Edible Rooftops Project Proposal

Fondation 3E
Awards

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Edible Rooftops

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Project Summary

The Edible Rooftops Program proposes to bring food production to cities in the form of rooftop greenhouses in order to reduce energy in urban food systems. In conventional food systems, energy is used in clearing land, planting, cultivating, and harvesting of crops, in manufacturing and transporting inputs (such as pesticides, fertilizers, and machinery) and in processing, packaging, and distribution of final products. In contrast, this project incorporates hydroponics, waste heat recuperation and rainwater harvesting to provide local year-round energy efficient food production in greenhouses atop all newly built schools and those set for renovation for the Commission Scolaire de Montréal (CSdM). This project is especially recommended for schools located in food deserts although this is not a requirement.

This paper analyzes the types of energy used at all points of the production, processing, packaging, storage, and distribution stages of conventional agriculture compared to that of an inner city rooftop hydroponic greenhouse garden. Additionally, we will provide a pilot project model and assess its potential energy, financial and social impacts as well as its political feasibility and replicability.

1. Context

There are no current policies in Montréal regarding the necessity for urban agriculture. However, this is expected to change. The mayor of Montréal, Gérald Tremblay, announced a public consultation alongside the Office de Consultation Publique de Montréal to be held next spring, 2012 on the topic of urban agriculture after receiving a petition with more than 25,000 signatures filed November 15, 2011[1] .

Gardening in the Canadian context presents a particular set of challenges, one of the most important being a short growing season associated with a moderate to severe winter climate. The idea of a greenhouse arose in response to the climatic difficulties of production in Canada although the structure must be able to accommodate for heavy snowfall.

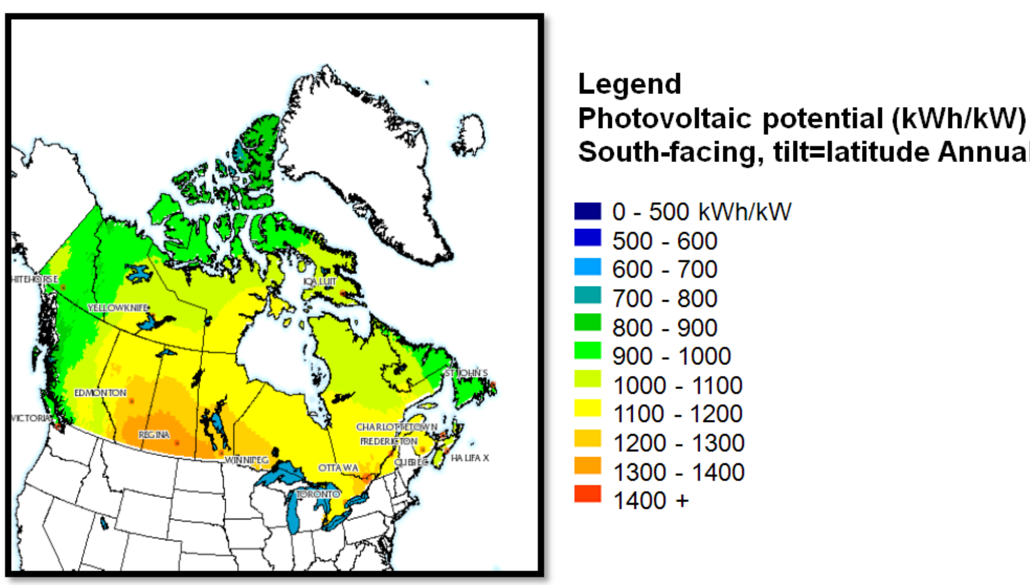
Furthermore, Montréal's latitude makes it good for growing food in a greenhouse because of the amount of sun and relatively low overcast/precipitation in the city (Figure 1).

Montréal also has a relatively serious "heat island" situation where temperatures in the city can rise up to 6 to 10 degrees warmer than outside the urban area. Rooftop greenhouses would help mitigate this situation[2].

The Edible Rooftops program aims to provide cities with food production that consumes less energy than conventional agriculture by building rooftop greenhouses on new school buildings and those under renovations. Our project focuses on school buildings within the Commissions Scolaire de Montreal(CSDM), a French school board that serves 9 boroughs (Ahuntsic-Cartierville, Côte-des-Neiges–Notre-Dame-de-Grâce, Le Plateau-Mont-Royal, Le Sud-Ouest, Mercier–Hochelaga-Maisonneuve, Rosemont–La Petite-Patrie, Ville-Marie, Villeray–Saint-Michel–Parc-Extension) and Westmount, a separate municipality. The CSDM has over 128 schools that are currently restructuring or replacing their roofs[3].

Already Montréal has implemented a family policy to encourage families to move to the island[4] . We are assuming that this policy intended for families to settle on the island of Montreal is successful and that new schools will need to be built.

Figure 1. Solar Radiation in Canada



Source: Natural Resources Canada. "The Atlas of Canada: Annual Solar Radiation". Available from <http://atlas.nrcan.gc.ca/site/english/maps/archives/5thedition/environment/climate/mcr4076> Accessed March 15, 2012

2. Project Precedents

Similar projects exist throughout North America. First, there are school programs available for gardening, food production and greenery. For example, Toronto has many children nutrition and greening programs such as the Toyota Evergreen Learning Grounds Program, Field to Table Schools program, and Student Nutrition. The first school based garden occurred in metro Toronto at the Bendale Business and Technical Institute where high school students grow food in a greenhouse for course credit and for sale to the community[5] . Closer to home, there is a project called the South West Community Fellowship, born from the desire to develop a partnership between Concordia University, and primary schools and organizations in Montréal's South-West district. This initiative has provided internships for the university students to help organize an environmental after-school club as well as a cooking club and a composting project using the vegetables grown in the schoolyards container gardens at several primary schools mainly in Verdun[6] .

Rooftop gardens have also been implemented in educational facilities through the *Making the Edible Landscape* project at McGill as well as at the Concordia greenhouse. The greenhouse at Concordia grows various plants using container gardens and a small hydroponics system. Concordia then sells the produce to students and the public at affordable prices.

Numerous examples exist for hydroponics in rooftop greenhouses. Overall, our key findings suggest that rooftop hydroponic agriculture has a high probability of being increasingly used throughout many cities in the near future. The projects mentioned below have laid the groundwork for how our concept can move forward.

Lufa Farms is a 2,880 square meter commercial operation on top of a Montréal office building situated in the Ahuntsic-Cartierville borough. Lufa Farms believe that they are able to grow and distribute high quality vegetables using half the energy required by traditional growers and distributers[7] .

Likewise, there is a rooftop hydroponic farm being built in Brockton, Massachusetts by the company Sky Vegetables. The Brockton farm covers 6132 square meters on top of an old shoe factory and is expected to grow 850,000 pounds of herbs and greens and distribute this food to local schools, hospitals, retailers, restaurants, and food banks[8] .

Gotham Greens is a 1,400 square meter commercial greenhouse atop a warehouse in Brooklyn New York. It started delivery to New York supermarkets in June 2011.The greenhouse produces over 80 tonnes of quality produce annually[9] . They deliver vegetables and herbs from their rooftop greenhouses using clean, renewable energy and captured rainwater.

BrightFarms designs, finances, builds and operates hydroponic greenhouse farms at, or near, supermarkets in the United States (mainly New York) eliminating time, distance and cost from the food supply chain[10].

In November 2010 BrightFarm Systems was commissioned to design an environmental education center and local food production facility on the roof of the Manhattan school for children by an organization called New York Sun Works[11]. The center uses hydroponic greenhouse technology, powered by renewable energy, to grow food. The project is part of the New York Sun Works Initiative to bring the concepts of urban sustainability and environmental science to NYC's schools.

