living in R-2000 homes can reduce ecological impacts, improve soil, air, and water quality, save energy, and minimize the amount of harmful chemical that are expelled into the environment and which may contribute to health related illnesses.

Despite the benefits associated with these or any new practice or technology the problem remains in altering the fundamental doctrines that have dictated the formation of modern development. Convictions, whether political or economical, that believe progress is directly linked to the harvesting and consumption of raw materials in spite of contrary evidence, may prevent the adoption of environmental responsible practices or technologies. Perhaps this occurs because some people may not view the environment as a constraint for industrial or economic progress. Therefore, before any significant environmental changes can occur, the benefits of 'green' practices and technologies will need to be fully accepted for their advantages, while current unsustainable methods are recognized for their deficiency. On the other hand, change, however small or conventional, must not evolve too quickly, or interfere with accepted standards of modern progress. This is because there is a chance that the common fear associated with change may get the better side of any attempt aimed at sustainable progress.

In the words of Reverend Jesse Jackson, "We need to come together and choose a new direction. We need to transform our society into one in which people live in true harmony – harmony among nations, harmony among the races of humankind, and harmony with nature...We will either reduce, reuse, recycle, and restore – or we will perish."

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Appendix A
Hamilton and Air Pollution

Introduction to Air Quality in Hamilton

In October of 2002, the National Post published a seven-day report in their 'Review' section comparing 14 prominent Canadian cities, Calgary, Charlottetown, Edmonton, Halifax, Hamilton, Mississauga, Montreal, Ottawa, Saint John, Saskatoon, St. John's, Toronto, Vancouver, and Winnipeg (the 10 largest plus 4 additional cities that were the largest in each province that was not represented by the initial 10) (Vallis, 2002). The goal of the 'Healthiest Cities Project was to determine which Canadian city was the most health conscious. Air quality was one of the categories studied because poor air quality has the potential to affect healthy living conditions in an urban environment.

Air quality can be defined as the allowable level of prescribed atmospheric pollution of a certain compound during a specific time in a particular geographical area. Interestingly enough, the authors of the 'Healthiest Cities' project expected that as a result of the constant summer haze hovering over the Golden Horseshoe area in Ontario, Toronto, Hamilton, and Mississauga would get one of the worst scores in the air quality category in comparison with the other 11 cities. They were partially correct. Although, Hamilton, Toronto, and Mississauga all experienced ground level ozone (O_3) levels approximately 20% higher than the Canadian average of 65 ppb over 8 hours, Montreal was not far behind with a recorded average of 76 ppb over an 8 hour period. In regards to particulate matter, the summer haze did not seem to indicate that the Golden Horseshoe area was the heaviest sufferer from this pollutant. Edmonton and Vancouver experienced the highest levels and thus the poorest air quality in respect to inhalable particulate matter (PM) less than 2.5 microns. However, aside from Edmonton and Vancouver, only Hamilton, Toronto, and Mississauga were the only other cities to exceed the national standard level of 30 ppb for particulate matter.

In Hamilton, air quality has long been a concern, even before the Post revealed Hamilton's less than commendable air quality levels. Organizations such as Clean Air Hamilton, McMaster University and local residents, businesses and associations have banned together for years in an attempt to develop, implement, and support 'healthy' air quality initiatives. Air quality studies have been conducted, reports have been written and websites have been created in order to keep local citizens informed about the quality of the air that they are breathing.

Table 17: Air Quality of 14 Canadian Cities as per the National Post's 'Healthiest Cities Project'

City	O_3 (ppb averaged over 8 hours)	$PM_{2.5}$ (ppb on average over an 8 hour period)
Calgary	59	-
Charlottetown	-	-
Edmonton	24	65
Halifax	63	-
Hamilton	80	37
Mississauga	85	32
Montreal	76	29
Ottawa	65	25
Saint John	64	-
Saskatoon	44	-
St. John's	48	15
Toronto	84	33
Vancouver	29	48
Winnipeg	58	20
Canada	**65**	**30**

(Vallis, 2002)

Sources of Air Pollution in Hamilton

The City of Hamilton is geographically situated on the southwest end of Lake Ontario. Most of Hamilton's naturally sheltered harbour is home to heavy production industries such as Stelco and Dofasco Steel. Both companies are known producers of chemical compounds such as ammonia, benzene, lead, nickel, mercury, and sulphuric acid. Some of these compounds are recognized as potential risk factors to both the environment and human health through prolonged exposure in high enough concentrations (Environment Canada, 2003).

