SUSTAINABLE HOUSING: REDUCING THE "ECOLOGICAL FOOTPRINT" OF NEW WOOD FRAME SINGLE-FAMILY DETACHED HOUSES

by

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ABSTRACT

Sustainability will require that human activity become significantly less material and energy intensive than at the present time. Single family detached housing is one area that has to meet the challenge of sustainability. This thesis investigates the extent of the potential improvement in the environmental performance of wood frame single family detached houses. The Ecological Footprint or Appropriated Carrying Capacity method (EF/ACC) is used to evaluate the environmental performance of the houses examined throughout the study. The thesis came to the following key conclusions:

- Land areas required to absorb CO_2 emissions are the largest constituent of the Ecological Footprint of single family detached houses followed by land area required to produce energy. These results show clearly that energy, as a major contributor to CO_2 emission today and as a resource in the post-fossil fuel era, is the most important environmental concern that has to be addressed.

- Operating energy represents the largest component of energy consumption in a house. It constitutes 76% and 73% of the total life cycle energy in the base case study house and the improved house respectively.

- The reductions obtained in the improved house compared to the base case study house were:

Directly occupied land	48.0%
Building materials use	49.2%
Life cycle energy consumption	34.0%
Life cycle CO_2 emission	33.0%

- The reduction in the ecological footprint of the house is obtained by reducing its size, improving its design and adopting only energy efficient strategies which are cost effective.

- A 35.6% reduction in the Ecological Footprint of the base study house is obtained. The Ecological Footprint of the improved house is 58.68 in comparison to 91.06 ha in the base case study house. A greater reduction could have been achieved without the limits imposed by EF/ACC method use and the commitment to the principles of cost effectiveness and minimum change in life style.

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CHAPTER I: INTRODUCTION

To achieve sustainable development and a higher quality of life for all people, states should reduce and eliminate unsustainable patterns of production and consumption

Principle 8- Rio Declaration-1992 (Rogers, 1993)

This thesis investigates the extent of the potential improvement in the environmental performance of a wood frame single family detached house. It is based on the premise that "Sustainable Development" will require that human activity remain within the limited regenerative and assimilative capacities of the biosphere. One area that has to meet the challenge of sustainability is single family detached housing. Despite the significant ecological cost, this housing type has certain characteristics that continue to make it the "dream home" for most Canadians. Furthermore the potential for improvement in the environmental performance of single family house is believed to be greater than any other housing type (Burby et al, 1982, Marbek, 1993).

The thesis makes extensive use of the Ecological Footprint or Appropriated Carrying Capacity method developed at Planning School, University of British Columbia. The method is used to evaluate the environmental performance of single family detached houses examined throughout the study. The thesis offers a critique of the value of the method for assessing the impact of buildings.

1.1. STATE OF THE ENVIRONMENT

Human activity has changed in the last two hundred years at unprecedented rate and magnitude. Deterioration of the global environment is one of the negative changes. The uncontrolled exploitation of resources and industrial pollution have reached a level that is unsustainable by the biosphere. The biosphere is the 'source' of all the resources consumed by humans and the 'sink' for their waste. The components of the biosphere (ecosystems) are limited in the amount of resources they can produce and waste they can absorb. Historically the scale of human activity has been small relative to these limits (Goodland, 1992) and the environment was capable of absorbing the impact of human activity without serious consequences. Environmental degradation, when it occurred, had local characteristics and related mainly to the supply function. The increase of the human population and the per-capita consumption rate of natural resources have changed these conditions. "World population has grown at around 2 percent annually, doubling every thirty-five years, and world consumption has grown at about 4 percent annually, doubling every seventeen or eighteen years" (Daly, 1989). Human activity is currently growing so rapidly that it will take only two years for the economy to grow as much as it did throughout human history until 1900 (Speth in Goodland, 1992).

The current scale of human activity consumes natural resources and produces waste at a rate that is higher than the assimilative and regenerative capacity of the environment in many areas. This leads to the depletion of planet's natural capital and the accumulation of the unabsorbed pollution in the air, water, and land. Environmental problems such as ozone layer depletion, desertification, global warming, acid rain, biodiversity reduction, and urban air pollution, are some critical aspects of growth-induced depletion and pollution.

A continuous growth in human activity would require an infinite supply of natural resources. On this planet, where the total amount of matter is fixed, continuous growth is not possible. It would lead to a continuous reduction in the carrying capacity of the environment, which could reach a point where the ability of the environment to sustain future human and other forms of life on the planet will be seriously threatened.

1.2. SUSTAINABLE DEVELOPMENT

Protecting the right of future generations to a healthy environment was the reason given by the United Nation's World Commission on Environment and Development for embracing the concept of sustainable development. The report entitled "Our Common Future," released by the Commission in 1987, defined sustainable development as;

> *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987)

In order to achieve the objectives of sustainable development, the policies and practices that perpetuate continuous material and population growth must be changed. The negative environmental consequences in each area of human activity should be minimized. Greater emphasis should be given to resource efficiency, and greater reliance on renewable energy. It is essential to minimize waste, maximize reuse and recycling, avoid the use of hazardous materials, and preserve biodiversity. Development of more environmentally benign production technologies, and design products to be more durable and repairable (Renner, 1991).

Planning is an indispensable tool to achieve sustainability. Existing planning instruments should be modified to incorporate the principles of sustainability. The ecological implication of any future activity, in terms of resource supply and waste absorption, should be analyzed throughout it's life cycle prior to its realization. The Ecological Footprint or Appropriated Carrying Capacity method (EF/ACC) was developed by Rees and Wackernagel for this purpose (Wackernagel, 1994). The method calculates the aggregate land area in various categories required to continuously provide an activity with resources and to absorb the waste discharged. The method is already used as planning tool (e.g., Urban Form and Appropriated Carrying Capacity: An Examination of the city center of Richmond, B.C. by Parker, 1993) and to evaluate the sustainability of economic practices (e.g., the Ecological Footprint of hydroponic Greenhouse by Wada, 1993 and the Ecological Footprint of the average Canadian, by Wackernagel, 1993).

1.3. BUILDINGS AND THE ENVIRONMENT

The building sector is an area that has to be planned to be within the carrying capacity of the environment. The number, and the design of contemporary buildings make them a heavy burden on the environment. The destruction of large green areas, the consumption of large amounts of energy and natural resources, and the generation of air, water, and soil pollution during the construction, maintenance and operation of buildings have made the city "an entropic black hole drawing on the concentrated material resources and low-entropy production of a vast and scattered hinterland many times the size of the city itself " (Rees, 1992).

Housing is the main component of buildings in Canadian cities. Residential areas take up 70% of Canada's urban land (D'amour, 1991). The Canadian housing sector consumes 20% of the total national energy consumption (Cole, 1993 and D'amour, 1991).

Single-family detached houses comprise 60% of housing units in Canada (D'amour, 1991). Statistics show that they continue to be the most desired form of housing (CMHC, 1994). Unfortunately, the local, urban, global ecological impact of currently developed single-family detached houses is very high. The area of land, materials, energy, and water consumed and soil, water, and air pollution generated by existing single-family detached houses make their Ecological Footprint unsustainable (see chapter II & III). Therefore, a drastic reduction in the "Ecological

Footprint" of single-family detached houses is needed. Achieving this requires significantly improving the environmental performance of its design. The principles of energy-conscious design are already used to produce a small percentage of existing single-family detached houses with improved thermal performance. However, the thermal upgrading of conventional houses affects only their operating energy. An underlying principle of a sustainable house, by contrast, is to minimize not only the consumption of energy but any "throughput" such as land, materials, and water.

In contrast to the extensive knowledge base and many existing examples of energy-efficient house design, the principles of a sustainable house design are still evolving. A number of houses have been developed lately as expression of 'sustainability (e.g., winners of healthy house Competition in Toronto and Vancouver, 1993).

1.4. THESIS OBJECTIVES

This thesis has the following objectives:

- To examine the constituents of the Ecological Footprint of a wood frame single-family detached house (land, material, energy, and water consumption and waste and pollution generation).

- To identify design strategies which lead to the reduction of the Ecological Footprint of single-family detached houses.

- To redesign the single family house using the above strategies and verify the effectiveness of the strategies.

1.5. METHOD

The first objective is achieved by calculating the Ecological Footprint of a conventional wood frame single family detached house. A life cycle analysis is conducted to estimate land, material, and energy consumption and waste and pollution generation to use them in Ecological Footprint calculation.

The second objective is achieved by critically reviewing the current literature on sustainable house design. A series of strategies that reduce land, material, and energy use and CO_2 emissions were examined.

The third objective is achieved by using design strategies identified in the fulfillment of the second objective to redesign the base case study, and comparing the Ecological Footprint of the new design with the Ecological Footprint of the base case study.

The following programs and methods are used throughout the thesis:

- The Appropriated Carrying Capacity method developed at the UBC Planning School by Rees and Wackernagel (Wackernagel et al, 1993). The method calculates the aggregate land area in various categories required to provide an activity with resources and to absorb the waste discharged throughout its life cycle.

- Life Cycle Analysis is used to quantify energy and material consumption, pollution emission, and waste generation by each project throughout its life cycle which include:
  - the production of the building;
  - the use of the building;
  - the maintenance of the building;

- the demolition of the building

- The HOT 2000 program is used to estimate operating energy for each house. HOT 2000 is a computer program designed to aid in simulation and design of buildings for thermal effectiveness, passive solar heating, and the operation and performance of heating systems by using heat-loss/gain and system performance models.

1.6. THESIS LAYOUT

The thesis is divided into six chapters.

Chapter 2 introduces Canadian single family housing, the development process, reasons of its continued popularity, its environmental implications, and the extent to which it contributes to the current environmental crisis. The concept of sustainable development is introduced as a possible solution for environmental problems. The chapter concludes with the implication of sustainable development in the single family housing sector.

Chapter 3 estimates the "Ecological Footprint" of a conventional wood frame, single-family detached house. A detailed analysis of the components of the Ecological Footprint is presented.

Chapter 4 examines various strategies that could be used for land, energy, and material conservation and pollution prevention in single family housing. The criteria for selecting the strategies to be used in redesigning the base case study are presented.

Chapter 5 estimates the Ecological Footprint of the improved house and compares the results with the Ecological Footprint of the base case study house.

Chapter 6 concludes the thesis by presenting the findings of the study and comments regarding the method.

CHAPTER II : HOUSING AND SUSTAINABLE DEVELOPMENT

2.1. INTRODUCTION

Housing quality[1] is an important indicator of the health and prosperity of a given population. Housing people and housing them in the best possible manner is an important goal in a sustainable society (BC. Round Table in Economy and Environment, 1990).

Housing is a form of built environment designed for "private" activities. Space arrangements within a housing unit are based on cultural, economic, climatic, and technological considerations. Different dwelling types have different ecological implications. Housing choices, directly and indirectly, influence the extent of resource depletion and pollution generation. The direct influence is through the building's construction, operation, and maintenance. The indirect influence occurs through the pattern of transportation and infrastructure in a city.

2.2. HOUSING TYPES

The most common housing types in Canada are:

- **Single Family Detached House**: a housing type designed for occupancy by one family. It consists of one dwelling unit built on its own property and completely separated on all sides from any other dwelling or structure.

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[1]The quality of housing is determined by indicators such as affordability, adequacy, suitability, safety, security, privacy, image and form, open spaces, accessibility to services and transportation, management and maintenance, and community facilities (CMHC, 1992).

- **Semi-detached House (Duplex)**: a housing type that represent the first step toward multiple units housing. Two dwellings (adjoining no other structure) separated by a party wall extended from ground to roof and built on one parcel of land.

- **Row House (Town Houses):** a series of similar dwellings attached horizontally. The resulting row structure contains three or more units, each with a private entrance and a small yard at front and rear.

- **Low Density Apartments**: generally three to four storey wood frame buildings. All units share a common entrance and services. This type consists of bachelor, one- and two-bedroom units. Most low density apartment buildings are located near major shopping centers, basic civic and community facilities, and with public transit and major arterial roads close at hand.

- **High rise Apartments**: usually located in highly centralized urban areas of high land value. Underground parking and common facilities such as a swimming pool, and a recreation room are usually provided. Units are usually, composed of bachelor and one-bedroom and a small number of two bedrooms.

Single-family house is the most desired housing type by Canadians. There are approximately 6 million single family detached houses in Canada (Statistics Canada, 1991[2]) which constitute 60% of Canada's housing stock (CMHC, 1994)[3]. Statistics for the last five years indicate that single-family houses continue to grow at approximately the same percentage (CMHC, 1994).

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[2] There are 5,702,915 single family detached houses in Canada (Statistics Canada, 1991).

[3] The diagram of Canadian Housing Statistics from CMHC for the years 1950-1985 indicates that the percentage of starting single family housing from all housing units was

2.3. POPULARITY OF SINGLE FAMILY HOUSES.

There are many reasons behind the preference of Canadians for this type of housing:

- **Self-reflection:** a psychological reasoning of the desire to live in a single-family is based on defining the home as the symbol of the self (Cooper, 1971). People refer to their home as a symbol of how they see themselves and want to be seen by others (Despres, 1991). The freestanding house in its clearly defined plot of land facing an ordinary road avoiding any form of grouping expresses the desire to be independent (Cowburn in Rapaport, 1969).

- **Social recognition:** The housing unit, particularly its exterior, transmits information about the household's social position in terms of economic and professional status. The desire to own a single-family detached house was found to be related to a desire for living in a neighborhood of a given economic level. Rental neighborhoods are often described as being of lower status by home owners (Anderson-Khleif, 1981 in Despres, 1991). Having a monthly mortgage payment for a house is also perceived as a sign of "having made it" since obtaining a loan for the purchase of a home gives one some mark of respectability (Perin, 1977, Jackson, 1985 in Despres, 1991).

- **Financial investment:** Owning a single-family house is considered to be a solid economic investment in North America. The resale value of the house is an important factor in the acquisition of a house. Land ownership reinforces the value of single family house, whereas

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approximately 70% for the years 1950- 60, 47% for 1961-1970, 48% for 1971-80, and 60% for the first five years of the eighties (CMHC, 1987).

the exclusion from land ownership of the high-rise apartment buildings is considered the main reason for the low desire to own them.

- **Suitability for families with children:** privacy, low floor levels, larger spaces than other units, and access to private open areas are some of the reasons that make single family house popular among families with children.

2.4. DEVELOPMENT OF SINGLE FAMILY HOUSE

Technology and life style during the twentieth century have undergone rapid changes. However, the changes in single family house design have occurred much slower. The basic form of most houses today is similar to those popular at the turn of the century. Rapaport suggests that housing design changes as the social image of "right" and "adequate" housing changes. Most North Americans still hold an image of "right" housing as being a private house with a fence, trees, and open space (Stewart, 1979).

Although the form of single family houses has seen little change, their size has increased noticeably, inspite of a decline in the size of the average Canadian household. An average new house in 1912 was 140 m^2 which was reduced to 93 m^2 during the depression of 1930. Sizes began to increase again after World war II, until the 1960's, the average house area was 135 m^2; in 1989, it jumped to 186 m^2. Consequently the average living space for each family member increased from 24 m^2 in 1912 to 60 m^2 in 1989. The living space per person has increased inspite of the change of life style. In the past home was the center of the social life. There were no cinemas, sport arenas, shopping malls, and automobiles. Home was the place where women and children spent most of their time, only adult males used to go outside to work. (Grady, 1993).

Technological development and the general improvement in economic conditions in Canada and other developed countries, particularly following the second world war, have reduced physical and economic constraints, allowing people to do very much more than what was possible in the past. A larger part of the population were able to choose rather than be constrained to live in a certain life style. Furthermore, these choices, increasingly, were based on desires rather than needs. This lead to the production of large amount of industrial products , including houses, in relatively short time. The unprecedented material growth was attained with severe environmental consequences.

2.5. ENVIRONMENTAL IMPLICATIONS OF SINGLE FAMILY HOUSING

The large number and growing size of single family houses made them a burden on the biosphere. Single family houses are the most ecologically "expensive" housing type in terms of land, energy, and material consumption and pollution generation to house a given number of occupants.

2.5.1. Land Occupation

At an average of 45 persons per net hectare, the number of single family homes occupants is 41.6% of those housed by row houses (an average of 108 persons per net hectare), 28% of those housed by walk-up apartments (an average of 156 persons per net hectare), and anywhere from 3% to 23 % of the occupants of high density, multi-family housing (D'amour, 1991). Land use for single family houses results in the loss of large areas of biologically productive lands and negative urban implications. Urban areas with single family detached houses are low density areas and difficult to plan for mixed uses. These characteristics other than giving the cities certain shape, create transportation problems (Automobile dependency, long distance driving, traffic congestion, necessity of long streets, highways, bridges), and lead to overextended municipal services.[4]

[4] A Single family House requires at least four times more linear infrastructure per unit than duplex (Gagnon, in D'amour, 1991).

2.5.2. Resource Consumption

Single family house units are usually larger than other types of housing units per the number of occupants. This implies that more resources will be used in constructing and maintaining them. Timber is the main renewable source of building materials used in housing construction in Canada. Timber is a product of the forest. Forests take from 30 to 400 years to regenerate, depending upon species composition and the local environment. Before being cut and used as building materials and other purposes, trees serve many important ecological functions. Trees act as watersheds and absorb, hold and release water; they protect soil and play a major role in preserving the life-support system of the entire ecosphere, absorbing carbon dioxide, and producing oxygen. They provide habitats for a rich variety of animal and plant life and are capable of withstanding relatively heavy recreational pressure. Locally, trees help to absorb pollutants and noise, everywhere they are a source of beauty and aesthetic pleasure (Miller and Armestrong, 1982). Trees are the most effective tools in fighting a very serious environmental problem which is global warming. They are an essential part of the carbon absorption function of the environment. Harvesting trees for use in house construction reduces the capacity of the environment to carry out this function. Ecologist Howard Odum developed a formula to put a dollar value on the "ecological value" of natural elements. He found that the dollar value of an average tree is $ 13,000 or about $ 130 a year over a 100 year life span. (Miller and Armstrong, 1982).

The extraction of non-renewable resources (such as composite materials and metals) to be used in Canadian single family houses leads to the immediate destruction of important ecosystems and to air, soil, and water pollution.

2.5.3. Energy Consumption

Single-family detached houses, because they have a greater exposed surface area, consume significantly more energy for heating and cooling than townhouses or apartments. Single-family dwellings require more energy to construct and operate, and more energy for neighborhood facilities and services (Burby et al, 1982). The production of energy whether it is based on hydro, fossil fuel, or nuclear fuels induces substantial ecological costs. Trees in many areas of the world show traces of damage, a considerable portion of them are virtually dying, mainly due to the pollution generated from the production of energy by combustion processes (e.g., acid rain). The incident at Chernobyl illustrates the high price in human and ecological terms that nuclear generators of energy can induce (Hohmeyer, 1992). Even hydroelectricity has severe ecological costs in terms of damages to the flora and fauna and water supply and quality.

2.5.4. Water Consumption

A large quantity of water is used in single family houses throughout their life cycle. "Water is the lifeblood of the planet, without a steady supply of clean, fresh water, all life, including human, would cease to exist" (Environment Canada, 1990). The average daily Canadian domestic water consumption is 350 liters (Ministry of Environment, 1990) more than twice that of UK average of 160 liters and more than 1.5 times the US. average of 220 liters (Vale, 1991). The water to supply human demands is drawn almost entirely from rivers. Only 0.0001 per cent of the earth's water is in rivers. There is enough water in the rivers to supply world population with a little less than 26000 liter/person/year. Despite the apparent abundance in water many people in the world have little or no clean drinking water because rivers are contaminated (Vale, 1991).

2.5.5. Pollution Generation

A large amount of solid waste is also generated by single family houses. Waste generation starts with the first step, the extraction of raw materials, and continue throughout the life cycle of the building ending with the demolition of the building. The environmental consequences of construction waste are the loss of valuable resources, the loss of the energy embodied in these resources, valuable land occupied as landfill, damage to health, and soil, water, and air pollution.

Single family houses are a major contributor to global warming which is one of most serious threat facing our planet. The excessive concentration of CO2 and other so called green house gases could lead to an increase of 1.5-4.5 degree Celsius before the year 2030. This increase in the earth temperature will have global physical, chemical, and biotic effects. The Inter-Governmental Panel on Climate Change (IPCC) predicts that 100-200 million hectares of forests will disappear with most of the species living in them. The sea-level will rise between 30-100 centimeters as a consequence of thermal expansion and the melting of glaciers. This will pose serious problems for the low lying nations and coastal zones. IPCC predicts the displacement of millions of people, destruction of low-lying urban infrastructures, inundation of arable lands, and contamination of fresh-waters (Leggett, 1991).

Choices in housing type made by Canadians and people of other developed countries, is part of a general trend that includes all areas of human activity. The environmental impact of these choices, combined with the needs of a large population in developing countries, has placed increased pressure on the available resources on the planet. The consequences of uncontrolled resource exploitation and industrial pollution are too high to be sustained by the regenerative and absorptive capacities of the biosphere. The future of human life on this planet could be jeopardized if environmental degradation continues. However, there is increased awareness among people around the world, their governments, and the international institutions of the seriousness of the threats that environmental problems pose. The general secretary of the United Nation formed a commission to study the state of the global environment, and the relationship between the environment and economic development. In 1987, the commission released a document called "Our Common Future" presenting the concept of sustainable development as a solution for the environmental problems facing the planet.

2.6. SUSTAINABLE DEVELOPMENT

The World Conservation Strategy, prepared by the International Union for the Conservation of Nature along with United Nations Environment Program and the World Wildlife Fund, was the first international document to define the concept of "sustainable development" ;

> *"For development to be sustainable it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions."*
>
> (World Conservation Strategy, 1980)

But it was the United Nation's Commission on Environment and Development report "Our Common Future," released in 1987, that popularized the concept of sustainable development. Dr. Brundtland, the Prime Minister of Norway, chaired the Commission composed of a group of 22 members from developed and developing countries. The Commission has defined sustainable development as

> *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987).

The ability of future generation to meet their needs will be insured by not compromising the productivity of the natural environment. The productivity of the environment can be preserved by keeping the scale of the economy within the carrying capacity of the environment. Defining the carrying capacity of the environment and how it varies across regional, national, or global environments is crucial for determining the implications of sustainability.

Carrying capacity is "the maximal population size of a given species that an area can support without reducing its ability to support the same species in the future" (Daly and Ehrlich 1992). The available natural capital, population size and the per capita rate of material consumption and waste generation are factors which affect the carrying capacity of an environment. Not balancing population number and consumption rate will result in consuming the natural capital of the environment rather than living on its "interest". The consequence is the degradation of the environment. Therefore, sustainability requires that a "constant capital stock" (Rees, 1992) be kept to ensure that "each generation could inherit an adequate stock of natural assets alone no less than the stock of such assets inherited by previous generation" (Daly 1989, Constanza and Daly 1990, in Rees 1992). "It is best to at least provisionally assume that we are at or below the range of sustainable stock levels" (Constanza, 1991). So "humankind must learn to live on the annual flows - the 'interest'- generated by remaining stock of natural capital" (Rees, 1990) and allow no further deterioration of the natural capital. The current human per capita resource consumption and waste generation should not exceed what is within the carrying capacity of today's environment.

The biologically productive lands and water areas present in the ecosystems of various regions of the planet are natural capital requirements of human carrying capacity. The per capita biologically productive land on the planet is currently approximately 1.6 hectares (WRI, 1992). This figure is diminishing every year as result of the increase in world population and the loss of biological productivity due to deforestation, desertification, urbanization. The rivers and oceans are used primarily, as dumping grounds for waste generated by increasing human activity. This leads to the reduction of the life supporting services offered by these ecosystems. For example, wild fish stocks, the main renewable resource from fresh-water and marine ecosystems, currently provide less than two and a half percent of the human food requirements, and most fisheries are already over-harvested (Wackernagel, 1994). While there are methods available to measure the areas of biologically productive lands and the productivity of these lands, no such methods are available for water areas. Oceanic currents, for example, lead to a significant material and heat exchange between the various areas of the oceans rendering next to impossible, for most cases, to determine the area that corresponds for a certain ecological productive or absorptive function.

The analysis of the Ecological Footprint of the Canadian economy, shows that the current per capita appropriated carrying capacity from natural resources in Canada is approximately 4.2 hectares of biologically productive land, (Wackernagel et al, 1993) which is almost three times the per capita biologically productive land currently available on the planet. In a sustainable world economy, the average Canadian would have to reduce his/her Ecological Footprint to less than half of its current size[5].

The debate about the implications of sustainable development concept for various areas of human activity in Canada and around the world has continued for the last decade. Canadian housing sector, dominated by single family houses, is one of these areas.

2.7. SUSTAINABLE HOUSING

The implications of sustainable development on housing can be examined at a variety of levels ranging from the macro to the micro scales. The implications of sustainability on the macro-scale involve the relation between housing sector and other sectors of the built environment (e.g., commercial and transportation areas) and the relationships among different types of housing within

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[5] Assuming that the global carrying capacity will be considered as the measure of sustainability.

the housing sector (e.g., between single family housing and multi family developments). This study is on the micro scale, concerned specifically with the implication of sustainability on a base case study single family detached house.

The ecological sustainability of a house depends on three factors; the carrying capacity of the environment, the environmental effectiveness of building's design, and the way in which the house is used.

2.7.1. Sustainable Resources:

The sustainable per capita resource consumption and pollution generation level is based on the carrying capacity of the environment. The carrying capacity of an environment is determined by its physical boundaries. Different models (regional, national, or global environments) give different values to determine the sustainability of a house, or any other human activity, because of the uneven distribution of natural resources on the planet. If the measure is the regional environment, the sustainability of an activity depends on the available resources in a region. A level of resource and energy consumption for housing could be sustainable in Vancouver yet not in Toronto. If the measure is the national environment, the amount of resources required by a house could be sustainable in Canada (the Canadian per capita is higher than most of the other countries of the world) but not in Japan. If the measure is global, the determination of the sustainability of a consumption level for a house would be independent from it's geographic location.

Once the sustainable limits of resource consumption available for housing in a community are defined, the Ecological Footprint of housing units needed by members of the community should be planned to fall within these limits. The decision would be made, by planning authorities, of how to distribute these units among various housing types. Single family detached house has, and will continue to have (even after optimizing the environmental performance of housing types) the largest Ecological Footprint per occupant. Therefore, it is possible that the available resources for housing in a community will not be enough to build any of these units as single family houses.

2.7.2. The Use of the House:

A sustainable house is designed to be operated within certain per capita energy and material consumption levels. A sustainable house designed for four persons may not be sustainable anymore if it is occupied by two persons only. This would represent a waste of land, materials, and energy. The behavior of the occupants also influence the effectiveness of the strategies used in a house in order to make its operation sustainable. The most efficiently designed system may not be efficient if it is used carelessly (e.g., efficient lighting and hot water devices left on when they are not needed).

2.7.3. The design of the house:

A sustainable house has to be built, operated and maintained within the sustainable energy and resource limits available to its occupants. Therefore, floor area, available spaces, energy and material consumption should be based on the number of its occupants.

The limits of sustainability in Canada, as elsewhere, are currently undetermined, but in a planet so over-stressed ecologically, and where a large number of humans are in desperate need for resources to survive, every effort should be made to minimize the Ecological Footprint of new single family houses. However, even in a housing sector with unsustainable Ecological Footprint such as exists in Canada, there is large difference in the Ecological Footprint of single houses, based mainly on the financial status of their owners. Different house designs should be treated differently. Most of the pressure should be put, by planning authorities, on house designs with large Ecological Footprints. The pressure could be exercised through high levels of taxation and by imposing low operating energy consumption levels obtainable through the use of advanced technologies. The requirements from houses with modest Ecological Footprints should be limited to cost effective strategies (see CHAPTER IV).

CHAPTER III: THE "ECOLOGICAL FOOTPRINT" OF A CONVENTIONAL WOOD FRAME SINGLE FAMILY DETACHED HOUSE

3.1. INTRODUCTION

The Ecological Footprint of a wood frame single family detached house is defined as the biologically productive land area continuously required to supply the house throughout its life-cycle with energy and resources, and to absorb the waste it discharges. The calculation of the land area is based on the Ecological Footprint/Appropriated Carrying Capacity (EF/ACC) method developed by Rees and Wackernagel (Wackernagel, 1993). The method calculates the land area whose carrying capacity has to be "appropriated" to supply an activity with energy and resources and to absorb the waste it discharges throughout its life cycle.

3.1.1. Objectives

The purposes of studying the Ecological Footprint of a single family house are:

- To provide a better understanding of the environmental consequences of single family houses through the quantification of resources consumed and waste discharged.
- To identify areas for potential resource conservation and pollution reduction which may contribute to the improvement of the environmental performance of single family houses.

3.1.2. Approach

The calculation of the "Ecological Footprint" is based on a life-cycle analysis of the energy and material use of a house distinguishing between initial and recurring values. Materials and energy estimates are converted to areas of biologically productive land using land equivalency procedures. The various categories of biologically productive land are subsequently added to give the Ecological Footprint of the house.

3.1.2.1. Life Cycle Analysis

A life cycle analysis is the process of documentation and evaluation of material and energy flow in a product, process, or activity (Lützkendorf, 1992).

The life cycle of a building includes:

- the production of the house
- the use of the house
- the maintenance of the house
- the demolition of the house

Resource depletion factors included in a life cycle analysis of a building are:

- Land occupation
- Resource consumption
- Energy Consumption
- Water Consumption

Pollution generation factors included in a life cycle analysis of a building are:

- Air Pollution (e.g. Ozone layer depleting substances and global warming gases)
- Water Pollution
- Soil Pollution

The newly developed EF/ACC method, currently, considers only direct land degradation, renewable resources, and renewable energy factors from consumption area, and CO_2 emission from pollution area. Research is needed to resolve the difficulties associated with accurate quantification of other factors that should be included in the Ecological Footprint calculation (e.g., the inclusion of water consumption, the regenerative and assimilative role of the oceans, and land requirements of extracting non-renewable resource). These omissions could result in an Ecological Footprint of the house smaller than its actual size.

A detailed life cycle analysis of the house is carried out for the following factors:

- Land areas occupied directly as a result of developing the house

- Building materials used to construct, and maintain the house

- Energy consumption of the house throughout its life cycle

- CO_2 emission throughout the life cycle of the house for both energy use and materials production.

3.1.2.2. Land Equivalency Calculations

Land area equivalency procedures are used to calculate land requirements for the following categories:

- Land to produce renewable energy (ethanol).
- Forest land to absorb CO_2 emission.
- Forest land to produce wood.

3.2. HOUSE DESCRIPTION:

The base case study is a two storey house with an unfinished full depth basement and attached double garage. The house is designed for 4 persons and composed of 3 bedrooms, 3 bathrooms, a family room, a kitchen, a living and dining rooms. The total floor area of the house is 350 m^2: 111.6 m^2 are the main floor, 80.6 m^2 are the second floor (Figure 1), 111.6 m^2 are the unfinished full depth basement, and 46.2 m^2 are the attached double garage.

- The basement foundation walls are of poured concrete, and are insulated with 89 mm fiberglass batts (RSI 2.2).

- Exterior walls are 38x89 mm framed and insulated with 89 mm fiberglass batts (RSI 2.2). Interior walls are 38x89 mm framed.

- The attic is insulated with 225 mm blown mineral wool (RSI 5.3).

- Interior finish on walls and ceilings is a single coat paint plus primer on 12 mm gypsum board.

- The floor finish is 3 mm vinyl in the kitchen and bathrooms and carpet everywhere else.
- The exterior finish is cedar siding and brick veneer.
- Roofing is asphalt shingles.
- All windows are double glazed.

The design of this house is similar to most currently built Canadian single family detached houses. The results obtained in this study, therefore, reflect the conditions of new Canadian single family detached houses.

3.3. LIFE CYCLE ANALYSIS

A detailed life cycle analysis of the house was carried out for the following factors:

3.3.1. Land Occupation:

There are two categories of land occupied as a result of developing a single family house:

- Directly occupied land areas which include the lot on which the house is built and the area from property lines to the center of both the street in front and the back lane.
- Indirectly occupied land areas which include lands occupied by the premises for the production and transportation of the energy and materials related to the house, water consumed by the house, and the transportation and treatment of the waste generated

throughout the house's life cycle (e.g., hydro reservoirs, factories to produce building materials and components, bridges).

Because of the difficulties associated with indirectly occupied land area calculations, only the directly occupied land areas are included in the calculation of the Ecological Footprint of the house. Occupied land is one constituent of the Ecological Footprint that is already expressed in land area units.

Table 3-1. Detail of Land Areas Occupied Directly By The Base Case Study House

LAND CATEGORY	AREA
Lot size	622.43 m^2
Half the area of the street in front of the house	205.40 m^2 [6]
Half the area of back lane	62.24 m^2
Total Occupied Land Area	890.07 m^2

Biologically productive land area lost as a result of developing the base case study house is 0.089 ha (Table 3-1). Almost one tenth of a hectare is a large area, and considering the large number of houses built in Canada it represents a major damage of biological productivity. In 1995 alone this would account for the degradation of approximately 89,000 ha of biologically productive land, directly, by single family detached housing.

The Ecological Footprint of the house calculates the occupation of the area estimated above throughout 40 years of life cycle. However, the area of biologically productive land degraded as a

[6] The distance between the property lines of the two houses facing each other across the street is assumed to be twenty meters (Nichols Vandenberg Architects).

result of developing a single family house could be much larger than the land occupied by it, and the duration of that loss could be much longer than the useful life of the house because;

- These lands are often part of an ecosystem and the occupation of a portion of that ecosystem could degrade an area much larger than the area estimated.

- The land, to return to biological productivity, requires that every impact of the house to be eliminated. The land, instead, could be left non productive biologically long after the useful life of the house. The land occupied by streets are much more permanently removed from productivity.

3.3.2 Material Consumption:

All building materials, from renewable and non-renewable sources, used throughout the life cycle of the house were estimated. These estimates include:

- Initial material required to build the house

- Recurring material required to maintain the house.

The estimate of both the initial and recurring material consumption includes materials expected to be wasted during construction activities.

The Ecological Footprint method currently considers land implication of only renewable resources. Land areas affected by non-renewable resources extraction are excluded because of the difficulty associated with their precise calculation and more importantly because the size of land areas affected by non-renewable resources extraction are irrelevant taken on global scale. Wood is the main source of renewable building materials used in Canadian house construction.

The amount of non-renewable materials is estimated despite their exclusion from the Ecological Footprint, so as to understand their relative proportion and the need for such data in life cycle energy analysis.

3.3.2.1. Initial Material Consumption

The analysis of the materials used initially to build the house (Table 3-2) shows that the weight of three materials constitute almost 90% of the total weight of the materials used in the house. These materials are; concrete (64.1%), sand and gravel (14.8%), and wood products (9.34%). Concrete is used in two forms; ready-mix Concrete (63.6%), and Concrete Products (0.69%). Wood is used in four forms; lumber and timber (7%), veneer and plywood (1.6%), millwork (0.79%), and paper (0.05%).

The total weight of building materials of renewable sources included in the Ecological Footprint is 30385.3 kilograms or 3.04 tonnes·

Table 3-2 Weight of Building Materials Used In Various Parts Of The House Throughout 40 years of life cycle

Commodities	Initial Kg	Percent	Recurring Kg	Percent	Total Kg	Percent
Concrete	195347.8	64.13	2090.8	12.32	197438.5	61.39
Wood Products	28462.6	9.34	1922.7	11.33	30385.3	9.45
Sand and Gravel	45142.3	14.82	0	0	45142.3	14.04
Gypsum Products	12064.5	3.96	1206.5	7.11	13271	4.13
Bricks and Tile	11888.4	3.9	1046.9	6.17	12935.3	4.02
Mortar	100	0.03	10	0.06	110	0.03
Insulation	2218.7	0.73	547.0	3.22	2765.7	0.86
Steel	1774.4	0.58	1497.0	8.82	3271.3	1.02
Glass	1276	0.42	85.9	0.51	1361.9	0.42
Paints	138.2	0.05	967.7	5.7	1105.9	0.34
Carpet	464.8	0.15	1766.4	10.41	2231.2	0.69
Asphalt	2529.9	0.83	5057.3	29.8	7587.2	2.36
Plastics	533.9	0.18	475	2.8	1008.9	0.31
Joint Compounds	1854.8	0.61	79.5	0.47	1934.3	0.60
Aluminum	205	0.07	24.6	0.14	229.6	0.07
Cooper	122.2	0.04	145.2	0.86	267.4	0.08
Others	503.6	0.17	46.6	0.27	550.2	0.17
Total	304627	100	16969	100	321596	100

3.3.2.2. Waste Materials

The percentages used to estimate construction waste are collected from the following sources:

- "Waste Prevention on Site" by Skoyles and Skoyles which is an in-depth study of British construction practices (OPTIMIZE, 1992).
- Data contained in ERG-UBC School of Architecture files.
- Construction industries operating in British Columbia.

The largest component of construction waste was found to be wood products (44.7%) followed by Gypsum board (21.7%), and concrete (19.03%).

Construction waste estimated by this study is higher than figure given by Canadian Builders Association study as the average weight of construction waste in single family houses. The 2.5 ton figure given by the Association seems to be low, the EnviroHome (Nova Scotia's advanced house), for example, despite its on-site waste management program, has generated 3418 kg of on-site construction waste.

