DESIGN OF AN ECOLOGICALLY SUSTAINABLE FAMILY DWELLING

BREE 495 DESIGN 2
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ABSTRACT

This report is the design of an ecologically sustainable family dwelling. The design of a family dwelling entails many aspects, from housing principles to the construction process, to the mechanical systems. All of these aspects are discussed and alternative ecologically sustainable alternatives are implemented wherever possible. This report includes research for selection criteria of various energy efficient practices and material selection. The house will be a small seven bedroom home, with the exterior envelope constructed of low-embodied masonry with pre-consumer recycled siding and recycled aluminum trim. The construction will use techniques to ensure tight seals and insulation will be blown into cavities and onto walls. The flooring will be made from farmed bamboo and recycled glass tiles. The landscape will use as little water possible with emphasis on reducing grass areas and replacing these areas with native Quebec plants and mulch cover. Passive solar design will be incorporated into the design. The location of the house will be in the Island of Ile Bizard. The estimated cost of the design, structure and lot is $257 000.

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INTRODUCTION

One of the basic human needs is adequate housing. The need for housing is experienced by all people, across cultures, continents and time. As the world continues to grow, and the population increases, humanity is presented with several conflicts of interest. People need somewhere affordable and comfortable to live, people need a home that will protect them from the various weather elements and people need a home where they are safe, secure and happy. The conflict of interest occurs when we examine the need for adequate housing with the need for environmental integrity. The environment often suffers as a result of stresses imposed upon it by people's activities, and housing and home-building is no exception.

It is estimated that buildings use approximately 48% of all energy consumed in the United States on an annual basis and that they are responsible for half of American greenhouse gas emissions, which is the driving force behind global warming. (Stang, 2005). Housing plays a small but vital role in energy consumption. With the advent of newer greener technologies in the housing and buildings sector, architects and engineers can incorporate environmentally-friendly technologies into their designs and structures. An example of this is that in Tokyo, any building with a floor area greater than 30 000m^2 has to have a grey water recycling and treatment system incorporated into it (Stang, 2005).

This project has many different aspects of sustainability, ecofriendliness, and engineering incorporated into it. Before defining the project and its context, we will first define the terms associated with it.

Sustainability is a term that was brought into popular use by the Brundtland Report, a 1987 United Nations document that defined sustainable development as meeting “the needs of the present without compromising the ability of future generations to meet their own.” (Stang, 2005)

This does not entail leaving the exact same number of trees or any other precious resource to the next generation, it means leaving the next generation with the ability to meet their own needs and aspirations with the resources available. These needs can be economic, environmental, socio-political or any other needs or aspirations that they may have. In the context of this project, we will examine sustainability dealing primarily with natural resources that comprise the needs of daily living in the context of the home or the household. This means that the design will examine several factors and make several decisions that will affect sustainability as we have defined it, and the factors will be discussed in full with explanations as to why a decision was made and in what context.

Ecofriendliness, and more broadly, environmental friendliness is a relatively new term that is making its way into our daily language and indeed into business and other sectors, on a growing scale. In the context of this project, ecofriendliness entails designing and building a family dwelling structure with “a flexible and holistic approach that involves making careful, ecologically conscious decisions at every point in the planning, design, and construction processes while keeping in mind that the ideal solution may not always be evident”, (Stang, 2005).

Engineering is a broad term that implies the application of science to meet the needs of humanity. A fitting definition when dealing with the planning, design and construction of a housing unit meant for a family to abide therein.

This project will deal with all aspects of housing design. The first aspect of sustainable housing design is the design principle. Secondly the construction and material detailing will be discussed. Mechanical systems are another topic that will be discussed with emphasis on energy conservation, water reduction technologies, waste management and reduction. Indoor air quality and indoor environment will also be an important aspect of this design. The housing environment and landscaping are important areas of sustainable housing and will also be dealt with and finally the specific details of the dwelling and the chosen materials and products are included in this report.

PART I: PRODUCTS, METHODS AND PRACTICES

1.0 INTRODUCTION

When designing an ecologically friendly house there are many aspects to take into account. The products that will be used, the methods that will be employed and the practices involved are all vital to the structural soundness of the home and the environmental aspect of it as well. There are guidelines to follow that have been set by the building code of Quebec and there are various other restraints, including financial and cost restraints, esthetic constraints and other constraints due to weather, availability of the consulting group etc.

To say that a house is “green” is a difficult term to define with a complete precision. One definition is “any building that has significantly lower negative environmental impact than traditional buildings qualifies as green” (Stang, 2005). Experts agree that it is a flexible and holistic approach that involves making careful, ecologically conscious decisions at every point in the planning, design, and construction processes while keeping in mind that the ideal solution may not always be evident.

Some of the criteria for building principles are to keep it as small as possible, position the building to take advantage of the winter sun and summer shade, minimize damage to the plants, animals, soil etc that is already there. The building should be as close to public transportation, workplaces, schools, and/or shopping as realistically possible.

1.1 DWELLING PLANNING PRINCIPLES

The objective of home building is to design a structure that is economical and environmentally responsible without compromising the occupants living comfort. The principles of unit planning are five, they are discussed as follows:

1. Building Configuration/Plan Simplification: The building should be kept as simple as possible with no complicated corners or forms. This will ensure that the envelope around the structure is well fitted and will prevent heat loss. As well, construction costs will be decreased. The floor area to perimeter ratio should be maximized. This will be demonstrated in the design section.

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2. Dimensioning and Efficient Framing: The design is dimensioned to accommodate the modular configuration of the building. This means that standard dimensions are used for the structural framing members such as studs, joists and plywood. A typical dimension for stud spacing is 405mm. This dimension ensures efficient material use and reduces labor and construction costs.
3. Area Distribution: The vertical distribution of a units' floor area will have the greatest impact on land use efficiency. Floor stacking can also decrease the cost, as fewer materials are used in the structure. According to the School of Architecture of McGill University, "vertical designs make most efficient use of space, since more stacking results in the need for less construction material. The cost of a two-storey square house, for instance, is less per square foot than one-storey with equivalent area,

since it has half the foundation and roof area. Floor to floor heights, which are affected by such factors as the floor thickness and the presence of suspended ceilings, will also have an impact on the amount of raw materials that go into construction, especially in the building envelope. Generally, buildings with a smaller ratio of surface area to volume make the most efficient use of materials and require less energy to heat. Bungalows which have an average surface to volume ratio of 0.38 are considered to be wasteful. Split-level-type plans, which accommodate the same floor area on 1.5 storeys, have a lower ratio, usually in the area of 0.25" (Freidman, 1993).

4. Grouping and Joining Units: One of the most effective ways to reduce construction costs and to increase energy efficiency is to join housing units together. This is an effective way to decrease the cost of construction, as fewer materials are used, and the same design is repeated. Energy is used in a more efficient manner because heating is shared between the units. This concept is important to note, though it will not be used in this design project.

5. Size Reduction and Efficient Planning: This is one of the most important factors in reducing energy demand and in decreasing construction costs. One of the objectives of this design project is to design a house that is comfortable and healthy to live in without damaging the environment. Though a larger house may be more comfortable, a smaller house is preferable and can be made to feel more comfortable by maximizing the

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useable floor space. This is achieved with an efficient layout. The internal layout should follow an ‘open concept’, which is essentially, making spaces look bigger by “emphasizing horizontal lines, removing parts of the wall between two adjacent spaces, using gently sloping ceilings and interior walls 6.5” tall”, (Friedman, 1993). Another technique to maximize floor space is to group spaces with similar functions. For example, all bathrooms, kitchens and laundry facilities should be placed in close proximity with sinks ideally faced back to back. The layout of the house in this design project will follow a typical split-level dwelling as it is considered an efficient use of floor space and makes for a comfortable home.

1.2 Building Technology

The main objective of Natural Resources Canada's Office of Energy Efficiency (OEE) is to reduce energy consumption while protecting the environment. This is achieved by several programs that have been designed and implemented by the OEE, of which the following are in the residential sector in particular:

- The EnerGuide Program: This program supplies information on the energy efficiency of major household appliances as well as heating, ventilation, and air-conditioning equipment on the market. This design project will exam all EnerGuide products and will implement them into the major household systems as well as the household appliances.
- The EnerGuide for House Program: This program helps homeowners obtain an independent evaluation and list of recommendations regarding energy efficiency to help improve comfort and reduce heating and cooling costs.
- The R-2000 Home Program: The R-2000 program offers on a voluntary basis by new home builders which establishes energy efficiency standards that exceed residential building codes while using environmentally responsible building materials and practices.

This design project will comply with the R-2000 design principles and requirements. There are three general areas that the R-2000 focuses on. They are the site design and planning, the building envelope and air-tightness of the building and the mechanical ventilation and space-conditioning of the home.