But aside from the 84 local industrial polluters, as per recorded by the National Pollutant Release Inventory (Environment Canada, 2003), Hamilton also receives air pollution from the United States and other major Canadian metropolitan areas. Approximately 50% of all particulate matter, ground level ozone, carbon and sulphur dioxides drift into the area from prevailing southern and westerly winds from the United States of America (Clean Air Hamilton, 2002). Hamilton's geographic and meteorological conditions help to trap both the domestic and foreign emissions through temperature inversions (Clean Air Hamilton, 2002) creating a heat island effect in the city.

"Hamilton is also the gateway to the Niagara Peninsula" and as a result it receives the majority of the traffic between southern Ontario and the United States (HAQI, 1997). Although vehicular traffic is one of the more affordable and convenient forms of transportation available, the longer and more frequent the trips are, the greater the potential risk is of contributing to the region's air pollution problems. For instance, it is estimated that 33% to 50% of nitrogen oxides (NO_x), 33% to 97% of carbon monoxides (CO), 40% to 50% hydrocarbon (HC), 50% of all ozone precursors, and at least one-fourth of volatile organic compounds (VOC) are produced by motor vehicles alone (USEPA, 1995; USDOT, 1993).

Various studies on urban form and travel behaviour have indicated that a significant portion of vehicular traffic is directly linked to urban sprawl. Urban sprawl is the scattered, low-density, land intensive, development of residential homes in outer suburban and urban-rural fringe areas (Irwin, 2002). These low-density, suburban sprawl communities help to separate home and work environments, which subsequently increases a suburbanite's dependency on their automobile as the primary mode of transportation to work, school or recreational activities.

In a study conducted in 1989, Newman and Kenworthy demonstrated that automobile energy consumption patterns, in more than 30 large cities around the world, was inversely proportional to population density (Newman, 1989). Essentially areas with lower densities indicated higher rates of energy consumption per automobile usage. This suggested that people who live in sprawl communities were more likely to drive rather than walk or bike, to work, school, or some other subsequent activities. The ramifications were an increase in regional traffic congestion and the release of NOx, SO_2, CO and HC emissions in the area.

However, not everyone is convinced that urban sprawl is necessarily to blame for poor air quality. Pierre Desrochers, an Economist from Montreal explains "an increase in the number of cars does not automatically lead to a decline in urban air quality", it is also the technology of the vehicles, which bears more relevance than their numbers (2002). "That the level of pollution emitted by a car depends more on the nature of the travel than on the distance", whether the travel is continuous, stop-and-go, a vehicle of mass transportation or that consisting of environmentally friendly technology " (Desrochers, 2002). And finally he believes that if "many businesses relocate closer to the suburban homes of their employees" (2002) the length and perhaps the number of trips that the residents engaged in would be reduced.

However, the drawback of vehicular transportation, whether it is a result of urban commuting, or the transport of goods and services, and despite its convenience, comes at a price. Automobile transportation is one of the largest contributors to air pollution in Canada (Environment Canada, 2002a). "The use of engines to power vehicles and equipment and the combustion of transportation fuels have major impacts on the environment and health of Canadians" (Environment Canada, 2002b). Studies have shown that air pollutants such as carbon dioxide, along with sulphur dioxides, nitrogen oxides, ground level ozone and inhalable particulate matter can cause more than 5000 premature deaths across Canada (Environment Canada, 2002b).