Of the above examples, the precedents involving hydroponics in greenhouses are most significant in terms of energy reduction. The greenhouses are designed to absorb as much natural heat from the sun and the building as possible. By capturing rainwater that falls on the greenhouses, it is recirculated and used in the irrigation of the plants, thus reducing the demand for potable water and the energy needed to pump and treat this water. Because of their proximity to the city and its consumers, these rooftop farms use much less energy on processing, packaging, storing, transporting and distributing their food, which thereby sharply reduces transportation fuel consumption, and associated carbon emissions and air pollution. Lufa farms believe that rooftop hydroponic greenhouses can grow and distribute vegetables using half the energy required by traditional growers and distribution[12] .

The hydroponic farms have been proven successful in multiple economic and social aspects. Not only have they offered new job opportunities in their communities, but because of the increase in growth rate and vigor, there's a greater chance of success. Another positive aspect is that under-served communities can participate in sustainable crop production through hydroponics and help ensure a secure food supply at a lower cost than gardens that use soil or other planting media. In certain cases, workshops were provided to increase visibility and education opportunities around sustainable food systems. This has resulted in strengthening the culture of healthy and conscious approaches to food.

We have been in contact with the New York Sun Works (see below) who have demonstrated a high level of interest in expanding their program to Canada and to Montreal. Using that scenario, the New York Sun Works would become the lead agency in a public private partnership between themselves and the Comission Scolaire de Montreal. We have developed a pilot project based on this relationship, using L'Ecole les Enfants du Monde, a primary school located at 5350 avenue Rosedale in Côte-des-Neiges–Notre-Dame-de-Grâce. We will further discuss this project in a later section.

3. Project Description

The general issue we are addressing is high-energy consumption food systems. Food is a basic human need, therefore it is important to find ways to make food consumption patterns sustainable. The life cycle of food, in the conventional system, including agricultural production, storage, transportation, processing, packaging and waste disposal, consumes high levels of energy and resources and releases significant greenhouse gas emissions into the environment. The push for higher densities in cities pushes the proportion of the demand for food to cities. By bringing food production to cities that functions using renewable resources, the pressure to meet the demands for food placed by growing urbanization and population increases would place less stress on remaining land and energy resources.

The Canadian and American entire food system consumes about 10 quadrillion Btu from fossil fuel every year: 1 quadrillion Btu to make farm inputs like fuel, fertilizer, and machinery, 1 quadrillion to farm, 1 quadrillion to haul, 4 quadrillion to process and package, and 3 quadrillion to run the fridges, freezers, and other appliances that store and preserve our food[13&14.]

Conventional agriculture's role in both climate change and non-renewable resource consumption desperately needs to be analyzed in accordance with the global discussion of curbing greenhouse gas emissions and reducing dependency on oil. Our proposed method of food production changes the energy use patterns in food production by removing the need to clear land, decreasing the distance traveled to meet the demand for food in cities, eliminating the need for nitrogen fertilizers, pesticides, food preservation additives as well as reducing the need for storage and refrigeration.

This project aims to reduce the amount of energy in the food system through urban agriculture by proposing to the CSDM to implement hydroponic rooftop greenhouses atop any new high schools or those under construction. Bringing food production to school rooftops will not only bring food systems that consume less land and resources, but will also teach people across generations that the basic human need for food of tomorrow should not have to be sacrificed to meet the basic human need of food of today. The greenhouse model will conserve an enormous amount of energy by being located on a rooftop. In the wintertime, the heating costs of the greenhouse will be substantially reduced because of heat gain from the school building below, as well as from surrounding structures. Locating the greenhouse on the roof enables better protection from vandalism and air pollution. In addition, this method of growing food on rooftops provides year-round food production in a way that saves land, uses maximum sunlight, and recycles storm water and waste heat. The following list is a breakdown of the greenhouse technology and components needed for our endeavor.

Hydroponic system: The hydroponic system will operate in a very similar way to the Lufa farm model (seen below). At Lufa Farms, water that is used for the plants is taken down to the basement, run through a filter, and nutrient content is assessed. More nutrients are added to the mixture and re-circulated back into the hydroponic system and into the plants. The nutrient solutions supply the plants with all the necessary elements and ions needed for growth and development – calcium, nitrate (nitrogen), potassium, phosphate (phosphorus), magnesium, sulfur, iron, manganese, zinc, copper, boron, and molybdenum. The solutions are made up with salts, such as calcium nitrate and magnesium sulfate, which are mined and/or refined to generate sufficiently soluble compounds for use in nutrient solutions[15]. This process is done on site and on a small scale so the transportation energy component is minimal and the processing energy component is negligible.

Rainwater Capture: Rainwater will be collected from the greenhouse roof via gutters and diverted to a plastic storage tank after passing through a first flush device. The greenhouse will collect, filter, and re-use all of its irrigation solution, reducing water and nutrient consumption. In addition, it will harvest and utilize rainwater to supplement city water for its irrigation.

(Nutrient Film Technique) NFT system: The system is made up of channels with growing spaces for individual plants, through which nutrient solution flows at a consistent rate (roots grow in film of nutrient solution). Used primarily in the cultivation of greens, herbs, and other short-term crops.

Waste disposal: Similar to Lufa farms, the organic waste from the plants will be collected in separate containers from regular garbage and will be composted. All plant matter and growing medium will be composted.

Heating: For greenhouse heating requirements (which are largely concentrated to cold winter nights), our pilot project will use three high-efficiency boilers. Minimal energy requirements are met by the effectiveness of the gas boilers, which are 20% more productive than regular water heaters[16].

Lighting: Intensive supplemental lighting will not be necessary for this project, although some additional lighting will[17]. Proper greenhouse design for light admittance and, especially, greenhouse maintenance to keep the structure as bright as possible will be an important focus of our greenhouse operations.

Thermal curtains: Thermal curtains or movable shade systems are deployed on cold nights to insulate the greenhouse. They cover the walls and ceiling and trap heat accumulated during the day to reduce heating requirements. They provide the option of closing on bright days and remaining open on sunny day to obtain a consistent daily solar integral. These thermal curtains reduce the greenhouse heating needs by 40% during the night[18]. Moreover, a screen used at night reduces radiative heat loss from the crop canopy to the greenhouse roof or the sky, reducing condensation and disease. They are also implemented as shading in the summer.

Ventilation: Ventilation is a high-energy component of any greenhouse structure. The technology needed will involve an exhaust fan, a pad shutter and a roof vent[19].

Cooling Pads: In the Summer, cooling is achieved with the roof vents and/or cooling pads as used in the Lufa farms model. The cooling pad acts to cool through evaporative cooling. This system works by having water run through and evaporate as air passes through the pad. The evaporation is an endothermic reaction where heat is removed from air, allwing cooler air to enter the greenhouse[20].

Controlled Environment Ggriculture: All of the systems, including irrigation and environment (temperature, light, humidity, etc.), will be monitored and controlled automatically with a computer program, which incorporates various equations and parameters to generate the desired output settings. This program also allows the user to view and record data on irrigation and environment settings. We estimate that the highly controlled system will allow for almost no produce loss.

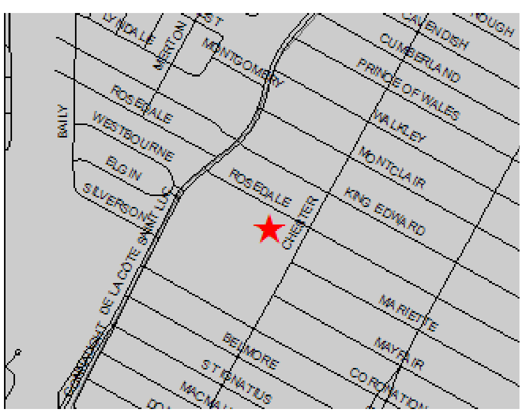
4. Pilot Project

The first pilot project to launch the Edible Rooftops program will take place on l' École Les Enfants du Monde, located at 5350 avenue Rosedale in Côte-des-Neiges–Notre-Dame-de-Grâce (see below). The energy and financial analysis presented in this report will focus on this pilot project, rather than the wider CSdM territory. The greenhouse pilot project on l'École Les Enfants du Monde stems from a previous business plan for a rooftop greenhouse on the school by Action Communiterre in 2007[21]. The greenhouse will be 74.32m2 in area and contain 80% productive space (59.5m2) and leaves 20% for holding small group workshops (14.9m2). The roof at L'École les Enfants du Monde is currently accessible via a set of stairs and will be suitable for educational activities to be held on site. The New York Sun Works, the primary agency that will own and operate the greenhouse, will formalize an agreement with l'École les Enfants du Monde to have rent-free access on the roof in exchange for coordinating educational activities for students. There is also the option for the NYSW to allocate a proportion of the produce to the school either for free or at a discounted rate.