The site design and planning states that with proper landscape planning, a home can be protected from excessive exposure to wind, snow and various weather elements. Also, the layout of the house is such that the solar heat is trapped passively in the winter season with the proper window placements. Shading devices are in place for the summer months when it is less desirable to trap solar heat.

The building envelope is one of the most important aspects of building an energy efficient home. The building envelope is designed and detailed such that the home is completely insulated, air-tight and heat losses are minimized. Water, vapor pressure and air migration are controlled to avoid penetration and condensation, which is damaging to a building. See Figure 1.1 for the principles of envelope design and construction.

The third area of the R-2000 guide is involved in the mechanical systems in the house. The air-tight envelope is necessary for reducing losses and wasteful energy use, but it also affects the indoor air quality. There is a need for a fresh air distribution system. This is where efficient mechanical ventilation, space-conditioning and water heating units are utilized to ensure a comfortable atmosphere for the home inhabitants. This will be discussed further on in the project.

Function		Mechanism	Solution	Materials/Processes
Control Heat Flow	Heat Loss	Conduction	Insulate; avoid thermal bridges, particularly at foundation wall, floor/wall junctions, roof/wall junctions and window frames	Batt, rigid board, blown or sprayed insulation; careful detailing to avoid thermal ridges
		Radiation	Reflective coatings (where air spaces are present); low emissivity coatings in glazing units	Aluminum-coated papers; proprietary coatings
		Convection	Keep air spaces narrow and/or interrupt convective currents with grid patterns; fill in wide air spaces with insulation	Use appropriate designs/processes eg. Apply adhesives for rigid boards on foundation walls to form squares/rectangles
		Air Leakage	see 'control of air flow'	
	Heat Gain	Solar	Control heat gain for summer and winter conditions through appropriate design and window size, location and orientation	Overhangs; solar shading devices; low-emissivity windows
Control Air Flow	Infiltration/Exfiltration	Diffusion	Provide continuous layer of sheet materials that are impervious to air	Air barriers: rigid sheet materials (drywall, plywood, etc) or a combination of both
		Leakage	Seal all gaps to form a continuous air-tight building envelope, particularly at windows, electrical boxes and service penetrations	Sealants, caulking beads, tapes and gaskets; polyurethane foams; air-tight boxes and wraps for electrical fixtures

Function		Mechanism	Solution	Materials/Processes
Control Moisture Flow	Water	Gravity	Slope exterior finishes and flashings away from wall and joints; slope grade away from foundation wall; use overhangs with drips (where applicable)	Weather barriers: olefin sheets, building paper, tar coatings, polyurethane, exterior finishes, waterproof paints etc.; gaps sealed with sealants, caulks and gaskets.
		Capillary Action	Keep exterior finishes away from soil; interrupt flow of water from soil with a weather/moisture barrier	
		Momentum	Keep exterior finishes away from soil; use appropriate flashing materials; provide roof overhangs	
		Pressure Difference	Use rainscreen principle ie. Provide a sealed, drained air space between exterior finishes and wall to equalize pressure differences	
	Vapour	Diffusion	Provide a continuous layer of sheet materials that are impervious to vapour; located on the warm side of the insulation to control outgoing vapour	Vapour diffusion retarders (VDR's) or "vapour barriers": aluminum-coated kraft paper, polyethylene, vapour-resistant paints, extruded polystyrene; multiple layers of building paper and other materials may also act as VDR's
		Air Flow	See 'control air flow'	

Figures 1.1: Envelope Design

1.3 CONSTRUCTION DETAILING

Proper detailing in the construction can increase the energy-efficiency of a home as well as aid maintaining the integrity of the materials used to build the home. An air-tight construction is essential in an eco-friendly home, and with the proper engineering and construction detailing; an eco-friendly home can surpass any average home in terms of energy-efficiency and durability.

Air tightness is ensured using many techniques. A green home would be as air tight as possible and this would be achieved by using advanced sealing techniques on top of basic sealing techniques. The plates, corners and cavities would be sealed with caulk, as well as all gaps between exhaust fans outside of housing. All possible air penetrations from outside to inside are sealed using caulking.

In an average home, half of the indoor air volume is replaced every hour by outdoor air which leaks into the house (Friedman, 1993). This air leakage accounts for approximately 25% of the total heat loss through the building envelope.

The implications of this are many.

- A large amount of heat is lost, which can be damaging to the environment, depending on the source of heat. In the United States, over 90% of domestic energy is derived from burning fossil fuel, namely coal. Burning coal is damaging to the environment; it contributes to the green house effect; it contributes to acid rain; it is a non renewable source of energy and it can be damaging to the health of the general population because of its contribution to poor air quality, as many studies have indicated.

- The added cost for heating ‘outdoor’ air is wasteful and expensive. Warmed air is released to the environment and cold air is brought indoors; Occupants are paying money to heat air that will be released outside; this is a perpetuating cycle that results in loss of money, amongst other negative effects.
- The thermal pollution added to the outdoor contributes to the urban heat sink effect. Urban areas can be 2-6^{o}C warmer than surrounding areas, what is commonly called the ‘heat sink effect’, this is due in part to warm air being released from housing.
- Buildings rapidly deteriorate when this warm air is released and indoor air is replaced by outdoor air. This is because warm, exfiltrating air carries with it vapor from within the building, which may condense inside the envelope as it cools causing concealed moisture damage. Infiltrating air, on the other hand, carries pollutants from exterior sources as well as harmful emissions from building materials inside the envelope to the interior of the home (Friedman, 1993). In the past, it was thought that air-tight construction lead to poor indoor air quality and that ‘fresh’ air should be brought into the home. However, it is now recognized that there aren’t any benefits to this, and indoor air quality is dependant on proper ventilation and proper materials selection.

Thus, one of the important aspects of designing an environmentally healthy home is to ensure the air-tightness, insulation and controlling air flow.

The air changes per hour (ACH) rate of a typical Montreal home is between 0.5-1 (Friedman, 1993). Outdoor air is carried indoors via holes, cracks and ducts that are a result of accumulated damage to the house, or that which were incurred during construction. When a house is being built, many people are working simultaneously with different objectives; the plumber is fitting drains and pipes, the electrician is fitting the electrical components of the household and so on. Holes are drilled, ducts are made and often times, the housing envelope is not properly installed or is damaged because of this work. The air changes per hour rate, thus is somewhat dependent on the quality of construction and the natural wear-and-tear on a building.

Assuming a house size of 150m^2 (1600 ft^2) would thus lose approximately 348m^2 of air. The cost of heating that amount of air is upwards of $600. A heat-recovery ventilator installed to replenish indoor air can save up to $200 annually as it reduces the ACH rate to 0.1-0.05. The eco-home is designed as such that the house envelope will properly seal all ducts and holes to make an air tight house, using an envelope with methods that will be discussed further on. As well, a ventilation system is installed to recover and reuse heat from the exfiltrated air before releasing it into the environment.

The vapor barrier is an important aspect of designing and constructing an air-tight structure. A vapor barrier is a membrane that restricts the migration of moisture by diffusion from an area of high humidity. The vapor barrier is located on the warm side of the walls and ceilings so that the condensation in the cold region of the structure does not occur. Placing the vapor barrier on the warm side of the insulation prevents water from gathering, cooling and condensing on the insulation.

1.4 Building Materials, Foundations, Wall Panels, Windows

Before stating the materials used in this design, the material selection criteria will be discussed as well as the different aspects of available materials, namely concrete, wood, steel and glass.

Materials are selected based on the following criteria:

1. The materials' impact on the global environment, e.g. CO_2 emissions, destruction of the ozone layer etc.
2. The impact on the local environment of sourcing the materials.
3. The impact on the local or global environment of processing the materials.
4. The embodied energy content; the energy used in sourcing, transporting and processing the materials.
5. The health hazards associated with processing, fabricating or preserving the materials and similarly the materials should be examined for their effect on the health of the building's occupants.
6. The life expectancy of the materials and their potential for reuse or future recycling.

In addition to selecting materials based on their low embodied-energy content, the contractor will be encouraged to source materials from within 83 km radius wherever possible in order to minimize CO_2 emissions released in transport.

It is important to note that for a typical house, approximately 75% of the total energy consumed in producing the building materials is for concrete, plasterboard, bricks and mortar; glass, steel, copper and paint account for 13% and timber 8% (Thomas, 2005).

A further examination of the potential building materials is presented in more detail:

1. Wood: Wood is seen as one of the most environmentally friendly materials. It is a renewable resource and some of it can be sourced locally. The only problem with wood is that there tends to be a mismatch between where timber is grown and where it is consumed in the world as a whole. In this case, the environmental impact and embodied energy can be exceptionally important.

Tropical hardwoods should never be used because they are considered to be from unsustainable sources. There is no re-planting project for tropical hardwoods and the removal and sale of these woods wreaks havoc on the natural tropical environment (Thomas, 2005).