Clearly, any initiatives undertaken to reduce harmful emissions from industries, vehicle, engines and fuel combustion can have a significant effect on the quality of air in the region. Positive effects may include a reduction in the amount of acid rain, and the expulsion of hazardous air pollutants and greenhouse gases into the air. This can be achieved through the promotion of sustainable transportation through the use of public buses, electric train, or by ensuring efficient modes of transportation are improved through progressive landuse and transportation planning tools and practices.

Air Quality Health Concerns

On December 2, 1996, a research study was conducted by various individuals associated with McMaster University, and the Regional Public Health Department of Hamilton (Elliott, 1999) in the north end of Hamilton. The project was facilitated as a means to solicit the unprompted levels of concerns from local citizens regarding exposure levels from regional air pollution. 600 of the possible 18, 166 candidate households were randomly chosen, in which an adult, 18+ years, was asked to participate in the phone survey. The survey was approximately 13 minutes in duration, and had an overall response rate of 67%, which according to the authors served as a fairly good representation of the population (Elliott, 1999).

Respondents in the north end neighbourhoods reported pollution concerns from industrial smoke stacks and traffic exhaust, particularly in the form of black soot. When asked how they perceived the pollution affected their health and daily lives, the residents reported that it contributed to:

- Respiratory problems
- Psychosocial effects, such as "neighbourhood stigmas and worrying about their future health,
- Physical effects "such as nausea and headaches"
- And general lifestyle disruptions "i.e. having to keep windows closed or remain indoors"

72% of the respondents believed that the air pollution would directly affect their personal selves while 66% reported that it would likely effects other members of their households.

Another health concern not addressed by the previous study, but identified by Environment Canada, is urban smog. Smog, which is a mixture that consists primarily of ground-level ozone and particulate matter (PM), is problematic for individuals with respiratory difficulties and heart disease. The fine airborne particle can become lodged deep within the human respiratory system and can cause inflammation and tissue damages (Environment Canada, 2002c).

Finally, another health concern is related to the effect air pollution has on climate change. Higher temperatures can cause sulphur compounds to breakdown and form acid-forming sulphates that can accumulate in wetlands and soils altering the natural pH balance of the systems. Also, an increase in wet weather can flush the sulphates into the surrounding lakes thereby causing acid depositions that can lead to lake acidification, corrosion and haze.

Effects of Air Quality on Health

Various studies conducted by the Toronto Public Health Department, the Government of Canada and the Ontario Medical Association all show that there is a strong link between air pollution and health problems (Environment Canada, 2002a). Individuals who are most susceptible to poor air quality are those who suffer from respiratory and cardiac problems, particularly the elderly and young children. In addition, any one who lives in a city that is home to industries, power plants and experiences heavy vehicle traffic are more likely to suffer from higher rates of asthma, chronic bronchitis, heart disease, and lung cancer. But overall, prolonged exposure to "air pollution can lead to premature death, increased hospital admissions, more emergency room visits and higher rates of absenteeism" (Environment Canada, 2002a).

Asthma, for example, is a respiratory disease that affects more than one million Canadians. More than 60,000 hospital admissions and 250,000 overnight stays, annually from 1990 to 1993 and more than 450 deaths annually from 1990 to 1995 are asthma related. In 1990, the total cost of asthma treatment and education was estimated at over $500 million (Health Canada, 1997).

Asthma is a common chronic illness among children and is the leading cause of school absenteeism. The rate of hospitalization for asthma has increased by 27% for boys and by 18% for girls in the last decade (Health Canada, 1997).

According to the 'Healthiest Cities' project conducted by the National Post in October of 2002, Hamilton experienced the highest asthma rate, at 10.4% in comparison with the other 14 cities studies, which is exactly 2% higher than the national average at 8.4% (Vallis, 2002).

Mary Vallis, author of one of the articles published in the series suggested that the reason for Hamilton's high asthma rate might be linked to its blue-collar working population. Essentially, these individuals would have good health coverage from the companies who employ them and therefore be more willing to further investigate any health problems, which in turn boosts the diagnosis rate (2002).