One of the environmental consequences of construction waste is the loss of further land area to serve as landfill. There are various types of landfills with different land implications. In a landfill with maximum allowable height of 6 meters, for example, (e.g., Eco-waste in Richmond, B.C.), each m^2 of land is able to take 1.5 tonne of construction waste (based on weight to volume ratio of

1 tonne = 4 m^3)· Assuming that all the construction waste produced in this project will end in landfill, the land area required for construction waste of this house is

$$\frac{\text{Total construction waste (5.1 t)}}{1.5\ t/m^2} = 3.4\ m^2$$

This area appears to be small, nevertheless, considered on national basis, It means 340,000 m^2 of biologically productive land wasted. There are however, problems related to determining how long the land will be occupied by construction waste. This depends on the characteristics of the landfill (size, depth of waste, type of waste materials) and the economic value of the land. There are techniques followed to reclaim and develop waste landfills. A landfill could be developed for various purposes in just few years after being closed (GVRD, 1995).

Because of the difficulty in estimating the duration for which the land will be used as a landfill and the growing tendency to re-use and recycle building materials, land area required for construction waste will not be included in the Ecological Footprint calculation.

3.3.2.3. Recurring Material Consumption

The estimation of recurring material consumption is based on the following assumptions:

- Maintenance involves replacing less than 100% of a material or component. For a product, the number of repair cycles required is the product life divided by repair intervals corrected for the possibility of forgone repairs near the end of the product life.

- Replacement refers to the total replacement (100%) of a material or component. The number of times a component is replaced is given by the building life time divided by product life corrected for the possibility of forgone repairs near the end of the building life.

Recurring materials are calculated by first obtaining a replacement factor for each building material used. Replacement factor is created by using a formula which relates the maintenance interval with the expected lifetime of the product and the lifetime of the house[7]. Recurring amount of a material is obtained by applying the replacement factor to the initial amount of that material. Figures used in the formula for product life (yr), repair intervals (yr), repair percentage (%), and replacement intervals are taken from OPTIMIZE program.

Analysis of recurring materials for 40 years of life cycle [8](Table 3-2) shows that the weight of asphalt used as roof shingles (replacement frequency of 15 years) is the main material consumed constituting 29.8% of all recurring materials. The second material is concrete with 12.32% followed by wood with 11.3% (used mainly for kitchen cabinet replacement), carpet with 10.4%, steel with 8.8% (used mainly in appliances), gypsum (7.1%), brick and tile (6.2%), and paint (5.7%). The frequent repair and replacement requirements are the reasons for the high consumption of these materials. Many of the materials used do not need maintenance during a life cycle of 40 years and most of these materials do not need replacement during this period.

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[7]Detail information about the derivation of replacement factor may be seen in Optimize Appendices, 1991: Appendix IV-p x.

[8] Assessing the lifespan for a building is a major problem with life cycle analysis. There are factors other than the physical life of a building which influence the termination of a building. These include escalating repair costs and functional and technological obsolescence (OPTIMIZE, 1991). A life cycle of 40 years is used by other studies of life cycle analysis such as Optimize, 1991 and Hood, 1995.

Recurring material consumption for two additional life cycles were estimated to assess the performance of recurring materials for periods longer than 40 years life cycle (Table 3-3). The percentage of initial and recurring material consumption from the total life cycle consumption changes in these three life cycles. Initial consumption continues to be higher than the recurring consumption in each of these periods despite a decrease in magnitude with the prolonging of life cycle.

Table 3-3. Initial and Recurring Material Relationship Throughout Three Life Cycles.

Life Cycle	Initial kg	%	Recurring kg	%	Total kg	%
40 years	304,627	95%	16,969	5%	321,596	100%
60 years	304,627	72%	121,128	28%	425,755	100%
80 years	304,627	68%	140,813	32%	445,440	100%

Analysis of recurring material through these three life cycle periods show that recurring material consumption during 60 years life cycle is 121,128 kg which is 613% higher than that of a life cycle of 40 years (16,969 kg), while recurring material consumption in a life cycle of 80 years (140,813 kg) is higher than that of a life cycle of 60 years by only 16%. The reason behind the large increase in the amount of recurring material consumption in the second period (60 years life cycle) is that a large proportion of materials used have a life cycle of 40 to 50 years. Therefore, recurring material consumption during the first 40 years are, primarily, due to maintenance, recurring materials consumed over 60 years of life cycle, instead, include the replacement of large part of the materials used in the building. Recurring consumption over 80 years life cycle is once again due, mainly, to maintenance.

3.3.3. Life Cycle Energy Analysis

A life cycle energy analysis is the process of determining how much energy a building requires throughout its life cycle. Energy in a buildings is consumed in three ways; operating, embodied, and demolition energy.

- Operating energy is the energy consumed in heating, cooling, lighting, and operating domestic appliances.

- Embodied energy is the energy used to extract or recycle, manufacture, transport and install building products.

- Demolition energy is the energy used to demolish a building and haul the debris

In analyzing the embodied energy of the house a distinction was made between the initial and recurring embodied energy.

- Initial embodied energy is the energy embodied in materials required to initially produce the house; and

- Recurring embodied energy is the energy embodied in materials required to maintain the house.

The embodied energy includes the energy associated with construction waste.

3.3.3.1. Initial Embodied Energy

The analysis of initial embodied energy for the house required the evaluation of its two main components; direct and indirect energy.

- Indirect energy is the energy consumed in the production of building materials, their associated transportation during processing and to distribution centers within a region. It forms the larger portion of embodied energy.

- Direct energy is the energy actually consumed in the construction of buildings. It represents the final transportation and installation of a component or assembly. Direct energy is estimated to be 7-10% of the initial embodied energy.

Calculation of the indirect embodied energy in a house requires the energy intensity of the materials used in that house. Energy intensity is the energy used to produce a given amount of a material. It represents the indirect energy in unit terms either expressed as energy/mass or volume such as MJ/kg or MJ/m^3 or energy/standard unit such as MJ/sheet or block etc. (Cole and Rousseau, 1992). A review of literature from various sources and covering different periods included amongst others' Stein (USA, 1976), Baird and Aun (New-Zealand, 1983), Optimize and Forintek Corp (Canada, 1992 and 1994) has revealed a large variation in energy intensity values for a given material from one source to another. These differences could be accounted for by:

- Different Methods of Energy Analysis: Energy analysis is a formalized method for calculating the energy consumed in the production/prevision of goods and services. There are four methods of analysis available (Baird and Aun, 1983): Statistical Analysis, Input-Output Analysis, Process Analysis, Eco-Energetic Analysis. The method used depends mainly on the overall objectives of the analysis and the available data. Statistical analysis, input-output analysis, and process analysis are the most widely used methods to calculate energy intensity of building materials. "Calculation of energy requirements carried out using different conventions and methods will often give different results" (Baird and Aun, 1983).

- System Boundary Level: there is no absolute or correct energy intensity of a material (Kohler, 1991). The stated value is a direct function of what was included and what was excluded from its derivation (Cole and Rousseau, 1992). According to IFIAS (Baird and Aun, 1983) there are four boundary levels that can be drawn in calculating energy intensity of a material; Energy to process only, energy to extract material, energy to make capital equipment, and energy to make machines to make machines. The first and the second boundaries cover almost 90% of the total embodied energy in a material.

- Production Efficiency: Level of efficiency of the production process is another reason behind these differences. Technology and efficient use of resources are factors that influence the energy intensity figures from different times and geographic areas.

- Transportation: the distances that building materials are transported and transportation method used are other reasons that cause differences in energy intensity figures.

Energy intensity figures for building materials were collected, mainly, from the following sources;

- Forintek Canada Corp. reports "Building Materials in the Context of Sustainable Development". Energy intensity figures in these studies are based on process analysis provided by major Canadian wood, concrete and steel industries directly participant in the studies.

- The OPTIMIZE program developed for Canadian Mortgage and Housing Corporation (CMHC, 1991). The program uses Statistics Canada Input/Output model of the Canadian economy to generate energy intensity values for 58 commodities produced in Canada, categorized for each of the 8 energy sources (oil, nuclear electric,... etc.). The program has a comprehensive scope, which covers energy requirements from harvesting/mining of raw materials to the distribution of products to retail outlets. The first problem with the program is that limiting the data to only 58 commodities makes the data lack in precision and the second is that time lag between the age of the data and publication of the tables may result in an over-estimation of the energy intensity of current building materials[9] (Hood, 1995).

- Data contained in the records of UBC Environmental Research Group derived from group's work, national, and international studies.

Energy intensity figures were chosen for being the most recent and accurate, and related to the Canadian situation. Energy intensity per unit weight (kg) of each building material were applied to the initial amounts of the material used to obtain the indirect initial embodied energy.

The direct initial embodied energy in a building is estimated to constitute 7-10% of the total embodied energy in a building (Stein et al., 1976, Salokangas, 1990 in Cole, 1994). Construction

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[9]There has been a steady decrease in the embodied energy of commodities produced in Canada of approximately 1.0% per year (Hood, 1995).

energy in a house depends on the degree of on-site equipment usage, and the distance of the site from distribution centers and workers residence. In estimating the direct embodied energy, a general figure of 7% has been applied to the total initial indirect embodied energy.

The estimates of the direct and indirect embodied energy include embodied energy associated with construction waste.

The analysis of initial embodied energy (Table 3-4) shows that finish materials (21.18%) have the highest initial embodied energy. Finish materials, carpentry (20.45%), insulation and moisture protection (18.79%), and concrete(14.35%), constitute more than 75% of the total initial embodied energy in the house.

Table 3-4 Indirect initial Embodied Energy (See Appendix C1 for detail)

Sections	MJ	Percent
Section-1. Site Work	44413.2	4.77
Section-2. Concrete	133681.5	14.35
Section-3. Masonry	31839.7	3.42
Section-4. Metals	8887.6	0.95
Section-5. Carpentry	190466.6	20.45
Section-6. Insulation And Moisture Protection	175064.6	18.79
Section-7. Doors, Windows And Finish Hardware	29729.5	3.19
Section-8. Finishes	197340.6	21.18
Section-9. Specialties	6939.6	0.74
Section-10. Cabinets And Appliances	50891.5	5.46
Section-11. Mechanical	51407.8	5.52
Section-12. Electrical	10906.1	1.17
Total	931568.3	100

Initial embodied energy = 931568.3 x 1.07 = 996,778 MJ.

Initial embodied energy per m^2 of floor area of the house for a life cycle of 40 years

= Initial embodied energy (MJ)/ Total floor area of the house (m^2)

= 996,778 MJ / 350 m^2 =2848 MJ

3.3.3.2. Recurring Embodied Energy

The recurring embodied energy, like the initial embodied energy is sub-divided into direct and indirect embodied energy. The estimate of indirect recurring embodied energy for the house is obtained by applying building material's energy intensity figures to the amount of recurring building materials. A general figure of 7% has been applied to the total indirect recurring embodied energy to estimate the direct recurring embodied energy. In calculating recurring embodied energy, no provision was made for possible future changes in the energy intensity of building materials needed to maintain the house.

The analysis of recurring embodied energy (Table 3-5) shows that finish materials (57.44%), as in initial embodied energy, have the highest embodied energy but in much higher percentage followed by insulation And moisture Protection (20.56%) cabinets and appliances (13.13%), mechanical equipment (3.51%). These high values are due to high replacement rate of the materials included in these sections.

Table 3-5. Indirect Recurring Embodied Energy For 40 Years Life Cycle (See Appendix C1 for detail)

Sections	MJ	Percent
Section-1. Site Work	1354.49	0.18
Section-2. Concrete	0	0
Section-3. Masonry	3289.23	0.44
Section-4. Metals	428.65	0.06
Section-5. Carpentry	14793.4	1.98
Section-6. Insulation And Moisture Protection	153409.6	20.56
Section-7. Doors, Windows And Finish Hardware	5691.23	0.76
Section-8. Finishes	428665.47	57.44
Section-9. Specialties	0	0
Section-10. Cabinets And Appliances	98010.24	13.13
Section-11. Mechanical	26197.98	3.51
Section-12. Electrical	14406.64	1.93
Total	746246.94	100

Recurring embodied energy = 746246.94 x 1.07= 798,484.2 MJ

Recurring embodied energy per m^2 of floor area of the house throughout 40 years of life cycle=

Recurring embodied energy (MJ)/ Total floor area of the house (m^2)=

798,484.2 MJ / 350 m^2= 2281 MJ.

Recurring embodied energy for two additional life cycles were estimated (Table 3-6). The percentage of initial and recurring energy from the total embodied energy changes in these three life cycles. Initial embodied energy goes from being the major component of the embodied energy during a life cycle of 40 years to becoming a relatively minor contributor during a 60 and 80 year of life cycles.

Table 3-6. Initial and Recurring Energy Relationship Throughout Three Life Cycles.

Life Cycle	Initial Energy (MJ)	%	Recurring Energy (MJ)	%	Total (MJ)	%
40 years	996778	56%	798484	44%	1795262	100%
60 years	996778	37%	1697310	63%	2694088	100%
80 years	996778	31%	2260927	69%	3257705	100%

Comparing recurring embodied energy during these three life cycles shows that prolonging the life cycle of the house by 20 years (from 40 years to 60 years) the recurring embodied energy will increase by 112%. In an additional increase of 20 years (from 60 years to 80 years) there will be an increase in embodied energy of 33% with respect to a life of 60 years. The reason behind the large increase in the recurring embodied energy in the second period examined (60 years life cycle) is that a large part of the materials used have a life cycle of 40 to 50 years. Therefore the recurring embodied energy during the first 40 years is primarily due to maintenance. Recurring energy consumed over 60 years of life cycle, instead, include replacement. Recurring consumption between 60 and 80 years of building life is once again due to maintenance.

It is interesting to note the different performances of recurring materials (Table 3-3) and recurring embodied energy (Table 3-6) during these three different life cycles. The percentage of both recurring material and recurring energy is increasing in 60 and 80 years life cycles causing a decline in the percentage of initial materials and energy, however initial materials continues to be the major component of the life cycle material consumption while the percentage of recurring embodied energy is exceeding that of the initial embodied energy. This indicates that the increase in the recurring embodied energy is much higher proportionally than the amount of recurring materials which means that while materials used for repair and replacement are lighter than initial materials but their energy intensities are higher.

3.3.3.3. Demolition Energy:

Demolition embodied energy includes the energy consumed in demolishing the house and hauling away debris to landfill. Any use of demolished materials other than as debris (recycle or reuse of materials, components or parts of the house) should be accounted for as the embodied energy of the buildings which they will be used in. There are, currently, no reliable estimates of the demolition embodied energy (ERG, 1994). Because of the uncertainties surrounding demolition embodied energy, it is not included in estimating the total life cycle energy of the house.

The total embodied energy of the house (demolition energy excluded) for a life cycle of 40 years is 1,795,262 MJ. The percentage of initial embodied energy from the total embodied energy is 56%

and recurring energy is 44%. The total embodied energy per m^2 of floor area of the house is 5.13 GJ.

3.3.3.4. Operating Energy

The HOT 2000-Version 6 energy analysis program was used to estimate operating energy for the house. This program was developed under the direction of the R-2000 Home program of Energy, Mines and Resources Canada. HOT 2000 is a computer program designed to aid in simulation and design of buildings for thermal effectiveness, passive solar heating, and the operation and performance of heating systems by using heat-loss/gain and system performance models (CHBA, 1991).

The program estimates the annual operating energy requirements in a house taking into account space heating, water heating, appliances, and lighting (Table 3-7). The program requires input about the geographic location, desired temperature levels, specific building components, and mechanical systems.

Space heating in the case study house is provided by a natural gas furnace and forced air system. No central ventilation system is used. The house is located in Vancouver, B. C.. Therefore the results obtained below are based on Vancouver's weather data.

Table 3-7. Various Uses of Operating Energy in the House

Use	Amount GJ/yr	Percentage
Space Heat	65.35	50.3
DHW	38.13	29.4
others	26.35	20.3
Total	129.83	100

Heating (Space + DHW) energy consumption of the house is 103.48 GJ, while the annual R-2000 target[10] for this house is 75.12 GJ. This means that a 27% reduction in heating requirements would be needed to meet R-2000 target.

Comparing operating energies of the base case study (Table 3-7) to that of the average Canadian house, as reported by STAR-HOUSING Database (Table 3-8), the base case study house is 17% lower. This is due largely to climate differences and because the database considers all Canada's housing stock part of which has lower insulation and higher air leakage level than those in the base case study house.

Table 3-8. Energy Consumption of A Typical Canadian House As Reported By Star-Housing Database (Hamilton, 1992).

USE	AMOUNT GJ/yr	PERCENTAGE
Space Heat	110.9	71%
DHW	21.4	14%
others	23.9	15%
TOTAL	156.2	100%

The Building Energy Performance (BEPI)[11] of the base case study single family house is =

[10] This energy use target is set by NRCan with partners in the industry. The target must be met in order for a house to be certified as an R-2000 house. The description of how the target is set may be found in "R-2000 Design Approval Procedures and Guidelines".

[11] The Building Energy Performance Index (BEPI) is a unit that is used to measure operating energy performance in buildings. It is measured in Giga joules per square meter per year (GJ/m2/yr.)

Operating energy (GJ)/ Floor area of the heated spaces in the house (m^2)=

=129.83/303.55= 0.427 GJ/m2/yr.

Operating energy of the base case study house constitutes 73% of energy consumption during 40 years life cycle. This shows the significance of operating energy in single family houses.

3.3.4. Life Cycle CO_2 Emission

Life cycle CO_2 emission takes into account the CO_2 emitted during the initial construction, the operation, and the maintenance of the house.

The two types of CO_2 emission during the life cycle of the house are; energy related and non-energy related emissions :

- energy-related emission is the CO_2 generated as a result of fuel combustion. It forms the major component of life cycle CO_2 emitted by the house.

- non energy-related emission is the CO_2 generated as a result of processing materials used throughout the life cycle of the house.

The amount of energy consumed is not the only factor determining CO_2 emission. The type of fuel used to generate the energy is another important factor (Table 3-9). The quantity of CO_2 generated by a given fuel type is the product of three parameters: the quantity of fuel consumed, the carbon content of the fuel, and the fraction of the fuel oxidized.

Table 3-9. CO_2 Emissions For Common Stationary Uses Of Conventional Fuels (Cole and Rousseau, 1992)

FUEL/USE	CO2 (g/ MJ)
Distillate Oil (0.5% S)	72.1
Natural Gas/LPG	50.5
Coal (Bituminous, 3% S)	87.5
Canadian Electricity	52.3

The contribution of CO_2 emission to the Ecological Footprint of the house is based on calculating CO_2 emission during the various stages of the life cycle.

3.3.4.1. Initial CO_2 Emission:

Initial CO_2 is the sum of the CO_2 emitted during production of building materials and in the construction of the house.

Many published sources were reviewed to determine CO_2 emission figures for the materials used in the base case study house. Because of the direct connection of CO_2 emission to energy usage the problems in evaluation of energy consumption also apply to CO_2 analysis. Figures for CO_2 emission are, therefore, even less accurate than energy figures. CO_2 emission figures for various building materials used were collected from the following sources;

- "Building Materials in the Context of Sustainable Development" reports (Forintek Canada Corp., 1994).

- Data contained in the records of the U.B.C. Environmental Research Group derived from the group's own work, and from national and international studies.

- "Healthy House" project final report prepared by Habitat Design+Consulting and Archemy Consultants (CMHC, 1994).

For those materials where it was not possible to obtain accurate CO_2 emission figures, These figures were calculated by multiplying the global CO_2 emission value of 67 mg/MJ (See 3.4.2) to each material's energy intensity figure. Collected CO_2 emission figure (g/kg) for each building material was multiplied to the initial amount of that material (kg). CO_2 emission associated with construction waste and direct embodied energy are also part of the initial CO_2 emissions in the house.

Initial CO_2 emission data (Table 3-10) shows that concrete has the highest CO_2 emission (24.8%) followed by carpentry, finish materials, insulation and moisture protection which together constitute more than 77% of the total initial CO_2 emission in the house.

Table 3-10. Initial CO_2 Emissions

Sections	Initial (kg)	Percent
Section-1. Site Work	2787.6	4.8
Section-2. Concrete	14465.1	24.8
Section-3. Masonry	1920	3.3
Section-4. Metals	548.1	0.9
Section-5. Carpentry	13587.9	23.3
Section-6. Insulation And Moisture Protection	5566.7	9.5
Section-7. Doors, Windows And Finish Hardware	1881.9	3.2
Section-8. Finishes	11500.7	19.7
Section-9. Specialties	329.6	0.6
Section-10. Cabinets And Appliances	2284.3	3.9
Section-11. Mechanical	2701.3	4.6
Section-12. Electrical	743.1	1.3
Total	58316.3	100

The total initial CO_2 emission of the house is found to be 58316.3 kg (58.316 tonnes) or 166.62 kg/m^2.

3.3.4.2. Recurring CO_2 Emission

Recurring CO_2 of the house (Table 3-11) is obtained by multiplying CO_2 emission figures to the estimated amount of materials to maintain the house. Because of the high replacement rate of materials involved in finish materials section, they are responsible for the largest recurring CO_2 emission (69.9%), followed by insulation (10.9%), cabinets and appliances(10.2%), Electrical (2.7%) and mechanical Section (2.6%).

Table 3-11. Recurring CO_2 Emission Throughout 40 Years Of Life Cycle

Sections	CO2 (kg)	Percent
Section-1. Site Work	144.9	0.4
Section-2. Concrete	0	0
Section-3. Masonry	198.9	0.5
Section-4. Metals	28.3	0.1
Section-5. Carpentry	566.9	1.5
Section-6. Insulation And Moisture Protection	3986	10.9
Section-7. Doors, Windows And Finish Hardware	456.3	1.2
Section-8. Finishes	25641.4	69.9
Section-9. Specialties	0	0
Section-10. Cabinets And Appliances	3732.5	10.2
Section-11. Mechanical	953.4	2.6
Section-12. Electrical	992.2	2.7
Total	36700.9	100

The total recurring CO_2 throughout 40 years life cycle of the house is found to be 36700.9 kg or 104.86 kg/m^2.

3.3.4.3. Operating CO_2

The HOT 2000 program-Version 6 estimates the amount of various fuel types needed to meet the annual operating energy requirements for the house (Table 3-12).

Table 3-12. The Annual Operating Fuel Requirements in The Base Case Study House.

Fuel	Space	DHW	Appliances	Total
N. Gas m3/yr	1625	1023.5	0	2648.5
Elect. kWh/yr	1335.5	0	7320.5	8656

To estimate CO2 emission associated with operating energy (Table 3-13), the amount of each fuel used is multiplied to the CO2 emission factor for that fuel (Table 3-9). The sum of CO_2 emission from these two energy sources is the annual CO_2 emission expected to arise from operating the house.

Table 3-13. The Annual Operating CO2 Emissions in The Base Case Study House.

Fuel type	Fuel amount	Energy production MJ	CO2 Emission kg
N. Gas	2648.5 m^3/yr	98683	4983.5
Electricity	8656 kWh/yr	31162	1629.8

The total amount of CO_2 emission associated with operating energy throughout 40 year of life cycle of the house is 264530.6 kg. The annual operating CO_2 emission for a m^2 of heated floor area of the house is found to be 21.8 kg.

3.4. LAND EQUIVALENCY CALCULATION PROCEDURES

Having estimated the quantity of land, energy, renewable resources, and CO_2 emission, the next step was to use land equivalency procedures to determine the biologically productive land area capable of producing the resources required and to absorb CO_2 emission.

The following land equivalency procedures were used to calculate the Ecological Footprint of the house.

3.4.1. Land Required For Renewable Energy (Ethanol) Production

The authors of EF/ACC method consider ethanol as the ideal renewable substitute for liquid hydrocarbons. It exhibits similar physical properties, such as heating value or homogeneity, and its ease of transportation and storage. Ethanol could also be a substitute for natural gas because of its low entropic value, and most probably it is superior to coal.

Ethanol production depends on two factors; the biological productivity of biomass on a given land area, and the technological efficiency for conversion of biomass into ethanol.

Wackernagel has reviewed various studies about how much ethanol can be produced per hectare of arable land (Wackernagel, 1994). The studies are conflicting in their results. They go from a net loss in available energy (Pimentel 1991, Kendrick et al. 1978) to a net yield of a maximum of 101

GJ/ha/yr. (Kirk-Othmer 1980). Differences arise due to the assumed source of the energy used in processing biomass into ethanol. All studies which assumed a process energy powered by fossil fuel concluded that ethanol production amounts to a net loss, whereas those assuming a process powered by agricultural waste registered high net yields.

In order to make these studies comparable, the different measurements and standards of efficiency used in them were normalized. The farming and harvesting energy for all the studies assumed to be powered by ethanol while the thermal energy for the ethanol processing was assumed to be provided by agricultural waste. Re-evaluation on this bases shows that many of the studies which initially reported a net loss, now show a net gain in low entropy energy.

The productivity proposed by a study from the National Renewable Energy Laboratory (NREL 1992) in Golden, Colorado is chosen as the energy-land equivalence ratio for ethanol production. This state of the art process depends on fast growing poplar trees as its input and reaches a net ethanol productivity of 80 GJ/ha/yr. Using this value and assuming that the energy required for the base case study house had to be provided by biomass, the calculation of life cycle Ecological Footprint is as follows:

Ecological Footprint of the energy required to build the house =

$$\frac{\text{Initial embodied energy (996.78 GJ)}}{\text{80 GJ/ha/yr}} = 12.46 \text{ ha/yr}$$

Ecological Footprint of operating energy throughout a life cycle of 40 years would be =

$$\frac{5{,}193{,}680 \text{ MJ}}{80 \text{ GJ/ha/yr}} = 64.92 \text{ ha/yr}$$

Ecological Footprint of maintenance energy =

$$\frac{\text{Recurring embodied energy (798.48 GJ)}}{80 \text{ GJ/ha/yr}} = 9.98 \text{ ha/yr}$$

Despite the strong argument that fossil fuel is the product of biologically productive lands of the past, and that current consumers should be debited for consuming it, this land will not be included with other land areas in calculating the Ecological Footprint of base case study house because it is an available resource and its generation is not an active part of the environmental mechanism. Fossil fuel availability reduces the current dependency on biomass as an energy source, especially in the developed world. However, the situation in the post-fossil fuel era will be different; biomass could become a major source of renewable energy. But in contrast with current conditions, the land area required for purposes such as CO_2 absorption is expected to be considerably reduced.

The analysis of renewable energy-land equivalency calculation was useful to show:

- the pressure that will be put on biologically productive lands in the post fossil fuel era.
- the difficulty associated with renewable energy production and the importance of conserving fossil fuel energy.

3.4.2. Land Required For CO_2 Absorption

The equilibrium temperature at the earth's surface is a function of the concentration of carbon dioxide in the atmosphere. The rise of CO_2 concentration would cause the mean earth surface temperature to rise likewise. Following the industrial revolution, the concentration of CO_2 in the atmosphere has been rising. Carbon dioxide has been released in large and increasing quantities as a consequence of fossil fuels combustion and through continuing decrease in the total mass of terrestrial biosphere, i.e., through the destruction of forests. The excessive concentration of CO_2 is the main contributor to global warming which is one of most serious threats facing the planet. (Chapter 2). It is essential to find sufficient sinks to absorb CO_2 and avoid its accumulation in the atmosphere. The most obvious and direct solution is to use photosynthesis to capture the newly emitted fossil CO_2. Indeed tree planting and the maintenance of "carbon sink" forests is the only currently practical means of sequestering excess atmospheric carbon (Wackernagel, 1994).

While the deliberate use of forest as a carbon sink is a relatively new idea, it is estimated that there is 2000 billion metric tones carbon in the world's remaining biomass and soils. This is three times the amount in the atmosphere (Brown et al. 1988:93 in Wackernagel, 1994).

The authors of the EF/ACC method provide a simple calculation procedure to determine the land area capable of absorbing CO_2 emitted by the consumption of a given amount of energy. The energy-land equivalence ratio is 100 GJ/ha/year. This ratio is based on a study by Siegenthaler *et al.* reporting that every year about $5{,}400 \times 10^6$ t of carbon is released as a result of fossil fuel combustion. This emission corresponds to a fossil fuel consumption of 300,000 PJ. In other words one GJ of fossil fuel emits about 18 kg of carbon into the atmosphere. Based on the average sequestering capacity of forests (Table 3-14), this means that one hectare of forest could annually sequester the CO_2 emission of 100 GJ of fossil fuel.

Table 3-14. The Average CO_2 Absorption Capacity of Different Types of Forests (Apps *et Al. 1993*, Dixon *et al.* 1994, Birdsay 1992, And Marland 1988 In Wada, 1994)[12]

Forest Type	CO_2 Absorption	Global Percentage
Average boreal forest	0.5 t carbon/ha/yr	33%
Average temperate forest	1.5 t carbon/ha/yr	25%
Average tropical forest	3.0 t carbon/ha/yr	42%
Average global forest	1.8 t carbon/ha/yr	100%

CO_2 emission calculation procedure followed in this study which consist in determining CO_2 emissions of each material and process should produce more accurate results. The calculation of CO_2 contribution to the Ecological Footprint of the house was made in two steps. First, finding CO_2 emissions for each material according to various energy sources used, Second, converting the CO_2 values to areas of forest land. For this calculation it is essential to find carbon content of a certain amount of CO_2.

$$\text{Initial Carbon (t)} = \text{Initial } CO_2 \text{ (t)} \times \text{Carbon content of tonne of } CO_2 = 58.3 \times 0.273 = 15.9 \text{ t}$$

Then the amount of carbon is converted to its equivalence land area according to the global average of CO_2 absorption capacity of the forest.

12 The global average of grassland adds up to about 0.12 t carbon/ha/yr.

$$\text{Ecological Footprint of initial } CO_2 = \frac{\text{Initial Carbon 15.9 t}}{\text{1.8 t carbon/ha/yr}} = 8.84 \text{ ha/yr}$$

Ecological Footprint of maintenance and operating CO_2 throughout 40 years of life cycle =

$$\frac{(\text{Recurring } CO_2 + \text{Operating } CO_2) \times \text{Carbon content}}{\text{1.8 t /ha/yr}} =$$

$$\frac{(36.7+264.53) \times 0.273}{\text{1.8 t/ha/yr}} = 45.69 \text{ ha/yr}$$

The base case study house requires the absorption capacity of 8.84 ha of forest land to absorb the initial CO_2 and 45.69 ha of land to absorb the CO_2 emitted throughout the 40 years life cycle of the house due to maintenance and operation.

The Ecological Footprint calculation of CO_2 emissions was repeated by using the procedure followed by Wackernagel and other researchers at UBC Planning school. They estimate the land area required to absorb CO2 emitted by a given amount of energy by using 100 GJ/ha/yr ratio. The results obtained as the life cycle CO_2 Ecological Footprint differs from the calculation followed by the study, based on the CO_2 emission for every single material, by only 0.5 ha/yr.

3.4.3. Land Required For Wood Production

Wood is the only renewable resource that is processed to produce building materials for this house.

In calculating the Ecological Footprint, the annual productivity of one hectare of forested land is assumed to be 2.3 m3 of roundwood. This is based on the average productivity of Canadian forests which is assumed to be 163 m3/ha (Table 3-15) and based on a 70 years rotation period (*the state of Canada's Environment* sets cutting cycles of 50-80 years) the average annual productivity of Canadian forest becomes =

$$\frac{163\ m^3/ha}{70\ yr} = 2.3\ m^3/ha/yr.$$

Table 3-15 The Quantity of Wood Fiber in Various Forest Types in Canada (Canada Environment, 1991, in Wackernagel 1994)

Forest type	Productivity m3/ha
Overmature forest in B.C. (only 0.18%)	350
Mature forest in B.C. (B.C. average)	255
Average forest in Canada	107
Mature forest (Canadian average)	163

The land area requirement in non-sustainable harvest of the forest is different. In 1986, for example, the Canadian roundwood industry harvested 177,097,000 m3 of roundwood from 930,000 ha. This resulted in a "productivity" of

$$\frac{177{,}097{,}000\ m^3}{930{,}000\ ha} = 190\ m^3/ha$$

The first step in estimating the land area required to produce wood is to convert the various processed wood materials used in the house to roundwood. Two ratios were used; one to convert processed lumber to roundwood (P-R) and the second to convert weight to volume (density).

$$\frac{\text{Initial wood (t) x (P-R)}}{\text{density (t/m}^3\text{)}} = \frac{28.5 \times 1.29}{0.52} = 70.7 \text{ m}^3 \text{ of roundwood}$$

The second step is to convert the roundwood to forest land.

$$\frac{\text{roundwood (70.8 m}^3\text{)}}{2.3 \text{ m}^3\text{/ha/yr}} = 30.78 \text{ ha/yr}$$

Ecological Footprint of wood supply to build the house = 30.78 ha/yr

Ecological Footprint of wood needed for maintenance of the house throughout a life cycle of 40 years =

$$\frac{28.5 \text{ (t)} \times 1.29}{0.52 \text{ (t/m}^3\text{)} \times 2.3 \text{ (m}^3\text{/ha/yr)}} = 2.1 \text{ ha/yr}$$

3.4.4. Total Ecological Footprint Calculation

The total Ecological Footprint of the house includes land area occupied by the house, forest land area required for CO_2 absorption, and the land area required to produce renewable resources.

The Ecological Footprint of the house is the sum of initial Ecological Footprint and recurring Ecological Footprint obtained, by converting initial and recurring energy and material requirements, separately.

Initial Ecological Footprint = directly occupied land + land area for wood productivity + land area for initial CO_2 absorption =

$$0.089 + 30.78 + 8.84 = 39.71 \text{ ha/yr}$$

Recurring Ecological Footprint throughout 40 years of life cycle = directly occupied land + land area for maintenance wood production + land area for operating and recurring CO_2 absorption = 3.56 + 2.1 + 45.69 = 51.35 ha/yr

Each year the productivity of 1.28 ha has to be appropriated to operate and maintain the house.

The total Ecological Footprint = 39.71 + 51.35 = 91.06 ha/yr of biologically productive land area.

The average annual Ecological Footprint of the house would be 2.28 ha

The annual per capita housing Ecological Footprint of the occupants will be 0.57 ha.

The area of the Ecological Footprint of the house is 1,023 times the area of its physical footprint.

Table 3-16. Constituents of The Base Case Study House's Ecological Footprint

	Land	Material	CO2	Total
Initial Ecological Footprint	.089	30.78	8.84	39.71
Recurring Ecological Footprint	3.56	2.1	45.69	51.35
Total Ecological Footprint	3.65	32.88	54.53	91.06

3.5. CONCLUSION

The quantification of resources consumed and waste generated has provided an improved understanding of the environmental consequences of single family houses. The use of hectares of productive lands as a yardstick by EF/ACC method made it easy to visualize the impact of single family houses on nature. However, the most important results obtained by this study is the identification of areas to be targeted in the process of improving the environmental performance of a single family house.

Land area required to absorb CO_2 is the largest constituent of the Ecological Footprint followed by land area required to produce biomass to generate energy[13]. These results show clearly that energy as generator of pollution today, and as a resource in the post -fossil fuel era is the most important environmental issue that has to be addressed. Reducing energy consumption as much as possible and using fuel types with low CO2 emission should be given the priority when choosing the environmental strategies to reduce the Ecological Footprint of the base case study house.

[13] The calculation of Land area required to produce energy (not included in the ecological footprint of the base case study house) has served to reach this conclusion.

CHAPTER IV: STRATEGIES EXAMINED IN IMPROVING THE ENVIRONMENTAL PERFORMANCE OF THE BASE CASE HOUSE

4.1. INTRODUCTION:

Analysis of the Ecological Footprint of the base case study house has shown that the most significant environmental impacts are energy-related. In designing an environmentally responsible house, priority should be given to reducing its energy requirements and using energy sources with minimum CO_2 emission. The various specialists working in a house should coordinate their efforts, from the initial steps of their work, to consider all factors that can contribute to the reduction of the embodied and operating energy of the house.

This Chapter identifies a series of energy and resource efficient strategies which were examined in order to improve the environmental performance of the base case study house.

4.2. STRATEGIES TO MINIMIZE LAND OCCUPATION

Two steps were taken to reduce the land area directly occupied by a single family detached house; minimizing lot area and reducing street width.

Reducing lot size is a crucial step in improving the environmental performance of a single family house. Generally, municipal by-laws tie the maximum allowable size of a house to the size of the lot in which it is located. Smaller lots result in smaller houses, reduce the length of streets, sidewalks, curbs, gutters, and utilities and produce substantial savings in site preparation. Zoning requirements generally include minimum front-, side- and rear-yard setbacks. These requirements limit the usability of small lots. Affordable housing design has a rich tradition in overcoming these limits. Zero lot line, Z lot configuration, and clustering arrangements are some of the options available to maximize the benefits of a small lot. Zero lot line permits units to be sited on one or more lot lines, making efficient use of available space by creating a single, usable yard area rather than two small and difficult to use narrow sideyards. "Z" lot concept is an adaptation of Zero Lot Line approach. These angled lots expand frontages and expose more of the home to the street. Clustering arrangements are designed to combine higher density, aesthetics, and livability. Clustering can be incorporated into site development plans to preserve open space for community use while reducing development land requirement.

Reducing street width in residential areas could result in a substantial land reduction. The width of the street in front of the improved house is assumed to be 16 meters instead of the current 20 meters (Nichols Vandenberg Architects, 1992).

Other strategies which could minimize the loss of productive land are:

- Avoid building in highly sensitive ecological areas.
- Design with minimum impact on the site (e.g., earth sheltered homes)
- Locate new developments in areas with minimum damage to the biologically productive lands (within existing urban areas, e.g., infill projects).
- Maximize efforts to protect existing natural flora on site.
- Minimize out-side covered areas and maximize areas of vegetation.