The preservation methods for timber need careful consideration, as toxicity can be an issue.

2. Concrete: Concrete is a versatile material which has the added advantage that it provides thermal mass. The key ingredients in concrete are cement, water and aggregates (sand and gravel or crushed rock). The impact on the environment of acquiring the aggregated and the embodied energy of the cement, the most energy intensive ingredient, pose some concern. Concrete has an estimated energy embodiment of 417-695 kWh/m^2 of floor (Thomas, 2005), which is less than steel, which has an energy embodiment content of 723-806 kWh/m^2 of floor. It is important to

note, though, that the thermal capacity of concrete is much better than that of steel.

3. Metals and Steel: The embodied energy content of metals is high, which can be seen as acceptable when metals are clearly the materials that best suit a particular function. Also, metals are generally recyclable, which will decrease the embodied energy content. For example, commercial aluminum (with 30% recycled content) has an energy content that is about 25% less than that of primary aluminum.

The structural frame of the eco-home would be made from engineered woods. An example of an engineered wood is glulam, which is glued-laminated timber. Glulam can be used in a variety of applications, which include using it for beams, joists and headers. Glulam can be made into a variety of shapes, into “I” beams for floors and trusses for roofs. In Canada, glulam is made from Douglas Fir-Larch, Hem-Fir and Spruce-Pine combinations. These are considered sustainable products they are currently available on the market.

Another type of wood that is suitable for an eco-home is FSC certified wood, which is wood that is from sustainable forests. In the U.S., one of the criteria when designing a green home is to have at least 50% of wood products originating from sustainable forests. The wood products should also be regionally grown, milled and produced. This is not always possible; it can depend on the location of the housing, however in Quebec it is possible and as such it is taken into account for this design project.

The cost of using wood for housing frames is estimated to be CN $30-50.

Roofing materials can vary; an assortment of materials can be appropriate for roofing, these include asphalt, concrete, slate, clay, metal, rubber, composite or fiberglass. Ecological housing uses roofing materials that are durable with a 40-year lifespan. Another aspect of roofing that will not be incorporated into this design project, but worth mentioning is green roofs. Green roofs are environmentally friendly roofs that are beneficial to use on single homes or apartment blocks. They have the added benefit of greenery, insulation and can even act as temporary carbon sequesters. Green roofs aren't used in this design because they are an added stress on a building and can be costly.

Foundations are typically made from concrete. Concrete is beneficial because of its thermal mass, but as mentioned it has a high embodied energy content. A sustainable way to use concrete is to use cast-in-place insulated concrete frames. Drainage pipes are easily installed on site. This is the type of foundation that is incorporated into this design.

The exterior of the house is an important aspect of building materials. The most appropriate material to use for this design is a combination of masonry, pre-consumer recycled siding and aluminum trim. Exterior decks are composed of low-toxic, recycled, and certified sustainable wood. This is considered to be part of a sustainable design because these materials contain a lower amount of embodied energy than the alternatives. Vinyl is a typical material used for siding, and although it is not toxic or dangerous to people or animals, there are several environmentally damaging processes that take place in the fabrication of it.

Glazing material is selected for its ability to transmit incoming light and heat. EnerGuide provides certain criteria for choosing glazing. Windows should be fully insulated with an air leakage rate of less than 0.06 cfm/ft. Please see the design section for specific brand of windows chosen in this project.

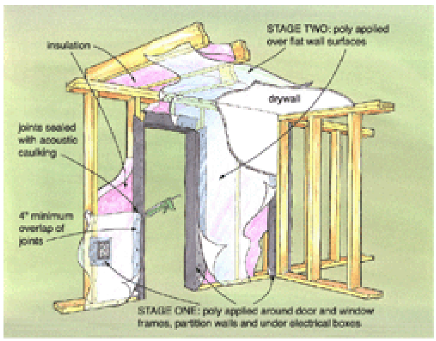

Figure 1.2 Window and frame insulation

1.5 MECHANICAL SYSTEMS AND ENERGY EFFICIENCY

Energy efficiency is one of the main focuses when designing an environmentally sustainable home. Energy is indeed one of the most important aspects of the modern world, with many countries economies' based on non renewable energy resources. It is no wonder that people are becoming conscious of energy use and energy efficiency. Non renewable resources don't last at infinitum and scientists predict that scarcity of fossil fuels will be experienced within the next two decades. Energy plays an important role in the daily life of Canadians; energy is important for transport, for comfort from the various weather elements, for the transportation of food and for housing.

Canadians use, on a per capita basis, the most energy in the world (Suzuki, 2006), with the United States and Australia close runner ups. Energy is primarily used to heat homes, heat water and run appliances. The following chart shows the energy use breakdown in Canadian homes:

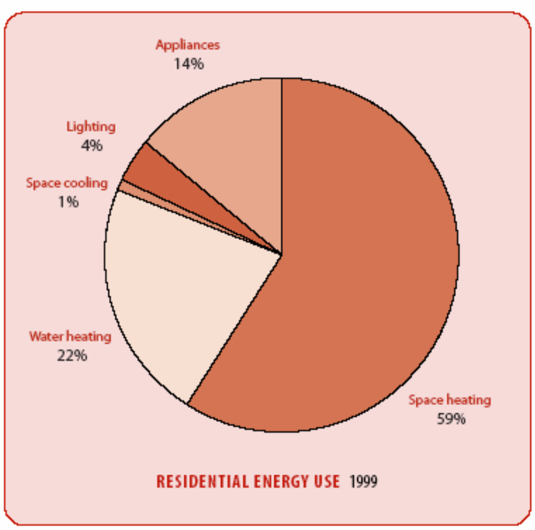

Figure 1.3: Residential Energy Use (Suzuki, 2006)

The1997 Canadian Survey of Household Energy Use was a survey conducted by the Canadian Office of Energy Use and Efficiency. A statistical analysis of various aspects of in home energy use provided information about different energy sources used by Canadians, average heated areas in homes, energy use for appliances etc. This study is useful when designing a green home as it provides background information as to what the current situation is.

When designing a green house, one of the first important decisions is the size of the house. A smaller house requires less energy and, as mentioned in the Introduction section. A small house has less area to heat, fewer materials are used in the construction, and they tend to have less overall impact on the environment.

Houses are divided into three categories: single detached dwelling (82% of houses in Canada), semi-detached (15%) and mobile home (3%). The average house size in Canada is 130 m^2 (1405 sq. ft), with an average of 6.6 heated rooms with 2.8 of these rooms being bedrooms. Quebec homes fall slightly below the national average with 6.1 heated rooms.

Canadian households that use electricity as their only source of energy consume an average 23 367 kWh (84.1GJ) annually. This represents the energy used exclusively for running the household, which includes heating, air conditioning, lighting and running appliances. Approximately 18% of all households in Canada use electric baseboards as their source of heating.

Households that use a dual source of energy, namely natural gas and electricity combined, consumed 82% more energy than households that used electricity exclusively. This figure is broken down into two parts: electricity consumption is 8587 kWh (30.9 GJ) annually and natural gas consumption is 122.1 GJ. The difference between using electricity exclusively and in conjunction with natural gas is because of the amount of energy inefficiency associated with natural gas combustion. Despite the fact that natural gas combustion is a non-renewable source of energy, the trend in housing is to use it, because it provides comfortable heat and is, for the most part, readily available. There has been an increase of 50% of natural gas use in houses built since 1990. The average energy intensity for natural gas is 0.114 GJ per sq. ft; comparing this to 0.076 GJ per sq. ft for electric energy, and it can be said that natural gas as the energy source in an eco-friendly house is not an option.

Before designing an improved heating and energy use system, it is important to know the current situation. In Canada, heat pumps are in relatively little in use comparison to other energy sources. Heat pumps account for less than 5% of heating in Canadian homes. The most popular form of heating is hot air furnace, which accounts for 67% of all heating systems. Hot air furnaces can be further broken down into the source of energy for the furnace: 45% of hot air furnaces function with natural gas; 10% function with oil; 2% function with electricity and the last 9% function with various other energy sources. Electric baseboards account for 18% of heat sources; wood stoves for 5% and hot-water furnaces for 5%. These figures are shown below:

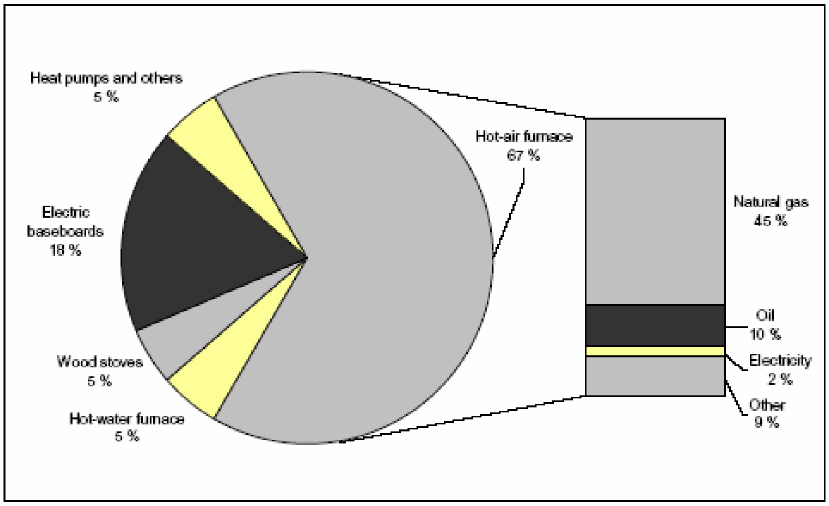

Figure 1.4: Description of Main Heating Systems in Canada (NRC 1997).