The CSdM, specifically their sustainability office will partner with the New York Sun Works in a joint collaborative responsibility for the implementation of the project. The mandate of the CSdM is to organize educational services in preschool, primary school, secondary school and special schools for the physically and mentally handicapped, as well as professional training centres for adults. The institution has recently adopted a Plan Vert in order to guide all future projects and developments in its establishments to be environmentally friendly and ecologically sustainable[22].

The New York Sun Works has a Greenhouse project initiative with the objective of bringing urban sustainability and environmental science to schools in New York City. They have experience with creating rooftop greenhouses based on hydroponics. The New York Sun Works would be the main organization responsible for the Greenhouse Project. However, it would be a collaborated team effort between the business and the school to get the greenhouses implemented, running and maintained. The NYSW would design, build, operate and own the greenhouse while the CSdM would provide the space and the curriculum for educational activities.

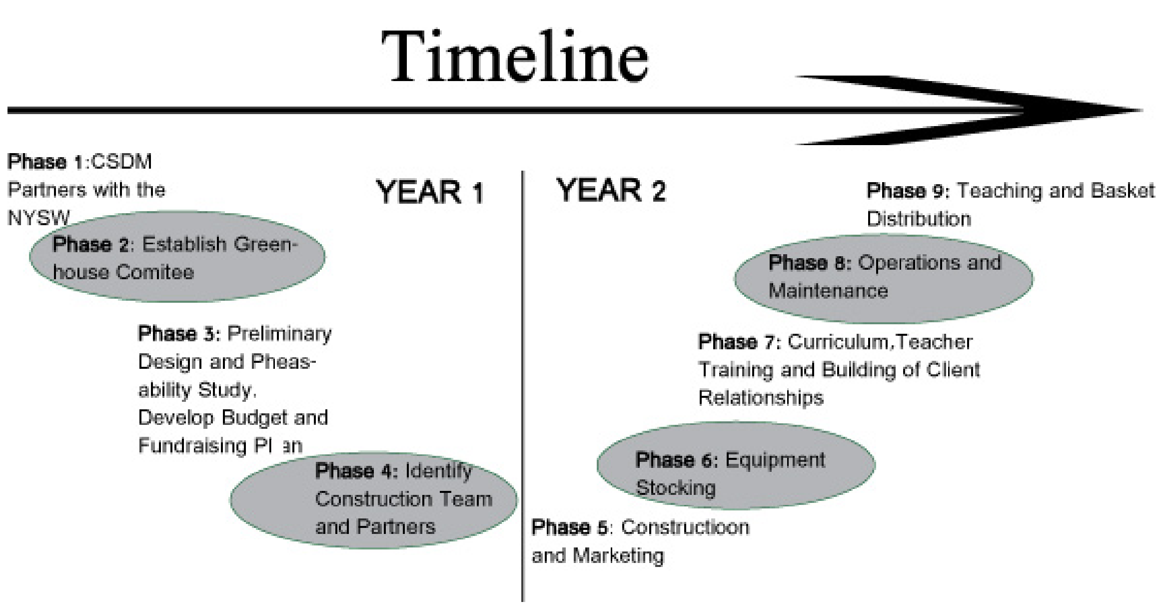
The NYSW is highly interested in our proposal as well as Lufa Farms (for help with research and implementation). The CSdM has also expressed interest in the program as rooftop greening and food security are stated objectives of theirs.



5. Implementation Plan

The entire project will take 2 years to plan and construct. The following section demonstrates the steps involved in implementing the pilot project, the time line as well as the potential allies and opposition.

5.1 Timeline



5.2 Allies

As mentioned, rooftop greening and food security projects are a stated objective of the CSdM as well as the City of Montreal. Our contact person at the CSdM, Carol Marcoux, conseillère pédagogique en environnement, expressed high interest in the project proposal , as long as the school board was not responsibile for funding. The CSdM will provide guidelines for student accessibility such as our greenhouse needing to be accessible to handicapped students. Developers will need to install a fire alarm and other student safety measures as well as make sure the hydroponic system is spaced so that a person with a wheelchair can easily move between rows.

Action Communiterre has already partially analyzed the feasibility of our pilot project on the roof of L'École les Enfants du Monde . Action Communiterre is a non-profit organization dedicated to fostering social solidarity, promoting local community food security, and improving the access to healthy produce through urban agriculture. The organisation would be a key partner, as they would help the business and the school to engage in a variety of activities designed to raise public awareness of the value of community-based food production and distribution.

Capital greenhouse is an engineering firm that specializes in research and institutional greenhouses as well as other facilities for growing plants. They will conduct a review of the building's condition, an energy savings analysis, feasibility studies, and provide operation cost estimates. They think it is a good idea to put the greenhouse on the roof.

Westbrook Greenhouse Systems Limited is one of the advisors of Lufa Farms. They will provide the greenhouse, energy curtain, heating system, and irrigation system.

Another key partner would be Lufa Farms who would be involved in sharing technological information and implementation actions that are distinct to Montreal. Carrefour BLE would provide job training and insertion. Equiterre would help connect the business with local food systems and be a possible connection for getting food into local hospitals. Santropol Roulant and Alternatives would be partners in integrating the project into the current rooftop and school yard greening initiative. The Urban Agriculture Coordinator at Alternatives showed interest in working with the project proposal in order to make sure that the results fit the needs of the community.

5.3 Opposition

While there is no distinct organised opposition, we can anticipate that this program may not be favoured by all. A potential competition may arise between schools that want greenhouses on their roof versus those who want solar panels. In addition, there may be some resistance among Montreal communities against having a foreign business (which in this case, is New York Sun Works) operating on school rooftops. Furthermore, a stigma may exist against hydroponics for not being natural, or certified organic.

Based on the success of Lufa Farms in generating a profit less than a year after opening, we can assume that there is a sufficient demand for food grown from hydroponics. If the crops grown in the greenhouse are in demand by existing restaurants, we can assume much support from these businesses as well. Hence, those that would favour the project seem to outweigh those opposed.

To build support among environmentalists who favour solar panels and those who oppose hydroponics, the Edible Rooftops program needs to be framed as a mechanism of getting cities to produce food in more sustainable ways. Conventional agriculture is the biggest user of land and water; the greatest source of water pollution; and second largest carbon emitting sector. In contrast, Edible Rooftops produce requires no shipping or storage, resulting in produce that is fresher, tastier, more nutritious and with a smaller carbon footprint.

6.Impact Analysis

Our project aims at reducing energy consumption in the current food system. We have focused on the crops that would be potentially displaced by a hydroponic greenhouse. Due to issues in data availability, our analysis focuses on the particular energy consumption in producing tomatoes, spinach, and lettuce in the conventional agriculture system versus estimates of energy use in our proposed greenhouse. We compare the amount of embodies energy energy for these crops per kg per year. These are crops that Quebec imports on a large scale from the United States and therefore have a large amount of energy (food miles) embedded in them[23.] The produce grown in the proposed greenhouses are not limited to these vegetables alone. Nonetheless, only crops that are not root vegetables can be produced in hydroponic greenhouses, some of which are outlined in figure 2. We have also calculated the potential energy impact of our project on the host school building.

6.1 Energy Use in The Conventional Food System

Our energy calculations for the conventional food system derive from the findings of Professor Lou Albright from Cornell University in Energy Investments And CO Emissions for Fresh Produce Imported Into New York State Compared To The Same Crops Grown Locally[24.] This report was initially written for the New York State Energy Research and Development Authority (NYSERDA).The calculations, summarized in Table 2, consider itemized energy use by area, all fuels and electricity, all soil amendments and transportation as well as energy lost to spoilage. The report highlights the inefficiencies of the current food system due to spoilage, which accounts for approximately 40% to 60% of the total food produced[25]. The structural engineer from Bright Farms confirmed that 50% of produce from conventional farms is lost to spoilage, which effectively doubles the amount of energy per kilo of imported produce consumed.