4.3. STRATEGIES TO MINIMIZE MATERIAL CONSUMPTION

There are two basic material use strategies in designing environmentally responsible buildings; substitution and reduction (Cole, 1995).

- Substitution is using building materials that are considered "environmentally friendly" for characteristics such as durability, renewable source, low energy content, low off-gassing, and recycled content instead of currently used materials that do not have these characteristics.

- Reduction involves reducing the quantity of materials normally used in a conventional house. The premise is that buildings could be smaller and less massive and yet meet the needs for which they are built.

The combination of material substitution and reduction strategies could potentially result in much more environmentally responsible buildings.

The quantity of materials used in the base case house is reduced by designing a smaller house and incorporating other design strategies. A smaller house is considered as the most important feature in a more sustainable house (A.C.E., 1991). The size of the base case study house was reduced without losing any of the amenities. The floor area in the improved version became 129.7 m^2 which is a 33% smaller than the base case study house. The reduction was achieved by designing spaces strictly for the need of actual occupants of the house, reducing excess circulation spaces and the size of less frequently used areas such as entrance foyers. Large under-used spaces are a waste not only of materials but also of land and energy.

Other choices made to reduce material use are:

- Eliminating the basement, and thereby conserving a large amount of concrete, steel, and formwork materials.

- Obtaining a more compact design and reducing exterior surface area which is one of the most material intensive assemblies in the house.

- Minimizing interior walls and doors on the main floor.

The strategy of using more environmentally friendly materials was not fully implemented in the improved house. The type of materials are kept the same as the original project to achieve a direct comparison between the Ecological Footprints of the two versions. However, this has eliminated the opportunity to choose materials which would have contributed to a further reduction of resource consumption by having recycled content and being durable, reusable, and recyclable. The following are some such strategies ;

- Using advanced framing techniques.

- Substituting a carport for the garage.

- Using concrete with 20% fly ash additive, which increases its strength from 3000 p.s.i. to 3400 p.s.i. and allows a reduction in the thickness of foundation walls from 200 mm to 150 mm (Loken, 1993).

- Reducing the use of solid dimensional lumber products and increasing the use of engineered wood products (finger-jointed studs, stress skin foam core panels, structural panels of plywood skins and honycomb core of phenolic-resin-saturated kraft paper)

- Using pre-cast concrete to reduce the amount of materials used and wasted, the amount of formwork, noise, dust, and damage to natural and built structures on the job-site and surrounding area.

- Using pre-assembled homes or components.

- Replacing wall to wall carpeting with wood flooring.

4.3.1. Strategies to Minimize Material Wastage

Analysis of the Ecological Footprint of the base case study house shows a large amount of material wasted during construction and maintenance of the house. The reduction principle followed throughout the improvement process should be embraced again to reduce construction waste.

Waste reductions could be achieved at the various stages of construction (SPARK, 1991 and CMHC, 1991):

- Minimization of site-clearing waste.

- Specification of durable and low-packaging materials.

- Optimization of materials handling during transportation and delivery.

- Improvement of material storage procedures.

- Avoidance of inappropriatly ordered materials or materials ordered in surplus which are non-returnable.

- The use of experienced workforce to optimize the use of purchased materials.

- The use of prefabricated elements wherever possible.

- Creation of financial incentives for workers to reduce waste.

Re-use and recycling strategies should also be followed in waste management. Re-usable materials, components, and parts of the previous building should be diverted from the landfill and re-used in the construction of new houses. Materials that normally are thrown into the disposal bin, such as off-cuts from framing lumber should be re-used as bridging, blocking or forming stakes. Similarly, waste sheet metals should be used for patching. The future re-usability and recyclability of materials used in the new project has to be considered at design and construction stages. Planning for future re-use of materials and components includes the use of durable materials, the use of easy to separate materials and components. Durability and ease of separation of a material increases the probability of it being salvaged and reused.

Recycling is the third strategy in waste management and is becoming a growing option in Canada. There are, already, many companies in B.C. which recycle various building materials including, asphalt, cardboard, concrete, gypsum board, land clearing waste, metals and others (SPARK, 1991). Effective waste management requires knowledge of the existence of these centers and planing the transfer of recyclable materials to these centers as early as possible.

4.4. STRATEGIES TO MINIMIZE EMBODIED ENERGY

The embodied energy of a smaller house is reduced due to the reduction in the amount of materials and the energy required to construct them. Eliminating the basement drastically reduces the amount of concrete usage in the house. The production of cement, a component of concrete, is one of the most energy intensive of all industrial manufacturing processes. About 5000 MJ are consumed to produce one tonne of cement.

Further reduction in embodied energy could be achieved by:

- Choosing alternative materials with low energy intensities (e.g., wood flooring instead of wall-to-wall carpeting).
- Using local materials and labor to reduce transportation of material and personnel.
- Using efficient construction equipment.
- Using the equipment efficiently.
- Eliminating exterior sheathing.

4.5. STRATEGIES TO MINIMIZE OPERATING ENERGY

Operating energy, as shown in the analysis of the base case house, represents 76% of the life cycle energy consumption. Operating energy is the energy consumed for:

- Space heating
- DHW
- Lighting
- Operating appliances.

4.5.1. Space Heating

Space heating represents 50.3% of operating energy in the base case study, reducing space heating energy therefore, becomes a major goal in improving the environmental performance of single family houses. Space heating energy requirements are a function of Auxiliary space heating = (envelope loss + Air Exchange Losses) - (Useful solar heat gain[14] + Useful internal gains[15]).

Reducing envelope and air exchange heat loss and increasing the useful solar gain, therefore, are the main objectives to persue in order to reduce space heating requirements. The use of energy efficient heating equipment could reduce energy consumption further.

4.5.1.1. Improving Envelope Thermal Resistance

The envelope of the house includes the exterior walls, roof, floor, windows, and doors. Heat loss through the envelope accounts for 73% of the total heat loss in a typical house (Lencheck et al,

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[14]Useful solar gain is the proportion of solar gain that contribute to the reduction in output of a house's heating equipments. The quantity of solar gain that is above the desired heating level is unwanted and solar gain that is not sensed by the thermostat could be considered not useful solar gain.(Yannas, 1994)

[15]A house is considered to be a skin dominated building where operating energy is strongly linked to the thermal characteristics of the envelope.

1987). Table 4-1 shows the contribution of each envelope component to total heat loss (CHBA, 1987).

Table 4-1. Heat Loss Through Envelope Components.

Envelope component	Percentage of heat loss
Ceiling	11-12%
Walls	10-17%
Basement floor	15-21%
Windows and doors	28-30%

Heat flow through an envelope component depends on its thermal resistance and the temperature difference between the inside and outside. The thermal resistance of the envelope is improved by using insulation materials in the walls, roof, floor, and selecting improved performance windows and doors.

Insulation Materials:

Effective insulation materials should have the following characteristics (EMRC, 1990) :

- Resistance to heat flow
- Ability to fill the space completely and evenly
- Durability
- For some locations, ability to withstand exposure to light, heat or moisture.

There are four basic forms of insulation.

- Batt or blanket
- Loose fill

- Rigid boards
- Foamed in-place:

Table 4-2. Presents Various Type of Insulation Materials (EMRC, 1990, Lencheck et al, 1987, GBG, 199).

TYPE	MATERIAL	BEST USE	RSI/mm
Bat	Glass fiber	Exposed walls and attics	0.022
Bat	Mineral wool	as above	0.023
Bat	Agricultural fiber	as above	
Loose	Cellulose-blown	Irregul. and inaccessible spaces	0.025
Loose	Cellulose-poured	as above	0.024
Loose	Glass fiber-blown	as above	0.02
Loose	Glass fiber-poured	Open horizontal surfaces	0.021
Loose	Mineral wool-blown	Vertical and horizontal	0.021
Loose	Mineral wool-poured	Attics and walls	0.022
Loose	Vermiculite-treated	Vertical and horizontal	0.016
Loose	Vermiculite-untreated	Vertical and horizontal	0.017
Loose	Perlite insulation	Concrete block cavities	
Rigid	Glass fiber board-below grade	Below grade exterior	0.029
Rigid	Glass fiber board-above grade	Above grade sheathing	0.031
Rigid	Expanded Polystyrene-low density	Interior and ext. sheathing	0.026
Rigid	Expanded Polystyrene-high density	Ext. foundation walls	0.028
Rigid	Extruded Polystyrene-low density	Int. and ext. sheathing	0.034
Rigid	Extruded Polystyrene-high density	Ext. foundation walls	0.035
Rigid	Polyurethane and polyisocyanrate	At premium spaces	.040-.050
Rigid	Phenolic foam board-open cell	At premium spaces	0.3
Rigid	Phenolic foam board-closed cell	At premium spaces	1.46
Foam	Polyurethane	cavities	0.042
Foam	Cementitious foam		
Foam	Semi-flexible isocyanurate plastic foam	cavities	0.03

In addition to the thermal effectiveness of an insulation material other characteristics are also considered in an environmentally responsible design. The impact on human health, resource and energy use, and ozone layer depleting content should be considered in selecting the type of insulation. Fiberglass batts are currently the most common form of wall insulation and often used under floor cavities and cathedral ceilings. Fiberglass is manufactured by melting silica sand and recently some manufacturers have started to add recycled glass to their mix. This process of manufacturing fiberglass insulation is, therefore, very energy intensive. The possible damage to human health is an important disadvantage of this type of insulation. Fiberglass fibers may constitute a health hazard for workers manufacturing the product as well as those installing it. The International Agency for Research on Cancer has designated all man made mineral fibers as "possibly carcinogenic to humans" (Grady, 1992). Mineral wool consists of natural rock or industrial slag and does not contain toxic additives. Cellulose fiber is made from shredded newsprint and treated with chemicals (borax, and boric acid) that resist fire and fungal growth. Agricultural fiber insulation is available in the form of cotton insulation made with mill waste, low grade, and recycled cotton. It is treated with a non-toxic fire retardant (GBG, 1991).

Rigid insulation's employed as sheathing in houses have played an important role in achieving high RSI values. The use of ozone depleting materials used in manufacturing many of these insulation causes environmental concern. Rigid fiberglass, produced from glass fibers, is thought to be the most environmentally benign of the rigid insulation material. Extruded polystyrene insulation is foamed with (CFC) or (HCFC) both of which contribute to ozone depletion. Expanded polystyrene, by contrast, is free from ozone depleting substances.

The selection of a certain type and thickness of insulation is influenced by type of structure and the characteristics of other materials composing the assembly. A 38x140 mm exterior wall frame offers the opportunity for higher insulation than 38x89 mm wall and a double wall construction offers the opportunity for even higher insulation levels. The combined RSI value of all the parts that make up the assembly, called the composite RSI value, can be evaluated as if they were one homogeneous material with an average value (Lencheck et al, 1987). Table 4-3 presents RSI values of various envelope components.

Table 4-3. The Composite RSI Values of Various Wall and Roof Assemblies (SAR engineering ltd. & Habitat Design+Consulting Ltd.)

WALLS		ROOFS	
Description	R-Value (m^2 C/W)	Description	R-Value (m^2 C/W)
38x89; RSI 2.4 bat	2.35	RSI 4.9 Blown	5.12
38x89; 25 mm xtps II	2.98	RSI 5.6 Blown	5.83
38x140 filled cavity	3.06	RSI 7.0 Blown	7.24
38x89; 37 xtps I	3.43	RSI 8.8 Blown	9.05
38x140; 25 mm xtps II	3.97	RSI 10.6 Blown	10.85
38x140; 38 mm xtps II	4.16		
38x140; 38 mm xtps I	4.44		

Windows: Historically, windows have had relatively low thermal resistance due, mainly, to the poor insulating properties of glass. However, window technology is advancing faster than any other single building technology. Windows have, already, undergone substantial improvement in their thermal performance during the last few years. This is due to the following developments;

- Use of multiple glazing (double, triple, and quadruple)

- Use of low-emissivity coating on the glass surface. Low-e coatings block some of the solar heat (near infrared) from passing through the window; the fraction of solar radiation blocked depends on the amount of coating applied (low, medium, and high levels). Low-e windows also reflect back into the house most of the radiation being emitted by indoor objects.

- Use of heat mirror films. This works in the same way as low-e windows, except the special low-e coating is applied to thin plastic Heat Mirror films suspended between the two panes of glass rather than onto the glass itself.

- Reduction of conductive heat losses by filling between glazings with low-conductivity gas such as argon and Krypton.

- Replace aluminum spacers with insulating spacers (e.g., fiberglass, silicone foam) to reduce heat loss through the spacer separating the panes of glass in sealed insulating windows.

- Use of vinyl, wood, and thermal broken aluminum frame instead of solid aluminum.

Table 4-4. Different Window Types and Their U-Values

DESCRIPTION	U-VALUE W/m^2 C
Double Glazing and low-e	2.01
Double Glazing low-e argon	1.88
Double Glazing, low-e, argon, and insulating spacer	1.77
FFV Double Glazing low-e, argon, and insulating spacer	1.61
FFV TG low-e argon insulating spacer	1.25
FFV TG 2 low-e argon 2a	1.06
FG TG 2 low-e 2 argon	1.06

Doors:

There are various types of exterior doors with different levels of resistance to heat loss and different environmental characteristics. Wood, steel, and fiberglass doors are available (Kokko and Carpenter, 1993).

- Wood Doors: the door industry, forced by declining supply of high quality clear lumber, has moved to innovative ideas to reduce the demand on the traditional solid-wood doors. Products such as finger-jointing and edge gluing of low quality woods are covered with high quality veneers from clear heartwood. Wood doors have lower embodied energy and insulating value than steel and fiberglass doors. The thermal resistance of a typical wood door is 0.45 m^2.K/W

- Steel Doors: Steel doors are made with a thermally broken steel skin over a wood perimeter frame and the center filled with polyurethane foam. A typical steel door offers twice the thermal resistance of a wood door (0.88 m^2·K/W) although the embodied energy is 52% higher. Water-blown polyurethane cores are being developed to replace the current CFC blown polyurethane.

- Fiberglass Doors: the construction of fiberglass doors is similar to steel doors. However, the environmental impacts of producing this type of door is lower than steel doors. A fiberglass door has 75% the thermal resistance of a steel door (0.65 m^2.K/W) and has the same embodied energy and life expectancy.

4.5.1.2. Improving Air tightness

Air infiltration refers to leakage of cold air into the house and the escape of heated air to the exterior through cracks, windows, and doors. The loss of heat through infiltration is a function of :

- The overall air tightness of the house
- The temperature and pressure difference between the interior and exterior

Wind forces, stack effect, forced ventilation (e.g. bathroom and kitchen exhaust fans) and combustion appliances that draw unheated air into the house through cracks and openings (Table 4-

5), are all mechanisms which drive air infiltration. Airtightness can be expressed as an air change rate per hour (ACH). Air leakage for a typical house could be as high as 1.5 ACH at normal pressure, whereas in an energy efficient house it could be as low as 0.1 ACH (CHBA, 1987).

Table 4-5. The Contribution of Envelope Components To Air Infiltration (National Research Council in ERDG-U.S., 1981)

Walls and basement floor	60%
Ceiling	20%
Window and door	20%

The airtightness of a house can be quantified by using "Air leakage testing" that measures air changes rate per hour in a house at standardized pressure difference of 50 pascals between indoors and outdoors. This difference is maintained by using equipment to de-pressurize or pressurize the house. Air leakage in new Canadian housing ranges between 2.5-12 ACH at 50 Pa (Mattock, 1995). Another measure of air tightness is Normalized Leakage Area (NLA). This method rates a building envelope in terms of average area of cracks and holes in cm^2 per square meter of envelope area. NLA is considered to be the best comparative measure of airtightness (Mattock, 1995). NLA for new Canadian housing ranges from 0.35 cm^2/m^2 to 6 cm^2/m^2 (Mattock, 1995).

The improved house will be assumed to incorporate a continuous air barriers which will minimize air infiltration.

4.5.1.3. Solar Design

Solar design can reduce the need for auxiliary heating. The degree of benefits from solar heating depends on general climatic and site-specific conditions. Climatic conditions include; daily and seasonal variation in air temperature, the speed, direction, and frequency of seasonal winds, and the amount of solar radiation. Site specific conditions include; topography and surrounding urban development and vegetation. Effective orientation is the most important prerequisite of solar design. The house and the glazed areas should be designed to maximize the useful solar energy by.

- Providing a southern exposure to the widest elevation

- Avoiding permanent obstruction of sunlight by parts of the same house or other buildings and vegetation.

- Shielding the house from winter winds while promoting summer breezes.

- Shielding the south glazing from excessive summer sun.

The following are three passive solar heating systems.

Direct gain:

This is the process where the solar energy penetrates glazed areas in a house (windows, clerestories) and strikes the floor and walls which then act as thermal storage elements. Glazing material properties, area, orientation, amount of sunlight, and the availability of shading devices are factors that determine the effectiveness of direct gain.

Thermal storage wall:

This heating mode involves the use of a dark colored massive wall (positioned between a glazed opening and a living space) that collects solar radiation incoming through the glass and releases it to the living space. Thermal storage walls have found limited acceptance due to their architectural limitations and because of the extreme difficulty in incorporating an effective night-time insulation between the glazing and the wall (Cole, 1993).

Attached Sunspace:

This strategy develops thermal storage concept by widening the glazed area to form a greenhouse. The greenhouse in addition to providing solar heat creates a new space usable as living space and to grow plants.

4.5.1.4. Mechanical Space heating system:

The capacity of space heating equipment is an important factor to determine its efficiency. "It has long been a common practice for residential furnaces and furnace fans to be oversized often by 40% or more" (Marbek, 1993). Heating requirements for an energy efficient house are less than a conventional house. Therefore traditional rules of thumb for sizing of a system will result in further oversizing. A room by room heat loss analysis is necessary in order to have proper sizing of the system.

Electric, gas-, oil-, and wood-fired space heating equipment is available. A gas-fired equipment is considered to be the most environmentally benign form of space heating (Yannas, 1994). It has the highest overall efficiency from primary energy to useful heat. Furthermore, gas has the lowest level of CO_2 emission among fossil fuel types. Electric space heating system is the most efficient system at the point of use, but there is large amount of heat wasted during the generation of electricity. A nuclear plant, for example, produces an amount of heat which is three times the electricity generated. Further 10% of the electricity generated by various plants (nuclear, hydro, fossil fuel) is lost to resistance in transmission lines (Grady, 1992). Heating a house is not considered to be the most efficient use of electricity[16] (CMHC,1991). A large number of older houses still use oil fired furnaces, and there are also wood firing equipment in use, mainly as a secondary heat source. Oil and wood fired equipment generates large amount of CO_2 and other pollutants both in and out of the house. In an efficient mechanical system, combustion equipment must have an induced venting system or a sealed combustion system which directly draws combustion air from and discharges combustion gases to outside.

Active solar space heating systems can provide part of the home's space heating needs. Active solar systems differ from passive systems in using external energy (usually electricity) to pump water or blow air from a solar collector to a separate store or living space.

Photovoltaic is a form of active solar systems which can provide clean renewable electricity to be used in operating a house. A photovoltaic system is composed of panels, inverters, charge controllers, wiring, and batteries. The productivity of PV panels depends on their size, rating (the power generated in an hour of direct sunlight), and on daily operating time. PV arrays must be oriented to receive the maximum sunlight. Inverters are used to convert the direct current (DC) produced by the system to alternating power (AC) which is typically used by domestic appliances. Batteries are used to store energy from a PV system for the periods when there is insufficient sunlight. Charge controllers regulate the voltage entering batteries to avoid overcharging the batteries.

Mechanical Ventilation: The continuous renewal of indoor air is essential for occupant health and well being. The use of mechanical ventilation is required in an energy efficient house.

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[16] Not matching resources to the best uses is considered a waste. Using electricity for residential space heating is considered to be a waste of a "high quality resource" in a function that could be accomplished by a "lower quality" fuel.

Ventilation system controls the introduction of fresh, clean outdoor air and the extraction of stale, polluted and moisture-laden air from the house. A central system operates more efficiently than a separate system for each function (Lenchek et al, 1987). An efficient ventilation system should be capable of supplying fresh air and exhausting polluted air in each room at a rate that prevents the accumulation of indoor air pollutants.

4.5.2. Domestic Hot Water

Domestic hot water consumes more than 20% of heating requirement in the base case study house. Hot water energy requirement depends on hot water use characteristics, water heater efficiency, and tank heat loss. The average daily demand for hot water in Canada is 78 liters per house. The typical temperature rise for domestic hot water is 45o C (Marbek, 1993). There are two types of domestic hot water systems; the tank type that heats and stores the water and the instantaneous heater. Water is heated by electricity, gas burners, or oil burners. An efficient gas fired hot water tank should be of the induced draft or sealed combustion type.

Solar water heating systems are a viable option which could provide up to 40-50% of a family's annual hot water needs. Water solar heating system is composed of solar collectors, circulation system, storage tank, backup heating system, and control system to regulate the overall system operation. Water heating requirements could be reduced as much as 70% by conservation measures such as; installing low-flow shower heads, insulating pipes near the tank and increasing tank insulation (Lenchek et al, 1987).

4.5.3. Lighting

Daylighting should be maximized in an environmentally responsible house. Daylighting provides a better quality of illumination than electric lighting. Designing for daylight can result in substantial savings in electricity use.

The electricity consumed for lighting depends in the size of the house, number of occupants, the amount of natural lighting, number of light fixtures, and the efficiency of lamps used. Almost all residents in BC use incandescent lamps for lighting (Marbek, 1993). Lighting energy use could be reduced through:

- Use of energy efficient lamps
- Use of task lighting
- Use of sophisticated lighting controls

Fluorescent lamps should become the first choice in lighting an energy efficient house. Fluorescence produce much higher lumens per watt of electricity consumed (a compact fluorescent bulb delivers about 50 lumens per watt compared to 13 lumens per watt delivered by an incandescent bulb) and last 8 to 24 times longer than incandescent lamps (Grady, 1992).

4.5.4. Efficient appliances

More than 50% of all the electricity consumed in the residential sector is used to operate appliances (Marbek, 1993). There are major and minor domestic appliances. Major appliances include; refrigerator, freezer, clothes washer, clothes dryer, dishwasher, and range/microwave. Minor appliances include; small cooking appliances (e.g., toaster, frying pans), television and video recorder, music systems, computers, and electric lawnmowers.

The energy consumed by each of these appliances could be reduced drastically by using energy efficient models and by using them efficiently. The efficiency of appliances is improving rapidly. There are new models for all type of appliances that are at least 50% more efficient than models considered efficient just 15 years ago.

4.5. CHOOSING A LEVEL OF ENERGY CONSERVATION

An important question to be addressed in energy efficient building design is which of the various strategies examined above should be adopted and on what basis. The factors to consider in adopting an energy conservation strategy are:

- Capital cost effectiveness
- Life style implications
- Balance and Compatibility with other strategies

4.5.1. Cost Effectiveness

Technological development in the last twenty years has made achieving any target of operating energy reduction possible. The Fraunhofer Institute for Solar Energy Systems, for example, has built a completely self-sufficient solar house in Freiburg, Germany. The entire energy demand for heating, domestic hot water, electricity, and cooking is supplied by the sun (Stahl et al, 1994). In Canada, all entries to CMHC's "Healthy house" competition were able to reduce their operating energy needs to 50% of the R-2000 target. These results are obtained by using technologically advanced products and high level of insulation. The use of these products result in very high construction and maintenance costs which make them not cost effective.

The adoption of energy efficient strategies is cost effective for the owner as long as the cost of the energy conserved by using them is higher than their capital cost. Cost effectiveness of an energy efficient strategy is not a fixed matter, it depends on climatic conditions, energy cost, capital cost, and the possible inclusion of "external" costs of providing energy. Cost effectiveness seems to be the main obstacle preventing the widespread adoption of advanced energy conserving technologies. This could be overcome through strict energy and material conserving regulations and energy taxes. Tax exemption and subsidies, by governments and utility companies, for modest income people to ensure the affordability of single family houses. Energy codes could also be effective in achieving this goal by assessing houses with different ecological footprint differently. Energy codes, including the national energy code which is expected to be implemented in 1996, are based on a general prescriptive envelope and mechanical system requirements rather than an evaluation of the overall energy performance of the house examined. For example, two houses, "A" and "B" designed to house the same number of people. The energy requirement of "A" is lower than "B" 's because of its efficient design. However, "A" can be penalized if the thermal resistance of some of its envelope does not meet code requirements, whereas "B" can pass by meeting those requirments. The evaluation of energy performance should not be based on the efficiency of certain components of the house, but should instead cover the overall performance of the house. New houses should aim to achieve a standard target of energy consumption considered to be sustainable. This level should be set based on the floor area of the house and on the number of its occupants. Small and efficiently designed houses should be able to meet the target by using only cost effective energy strategies (real or subsidized). All other houses should improve their energy efficiency as much as necessary to meet the target.

4.5.2. Life Style Implications

There are many examples around the world of "Autonomous" houses that have achieved complete autonomy from power utilities. Most of these buildings are not technologically sophisticated, but depend instead on various energy and resource efficient features that require continuous occupant involvement. The occupants of these houses, usually experience low comfort levels, especially in extreme weather conditions.

The health and well being of occupants should not be sacrificed in order to reduce energy and resource use in a house. Continuous user involvement could be desirable by highly motivated individuals but experience has shown that the public at large do not desire such level of involvement. This is the main reason for the scarcity of the autonomous house experience (Rousseau, 1994).

4.5.3. Balance and Compatibility Among the Various Strategies

A building is a system in which each part is related and dependent on other parts of the system. Many of the energy conservation strategies examined could effect positively or negatively other strategies in the specific area or those in other areas. A strategy, therefore, should not be applied in isolation from others. A design strategy to eliminate wasteful spaces, for example, will have positive implication for embodied and operating energy of a building while reducing north facing window area could reduce natural lighting opportunities. A balance should be achieved between various strategies to improve the environmental performance of the house.

4.5.4. Strategies Adopted:

The challenge of providing future sustainable houses is to make them affordable and have minimum impact on the life style of the people living in them. The objective of minimizing life style change was already been followed in the design improvement process which led to keeping all the amenities offered in the base case study house. Strategies adopted to reduce operating energy requirements will also have minimum impact on occupants life style.

Considering the efforts made to improve the overall environmental performance of the new design, only energy efficient strategies that are cost effective were adopted in the improved project. The strategies adopted to improve thermal performance of the improved house are based on a study prepared by SAR engineering ltd. and Habitat Design+Consulting Ltd. for the British Columbia Ministry of Energy called BCMEMPR NECH Evaluation. The report contains a detailed costing of envelope components that was carried out using information obtained from building material suppliers and construction contractors in the lower mainland. The results of a detailed life cycle costing analysis for electric, oil and gas heating for five regions[17] of B.C. are reported. The report presents a table for each envelope component with the LCC values for different RSI levels of that component.

The evaluation of the cost effectiveness of each strategy is based on whether the estimated cost of adopting the strategy is lower than the estimated cost of the energy conserved by that strategy. Life cycle cost analysis takes into consideration the fact that the cost of adopting the strategy has to be paid for immediately, yet its benefits will be spread over the life cycle of the component. To find the present worth of the energy conserved over the life span of the strategy, the concept of a "present worth factor" (P) is used. The present worth is calculated by (NECH 1995):

$$PW = C \times P$$

or

$$PW = C \times \frac{1-(1+a)-n}{a}$$

[17]These regions are; Lower Mainland (Zone A), Northern Interior (Zone B), Centra Gas Distribution (Zone C), Southern Interior, BCHPA Distribution (Zone D), and Southern Interior, WKPL Distribution (Zone E)

Where

a = the effective interest rate

PW = the present worth of the heating costs over n years

P = the present worth factor

C = the annual heating cost in the first year

n = the number of years under consideration.

The calculations of LCC for natural gas heating in the lower mainland were based on the following assumptions;

a = 4.95%

P = 15.5

C = based on $/m3=.213

n = 30 years.

The most cost effective strategy for each component examined in the study, in gas heating Zone A (Lower Mainland) is chosen for the house (Table 4-5).

Table 4-6. Cost Effective Strategies for B.C. - Zone A, Gas Heating. (SAR engineering ltd. & Habitat Design+Consulting Ltd.)

ASSEMBLY	DESCRIPTION	RSI
Walls	38x89 wall, 89 mm batt, 25 xtps II	2.98
Roof	202 mm Cellulose-Blown (RSI-4.9)	5.12
Windows	Double Glazing	.393
Ventilation	Without heat recovery	N/A

4.6. STRATEGIES TO MINIMIZE LIFE CYCLE CO2

CO_2 emission is, mainly, a result of the amount and type of energy used in the house. All strategies used, in every stage of the house's life cycle, to reduce energy consumption will also reduce CO_2 emission. The main source of energy used in operating the house will be natural gas which has the lowest amount of CO2 emission per MJ of energy consumed. There are many other strategies that could be used to reduce CO2 emissions further. Using passive and active solar energy strategies such as solar water heating system and photopholtaic panels would reduce dramatically fossil fuel energy consumption and associated CO_2 emission.

The reduction of concrete use in the improved house have reduced the amount of a non energy-relalated CO2 emission. The production of cement is a major source of CO2 emission around the world.

4.7. CONCLUSION:

This chapter has presented the various possible strategies examined to reduce the Ecological Footprint of the base case study house. The strategies examined offer high potential for Ecological Footprint reduction. However, the adoption of strategies were conditioned by the limits imposed by the method and by the commitment to the principles of cost effectiveness and minimum life style modification.

CHAPTER V: THE "ECOLOGICAL FOOTPRINT" OF THE IMPROVED BASE CASE STUDY HOUSE

5.1. INTRODUCTION

5.1.1. Objectives

The Ecological Footprint of the improved version of the base case study house is calculated for the following purposes:

- To evaluate the consequences of adopting various resource conservation and pollution prevention strategies.
- To evaluate the effect of a such reduction on the Ecological Footprint of new Canadian single family houses built each year.

5.1.2. Approach

The Ecological Footprint of the improved house is determined, as in the base case study house, by conducting a life-cycle analysis to estimate material and energy consumption, and then using land equivalency procedures to convert the estimates to biologically productive land areas. Life cycle analysis included the same resource depletion and pollution generation factors used in the base case study house. They are land, renewable resources, and energy from resource consumption area and CO_2 emission from pollution area. The same land equivalency values were used to calculate the Ecological Footprint. They include the productivity of 80 GJ/ha/yr for renewable energy supply, the global average CO_2 absorption capacity of forest at 1.8 ton per ha, and the average annual productivity of Canadian forests of 2.3 ton of wood per ha for wood supply. The calculation of the Ecological Footprint of the improved house is based on the same methods, techniques, figures, and assumptions used in calculating the Ecological Footprint of the base case study house.

5.2. HOUSE DESCRIPTION:

The improved house is designed for 4 persons. It is a wood frame two storey house with attached double garage. The total floor area of the house is reduced to 175.9 m^2: 75.8 m^2 on the main floor, 53.9 m^2 on the second floor and 46.2 on the attached double garage. A total reduction of 49.7% in floor area is achieved compared to the base case study house (Table 5-1).

Table 5-1 A comparison between the area of the improved house and the base case study house.

Floor	Base Case House m^2	Improved House m^2	Reduction %
Basement	111.6	0	100
Main	111.6	75.8	32
Second	80.6	53.9	33
Garage	46.2	46.2	0
Total	350	175.9	49.7

The size of the house is reduced without losing the amenities found in the base case house (Table 5-2). The size of all the spaces in the improved house meet building code requirements.

Table 5-2 A comparison between the spaces in both houses.

Room	Base Case House		Improved House	
	No	Area (m^2)	No	Area (m^2)
Living	1	19.51	1	14.49
Dining	1	11.64	1	11.15
Family room	1	22.60	1	11.15
bedrooms	3	19.22 10.19 8.89	3	10.03
Kitchen	1	14.72	1	12.26
bathrooms	3	2.16 5.76 9.40	3	2.23 3.25 3.90
Den	1	7.64	0	-
Sunspace	0	-	1	3.34
Utility room	1	4.00	1	4.00
Mechanical room	1	4.63	1	4.98
Double garage	1	41.5	1	41.5

The following is a description of the improved house.

- The foundation is a poured concrete slab on grade. 68 mm rigid insulation is used for foundation wall and 68 mm expanded polystyrene insulation below concrete floor slab.

- Exterior walls (RSI-2.98) are framed with 38x89 mm wood studs and insulated with 89 mm batt (RSI-2.1) and 25 mm extruded polystyrene insulating sheathing (RSI-0.88). Interior walls are 38x89 mm framed.

- The attic (RSI-5.12) is insulated with 202 mm (RSI 4.9) cellulose-blown.

- Interior finish on walls and ceilings is single coat paint plus primer on 12 mm gypsum board.

- The floor finish is 3 mm sheet vinyl in the kitchen and bathrooms with carpet elsewhere.

- The exterior wall finish is cedar siding.

- Roofing is asphalt shingles.

- All windows are double glazed.

5.3. LIFE CYCLE ANALYSIS

A detailed life cycle analysis of the improved house was carried out based on the following factors:

5.3.1. Land Occupation:

A 43% reduction in the total land area directly occupied by the improved house was achieved (Table 5-3) by decreasing lot size and reducing the width of the street in front of the house. Lot size was reduced by decreasing the floor area of the house (Table 5.1) and reducing setbacks. The front-setback is reduced from 6 to 3 meters, rear-setback from 7.6 to 6 meters, western side setback from 1.5 meters to zero lot line. The eastern side setback is increased from 1.5 meters to 2.4 meters.

A 43% reduction in the land area occupied by a single family house can reduce, considerably, transportation distances and the length of urban infrastructure. These changes are based on proposals presented in a study prepared for the Regional Municipality of Ottawa (Vandenberg Architects, 1992).

Table 5-3. A Comparison Between The Land Occupied Directly by the Base Case and Improved House.

The Use	Base Case m^2	Improved m^2	Reduction %
Lot size	622.42	320.72	48
Area of the street	205.4	120.8	41
Total	890.07	503.76	43

5.3.2 Material Consumption:

All building materials, from both renewable and nonrenewable sources, used throughout the life cycle of the house were estimated. These estimates include initial and recurring material consumption. An analysis of the results shows a 49.2% reduction in material consumption compared to the base case study house (Table 5-4).

Table 5-4 A comparison of material Consumption in both houses over 40 years

Material Consumption Cycle	Base Case (kg)	Improved (kg)	Reduction %
Initial	304,627	153,039	49.8
Recurring	16,969	10,394	38.7
Total	321,596	163,433	49.2

The largest reduction in building material use is in concrete. Concrete represent 71.5% of the total weight of the materials conserved in the improved house, followed by brick (7.6%), sand and gravel (6%), lumber and timber (5%), and gypsum products (4%). The remaining (6%) is distributed among all other building materials. A 43.4% reduction in wood products use in the improved house (Table 5-5) was achieved.

Table 5- 5. A comparison of Wood-based materials use in both houses over 40 years.

The use	Base Case kg	Improved kg	Reduction %
Lumber and Timber	21,187	11,690.3	44.8
Veneer and Plywood	5,502	3,277.4	40.4
Millwork	3,584	2,138.6	40.3
Building Paper	159	121.2	23.8
Total	30,432	17,227.5	43.4

The estimate of construction waste (Table 5-6) shows that four building materials; wood products (50.22%), gypsum board (22.95%), concrete (15.14%), and asphalt (4.04%) constitute 90% of the total initial construction waste. The total construction waste from the improved house was reduced by 48% compared to the base case study house. Applying waste reduction strategies examined in Chapter 4 will considerably reduce the amount of waste material that will end up in landfill. In the EnviroHome (Nova Scotia's advanced house), for example, the on-site waste management program was successful in reducing the amount of construction waste ending up landfill to only 33%. 66% of total construction waste was recycled and 6% was reused (CHBA-NS).

Table 5-6. The Estimates of Construction waste in the Improved House.

Material	Amount of Waste kg	Percentage of total
Ready-mix Concrete	402.3	15.14
Wood Products	1334.40	50.22
Gypsum basic Products	556.7	20.95
Insulation	50.5	1.90
Steel	6.7	0.25
Glass	21.3	0.80
Paints	0.9	0.03
Asphalt	107.4	4.04
Carpet	13.98	0.53
Plastics	20.4	0.77
Joint compound	33.4	1.26
Aluminum	8.9	0.34
Others	100.18	3.77
Total	2657.00	100.00

5.4.3. Life Cycle Energy

A life cycle energy analysis was conducted to estimate energy consumption in the improved house including both embodied and operating energy.

5.4.3.1. Embodied Energy

In analyzing the embodied energy of the house a distinction was again made between initial and recurring embodied energy.

A total of a 31.9% reduction in total embodied energy was achieved (Table 5-7). The changes made were more effective in reducing initial embodied energy (37.7%) than that of recurring embodied energy (24.8%). This is due mainly, to the maintaining of the same materials used in the base case study house in the new project. Choosing alternative materials would result in much higher reduction in recurring embodied energy. Replacing wall to wall carpeting with wood floor alone, would conserve 174,353 MJ in recurring embodied energy throughout 40 years of life cycle. This represents 29% of the total recurring embodied energy of the improved house.

Table 5-7. Embodied energy comparison

Type of Embodied Energy	Base Case MJ	Improved MJ	Reduction %
Initial	996,778	621,159	37.7
Recurring	798,484	600,794	24.8
Total	1,795,262	1,221,953	31.9

Maintaining the same materials is also the reason why the embodied energy per square meter of floor area in the improved house for a life cycle of 40 years (6.94 GJ) is higher than the embodied energy per square meter of the base case study house (5.13 GJ).