When designing the heating and energy system for an environmentally friendly house in Quebec, there are various considerations to be taken into account, most notably is the weather. In Quebec, with an average winter temperature of -9.6^{o}C and an average summer temperature of 17.6^{o}C, homes need to be heated in the winter and cooled in the summer to be comfortable for the inhabitants.

An eco-friendly heating system has to be able to comfortably heat a household on a daily basis, and just as importantly on days of extreme of extreme weather. The following table shows data collected over a 30 year period in Quebec.

	J	F	M	A	M	J	J	A	S	O	N	D
Max ^{o}C	-7	-5	0	8	17	22	25	23	18	11	3	-4
Min ^{o}C	-16	-15	-8	-1	5	10	13	12	7	2	-3	-12
Mean ^{o}C	-11	-10	-4	3	11	16	19	18	13	7	0	-8
Temp<=0^{o}C (days)	31	28	29	19	4	0	0	0	1	11	24	31

Table 1.1: Quebec Weather Stats average from 1961-1990
(source: The Weather Network).

There are many different types of renewable alternative energy that can be used to heat and cool a home, as well as providing energy for appliances and lighting. These will be examined as well as their applicability to an eco-friendly home.

- Solar Power: The sun radiates 16 000 000 kWh/y onto the earth. If we had the technology to be able to harvest 10% of this energy then 1 600 000 kWh/y would be harvested for uses such as heating, lighting and even transport. 1 600 000 KWh/y represents 1.5 times our primary energy demand for heating very efficient energy-efficient housing (Thomas, 2005). Solar energy is one of the fastest developing energy sources in the world (Suzuki, 2006). Photovoltaic cells capture solar energy and deliver clean, fuel free electricity that can be used to heat homes, water or for lighting and running appliances. More than 29 million homes around the world use solar energy for their electricity needs, with Japan and Germany being the leading countries for implementing and developing solar power. In Canada, there is a potential for solar energy to provide 50% of all residential hot water heating and 15% of industrial water heating. This represents a large amount of energy and although solar energy isn't as popular in Canada as it is internationally, Canadian solar power firms are amongst the best in the world. An ecologically friendly house could benefit from solar power. Photovoltaic cells can be attached to the roof of a house, as shown in the figure below.

Figure 1.5: Photovoltaic Cells attached to roof.

Passive solar design is another form of capturing solar energy and it is simple and an effective way of orienting the home correctly and having the right amount of south glass along with some thermal mass to store the heat. Insulation is needed to keep the indoor temperature more stable. Passive solar design is part of any eco-friendly house as it is economical and efficient. It is suitable to the climate in Canada and has a lot of potential in even warmer countries.

- Wind Power: Along with solar power, wind power is a growing and developing source of energy. Wind turbines offer a clean, efficient way to produce electricity, with the added incentive of many economic benefits. Germany is a world leader for wind energy with some 16 600MW of wind power (Suzuki, 2006). Spain has also developed a large market for wind power with 8300MW. Canada, unfortunately, lags behind these countries, but the potential for development in this sector is great. Canada has thousand of kilometers of shoreline available to be sites for wind power plant installations. Some provinces, such as Prince Edward Island have proposals to supply all electricity demand with wind power; indeed if wind power is developed and harvested Canada-wide, there would be some 30 000MW of wind power available for use (Suzuki, 2006). The drawback to using wind power is the cost of equipment and installation, though these costs have decreased significantly over the past two decades. An eco-friendly house could benefit from using wind power. Although wind power is not practical for small scale use in someone's yard, for example, it is practical when used province wide or even community wide. Therefore the responsibility lies with the government, or governing body, and there has to be an incentive to use it. Having said that, though, there are vast economic incentives to using wind power, as it has become a multi-billion dollar industry. In 2003, 28 billion dollars of revenue was generated from wind power, and in Europe 80 000 people are employed in the wind power energy sector (Suzuki, 2006).

- Hydroelectric Power: Quebec's main energy source is hydropower. An estimated 97% of all energy needs are sufficed by hydroelectric power (Suzuki, 2006). Hydropower is often referred to as 'clean' power because there are no direct emissions associated with it and it is a renewable source of energy. The problems related with hydropower occur mainly at the time of development and construction. When a dam is being built for the installation of a hydropower plant, ecosystems can be destroyed and devastated. Diversions, land flooding and changes in water flow can devastate natural ecosystems and wildlife habitat. When an area is flooded, mercury can seep out and many people as well as animals could been subject to mercury poisoning as a result of Quebec power plants in places such as James Bay. Mercury is naturally present in the ground but not considered to be harmful until it is released by flooding. In addition to mercury seepage, there is a growing concern of methane production from hydropower plants; methane is a potent greenhouse gas that contributes to global warming. It is produced when vegetation undergoes anaerobic biodegradation, which occurs when an area is flooded. Most hydropower plants in Quebec are large and require a large amount of area to be dammed and flooded, and thus the environmental impacts are great. A solution to this would be to build smaller scale power plants that require less area and serve smaller communities. Hydropower is, without a doubt, a better source of energy than fossil fuel or coal combustion and deserves to be studied when designing an environmentally friendly dwelling. Hydropower could be used as a source of energy for this type of house, or as a backup source of energy. When hydropower is couple with another renewable power source, such wind power, it becomes a practical means of achieving a comfortable way of benefiting from energy without compromising the environment or contributing its destruction.

- Biomass: Energy from biomass originates from organic matter. This includes forested products such as sawdust and bark, as well as agricultural products such as straw, corn and manure (Suzuki, 2006). The advantage of biomass energy is that it can be stored as used when needed, as well, it provides constant non-fluctuating electricity and heating. The biomass energy sector is underdeveloped in Canada when compared to European countries such as Finland and Sweden, where it accounts for 19% and 15% of energy use respectively (Suzuki, 2006). There is a lot of potential for development of the biomass energy sector in Canada. Rural farmers could potentially supplement their income by growing switchgrass for biofuel or harvesting manure and using it in anaerobic digesters. Developing this can create a lot of jobs and revenue in Canada. Though it is not suitable for an eco-friendly house at this time, biomass energy will play an important role in the future. Small scale rural operations as well as large scale urban centers would benefit form biomass energy.

- Nuclear Energy: Nuclear energy is a non renewable energy form that accounts for 55% of all energy use in Ontario, and 19% Canada-wide (Suzuki, 2006). Nuclear energy doesn't produce any greenhouse gases or sulfur or nitrogenous wastes; the pitfalls with nuclear energy are that it is highly expensive because of the costs associated with the waste disposal of the radioactive byproducts formed when using it. It is estimated that Canada has some 1.3 million cubic meters of solid nuclear waste, 203 million cubic meters of low level radioactive waste and 17 000 metric tons of high level radioactive waste. This is not a sustainable form of energy yet, though it may be some day in the future when some of the problems associated with it are solved. An eco-friendly house would not use nuclear energy for its energy needs.

When selecting a mechanical system, there are several factors to be taken into consideration. Mechanical systems function to heat, cool, humidify and purify air and space. Having discussed different energy sources, now the mechanical systems that utilize this energy will be discussed. There are two main types of air distribution systems that will be examined and their applicability to a greenhouse will be considered. Forced-air and convection are the two types of mechanical systems that will be analyzed in the context of electrical heat.

Electrical Systems: Electrical systems use electricity as their source of power. Electricity is mainly derived from hydropower in Quebec, as mentioned, with 97% of households using power from Hydro-Quebec. All energy in the system is converted into heat, and thus, the efficiency is considered to be 100%. The system functions such that a current is passed through a resistor, which, in turn, generates heat (Friedman, 1993). There are three main types of electrical distribution systems: forced-air, baseboard, and fan-assisted units.