In addition to asthma, it is estimated that the City of Hamilton will experience anywhere between 90-321 premature deaths per year as a result of foul air quality. The region closely studies the number of premature deaths, hospital admissions and cancer cases that are related to inhalable particulate matter, sulphates, ground level ozone, sulphur dioxides, nitrogen oxides, carbon monoxides and other toxins. The following table illustrates the number of premature deaths and hospital admissions in Hamilton that were found to be directly linked to any one of the aforementioned air pollutants.

Table 18: Number of Premature Deaths and Hospital Admissions in Hamilton, 1997

	Premature Deaths	Hospital Admissions
Inhalable Particulate Matter (PM_{10})	85	150
Sulphates	50	190
Ground Level Ozone	5	50
Sulphur Dioxide	40	30
Nitrogen Oxides	0	40
Carbon Monoxides	0	20
Toxics	0	0

(HAQI, 1997 & Clean Air Hamilton, 2002)

Aside from the potential health risk associated with air pollution, poor air quality can also be harmful to food crops, fresh water resources, forests, wildlife and ecosystems in general. The physical effects of air pollution may also be seen on buildings and monuments, as well as on textiles, rubber and other materials.

But what are the environmental and health implications of the 'criteria pollutants'[9] as identified by NAAQO, such as carbon monoxide, nitrogen dioxide, ground level ozone, and sulphur dioxide, when they reach one of the specified air quality index level as mentioned earlier? The following chart, which was prepared by the Ministry of the Environment, and can be found in Chapter 5 of the *Air Quality in Ontario: 2000 Report*, summarizes the various implications to an area when the following pollutants reached one of the AQI[10] levels.

Table 19: Selected 'Criteria Pollutants' and their Impacts

AQI	Carbon Monoxide (CO)	Nitrogen Dioxide (NO_2)	Ozone (O_3)	Sulphur Dioxide (SO_2)
Very Good (0)	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
Good (16-31)	No known harmful effects	Slight odour	No known harmful effects	Can damage some vegetation in combination with ozone
Moderate (32-49)	Blood chemistry changes, but no noticeable impairment	Odour	Respiratory irritation in sensitive people during vigorous exercises; people with heart/lung disorders at some risk; damages very sensitive plants	Damages some vegetation
Poor (55-99)	Increased symptoms of smokers with heart disease	Air smells and looks brown. Some increase in bronchial reactivity in people with asthma	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/lung disorders at greater risk; damages some plants	Odourous; increasing vegetation damage

[9] Please refer to Appendix C for a complete list and description of 'Criteria Pollutants'.
[10] AQI – Air Quality Index

AQI	Carbon Monoxide (CO)	Nitrogen Dioxide (NO_2)	Ozone (O_3)	Sulphur Dioxide (SO_2)
Very Poor (100+)	Increasing symptoms in non-smokers with heart disease; blurred vision; some clumsiness	Increasing sensitivity for people with asthma and bronchitis	Serious respiratory effects, even during light physical activity; people with heart/lung disorders at high risk; more vegetation damage	Increasing sensitivity for people with asthma and bronchitis

(Ministry of the Environment, 2000)

Air Quality in Hamilton

The Air Quality Index is a recognized practice for government agencies across Canada to monitor 'criteria pollutant' levels all year round in particular cities. The following table is a compilation of the number of hours that Hamilton, Burlington and Toronto experienced in the indicated years. Although there does not seem to be any particular trend over the four year period, AQI readings are known to vary depending on the wind direction, industrial output, traffic levels, and smog conditions. Therefore, AQI reading cannot only differ from year to year, but from day to day.