3.4.3.2. Operating Energy

A reduction of 35% in operating energy requirements in the improved house is achieved (Table 5-8). However, the Building Energy Performance Index (BEPI) of this house is 0.478 GJ/m2/year which is higher than the BEPI of the base case study (0.427 GJ/m2/year). The lack of improvement in improved house's BEPI is due to limiting the improvement in operating energy to cost effective strategies and because the unfinished basement is included in base case study house's BEPI calculation despite it is heated at a lower degree than other areas of the house.

Table 5-8 Comparison of Life Cycle Energy Consumption in the two houses.

Type of Energy	Base Case MJ	Improved MJ	Reduction %
Embodied	1,795,262	1,221,953	32
Operating	5,193,680	3,369,866	35
Total	6,988,942	4,591,819	34

In a parallel exercise to explore the potential for operating energy reduction in the improved house, a series of widely available strategies were adopted (Table 5-9). These strategies which are currently not cost effective, have reduced space and domestic water heating requirements to 24,089 MJ, 50% lower than R-2000 target figure. This represents a 60% and 76% reduction in heating requirements with respect to the improved house and the base case study house respectively. The percentage of embodied energy in the total life cycle energy for 40 years becomes 33%, and operating energy 67%.

Table 5-9 Various strategies adopted to examine the potential for operating energy reduction in the improved house

	Advanced Strategies	Cost-effective strategies
Windows	TG + coated/DG + 2 films, Low-E/Heat Mirror, Argon, Insulating, Vinyl, Shutters	DG
HRV	Heat Recovery Ventilator	Without (HRV)
Heating	Air Source Heat Pump	Condensing Furnace
DHW	Solar collector and Gas	Gas-fired
Walls	38x140; 37 mm xtps I	38x89, 25 mm xtps II
Roof	RSI 10.6 Blown	RSI 4.9 Blown

5.3.4. Life Cycle CO_2 Emission Analysis

An estimated 33% reduction in life cycle CO_2 emission was achieved in the improved house (Table 5-10). The improvement in recurring CO_2 emissions is the lowest recurring because fast replaced materials such as carpet and asphalt shingles dominate recurring material use.

Table 5-10 A comparison between life cycle CO_2 emission in both houses Over 40 years.

Type of CO_2 emission	Base Case kg	Improved kg	Reduction %
Initial	58,316	36,240	38
Recurring	36,701	33,063	10
Operating	264,530	171,976	35
Total	359,547	241,279	33

5.4. TOTAL ECOLOGICAL FOOTPRINT CALCULATION

The Ecological Footprint of the improved house is the sum of initial and recurring Ecological Footprints.

Initial Ecological Footprint = directly occupied land + initial materials + initial CO_2 (Table 5-11)

Recurring Ecological Footprint = directly occupied land + recurring materials + recurring CO2 absorption (Table 5-11)

Table 5-11 Improved house's total Ecological Footprint constituents

Life cycle period	Direct land ha	Material ha	CO_2 ha	Total ha
Initial E F	0.05	18.58	5.500	24.13
Recurring E F	2.02	1.44	31.090	34.55
Total E F	2.07	20.02	36.59	58.68

The Ecological Footprint of the improved house is 58.68 ha of biologically productive lands which is 35.6% smaller than the Ecological Footprint of the base case study house (Table 5-10).

Table 5-12 Ecological Footprint Comparison

Ecological Footprint	Base Case House ha	Improved House ha	Reduction %
Initial	39.71	24.13	39.2
Recurring	51.35	34.55	32.7
Total	91.06	58.68	35.6

A reduction of this magnitude in the Canadian single family housing sector would result in the conservation of vast areas of Canada's biologically productive land used to build new single family houses and maintain and operate them throughout their life cycle.

CHAPTER VI: CONCLUSIONS

6.1. INTRODUCTION

There is general agreement that sustainability will require that human activity become, significantly, less material and energy intensive than at the present time. This thesis has contributed to the sustainability debate by studying the potential for energy and material conservation and pollution prevention in single family detached housing.

6.2. FINDINGS

The thesis has determined the following key conclusions:

- Energy is the most important environmental issue related to single family houses. Land areas required to absorb CO_2 emission are the largest constituent of the Ecological Footprint of houses followed by land areas required to produce biomass to generate energy. These results show clearly that energy, as a major contributor to CO_2 emission today and as a resource in the post-fossil fuel era, is the most important environmental concern that has to be addressed.

- Operating energy represents the largest component of energy consumption in a house. It constitutes 76% of the total life cycle energy in the base case study house. Despite the large reduction in the overall operating energy requirements in the improved house, operating energy still accounts for 73% of life cycle energy consumption. The percentage of operating energy was reduced to 67% in the improved house, only, when the use of a series of expensive, technologically advanced strategies were assumed.

- The reductions obtained in the improved house compared to the base case study house were:

Directly occupied land	48.0%
Building materials use	49.2%
Life cycle energy consumption	34.0%
Life cycle CO_2 emission	33.0%

- To maintain the affordability of single family detached house, the reduction of the ecological footprint is obtained by reducing its size, improving its design and adopting only energy efficient strategies that are cost effective.

- A 35.6% reduction in the Ecological Footprint of the base study house is obtained. The Ecological Footprint of the improved house is 58.68 ha in comparison to 91.06 ha in the base case study house. A greater reduction could have been achieved without the limits imposed by EF/ACC method use and the commitment of the Ecological Footprint reduction process to the principles of capital cost effectiveness and minimum change in life style.

- In a parallel exercise to explore the potential for operating energy reduction, the adoption of a series of advanced technologies which, currently, are not cost effective were assumed. The Ecological Footprint of the improved house was reduced to 41.63 ha of biologically productive land. This represents a greater than 54% reduction of the Ecological Footprint over that of the base case study house.

6.3. THE VALUE OF THE EF/ACC METHOD

- The Ecological Footprint method provides the basis for comparing the magnitude of various environmental factors by using a single indice (hectares of productive land areas) to measure elements (land, energy, materials) which otherwise have different measurement units with no immediate connection among them.

- Using land area which is a tangible direct physical unit made the environmental impact of single family house easy to visualize. It is much easier to relate to a m^2 of land area rather than a GJ of energy or a kg of CO_2.

- The method clearly shows the link between the various competing human activities and available natural resources and how the carrying capacity appropriated by one activity diminishes the carrying capacity that can be appropriated by others.

- By defining resource consumption and pollution in terms of biologically productive land area, whose availability is limited, the method has effectively demonstrated the limits to growth in human economy. Continuing growth in human activity would require an infinite supply of biologically productive lands.

- The method was effective in analyzing the environmental impact of the base case study house and identifying the areas to be targeted in the process of improving the environmental performance of the house.

- The Ecological Footprint of the house does not include indirectly occupied land areas, land implications of extracting non-renewable materials, construction and demolition waste landfills, and demolition energy because of the difficulties associated with their calculation. As result of these omissions, the Ecological Footprint of the projects examined in this thesis are smaller than their actual size.

- Not including every possible impact of the materials that could potentially be used in a house, has limited the ability of the study to use more environmentally benign materials in place of those used by base case study. The use of a material whose impacts are all included in its Ecological Footprint instead of another for which they are not, or vice versa, would lead to an unfair comparison.

- The magnitude of the environmental impact of an activity can be underestimated by some of current Ecological Footprint procedures. The area of biologically productive lands degraded by a building or any other project, for example, could be much larger than the specific land it occupies. The specific land area is often part of an ecosystem and the occupation of a portion of that ecosystem could destroy a large part, if not the entire ecosystem.

6.5. SUGGESTIONS ABOUT THE METHOD

- The method, currently, considers biomass as the only choice to supply an activity with renewable energy. Renewable energy sources other than biomass (wind, solar, hydro, hydrogen, geothermal) should be considered as potential suppliers of energy.

- To be precise and effective in evaluating technological products, the method has to include land implication of greater range of materials and processes (e.g., extracting non-renewable materials, hydro-electricity, and providing water).

- The precise share of the biologically productive lands of the planet from human resource supply and waste absorption is unknown. The contribution of factors such as oceans has to be investigated.

6.4. SUGGESTIONS

The thesis has identified a series of key directions for future work:

- Determining the per-capita sustainable level of material and energy consumption that could be allocated for housing, based on the carrying capacity of regional, national and global environments would help in assessing the sustainability of a housing unit.

- Examining the relationship between global resource conservation and pollution prevention which concerns this method and other environmental issues which are related to buildings such as site ecology and indoor air quality.

- Examining the apparent conflict between regulations that constrain resource use, needed to implement sustainability, and the principles of an economy based on maximizing material growth opportunities.

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APPENDIX A1: BASE CASE STUDY HOUSE LIFE CYCLE CALCULATIONS: INITIAL.

Item/Location	Qnty	No	Units	Tot Qty	Conver-sion	As Buit	Waste	Initial Wt	Unit E E	Initial E E	CO2	Initial CO2
					to kg	kg	kg	kg	MJ/kg	MJ	g/kg	kg
SECTION 1 SITE WORK												
CONCRETE FLATWORK												
Driveway	14.0	1.00	Yd3	14	1,797	25158	125.79	25,283.8	0.75	18,962.8	75	1,896.3
Sidewalks	1.0	1.00	Yd3	1	1,797	1797	8.99	1,806.0	0.75	1,354.5	75	135.4
Patio	3.0	1.00	Yd3	3	1,797	5391	26.96	5,418.0	0.75	4,063.5	75	406.3
SITE DRAINAGE												
4" perforated plastic pipe perimeter footing drainage	220.0	1.00	Ft	220	0.500	110	5.50	115.5	160	18,480.0	508	58.6
3/4" course gravel backfill	11.8	1.00	Yd3	11.75	1,468	17249	0.00	17,249.0	0.09	1,552.4	6	108.5
SECTION 2 CONCRETE												
FORMWORK												
BASEMENT FOUNDATION												
Strip footing forms	428.0	0.20	Ft	85.6	1.695	145.092	7.25	152.3	5.8	883.6	449	68.4
Pad footing forms	92.0	0.20	Ft	18.4	0.339	6.2376	0.31	6.5	5.8	38.0	449	2.9
Pedestal forms	25.0	0.20	Ft	5	1.018	5.09	0.25	5.3	5.8	31.0	449	2.4
Slab edge forms	18.0	0.20	Ft	3.6	0.678	2.4408	0.12	2.6	5.8	14.9	449	1.2
Grade beam forms	3.0	0.20	Shts	0.6	24.390	14.634	0.73	15.4	5.8	89.1	449	6.9
Foundation wall forms	106.0	0.20	Shts	21.2	24.390	517.068	25.85	542.9	5.8	3,148.9	449	243.8
Retaining wall forms	13.0	0.20	Shts	2.6	24.390	63.414	3.17	66.6	5.8	386.2	449	29.9
1x2 level strip	271.0	0.20	Ft	54.2	0.169	9.1598	0.46	9.6	5.8	55.8	449	4.3
Exterior bsmnt strs frms	40.0	0.20	Ft	8	1.018	8.144	0.41	8.6	5.8	49.6	449	3.8
Exterior steps forms(ply)	1.0	0.20	Shts	0.2	24.390	4.878	0.24	5.1	10.04	51.4	559	2.9
Exterior steps forms(lmbr)	16.0	0.20	Ft	3.2	1.018	3.2576	0.16	3.4	5.8	19.8	449	1.5
2x4 keyway	214.0	0.20	Ft	42.8	0.678	29.0184	1.45	30.5	5.8	176.7	449	13.7
CAST IN PLACE CONCRETE												
BASEMENT FOUNDATION												
Strip Footings	8.0	1.00	Yd3	8	1797	14376	71.88	14,447.9	0.75	10,835.9	75	1,083.6
Footing pads	2.5	1.00	Yd3	2.5	1797	4492.5	22.46	4,515.0	0.75	3,386.2	75	338.6
Basement floor slab	12.3	1.00	Yd3	12.25	1797	22013.25	110.07	22,123.3	0.75	16,592.5	75	1,659.2
Garage floor slab	6.0	1.00	Yd3	6	1797	10782	53.91	10,835.9	0.75	8,126.9	75	812.7
Grade beam	2.3	1.00	Yd3	2.25	1797	4043.25	20.22	4,063.5	0.75	3,047.6	75	304.8
Foundation wall	51.5	1.00	Yd3	51.5	1797	92545.5	462.73	93,008.2	0.75	69,756.2	75	6,975.6
Ext basement stairs	1.3	1.00	Yd3	1.25	1797	2246.25	11.23	2,257.5	0.75	1,693.1	75	169.3
Exterior steps	0.5	1.00	Yd3	0.5	1797	898.5	4.49	903.0	0.75	677.2	75	67.7
Retaining walls	4.8	1.00	Yd3	4.75	1797	8535.75	42.68	8,578.4	0.75	6,433.8	75	643.4
REINFORCING												
Structural slabs rebar	65.0	1.00	Ft	65	0.473	30.745	1.54	32.3	36.05	1,163.8	2326	75.1
Garage floor slab w.w.m.	495.0	1.00	Ft2	495	0.100	49.5	2.48	52.0	48	2,494.8	2648	137.6
CONCRETE ACCESSORIES												

1/2" dia Anchor bolts	58.0	1.00	No	58	0.130	7.54	0.15	7.7	45	346.1	2747	21.1
Dampproofing	1475.0	1.00	Ft2	1475	0.680	1003	50.15	1,053.2	2.5	2,632.9	632	665.3
Granular fill under bsmnt slab	17.0	1.00	Yd3	17	1127.0	19159	0.00	19,159.0	0.03	574.8	6	120.5
Granular fill under garage slab	7.8	1.00	Yd3	7.75	1127.0	8734.25	0.00	8,734.3	0.03	262.0	6	54.9
6 mil poly moisture barrier	1094.0	1.00	Ft2	1094	0.013	14.222	0.71	14.9	28.6	427.1	508	7.6
1/2" expansion joint filler	159.0	1.00	Ft	159	0.045	7.155	0.36	7.5	38	285.5		0.0
SECTION 3 MASONRY												
CONC. BLOCK WALLS												
8"x8"x16" solid blocks	32.0		No	32	22.680	725.76	14.52	740.3	1.32	977.2	81	60.3
Reinforcing wall ties	28.0		No	28	0.057	1.596	0.08	1.7	45	75.4	2747	4.6
MASONRY VENEER												
Common bricks	1710.0		No	1710	3.100	5301	106.02	5,407.0	2.50	13,517.6	139	750.7
Mortar	1.5	1.00	Yd3	1.5	31.750	47.625	2.38	50.0	1.80	90.0	106	5.3
Metal wall ties	170.0		No	170	0.057	9.69	0.48	10.2	45	457.9	2747	27.9
Split face conc. block-4"x12"x16"	84.0		No	84	15.500	1302	65.10	1,367.1	1.32	1,804.6	81	111.4
MASONRY FIREPLACES												
Common bricks	1747.0		No	1747	2.040	3563.88	71.28	3,635.2	2.50	9,087.9	139	504.7
Fire bricks	180.0		No	180	3.310	595.8	0.00	595.8	2.5	1,489.5	139	82.7
12"x16"x8" flue linings	20.0		No	20	12.700	254	5.08	259.1	2.5	647.7	139	36.0
Mortar	1.5	1.00	Yd3	1.5	31.750	47.625	2.38	50.0	1.8	90.0	106	5.3
Metal wall ties	190.0		No	190	0.057	10.83	0.54	11.4	45	511.7	2747	31.2
8"x8" cast iron clean out doors	1.0		No	1	4.536	4.536	0.00	4.5	28	127.0	1730	7.8
5"x8" cast iron ash dumps	1.0		No	1	3.180	3.18	0.00	3.2	28	89.0	1730	5.5
Metal dome damper	1.0		No	1	10.210	10.21	0.00	10.2	28	285.9	1730	17.7
Fireplace lintel angles	1.0		No	1	6.270	6.27	0.31	6.6	28	184.3	1730	11.4
Hearth finish	1.0		No	1	10.000	10	0.50	10.5	2.5	26.3	139	1.5
Combustion air kit	1.0		No	1	5.000	5	0.25	5.3	28	147.0	1730	9.1
Tight fitting glass doors	1.0		No	1	40.000	40	0.00	40.0	20	800.0	1044	41.7
brick	181.0		No	181	3.100	561.1	11.22	572.3	2.50	1,430.8	139	79.5
SECTION 4 METALS												
STRUCTURAL STEEL												
Steel angle lintels	30.0	1.00	Ft.	30	2.430	72.9	3.65	76.5	28	2,143.3	1730	132.4
NAILS												
	314.4	1.00	Lb	314.4	0.454	142.7376	7.14	149.9	45	6,744.4	2534	379.8
SECTION 5 CARPENTRY												
ROUGH CARPENTARY												
BASEMENT FOUNDATION FRAMING												
Exterior Walls												
Precut 2x6	25.0	7.77	Ft	25	7.910	197.75	19.78	217.5	5.80	1,261.6	449	97.7
Plates												
2x6	88.0	1.00	Ft	88	1.018	89.584	8.96	98.5	5.80	571.5	449	44.2
Interior Walls												
Headers												
2x10	32.0	1.00	Ft	32	1.696	54.272	5.43	59.7	5.80	346.3	449	26.8
Furring studs												0.0
2x3	125.0	1.00	Ft	125	0.509	63.625	6.36	70.0	5.80	405.9	449	31.4
Furring Plates												
2x3	326.0	1.00	Ft	326	0.509	165.934	16.59	182.5	5.80	1,058.7	449	82.0

Beams												
Built up D.Fir												
2x10	114.0	1.00	Ft	114	2.142	244.188	24.42	268.6	5.80	1,557.9	449	120.6
2x12	300.0	1.00	Ft	300	2.572	771.6	77.16	848.8	5.80	4,922.8	449	381.1
Posts and Columns												
6x6	5.0	8.00	Ft	40	6.353	254.12	25.41	279.5	5.80	1,621.3	449	125.5
3" diameter steel columns	5.0		No	5	31.840	159.2	7.96	167.2	28.00	4,680.5	1996	333.7
45# Asphalt felt	25.0	1.00	Ft2	25	0.047	1.175	0.06	1.2	12.01	14.8	632	0.8
FIRST FLOOR FRAMING												
Joists												
2x10 D. Fir	1128.0	1.00	Ft	1128	2.142	2416.176	241.62	2,657.8	5.80	15,415.2	449	1,193.3
2x2	188.0	1.40	Ft	263.2	0.509	133.9688	13.40	147.4	5.80	854.7	449	66.2
2x2	36.0	1.20	Ft	43.2	0.396	17.1072	1.71	18.8	5.80	109.1	449	8.4
Solid Blocking												
2x10	62.0	1.00	Ft	62	1.695	105.09	10.51	115.6	5.80	670.5	449	51.9
Sill Plates												
2x4	165.0	1.00	Ft	165	0.678	111.87	11.19	123.1	5.80	713.7	449	55.3
Capillary Break												
Polyethylene foam sill gasket	165.0	1.00	Ft	165	0.001	0.165	0.02	0.2	160.00	29.0	4836	0.9
Subflooring												
5/8" T&G Plywood	38.0		Shts	38	24.390	926.82	46.34	973.2	10.04	9,770.5	559	544.0
Subfloor adhesive	12.0		No.	12	0.910	10.92	0.55	11.5	97.00	1,112.2	1551	17.8
FIRST STOREY EXTERIOR WALLS												
Walls												
Precut 2x6	165.0	7.77	Ft	165	7.910	1305.15	130.52	1,435.7	5.80	8,326.9	449	644.6
2x6	75.0	1.00	Ft	75	1.018	76.35	7.64	84.0	5.80	487.1	449	37.7
Plates												
2x6	960.0	1.00	Ft	960	1.018	977.28	97.73	1,075.0	5.80	6,235.0	449	482.7
Headers												
2x10	34.0	1.00	Ft	34	1.695	57.63	5.76	63.4	5.80	367.7	449	28.5
Sheathing												
3/8" Plywood	50.0		Shts	50	14.630	731.5	73.15	804.7	10.04	8,078.7	559	449.8
Beams												
Built up D.Fir												
2x8	14.0	1.00	Ft	14	1.717	24.038	2.40	26.4	5.80	153.4	449	11.9
2x10	170.0	1.00	Ft	170	2.142	364.14	36.41	400.6	5.80	2,323.2	449	179.8
2x12	310.0	1.00	Ft	310	2.572	797.32	79.73	877.1	5.80	5,086.9	449	393.8
Posts and Columns												
6x6	1.0	8.00	Ft	8	3.053	24.424	2.44	26.9	5.80	155.8	449	12.1
FIRST STOREY INTERIOR WALLS												
Walls												
Precut 2x4	105.0	7.77	Ft	105	5.268	553.14	55.31	608.5	5.80	3,529.0	449	273.2
Plates												
2x4	420.0	1.00	Ft	420	0.681	286.02	28.60	314.6	5.80	1,824.8	449	141.3
SECOND STOREY FLOOR SYSTEM												
Joists												
2x10 SPF	800.0	1.00	Ft	800	1.695	1356	135.60	1,491.6	5.80	8,651.3	449	669.7
Cross bridging												
2x2	66.0	1.40	Ft	92.4	0.509	47.0316	4.70	51.7	5.80	300.1	449	23.2
2x2	30.0	1.20	Ft	36	0.396	14.256	1.43	15.7	5.80	91.0	449	7.0
Solid Blocking												
2x10	27.0	1.00	Ft	27	1.695	45.765	4.58	50.3	5.80	292.0	449	22.6

Subflooring												
5/8" T&G Plywood	26.0		Shts	26	24.390	634.14	63.41	697.6	10.04	7,003.4	559	389.9
Subfloor adhesive	12.0		No	12	0.910	10.92	1.09	12.0	97.00	1,165.2	1551	18.6
SECOND STORY EXTERIOR WALLS												
Walls												
Precut 2x6	110.0	7.77	Ft	110	7.910	870.1	87.01	957.1	5.80	5,551.2	449	429.7
2x6	10.0	1.00	Ft	10	1.018	10.18	1.02	11.2	5.80	64.9	449	5.0
Plates												
2x6	588.0	1.00	Ft	588	1.018	598.584	59.86	658.4	5.80	3,819.0	449	295.6
Headers												
2x10	32.0	1.00	Ft	32	1.695	54.24	5.42	59.7	5.80	346.1	449	26.8
Sheathing												
3/8" Plywood	33.0		Shts	33	14.630	482.79	24.14	506.9	10.04	5,089.6	559	283.4
Beams												
Built up D.Fir												
2x10	48.0	1.00	Ft	48	2.142	102.816	10.28	113.1	5.80	656.0	449	50.8
SECOND STORY INTERIOR WALLS												
Walls												
Precut 2x4	100.0	7.77	Ft	100	5.268	526.8	52.68	579.5	5.80	3,361.0	449	260.2
Plates												
2x4	420.0	1.00	Ft	420	0.678	284.76	28.48	313.2	5.80	1,816.8	449	140.6
ROOF SYSTEM												
Ceiling Joists												
2x4 SPF	40.0	1.00	Ft	40	0.678	27.12	2.71	29.8	5.80	173.0	449	13.4
2x6 SPF	160.0	1.00	Ft	160	1.018	162.88	16.29	179.2	5.80	1,039.2	449	80.4
Dropped ceiling furring												
2x4	284.0	1.00	Ft	284	0.678	192.552	19.26	211.8	5.80	1,228.5	449	95.1
Roof Framing												
Rafters												
2x8 SPF	546.0	1.00	Ft	546	1.359	742.014	74.20	816.2	5.80	4,734.0	449	366.5
2x10 SPF	132.0	1.00	Ft	132	1.695	223.74	22.37	246.1	5.80	1,427.5	449	110.5
2x12 SPF												
Rafters												
2x4	42.0	1.00	Ft	42	0.678	28.476	2.85	31.3	5.80	181.7	449	14.1
Ridge board												
2x10	4.0	1.00	Ft	4	1.695	6.78	0.68	7.5	5.80	43.3	449	3.3
Exterior Soffit Framing												
2x4	471.0	1.00	Ft	471	0.678	319.338	31.93	351.3	5.80	2,037.4	449	157.7
Ledgers												
2x4	9.0	1.00	Ft	9	0.678	6.102	0.61	6.7	5.80	38.9	449	3.0
Sheathing												
1/2" Plywood	79.0		Shts	79	19.500	1540.5	77.03	1,617.5	10.04	16,240.0	559	904.2
Strapping												
1x4	4321.0	1.00	Ft	4321	0.339	1464.819	146.48	1,611.3	5.80	9,345.5	449	723.5
H Clips	316.0	1.00	Ft	316.0	0.540	170.64	0.00	170.6	28.00	4,777.9	1730	295.2
EXTERIOR FINISH CARPENTRY												
EXTERIOR FINISH												
Siding												
Wood												
1x6	3456.0	1.00	Ft	3456	0.434	1499.904	149.99	1,649.9	5.80	9,569.4	449	740.8
Building Paper	2613.0	1.00	Ft2	2613	0.022	57.486	0.00	57.5	33.60	1,931.5	1045	60.1
Plywood												
1/2" Plywood	2.0		Shts	2	19.500	39	1.95	41.0	10.04	411.1	559	22.9

Corner trim												
1x4	185.0	1.00	Ft	185	0.340	62.9	6.29	69.2	5.80	401.3	449	31.1
SOFFIT AND FASCIA												
Fascia board												
2x8	278.0	1.00	Ft	278	1.359	377.802	26.45	404.2	5.80	2,344.6	449	181.5
Barge board												
2x10	16.0	1.00	Ft	16	1.695	27.12	1.90	29.0	5.80	168.3	449	13.0
Soffit												
Perforated aluminum	429.0	1.00	Ft2	429	0.091	39.039	1.95	41.0	274.00	11,231.5	4667	191.3
INTERIOR FINISH CARPENTRY												
STAIRS												
Basement to first storey												
Stringers												
2x10	28.0	1.00	Ft	28	1.695	47.46	3.32	50.8	5.80	294.5	449	22.8
Treads												
2x12	42.0	1.00	Ft	42	2.036	85.512	5.99	91.5	5.80	530.7	449	41.1
Risers												
Plywood												
1/2" Plywood	1.0		Shts	1	19.500	19.5	1.37	20.9	10.04	209.5	559	11.7
Handrail												
2x8 SPF	24.0	1.00	Ft	24	1.395	33.48	2.34	35.8	5.80	207.8	449	16.1
Landing sheathing												
5/8"Plywood	1.0		Shts	1	24.390	24.39	1.22	25.6	10.04	257.1	559	14.3
First to second storey												
Stringers												
2x10	28.0	1.00	Ft	28	1.695	47.46	3.32	50.8	5.80	294.5	449	22.8
Treads												
2x12	42.0	1.00	Ft	42	2.036	85.512	5.99	91.5	5.80	530.7	449	41.1
Risers												
Plywood												
1/2" Plywood	1.0		Shts	1	19.500	19.5	1.37	20.9	10.04	209.5	559	11.7
Handrail						0	0.00	0.0				
2x4	19.0	1.00	Ft	19	0.678	12.882	0.90	13.8	5.80	79.9	449	6.2
Balusters	56.0		No	56	0.239	13.384	0.94	14.3	5.80	83.1	449	6.4
Newels	2.0		No	2	7.080	14.16	0.99	15.2	5.80	87.9	449	6.8
Landing joists												
2x8 SPF	24.0	1.00	Ft	24	1.359	32.616	2.28	34.9	5.80	202.4	449	15.7
Landing sheathing												
5/8"Plywood	1.0		Shts	1	24.390	24.39	1.71	26.1	10.04	262.0	559	14.6
SECTION 6 INSULATION AND MOISTURE PROTECTION												
INSULATION												
Basement walls												
Fiberglass												
89mm (3 1/2") batt	1600.0	1.00	Ft2	1600	0.104	166.4	8.32	174.7	22.3	3,896.3	904	157.9
First floor walls												
Fiberglass												
152 mm (5 1/2") batt	1544.0	1.00	Ft2	1544	0.171	264.024	13.20	277.2	22.3	6,182.1	904	250.6
Second floor walls												
Fiberglass												
152 mm (5 1/2") batt	900.0	1.00	Ft2	900	0.171	153.9	7.70	161.6	22.3	3,603.6	904	146.1
Fiberglass												
Vaulted ceiling/152 mm (5 1/2") batt	235.0	1.00	Ft2	235	0.171	40.185	2.01	42.2	22.3	940.9	904	38.1
Attic Insulation/M.wool (R40)	1709.0	1.00	Ft2	1709	0.871	1488.539	74.43	1,563.0	22.3	34,854.1	904	1,412.9
DAMPROOFING												
Basement under slab 6 mil poly	1710.0	1.00	Ft2	1710	0.013	22.23	1.11	23.3	28.6	667.6	508	11.9
Basement wall spray on damp	1596.0	1.00	Ft2	1596	0.680	1085.28	54.26	1,139.5	2.5	2,848.9	508	578.9

Basement wall 6 mil poly damp	1470.0	1.00	Ft2	1470	0.013	19.11	0.96	20.1	28.6	573.9	508	10.2
Sill gasket	193.0	1.00	Ft	193	0.001	0.193	0.01	0.2	160.0	32.4	4836	1.0
VAPOUR BARRIER											
Basement walls	1596.0	1.00	Ft2	1596	0.013	20.748	1.04	21.8	28.6	623.1	508	11.1
First floor walls	1544.0	1.00	Ft2	1544	0.013	20.072	1.00	21.1	28.6	602.8	508	10.7
Second floor walls	900.0	1.00	Ft2	900	0.013	11.7	0.59	12.3	28.6	351.4	508	6.2
Attics	1709.0	1.00	Ft2	1709	0.013	22.217	1.11	23.3	28.6	667.2	508	11.9
Band joists	236.0	1.00	Ft2	236	0.013	3.068	0.15	3.2	28.6	92.1	508	1.6
						0	0.00	0.0				
AIR BARRIER						0	0.00	0.0				
Basement walls											
Caulking	3.0		No	3	0.227	0.681	0.03	0.7	160.0	114.4	4836	3.5
First floor walls											
Caulking	3.0		No	3	0.227	0.681	0.03	0.7	160.0	114.4	4836	3.5
Second floor walls											
Caulking	4.0		No	4	0.227	0.908	0.05	1.0	160.0	152.5	4836	4.6
Attic Ceiling											
Caulking	4.0		No	4	0.227	0.908	0.05	1.0	160.0	152.5	4836	4.6
Band joists											
Caulking	6.0		No	6	0.227	1.362	0.07	1.4	160.0	228.8	4836	6.9
FLASHING AND SHEET METAL											
Wall to roof flashing	100.0	1.00	Ft	100	0.042	4.2	0.21	4.4	26.0	114.7	1945	8.6
Window and door head flashings	97.0	1.00	Ft	97	0.042	4.074	0.20	4.3	26.0	111.2	1945	8.3
2" aluminum soffit vent	278.0	1.00	Ft	278	0.400	111.2	5.56	116.8	274.0	31,992.2	4667	544.9
Gutter-Aluminium	278.0	1.00	Ft	278	0.162	45.036	2.25	47.3	274.0	12,956.9	4667	220.7
Valley flashing	115.0	1.00	Ft	115	0.233	26.795	1.34	28.1	26.0	731.5	1945	54.7
Skylight flashing	40.0	1.00	Ft	40	0.042	1.68	0.08	1.8	26.0	45.9	1945	3.4
Roof vents	5.0		No	5	0.200	1	0.00	1.0	26.0	26.0	1945	1.9
Roof edge	278.0	1.00	Ft	278	0.042	11.676	0.58	12.3	26.0	318.8	1945	23.8
5"x7" leaf flashing	8.0	1.00	Ft	8	0.042	0.336	0.02	0.4	26.0	9.2	1945	0.7
Chimney chase caps	1.0		No	1	2.000	2	0.10	2.1	26.0	54.6	1945	4.1
ROOFING MATERIALS											
15# Building Paper	2527.0	1.00	Ft2	2527	0.022	55.594	2.78	58.4	33.6	1,961.4	1045	61.0
Roofing finish											
Asphalt shingles	2527.0	1.00	Ft2	2527	0.953	2408.231	120.41	2,528.6	27.7	70,043.4	632	1,598.1
SECTION 7 DOORS WINDOWS AND FINISH HARDWARE											
DOORS & FRAMES											
EXTERIOR SWINGING											
3'-0"x6'-8"											
1 3/4" thick metal	3.0		No.	3	20.480	61.44	0.00	61.4	28	1,720.3	1945	119.5
2'-8"x6'-8"											
1 3/4" thick metal	1.0		No.	1	30.300	30.3	0.00	30.3	28	848.4	1945	58.9
1 3/4" thick metal	2.0		No.	2	30.300	60.6	0.00	60.6	28	1,696.8	1945	117.9
SIDELIGHTS											
1'-0"*5'-0" wood frame:wood	2.0		No.	2	3.000	6	0.00	6.0	5.8	34.8	449	2.7
1'-0"*5'-0" wood frame:glass	2.0		No.	2	15.100	30.2	1.51	31.7	20	634.2	1044	33.1
INTERIOR SWINGING						0	0.00	0.0		0.0		
2'-8"x6'-8"	1.0		No.	1	13.150	13.15	0.00	13.2	5.8	76.3	449	5.9
2'-6"x6'-8"	7.0		No.	7	12.250	85.75	0.00	85.8	5.8	497.4	449	38.5
2'-4"x6'-8"	2.0		No.	2	11.340	22.68	0.00	22.7	5.8	131.5	449	10.2
BI-FOLD DOORS											
2'-0"x6'-8"	1.0		No.	1	12.700	12.7	0.00	12.7	5.8	73.7	449	5.7
3'-0"x6'-8"	1.0		No.	1	17.620	17.62	0.00	17.6	5.8	102.2	449	7.9
4'-0"x6'-8"	2.0		No.	2	24.950	49.9	0.00	49.9	5.8	289.4	449	22.4
5'-0"x6'-8"	1.0		No.	1	30.370	30.37	0.00	30.4	5.8	176.1	449	13.6
POCKET DOORS											
c/w track and hardware											
2'-6"x6'-8"	1.0		No.	1	16.330	16.33	0.00	16.3	5.8	94.7	449	7.3
2'-8"x6'-8"	1.0		No.	1	16.780	16.78	0.00	16.8	5.8	97.3	449	7.5