- Forced-air Electrical System: The electrical furnace is a central unit that distributes hot air in the house through a network of ducts. Such systems produce heat efficiently and effectively as heat is forced through the different rooms of the house (Friedman, 1993). The main problem with this system is that it is not suitable for small home with relatively little energy demand, as the cost benefit ratio is small (please see cost section).

- Room Heater (baseboard): The most common type of heater in Quebec. It is generally installed under windows and has a gross efficiency of 100%. The problem with this system is the effectiveness; only a portion of the heat delivered is actually used to heat the air (Friedman, 1993). Individual rooms usually have a thermostat and the temperature is controlled in each room. The delay between when the temperature is changed and when the change occurs at the baseboard accounts for the low effectiveness. A lot of energy is wasted, and the temperature is not evenly distributed; the area around the heater is very warm compared to the rest of the space. However, given that the initial cost is relatively inexpensive, baseboard room heaters are often used and are popular.
- Fan-Assisted Room Heater: This type of heater is wall-mounted and works by circulating the air around the room. It is gaining in popularity because it is more efficient than baseboard room heaters and comes in a variety of sizes, shapes and capacities. The fan assisted units consume less energy than the standard baseboards due to forced convection, the pre-heat device and the built-in electronic thermostat provide better temperature control (Friedman, 1993).

Heat Pumps: Heat pumps function by transferring energy from one place to another. Heat pumps are gaining popularity in Canada because of the comfort that they provide and because they are highly efficient. An estimated 5% of Canadians use heat pumps to warm and cool their homes (NRC, 1997); heat pumps are reversible and can be used as a source of heating in the winter season and a source of cooling in the summer season.

Heat pump efficiency is measured in terms of Coefficient of Performance (COP), which is the ratio of overall energy output over the energy input. A COP reading can be greater than unity because the heat pump transfers electrical energy to heat and the energy output is greater than the energy input.

Heat pumps function by mechanisms similar to refrigerators; a refrigerant is circulated and goes through a cycle of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed en route to the other coil where it condenses at high pressure. At this point, it releases the heat absorbed earlier in the cycle (EnerGuide, 2004).

As mentioned, the heat pump is fully reversible; a reversing valve functions to control the direction of flow of the refrigerant and can change the heat pump from heating to cooling and vice versa.

- Geothermal Heat Pump: The geothermal heat pump is also called the ground heat pump, earth-energy or geoexchange pump. This type of heat pump is gaining popularity in places such as British Columbia, the Prairies and Central Canada. A geothermal heat pump functions by drawing heat from the ground or from the groundwater. It is fully functional on cold days because there is always some heat in the ground or in groundwater.

- Air-Air Heat Pump: Air to air heat pumps are the most common types of heat pumps used in Canada. They function by drawing heat from outside air during the heating season and rejecting heat during the cooling season.

Using a heat pump is an excellent way to heat a greenhouse. Air-air heat pumps are best suited for the Quebec climate, though it would have to be used in conjunction with another energy source, probably electric. Heat pumps can be used as the primary source of energy, with an electrical system (such as baseboards or central furnace) serving as a back up for extreme weather events.

A comparison of various heating systems is provided:

	Systems	Efficiency	Advantages	Disadvantages
A	**Electrical**			
	Central	100%	High efficiency High air quality	High initial cost; Central control; Space requirement
	Baseboard	100%	Very low initial cost; Individual room control; Silent Easy to install	Poor heat distribution; Low effectiveness
	Fan-assisted	100%	Low initial cost; Good heat distribution; Excellent thermostat control; Silent	Space restriction (furniture)
B	**Heat Pumps**			
	General characteristics		Very high efficiency; Low operation cost; Environmentally friendly; Reversible (heat and cool)	High initial cost; Auxiliary system (cold climate); Outside heat exchanger
	Geothermal	COP 4	Highest efficiency (COP)	Land requirement; central control
	Air central	COP 3.5	High efficiency	Central control
	Ductless	COP 3.5	Excellent thermostat control; Individual control	
C	**Oil/Gas**			
	Central	90%	High air quality; High efficiency	High initial cost; Fossil fuels; Central control

Table 1.2: Heat Pumps vs. Electrical system

The ventilation system of a eco-home is a mechanical system that works to remove old stale air and replace it with fresh air. There are different ventilation requirements for different rooms. A kitchen requires a minimum of 40cfm vented to the outside. A bathroom requires 50cfm spot ventilation or 10cfm continuous ventilation. Each room should have one exhaust fan and be ventilated at a rate of 10cfm or more. Since a green home is constructed to be as air tight as possible, less outdoor air is incorporated into indoor air and as a result, the air quality is maintained through a ventilation system. The disadvantage of this is that potentially cold outdoor air is brought inside and warmed stale air is sent out; this is disadvantageous because energy is used to heat air that is lost to outdoors. The solution to this is to use an energy recovery system. This system uses the warm air to warm the incoming cool air and thus, less energy is lost. This is an efficient system for this design project and a heat recovery ventilation system is practical and useful.

1.6 WATER USAGE AND EFFICIENCY

The typical domestic water use for the average Quebec household is as follows:

ACTIVITY	AMOUNT
Drinking & Cooking	6%
Gardening & Car Washing	4%
Hand basins	3%
Clothes Washing	12%
Dishwashing	10%
Bath and Showers	25%
Toilet Flushing	40%

Table 1.3: Domestic water use (Thomas, 2005)

It is important to note that only 6% of domestic water is used for drinking and cooking, even though all domestic water is to international standards for potable water. It is a bit like using our highest source of energy, electricity, for all power and heating in the home when we have access to a lower-grade source. Note also that about 1/3 is used for toilet flushing and that clearly this water could be of a lower quality. Thus, one must ask the question of whether there is a better way of meeting our water needs.

There are several ways to improve domestic water use, these include reduce demand, use efficient appliances and harvest grey water to recycle. Each of these will be examined in further detail with an emphasis on water reduction.

The first aspect of improving water use efficiency is to reduce demand. This means using efficient dishwashers, washing machines, low-water-volume toilets, and low-flow showerheads. Being vigilant about water demand can save an estimated 100 liters/person/day. Considering that the average Quebecer consumes an astonishing 400 liters/day, this represents a large amount of water.

Considering the fact that two thirds of rivers in Canada flow northward, away from the most populated areas, and that the demand for potable water in Canada has increased more than six-fold in the past 90 years, then water becomes an important issue for Canadians, though it can be noted that there is a seemingly abundance of water in this country.

The increase demand for potable water in Canada is not the only increase that has occurred in this sector. An increase in water supply means an increase in water treatment and water purification. Sewage and wastewater have to be treated and this can be a costly operation, which, if not done correctly, can be hazardous to environmental health. In Montreal, all sewage water is collected and chemically treated before being dumped in the St-Lawrence River. Dumping, unclean, or BOD rich treated water into a river is hazardous to marine life as well as to downstream users.

An eco-friendly house would have to have a system that deals with water demand, water treatment and wastewater. Indeed, with water being such a large global issue that affects the each and every individual on the planet, being responsible with regards water use is significant.

Municipal water use accounts for 44% of water use in Quebec (Friedman, 1993), and although many people assume that industries use most of the water, this is a false assumption.

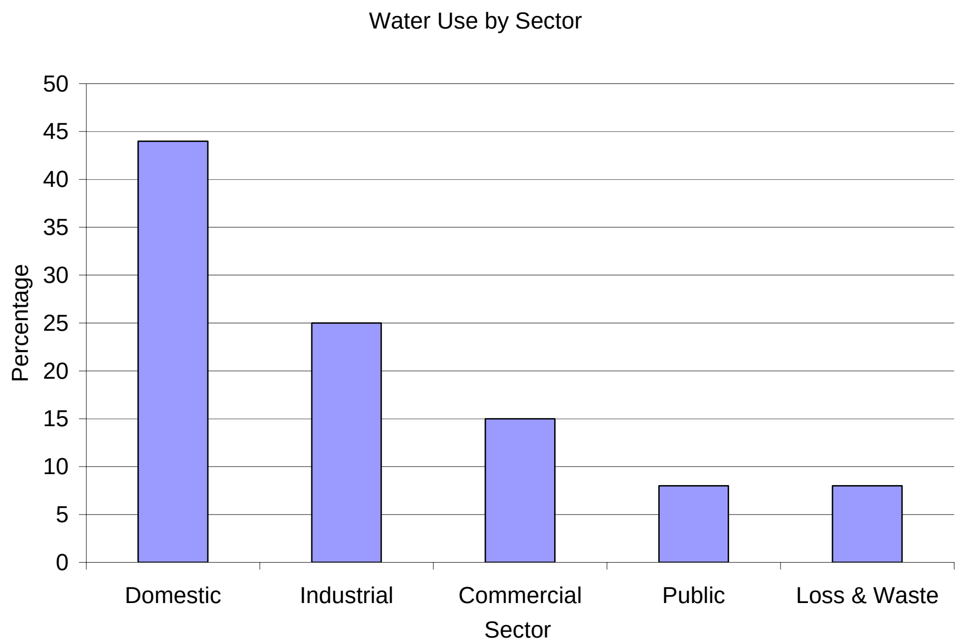

Figure 1.6: Water Use by Sector

In Quebec an estimated 50% of water use occurs in the washroom. Some estimates are that washroom water accounts for 75% of domestic water use. The first area to exam when designing a water system for an eco-friendly home is in the washroom, namely toilet flushing and showerhead to narrow it down. An ecologically friendly house should use at least 45% less water than a typical household, though improvements can be easily incorporated to any home.