Tomatoes:
Although California dominates in processing tomato production, our analysis concentrates on production methods in Florida and California as they account for 72% of fresh tomato production in the United States[26]. Particularly, we narrow down our focus on field-grown slicing tomatoes. Using data from Albright's paper, it is estimated that the average embodied energy of imported tomatoes is 70 MJ/kg.

Lettuce:
In 2004 and 2005, more than 98% of head lettuce shipped in the US originated in California, Arizona and Mexico. Assuming marginal changes in these figures, it is determined that the average embodied energy for imported lettuce is 48 MJ/kg.

Spinach:
Spinach for eastern regions is bulked in bins, chilled using forced air or vacuum cooling means directly after harvest, and sent to the east coast washing and packing facilities where it then proceeds to being sold in wholesale distribution centers. The crop profiles referenced by Lou Albright (2008) were documented before the cut-salad greens trend had taken hold and at a time when production methods for salad greens were unsettled[27.] For this reason, this analysis discusses energy consumption for spinach produced before this trend. The average embodied energy for imported spinach is estimated at 98 MJ/kg.

Table 1: Summary of crop energy data for Tomato, Lettuce and Spinach (MJ/kg/year)	
CROP	EMBEDDED ENERGY
Fresh tomato	70
Head lettuce	48
Fresh spinach	98
AVERAGE	71

Table 1 summarizes energy consumption in these three crops. Since 40-60% of food is wasted from spoilage, the figures in Table 1 are double of what was in Albright's report. Using the mean of these figures, we conclude that the average embodied energy for imported produce from a conventional farm is thus **71 MJ/kg of produce annually.**

The energy figures we found for these three crops were estimated for imports into New York City. We will keep these figures but one should keep in mind that the current situation involves additional transportation energy from New York to Montreal (although minimal).

Figure 2: List of Possible Greenhouse Crops to be Displaced from The Conventional System

Tomato
Cucumber
Pepper
Eggplant
Lettuce
Cress
Herbs
Bok choy
Swiss chard
Microgreens
Salad mix

6.1.2. Energy Use in School Buildings

Although the Edible Rooftops program is not specifically geared towards reducing energy consumption in school buildings, this dimension is still worth analyzing to identify opportunities for recycling waste energy. A 2007 report done by Natural Resources Canada demonstrates that an average educational facility uses 50% of its energy consumption on space heating, including ventilation air heating. The average Canadian school consumes 214 ekWh per m2 annually (equivalent kilo watt hours per square meter)[28]. Based on these findings, to provide energy for École les Enfants du Monde (14779.5 m2) would result in approximately 1,581,406.5 ekWh annually for heating alone.

6.2 Energy Use in Our Project Scenario

The proposed greenhouse for l'École Les Enfants du Monde will be powered by natural gas for heating and electricity (largely generated from hydro but also from biomass, hydrogen, solar, nuclear power, wind power, and fossil fuel) for all other functions such as lighting and ventilation.

To reduce energy consumption from ventilation, we will consult with architects, engineers and greenhouse specialists for advice on how to construct the greenhouse in a way that maximizes natural ventilation. Nonetheless, the greenhouse will also use mechanical ventilation using exhaust fans for situations where natural ventilation is inefficient.

Typically, greenhouse production requires significant heating demands during the winter. However, the rooftop location of our project allows the greenhouse to use the 'lost' or underused space (rooftop) with greater access to the sun, and the waste heat from the building below. The rooftop location allows the greenhouse to operate using less energy compared to typical facilities on cold ground . For greenhouse heating requirements which are largely confined to cold winter nights), our pilot project will minimize energy requirements by using the waste heat from the school building below.

The following discusses energy consumption from our 2 main sources: electricity and natural gas. We will also analyse the potential energy decrease to the host building.

6.2.1 Electricity

We will be calculating energy consumption for electricity based on Science Barge, a hydroponic greenhouse which later branched off into New York Sun Works. This project consumed 0.2kWh daily[29]. This estimate is equivalent to approximately 359590 MJ annually for electricity to provide power for 80% of the greenhouse allocated for production.

Table 2. Electricity Requirements for Pilot Project Scenario (59.459 m2 of Productive Space)

ENERGY CONSUMER	ENERGY CONSUMPTION PER UNIT	UNIT TYPE	NUMBER OF UNITS/ year	UNIT TYPE	ANTICIPATED CONSUMPTION FOR PROPOSED GREENHOUSE
ELECTRICITY	0.2	kWh/m2/ day	59.456 m2	m2	359589.9

6.2.2. Energy Consumed from Natural Gas to Provide Heating

The New York Sun Works provided us with information on energy consumption from electricity but not for natural gas. In order to calculate the energy needed for heating, we used a standard rule of thumb recommended by Bruno Faucher, a greenhouse engineer from Capital Greenhouse who specializes in greenhouse energy use analysis and in planning greenhouses for educational institutions[30] . He recommends 500 watts per m2 to heat a greenhouse during the winter season. Taking this into account, we can assume that a typical greenhouse uses 4838.4 MJ/m2 annually for heating. The greenhouse uses high-efficiency boilers that use 20% less energy than typical gas boilers. Factoring these assumptions into our calculations generates an estimated annual total of 172 603 MJ of energy to heat the area used for production.

Table 3. Heating Requirements for Pilot Project Scenario (59.459 m2 of Productive Space)

ENERGY CONSUMER	ENERGY CONSUMPTION PER UNIT	UNIT TYPE	NUMBER OF UNITS/ year	UNIT TYPE	ANTICIPATED CONSUMPTION FOR PROPOSED GREENHOUSE MJ/ year
HEATING	3628.8	MJ/sq m/ year	59.456	sq m	172603.1

6.2.3 Energy Saving to the Schoool Building

Replacing a roof covered with snow with a greenhouse can also insulate the building. In this manner, Lufa Farms was able to reduce the buildings heating needs by approximately 20%. Using their model, our pilot project scenario would reduce energy for heating purposes by 316,281.3 ekWh annually, equivalent to approximately 1 138 613 MJ annual savings. This component is not included in our calculations.

6.3 Net Energy Savings (Food System)

As demonstrated in the previous sections, our project scenario will use approximately 287672 MJ annually for heating and 1156MJ annually for electricity. Using these figures, Table 4 presents the total annual energy consumption for our project per kg of produce compared it to the total annual energy consumption of the conventional system for the same yield. **We conclude that our project scenario will save approximately 109 614 MJ, or nearly 21% of the energy from the food system annually.**

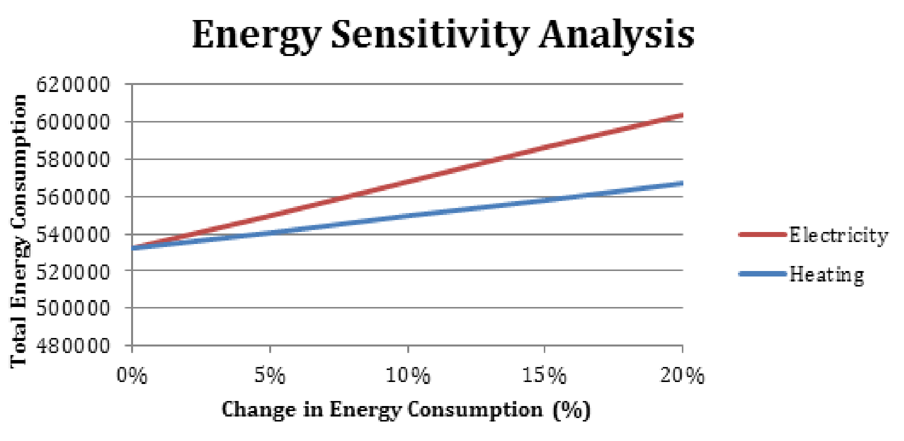
Table 4. Annual Energy Savings for our Project Scenario (per kg of produce)

ANNUAL COMPARISON	UNIT	OUR PROJECT SCENARIO	CONVENTIONAL SYSTEM
TOTAL ENERGY PER KG OF YIELD	kWh	16.4	19.8
	MJ	59.1	71.3
TOTAL PRODUCE PER YEAR	kg	8998.9	8998.9
TOTAL ANNUAL ENERGY CONSUMPTION	MJ/year	532193	641807
PERCENTAGE OF ENERGY SAVINGS			21%

6.4 Energy Sensitivity Analysis

Our energy sensitivity analysis in figure 3 illustrates that the cumulative energy consumption is relatively more sensitive to changes in energy consumption from electricity than to changes in energy consumption from natural gas. This is because more energy used comes from electricity.