OVERHEAD DOORS												
9'x7'	2.0		No.	2	51.450	102.9	0.00	102.9	5.8	596.8	449	46.2
AUTOMATIC OPENER												
	2.0		No.	2	18.140	36.28	0.00	36.3	5.8	210.4	1898	68.9
WINDOWS (wood)												
Size												
2'-0"x5'-0"-F	4.0		No.	4	3.770	15.08	0.00	15.1	5.8	87.5	449	6.8
2'-0"x5'-0"-g	4.0		No.	8	15.120	120.96	6.05	127.0	20	2,540.2	1044	132.5
3'-0"x3'-0"-F	1.0		No.	1	3.170	3.17	0.00	3.2	5.8	18.4	449	1.4
3'-0"x3'-0"-g	1.0		No.	2	13.610	27.22	1.36	28.6	20	571.6	1044	29.8
3'-0"x4'-0"-F	2.0		No.	2	4.530	9.06	0.00	9.1	5.8	52.5	449	4.1
3'-0"x4'-0"-G	2.0		No.	4	18.400	73.6	3.68	77.3	20	1,545.6	1044	80.6
3'-0"x5'-0"-F	1.0		No.	1	5.430	5.43	0.00	5.4	5.8	31.5	449	2.4
3'-0"x5'-0"-G	1.0		No.	2	22.680	45.36	2.27	47.6	20	952.6	1044	49.7
4'-0"x2'-0"-F	2.0		No.	2	3.020	6.04	0.00	6.0	5.8	35.0	449	2.7
4'-0"x2'-0"-G	2.0		No.	4	12.100	48.4	2.42	50.8	20	1,016.4	1044	53.0
4'-0"x3'-0"-F	1.0		No.	1	4.530	4.53	0.00	4.5	5.8	26.3	449	2.0
4'-0"x3'-0"-G	1.0		No.	2	18.150	36.3	1.82	38.1	20	762.3	1044	39.8
4'-0"x3'-6"-F	2.0		No.	2	5.290	10.58	0.00	10.6	5.8	61.4	449	4.8
4'-0"x3'-6"-G	2.0		No.	4	21.170	84.68	4.23	88.9	20	1,778.3	1044	92.8
4'-0"x5'-0"-F	1.0		No.	1	7.560	7.56	0.00	7.6	5.8	43.8	449	3.4
4'-0"x5'-0"-G	1.0		No.	2	30.240	60.48	3.02	63.5	20	1,270.1	1044	66.3
4'-0"x4'-0"-F	1.0		No.	1	6.050	6.05	0.00	6.1	5.8	35.1	449	2.7
4'-0"x4'-0"-G	1.0		No.	2	24.190	48.38	2.42	50.8	20	1,016.0	1044	53.0
4'-0"x5'-0"-F	1.0		No.	1	7.560	7.56	0.00	7.6	5.8	43.8	449	3.4
4'-0"x5'-0"-G	1.0		No.	2	30.240	60.48	3.02	63.5	20	1,270.1	1044	66.3
5'-0"x2'-6"-F	1.0		No.	1	4.830	4.83	0.00	4.8	5.8	28.0	449	2.2
5'-0"x2'-6"-G	1.0		No.	2	18.900	37.8	1.89	39.7	20	793.8	1044	41.4
5'-0"x3'-0"-F	1.0		No.	1	5.440	5.44	0.00	5.4	5.8	31.6	449	2.4
5'-0"x3'-0"-G	1.0		No.	2	22.680	45.36	2.27	47.6	20	952.6	1044	49.7
5'-0"x4'-0"-F	1.0		No.	1	7.560	7.56	0.00	7.6	5.8	43.8	449	3.4
5'-0"x4'-0"-G	1.0		No.	2	30.240	60.48	3.02	63.5	20	1,270.1	1044	66.3
6'-0"x4'-0"-F	1.0		No.	1	9.070	9.07	0.00	9.1	5.8	52.6	449	4.1
6'-0"x4'-0"-G	1.0		No.	2	36.290	72.58	3.63	76.2	20	1,524.2	1044	79.5
5' diameter 1/2 -F	1.0		No.	1	3.290	3.29	0.00	3.3	5.8	19.1	449	1.5
5' diameter 1/2- G	1.0		No.	2	22.680	45.36	2.27	47.6	20	952.6	1044	49.7
4' diameter 1/2 -F	1.0		No.	1	2.820	2.82	0.00	2.8	5.8	16.4	449	1.3
4' diameter 1/2- G	1.0		No.	2	20.410	40.82	2.04	42.9	20	857.2	1044	44.7
FINISH HARDWARE												
Locksets	5.0		No.	5	1.500	7.5	0.00	7.5	60	450.0	2747	20.6
Passage Sets	6.0		No.	6	1.500	9	0.00	9.0	60	540.0	2747	24.7
Privacy Sets	5.0		No.	5	1.500	7.5	0.00	7.5	60	450.0	2747	20.6
Bifold Pulls	8.0		No.	8	0.057	0.456	0.00	0.5	60	27.4	2747	1.3
Door Stops	15.0		No.	15	0.400	6	0.00	6.0	45	270.0	2747	16.5
Threshdolds	5.0		No.	5	0.500	2.5	0.00	2.5	60	150.0	2747	6.9
Sweeps	5.0		No.	5	0.023	0.115	0.00	0.1	60	6.9	2747	0.3
Weather stripping	5.0		No.	5	0.089	0.445	0.00	0.4	60	26.7	2747	1.2
Latch	2.0		No.	2	0.300	0.6	0.00	0.6	60	36.0	2747	1.6
Dead bolts	3.0		No.	3	1.500	4.5	0.00	4.5	60	270.0	2747	12.4
Safety chain	3.0		No.	3	0.500	1.5	0.00	1.5	60	90.0	2747	4.1
Closets												
Rods	29.0	1.00	Ft	29	0.084	2.436	0.12	2.6	5.8	14.8	449	1.1
Shelves	49.0	1.00	Ft	49	0.914	44.786	2.24	47.0	5.8	272.7	559	26.3
Rod Brackets	14.0		No.	14	0.914	12.796	0.64	13.4	5.8	77.9	449	6.0
Shelf Brackets	24.0		No.	24	0.454	10.896	0.54	11.4	5.8	66.4	449	5.1
SECTION 8 FINISHES												
GYPSUM BOARD												
Joint tape 500'	14.0	1.00	No	14	1.590	22.26	1.11	23.4	28	654.4	1045	24.4
Joint compound	1425.0	1.00	No	1425	0.454	646.95	32.35	679.3	2	1,358.6	134	91.0
Metal corner beads	30.0	1.00	No	30	0.054	1.62	0.08	1.7	28	47.6	1730	2.9
BASEMENT EXTERIOR WALLS												
1/2" regular	1596.0	1.00	Ft2	1596	0.911	1453.956	145.40	1,599.4	7.4	11,835.2	352	563.0
BASEMENT CEILINGS												
5/8" regular	1201.0	1.00	Ft2	1201	1.134	1361.934	136.19	1,498.1	7.4	11,086.1	352	527.3
FIRST FLOOR EXTERIOR WALLS												
1/2" regular	1544.0	1.00	Ft2	1544	0.911	1406.584	140.66	1,547.2	7.4	11,449.6	352	544.6

FIRST FLOOR INTERIOR WALLS												
1/2" regular	2240.0	1.00	Ft2	2240	0.911	2040.64	204.06	2,244.7	7.4	16,610.8	352	790.1
FIRST FLOOR CEILINGS												
5/8" regular	868.0	1.00	Ft2	868	1.134	984.312	98.43	1,082.7	7.4	8,012.3	352	381.1
SECOND FLOOR EXTERIOR WALLS												
1/2" regular	900.0	1.00	Ft2	900	0.911	819.9	81.99	901.9	7.4	6,674.0	352	317.5
SECOND INTERIOR FLOOR WALLS												
1/2" regular	1756.0	1.00	Ft2	1756	0.911	1599.716	159.97	1,759.7	7.4	13,021.7	352	619.4
1/2" water resistant	100.0	1.00	Ft2	100	1.134	113.4	11.34	124.7	7.4	923.1	352	43.9
SECOND FLOOR CEILINGS												
5/8" regular	1047.0	1.00	Ft2	1047	1.134	1187.298	118.73	1,306.0	7.4	9,664.6	352	459.7
FLOORING												
Vynel	198.0	1.00	Ft2	198	0.635	125.73	6.29	132.0	160	21,122.6	10496	1,385.6
Carpet	1900.0	1.00	Ft2	1900	0.233	442.7	22.14	464.8	160	74,373.6	10496	4,878.9
PAINT												
Basement interior walls	1596.0	1.00	Ft2	1596	0.012	19.152	0.19	19.3	76	1,470.1	858	16.6
Basement ceiling	1201.0	1.00	Ft2	1201	0.012	14.412	0.14	14.6	76	1,106.3	858	12.5
First floor exterior walls	1544.0	1.00	Ft2	1544	0.012	18.528	0.19	18.7	76	1,422.2	858	16.1
First floor interior walls	2240.0	1.00	Ft2	2240	0.012	26.88	0.27	27.1	76	2,063.3	858	23.3
First floor ceiling	1201	1.00	Ft2	1201	0.012	14.412	0.14	14.6	76	1,106.3	858	12.5
Second floor exterior walls	900.0	1.00	Ft2	900	0.012	10.8	0.11	10.9	76	829.0	858	9.4
Second floor interior walls	1856.0	1.00	Ft2	1856	0.012	22.272	0.22	22.5	76	1,709.6	858	19.3
Second floor ceilings	868.0	1.00	Ft2	868	0.012	10.416	0.10	10.5	76	799.5	858	9.0
SECTION 9 SPECIALTIES												
BATHROOM ACCESSORIES												
Towel bar	3.0		No	3	0.91	2.721	0.00	2.7	60	163.3	1996	5.4
Paper holder	3.0		No	3	0.45	1.362	0.00	1.4	90	122.6	1996	2.7
Soap holder/grab bar	3.0		No	3	4.00	12	0.00	12.0	29.4	352.8		0.0
Shower doors	1.0		No	1	60.00	60	0.00	60.0	20	1,200.0	1044	62.6
Bath tub doors	1.0		No	1	50.00	50	0.00	50.0	20	1,000.0	1044	52.2
Medicine Cabinets	2.0		No	2	16.00	32	0.00	32.0	28	896.0	1945	62.2
Mirrors												
5'-0"x4'-0"	1.0		No	1	30.00	30	0.00	30.0	27.23	816.9	1044	31.3
6'-6"x4'-0"	1.0		No	1	39.30	39.3	0.00	39.3	27.23	1,070.1	1044	41.0
8'-0"x4'-0"	1.0		No	1	48.40	48.4	0.00	48.4	27.23	1,317.9	1044	50.5
SECTION 10 CABINETS AND APPLIANCIES												
CABINETS												
Kitchen counter tops & wall splash	22.0	1.00	Ft	22	7.50	165	8.25	173.3	10.4	1,801.8	559	96.8
Kitchen base cabinets	20.0	1.00	Ft	20	20.00	400	20.00	420.0	10.4	4,368.0	559	234.8
Kitchen upper cabinets	21.0	1.00	Ft	21	15.00	315	15.75	330.8	10.4	3,439.8	559	184.9
Pantry & Broom closets	1.0	1.00	No	1	82.00	82	4.10	86.1	10.4	895.4	559	48.1
Bathroom vanity tops & wall splash	21.0	1.00	Ft	21	7.50	157.5	7.88	165.4	10.4	1,719.9	559	92.4
Bathroom base cabinets	21.0	1.00	Ft	21	20.00	420	21.00	441.0	10.4	4,586.4	559	246.5
Laundry counter tops & wall splash	5.0	1.00	Ft	5	7.50	37.5	1.88	39.4	10.4	409.5	559	22.0
Laundry room base cabinets	5.0	1.00	Ft	5	20.00	100	5.00	105.0	10.4	1,092.0	559	58.7
Laundry room upper cabinets	5.0	1.00	Ft	5	15.00	75	3.75	78.8	10.4	819.0	559	44.0
Dropped fluorecent ceiling	1.0	1.00	No	1	4.00	4	0.20	4.2	10.4	43.7	559	2.3
Island	1.0	1.00	No	1	20.00	20	1.00	21.0	10.4	218.4	559	11.7
KITCHEN & LAUNDRY EQUIPMENT												
Washer	1.0		No	1	70.00	70	0.00	70.0	80	5,600.0	2837	198.6

Dryer	1.0		No	1	70.00	70	0.00	70.0	80	5,600.0	2837	198.6
Refrigerator	1.0		No	1	80.00	80	0.00	80.0	80	6,400.0	2837	227.0
Range Hood	1.0		No	1	10.00	10	0.00	10.0	80	800.0	2837	28.4
Range	1.0		No	1	50.00	50	0.00	50.0	93.952	4,697.6	2837	141.9
Microwave	1.0		No	1	35.00	35	0.00	35.0	80	2,800.0	2837	99.3
Dishwasher	1.0		No	1	55.00	55	0.00	55.0	80	4,400.0	2837	156.1
Garburator	1.0		No	1	15.00	15	0.00	15.0	80	1,200.0	2837	42.6
SECTION 11 MECHANICAL												
ROUGH IN PLUMBING												
Polybutylene Supply Lines												
1/2" dia piping	260.0	1.00	Ft	260	0.021	5.46	0.27	5.7	87	498.8	508	2.9
3/4" piping	64.0	1.00	Ft	64	0.039	2.496	0.12	2.6	87	228.0	508	1.3
1/2" t's	12.0		No	12	0.025	0.3	0.02	0.3	87	27.4	508	0.2
1/2" connectors	20.0		No	20	0.227	4.54	0.23	4.8	87	414.7	508	2.4
Supply header	1.0		No	1	6.804	6.804	0.34	7.1	87	621.5	508	3.6
ABS Waste Lines						0	0.00	0.0				
1 1/2" pipe	138.0	1.00	Ft	138	0.136	18.768	0.94	19.7	87	1,714.5	508	10.0
1 1/2" 90 el	15.0		No	15	0.066	0.99	0.05	1.0	87	90.4	508	0.5
1 1/2" 45 el	10.0		No	10	0.041	0.41	0.02	0.4	87	37.5	508	0.2
1 1/2" T	3.0		No	3	0.090	0.27	0.01	0.3	87	24.7	508	0.1
1 1/2" Trap	5.0		No	5	0.150	0.75	0.04	0.8	87	68.5	508	0.4
1 1/2" Clean Out	2.0		No	2	0.098	0.196	0.01	0.2	87	17.9	508	0.1
2" 90 el	78.0		No	78	0.095	7.41	0.37	7.8	87	676.9	508	4.0
2" 45 el	15.0		No	15	0.060	0.9	0.05	0.9	87	82.2	508	0.5
2" T	10.0		No	10	0.145	1.45	0.07	1.5	87	132.5	508	0.8
2" Trap	3.0		No	3	0.299	0.897	0.04	0.9	87	81.9	508	0.5
2" Clean Outs	4.0		No	4	0.150	0.6	0.03	0.6	87	54.8	508	0.3
3" 45 el	44.0		No	44	0.204	8.976	0.45	9.4	87	820.0	508	4.8
4" T	52.0		No	52	0.812	42.224	2.11	44.3	87	3,857.2	508	22.5
PLUMBING FIXTURES												
Water heaters	1.0		No	1	75.000	75	0.00	75.0	80	6,000.0	2837	212.8
Water closet	3.0		No	3	40.000	120	0.00	120.0	29.4	3,528.0	2837	340.5
Bathroom sink	3.0		No	3	20.000	60	0.00	60.0	29.4	1,764.0	1929	115.7
Kitchen sink	1.0		No	1	25.000	25	0.00	25.0	45	1,125.0	2454	61.4
Showers	1.0		No	1	50.000	50	0.00	50.0	29.4	1,470.0	1929	96.4
Tub/shower	2.0		No	2	300.000	600	0.00	600.0	29.4	17,640.0	1929	1,157.2
Hose bibs	2.0		No	2	0.100	0.2	0.00	0.2	29.368	5.9	1927	0.4
Laundry tub	1.0		No	1	10.000	10	0.00	10.0	29.4	294.0	1929	19.3
HEATING												
FORCED AIR												
Furnace												
Gas Furnace	1.0		No	1	85.000	85	0.00	85.0	80	6,800.0	2837	241.2
Filter	1.0		No	1	0.100	0.1	0.00	0.1	12	1.2	787	0.1
Floor registers	16.0		No	16	0.500	8	0.00	8.0	45	360.0	2837	22.7
R/A grilles	5.0		No	5	0.500	2.5	0.00	2.5	45	112.5	2837	7.1
Dampers	2.0		No	2	0.250	0.5	0.00	0.5	45	22.5	2837	1.4
Gas piping	150.0	1.00	Ft	150	0.500	75	3.75	78.8	28.23	2,223.1	1945	153.2
Electrical connection	1.0		No	1	0.100	0.1	0.01	0.1	23.071	2.4	1513	0.2
VENTILATION												
Bath fans	2.0		No	2	2.500	5	0.00	5.0	60	300.0	3936	19.7
Bath fan low sone	1.0		No	1	5.000	5	0.00	5.0	60	300.0	3936	19.7
Controls	1.0		No	1	0.300	0.3	0.00	0.3	32.956	9.9	2162	0.6
						0	0.00	0.0				
SECTION 12 ELECTRICAL						0	0.00	0.0				
ELECTRICAL ROUGH IN						0	0.00	0.0				
U/G PVC connection box	1.0		No	1	0.272	0.272	0.00	0.3	87	23.7	508	0.1
2" PVC conduit	8.0	1.00	Ft	8	0.322	2.576	0.00	2.6	87	224.1	508	1.3
2" PVC L.B. Box	1.0		No	1	0.771	0.771	0.00	0.8	87	67.1	508	0.4
2" PVC couplings	4.0		No	4	0.100	0.4	0.00	0.4	87	34.8	508	0.2
Circuits						0	0.00	0.0				
#2 bare copper wire	20.0	1.00	Ft	20	0.091	1.82	0.09	1.9	29.457	56.3	1932	3.7
6'x5/8" galv st grndng rds	2.0	1.00	No	2	3.000	6	0.30	6.3	32.956	207.6	2162	13.6

200 amp main breaker	1.0	1.00	No	1	30.000	30	0.00	30.0	32.956	988.7	2162	64.9
14-2 NMD copper wire	2000.0	1.00	Ft	2000	0.029	58	2.90	60.9	29.457	1,793.9	1932	117.7
14-3 NMD copper wire	1000.0	1.00	Ft	1000	0.038	38	1.90	39.9	29.457	1,175.3	1932	77.1
12-2 NMD copper wire	35.0	1.00	Ft	35	0.072	2.52	0.13	2.6	29.457	77.9	1932	5.1
10-3 NMD copper wire	6.0	1.00	Ft	6	0.122	0.732	0.04	0.8	29.457	22.6	1932	1.5
8-3 NMD copper wire	30.0	1.00	Ft	30	0.182	5.46	0.27	5.7	29.457	168.9	1932	11.1
FIXTURES												
WALL OUTLETS												
Duplex	45.0		No	45	0.250	11.25	0.00	11.3	71.02	799.0	4659	52.4
Half switched	5.0		No	5	0.250	1.25	0.00	1.3	71.02	88.8	4659	5.8
G.F.I.	3.0		No	3	0.250	0.75	0.00	0.8	71.02	53.3	4659	3.5
Waterproof	2.0		No	2	0.250	0.5	0.00	0.5	71.02	35.5	4659	2.3
SWITCHES						0	0.00	0.0		0.0		0.0
Single pole	15.0		No	15	0.250	3.75	0.00	3.8	71.02	266.3	4659	17.5
3 way	16.0		No	16	0.500	8	0.00	8.0	71.02	568.2	4659	37.3
4 way	3.0		No	3	0.500	1.5	0.00	1.5	71.02	106.5	4659	7.0
timers	1.0		No	1	0.250	0.25	0.00	0.3	71.02	17.8	4659	1.2
LIGHT FIXTURES (interior)												
Surface mounted	21.0		No	21	2.000	42	2.10	44.1	71.023	3,132.1	4659	205.5
LIGHT FIXTURES (exterior)												
Surface mount	5.0		No	5	2.000	10	0.50	10.5	71.023	745.7	4659	48.9
MISC. CONNECTIONS												
Door chimes	1.0		1.00	1	0.500	0.5	0.00	0.5	50.449	25.2	3309	1.7
Smoke detector	2.0		No	2	0.250	0.5	0.00	0.5	50.449	25.2	3309	1.7
Burglar Alarm	1.0		No	1	0.500	0.5	0.00	0.5	50.449	25.2	3309	1.7
Air conditioner	3.0		No	3	0.500	1.5	0.00	1.5	71.02	106.5	4659	7.0
Heat recovery ventilator	1.0		No	1	0.500	0.5	0.00	0.5	71.02	35.5	4659	2.3
Overhead door operator	1.0		No	1	0.250	0.25	0.00	0.3	71.02	17.8	4659	1.2
30 amp. dryer outlet	1.0		No	1	0.500	0.5	0.00	0.5	32.956	16.5	2162	1.1
						299525	5101	304,626.5		931,568.3		54,501.2
ITEM/LOCATION	**QNTY**	**No**	**UNITS**	**TOT QTY**	**CONVERSION**	**AS BUILT**	**WAST**	**INITIAL WT**	**UNIT EE**	**INITIAL EE**	**CO2**	**INITIAL CO2**

APPENDIX A2: BASE CASE STUDY HOUSE LIFE CYCLE CALCULATIONS: RECURRING.

							Building Life (Years)		**40**					
	RP	**RI**	**PL**	**TR**	**RCC**	**RCI**	**RF**							

ITEM/LOCATION				40				RECURR -ING MATER- IALS	RECURR -ING ENERY	RECURRING CO2			Waste %	
								kg	MJ	kg				
SECTION 1 SITE WORK														
CONCRETE FLATWORK														
Driveway	0	1	50	0	49	39	0.0	0	0	0			0.01	
Sidewalks	0	1	20	1	19	19	1.0	1806	1354	135			0.01	
Patio	0	1	50	0	49	39	0.0	0	0	0			0.01	
SITE DRAINAGE														
4" perforated plastic pipe perimeter footing drainage	0	1	50	0	49	39	0.0	0	0	0			0.05	
3/4" course gravel backfill	0	1	50	0	49	39	0.0	0	0	0			0.00	
SECTION 2 CONCRETE														
FORMWORK														
BASEMENT FOUNDATION														
Strip footing forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Pad footing forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Pedestal forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Slab edge forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Grade beam forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Foundation wall forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Retaining wall forms	0	1	200	0	199	39	0.0	0	0	0			0.05	
1x2 level strip	0	1	200	0	199	39	0.0	0	0	0			0.05	
Exterior bsmnt strs frms	0	1	200	0	199	39	0.0	0	0	0			0.05	
Exterior steps forms(ply)	0	1	200	0	199	39	0.0	0	0	0			0.05	
Exterior steps forms(lmbr)	0	1	200	0	199	39	0.0	0	0	0			0.05	
2x4 keyway	0	1	200	0	199	39	0.0	0	0	0			0.05	
CAST IN PLACE CONCRETE														
BASEMENT FOUNDATION														
Strip Footings	0	1	75	0	74	39	0.0	0	0	0			0.01	
Footing pads	0	1	75	0	74	39	0.0	0	0	0			0.01	
Basement floor slab	0	1	75	0	74	39	0.0	0	0	0			0.01	
Garage floor slab	0	1	75	0	74	39	0.0	0	0	0			0.01	
Grade beam	0	1	75	0	74	39	0.0	0	0	0			0.01	
Foundation wall	0	1	75	0	74	39	0.0	0	0	0			0.01	
Ext basement stairs	0	1	75	0	74	39	0.0	0	0	0			0.01	
Exterior steps	0	1	75	0	74	39	0.0	0	0	0			0.01	
Retaining walls	0	1	75	0	74	39	0.0	0	0	0			0.01	
REINFORCING														
Structural slabs rebar	0	1	75	0	74	39	0.0	0	0	0			0.05	
Garage floor slab w.w.m.	0	1	75	0	74	39	0.0	0	0	0			0.05	
CONCRETE ACCESSORIES														
1/2" dia Anchor bolts	0	1	75	0	74	39	0.0	0	0	0			0.02	
Damproofing	25	40	75	0	1	0	0.0	0	0	0			0.05	
Granular fill under bsmnt slab	0	1	200	0	199	39	0.0	0	0	0			0.00	

Granular fill under garage slab	0	1	200	0	199	39	0.0	0	0	0			0.00	
6 mil poly moisture barrier	25	40	75	0	1	0	0.0	0	0	0			0.05	
1/2" expansion joint filler	0	1	200	0	199	39	0.0	0	0	0			0.05	
SECTION 3 MASONRY														
CONC. BLOCK WALLS														
8"x8"x16" solid blocks	20	25	75	0	2	1	0.2	148	195	12			0.02	
Reinforcing wall ties	20	25	75	0	2	1	0.2	0	15	1			0.05	
MASONRY VENEER														
Common bricks	10	25	75	0	2	1	0.1	541	1352	75			0.02	
Mortar	10	25	75	0	2	1	0.1	5	9	1			0.05	
Metal wall ties	10	25	75	0	2	1	0.1	1	46	3			0.05	
Split face conc. block-4"x12"x16"	10	25	75	0	2	1	0.1	137	180	11			0.05	
MASONRY FIREPLACES														
Common bricks	10	20	60	0	2	1	0.1	364	909	50			0.02	
Fire bricks	10	20	60	0	2	1	0.1	60	149	8				
12"x16"x8" flue linings	10	20	60	0	2	1	0.1	26	65	4			0.02	
Mortar	10	20	60	0	2	1	0.1	5	9	1			0.05	
Metal wall ties	10	20	60	0	2	1	0.1	1	51	3			0.05	
8"x8" cast iron clean out doors	10	20	60	0	2	1	0.1	0	13	1			0.00	
5"x8" cast iron ash dumps	10	20	60	0	2	1	0.1	0	9	1			0.00	
Metal dome damper	10	20	60	0	2	1	0.1	1	29	2			0.00	
Fireplace lintel angles	10	20	60	0	2	1	0.1	1	18	1			0.05	
Hearth finish	10	20	60	0	2	1	0.1	1	3	0			0.05	
Combustion air kit	10	20	60	0	2	1	0.1	1	15	1			0.05	
Tight fitting glass doors	10	20	60	0	2	1	0.1	4	80	4			0.00	
brick	10	20	60	0	2	1	0.1	57	143	8			0.02	
SECTION 4 METALS														
STRUCTURAL STEEL														
Steel angle lintels	20	25	75	0	2	1	0.2	15	429	26			0.05	
NAILS														
	0	1	50	0	49	39	0.0	0	0	0			0.05	
SECTION 5 CARPENTRY														
ROUGH CARPENTARY														
BASEMENT FOUNDATION FRAMING														
Exterior Walls														
Precut 2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Plates														
2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Interior Walls														
Headers														
2x10	0	1	40	0	39	39	0.0	0	0	0			0.10	
Furring studs														
2x3	0	1	50	0	49	39	0.0	0	0	0			0.10	
Furring Plates														
2x3	0	1	50	0	49	39	0.0	0	0	0			0.10	
Beams														
Built up D.Fir														
2x10	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x12	0	1	50	0	49	39	0.0	0	0	0			0.10	

Posts and Columns														
6x6	0	1	40	0	39	39	0.0	0	0	0			0.10	
3" diameter steel columns													0.05	
45# Asphalt felt	0	1	40	0	39	39	0.0	0	0	0			0.05	
FIRST FLOOR FRAMING														
Joists														
2x10 D. Fir	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x2	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x2	0	1	50	0	49	39	0.0	0	0	0			0.10	
Solid Blocking														
2x10	0	1	50	0	49	39	0.0	0	0	0			0.10	
Sill Plates														
2x4	0	1	50	0	49	39	0.0	0	0	0			0.10	
Capillary Break														
Polyethylene foam sill gasket	10	8	18	2	2	0	2.4	0	70	2			0.10	
Subflooring														
5/8" T&G Plywood	5	5	50	0	9	7	0.4	341	3420	190			0.05	
Subfloor adhesive	5	5	50	0	9	7	0.4	4	389	6			0.05	
	5	5	50	0	9	7	0.4	0	0	0				
FIRST STOREY EXTERIOR WALLS														
Walls														
Precut 2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Plates														
2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Headers														
2x10	0	1	40	0	39	39	0.0	0	0	0			0.10	
Sheathing														
3/8" Plywood	10	25	50	0	1	1	0.1	80	808	45			0.10	
Beams														
Built up D.Fir														
2x8	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x10	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x12	0	1	50	0	49	39	0.0	0	0	0			0.10	
							0.0	0	0	0				
Posts and Columns														
6x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
FIRST STOREY INTERIOR WALLS														
Walls														
Precut 2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Plates														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
SECOND STOREY FLOOR SYSTEM														
Joists														
2x10 SPF	0	1	50	0	49	39	0.0	0	0	0			0.10	
Cross bridging														
2x2	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x2	0	1	50	0	49	39	0.0	0	0	0			0.10	
Solid Blocking														
2x10	0	1	50	0	49	39	0.0	0	0	0			0.10	
Subflooring														
5/8" T&G Plywood	5	5	50	0	9	7	0.4	244	2451	136			0.10	

Subfloor adhesive	5	5	50	0	9	7	0.4	4	408	7			0.10	
SECOND STORY EXTERIOR WALLS														
Walls														
Precut 2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Plates														
2x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Headers														
2x10	0	1	40	0	39	39	0.0	0	0	0			0.10	
Sheathing														
3/8" Plywood	10	25	50	0	1	1	0.1	51	509	28			0.05	
Beams														
Built up D.Fir														
2x10	0	1	50	0	49	39	0.0	0	0	0			0.10	
SECOND STORY INTERIOR WALLS														
Walls														
Precut 2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Plates														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
ROOF SYSTEM														
Ceiling Joists														
2x4 SPF	0	1	40	0	39	39	0.0	0	0	0			0.10	
2x6 SPF	0	1	40	0	39	39	0.0	0	0	0			0.10	
Dropped ceiling furring														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Roof Framing														
Rafters														
2x8 SPF	0	1	40	0	39	39	0.0	0	0	0			0.10	
2x10 SPF	0	1	40	0	39	39	0.0	0	0	0			0.10	
2x12 SPF									0	0				
Rafters														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Ridge board														
2x10	0	1	40	0	39	39	0.0	0	0	0			0.10	
Exterior Soffit Framing														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Ledgers														
2x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
Sheathing														
1/2" Plywood	0	1	40	0	39	39	0.0	0	0	0			0.05	
Strapping														
1x4	0	1	40	0	39	39	0.0	0	0	0			0.10	
H Clips	0	1	40	0	39	39	0.0	0	0	0				
EXTERIOR FINISH CARPENTRY														
EXTERIOR FINISH														
Siding														
Wood														
1x6	0	1	50	0	49	39	0.0	0	0	0			0.10	
Building Paper														
Plywood														
1/2" Plywood	0	1	50	0	49	39	0.0	0	0	0			0.05	
Corner trim								0	0	0				
1x4	0	1	50	0	49	39	0.0	0	0	0			0.10	

SOFFIT AND FASCIA														
Fascia board														
2x8	0	1	50	0	49	39	0.0	0	0	0			0.07	
Barge board														
2x10	0	1	50	0	49	39	0.0	0	0	0			0.07	
Soffit														
Perforated aluminum	20	12	40	0	3	3	0.6	25	6739	115			0.05	
INTERIOR FINISH CARPENTRY														
STAIRS														
Basement to first storey														
Stringers														
2x10	25	40	60	0	1	0	0.0	0	0	0			0.07	
Treads														
2x12	25	40	60	0	1	0	0.0	0	0	0			0.07	
Risers														
Plywood														
1/2" Plywood	25	40	60	0	1	0	0.0	0	0	0			0.07	
Handrail														
2x8 SPF	25	40	60	0	1	0	0.0	0	0	0			0.07	
Landing sheathing														
5/8"Plywood	25	40	60	0	1	0	0.0	0	0	0			0.05	
First to second storey														
Stringers														
2x10	25	40	60	0	1	0	0.0	0	0	0			0.07	
Treads														
2x12	25	40	60	0	1	0	0.0	0	0	0			0.07	
Risers														
Plywood														
1/2" Plywood	25	40	60	0	1	0	0.0	0	0	0			0.07	
Handrail														
2x4	25	40	60	0	1	0	0.0	0	0	0			0.07	
Balusters	25	40	60	0	1	0	0.0	0	0	0			0.07	
Newels	25	40	60	0	1	0	0.0	0	0	0			0.07	
Landing joists														
2x8 SPF	25	40	60	0	1	0	0.0	0	0	0			0.07	
Landing sheathing														
5/8"Plywood	25	40	60	0	1	0	0.0	0	0	0			0.07	
SECTION 6 INSULATION AND MOISTURE PROTECTION														
INSULATION														
Basement walls														
Fiberglass														
89mm (3 1/2") batt	15	40	50	0	1	0	0.0	0	0	0			0.05	
First floor walls														
Fiberglass														
152 mm (5 1/2") batt	15	40	50	0	1	0	0.0	0	0	0			0.05	
Second floor walls														
Fiberglass														
152 mm (5 1/2") batt	15	40	50	0	1	0	0.0	0	0	0			0.05	
Fiberglass														
Vaulted ceiling/152 mm (5 1/2") batt	15	40	50	0	1	0	0.0	0	0	0			0.05	
Attic Insulation/M.wool (R40)	5	5	50	0	9	7	0.4	547	12199	495			0.05	
DAMPROOFING														
Basement under slab 6 mil poly	25	40	50	0	1	0	0.0	0	0	0			0.05	
Basement wall spray on damp	25	40	50	0	1	0	0.0	0	0	0			0.05	
Basement wall 6 mil poly damp	25	40	50	0	1	0	0.0	0	0	0			0.05	
Sill gasket	10	8	18	2	2	0	2.4	0	78	2			0.05	

VAPOUR BARRIER														
Basement walls	0	1	50	0	49	39	0.0	0	0	0			0.05	
First floor walls	0	1	50	0	49	39	0.0	0	0	0			0.05	
Second floor walls	0	1	50	0	49	39	0.0	0	0	0			0.05	
Attics	0	1	50	0	49	39	0.0	0	0	0			0.05	
Band joists	0	1	50	0	49	39	0.0	0	0	0			0.05	
AIR BARRIER														
Basement walls														
Caulking	30	15	50	0	3	2	0.6	0	69	2			0.05	
First floor walls								0	0	0				
Caulking	30	15	50	0	3	2	0.6	0	69	2			0.05	
Second floor walls								0	0	0				
Caulking	30	15	50	0	3	2	0.6	1	92	3			0.05	
Attic Ceiling								0	0	0				
Caulking	30	15	50	0	3	2	0.6	1	92	3			0.05	
Band joists								0	0	0				
Caulking	30	15	50	0	3	2	0.6	1	137	4			0.05	
FLASHING AND SHEET METAL														
Wall to roof flashing	0	1	50	0	49	39	0.0	0	0	0			0.05	
Window and door head flashings	0	1	50	0	49	39	0.0	0	0	0			0.05	
2" aluminum soffit vent	0	1	50	0	49	39	0.0	0	0	0			0.05	
Gutter-Aluminium	0	1	50	0	49	39	0.0	0	0	0			0.05	
Valley flashing	0	1	50	0	49	39	0.0	0	0	0			0.05	
Skylight flashing	0	1	50	0	49	39	0.0	0	0	0			0.05	
Roof vents	0	1	50	0	49	39	0.0	0	0	0			0.00	
Roof edge	0	1	50	0	49	39	0.0	0	0	0			0.05	
5"x7" leaf flashing	0	1	50	0	49	39	0.0	0	0	0			0.05	
Chimney chase caps	0	1	50	0	49	39	0.0	0	0	0			0.05	
ROOFING MATERIALS														
15# Building Paper	10	10	40	0	3	3	0.3	18	588	18			0.05	
Roofing finish								0	0	0				
Asphalt shingles	0	1	15	2	14	9	2.0	5057	140087	3196			0.05	
SECTION 7 DOORS WINDOWS AND FINISH HARDWARE														
DOORS & FRAMES														
EXTERIOR SWINGING														
3'-0"x6'-8"														
1 3/4" thick metal	15	14	70	0	4	2	0.3	18	516	36			0.00	
2'-8"x6'-8"								0	0	0				
1 3/4" thick metal	15	14	70	0	4	2	0.3	9	255	18			0.00	
1 3/4" thick metal	15	14	70	0	4	2	0.3	18	509	35			0.00	
SIDELIGHTS														
1'-0"*5'-0" wood frame:wood	25	20	60	0	2	1	0.3	2	9	1			0.00	
1'-0"*5'-0" wood frame:glass	25	20	60	0	2	1	0.3	8	159	8			0.05	
INTERIOR SWINGING								0	0	0				
2'-8"x6'-8"	15	7	30	1	4	1	1.8	23	133	10			0.00	
2'-6"x6'-8"	15	7	30	1	4	1	1.8	150	870	67			0.00	
2'-4"x6'-8"	15	7	30	1	4	1	1.8	40	230	18			0.00	
BI-FOLD DOORS														
2'-0"x6'-8"	15	7	30	1	4	1	1.8	22	129	10			0.00	
3'-0"x6'-8"	15	7	30	1	4	1	1.8	31	179	14			0.00	
4'-0"x6'-8"	15	7	30	1	4	1	1.8	87	506	39			0.00	
5'-0"x6'-8"	15	7	30	1	4	1	1.8	53	308	24			0.00	
POCKET DOORS														
c/w track and hardware														
2'-6"x6'-8"	15	7	30	1	4	1	1.8	29	166	13			0.00	
2'-8"x6'-8"	15	7	30	1	4	1	1.8	29	170	13			0.00	
OVERHEAD DOORS														
9'x7'	30	8	16	2	1	0	2.6	268	1552	120			0.00	

AUTOMATIC OPENER														
													0.00	
WINDOWS (wood)														
Size														
2'-0"x5'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
2'-0"x5'-0"-g	0	1	50	0	49	39	0.0	0	0	0			0.05	
3'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
3'-0"x3'-0"-g	0	1	50	0	49	39	0.0	0	0	0			0.05	
3'-0"x4'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
3'-0"x4'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
3'-0"x5'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
3'-0"x5'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x2'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x2'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x3'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x3'-6"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x3'-6"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x5'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x5'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x4'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x4'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4'-0"x5'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4'-0"x5'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
5'-0"x2'-6"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
5'-0"x2'-6"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
5'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
5'-0"x3'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
5'-0"x4'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
5'-0"x4'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
6'-0"x4'-0"-F	0	1	50	0	49	39	0.0	0	0	0			0.00	
6'-0"x4'-0"-G	0	1	50	0	49	39	0.0	0	0	0			0.05	
5' diameter 1/2 -F	0	1	50	0	49	39	0.0	0	0	0			0.00	
5' diameter 1/2- G	0	1	50	0	49	39	0.0	0	0	0			0.05	
4' diameter 1/2 -F	0	1	50	0	49	39	0.0	0	0	0			0.00	
4' diameter 1/2- G	0	1	50	0	49	39	0.0	0	0	0			0.05	
FINISH HARDWARE														
Locksets	0	1	50	0	49	39	0.0	0	0	0			0.00	
Passage Sets	0	1	50	0	49	39	0.0	0	0	0			0.00	
Privacy Sets	0	1	50	0	49	39	0.0	0	0	0			0.00	
Bifold Pulls	0	1	50	0	49	39	0.0	0	0	0			0.00	
Door Stops	0	1	50	0	49	39	0.0	0	0	0			0.00	
Threshdolds	0	1	50	0	49	39	0.0	0	0	0			0.00	
Sweeps	0	1	50	0	49	39	0.0	0	0	0			0.00	
Weather stripping	0	1	50	0	49	39	0.0	0	0	0			0.00	
Latch	0	1	50	0	49	39	0.0	0	0	0			0.00	
Dead bolts	0	1	50	0	49	39	0.0	0	0	0			0.00	
Safety chain	0	1	50	0	49	39	0.0	0	0	0			0.00	
Closets														
Rods	0	1	50	0	49	39	0.0	0	0	0			0.05	
Shelves	0	1	50	0	49	39	0.0	0	0	0			0.05	
Rod Brackets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Shelf Brackets	0	1	50	0	49	39	0.0	0	0	0			0.05	
SECTION 8 FINISHES														
GYPSUM BOARD														
Joint tape 500'	10	25	50	0	1	1	0.1	2	65	2			0.05	
Joint compound	10	25	50	0	1	1	0.1	68	136	9			0.05	
Metal corner beads	10	25	50	0	1	1	0.1	0	5	0			0.05	
BASEMENT EXTERIOR WALLS								0	0	0				
1/2" regular	10	25	50	0	1	1	0.1	160	1184	56			0.10	
BASEMENT CEILINGS														
5/8" regular	10	25	50	0	1	1	0.1	150	1109	53			0.10	
FIRST FLOOR EXTERIOR WALLS								0	0	0				
1/2" regular	10	25	50	0	1	1	0.1	155	1145	54			0.10	
FIRST FLOOR INTERIOR WALLS								0	0	0				
1/2" regular	10	25	50	0	1	1	0.1	224	1661	79			0.10	