- Toilets: An eco-friendly home would have low volume toilets. A low volume toilet uses 10-15L less water to flush than a conventional toilet, which typically uses 20L per flush. A low volume toilet is engineered to provide sufficient siphonic action to ensure that the waste is flushed out.

Manufacturers claim that low volume toilets work just as well as conventional toilets while providing remarkable water savings.

- Showerheads: A typical shower head uses 20 liters per minute. Thus, a five minute shower consumes 100 liters. An eco-friendly house would have efficient showerheads. The most efficient showerheads on the market consume half the water of conventional showerheads, thus consuming 10 liters per minute. The benefits of a low flow showerhead are twofold; less water is being wasted and less water has to be heated for the shower (and thus money and energy is saved on water heating).
- Faucets: Faucets typically dispense 13 liters per minute, which is more than what is needed. Faucet aerators can reduce the water dispensed from a faucet to 6 liters per minute for kitchen uses, and some can bring the amount down to 2 liters per minute for bathroom purposes. Aerators can be incorporated into the faucets upon installation or they can be retrofitted to existing faucets.
- Appliances: An ecologically friendly house would have appliances that work as efficiently as available on the market. The major water consuming appliances in a house are the laundry machine and the dishwasher. Clothes dryers, refrigerators, freezers and minor appliances require energy to run. In Canada, the EnerGuide guidelines provide the necessary information about which appliances to buy because of their energy and water efficiency.

- Cisterns: Cisterns that attach to eaves troughs are available on the market. They come in a variety of sizes and materials, depending on their intended use. Cisterns collect precipitation that falls on the roof. One inch of rain can collect up to 1.8 liters of water per square foot of roof, and a typical water-catching cistern can collect 75% of water that lands on the dwelling, (Freidman, 1993). If the collected water is to be used for domestic purposes, plumbing would be a factor to consider, for an eco-friendly house, as it would be more complicated. The home would require a system that carries the water indoors to be distributed to toilets, laundry machines etc. The main problem with this type of system is that municipalities don't allow for non potable water to be brought into a house for domestic use. The water would have to be well filtered, which would add to the cost, along with the added plumbing equipment required. Roof water can pose a health risk if it is mixed with bird or animal feces, organic matter or chemicals. As well, it is not considered reliable and the cistern is at risk of drying out, so a backup system is necessary. A cistern that collects water for gardening and used seasonally is a better option as it does not break any by-laws and is functional for a specific purpose.
- Grey water. Grey water is defined as all waste from domestic appliances with the exception of toilets. Most municipalities in Canada don't allow for grey water recycling, though the idea is being explored. Using grey water for toilet flushing appears to be the best use for grey water, however the same problem occurs as it does with cistern; the added plumbing costs

and implements are considered cumbersome and not worth the effort. Grey water would require pre-treatment as it could contain organic matter, soaps and detergents and dirt.

1.7 WASTE DISPOSAL

An ecologically sustainable dwelling would produce a minimal amount of waste without too much inconvenience to the people that live in the house. This is achieved by examining the different areas where waste is generated and applying alternative solutions to reduce the waste.

Landfills are sites where all forms of municipal and industrial garbage is placed. Landfills are a major source of pollution; methane gas is produced from decomposing organic wastes, leachate pollutes ground water and noxious odors fill the air around a site.

Landfills are neither sustainable, nor are they desirable. As they continue to fill with garbage, new landfills have to be constructed, which will eventually take its toll on the environment. There are profound economic, social, health and environmental consequences to using landfills and the primary solution is to slow the rate of filling and reduce the amount of waste entering the system.

The municipal solid waste stream in Canada is among the largest in the world on a per capita basis. It is estimated that Canadians produce 1.7 kg of waste per capita per day (Freidman, 1993).

Managing waste is an important aspect of a sustainable living lifestyle, as landfills continue to be filled at alarmingly fast rates, disposing of waste becomes more costly. Any costs associated with constructing, maintaining or improving landfill sites are passed on to the taxpayer, and thus, it is in everyone’s best interest to be responsible with the amount of waste that they generated. It is estimated that 75% of domestic waste can be diverted by several means which will be discussed in detail. The aspect of managing waste is to characterize it, to find out what sort of waste constitutes a typical Montreal domestic waste stream. This is shown in the following table:

Material	Composition %	Amount kg/capita/day
Compostables		
Food	28.0	0.160
Lawn + Garden Waste	5.5	0.031
Misc. Compostables	8.6	0.049
	42.1	0.240
Recyclables		
Newspaper	9.6	0.054
Kraft/Corrugated	4.7	0.027
Office Papers	1.8	0.010
Mixed Recyclable Paper	4.4	0.025
Glass Food/Beverage Containers	5.0	0.028
Aluminum Food/Beverage Containers	0.5	0.0028
Tin Food/Beverage Containers	2/3	0.013
Ferrous Materials	1.9	0.0017
Non-Ferrous Materials	0.6	0.011
PET Bottles	0.3	0.0034
HDPE Bottles	0.8	0.0045
Other Plastic Containers	0.2	0.0011
	32.1	0.1815
Non Recyclables		
Magazines/Glossy	5.2	0.029
Plastic Packaging/Film	4.0	0.023
Textiles	3.1	0.018
Rubber/Leather	2.0	0.011
Disposable Diapers	3.3	0.019
Wood Waste	1.0	0.0057
Hazardous Materials	0.8	0.0045
Misc. Non-compostables	6.4	0.036
	25.8	0.1462
Total	100.0	0.5677

Table 1.4: Domestic Waste Composition (source: Environment Canada 1992)

An environmentally sustainable home would have a convenient composing system incorporated into it. Composting is a process whereby biodegradable organic materials are subjected to bacterial decomposition. The end product is a humus-like material called compost (Tchobanoglous, 1993).

Table 1.4 shows that approximately 40% of all domestic waste can be diverted from going into the landfill; It can be composted and made into an end product that can be used in a garden as a nutrient rich add-in.

A bin composter is the ideal type of composter for an eco-house. It can be constructed from recycled materials or bought from the city of Montreal. It is placed in the yard and is of sufficient volume to hold kitchen waste as well as yard waste. Bin composters have the added benefit of retaining their heat, which is important for bacterial biodegradation. They are neat in appearance and require little maintenance.

The city of Montreal recently installed a compost program in conjunction with Eco-Cartier. Residents of downtown Montreal can bring their kitchen wastes to three composting centers throughout the year, and composted humus can be bought in the summer. This service is not available to all residents of Montreal, but any eco-home should be equipped with a home composter.

Recycling is another way to decrease waste and use goods in a sustainable fashion. Table 1.4 shows that approximately 32% of all household waste is potentially recyclable. Of this amount, 20.5% is paper, 5% is glass, 5.3% is metal and 1.3% plastic (Freidman, 1993). Montreal currently has a recycling program, and residents of the city leave their ‘blue bins’ on the side of the street for pick up. An eco-home would make use of this service as a means of reducing garbage output.

Composting and recycling are effective means of diverting a large amount of domestic waste from ending up in landfills. This design project is for a single-family environmentally sustainable dwelling, so any composting or recycling activity would take place on the individual level. However, if environmentally sustainable housing becomes more popular and blocks of sustainable housing are built or even entire neighborhoods, then composting and recycling becomes a means to save money. Currently in Montreal, sending waste to the landfill costs an estimated $8-15 in direct costs and an unknown amount in indirect costs which are related to landfill gas emissions and contribute to climate change. Though recycling costs roughly the same amount of money as landfilling (Freidman, 1993), it is a more sustainable practice as less resources have to be extracted from their natural environment and recycled materials undergo less processing than primary materials.

1.8 Indoor Environment

Ventilation is important in maintaining a healthy indoor air quality (IAQ). Buildings are constructed using a variety of materials, anything from wood composites, to thermally-efficient rigid insulation boards to a variety of coating and cleaning agents. Newly innovated products have changed the way building are built, and have more often than not, been an improvement in terms of material efficiency and cost efficiency.

However, some of these materials can emit hazardous fumes or particles that can contribute to poor IAQ and can contribute to a myriad of allergies and health problems for the people breathing the air.