Table 20: Number of Hours in AQI

	Hamilton			Burlington			Toronto Downtown		
Year	1996	1998	2000	1996	1998	2000	1996	1998	2000
	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)	(hr/yr)
Very Good (0)	4865	5188	5778	4620	4545	4783	6729	6245	5701
Good (16-31)	3495	2919	2721	3580	3001	3526	2000	1988	2595
Moderate (32-49)	418	530	266	533	502	452	53	350	290
Poor (55-99)	5	19	13	51	12	14	0	22	12
Very Poor (100+)	0	0	0	0	0	0	0	0	0

(Ministry of the Environment, 1996 & 2000, & Oakvillegreen.com, 2003)

In an attempt to keep local citizens informed about AQI levels, the Ministry of Environment for the Government of Ontario has established a website entitled Air Quality Ontario, at URL address http://www.airqualityontario.com/ where concerned citizens can log on and check their region's AQI forecast.

Industrial Pollution

There are 84 business facilities in Hamilton, Burlington, Stoney Creek, Troy, Waterdown and Mississauga, that are registered with Environment Canada and who contribute to the National Pollution Release Inventory (NPRI) for key air pollutants in the Hamilton region. The pollution produced from these facilities is further disseminated into either industrial sources or those that result from fuel combustion, transportation, incineration, and miscellaneous or open sources. Each company per annum is required to file an NPRI report to the government for monitoring purposes. The results for Hamilton indicate that the city is a large producer of total particulate matter, volatile organic compounds and carbon monoxide. The majority of Hamilton's carbon monoxide emissions is largely attributed to its heavy industrial sector, producing just over 1 million metric tonnes in a year. However, Toronto still produces more total particulate matter, particulate matter less than 2.5 and 10 microns, nitrogen dioxide, more than double the amount of volatile organic compounds, and nitric acid than Hamilton does.

Table 21: Information for Key Air Pollutants (CAC, 1995) (in metric tonnes) for the City of Hamilton (25 km reporting radius)

Source Category	TPM	PM_{10}	$PM_{2.5}$	SOx	NOx	VOC	CO	NH_3
Industrial	24185	9098	5405	53316	19325	40081	1002409	57
Fuel Combustion	3875	3762	3744	1172	4710	13973	25908	86
Transportation	1552	1497	1280	3251	23030	16114	144846	420
Incineration	24	11	8	34	41	77	504	8
Miscellaneous	376	344	303	0	2	34033	602	1043
Open Sources	163209	39672	4289	0	0	92	0	1555
Total	193221	54384	15029	57773	47108	104370	1174269	3169

(Environment Canada, 2003)

Table 22: Information for Key Air Pollutants (CAC, 1995) (in metric tonnes) in the City of Toronto (25 km reporting radius)

Source Category	TPM	PM_{10}	$PM_{2.5}$	Sox	NOx	VOC	CO	NH_3
Industrial	16865	7101	4028	12402	19198	14831	4040	2517
Fuel Combustion	17400	16685	16551	28715	37548	61768	114916	323
Transportation	5674	5170	4393	8607	78062	54683	471434	1174
Incineration	156	56	36	379	436	753	3396	31
Miscellaneous	1330	1314	1223	1	31	135499	2514	1651
Open Sources	450426	98241	8731	0	0	571	0	296
Total	491851	128567	34962	50104	135275	268105	596300	5992

(Environment Canada, 2003)

Air Quality Initiatives taken by the City of Hamilton

In order to obtain a higher standard of air quality, the identification of effects, impacts, and implications of potentially harmful pollutants and their sources need to be studied and understood. Therefore, in 1995, Hamilton initiated the Air Quality Initiative whose main function was to prioritize air quality management in the region and provided recommendations on air quality issues that would affect the city. "Using a co-operative, multi-stakeholder approach, the initiative used existing resources to make a comprehensive air quality assessment that was published in a 1997 as a summary report" (FCM, 2003). In 1998, Hamilton established the Hamilton Air Quality Improvement Committee (HAQIC) to act on the recommendations of the 1997 report, and to further support air quality research and the promotion of emission reduction strategies.