FIRST FLOOR CEILINGS								0	0	0				
5/8" regular	10	25	50	0	1	1	0.1	108	801	38			0.10	
SECOND FLOOR EXTERIOR WALLS								0	0	0				
1/2" regular	10	25	50	0	1	1	0.1	90	667	32			0.10	
SECOND INTERIOR FLOOR WALLS								0	0	0				
1/2" regular	10	25	50	0	1	1	0.1	176	1302	62			0.10	
1/2" water resistant	10	25	50	0	1	1	0.1	12	92	4			0.10	
SECOND FLOOR CEILINGS								0	0	0				
5/8" regular	10	25	50	0	1	1	0.1	131	966	46			0.10	
								0	0	0				
FLOORING								0	0	0				
Vynel	20	5	15	2	2	1	3.0	396	63368	4157			0.05	
Carpet	20	5	10	3	1	1	3.8	1766	282620	18540			0.05	
PAINT														
Basement interior walls	0	1	5	7	4	4	7.0	135	10291	116			0.01	
Basement ceiling	0	1	5	7	4	4	7.0	102	7744	87			0.01	
First floor exterior walls	0	1	5	7	4	4	7.0	131	9955	112			0.01	
First floor interior walls	0	1	5	7	4	4	7.0	190	14443	163			0.01	
First floor ceiling	0	1	5	7	4	4	7.0	102	7744	87			0.01	
Second floor exterior walls	0	1	5	7	4	4	7.0	76	5803	66			0.01	
Second floor interior walls	0	1	5	7	4	4	7.0	157	11967	135			0.01	
Second floor ceilings	0	1	5	7	4	4	7.0	74	5597	63			0.01	
SECTION 9 SPECIALTIES														
BATHROOM ACCESSORIES														
Towel bar	0	1	50	0	49	39	0.0	0	0	0			0.00	
Paper holder	0	1	50	0	49	39	0.0	0	0	0			0.00	
Soap holder/grab bar	0	1	50	0	49	39	0.0	0	0	0			0.00	
Shower doors	0	1	50	0	49	39	0.0	0	0	0			0.00	
Bath tub doors	0	1	50	0	49	39	0.0	0	0	0			0.00	
Medicine Cabinets	0	1	50	0	49	39	0.0	0	0	0			0.00	
Mirrors									0	0				
5'-0"x4'-0"	0	1	50	0	49	39	0.0	0	0	0			0.00	
6'-6"x4'-0"	0	1	50	0	49	39	0.0	0	0	0			0.00	
8'-0"x4'-0"	0	1	50	0	49	39	0.0	0	0	0			0.00	
SECTION 10 CABINETS AND APPLIANCIES														
CABINETS														
Kitchen counter tops & wall splash	10	10	30	1	2	0	1.2	208	2162	116			0.05	
Kitchen base cabinets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Kitchen upper cabinets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Pantry & Broom closets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Bathroom vanity tops & wall splash	10	10	30	1	2	0	1.2	198	2064	111			0.05	
Bathroom base cabinets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Laundry counter tops & wall splash	10	10	30	1	2	0	1.2	47	491	26			0.05	
Laundry room base cabinets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Laundry room upper cabinets	0	1	50	0	49	39	0.0	0	0	0			0.05	
Dropped fluorecent ceiling	0	1	50	0	49	39	0.0	0	0	0			0.05	
Island	0	1	50	0	49	39	0.0	0	0	0			0.05	
KITCHEN & LAUNDRY EQUIPMENT														
Washer	0	1	10	3	9	9	3.0	210	16800	596			0.00	
Dryer	0	1	10	3	9	9	3.0	210	16800	596			0.00	
Refrigerator	0	1	10	3	9	9	3.0	240	19200	681			0.00	
Range Hood	25	10	20	1	1	1	1.5	15	1200	43			0.00	
Range	0	1	10	3	9	9	3.0	150	14093	426			0.00	

Microwave	0	1	10	3	9	9	3.0	105	8400	298			0.00	
Dishwasher	0	1	10	3	9	9	3.0	165	13200	468			0.00	
Garburator	0	1	10	3	9	9	3.0	45	3600	128			0.00	
SECTION 11 MECHANICAL														
ROUGH IN PLUMBING														
Polybutylene Supply Lines														
1/2" dia piping	30	8	40	0	4	4	1.2	7	599	3			0.05	
3/4" piping	30	8	40	0	4	4	1.2	3	274	2			0.05	
1/2" t's	30	8	40	0	4	4	1.2	0	33	0			0.05	
1/2" connectors	30	8	40	0	4	4	1.2	6	498	3			0.05	
Supply header	30	8	40	0	4	4	1.2	9	746	4			0.05	
ABS Waste Lines														
1 1/2" pipe	0	1	40	0	39	39	0.0	0	0	0			0.05	
1 1/2" 90 el	0	1	40	0	39	39	0.0	0	0	0			0.05	
1 1/2" 45 el	0	1	40	0	39	39	0.0	0	0	0			0.05	
1 1/2" T	0	1	40	0	39	39	0.0	0	0	0			0.05	
1 1/2" Trap	0	1	40	0	39	39	0.0	0	0	0			0.05	
1 1/2" Clean Out	0	1	40	0	39	39	0.0	0	0	0			0.05	
2" 90 el	0	1	40	0	39	39	0.0	0	0	0			0.05	
2" 45 el	0	1	40	0	39	39	0.0	0	0	0			0.05	
2" T	0	1	40	0	39	39	0.0	0	0	0			0.05	
2" Trap	0	1	40	0	39	39	0.0	0	0	0			0.05	
2" Clean Outs	0	1	40	0	39	39	0.0	0	0	0			0.05	
3" 45 el	0	1	40	0	39	39	0.0	0	0	0			0.05	
4" T	0	1	40	0	39	39	0.0	0	0	0			0.05	
PLUMBING FIXTURES														
Water heaters	30	10	20	1	1	1	1.6	120	9600	340			0.00	
Water closet	0	1	40	0	39	39	0.0	0	0	0			0.00	
Bathroom sink	0	10	40	0	3	3	0.0	0	0	0			0.00	
Kitchen sink	0	10	40	0	3	3	0.0	0	0	0			0.00	
Showers	0	10	40	0	3	3	0.0	0	0	0			0.00	
Tub/shower	0	10	40	0	3	3	0.0	0	0	0			0.00	
Hose bibs	5	25	20	1	0	0	1.0	0	6	0			0.00	
Laundry tub	0	10	40	0	3	3	0.0	0	0	0			0.00	
HEATING														
FORCED AIR														
Furnace														
Gas Furnace	0	1	15	2	14	9	2.0	170	13600	482			0.00	
Filter	0	1	20	1	19	19	1.0	0	1	0			0.00	
Floor registers	10	20	50	0	2	1	0.1	1	36	2			0.00	
R/A grilles	10	20	50	0	2	1	0.1	0	11	1			0.00	
Dampers	10	20	50	0	2	1	0.1	0	2	0			0.00	
Gas piping	0	1	50	0	49	39	0.0	0	0	0			0.05	
Electrical connection	0	1	50	0	49	39	0.0	0	0	0			0.05	
VENTILATION														
Bath fans	15	10	20	1	1	1	1.3	7	390	26			0.00	
Bath fan low sone	15	10	20	1	1	1	1.3	7	390	26			0.00	
Controls	15	10	20	1	1	1	1.3	0	13	1			0.00	
SECTION 12 ELECTRICAL														
ELECTRICAL ROUGH IN														
U/G PVC connection box	30	8	40	0	4	4	1.2	0	28	0			0.00	
2" PVC conduit	30	8	40	0	4	4	1.2	3	269	2			0.00	
2" PVC L.B. Box	0	1	50	0	49	39	0.0	0	0	0			0.00	
2" PVC couplings	0	1	50	0	49	39	0.0	0	0	0			0.00	
Circuits													0.00	
#2 bare copper wire	30	8	40	0	4	4	1.2	2	68	4			0.05	
6'x5/8" galv st grndng rds	30	8	40	0	4	4	1.2	8	249	16			0.05	
200 amp main breaker	30	8	40	0	4	4	1.2	36	1186	78			0.00	
14-2 NMD copper wire	30	8	40	0	4	4	1.2	73	2153	141			0.05	

14-3 NMD copper wire	30	8	40	0	4	4	1.2	48	1410	93			0.05	
12-2 NMD copper wire	30	8	40	0	4	4	1.2	3	94	6			0.05	
10-3 NMD copper wire	30	8	40	0	4	4	1.2	1	27	2			0.05	
8-3 NMD copper wire	30	8	40	0	4	4	1.2	7	203	13			0.05	
FIXTURES														
WALL OUTLETS														
Duplex	25	12	25	1	1	1	1.5	17	1198	79			0.00	
Half switched	25	12	25	1	1	1	1.5	2	133	9			0.00	
G.F.I.	25	12	25	1	1	1	1.5	1	80	5			0.00	
Waterproof	25	12	25	1	1	1	1.5	1	53	3			0.00	
SWITCHES								0	0	0			0.00	
Single pole	25	12	25	1	1	1	1.5	6	399	26			0.00	
3 way	25	12	25	1	1	1	1.5	12	852	56			0.00	
4 way	25	12	25	1	1	1	1.5	2	160	10			0.00	
timers	25	12	25	1	1	1	1.5	0	27	2			0.00	
								0	0	0				
LIGHT FIXTURES (interior)								0	0	0				
Surface mounted	25	12	25	1	1	1	1.5	66	4698	308			0.05	
LIGHT FIXTURES (exterior)								0	0	0				
Surface mount	25	12	25	1	1	1	1.5	16	1119	73			0.05	
MISC. CONNECTIONS														
Door chimes	0	1	40	0	39	39	0.0	0	0	0			0.00	
Smoke detector	0	1	40	0	39	39	0.0	0	0	0			0.00	
Burglar Alarm	0	1	40	0	39	39	0.0	0	0	0			0.00	
Air conditioner	0	1	40	0	39	39	0.0	0	0	0			0.00	
Heat recovery ventilator	0	1	40	0	39	39	0.0	0	0	0			0.00	
Overhead door operator	0	1	40	0	39	39	0.0	0	0	0			0.00	
30 amp. dryer outlet	0	1	40	0	39	39	0.0	0	0	0			0.00	
								16969	746247	34300				
								Rec Materials	**Rec Energy**	**Rec CO2**			**Waste %**	

APPENDIX B1: IMPROVED HOUSE LIFE CYCLE CALCULATIONS: INITIAL.

ITEM/LOCATION	QNTY	No	UNITS	TOT QTY	CONVERSION	AS BUIT	WAST	INITIAL WT	UNIT EE	INITIAL EE	CO2	INITIAL CO2
					TO KG	KG	KG	KG	MJ/KG	MJ	g/kg	KG
SECTION 1 SITE WORK												
CONCRETE FLATWORK												
Driveway	7.0	1.00	Yd3	8	1,797	14376	71.88	14447.88	0.75	10836	75.00	1083.59
Sidewalks	1.0	1.00	Yd3	1	1,797	1797	8.99	1805.99	0.75	1354	75.00	135.45
Patio	3.0	1.00	Yd3	3	1,797	5391	26.96	5417.96	0.75	4063	75.00	406.35
SITE DRAINAGE												

4" perforated plastic pipe perimeter footing drainage	174.0	1.00	Ft	174	0.500	87	4.35	91.35	160	14616	507.70	46.38
3/4" course gravel backfill	9.3	1.00	Yd3	9.3	1,468	13652.4	0.00	13652.40	0.09	1229	6.29	85.87
SECTION 2 CONCRETE												
FORMWORK												
FOUNDATION												
Strip footing forms	500.0	0.20	Ft	100	1.695	169.5	8.48	177.98	5.8	1032	449.00	79.91
Pad footing forms	92.0	0.20	Ft	18.4	0.339	6.2376	0.31	6.55	5.8	38	449.00	2.94
Pedestal forms	14.0	0.20	Ft	2.8	1.018	2.8504	0.14	2.99	5.8	17	449.00	1.34
Slab edge forms	18.0	0.20	Ft	3.6	0.678	2.4408	0.12	2.56	5.8	15	449.00	1.15
Foundation wall forms	21.0	0.20	Shts	4.2	24.390	102.438	5.12	107.56	5.8	624	449.00	48.29
1x2 level strip	54.0	0.20	Ft	10.8	0.169	1.8252	0.09	1.92	5.8	11	449.00	0.86
2x4 keyway	249.0	0.20	Ft	49.8	0.678	33.7644	1.69	35.45	5.8	206	449.00	15.92
CAST IN PLACE CONCRETE												
FOUNDATION												
Strip Footings	7.1	1.00	Yd3	7.1	1797	12758.7	63.79	12822.49	0.75	9617	75.00	961.69
Floor slab	10.0	1.00	Yd3	10	1797	17970	89.85	18059.85	0.75	13545	75.00	1354.49
Garage floor slab	6.0	1.00	Yd3	6	1797	10782	53.91	10835.91	0.75	8127	75.00	812.69
Foundation wall	9.6	1.00	Yd3	9.56	1797	17179.32	85.90	17265.22	0.75	12949	75.00	1294.89
Footing pads	2.5	1.00	Yd3	2.5	1797	4492.5	22.46	4514.96	0.75	3386	75.00	338.62
										0		0.00
REINFORCING										0		0.00
Structural slabs rebar	65.0	1.00	Ft	65	0.473	30.745	1.54	32.28	36.05	1164	2326.00	75.09
Garage floor slab w.w.m.	495.0	1.00	Ft2	495	0.100	49.5	2.48	51.98	48	2495	2648.00	137.63
CONCRETE ACCESSORIES												
1/2" dia Anchor bolts	58.0	1.00	No	58	0.130	7.54	0.38	7.92	45	356	2747.00	21.75
Dampproofing	300.0	1.00	Ft2	300	0.680	204	10.20	214.20	2.5	536	631.70	135.31
Granular fill under M. floor slab	12.0	1.00	Yd3	12	1127.0	13524	0.00	13524.00	0.03	406	6.29	85.07
Granular fill under garage slab	7.8	1.00	Yd3	7.75	1127.0	8734.25	0.00	8734.25	0.03	262	6.29	54.94
NAILS	100.0	1.00	Lb	100	0.454	45.4	0.00	45.40	45	2043	2534.00	115.04
SECTION 5 CARPENTRY												
ROUGH CARPENTARY												
FIRST STOREY EXTERIOR WALLS												
2x4	2172.0	1.00	Ft	2172	1.018	2211.096	221.11	2432.21	5.80	14107	449.00	1092.06
Headers						0	0.00	0.00		0		0.00
2x10	80.0	1.00	Ft	80	1.695	135.6	13.56	149.16	5.80	865	449.00	66.97
						0	0.00	0.00		0		0.00
Sheathing						0	0.00	0.00		0		0.00
3/8" Plywood	52.0		Shts	52	14.630	760.76	76.08	836.84	10.04	8402	559.00	467.79
						0	0.00	0.00		0		0.00
						0	0.00	0.00		0		0.00
Beams						0	0.00	0.00		0		0.00
Built up D.Fir						0	0.00	0.00		0		0.00
2x8	14.0	1.00	Ft	14	1.717	24.038	2.40	26.44	5.80	153	449.00	11.87
2x10	170.0	1.00	Ft	170	2.142	364.14	36.41	400.55	5.80	2323	449.00	179.85
2x12	310.0	1.00	Ft	310	2.572	797.32	79.73	877.05	5.80	5087	449.00	393.80
Posts and Columns												
6x6	1.0	8.00	Ft	8	3.053	24.424	2.44	26.87	5.80	156	449.00	12.06
FIRST STOREY INTERIOR WALLS												
2x4	556.0	1.00	Ft	556	0.681	378.636	37.86	416.50	5.80	2416	449.00	187.01

SECOND STOREY FLOOR SYSTEM												
Joists												
2x10 SPF	590.0	1.00	Ft	590	1.695	1000.05	100.01	1100.06	5.80	6380	449.00	493.92
Cross bridging												
2x2	50.0	1.40	Ft	70	0.509	35.63	3.56	39.19	5.80	227	449.00	17.60
2x2	24.0	1.20	Ft	28.8	0.396	11.4048	1.14	12.55	5.80	73	449.00	5.63
Solid Blocking												
2x10	20.0	1.00	Ft	20	1.695	33.9	3.39	37.29	5.80	216	449.00	16.74
Subflooring												
5/8" T&G Plywood	20.0		Shts	20	24.390	487.8	48.78	536.58	10.04	5387	559.00	299.95
Subfloor adhesive	9.0		No	9	0.910	8.19	0.82	9.01	97.00	874	1551.00	13.97
SECOND STORY EXTERIOR WALLS												
2x4	1126.0	1.00	Ft	1126	0.681	766.806	76.68	843.49	5.80	4892	449.00	378.73
Header 2x10	58.0	1.00	Ft	58	1.695	98.31	9.83	108.14	5.80	627	449.00	48.56
Sheathing												
3/8" Plywood	30.0		Shts	30	14.630	438.9	21.95	460.85	10.04	4627	559.00	257.61
Beams												
Built up D.Fir												
2x10	48.0	1.00	Ft	48	2.142	102.816	10.28	113.10	5.80	656	449.00	50.78
SECOND STORY INTERIOR WALLS												
2x4	837.0	1.00	Ft	837	0.678	567.486	56.75	624.23	5.80	3621	449.00	280.28
ROOF SYSTEM												
Ceiling Joists												
2x4 SPF	260.0	1.00	Ft	260	0.678	176.28	17.63	193.91	5.80	1125	449.00	87.06
2x6 SPF	128.0	1.00	Ft	128	1.018	130.304	13.03	143.33	5.80	831	449.00	64.36
Rafters												
2x8 SPF	437.0	1.00	Ft	437	1.359	593.883	59.39	653.27	5.80	3789	449.00	293.32
2x10 SPF	106.0	1.00	Ft	106	1.695	179.67	17.97	197.64	5.80	1146	449.00	88.74
Rafters												
2x4	34.0	1.00	Ft	34	0.678	23.052	2.31	25.36	5.80	147	449.00	11.39
Ridge board												
2x10	3.0	1.00	Ft	3	1.695	5.085	0.51	5.59	5.80	32	449.00	2.51
Exterior Soffit Framing												
2x4	377.0	1.00	Ft	377	0.678	255.606	25.56	281.17	5.80	1631	449.00	126.24
Ledgers												
2x4	7.0	1.00	Ft	7	0.678	4.746	0.47	5.22	5.80	30	449.00	2.34
Sheathing												
1/2" Plywood	64.0		Shts	64	19.500	1248	62.40	1310.40	10.04	13156	559.00	732.51
Strapping												
1x4	3456.00	1.00	Ft	3456	0.339	1171.584	117.16	1288.74	5.80	7475	449.00	578.65
H Clips	253.0	1.00	Ft	316.0	0.540	170.64	0.00	170.64	28.00	4778	1730.00	295.21
EXTERIOR FINISH CARPENTRY												
EXTERIOR FINISH												
Siding												
Wood												
1x6	3217.2	1.00	Ft	3217.2	0.434	1396.2648	139.63	1535.89	5.80	8908	449.00	689.62
Building Paper	2298.0	1.00	Ft2	2298	0.022	50.556	0.00	50.56	33.60	1699	1045.00	52.83
Plywood												

1/2" Plywood	2.0		Shts	2	19.500	39	1.95	40.95	10.04	411	559.00	22.89
Corner trim												
1x4	185.0	1.00	Ft	185	0.340	62.9	6.29	69.19	5.80	401	449.00	31.07
SOFFIT AND FASCIA												
Fascia board												
2x8	236.0	1.00	Ft	236	1.359	320.724	22.45	343.17	5.80	1990	449.00	154.09
Barge board												
2x10	16.0	1.00	Ft	16	1.695	27.12	1.90	29.02	5.80	168	449.00	13.03
Soffit												
Perforated aluminum	236.0	1.00	Ft2	236	0.091	21.476	1.07	22.55	274.00	6179	4667.13	105.24
INTERIOR FINISH CARPENTRY												
STAIR												
Stringers												
2x10	28.00	1.00	Ft	28.00	1.70	47.46	3.32	50.78	5.80	294.54	449.00	22.80
Treads												
2x12	42.00	1.00	Ft	42.00	2.04	85.51	5.99	91.50	5.80	530.69	449.00	41.08
Risers												
Plywood												
1/2" Plywood	1.00		Shts	1.00	19.50	19.50	1.37	20.87	10.04	209.48	559.00	11.66
Handrail												
2x4	19.00	1.00	Ft	19.00	0.68	12.88	0.90	13.78	5.80	79.95	449.00	6.19
Balusters	56.00		No	56.00	0.24	13.38	0.94	14.32	5.80	83.06	449.00	6.43
Newels	2.00		No	2.00	7.08	14.16	0.99	15.15	5.80	87.88	449.00	6.80
Landing joists												
2x8 SPF	24.00	1.00	Ft	24.00	1.36	32.62	2.28	34.90	5.80	202.41	449.00	15.67
Landing sheathing												
5/8"Plywood	1.00		Shts	1.00	24.39	24.39	1.71	26.10	10.04	262.02	559.00	14.59
SECTION 6 INSULATION AND MOISTURE PROTECTION												
INSULATION												
First floor walls												
Batt												
89 mm (3 1/2")	1010.0	1.00	Ft2	1010	0.104	105.04	5.25	110.29	22.3	2460	314.00	34.63
25 mm extruded Polystyrene	1010.0	1.00	Ft2	1010	0.217	219.17	10.96	230.13	22.3	5132	904.00	208.04
Second floor walls												
Batt												
89 mm (3 1/2")	904.0	1.00	Ft2	904	0.104	94.016	4.70	98.72	22.3	2201	314.00	31.00
25 mm extruded Polystyrene	904.0	1.00	Ft2	904	0.217	196.168	9.81	205.98	22.3	4593	904.00	186.20
CEllulos												
Attic/208 mm Blown (RSI 5.3)	816.0	1.00	Ft2	816	0.486	396.576	19.83	416.40	4.7	1957	314.00	130.75
DAMPROOFING												
M floor under slab 6 mil poly	1316.0	1.00	Ft2	1316	0.013	17.108	0.86	17.96	28.6	514	508.00	9.13
VAPOUR BARRIER												
First floor walls	1010.0	1.00	Ft2	1010	0.013	13.13	0.66	13.79	28.6	394	508.00	7.00
Second floor walls	904.0	1.00	Ft2	904	0.013	11.752	0.59	12.34	28.6	353	508.00	6.27
Attics	1316.0	1.00	Ft2	1316	0.013	17.108	0.86	17.96	28.6	514	508.00	9.13
Band joists	236.0	1.00	Ft2	236	0.013	3.068	0.15	3.22	28.6	92	508.00	1.64
AIR BARRIER												
First floor walls												
Caulking	3.0		No	3	0.227	0.681	0.03	0.72	160.0	114	4836.00	3.46
Second floor walls												
Caulking	4.0		No	4	0.227	0.908	0.05	0.95	160.0	153	4836.00	4.61
Attic Ceiling												
Caulking	4.0		No	4	0.227	0.908	0.05	0.95	160.0	153	4836.00	4.61
Band joists												
Caulking	6.0		No	6	0.227	1.362	0.07	1.43	160.0	229	4836.00	6.92
FLASHING AND SHEET METAL												
Wall to roof flashing	100.0	1.00	Ft	100	0.042	4.2	0.21	4.41	26.0	115	1945.00	8.58

Window and door head flashings	97.0	1.00	Ft	97	0.042	4.074	0.20	4.28	26.0	111	1945.00	8.32
2" aluminum soffit vent	280.0	1.00	Ft	280	0.400	112	5.60	117.60	274.0	32222	4667.13	548.85
Gutter-Aluminium	280.0	1.00	Ft	280	0.162	45.36	2.27	47.63	274.0	13050	4667.13	222.29
Valley flashing	100.0	1.00	Ft	100	0.233	23.3	1.17	24.47	26.0	636	1945.00	47.58
Roof vents	5.0		No	5	0.200	1	0.05	1.05	26.0	27	1945.00	2.04
Roof edge	280.0	1.00	Ft	280	0.042	11.76	0.59	12.35	26.0	321	1945.00	24.02
5"x7" leaf flashing	8.0	1.00	Ft	8	0.042	0.336	0.02	0.35	26.0	9	1945.00	0.69
ROOFING MATERIALS												
15# Building Paper	2040.0	1.00	Ft2	2040	0.022	44.88	2.24	47.12	33.6	1583	1045.00	49.24
Roofing finish												
Asphalt shingles	2040.0	1.00	Ft2	2040	0.953	1944.12	97.21	2041.33	27.7	56545	1855.90	3788.50
SECTION 7 DOORS WINDOWS AND FINISH HARDWARE												
DOORS & FRAMES												
EXTERIOR SWINGING												
3'-0"x6'-8"												
1 3/4" thick metal	1.0		No.	1	20.480	20.48	0.00	20.48	28	573	1945.00	39.83
2'-8"x6'-8"												
1 3/4" thick metal	2.0		No.	2	30.300	60.6	0.00	60.60	28	1697	1945.00	117.87
INTERIOR SWINGING												
2'-6"x6'-8"	6.0		No.	6	12.250	73.5	0.00	73.50	5.8	426	449.00	33.00
2'-4"x6'-8"	1.0		No.	1	11.340	11.34	0.00	11.34	5.8	66	449.00	5.09
BI-FOLD DOORS												
4'-0"x6'-8"	3.0		No.	3	24.950	74.85	0.00	74.85	5.8	434	449.00	33.61
OVERHEAD DOORS												
9'x7'	2.0		No.	2	51.450	102.9	0.00	102.90	5.8	597	449.00	46.20
AUTOMATIC OPENER												
	2.0		No.	2	18.140	36.28	0.00	36.28	5.8	210	1898.00	68.86
WINDOWS (wood)												
Size												
3'-0"x3'-0"-F	1.0		No.	1	3.170	3.17	0.00	3.17	5.8	18	449.00	1.42
3'-0"x3'-0"-g	2.0		No.	2	13.610	27.22	1.36	28.58	20	572	1043.52	29.82
4'-0"x3'-0"-F	1.0		No.	1	4.530	4.53	0.00	4.53	5.8	26	449.00	2.03
4'-0"x3'-0"-G	2.0		No.	2	18.150	36.3	1.82	38.12	20	762	1043.52	39.77
4'-0"x4'-0"-F	3.0		No.	3	6.050	18.15	0.00	18.15	5.8	105	449.00	8.15
4'-0"x4'-0"-G	6.0		No.	6	24.190	145.14	7.26	152.40	20	3048	1043.52	159.03
4'-0"x5'-0"-F	2.0		No.	2	7.560	15.12	0.00	15.12	5.8	88	449.00	6.79
4'-0"x5'-0"-G	4.0		No.	4	30.240	120.96	6.05	127.01	20	2540	1043.52	132.54
1'-0"x3'-0"-F	2.0		No.	2.0	1.52	3.04	0.00	3.04	5.8	5	449.00	1.36
1'-0"x3'-0"-G	4.0		No.	2.0	4.53	9.06	0.45	9.51	20	43	1043.52	9.93
2'-0"x1'-6"-F	4.0		No.	4.0	1.754	7.016	0.00	7.02	5.8	12	449.00	3.15
2'-0"x1'-6"-G	8.0		No.	4.0	4.535	18.14	0.91	19.05	20	86	1043.52	19.88
6'-0"x7'-0"-F	1.0		No.	1.0	9.900	9.9	0.00	9.90	5.8	57	449.00	4.45
6'-0"x7'-0"-G	2.0		No.	1.0	68.250	68.25	3.41	71.66	20	1433	1043.52	74.78
FINISH HARDWARE												
Locksets	5.0		No.	5	1.500	7.5	0.00	7.50	60	450	2747.00	20.60
Passage Sets	6.0		No.	6	1.500	9	0.00	9.00	60	540	2747.00	24.72
Privacy Sets	5.0		No.	5	1.500	7.5	0.00	7.50	60	450	2747.00	20.60
Bifold Pulls	8.0		No.	8	0.057	0.456	0.00	0.46	60	27	2747.00	1.25
Door Stops	15.0		No.	15	0.400	6	0.00	6.00	45	270	2747.00	16.48
Threshdolds	5.0		No.	5	0.500	2.5	0.00	2.50	60	150	2747.00	6.87
Sweeps	5.0		No.	5	0.023	0.115	0.00	0.12	60	7	2747.00	0.32
Weather stripping	5.0		No.	5	0.089	0.445	0.00	0.45	60	27	2747.00	1.22
Latch	2.0		No.	2	0.300	0.6	0.00	0.60	60	36	2747.00	1.65
Dead bolts	3.0		No.	3	1.500	4.5	0.00	4.50	60	270	2747.00	12.36
Safety chain	3.0		No.	3	0.500	1.5	0.00	1.50	60	90	2747.00	4.12
Closets												
Rods	29.0	1.00	Ft	29	0.084	2.436	0.00	2.44	5.8	14	449.00	1.09
Shelves	49.0	1.00	Ft	49	0.914	44.786	0.00	44.79	5.8	260	559.00	25.04
Rod Brackets	14.0		No.	14	0.914	12.796	0.00	12.80	5.8	74	449.00	5.75
Shelf Brackets	24.0		No.	24	0.454	10.896	0.00	10.90	5.8	63	449.00	4.89

SECTION 8 FINISHES												
GYPSUM BOARD												
Joint tape 500'	14.0	1.00	No	14	1.590	22.26	1.11	23.37	28	654	1045.00	24.42
Joint compound	1425.0	1.00	No	1425	0.454	646.95	32.35	679.30	2	1359	135.00	91.71
Metal corner beads	30.0	1.00	No	30	0.054	1.62	0.08	1.70	28	48	1730.00	2.94
First Floor Exterior Walls												
1/2" regular	1010.0	1.00	Ft2	1010	0.911	920.11	92.01	1012.12	7.4	7490	352.00	356.27
First Floor Interior Walls												
1/2" regular	1020.0	1.00	Ft2	1020	0.911	929.22	92.92	1022.14	7.4	7564	352.00	359.79
First Floor Ceilings												
5/8" regular	816.0	1.00	Ft2	816	1.134	925.344	92.53	1017.88	7.4	7532	352.00	358.29
Second Floor Exterior Walls												
1/2" regular	904.0	1.00	Ft2	904	0.911	823.544	82.35	905.90	7.4	6704	352.00	318.88
Second Interior Floor Walls												
1/2" regular	1200.0	1.00	Ft2	1200	0.911	1093.2	109.32	1202.52	7.4	8899	352.00	423.29
1/2" water resistant	100.0	1.00	Ft2	100	1.134	113.4	11.34	124.74	7.4	923	352.00	43.91
Second Floor Ceilings												
5/8" regular	672.0	1.00	Ft2	672	1.134	762.048	76.20	838.25	7.4	6203	352.00	295.06
FLOORING												
Vynel	196.0	1.00	Ft2	196	0.635	124.46	6.22	130.68	160	20909	10720.0 0	1400.92
Carpet	1200.0	1.00	Ft2	1200	0.233	279.6	13.98	293.58	160.00	46973	10496.0 0	3081.42
PAINT												
First floor exterior walls	1010.0	1.00	Ft2	1010	0.012	12.12	0.12	12.24	76	930	858.40	10.51
First floor interior walls	2240.0	1.00	Ft2	2240	0.012	26.88	0.27	27.15	76	2063	858.40	23.30
First floor ceiling	816	1.00	Ft2	816	0.012	9.792	0.10	9.89	76	752	858.40	8.49
Second floor exterior walls	900.0	1.00	Ft2	900	0.012	10.8	0.11	10.91	76	829	858.40	9.36
Second floor interior walls	1856.0	1.00	Ft2	1856	0.012	22.272	0.22	22.49	76	1710	858.40	19.31
Second floor ceilings	580.0	1.00	Ft2	580	0.012	6.96	0.07	7.03	76	534	858.40	6.03
SECTION 9 SPECIALTIES												
BATHROOM ACCESSORIES												
Towel bar	3.0		No	3	0.91	2.721	0.00	2.72	60	163	1996.00	5.43
Paper holder	3.0		No	3	0.45	1.362	0.00	1.36	90	123	1996.00	2.72
Soap holder/grab bar	3.0		No	3	4.00	12	0.00	12.00	29.4	353		0.00
Bath tub doors	1.0		No	1	50.00	50	0.00	50.00	20	1000	1043.52	52.18
Medicine Cabinets	2.0		No	2	16.00	32	0.00	32.00	28	896	1945.00	62.24
Mirrors												
5'-0"x4'-0"	1.0		No	1	30.00	30	0.00	30.00	27.23	817	1043.52	31.31
6'-6"x4'-0"	1.0		No	1	39.30	39.3	0.00	39.30	27.23	1070	1043.52	41.01
SECTION 10 CABINETS AND APPLIANCIES												
CABINETS												
Kitchen counter tops & wall splash	22.0	1.00	Ft	22	7.50	165	8.25	173.25	10.4	1802	559.00	96.85
Kitchen base cabinets	20.0	1.00	Ft	20	20.00	400	20.00	420.00	10.4	4368	559.00	234.78
Kitchen upper cabinets	21.0	1.00	Ft	21	15.00	315	15.75	330.75	10.4	3440	559.00	184.89
Bathroom vanity tops & wall splash	21.0	1.00	Ft	21	7.50	157.5	7.88	165.38	10.4	1720	559.00	92.44
Bathroom base cabinets	21.0	1.00	Ft	21	20.00	420	21.00	441.00	10.4	4586	559.00	246.52
Laundry counter tops & wall splash	5.0	1.00	Ft	5	7.50	37.5	1.88	39.38	10.4	410	559.00	22.01
Laundry room base cabinets	5.0	1.00	Ft	5	20.00	100	5.00	105.00	10.4	1092	559.00	58.70
Laundry room upper cabinets	5.0	1.00	Ft	5	15.00	75	3.75	78.75	10.4	819	559.00	44.02
Dropped fluorecent ceiling	1.0	1.00	No	1	4.00	4	0.20	4.20	10.4	44	559.00	2.35
KITCHEN & LAUNDRY EQUIPMENT												
Washer	1.0		No	1	70.00	70	0.00	70.00	80	5600	2837.48	198.62
Dryer	1.0		No	1	70.00	70	0.00	70.00	80	5600	2837.48	198.62
Refrigerator	1.0		No	1	80.00	80	0.00	80.00	80	6400	2837.48	227.00