Figure 3. Sensitivity to Changes in Energy Consumption



6.5 Greenhouse Gas Emissions

As stated, there are only specific types of vegetables our project can displace due to the hydroponics system. Table 5 summarizes the carbon reductions of our project scenario compared to the conventional food system using estimates directly provided by Zak Adams, a structural engineer from Bright Farms[31] . Based on this precedent, the proposed project will consume less energy in spite of heating since its location allows it to produce and distribute food without wasting energy on spoilage and transportation.

Table 5: Comparing CO_2 Emissions among Conventional Farming Methods and the Proposed Greenhouse

CO_2 EMISSIONS IN CONVENTIONAL FARMING VS. EDIBLE ROOFTOPS (Yearly metric tonnes of CO_2 per $74m^2$ of Productive Space)		
SOURCE	CONVENTIONAL FARMING	EDIBLE ROOFTOPS
Heating	n/a	4.5
Growing Systems	1.6	0.2
Transportation	3.1	0
Spoilage	4	0
Total	8.7	4.7

We can summarize this table by saying that the Edible Rooftops pilot project would reduce yearly GHG emissions by almost half (54%), for the same crop area of conventional farming.

We have assumed that the figures we obtained for energy use and carbon reductions for importing food to New York City were applicable to Montreal, since both urban areas import produce from the similar locations in the United States. We have also assumed that the values for yearly GHG benefits per square meter from the Bright Farms structural engineer were transferable to our project scenario.

7. Ancillary Benefits & Costs

7.1 Other Environmental Benefits

Bringing food production closer to consumers removes some of the externalities caused by conventional farming. Not only is arable land an increasingly scarce resource, but cities contain innumerable unused spaces (rooftops) that can be converted to agricultural production. Locating the greenhouse on a roof prevents biodiversity loss, and disconnect from nature. Food miles are eliminated. Using hydroponics leaves no agricultural runoff. Food is grown and protected using integrated pest management rather than pesticides.

Additionally the rooftop greenhouse recycles waste heat, excess rainwater, and paper while making use of underused roof space. All of our packaging material will be recyclable or compostable in order to further benefit the environment. Furthermore, we hope to contribute to reducing the urban heat island effect since our greenhouses are replacing hot tar roofs with cool, transpiring plant surfaces, helping reduce cooling needs of the building below and hopefully contributing to an overall improvement in urban climates. The rooftop greenhouse recycles excess heat and storm water flow.

The greenhouse also has the potential of recycling waste CO_2 in the building. This is an element that has yet to be explored.

7.2 Environmental Costs

Environmental costs are associated with transporting materials both in the construction and operation phases. Lufa farm obtains their seeds from Dutch companies and it is uncertain how much GHG emissions result from this delivery process. The energy and GHG emissions associated with transporting such equipment and materials is uncertain but are nonetheless environmental costs associated with our project. Another key environmental concern is the pollution born from glass manufacturing would affect the residents living nearby the industry as well as the ecosystem that it may disrupt. These issues have not been factored into our calculations but they are acknowledged.

7.3 Social Benefits

Social benefits include enhanced food security, increased nutrition in the urban diet, a fresher product, enhanced local employment opportunities and more control over the food delivery chain. Using the Lufa Farms Model, an urban rooftop greenhouse has the capacity to grow 31 pounds of produce and feed 700 people per square meter, every year. In addition, certain types of vegetables grown in hydroponic conditions embody more than twice the nutritional value than those grown in a traditional manner[32]. The produce would be sold directly to customers through the ASC model (Agriculture Soutenue par la Communauté) which permits citizens to become partners with a local farm by purchasing and picking up vegetable baskets from the greenhouse (or possibly even through a farmers market kiosk event set up by the school)[33]. Placing food production in schools near residences keeps people aware of where their food is coming from, how it is produced, and gives them an opportunity to even participate in how their food is produced or distributed.

Furthermore, by constructing on-site science greenhouse laboratories on the schools, we aim to provide tomorrow's decision-makers with a broader understanding of concepts of sustainability, urban agriculture and healthy eating as well as critical thinking skills which will enable them to act in an environmentally responsible manner on a local, regional, and global scale.

Our project can also provide local job creation, foster community development, and bring a greater connection to nature by improving knowledge and awareness around the source of our food and the ways in which it can be grown and consumed.

Furthermore, the project is directly in line with the CSdM's "Plan Vert" by abiding to their objectives for a more sustainable school system in Montreal.

The children and staff of the school that the greenhouse will be built, the local residents and community will most directly receive the benefits of experiencing an improved quality of life with easier access to fresh and nutritious produce. Reality is that the power to wean the food system from fossil fuels rests with consumers, not farmers. The choices that we make do matter. This project will effectively diminish the energy use in our current food system but it will also reduce energy (especially in schools) by helping institutions with:

1. Choosing whole foods over processed foods;
2. Having more food produced on site, and having kids involved in that production;
3. Choosing food that was grown in a region well suited to the crop, using methods that rely primarily on sunshine for energy and rainfall for water;
4. Increasing food security.

Education is a key component of our proposal and an understanding of the food system helps put our various food choices into context.

8. Feasibility

8.1 Capital Costs

Since the lead agency responsable for building, maintaining and operating the greenhouse is New York Sun Works, we will use their budget analysis for our model. These costs cover engineering and design as well as installation of hydroponic garden systems and system equipment. In addition to building the greenhouse and other hard costs, the budget includes training operators and teachers how to use the greenhouse systems in order to provide an innovative educational curriculum to school[34]. Project budgets for a greenhouse are \$6,348/m2 on average. This amounts to approximately \$472,000 to cover our pilot project (74m2).

8.2 Variable Costs

Annual operating costs for the Manhattan School Project for New York Sunworks accumulated to approximately \$4000 for the greenhouse annual operating costs (for a 133.78m2 facility), which comes to roughly \$30/m2. With this in mind, to operate a greenhouse with 59.5m2 of productive space for our project on L'École des Enfants du Monde would cost \$1785 annually. This includes period equipment replacement costs such as replacing glass, nutrient solutions, barrels, computer software updates and repairs, integrated pest management, maintaining pipes, and seeds. For labour, we refered to the original greenhouse business plan for Action Communiterre who had planned to employ three employees for the same size greenhouse. The sum for labour costs would thus be \$40605.76 annually in order to pay a qualified hydroponics technician, an administrative assistant, and a part-time worker(table 6). The New York Sun Works, the primary agency that will own and operate the greenhouse, will formalize an agreement with l'École des Enfants du monde to have rent-free access on the roof in exchange for coordinating educational activities for students. Expenses from energy accumulate to \$5238. We assumed that Hydro Quebec will consider the greenhouse as a medium power business, that it will charge for 4.41cents/kWh and that our greenhouse will use electricity for fifty weeks[35]. Likewise, we assumed that natural gas energy from Gaz Metro would cost 4.83\$/GJ based on figures from 2010[36]. In all, these operating costs amount to approximately \$47 637 annually.