In 1998, Hamilton's Air Quality Improvement Committee changed its name to Clean Air Hamilton. The group currently consisted of approximately 60 members, some of which include McMaster University, the Ministry of the Environment, Environment Canada, the City of Hamilton, and local residents, businesses and associations. Their goal has been to help to support air quality initiatives under taken by the region of Hamilton through research and testing. The organization has helped promote programs such as 'Drive Clean', a vehicle emission reduction strategy, and they have encouraged the use of transportation emission modeling to determine the detrimental effects associated with urban form. Clean Air Hamilton has also been known to submit suggestions with the intention of advising municipalities on air quality related issues (The New City of Hamilton, 2001).

On December 14, 1999, Clean Air Hamilton presented the proceeding list of issues to the Environmental Services Committee for review for the Regional Official Plan (ROP). The group suggested that the following air quality and land use planning issues could be addressed in the future ROP:

- *"Specify land use policies that will reduce the number and length of trips for any number of purposes.*
- *Assess transportation measures against air quality impacts when considering downtown revitalization and future improvements of the Regional transportation network.*
- *Consider green belting vegetation management practices along regional lands.*
- *Establish policies that address the development and maintenance of public transit and alternative transportation modes.*
- *Encourage industry to adopt innovative approaches to address air quality and encourage government / non-government agencies to develop environmental management systems.*
- *Establish an administrative structure and procedure comparable to that used to address environmental significant areas in order to address air quality policies."*

(Clean Air Hamilton, 2001)

In addition to preparing statements for the ROP, Clean Air Hamilton and its affiliates took part in Hamilton's Commuter Challenge during National Environment work in 2000. It was, and still is, a clean air awareness program designed to reduce the number of single passenger commuters into and out of the city. Its goal is to encourage individuals to walk, bike, use public transit, or carpool to help improve local air quality (Green Venture, 2002).

However, while attempts are being made to reduce the amount of emissions produced from vehicular traffic, Clean Air Hamilton recognizes that it is currently an active problem in the city. The group, in conjunction with city officials, has developed several contingency plans such as the Smog Response Plan. The purpose of the Smog Response Plan is to alert the public of current smog conditions, providing tips and information on how to minimize health effects, and improve local air quality conditions. On Smog Alert day, which occur when the AQI is 50 or greater, the Smog Response Plan advises citizens to postpone any activities that involves the use of gas powered equipment, such as lawn mowers, gas stoves, or even using their car. The plan also indicates that the public should try and reduce the use of oil-based paints, solvents and cleaners while under a smog alert (Clean Air Hamilton, 2003).

Appendix B
Canadian Produce Availability

Legend	
P	Peak availability (more than 15% of crop available)
A	Regular availability (more than 4 to 15% of crop available)
L	Limited availability (1 to 4% of crop available)
Blank Space	Less than 1% of crop availability

Table 23: The Canadian Availability Guide for Fresh Vegetables

VEGETABLES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Artichoke		A	A	P	A	A	A	A	A	A	A	A
Asparagus	L	A	A	A	P	P	P	L	L	L	L	L
Beans	A	A	A	A	A	A	P	P	P	A	A	A
Beets	A	A	A	A	A	A	P	P	P	P	A	A
Broccoli	A	A	A	A	A	A	P	P	P	P	A	A
Brussels Sprouts	A	A	A	P	A	L	L	A	P	P	P	P
Cabbage	A	A	A	P	P	P	P	P	P	P	P	A
Carrots	A	A	A	A	A	A	A	P	P	P	P	A
Cauliflower	A	A	A	A	A	A	A	P	P	P	P	A
Celery	A	A	A	A	A	A	A	P	P	P	A	A
Corn, Sweet	L	L	L	A	P	P	P	P	P	A	L	L
Chicory (Curly Endive)	A	A	A	A	A	A	P	P	P	A	A	A
Cucumber, Field	A	A	A	A	A	A	P	P	P	A	A	A
Cucumber, Greenhouse	L	A	A	A	A	A	A	A	A	A	L	L
Eggplant	A	A	A	A	A	A	A	P	P	A	A	A
Escarole	A	A	A	A	A	A	P	P	P	A	A	A
Fiddleheads				A	P	P	A					
Garlic	A	A	A	A	A	A	P	P	P	A	A	A
Leeks	A	A	A	A	A	A	P	P	P	P	P	A
Lettuce, Head	A	A	A	A	A	A	P	P	P	A	A	A
Lettuce, Leaf	A	A	A	A	A	A	P	P	P	A	A	A
Mushrooms	A	A	A	A	A	A	A	A	A	A	A	A
Okra	A	A	A	A	A	A	A	A	A	A	A	A
Onions, Green	A	A	A	A	A	P	P	P	P	A	A	A
Onions, Cooking	A	A	A	A	A	A	A	A	A	A	A	A
Parsnips	P	P	P	A	A	A	A	A	P	P	P	P
Peas, Regular	A	A	A	A	A	P	P	A	A	A	A	A