Range Hood	1.0		No	1	10.00	10	0.00	10.00	80	800	2837.48	28.37
Range	1.0		No	1	50.00	50	0.00	50.00	80	4000	2837.48	141.87
Microwave	1.0		No	1	35.00	35	0.00	35.00	80	2800	2837.48	99.31
Dishwasher	1.0		No	1	55.00	55	0.00	55.00	80	4400	2837.48	156.06
Garburator	1.0		No	1	15.00	15	0.00	15.00	80	1200	2837.48	42.56
SECTION 11 MECHANICAL												
ROUGH IN PLUMBING												
Polybutylene Supply Lines												
1/2" dia piping	260.0	1.00	Ft	260	0.021	5.46	0.27	5.73	87	499	507.70	2.91
3/4" piping	64.0	1.00	Ft	64	0.039	2.496	0.12	2.62	87	228	507.70	1.33
1/2" t's	12.0		No	12	0.025	0.3	0.02	0.32	87	27	507.70	0.16
1/2" connectors	20.0		No	20	0.227	4.54	0.23	4.77	87	415	507.70	2.42
Supply header	1.0		No	1	6.804	6.804	0.34	7.14	87	622	507.70	3.63
ABS Waste Lines												
1 1/2" pipe	138.0	1.00	Ft	138	0.136	18.768	0.94	19.71	87	1714	507.70	10.00
1 1/2" 90 el	15.0		No	15	0.066	0.99	0.05	1.04	87	90	507.70	0.53
1 1/2" 45 el	10.0		No	10	0.041	0.41	0.02	0.43	87	37	507.70	0.22
1 1/2" T	3.0		No	3	0.090	0.27	0.01	0.28	87	25	507.70	0.14
1 1/2" Trap	5.0		No	5	0.150	0.75	0.04	0.79	87	69	507.70	0.40
1 1/2" Clean Out	2.0		No	2	0.098	0.196	0.01	0.21	87	18	507.70	0.10
2" 90 el	78.0		No	78	0.095	7.41	0.37	7.78	87	677	507.70	3.95
2" 45 el	15.0		No	15	0.060	0.9	0.05	0.95	87	82	507.70	0.48
2" T	10.0		No	10	0.145	1.45	0.07	1.52	87	132	507.70	0.77
2" Trap	3.0		No	3	0.299	0.897	0.04	0.94	87	82	507.70	0.48
2" Clean Outs	4.0		No	4	0.150	0.6	0.03	0.63	87	55	507.70	0.32
3" 45 el	44.0		No	44	0.204	8.976	0.45	9.42	87	820	507.70	4.78
4" T	52.0		No	52	0.812	42.224	2.11	44.34	87	3857	507.70	22.51
PLUMBING FIXTURES												
Water heaters	1.0		No	1	75.000	75	0.00	75.00	80	6000	5360.00	402.00
Water closet	3.0		No	3	40.000	120	0.00	120.00	29.4	3528	2837.48	340.50
Bathroom sink	3.0		No	3	20.000	60	0.00	60.00	29.4	1764	2837.48	170.25
Kitchen sink	1.0		No	1	25.000	25	0.00	25.00	45	1125	2454.18	61.35
Tub/shower	2.0		No	2	300.000	600	0.00	600.00	29.4	17640	1969.80	1181.88
Hose bibs	2.0		No	2	0.100	0.2	0.00	0.20	29.368	6	1967.66	0.39
Laundry tub	1.0		No	1	10.000	10	0.00	10.00	29.4	294	1969.80	19.70
HEATING												
Forced Air												
Furnace												
Gas Furnace	1.0		No	1	85.000	85	0.00	85.00	80	6800	2837.48	241.19
Filter	1.0		No	1	0.100	0.1	0.00	0.10	12	1	804.00	0.08
Floor registers	16.0		No	16	0.500	8	0.00	8.00	45	360	2837.48	22.70
R/A grilles	5.0		No	5	0.500	2.5	0.00	2.50	45	113	2837.48	7.09
Dampers	2.0		No	2	0.250	0.5	0.00	0.50	45	23	2837.48	1.42
Gas piping	150.0	1.00	Ft	150	0.500	75	3.75	78.75	28.23	2223	1945.00	153.17
Electrical connection	1.0		No	1	0.100	0.1	0.01	0.11	23.071	2	1545.76	0.16
VENTILATION												
Bath fans	2.0		No	2	2.500	5	0.00	5.00	60	300	4020.00	20.10
Bath fan low sone	1.0		No	1	5.000	5	0.00	5.00	60	300	4020.00	20.10
Controls	1.0		No	1	0.300	0.3	0.00	0.30	32.956	10	2208.05	0.66
SECTION 12 ELECTRICAL												
ELECTRICAL ROUGH IN												
U/G PVC connection box	1.0		No	1	0.272	0.272	0.00	0.27	32.956	9	2208.05	0.60
2" PVC conduit	8.0	1.00	Ft	8	0.322	2.576	0.00	2.58	32.956	85	2208.05	5.69
2" PVC L.B. Box	1.0		No	1	0.771	0.771	0.00	0.77	32.956	25	2208.05	1.70
2" PVC couplings	4.0		No	4	0.100	0.4	0.00	0.40	32.956	13	2208.05	0.88
Circuits												
#2 bare copper wire	20.0	1.00	Ft	20	0.091	1.82	0.00	1.82	29.457	54	1973.62	3.59
6'x5/8" galv st grndng rds	2.0	1.00	No	2	3.000	6	0.00	6.00	32.956	198	2208.05	13.25
200 amp main breaker	1.0	1.00	No	1	30.000	30	0.00	30.00	32.956	989	2208.05	66.24
14-2 NMD copper wire	2000.0	1.00	Ft	2000	0.029	58	0.00	58.00	29.457	1709	1973.62	114.47

14-3 NMD copper wire	1000.0	1.00	Ft	1000	0.038	38	0.00	38.00	29.457	1119	1973.62	75.00
12-2 NMD copper wire	35.0	1.00	Ft	35	0.072	2.52	0.00	2.52	29.457	74	1973.62	4.97
10-3 NMD copper wire	6.0	1.00	Ft	6	0.122	0.732	0.00	0.73	29.457	22	1973.62	1.44
8-3 NMD copper wire	30.0	1.00	Ft	30	0.182	5.46	0.00	5.46	29.457	161	1973.62	10.78
FIXTURES												
WALL OUTLETS												
Duplex	45.0		No	45	0.250	11.25	0.00	11.25	71.02	799	4758.34	53.53
Half switched	5.0		No	5	0.250	1.25	0.00	1.25	71.02	89	4758.34	5.95
G.F.I.	3.0		No	3	0.250	0.75	0.00	0.75	71.02	53	4758.34	3.57
Waterproof	2.0		No	2	0.250	0.5	0.00	0.50	71.02	36	4758.34	2.38
SWITCHES												
Single pole	15.0		No	15	0.250	3.75	0.00	3.75	71.02	266	4758.34	17.84
3 way	16.0		No	16	0.500	8	0.00	8.00	71.02	568	4758.34	38.07
4 way	3.0		No	3	0.500	1.5	0.00	1.50	71.02	107	4758.34	7.14
timers	1.0		No	1	0.250	0.25	0.00	0.25	71.02	18	4758.34	1.19
LIGHT FIXTURES (interior)												
Surface mounted	21.0		No	21	2.000	42	0.00	42.00	71.023	2983	4758.54	199.86
LIGHT FIXTURES (exterior)												
Surface mount	5.0		No	5	2.000	10	0.00	10.00	71.023	710	4758.54	47.59
MISC. CONNECTIONS												
Door chimes	1.0		1.00	1	0.500	0.5	0.00	0.50	50.449	25	3380.08	1.69
Smoke detector	2.0		No	2	0.250	0.5	0.00	0.50	50.449	25	3380.08	1.69
Burglar Alarm	1.0		No	1	0.500	0.5	0.00	0.50	50.449	25	3380.08	1.69
Air conditioner	3.0		No	3	0.500	1.5	0.00	1.50	71.02	107	4758.34	7.14
Heat recovery ventilator	1.0		No	1	0.500	0.5	0.00	0.50	71.02	36	4758.34	2.38
Overhead door operator	1.0		No	1	0.250	0.25	0.00	0.25	71.02	18	4758.34	1.19
30 amp. dryer outlet	1.0		No	1	0.500	0.5	0.00	0.50	32.956	16	2208.05	1.10
						150382	2657	153039		580523		33869
Item/Location	**Qnty**	**No**	**Units**	**Tot Qty**	**Conversion**	**As Built**	**Wast**	**Initial Wt**	**Unit EE**	**Initial EE**	**CO2**	**Initial CO2**

APPENDIX B2: IMPROVED HOUSE LIFE CYCLE CALCULATIONS: RECURRING.

							Building Life (Years)					
							40					
	RP	**RI**	**PL**	**TR**	**RCC**	**RCI**	**RF**					
				40				**REC.**	**REC.**			
ITEM/LOCATION								**MATERIAL**	**ENERGY**			
								KG	MJ			
SECTION 1 SITE WORK												
CONCRETE FLATWORK												
Driveway	0	1	40	0	39	39	0.0	0	0	0		
Sidewalks	0	1	40	0	39	39	0.0	0	0	0		
Patio	0	1	50	0	49	39	0.0	0	0	0		
								0.00	0.00	0.00		
								0.00	0.00	0.00		
SITE DRAINAGE								0.00	0.00	0.00		
4" perforated plastic pipe perimeter footing drainage	0	1	50	0	49	39	0.0	0	0	0		

3/4" course gravel backfill	0	1	50	0	49	39	0.0	0	0	0		
SECTION 2 CONCRETE												
FORMWORK												
FOUNDATION												
Strip footing forms	0	1	200	0	199	39	0.0	0	0	0		
Pad footing forms	0	1	200	0	199	39	0.0	0	0	0		
Pedestal forms	0	1	200	0	199	39	0.0	0	0	0		
Slab edge forms	0	1	200	0	199	39	0.0	0	0	0		
Foundation wall forms	0	1	200	0	199	39	0.0	0	0	0		
1x2 level strip	0	1	200	0	199	39	0.0	0	0	0		
2x4 keyway	0	1	200	0	199	39	0.0	0	0	0		
								0	0	0		
								0	0	0		
CAST IN PLACE CONCRETE								0	0	0		
								0	0	0		
FOUNDATION								0	0	0		
Strip Footings	0	1	75	0	74	39	0.0	0	0	0		
Floor slab	0	1	75	0	74	39	0.0	0	0	0		
Garage floor slab	0	1	75	0	74	39	0.0	0	0	0		
Foundation wall	0	1	75	0	74	39	0.0	0	0	0		
Footing pads	0	1	75	0	74	39	0.0	0	0	0		
								0	0	0		
REINFORCING								0	0	0		
Structural slabs rebar	0	1	75	0	74	39	0.0	0	0	0		
Garage floor slab w.w.m.	0	1	75	0	74	39	0.0	0	0	0		
								0	0	0		
								0	0	0		
CONCRETE ACCESSORIES								0	0	0		
1/2" dia Anchor bolts	0	1	75	0	74	39	0.0	0	0	0		
Dampproofing	25	40	75	0	1	0	0.0	0	0	0		
Granular fill under M. floor slab	0	1	200	0	199	39	0.0	0	0	0		
Granular fill under garage slab	0	1	200	0	199	39	0.0	0	0	0		
								0	0	0		
								0	0	0		
NAILS	0	1	50	0	49	39	0.0	0	0	0		
								0	0	0		
SECTION 5 CARPENTRY								0	0	0		
ROUGH CARPENTARY										0		
FIRST STOREY EXTERIOR WALLS										0		
2x4	0	1	50	0	49	39	0.0	0	0	0		
Headers								0	0	0		
2x10	0	1	40	0	39	39	0.0	0	0	0		
								0	0	0		
Sheathing								0	0	0		
3/8" Plywood	10	25	50	0	1	1	0.1	84	840	47		
								0	0	0		
								0	0	0		
Beams								0	0	0		
Built up D.Fir								0	0	0		
2x8	0	1	50	0	49	39	0.0	0	0	0		
2x10	0	1	50	0	49	39	0.0	0	0	0		
2x12	0	1	50	0	49	39	0.0	0	0	0		
Posts and Columns												
6x6	0	1	50	0	49	39	0.0	0	0	0		
FIRST STOREY INTERIOR WALLS												
2x4	0	1	40	0	39	39	0.0	0	0	0		
SECOND STOREY FLOOR SYSTEM												
Joists												
2x10 SPF	0	1	50	0	49	39	0.0	0	0	0		
Cross bridging										0		
2x2	0	1	50	0	49	39	0.0	0	0	0		

2x2	0	1	50	0	49	39	0.0	0	0	0		
Solid Blocking												
2x10	0	1	50	0	49	39	0.0	0	0	0		
Subflooring												
5/8" T&G Plywood	5	5	50	0	9	7	0.4	188	1886	105		
Subfloor adhesive	5	5	50	0	9	7	0.4	3	306	5		
SECOND STORY EXTERIOR WALLS												
2x4	0	1	40	0	39	39	0.0	0	0	0		
Header 2x10	0	1	40	0	39	39	0.0	0	0	0		
										0		
Sheathing										0		
3/8" Plywood	10	25	50	0	1	1	0.1	46	463	26		
Beams												
Built up D.Fir												
2x10	0	1	50	0	49	39	0.0	0	0	0		
										0		
										0		
										0		
SECOND STORY INTERIOR WALLS										0		
2x4	0	1	40	0	39	39	0.0	0	0	0		
ROOF SYSTEM												
Ceiling Joists												
2x4 SPF	0	1	40	0	39	39	0.0	0	0	0		
2x6 SPF	0	1	40	0	39	39	0.0	0	0	0		
Rafters												
2x8 SPF	0	1	40	0	39	39	0.0	0	0	0		
2x10 SPF	0	1	40	0	39	39	0.0	0	0	0		
Rafters												
2x4	0	1	40	0	39	39	0.0	0	0	0		
Ridge board												
2x10	0	1	40	0	39	39	0.0	0	0	0		
Exterior Soffit Framing												
2x4	0	1	40	0	39	39	0.0	0	0	0		
Ledgers												
2x4	0	1	40	0	39	39	0.0	0	0	0		
										0		
Sheathing										0		
1/2" Plywood	0	1	40	0	39	39	0.0	0	0	0		
Strapping												
1x4	0	1	40	0	39	39	0.0	0	0	0		
H Clips	0	1	40	0	39	39	0.0	0	0	0		
EXTERIOR FINISH CARPENTRY												
EXTERIOR FINISH												
Siding												
Wood												
1x6	0	1	50	0	49	39	0.0	0	0	0		
Building Paper								0	0	0		
Plywood												
1/2" Plywood	0	1	50	0	49	39	0.0	0	0	0		
Corner trim												
1x4	0	1	50	0	49	39	0.0	0	0	0		
SOFFIT AND FASCIA										0		
Fascia board										0		
2x8	0	1	50	0	49	39	0.0	0	0	0		
Barge board												
2x10	0	1	50	0	49	39	0.0	0	0	0		
Soffit												

Perforated aluminum	20	12	40	0	3	3	0.6	14	3707	63		
INTERIOR FINISH CARPENTRY												
STAIR												
Stringers												
2x10	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Treads												
2x12	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Risers												
Plywood												
1/2" Plywood	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Handrail												
2x4	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Balusters	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Newels	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Landing joists												
2x8 SPF	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
Landing sheathing										0.00		
5/8"Plywood	25.00	40.00	60	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
SECTION 6 INSULATION AND MOISTURE PROTECTION												
INSULATION												
First floor walls												
Batt												
89 mm (3 1/2")	25	40	50	0	1	0	0.0	0	0	0		
25 mm extruded Polystyrene	25	40	50	0	1	0	0.0	0	0	0		
Second floor walls												
Batt												
89 mm (3 1/2")	25	40	50	0	1	0	0.0	0	0	0		
25 mm extruded Polystyrene	25	40	50	0	1	0	0.0	0	0	0		
CEllulos												
Attic/208 mm Blown (RSI 5.3)	5	5	50	0	9	7	0.4	146	685	46		
DAMPROOFING												
M floor under slab 6 mil poly	0	1	50	0	49	39	0.0	0	0	0		
VAPOUR BARRIER												
First floor walls	0	1	50	0	49	39	0.0	0	0	0		
Second floor walls	0	1	50	0	49	39	0.0	0	0	0		
Attics	0	1	50	0	49	39	0.0	0	0	0		
Band joists	0	1	50	0	49	39	0.0	0	0	0		
AIR BARRIER												
First floor walls												
Caulking	30	15	50	0	3	2	0.6	0	69	2		
Second floor walls												
Caulking	30	15	50	0	3	2	0.6	1	92	3		
Attic Ceiling												
Caulking	30	15	50	0	3	2	0.6	1	92	3		
Band joists												
Caulking	30	15	50	0	3	2	0.6	1	137	4		
FLASHING AND SHEET METAL												
Wall to roof flashing	0	1	50	0	49	39	0.0	0	0	0		
Window and door head flashings	0	1	50	0	49	39	0.0	0	0	0		
2" aluminum soffit vent	0	1	50	0	49	39	0.0	0	0	0		
Gutter-Aluminium	0	1	50	0	49	39	0.0	0	0	0		
Valley flashing	0	1	50	0	49	39	0.0	0	0	0		
Roof vents	0	1	50	0	49	39	0.0	0	0	0		
Roof edge	0	1	50	0	49	39	0.0	0	0	0		
5"x7" leaf flashing	0	1	50	0	49	39	0.0	0	0	0		

ROOFING MATERIALS												
15# Building Paper	10	10	40	0	3	3	0.3	14	475	15		
Roofing finish												
Asphalt shingles	0	1	15	2	14	9	2.0	4083	113089	7577		
SECTION 7 DOORS WINDOWS AND FINISH HARDWARE												
DOORS & FRAMES												
EXTERIOR SWINGING												
3'-0"x6'-8"												
1 3/4" thick metal	15	14	70	0	4	2	0.3	6	172	12		
2'-8"x6'-8"												
1 3/4" thick metal	15	14	70	0	4	2	0.3	18	509	35		
INTERIOR SWINGING												
2'-6"x6'-8"	15	7	30	1	4	1	1.8	129	746	58		
2'-4"x6'-8"	15	7	30	1	4	1	1.8	20	115	9		
BI-FOLD DOORS												
4'-0"x6'-8"	15	7	30	1	4	1	1.8	131	760	59		
OVERHEAD DOORS												
9'x7'	30	8	16	2	1	0	2.6	268	1552	120		
AUTOMATIC OPENER												
								0	0	0		
WINDOWS												
Size												
3'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
3'-0"x3'-0"-g	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x3'-0"-G	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x4'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x4'-0"-G	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x5'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
4'-0"x5'-0"-G	0	1	50	0	49	39	0.0	0	0	0		
1'-0"x3'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
1'-0"x3'-0"-G	0	1	50	0	49	39	0.0	0	0	0		
2'-0"x1'-6"-F	0	1	50	0	49	39	0.0	0	0	0		
2'-0"x1'-6"-G	0	1	50	0	49	39	0.0	0	0	0		
6'-0"x7'-0"-F	0	1	50	0	49	39	0.0	0	0	0		
6'-0"x7'-0"-G	0	1	50	0	49	39	0.0	0	0	0		
FINISH HARDWARE												
Locksets	0	1	50	0	49	39	0.0	0	0	0		
Passage Sets	0	1	50	0	49	39	0.0	0	0	0		
Privacy Sets	0	1	50	0	49	39	0.0	0	0	0		
Bifold Pulls	0	1	50	0	49	39	0.0	0	0	0		
Door Stops	0	1	50	0	49	39	0.0	0	0	0		
Threshdolds	0	1	50	0	49	39	0.0	0	0	0		
Sweeps	0	1	50	0	49	39	0.0	0	0	0		
Weather stripping	0	1	50	0	49	39	0.0	0	0	0		
Latch	0	1	50	0	49	39	0.0	0	0	0		
Dead bolts	0	1	50	0	49	39	0.0	0	0	0		
Safety chain	0	1	50	0	49	39	0.0	0	0	0		
Closets												
Rods	0	1	50	0	49	39	0.0	0	0	0		
Shelves	0	1	50	0	49	39	0.0	0	0	0		
Rod Brackets	0	1	50	0	49	39	0.0	0	0	0		
Shelf Brackets	0	1	50	0	49	39	0.0	0	0	0		
SECTION 8 FINISHES												
GYPSUM BOARD												
Joint tape 500'	10	25	50	0	1	1	0.1	2	65	2		
Joint compound	10	25	50	0	1	1	0.1	68	136	9		
Metal corner beads	10	25	50	0	1	1	0.1	0	5	0		
First Floor Exterior Walls												
1/2" regular	10	25	50	0	1	1	0.1	101	749	36		
First Floor Interior Walls												
1/2" regular	10	25	50	0	1	1	0.1	102	756	36		

First Floor Ceilings											
5/8" regular	10	25	50	0	1	1	0.1	102	753	36		
Second Floor Exterior Walls												
1/2" regular	10	25	50	0	1	1	0.1	91	670	32		
Second Interior Floor Walls												
1/2" regular	10	25	50	0	1	1	0.1	120	890	42		
1/2" water resistant	10	25	50	0	1	1	0.1	12	92	4		
Second Floor Ceilings												
5/8" regular	10	25	50	0	1	1	0.1	84	620	30		
FLOORING												
Vynel	20	5	15	2	2	1	3.0	392	62728	4203		
Carpet	20	5.00	10.00	3	1	1	3.8	1116	178497	11709		
PAINT												
First floor exterior walls	0	1	5	7	4	4	7.0	86	6512	74		
First floor interior walls	0	1	5	7	4	4	7.0	190	14443	163		
First floor ceiling	0	1	5	7	4	4	7.0	69	5261	59		
Second floor exterior walls	0	1	5	7	4	4	7.0	76	5803	66		
Second floor interior walls	0	1	5	7	4	4	7.0	157	11967	135		
Second floor ceilings	0	1	5	7	4	4	7.0	49	3740	42		
SECTION 9 SPECIALTIES												
BATHROOM ACCESSORIES												
Towel bar	0	1	50	0	49	39	0.0	0	0	0		
Paper holder	0	1	50	0	49	39	0.0	0	0	0		
Soap holder/grab bar	0	1	50	0	49	39	0.0	0	0	0		
Bath tub doors	0	1	50	0	49	39	0.0	0	0	0		
Medicine Cabinets	0	1	50	0	49	39	0.0	0	0	0		
Mirrors									0	0		
5'-0"x4'-0"	0	1	50	0	49	39	0.0	0	0	0		
6'-6"x4'-0"	0	1	50	0	49	39	0.0	0	0	0		
SECTION 10 CABINETS AND APPLIANCIES												
CABINETS												
Kitchen counter tops & wall splash	10	10	30	1	2	0	1.2	208	2162	116		
Kitchen base cabinets	0	1	50	0	49	39	0.0	0	0	0		
Kitchen upper cabinets	0	1	50	0	49	39	0.0	0	0	0		
Bathroom vanity tops & wall splash	10	10	30	1	2	0	1.2	198	2064	111		
Bathroom base cabinets	0	1	50	0	49	39	0.0	0	0	0		
Laundry counter tops & wall splash	10	10	30	1	2	0	1.2	47	491	26		
Laundry room base cabinets	0	1	50	0	49	39	0.0	0	0	0		
Laundry room upper cabinets	0	1	50	0	49	39	0.0	0	0	0		
Dropped fluorecent ceiling	0	1	50	0	49	39	0.0	0	0	0		
KITCHEN & LAUNDRY EQUIPMENT												
Washer	0	1	10	3	9	9	3.0	210	16800	596		
Dryer	0	1	10	3	9	9	3.0	210	16800	596		
Refrigerator	0	1	10	3	9	9	3.0	240	19200	681		
Range Hood	25	10	20	1	1	1	1.5	15	1200	43		
Range	0	1	10	3	9	9	3.0	150	12000	426		
Microwave	0	1	10	3	9	9	3.0	105	8400	298		
Dishwasher	0	1	10	3	9	9	3.0	165	13200	468		
Garburator	0	1	10	3	9	9	3.0	45	3600	128		
SECTION 11 MECHANICAL												
ROUGH IN PLUMBING												
Polybutylene Supply Lines												
1/2" dia piping	30	8	40	0	4	4	1.2	7	599	3		
3/4" piping	30	8	40	0	4	4	1.2	3	274	2		
1/2" t's	30	8	40	0	4	4	1.2	0	33	0		

1/2" connectors	30	8	40	0	4	4	1.2	6	498	3		
Supply header	30	8	40	0	4	4	1.2	9	746	4		
ABS Waste Lines								0	0	0		
1 1/2" pipe	0	1	40	0	39	39	0.0	0	0	0		
1 1/2" 90 el	0	1	40	0	39	39	0.0	0	0	0		
1 1/2" 45 el	0	1	40	0	39	39	0.0	0	0	0		
1 1/2" T	0	1	40	0	39	39	0.0	0	0	0		
1 1/2" Trap	0	1	40	0	39	39	0.0	0	0	0		
1 1/2" Clean Out	0	1	40	0	39	39	0.0	0	0	0		
2" 90 el	0	1	40	0	39	39	0.0	0	0	0		
2" 45 el	0	1	40	0	39	39	0.0	0	0	0		
2" T	0	1	40	0	39	39	0.0	0	0	0		
2" Trap	0	1	40	0	39	39	0.0	0	0	0		
2" Clean Outs	0	1	40	0	39	39	0.0	0	0	0		
3" 45 el	0	1	40	0	39	39	0.0	0	0	0		
4" T	0	1	40	0	39	39	0.0	0	0	0		
PLUMBING FIXTURES												
Water heaters	30	10	20	1	1	1	1.6	120	9600	643		
Water closet	0	1	40	0	39	39	0.0	0	0	0		
Bathroom sink	10	10	40	0	3	3	0.3	18	529	51		
Kitchen sink	10	10	40	0	3	3	0.3	8	338	18		
Tub/shower	10	10	40	0	3	3	0.3	180	5292	355		
Hose bibs	5	25	20	1	0	0	1.0	0	6	0		
Laundry tub	10	10	40	0	3	3	0.3	3	88	6		
HEATING												
Forced Air												
Furnace												
Gas Furnace	0	1	15	2	14	9	2.0	170	13600	482		
Filter	0	1	20	1	19	19	1.0	0	1	0		
Floor registers	10	20	50	0	2	1	0.1	1	36	2		
R/A grilles	10	20	50	0	2	1	0.1	0	11	1		
Dampers	10	20	50	0	2	1	0.1	0	2	0		
Gas piping	0	1	50	0	49	39	0.0	0	0	0		
Electrical connection	0	1	50	0	49	39	0.0	0	0	0		
VENTILATION												
Bath fans	15	10	20	1	1	1	1.3	7	390	26		
Bath fan low sone	15	10	20	1	1	1	1.3	7	390	26		
Controls	15	10	20	1	1	1	1.3	0	13	1		
SECTION 12 ELECTRICAL												
ELECTRICAL ROUGH IN												
U/G PVC connection box	30	8	40	0	4	4	1.2	0	11	1		
2" PVC conduit	30	8	40	0	4	4	1.2	3	102	7		
2" PVC L.B. Box	0	1	50	0	49	39	0.0	0	0	0		
2" PVC couplings	0	1	50	0	49	39	0.0	0	0	0		
Circuits												
#2 bare copper wire	30	8	40	0	4	4	1.2	2	64	4		
6'x5/8" galv st grndng rds	30	8	40	0	4	4	1.2	7	237	16		
200 amp main breaker	30	8	40	0	4	4	1.2	36	1186	79		
14-2 NMD copper wire	30	8	40	0	4	4	1.2	70	2050	137		
14-3 NMD copper wire	30	8	40	0	4	4	1.2	46	1343	90		
12-2 NMD copper wire	30	8	40	0	4	4	1.2	3	89	6		
10-3 NMD copper wire	30	8	40	0	4	4	1.2	1	26	2		
8-3 NMD copper wire	30	8	40	0	4	4	1.2	7	193	13		
FIXTURES												
WALL OUTLETS												
Duplex	25	12	25	1	1	1	1.5	17	1198	80		
Half switched	25	12	25	1	1	1	1.5	2	133	9		
G.F.I.	25	12	25	1	1	1	1.5	1	80	5		
Waterproof	25	12	25	1	1	1	1.5	1	53	4		

SWITCHES										0		
Single pole	25	12	25	1	1	1	1.5	6	399	27		
3 way	25	12	25	1	1	1	1.5	12	852	57		
4 way	25	12	25	1	1	1	1.5	2	160	11		
timers	25	12	25	1	1	1	1.5	0	27	2		
LIGHT FIXTURES (interior)												
Surface mounted	25	12	25	1	1	1	1.5	63	4474	300		
LIGHT FIXTURES (exterior)												
Surface mount	25	12	25	1	1	1	1.5	15	1065	71		
MISC. CONNECTIONS												
Door chimes	0	1	40	0	39	39	0.0	0	0	0		
Smoke detector	0	1	40	0	39	39	0.0	0	0	0		
Burglar Alarm	0	1	40	0	39	39	0.0	0	0	0		
Air conditioner	0	1	40	0	39	39	0.0	0	0	0		
Heat recovery ventilator	0	1	40	0	39	39	0.0	0	0	0		
Overhead door operator	0	1	40	0	39	39	0.0	0	0	0		
30 amp. dryer outlet	0	1	40	0	39	39	0.0	0	0	0		
								10394	561490	30900		
ITEM/LOCATION								**Rec. Mater-ials**	**Rec. Energy**	**Rec. CO2**		

APPENDIX C1: BASE CASE STUDY HOUSE'S EMBODIED ENERGY DETAILED TABLE.

ITEM/LOCATION	INITIAL	PERCENT	RECURRING	PERCENT	TOTAL	PERCENT
	MJ		MJ			
SECTION 1 SITE WORK	**44413.2**	**4.77**	**1354.49**	**0.18**	**45767.7**	**2.73**
CONCRETE FLATWORK	24380.8	2.62	1354.49	0.18	25735.3	1.53
SITE DRAINAGE	20032.4	2.15	0.00	0.00	20032.4	1.19
SECTION 2 CONCRETE	**133681.5**	**14.35**	**0.00**	**0.00**	**133681.5**	**7.97**
FORMWORK-BASEMENT FOUNDATION	4945.1	0.53	0.00	0.00	4945.1	0.29
CAST IN PLACE CONCRETE-BASEMENT FOUNDATION	120549.5	12.94	0.00	0.00	120549.5	7.18
REINFORCING	3658.6	0.39	0.00	0.00	3658.6	0.22
CONCRETE ACCESSORIES	4528.3	0.49	0.00	0.00	4528.3	0.27
SECTION 3 MASONRY	**31839.7**	**3.42**	**3289.23**	**0.44**	**35128.9**	**2.09**
CONC. BLOCK WALLS	1052.6	0.11	210.51	0.03	1263.1	0.08
MASONRY VENEER	15870.0	1.70	1587.00	0.21	17457.0	1.04
MASONRY FIREPLACES	14917.1	1.60	1491.71	0.20	16408.9	0.98
SECTION 4 METALS	**8887.6**	0.95	**428.65**	**0.06**	**9316.3**	0.56
STRUCTURAL STEEL	2143.3	0.23	428.65	0.06	2571.9	0.15
NAILS	6744.4	0.72	0.00	0.00	6744.4	0.40
SECTION 5 CARPENTRY	**190466.6**	**20.45**	**14793.40**	**1.98**	**205260.0**	**12.23**
BASEMENT FOUNDATION FRAMING	16441.3	1.76	0.00	0.00	16441.3	0.98
FIRST FLOOR FRAMING	28675.1	3.08	3878.65	0.52	32553.7	1.94
FIRST STOREY EXTERIOR WALLS	31214.7	3.35	807.87	0.11	32022.6	1.91
FIRST STOREY INTERIOR WALLS	5353.8	0.57	0.00	0.00	5353.8	0.32
SECOND STOREY FLOOR SYSTEM	17502.9	1.88	2859.01	0.38	20361.9	1.21
SECOND STORY EXTERIOR WALLS	15526.7	1.67	508.96	0.07	16035.7	0.96
SECOND STORY INTERIOR WALLS	5177.8	0.56	0.00	0.00	5177.8	0.31
ROOF SYSTEM	41266.8	4.43	0.00	0.00	41266.8	2.46
EXTERIOR FINISH CARPENTRY	12313.4	1.32	0.00	0.00	12313.4	0.73
SOFFIT AND FASCIA	13744.5	1.48	6738.91	0.90	20483.4	1.22
INTERIOR FINISH CARPENTRY-STAIRES	3249.6	0.35	0.00	0.00	3249.6	0.19
SECTION 6 INSULATION AND MOISTURE PROTECTION	**175064.6**	**18.79**	**153409.60**	**20.56**	**328474.2**	**19.58**
INSULATION	49477.0	5.31	12198.95	1.63	61676.0	3.68
DAMPROOFING	4122.7	0.44	77.82	0.01	4200.5	0.25
VAPOUR BARRIER	2336.5	0.25	0.00	0.00	2336.5	0.14

AIR BARRIER	762.7	0.08	457.63	0.06	1220.4	0.07
FLASHING AND SHEET METAL	46360.9	4.98	0.00	0.00	46360.9	2.76
ROOFING MATERIALS	72004.8	7.73	140675.20	18.85	212680.0	12.68
SECTION 7 DOORS, WINDOWS AND FINISH HARDWARE	**29729.5**	**3.19**	**5691.23**	**0.76**	**35420.7**	**2.11**
DOORS & FRAMES	7280.4	0.78	5691.23	0.76	12971.6	0.77
WINDOWS (wood)	19700.3	2.11	0.00	0.00	19700.3	1.17
FINISH HARDWARE	2748.8	0.30	0.00	0.00	2748.8	0.16
SECTION 8 FINISHES	**197340.6**	**21.18**	**428665.47**	**57.44**	**626006.1**	**37.31**
GYPSUM BOARD	91338.1	9.80	9133.81	1.22	100471.9	5.99
FLOORING	95496.2	10.25	345987.60	46.36	441483.8	26.31
PAINT	10506.3	1.13	73544.06	9.86	84050.4	5.01
SECTION 9 SPECIALTIES	**6939.6**	**0.74**	**0.00**	**0.00**	**6939.6**	**0.41**
BATHROOM ACCESSORIES	6939.6	0.74	0.00	0.00	6939.6	0.41
SECTION 10 CABINETS AND APPLIANCIES	**50891.5**	**5.46**	**98010.24**	**13.13**	**148901.8**	**8.87**
CABINETS	19393.9	2.08	4717.44	0.63	24111.4	1.44
KITCHEN & LAUNDRY EQUIPMENT	31497.6	3.38	93292.80	12.50	124790.4	7.44
SECTION 11 MECHANICAL	**51407.8**	**5.52**	**26197.98**	**3.51**	**77605.8**	**4.63**
ROUGH IN PLUMBING	9449.3	1.01	2148.55	0.29	11597.9	0.69
PLUMBING FIXTURES	31826.9	3.42	9605.87	1.29	41432.7	2.47
HEATING	9521.7	1.02	13650.70	1.83	23172.4	1.38
VENTILATION	609.9	0.07	792.85	0.11	1402.7	0.08
SECTION 12 ELECTRICAL	**10906.1**	**1.17**	**14406.64**	**1.93**	**25312.7**	**1.51**
FIXTURES	4841.0	0.52	5686.92	0.76	10527.9	0.63
WALL OUTLETS	1935.3	0.21	2902.94	0.39	4838.2	0.29
LIGHT FIXTURES (interior)	3877.9	0.42	5816.78	0.78	9694.6	0.58
MISC. CONNECTIONS	251.9	0.03	0.00	0.00	251.9	0.02
	931568.3	100.00	**746246.94**	100.00	**1677815.2**	**100.00**

APPENDIX C2: BASE CASE STUDY HOUSE'S CO_2 EMISSIONS DETAILED TABLE.

ITEM/LOCATION	INITIAL	PERCENT	RECURRIN G	PERCENT	TOTAL	PERCENT
	KG		KG		KG	
SECTION 1 SITE WORK	**2605.2**	**4.78**	**135.45**	**0.18**	**2740.7**	**2.73**
CONCRETE FLATWORK	2438.1	4.47	135.45	0.18	2573.5	1.53
SITE DRAINAGE	167.1	0.31	0.00	0.00	167.1	1.19
SECTION 2 CONCRETE	**13518.8**	**24.80**	**0.00**	**0.00**	**13518.8**	**7.97**
FORMWORK-BASEMENT FOUNDATION	381.7	0.70	0.00	0.00	381.7	0.29
CAST IN PLACE CONCRETE-BASEMENT FOUNDATION	12054.9	22.12	0.00	0.00	12054.9	7.18
REINFORCING	212.7	0.39	0.00	0.00	212.7	0.22
CONCRETE ACCESSORIES	869.4	1.60	0.00	0.00	869.4	0.27
SECTION 3 MASONRY	**1794.4**	**3.29**	**185.93**	**0.44**	**1980.3**	**2.09**
CONC. BLOCK WALLS	64.9	0.12	12.99	0.03	77.9	0.08
MASONRY VENEER	895.4	1.64	89.54	0.21	984.9	1.04
MASONRY FIREPLACES	834.1	1.53	83.41	0.20	917.5	0.98
SECTION 4 METALS	**512.2**	**0.94**	**26.48**	**0.06**	538.7	0.56
STRUCTURAL STEEL	132.4	0.24	26.48	0.06	158.9	0.15
NAILS	379.8	0.70	0.00	0.00	379.8	0.40
SECTION 5 CARPENTRY	**12699.0**	**23.30**	**529.83**	**1.98**	13228.8	**12.23**
BASEMENT FOUNDATION FRAMING	1243.7	2.28	0.00	0.00	1243.7	0.98
FIRST FLOOR FRAMING	1937.8	3.56	198.73	0.52	2136.5	1.94
FIRST STOREY EXTERIOR WALLS	2240.8	4.11	44.98	0.11	2285.8	1.91
FIRST STOREY INTERIOR WALLS	414.5	0.76	0.00	0.00	414.5	0.32
SECOND STOREY FLOOR SYSTEM	1131.2	2.08	143.00	0.38	1274.2	1.21
SECOND STORY EXTERIOR WALLS	1091.4	2.00	28.34	0.07	1119.7	0.96
SECOND STORY INTERIOR WALLS	400.8	0.74	0.00	0.00	400.8	0.31
ROOF SYSTEM	2767.0	5.08	0.00	0.00	2767.0	2.46
EXTERIOR FINISH CARPENTRY	854.8	1.57	0.00	0.00	854.8	0.73
SOFFIT AND FASCIA	385.8	0.71	114.79	0.90	500.6	1.22

INTERIOR FINISH CARPENTRY-STAIRES	231.2	0.42	0.00	0.00	231.2	0.19
SECTION 6 INSULATION AND MOISTURE PROTECTION	**5202.5**	**9.55**	**3725.21**	**20.56**	8927.7	**19.58**
INSULATION	2005.7	3.68	494.52	1.63	2500.2	3.68
DAMPROOFING	601.9	1.10	2.35	0.01	604.3	0.25
VAPOUR BARRIER	41.5	0.08	0.00	0.00	41.5	0.14
AIR BARRIER	23.1	0.04	13.83	0.06	36.9	0.07
FLASHING AND SHEET METAL	871.2	1.60	0.00	0.00	871.2	2.76
ROOFING MATERIALS	1659.1	3.04	3214.50	18.85	4873.6	12.68
SECTION 7 DOORS, WINDOWS AND FINISH HARDWARE	**1758.8**	**3.23**	**426.41**	**0.76**	2185.2	**2.11**
DOORS & FRAMES	566.3	1.04	426.41	0.76	992.7	0.77
WINDOWS (wood)	1043.7	1.92	0.00	0.00	1043.7	1.17
FINISH HARDWARE	148.8	0.27	0.00	0.00	148.8	0.16
SECTION 8 FINISHES	**10748.3**	**19.72**	**23963.96**	**57.44**	34712.3	**37.31**
GYPSUM BOARD	4365.1	8.01	436.51	1.22	4801.6	5.99
FLOORING	6264.6	11.49	22696.79	46.36	28961.3	26.31
PAINT	118.7	0.22	830.66	9.86	949.3	5.01
SECTION 9 SPECIALTIES	**308.0**	**0.57**	**0.00**	**0.00**	308.0	**0.41**
BATHROOM ACCESSORIES	308.0	0.57	0.00	0.00	308.0	0.41
SECTION 10 CABINETS AND APPLIANCIES	**2134.9**	**3.92**	**3488.29**	**13.13**	5623.1	**8.87**
CABINETS	1042.4	1.91	253.56	0.63	1296.0	1.44
KITCHEN & LAUNDRY EQUIPMENT	1092.4	2.00	3234.73	12.50	4327.2	7.44
SECTION 11 MECHANICAL	**2524.6**	**4.63**	**891.00**	**3.51**	3415.6	**4.63**
ROUGH IN PLUMBING	55.1	0.10	12.54	0.29	67.7	0.69
PLUMBING FIXTURES	2003.7	3.68	340.88	1.29	2344.6	2.47
HEATING	425.8	0.78	485.57	1.83	911.4	1.38
VENTILATION	40.0	0.07	52.01	0.11	92.0	0.08
SECTION 12 ELECTRICAL	**694.5**	**1.27**	**927.31**	**1.93**	1621.8	**1.51**
FIXTURES	296.7	0.54	355.29	0.76	652.0	0.63
WALL OUTLETS	127.0	0.23	190.43	0.39	317.4	0.29
LIGHT FIXTURES (interior)	254.4	0.47	381.58	0.78	636.0	0.58
MISC. CONNECTIONS	16.5	0.03	0.00	0.00	16.5	0.02
	54501.2	100.00	34299.87	**100.00**	**88801.1**	**100.00**

APPENDIX D1: IMPROVED HOUSE'S INDIRECT EMBODIED ENERGY DETAILED TABLE.