Table 6. Labour Costs

Break out of Labour costs	Technical coodinato	Administrative Assista	Part-time staff	Total(annually)
Salaries	23296	8320	4160	35776
Benefits (13.5%)	3144.96	1123.2	561.6	4829.76
Sum	26440.96	9443.2	4721.6	**40605.76**

8.3 Revenue

Revenues are generated by the number of produce sold. Produce will be sold in baskets which customers can pick up at the greenhouse. A small basket holding 5-5.6 lbs of produce will be sold for \$19.25/week. The produce will be sold for \$3.50 per pound or \$7.72 per kg. Lufa farms produces and sells 31 pounds of produce per square foot of productive greenhouse space a year. Therefore, assuming that our greenhouse is equally productive, our project will yield \$1167.5/m2/year to produce 151kg/m2/year of vegetables. This assumes that all baskets will be sold.

Table 7. Revenu per Basket

LUFA FARMS			
kg/sq ft/yr	14.06136348	kg/sq m/yr	151.3552566

NUMBER OF YIELDS	AMOUNT OF YIELD PER UNIT	UNIT	AREA (sq m)	TIME (years)	TOTAL KG PRODUCED IN A YEAR
1	151.3552566	kg/sq m/yr	59.45794569	1	8999.272628

REVENUE	SELLING PRICE PER UNIT	UNIT	BASKET WEIGHT (kg)	COST PER BASKET	MAXIMUM POTENTIAL BASKETS/YR	ANNUAL MAXIMUM POTENTIAL REVENUE
BASKET	\$7.72	kg	2.494758037	\$19.25	3607.272727	\$69,440.00

Therefore, given these variable costs and potential revenues would generate net revenue of approximately \$21,803.43 as outlined in Table 8. This assumes that all produce will be sold and that none of the baskets will be allocated to the school or that the school would buy produce at regular price. The school can negotiate with the operating business to allocate a proportion of the produce for the school either for free or at a discounted rate which the school can give to children for free. Such options will be discussed in a later section.

Table 8. Summary of Costs and Revenues

		UNIT	Area of Productive Space (sq m)	
Baskets	\$1,167.88	revenue/m^2	59.45794569	**\$69,440.00**
Operating expenses	\$30.14	m^2		**\$1,792.00**
Human resources:	3	employees		**\$40,605.76**
Includes	Technical Coordinator	annual salary	\$26,440.96	
	Administrative Assistant	annual salary	\$9,443.20	
	Part-time Staff	annual salary	\$4,721.60	
Energy				**\$5,238.82**
	Electricity	4.41 cents	cents/kWh	
	Natural Gas	\$4.83	\$/GJ	
Produce allocated to the School	0	% of produce		**\$0.00**
Total:Gross Income (before tax)				**\$21,803.42**

8.4 Net Present Value

This section looks at the impacts of the level of funding and how it is distributed on net present value over a 10-year period starting from the initiation of construction. Capital costs must be paid during the first 2 years of the project while the net revenues will start generating throughout the next 8 years once construction is complete. We have assumed 3% inflation, 8% discount rate, that all produce will be sold, and that our capital and on-going costs resemble those of the New York Sun Works since they reflect the costs of constructing a glass greenhouse with similar elements. Similarly, we have assumed that we are eligible for all the funding programs, grants, contributions, tax credits and forgivable loans from various agencies at the local, provincial and federal level that Lufa Farms qualified for since we are providing similar services using a similar business model.

The project requires funding for the initial construction costs in order to sell baskets at an affordable price while still being able to generate positive net revenue within 10 years after construction. Table 7 illustrates funding provided to cover 100% of capital costs in the first year (assuming that it takes 2 years to construct the greenhouse), would generate a net present value of $107,421.45 (table 9). If the operating business had to pay for the construction costs and sell the baskets at the same price, it would bring down the net present value to -$329,615.59 (table 10).

Table 9. Net Present Value with Funding to Cover 100% Capital Costs

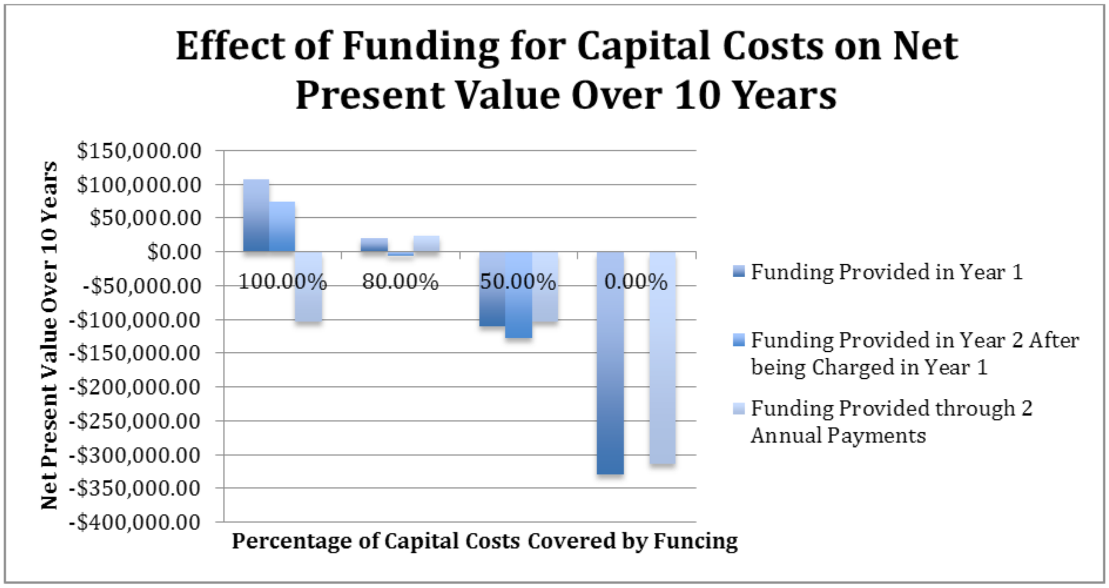
	YEAR	COSTS	REVENUE	NET REVENUE	PRESENT VALUE
CAPITAL	1	$472,000.00	$472,000.00	$0.00	$0.00
VARIABLE	2	$0.00	$0.00	$0.00	$0.00
	3	$47,636.58	$69,440.00	$21,803.42	$17,308.26
	4	$47,636.58	$69,440.00	$21,803.42	$16,026.16
	5	$47,636.58	$69,440.00	$21,803.42	$14,839.04
	6	$47,636.58	$69,440.00	$21,803.42	$13,739.85
	7	$47,636.58	$69,440.00	$21,803.42	$12,722.09
	8	$47,636.58	$69,440.00	$21,803.42	$11,779.71
	9	$47,636.58	$69,440.00	$21,803.42	$10,907.14
	10	$47,636.58	$69,440.00	$21,803.42	$10,099.20
NET PRESENT VALUE					$107,421.45

Table 10. Net Present Value without Funding

	YEAR	COSTS	REVENUE	NET REVENUE	PRESENT VALUE
CAPITAL	1	$472,000.00	$0.00	-$472,000.00	-$437,037.04
VARIABLE	2	$0.00	$0.00	$0.00	$0.00
	3	$47,636.58	$69,440.00	$21,803.42	$17,308.26
	4	$47,636.58	$69,440.00	$21,803.42	$16,026.16
	5	$47,636.58	$69,440.00	$21,803.42	$14,839.04
	6	$47,636.58	$69,440.00	$21,803.42	$13,739.85
	7	$47,636.58	$69,440.00	$21,803.42	$12,722.09
	8	$47,636.58	$69,440.00	$21,803.42	$11,779.71
	9	$47,636.58	$69,440.00	$21,803.42	$10,907.14
	10	$47,636.58	$69,440.00	$21,803.42	$10,099.20
NET PRESENT VALUE					-$329,615.59

Table 11 illustrates additional funding scenarios and how they would affect the net present value. It also compares how the distribution of funding throughout the construction period would affect the net present value. Receiving funding in year 1 for 100% of costs would yield the highest net present value while receiving no funding and paying all capital costs in year 1 would generate the lowest.