VEGETABLES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Peas, Snow	A	A	A	A	A	P	P	P	A	A	A	A
Peppers	A	A	A	A	A	A	A	P	P	P	A	A
Potatoes, New					P	P	P	P				
Potatoes, Storage	P	P	P	P	L	L	L	P	P	P	P	P
Pumpkin									A	P	P	L
Radishes	A	A	A	A	A	P	P	P	P	P	A	A
Rutabaga	P	P	P	P	P	A	A	A	A	P	P	P
Spinach	A	A	A	A	A	P	P	P	P	A	A	A
Squash	A	A	A	A	A	A	L	A	P	P	P	P
Sweet Potato	A	A	A	A	A	A	A	A	A	A	P	A
Tomatoes, Field	A	A	A	A	A	A	A	P	P	A	A	A
Tomatoes, Greenhouse	L	L	L	A	P	P	P	A	A	A	A	L
Turnip	L	L	A	A	A	A	A	P	P	P	P	P
Zucchini	A	A	A	A	A	A	P	P	P	A	A	A

(Canadian Produce Marketing Association, 2003)

Table 24: The Canadian Availability Guide for Fresh Fruit

FRUITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Apples	P	P	P	P	A	A	A	P	P	P	P	P
Apricots	L				A	P	P	P	L		L	L
Avocado	A	A	A	A	A	A	A	A	A	A	A	A
Banana	A	A	A	A	A	A	A	A	A	A	A	A
Blueberries	L	L	L	L	A	P	P	P	P		L	L
Cantaloupe	A	A	A	A	A	A	A	P	P	A	A	A
Cherries					L	P	P	L			L	L
Cranberries					L	L	L	L	A	P	P	A
Grapefruit	A	A	A	A	A	A	L	L	L	A	A	A
Grapes	A	A	A	A	A	A	A	P	P	A	A	A
Kiwi	A	A	A	A	A	A	A	A	A	A	A	A
Lemons/ Limes	A	A	A	A	A	A	A	A	A	A	A	A
Mandarins	P	L	L		L	A	A	L	L	A	P	P
Mango	L	L	L	A	P	P	P	A	L	L	L	L
Nectarine	L	A	L		A	P	P	P	A			L
Orange	A	A	A	A	A	A	A	A	A	L	A	A
Papaya	A	A	A	A	A	A	A	A	A	A	A	A
Peach	L	L			A	P	P	P	P	L		L
Pear	A	A	A	A	A	A	A	P	P	A	A	A
Pineapple	A	A	A	A	A	A	A	A	A	A	A	A

FRUITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Plums	L	A			L	L	A	P	P	A	L	
Raspberries	L	A	A	A	L	A	P	P	A	A	L	A
Rhubarb Field and Greenhouse	L	A	A	A	A	P	A	A	A	A	A	
Strawberries	L	L	A	P	P	P	P	A	A	L	L	L
Watermelon	L	L	L	A	A	P	P	P	A	L	L	L

(Canadian Produce Marketing Association, 2003)

Appendix C
Criteria Pollutants

In Canada, air quality standards are established by the National ambient Air Quality Objectives (NAAQOs), under the Canadian Environmental Protection Act (CEPA). The NAAQO monitors, measures, and records levels of any criteria pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxides (CO), ground level ozone (O_3), and inhalable particulate matter ($PM_{2.5}$ or PM_{10}), that may have an adverse effect to human health, animals, vegetation, soil, and water.