The indoor environment is comprised of several factors, some of which have been discussed for this design.

The humidity control contributes to environmental comfort; people are generally comfortable in humidity levels of 40-60% Relative Humidity. An excessively humid area promotes mould growth which is destructive to housing materials and potentially dangerous to the health of the inhabitants of the house. A de-humidifier can be used to remove excessive humidity if it ever becomes a problem, as well, a central air system aids in air circulation which controls humidity.

As mentioned previously, there should be a certain amount of air supplied to each room depending on the use. A kitchen needs ventilation to reduce humidity and odors that are released in the cooking process. A washroom would need a higher ventilation rate to remove humidity because showers and baths in hot water can make a room very humid, and a ventilation system would also remove odors. A green house would use efficient EnerGuide certified exhaust fans.

Some contamination can be released because of the actions of the contractors during the construction of the house or other contaminants can be generated by the inhabitants of the house due to activities such as smoking. These contaminants have to be controlled in order to maintain a comfortable indoor atmosphere.

During construction, ducts should be sealed off and efforts should be made so as to not use any materials that may lead to air contamination later on. This includes spay on insulation or caulking materials. The level of volatile organic compounds should be measured during and after the construction period.

Radon gas can leak into basements of homes. The house in this design project would have a basement and therefore, radon gas if of concern. There is no way to prevent radon gas from leaking besides sealing the basement as well as possible and mitigating any radon gas by installing a Radon Mitigation System.

A garage is included in the eco-home for this design project. A garage should always be a separate structure attached to the house because of the risk of carbon monoxide poisoning. The garage is attached to the house through a shared wall, but the shared surface between the garage and the home is to be tightly sealed. An exhaust fan is necessary in the garage.

PART II: HOUSING ENVIRONMENT

2.0 INTRODUCTION

The housing environment is comprised of several factors that will be considered in this design project: site planning comprises of deciding the actual location of the home and its placement. A site is chosen for is level of comfort, its neighborhood, its proximity to amenities and with some consideration to nearness to the workplace, schools, and public transport.

Another aspect of the housing environment is the lot size, which will be comprised of the house structure, vehicular parking spaces and the landscape area.

The landscape is another aspect of the housing environment; indeed landscapes and gardens play an important role in Canadian recreational activities and is an important aspect of an ecologically sustainable house. Careful planning will reduce the amount of water typically used on lawns and gardens, as well, a properly designed landscape can aid in energy reduction of the house, as will be discussed in this section.

2.1 SITE PLANNING

The site planning is important in designing a greenhouse because a well designed site is at a good location, has the right amount of greenery and is comfortable and enhances the wellbeing of the people living there. A good location is a location that is near all amenities (grocery stores, shopping malls, hospitals, pharmacy, restaurants etc). It should also be within walking distance to public transit, be near parks or close to some sort of outdoor greenery and it should be located in a safe residential area.

There exist many such sites in the West Island of Montreal. Dollard des Ormeaux, Pierrefonds, Kirkland, these are all places where a greenhouse could be constructed. The island of Ile Bizard is another area that would be ideal for a greenhouse, as it is spacious, has a lot of woods, beaches and green spaces and at the same time, has a bus service, ferry service and is within a bus ride to the Pierrefonds train station, or Fairview bus terminal.

The greenhouse in this design project would be situated on the island of Ile Bizard, for the above mentioned reasons. Ile Bizard has some undeveloped area that is available for purchase, and as this project is the construction of a greenhouse, an adequate lot size would be needed. Furthermore, having once lived on Ile Bizard, I am familiar with the community and find it a very comfortable place to live.

2.2 VEHICULAR CIRCULATION AND PARKING

Vehicles are a part of daily life. The family dwelling in this project takes into account that a parking space is needed for a vehicle. Most driveways are paved with asphalt and are impermeable. This can cause water to runoff and possible erosion; therefore the driveway should be made of permeable materials, such as gravel.

2.3 OUTDOOR SPACES

Landscaping is an important part of the housing environment and indeed an important part of an eco-friendly dwelling. Using plants that are native to a site and require little water are critical to having a green environment without compromising the environment. Furthermore, planting trees around a house can act as a crude form of insulation; trees can serve as windbreak, thus lessening the impact of wind on the structure. These two aspects of landscaping and their applicability to greenhouses will be examined further.

Xeriscapes are water efficient landscapes. The term “xeriscapes” is derived from Greek; “xeros” means dry (Freidman, 1993), so a xeriscape is essentially a dry landscape. Since water efficiency is an important aspect of an ecologically sustainable dwelling, any designed landscape should be as close to being a xeriscape as possible.

One of the objectives in designing an environmentally friendly house is to ensure the comfort of the inhabitants. As well, the principles of the design of the dwelling should be applicable to different regions, even if the specifics of the structure don’t necessarily apply. This means that there should be a beautiful and pleasant surrounding landscape whether the house is in Quebec, where water is abundant or Saskatchewan, where water is more tightly monitored.

Landscapes typically consume a large amount of water. Water demand can increase by up to 50% in the summer months (Freidman, 1993); this is a direct result of lawn-watering and other garden and landscape uses. In Canada, lawn watering accounts for 14% of annual household water use (Suzuki, 2006); In the United States it accounts for 29% of annual household water use which amounts to 140 000 liters of water sprinkled onto grass annually (Ferguson, 1987).

Landscapes require so much water that whenever a municipality is undergoing a water shortage, lawn watering is always the first activity that is restricted, and more often than not, restricting this activity is sufficient to mitigate the effect of the water shortage.

To decrease water demand from landscapes, several measures can be taken.

- Limiting the use of turf and grass areas will decrease the need to water. Grass areas should be placed in areas that are specific for social and recreational activities and should not comprise the entire landscape. Furthermore, less grass area means less pesticides or herbicides will be used, if they are used at all; A greenhouse would not use herbicides for dandelion control, rather any undesirable weeds can be removed manually or sprayed with soapy water.
- Water-efficient plants will be used that suit the soil type and site drainage characteristics of the location.

- Water use zones are defined based on their water requirements. For example, geraniums, which require daily watering, should be planted with other annuals that require daily watering. That way, water is used as efficiently as possible; the areas that require the most water are grouped together and are watered together.
- Trees and shrubs should be grouped together in beds.
- To improve water capacity of soil, mulches should be used. Mulch, when applied to soil, increases its water holding capacity, inhibits the growth of weeds, and reduces evaporation. Cedar mulches are aesthetically pleasing and enhance a garden.
- If the landscape requires a sprinkler form of irrigation, then it should be done in an efficient manner; this means that any watering that is to take place should be done either early in the day, or in the evening, otherwise water will be lost to evaporation.
- A rainwater collector should be used (this is discussed in the water efficiency section) for any watering purposes. Rainwater is suitable for any garden and there are no municipal by-laws in Montreal that prevent rainwater capture and use for gardening.

A properly designed landscape surrounding a home can contribute to energy savings up to 25% (Suzuki, 2006). Landscapes have to be tailored to each individual home based on the size of the home, the preference of the owners, the climate and weather conditions and the budget allocated to the landscape.

Climate is the most important factor in landscape design, because a landscape has to be suited for the climate in which it is located in order for it to thrive. Quebec has four distinct climate zones, which are listed as follows:

- Humid continental – south of the 50th parallel with a hot summer, a cold winter and abundant precipitation,
- Sub arctic - between the 50th and 58th parallels with colder, longer winters, shorter, cooler summers, less precipitation,
- Arctic climate in the far north with rigorous winter, brief annual thaw, continuous permafrost,
- Eastern maritime in the Iles-de-la Madeleine region (Source: Education Canada Online)

The landscape in this project will be designed for the humid continental region, which is the climate associated with Montreal.

When trees are planted in specific areas they can act as windbreaks, shade and can lead to a decrease in energy expenditures of up to 25%. Evergreens act as windbreaks because they retain their foliage during the winter and can protect a home from strong western winds. Evergreens should be place on the western side of the landscape. Deciduous trees should be place on the south side of the landscape. Deciduous trees will lose their foliage during the winter, and allow for sunlight to penetrate into the south facing windows during the winter months. This is to capture solar energy in the form of light and heat in a passive way in the winter; As well, this arrangement will provide shade from solar heat in the summer months, because foliage will be plentiful and cover the south facing windows.

PART III: DESIGN PROJECT

3.0 INTRODUCTION

All aspects of a sustainable housing design have been discussed in the previous sections. This section will focus on materials and details of the design project and the benefits of the chosen products.

Environmental housing is becoming more popular as gas and energy prices rise in Quebec and all over the world. Environmental housing can be interpreted in a variety of ways; whether it is small ecologically sustainable housing in Europe, or enormous eco-homes belonging to celebrity such as Randy Bachmann's.