ITEM/LOCATION	Initial	Percent	Recurring	Percent	Total	Percent
	MJ		MJ			
SECTION 1 SITE WORK	**32098.6**	**5.53**	**0.0**	**0.00**	**32098.6**	**2.81**
CONCRETE FLATWORK	16253.9	2.80	0.0	0.00	16253.9	1.42
SITE DRAINAGE	15844.7	2.73	0.0	0.00	15844.7	1.39
SECTION 2 CONCRETE	**54785**	**9.44**	**0.0**	**0.00**	**54785**	**4.80**
FORMWORK-BASEMENT FOUNDATION	1943.1	0.33	0.0	0.00	1943.1	0.17
CAST IN PLACE CONCRETE-BASEMENT FOUNDATION	47623.8	8.20	0.0	0.00	47623.8	4.17
REINFORCING	3658.6	0.63	0.0	0.00	3658.6	0.32
CONCRETE ACCESSORIES	1559.5	0.27	0.0	0.00	1559.5	0.14
SECTION 4 METALS	**2043**	**0.35**	**0.0**	**0.00**	**2043**	**0.18**
NAILS	2043.0	0.35	0.0	0.00	2043	0.18
SECTION 5 CARPENTRY	**116737**	**20.11**	**7201.5**	**1.28**	**123938.4**	**10.85**
FIRST STOREY EXTERIOR WALLS	31093.1	5.36	840.2	0.15	31933.2	2.80
FIRST STOREY INTERIOR WALLS	2415.7	0.42	0.0	0.00	2415.7	0.21
SECOND STOREY FLOOR SYSTEM	13157.8	2.27	2191.4	0.39	15349.2	1.34
SECOND STORY EXTERIOR WALLS	10802.3	1.86	462.7	0.08	11265.0	0.99
SECOND STORY INTERIOR WALLS	3620.6	0.62	0.0	0.00	3620.6	0.32
ROOF SYSTEM	34140.9	5.88	0.0	0.00	34140.9	2.99
EXTERIOR FINISH CARPENTRY	11419.3	1.97	0.0	0.00	11419.3	1.00

SOFFIT AND FASCIA	8337.4	1.44	3707.2	0.66	12044.6	1.05
INTERIOR FINISH CARPENTRY-STAIRES	1750.0	0.30	0.0	0.00	1750.0	0.15
SECTION 6 INSULATION AND MOISTURE PROTECTION	**123478.4**	**21.27**	**114638.4**	**20.42**	**238116.8**	**20.85**
INSULATION	16343.1	2.82	685.0	0.12	17028.1	1.49
DAMPROOFING	513.8	0.09	0.0	0.00	513.8	0.04
VAPOUR BARRIER	1353.1	0.23	0.0	0.00	1353.1	0.12
AIR BARRIER	648.3	0.11	389.0	0.07	1037.3	0.09
FLASHING AND SHEET METAL	46492.0	8.01	0.0	0.00	46492.0	4.07
ROOFING MATERIALS	58128.1	10.01	113564.5	20.23	171692.6	15.03
SECTION 7 DOORS, WINDOWS AND FINISH HARDWARE	**15528.7**	**2.67**	**3853.7**	**0.69**	**19382.3**	**1.70**
DOORS & FRAMES	4003.7	0.69	3853.7	0.69	7857.3	0.69
WINDOWS (wood)	8796.7	1.52	0.0	0.00	8796.7	0.77
FINISH HARDWARE	2728.3	0.47	0.0	0.00	2728.3	0.24
SECTION 8 FINISHES	**122075.2**	**21.03**	**293688.9**	**52.31**	**415764.1**	**36.41**
GYPSUM BOARD	47375.0	8.16	4737.5	0.84	52112.5	4.56
FLOORING	67882.1	11.69	241224.5	42.96	309106.6	27.07
PAINT	6818.1	1.17	47726.9	8.50	54545.0	4.78
SECTION 9 SPECIALTIES	**4421.7**	**0.76**	**0.0**	**0.00**	**4421.7**	**0.39**
BATHROOM ACCESSORIES	4421.7	0.76	0.0	0.00	4421.7	0.39
SECTION 10 CABINETS AND APPLIANCIES	**49080.1**	**8.45**	**95917.4**	**17.08**	**144997.5**	**12.70**
CABINETS	18280.1	3.15	4717.4	0.84	22997.5	2.01
KITCHEN & LAUNDRY EQUIPMENT	30800.0	5.31	91200.0	16.24	122000.0	10.68
SECTION 11 MECHANICAL	**49937.8**	**8.60**	**32444.9**	**5.78**	**82382.7**	**7.21**
ROUGH IN PLUMBING	9449.3	1.63	2148.6	0.38	11597.9	1.02
PLUMBING FIXTURES	30356.9	5.23	15852.8	2.82	46209.6	4.05
HEATING	9521.7	1.64	13650.7	2.43	23172.4	2.03
VENTILATION	609.9	0.11	792.9	0.14	1402.7	0.12
SECTION 12 ELECTRICAL	**10337.4**	**1.78**	**13744.8**	**2.45**	**24082.2**	**2.11**
FIXTURES	4457.0	0.77	5302.1	0.94	9759.0	0.85
WALL OUTLETS	1935.3	0.33	2902.9	0.52	4838.2	0.42
LIGHT FIXTURES (interior)	3693.2	0.64	5539.8	0.99	9233.0	0.81
MISC. CONNECTIONS	251.9	0.04	0.0	0.00	251.9	0.02
	580522.7	**100.00**	**561489.6**	**100.00**	**1142012.3**	**100.00**

APPENDIX D2: IMPROVED HOUSE'S CO_2 EMISSIONS DETAILED TABLE.

Item/Location	Initial	Percent	Recurring	Percent	Total	Percent
	kg		kg			
SECTION 1 SITE WORK	**1757.6**	**5.53**	**0.0**	**0.00**	**1757.6**	**2.81**
CONCRETE FLATWORK	1625.4	2.80	0.0	0.00	1625.4	1.42
SITE DRAINAGE	132.3	2.73	0.0	0.00	132.3	1.39
		0.00			0.0	
SECTION 2 CONCRETE	**5422.6**	**9.44**	**0.0**	**0.00**	**5422.6**	**4.80**
FORMWORK-BASEMENT FOUNDATION	150.4	0.33	0.0	0.00	150.4	0.17
CAST IN PLACE CONCRETE-BASEMENT FOUNDATION	4762.4	8.20	0.0	0.00	4762.4	4.17
REINFORCING	212.7	0.63	0.0	0.00	212.7	0.32
CONCRETE ACCESSORIES	297.1	0.27	0.0	0.00	297.1	0.14
		0.00			0.0	
SECTION 4 METALS	**115.0**	**0.35**	**0.0**	**0.00**	**115.0**	**0.18**
NAILS	115.0	0.35	0.0	0.00	115.0	0.18
		0.00				
SECTION 5 CARPENTRY	**7751.5**	**20.11**	**245.6**	**1.28**	**7997.1**	**10.85**

FIRST STOREY EXTERIOR WALLS	2224.4	5.36	46.8	0.15	2271.2	2.80
FIRST STOREY INTERIOR WALLS	187.0	0.42	0.0	0.00	187.0	0.21
SECOND STOREY FLOOR SYSTEM	847.8	2.27	109.9	0.39	957.7	1.34
SECOND STORY EXTERIOR WALLS	735.7	1.86	25.8	0.08	761.4	0.99
SECOND STORY INTERIOR WALLS	280.3	0.62	0.0	0.00	280.3	0.32
ROOF SYSTEM	2282.3	5.88	0.0	0.00	2282.3	2.99
EXTERIOR FINISH CARPENTRY	796.4	1.97	0.0	0.00	796.4	1.00
SOFFIT AND FASCIA	272.4	1.44	63.1	0.66	335.5	1.05
INTERIOR FINISH CARPENTRY-STAIRES	125.2	0.30	0.0	0.00	125.2	0.15
SECTION 6 INSULATION AND MOISTURE PROTECTION	**5343.5**	**21.27**	**7649.3**	**20.42**	**12992.8**	**20.85**
INSULATION	590.6	2.82	45.8	0.12	636.4	1.49
DAMPROOFING	9.1	0.09	0.0	0.00	9.1	0.04
VAPOUR BARRIER	24.0	0.23	0.0	0.00	24.0	0.12
AIR BARRIER	19.6	0.11	11.8	0.07	31.4	0.09
FLASHING AND SHEET METAL	862.4	8.01	0.0	0.00	862.4	4.07
ROOFING MATERIALS	3837.7	10.01	7591.8	20.23	11429.5	15.03
SECTION 7 DOORS, WINDOWS AND FINISH HARDWARE	**984.5**	**2.67**	**292.9**	**0.69**	**1277.4**	**1.70**
DOORS & FRAMES	344.5	0.69	292.9	0.69	637.4	0.69
WINDOWS (wood)	493.1	1.52	0.0	0.00	493.1	0.77
FINISH HARDWARE	147.0	0.47	0.0	0.00	147.0	0.24
		0.00			0.0	
SECTION 8 FINISHES	**6833.9**	**21.03**	**16678.7**	**52.31**	**23512.6**	**36.41**
GYPSUM BOARD	2274.6	8.16	227.5	0.84	2502.0	4.56
FLOORING	4482.3	11.69	15912.1	42.96	20394.5	27.07
PAINT	77.0	1.17	539.1	8.50	616.1	4.78
		0.00			0.0	
SECTION 9 SPECIALTIES	**194.9**	**0.76**	**0.0**	**0.00**	**194.9**	**0.39**
BATHROOM ACCESSORIES	194.9	0.76	0.0	0.00	194.9	0.39
		0.00			0.0	
SECTION 10 CABINETS AND APPLIANCIES	**2075.0**	**8.45**	**3488.3**	**17.08**	**5563.3**	**12.70**
CABINETS	982.6	3.15	253.6	0.84	1236.1	2.01
KITCHEN & LAUNDRY EQUIPMENT	1092.4	5.31	3234.7	16.24	4327.2	10.68
		0.00			0.0	
SECTION 11 MECHANICAL	**2697.9**	**8.60**	**1624.8**	**5.78**	**4322.7**	**7.21**
ROUGH IN PLUMBING	55.1	1.63	12.5	0.38	67.7	1.02
PLUMBING FIXTURES	2176.1	5.23	1073.5	2.82	3249.6	4.05
HEATING	425.8	1.64	485.6	2.43	911.4	2.03
VENTILATION	40.9	0.11	53.1	0.14	94.0	0.12
		0.00			0.0	
SECTION 12 ELECTRICAL	**692.6**	**1.78**	**920.9**	**2.45**	**1613.5**	**2.11**
FIXTURES	298.6	0.77	355.2	0.94	653.9	0.85
WALL OUTLETS	129.7	0.33	194.5	0.52	324.2	0.42
LIGHT FIXTURES (interior)	247.4	0.64	371.2	0.99	618.6	0.81
MISC. CONNECTIONS	16.9	0.04	0.0	0.00	16.9	0.02
	33869.1	**100.00**	**30900.4**	**100.00**	**64769.4**	**100.00**

Figure 1. Base Case Study House Plans.

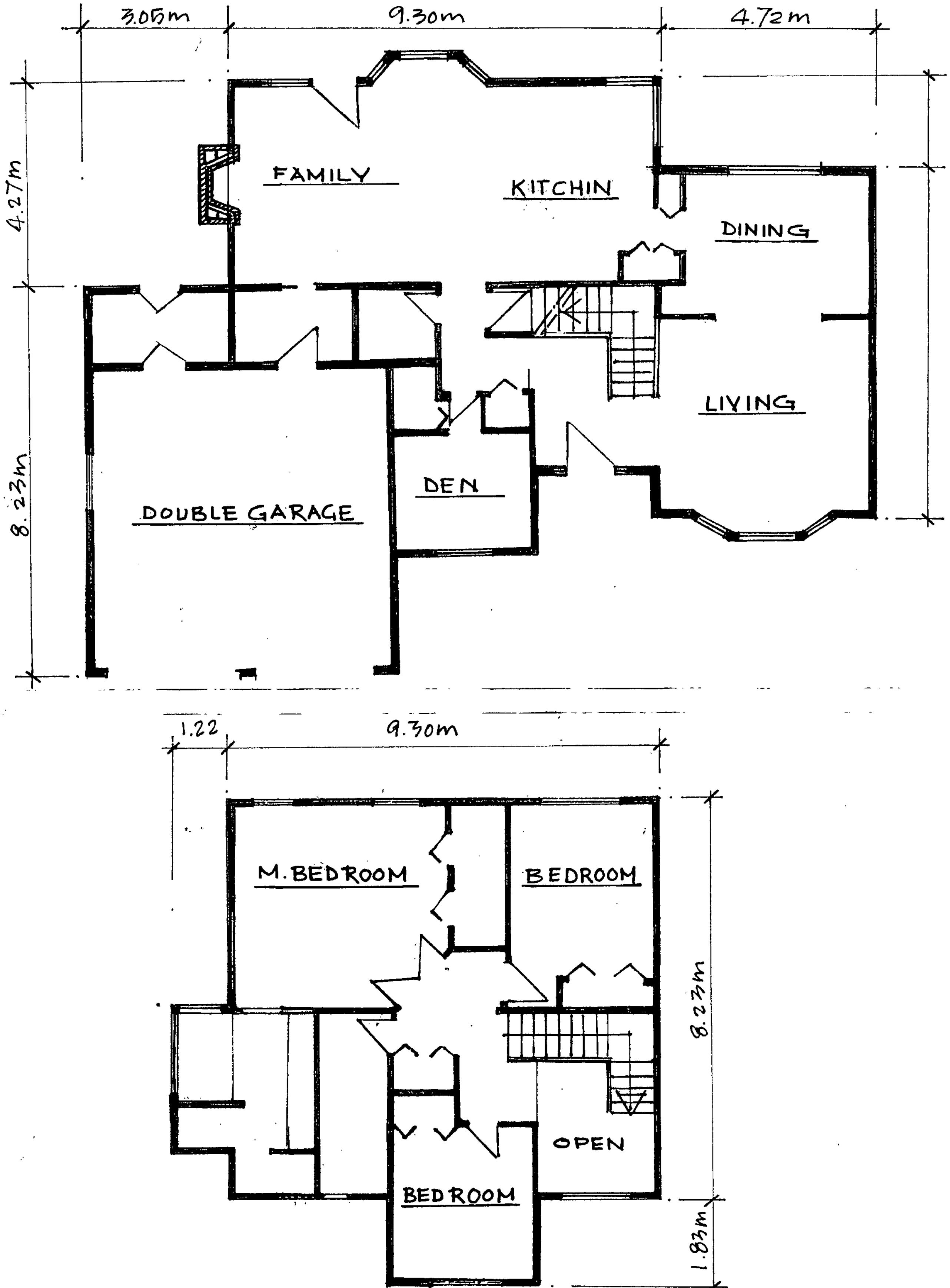


Figure 2. Base Case Study House - Elevations

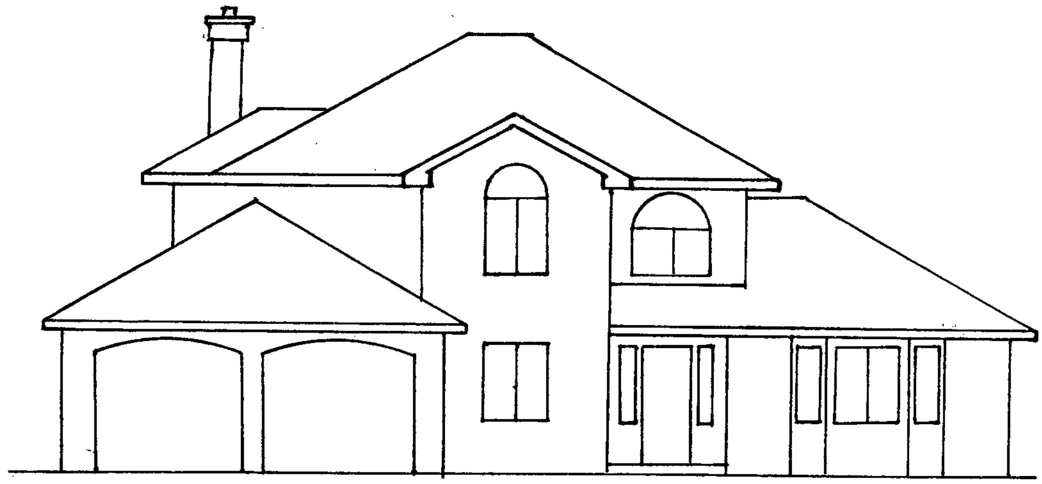
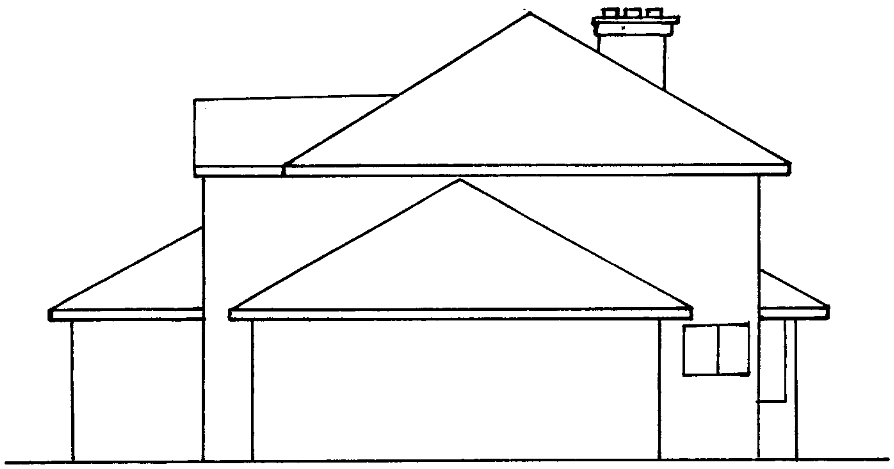


Figure 3. Base Case Study House - Elevations



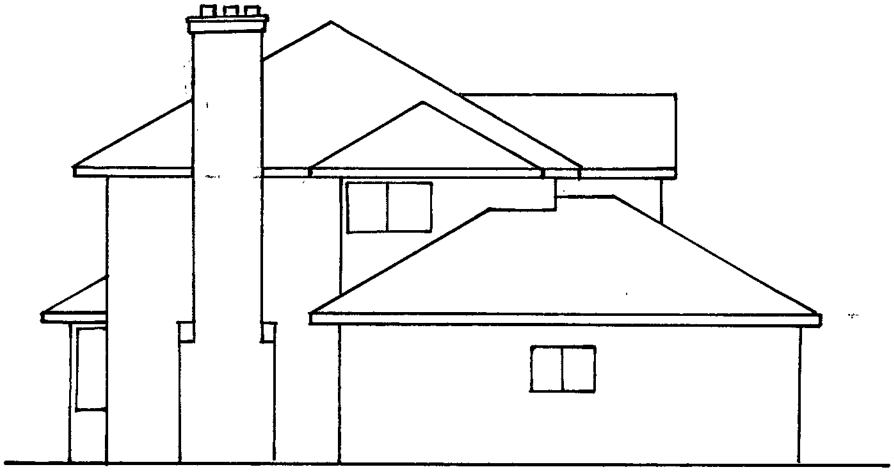


Figure 4. Improved House Plans

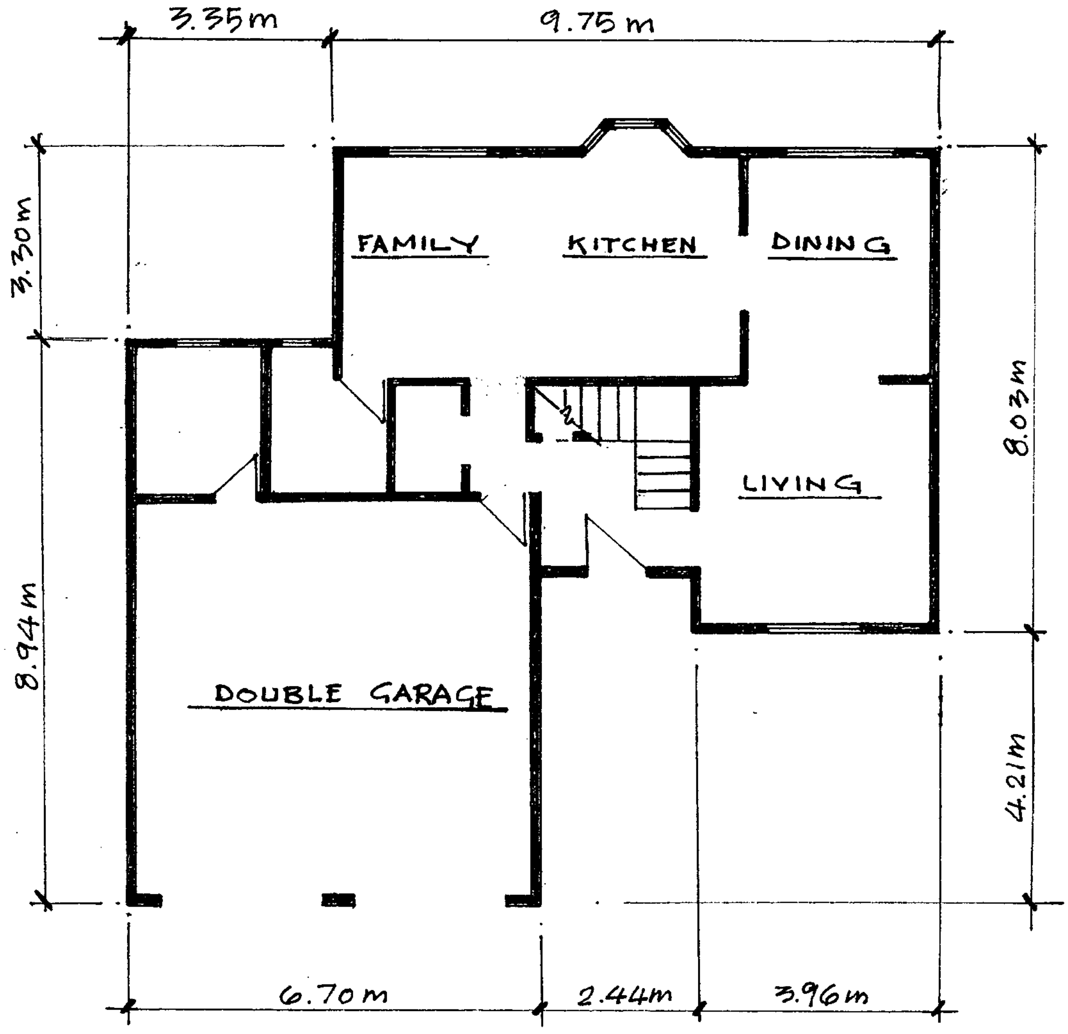


Figure 5. Improved House Plans

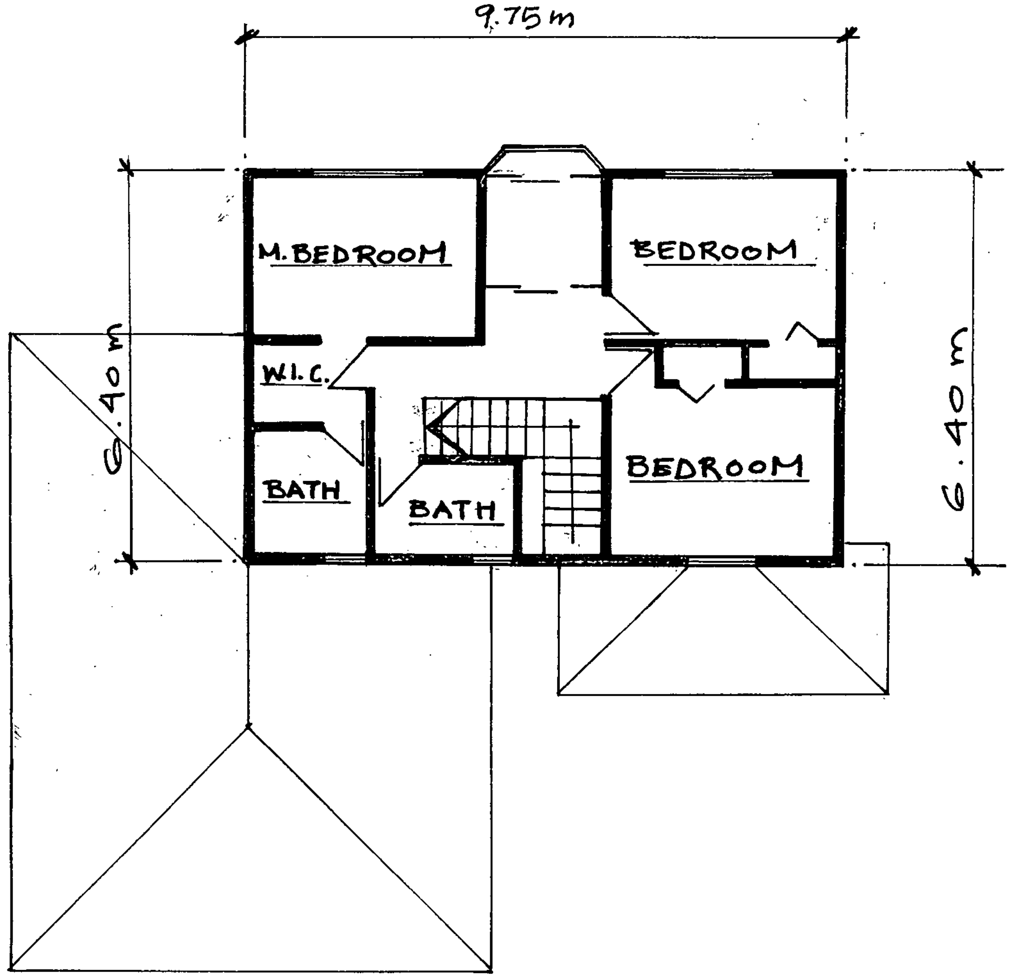
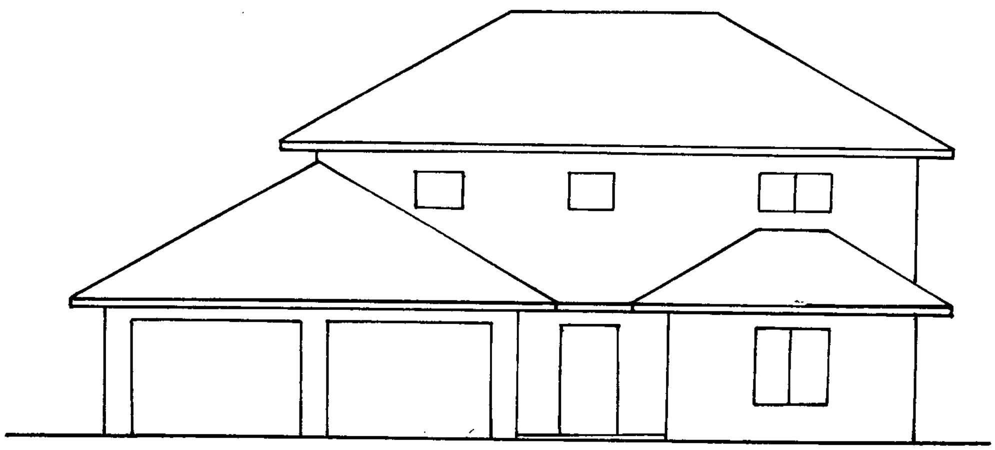


Figure 6. Improved House - Elevations



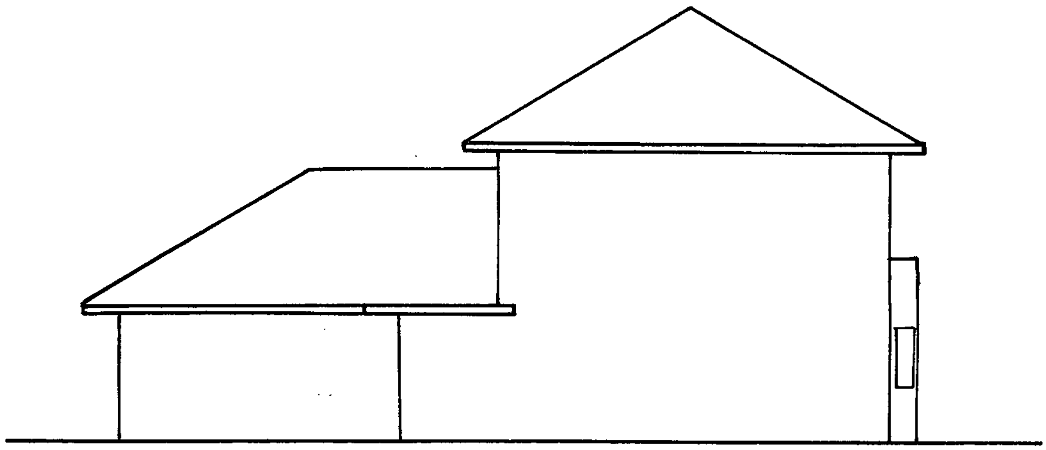


Figure 7. Improved House Elevations

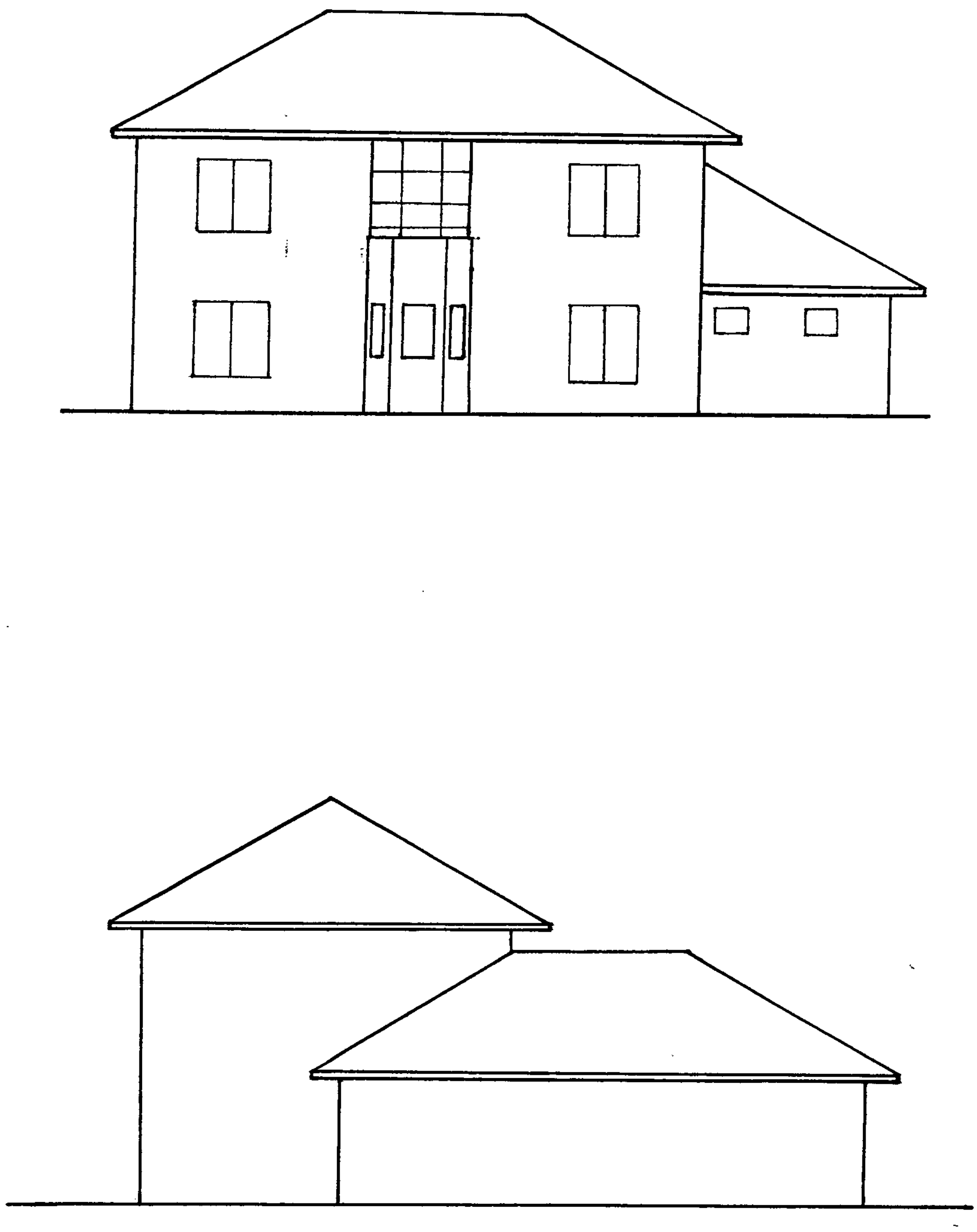


FIGURE 8 - LIFE CYCLE MATERIAL CONSUMPTION

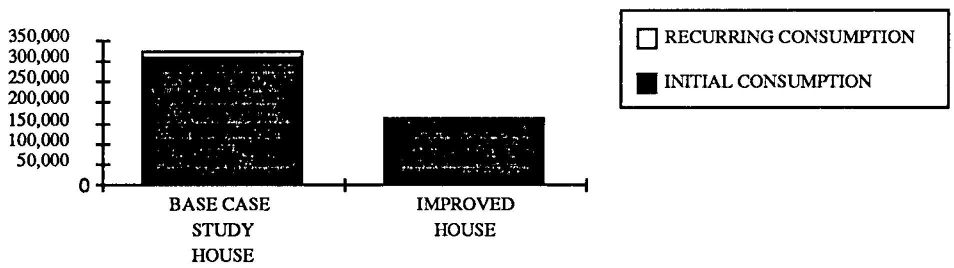


FIGURE 9-LIFE CYCLE ENERGY COMPARISON

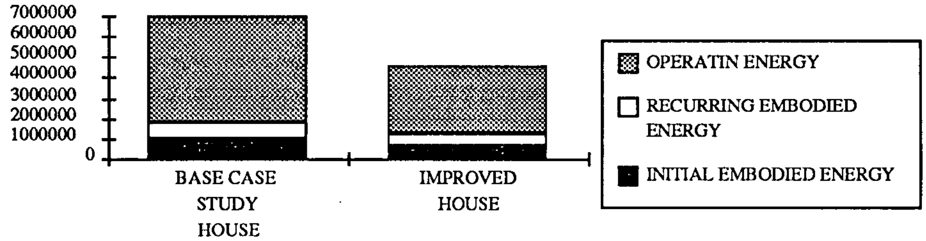


FIGURE10-LIFE CYCLE CO2 COMPARISON

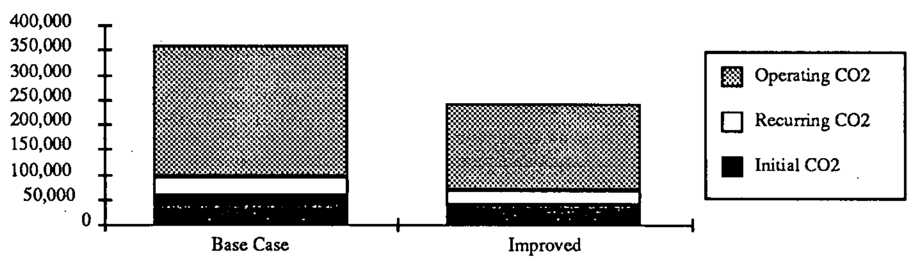


FIGURE 11-ECOLOGICAL FOOTPRINT COMPARISON