Sulphur dioxide (SO_2) is a colourless gas with a pungent smell. It is generated from the combustion of fossil fuels and can be easily converted into sulphuric acid and sulphate particles via a number of atmospheric reactions (HAQI, 1997). Approximately 83% of all the SO_2 emissions in the Hamilton area are generated from the iron and steel sectors (HAQI, 1997). Sulphur dioxide is also one of the major constituents of acid rain, which threatens the natural pH balance of local water systems leading to lake acidification. Prolonged periods of exposure to SO_2 emissions are linked to increased rates of persons developing asthma, and chronic bronchitis; it can aggravate existing cardiovascular disease, and it can also be a factor in inducing premature death in sensitive persons (HAQI, 1997).

Nitrogen Oxides (NOx) are a combination of nitrogen dioxide (NO_2) and nitric acid (NO). In the presence of sunlight, these two chemicals react with volatile organic compounds (VOC) to produce ground level ozone. VOC's are "a class of compounds that contains at least one carbon atom and are volatile" (HAQI, 1997). VOC's generally exist in the atmosphere as a gas. In Hamilton, NOx is locally produced from the combustion of fossil fuels from automobiles, industries, and residences that use oil or gas to heat or cool their homes (HAQI, 1997). Several studies examining the health effects of NO_2 emissions have concluded that aside from irritating people with asthma and bronchitis, it may also be a major contributor to the poor respiratory health and pulmonary functions disorders in children (HAQI, 1997).

Ground-level ozone (O_3) is a colourless gas with a strong smell. It is produced from the chemical reaction between VOC's and NOx's. More than 50% of all ground level ozone recorded in Canada originates from the United States (HAQI, 1997). Prolonged exposure to ground level ozone can causes inflammation of the respiratory airways, causing the person to cough, wheeze and/or experience chest tightness. The inhalation of O_3 can also aggravate existing cardiovascular and lung conditions. (Environment Canada (a), 2002). O_3 is of particular concern to crops, forests, and natural vegetation, (HAQI, 1997) as it can damage vital pores used for transpiration.

Carbon monoxide (CO) is a toxic, colourless, odourless, and tasteless gas. It is a by-product of the incomplete combustion of fuels from vehicles, furnaces, industries, and cigarette smoke (HAQI, 1997). In 1990, approximately 71% of all CO emissions recorded in the city emanated from the iron and steel industries, while 27% was attributed to vehicular traffic (HAQI, 1997). However, indoor exposure from cigarette smoke, and possibly, gas cooking stoves or portable non-electric space heaters, were documented as the primary source of exposure for individuals (HAQI, 1997). CO has long been recognized as a pollutant with significant health repercussions. In high enough concentrations CO can be lethal, but moderate levels of exposure have been linked to congestive heart failure in patients over 65 year old); it can impair visual perception, learning abilities and diminish a person's ability to performance complicated tasks (HAQI, 1997 & Ministry of the Environment, 1996).

Inhalable particulate matter ($PM_{2.5}$ or PM_{10}) are solid or liquid particles that stay suspended in the air in the form of dust, smoke, fumes, and aerosols and have a diameter less than 2.5 microns or 10 microns. Most PM accounts for 40-60% of all total suspended solids (TSP) in the atmosphere (HAQI, 1997). However, $PM_{2.5}$ is generally a greater health risk than PM_{10} to individuals who suffer from respiratory problems. Because the particles are so small, they have a greater chance of penetrating into the deepest parts of the respiratory track and creating health complications. Aside from respiratory health implications PM can also soil fabrics, paint surfaces, and buildings, which can result in the constant need for cleaning. This can reduce the life expectancy of the product or structures. Heavy exposure to inhalable particulate matter has also been documented as being the cause of a 1% increase in the total mortality rate of a region (HAQI, 1997).