There are a variety of consulting groups that specialize in environmental housing. Environmental housing is an emerging phenomenon, though it has gained acceptance in many markets in North America and Europe, it still needs to become widespread.

Eco-refurbishment is another aspect of environmental housing that is worth mentioning. Many people are renovating their homes in small but substantial ways to reduce their energy and water bills and lessen their impact on the environment. Eco-refurbishment can mean, simply changing all light bulbs from incandescent to fluorescent, to increasing attic and basement insulation, to installing new showerheads and toilets. All of these are improvements that can be applied without any inconvenience to the homeowner and they have a measurable positive effect on the environment.

As the trend towards urbanism continues, so does the trend towards environmental sustainability. This is a fact of life, because all of humanity will be affected by pollution in some way, and there are even larger global issues that humanity will be facing within the next few years; global warming, water shortages, food shortages and increased environmental degradation, all of these are end products of human activity and mismanagement of resources.

An ecologically sustainable house therefore, falls right into place in this context.

3.1 Design Aspects of the Project

The design will consist of

Studs: FSC certified wood is used for making studs of the structure. FSC certified wood, certifies wood products are made from recycled wood that is laminated for finger jointed. These products contain less embodied energy, are from sustainable sources and because they are engineered, they are stronger and more dimensionally accurate than standard studs.

Windows: Pella ® Smart Smash III windows with triple glazing and low-E glass.

House wrap: house wrap such as Tyvek that adds another membrane to the structure, reducing infiltration and moisture migration. House wrap wicks moisture from the inside from the house outward, but doesn't allow moisture in from the outside. Also polyurethane foam in the walls and roof is also a vapor barrier.

Window wrap: Window wrap is specially formulated wide plastic tape applied around the window openings before the windows are installed. The wrap is covered with the exterior finish material, usually stucco or siding, that buts up against the window frame. Window wraps tightens and waterproofs the space between the windows and the walls which significantly reduces the chances of developing window leaks in the future.

Insulation: Cocoon insulation will be used. It is a non-toxic natural product made from 80% recovered, post–consumer paper fiber, reducing landfill waste. The remaining contents consist of fire retardant chemicals and stabilizing additives. The insulation is processed by electrically-driven mills that consume relatively little energy when operating. The cocoon insulation can be blown in horizontal applications into wall cavities and attics in new construction as well as in crawl spaces. Cocoon insulation is made in the United States and is available to order.

Flooring: EcoTimber, a company based in the United States produces ecologically sustainable flooring materials. The eco-home in this design project will use bamboo flooring. Bamboo flooring from EcoTimber is derived from farmed bamboo that is completely renewable. The average time for harvesting is 4-6 years, and because the bamboo is not from wild sources, using this product does not damage the environment or deprive any animals that feed on bamboo of their food. Bamboo is suitable for humid climates as it has low moisture adsorption properties and is therefore suitable for Quebec’s climate.

Paints: An eco-friendly home would have silicate based interior paint. Many stores carry eco-paint in a variety of colors. Benjamin Moore has a line of environmentally friendly paints.

Stone and Tile: All tiles in the kitchen and bathrooms will be made from 100% recycled glass tiles available from a wide variety of companies, such as Sandhill Industries. These tiles contain less embodied energy, because they are recycled and they are available in many designs, shapes and colors.

Lighting: All indoor lighting fixtures of this ecological design will be energy efficient fluorescent light bulbs. Energy efficient fluorescent light bulbs typically provide light for 10 000 hours, which is 10 times the amount of light obtained from an incandescent bulb, and they consume 75% electricity.

Appliances: All appliances will be EnerGuide certified. These appliances are available at all major Canadian department stores. This includes water consuming appliances such the dishwasher and laundry machine, and energy consuming appliances such as clothes dryer, oven and refrigerator. These appliances are certified by a third party for being energy and water efficient.

3.2 Single Family Detached Housing

General Characteristics: Single Split- Level Family Dwelling

Rooms: 7
Bedroom: 3
Bathroom: 1
Powder Room:1

Garage:1
Exterior Parking: 2

Year Built: 2006
Exterior Finish: Masonry, siding, aluminum trim

Table 3.0: General Characteristics of Eco-home

Features

Heat Pump Air-to-Air Heating
Finished Basement
Eat-in Kitchen
Permeable Driveway
Garden Shed
Central Air
Air exchanger
Smart Smash III Windows
Aluminum Trim

Table 3.1: Features of Eco-home

DESCRIPTIONS	ROOM SIZE	DETAILS
Kitchen	9’4”x11’8”	Recycled Glass Tile
Dinette	9’3”x8’8”	Recycled Glass Tile
Family Room	15’x13’5”	Bamboo Floor
Master Bedroom	13’5”x15’	Bamboo Floor
Bedroom	10’x11’4”	Bamboo Floor
Bedroom	10’x11’4”	Bamboo Floor
Basement	10’10”x16’10”	Recycled Glass Tile
	Total size of structure: 1600sq. ft (100 m^2)	

Table 3.2: Descriptions of Rooms and Details

PART IV: COST ANALYSIS

4.0 INTRODUCTION

The Sunlight Home Company provided many of the estimated expenses and costs associated with building a home. The Sunlight Home Company is a company that operates outside of the United States; they are in the business of construction of ecological housing that is practical, comfortable and beautiful.

There are many costs associated with building a home, everything from the excavation and foundations to the cabinetry finishes in the kitchen. The fixed costs are those associated with the basic components of the home; the roofing materials, the excavation, the structure itself. The variable costs are associated with the materials that can be varied, where cheaper substitutions are available. These are for items such as the flooring, the finishes and the appliances. According to Marjorie Davis, the communications manager of Sunlight Homes, the amount of money that is spent in an eco-home can vary from $140-200 per square foot, making it more expensive than a conventional home. There are, however, saving associated with building and living in an eco-home; the energy costs are lower, the lighting costs are lower and the house is more durable and generally more efficient. The environmental benefits are numerous and even if a price tag cannot be put on the environmental benefits, they exist nonetheless.

4.1 Cost of Lot, Building and Taxes

General Cost of Structure:

Structure	Description	Cost
Walls	Forest Stewardship Council wood Engineered I beams Trusses Flooring	$15 per sq ft
Roof	Approximate 500 sq ft Medium slope High value shingles 25 year warranty Multiple Laminate Shingles	$8 per sq ft
Windows	Pella Smart Sash III windows	$3 per sq ft
Foundation	Insulated pre-fabricated concrete foundation	$16 per sq ft

Finishes:

Structure	Description	Cost
Flooring	Bamboo Flooring	$4 per sq ft
Lighting	Energy Star Certified lighting	$3000
Cabinetry	Endura Wood Products Inc.	$1000 - $5000 for kitchen

Other Costs:

Permits and Paperwork

Structure	Description	Cost
Building permit	Ile Bizard Municipality	$25
Jobsite builders risk insurance		$20 per person
Engineering documents	Grading, plumbing, site drainage, energy calculation From the OIQ	$3000

Site Engineering and contractor's costs

STRUCTURE	DESCRIPTION	COST
Site utilities		-
Site preparation		-
Excavation	Depends on the slope of the land and the soil type	\$5-\$15 per cubic yard; \$6.55-\$20 per cubic meter
Forklift to unload panels from delivery truck		\$100 per day of work
Crane to set roof panels		\$100 per day of work

The estimated cost for a contractor is \$90-\$120 per square foot.

Housing Details; these are variable costs but add to the cost of a home.

- Framing hardware
- Nails
- Shims
- Adhesives
- Bolts
- Joist hangers
- Metal connectors
- Fittings
- Fiberglass wall insulation
- Foam crack insulation
- Sill seal
- Caulks
- Sealants
- Interior doors (including closets)
- Exterior and interior doorknobs and lock sets
- Plumbing and plumbing fixtures
- Heating and cooling and mechanical systems

- Masonry work, including tiles
- All exterior finishes and finish lumber (railings, fascias, trim)
- Exterior wall finishes
- Automobile garage door and interior garage fire door
- Drywall and plastering
- Floor insulation
- Painting and staining
- Cabinetry, vanities and mirrors
- Bathroom accessories
- Window coverings
- Appliances
- Job site labor and clean up

The total cost of building this eco-home can be variable and dependant on the choice of products and the details. According to Sunlight Homes, an average house can cost $140 to $200 per sq foot. This home is estimated to cost $150 per sq foot. All accessories and appliances are extra.

General Details:

ASSESSMENT/EVALUATION
Lot: $57 000
Building: $150 per sq ft x 1000 sq ft = $150 000
Total: $257 000

Table 4.0: Cost Assessment

TAXES
Municipal: $3268
School: $1000
Total: $4268

Table 4.1: Taxes

4.2 Cost of Work

Cost of Engineering Work:

- Design: $50 per hour x 52 hours = $ 2600

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