Table 11. Effect of Funding on the Net Present Value



8.5 Funding Programs Available

Fortunately, this project is eligible for funding from programs related to urban agriculture, innovative technology and food security. The Appendix provides more details about the the grants that Lufa Farms is eligible to receive. Our calculations also include the J.W. McConnell Foundation. which distributes a total of $4.8 million for their Regional Value Chain program as part of their Sustainable Food Systems initiative. This program works towards "systemic change to increase regional, sustainable food production capacity while enhancing consumers' ability to make healthy food choices"[37]. We have assumed that we are qualified for all the funding programs, grants, contributions, tax credits and forgivable loans from various agencies at the local, provincial and federal level that Lufa Farms eligable for, although we have devised scenarios in which we are not.

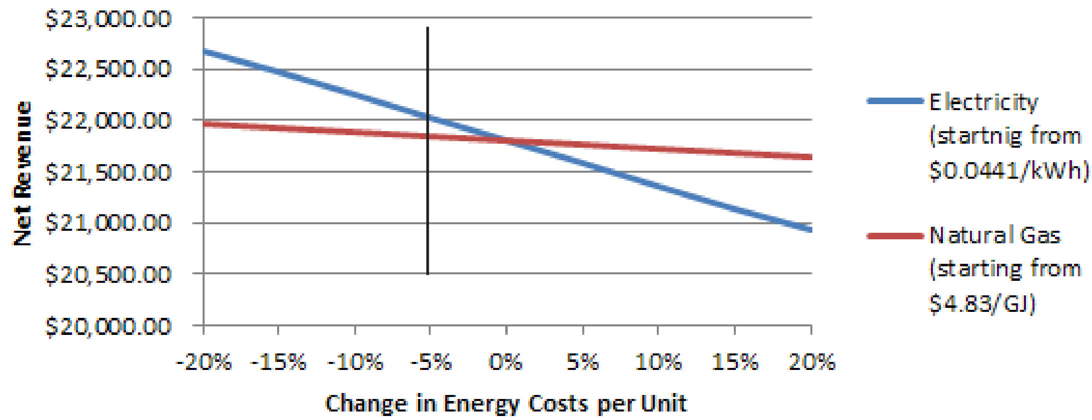
8.6 Financial Sensitivity Analysis

This section focuses on how various annual net revenues (during the operational phase) would be affected by changes in the costs of energy, labour, as well as changes in the selling price per kilogram and in the proportion of produce allocated to the school.

8.6.1 Energy Costs

Since the greenhouse derives a greater proportion of its energy from electricity, net revenues are more sensitive to changes in the price of electricity per kWh (figure 4). A decrease in the cost of electricity would mean a higher increase to net revenue than a decrease in the cost of natural gas.

Figure 4. Effect of Chanes in Energy Costs on Net Reveue



8.6.2 Selling Price

Edible Rooftops strives to provide affordable produce using less energy. To achieve this, we explored the feasibility of charging less for produce. The selling prices mentioned are not mandatory. The operating business ultimately determines the selling price. Figure 5 illustrates the effects of increase and decreasing the selling price per kg on annual gross revenue and annual net revenue. Selling produce beyond less than 25% of the originally mentioned price will generate will not be enough to pay the operating costs (table 12). Hence, produce cannot be sold for less than $5/kg or $14/basket.

Figure 5. Effect of Changes in Selling Price on Net Revenue

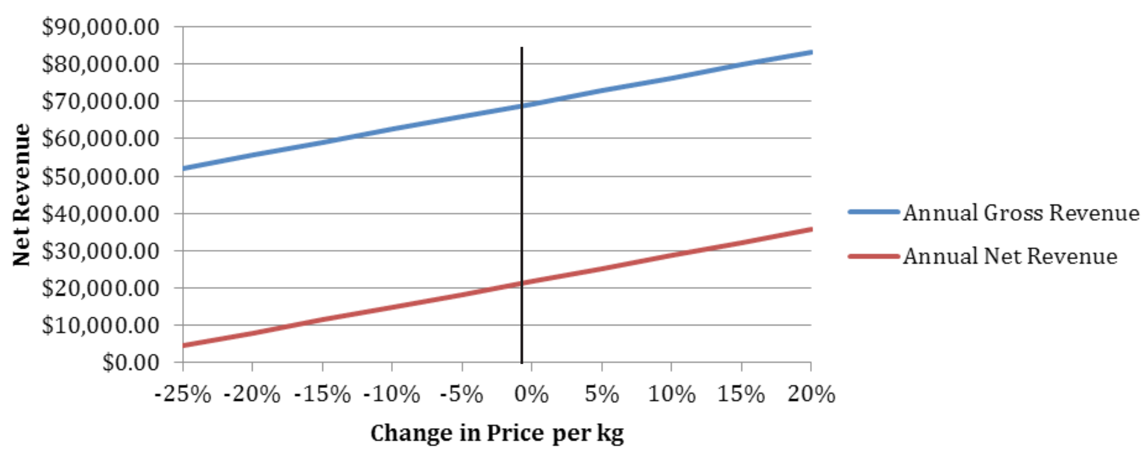


Table 12. Investigating Optimal Selling Prices

CHANGE IN UNIT PRICE (%)	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
UNIT PRICE	$5.79	$6.48	$7.21	$7.99	$8.80	$7.72	$8.10	$8.49	$8.87	$9.26
BASKET PRICE ($)	$14.44	$15.40	$16.36	$17.33	$18.29	$19.25	$20.21	$21.18	$22.14	$23.10
ANNUAL REVENUE ($) assumes variable costs are constant	$52,080.00	$55,552.00	$59,024.00	$62,496.00	$65,968.00	$69,440.00	$72,912.00	$76,384.00	$79,856.00	$83,328.00
ANNUAL NET REVENUE	$4,443.42	$7,915.42	$11,387.42	$14,859.42	$18,331.42	$21,803.42	$25,275.42	$28,747.42	$32,219.42	$35,691.42
SENSITIVITY/ CHANGE IN NET REVENUE	-79.62%	-63.70%	-47.77%	-31.85%	-15.92%	0.00%	15.92%	31.85%	47.77%	63.70%
*ROI	9%	14%	19%	24%	28%	31%	35%	38%	40%	43%
SENSITIVITY/ CHANGE IN ROI	-72.83%	-54.62%	-38.56%	-24.28%	-11.50%	0.00%	10.40%	19.86%	28.50%	36.41%

8.6.3 Labour

Our financial analysis for labour assumes that there are 3 employees: a technical coordinator/specialist in hydroponics, administrative staff, and part-time staff. Since the labour costs mentioned were fairly low, we explored how net revenue would be affected if salaries were to increase. Figure 6 demonstrates that net revenue is least sensitive to salaries paid to part-time staff. Net revenue is most sensitive to increasing salaries for the technical coordinator, the most vital labour capital. Table 13 outlines the effects of these changes in greater detail.

Figure 6. Impact of Salary Increase on Net Revenue

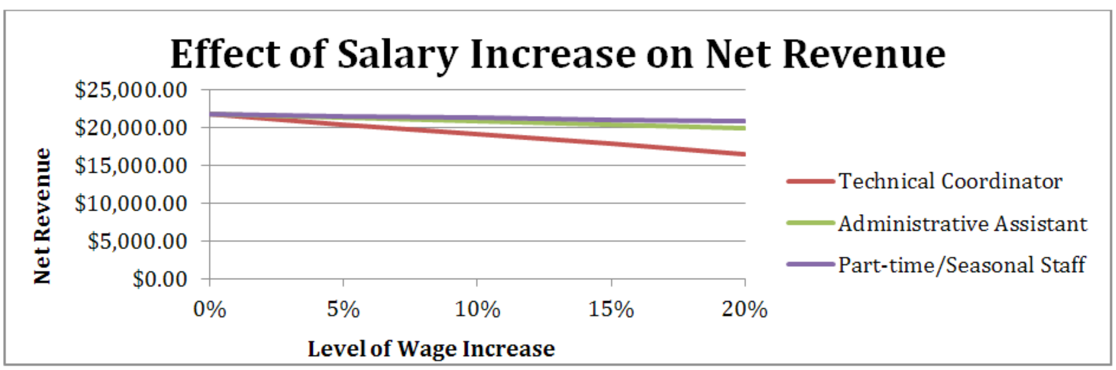


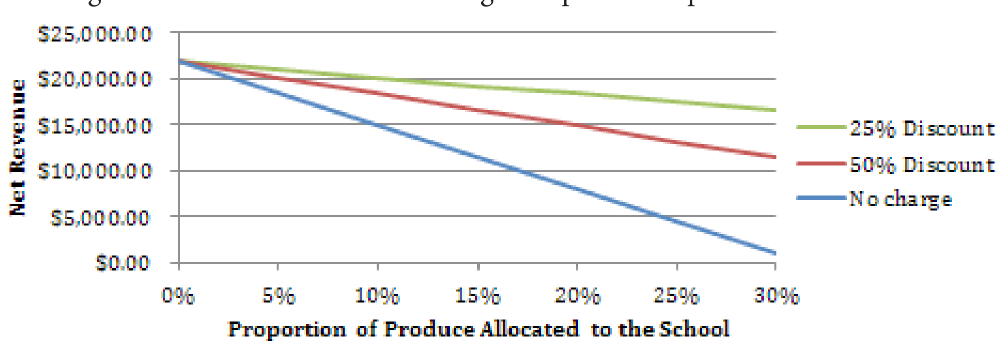
Table 13. Impact of Salary Increase on Total Labour Costs and Net revenue

	FINANCIAL SENSITIVITY TO WAGES	INDIVIDUAL COSTS	0%	5%	10%	15%	20%
TOTAL LABOUR COSTS	Technical coordinator	$26440.96	$40,605.76	$41,927.81	$43,249.86	$44,571.90	$45,893.95
	Administrative Assistant	$9443.2	$40,605.76	$41,077.92	$41,550.08	$42,022.24	$42,494.40
	Part-time staff	$4721.6	$40,605.76	$40,841.84	$41,077.92	$41,314.00	$41,550.08
IMPACT ON TOTAL LABOUR COSTS	Technical coordinator	As stated above	0.00%	3.26%	6.51%	9.77%	13.02%
	Administrative Assistant			1.16%	2.33%	3.49%	4.65%
	Part-time staff			0.58%	1.16%	1.74%	2.33%
NET REVENUE	Technical coordinator		$21,803.42	$20,481.37	$19,159.32	$17,837.28	$16,515.23
	Administrative Assistant			$21,331.26	$20,859.10	$20,386.94	$19,914.78
	Part-time staff			$21,567.34	$21,331.26	$21,095.18	$20,859.10
IMPACT ON NET REVENUE	Technical coordinator		0	-6.06%	-12.13%	-18.19%	-24.25%
	Administrative Assistant			-2.17%	-4.33%	-6.50%	-8.66%
	Part-time staff			-1.08%	-2.17%	-3.25%	-4.33%

8.6.4 Allocating Produce to the School

In order to provide affordable vegetables for children, schools and the operating business can negotiate on the proportion designated for this purpose and the payment strategy. Once the school receives the produce, it can when, how often, and how to distribute the food to the children. The school can decide if it wants to sell the produce in the school cafeteria or if it wants to provide children this food for free. We explored how annual net revenues would be affected by giving some of the produce to the school, either by having the school buy the produce at full price, half price, or receiving it at no cost (figure 7). Our findings show that the operating business can allocate no more than 30% of its produce to the school for free in order to be able to pay its operating costs.

Figure 7. Change in Net Revenue from Allocating a Proportion of produce to School



9. Replicability

9.1. Feasable Contexts

If the project is successful and the demand for local food continues to grow, the edible rooftops program could be transferable to other school boards on the island of Montreal. Using Bright Farms as a successful example, such a project could also eventually be expanded to grocery store rooftops as well. In terms of location, the edible rooftops project would be transferable throughout the parts of Canada where there is enough sunlight, particularly regions indicated in light and dark orange (figure 1).

9.2 Unfeasable Contexts

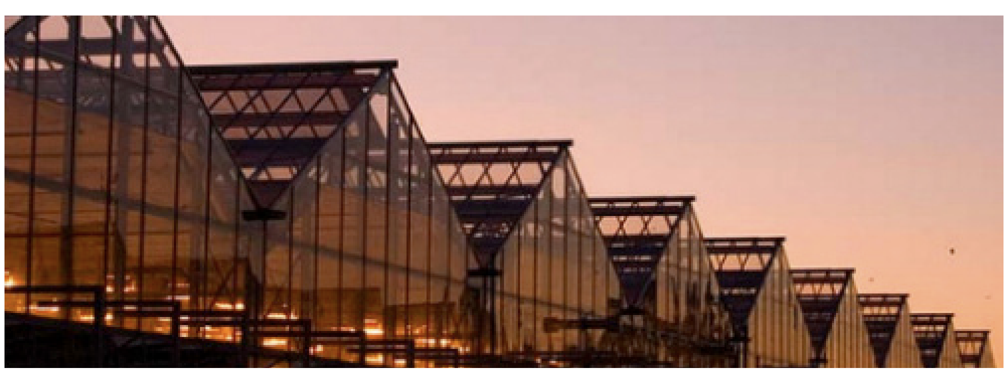
In the context of Montreal, not all schools will be eligible for the Edible Rooftops program. Eligibility depends on geographical location and the built environment. For schools to qualify, they must be located in an area that receives a lot of direct sun during the year. That being said, the school cannot be adjacent or near taller buildings or trees that may block sunlight.

This project is especially recommended for schools located in food deserts, although this is not a requirement. Indeed, if the program is successful and if enough funding is provided, this program can expand its eligibility to create more appropriate greenhouses for food desserts in areas that do not receive much sunlight, such as in the arctic near Inuit reserves. However, expanding the program to such areas would make it difficult to obtain the same energy savings.

9.3. Recommendations/Further Exploration

Improved technologies can improve the competitive position of Edible Rooftops. The project could effectively be improved in order to address issues of food insecurity. We envision that hydroponic rooftop greenhouses could be implemented in growing urban areas in the developing world. Although the technology is currently too expensive for such an endeavor, we have established several suggestions for enabling the project to be scaled up effectively.
Recommendations include the following:

1. Develop methods to enhance the insulation value of movable night curtains to reduce heating needs.
2. Investigate ways of recycling waste CO_2.
3. Encourage rapid adoption of LED greenhouse lighting as it becomes economically more attractive.
4. Develop methods and technologies to increase availability of renewable energy designed and scoped specifically for rooftop greenhouse operations.



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APPENDIX

1)PR@M(City of Montreal):

PR@M – Commerce is a one-of-a-kind development tool designed to help the business community carry out renovation projects. Under this program, merchants and business owners are eligible for grants to modernize their commercial infrastructure with a view to improving profitability. Their efforts may be aimed at securing customer loyalty, attracting new customers, renewing their commercial positioning or providing a cutting-edge sales environment. Financial support is offered to merchants and commercial real estate owners in two areas:

1. Design
Financial support of up to $4,000 per renovation project (covering 50% of design/planning costs)

2. Renovation
Financial support of up to $33,000 per building (covering 33% of eligible work costs)
• An enhanced grant of up to $30,000 is available for commercial buildings with at least four street-level businesses or with a facade measuring at least 30 metres.
• An enhanced grant of up to $20,000 is available for commercial buildings with two facades overlooking public thoroughfares

Eligibility

To qualify for this program, applicants must:
- Rent space in or own a commercial building located in a specific sector
- Contact the person in charge at the local municipal authority
- Complete the application form and attach the required documents
- Develop a renovation project in accordance with the sector's specific requirements
- Use the services of a professional designer to develop the project

Once their project has been approved, applicants are required to:
- Obtain the necessary permits to complete their project
- Complete the project in less than 24 months

Grant payment
Once their project has been completed, applicants are required to:
o Complete the project completion certificate
o Submit invoices, proofs of payment and copies of permits
o Facilitate a program official's visit to the renovation site

The grant is paid by cheque in one installment.

Source: Ville de Montreal. "PR@M-Commerce: Concrete Support for Business Vitality". Accessed at http://ville.montreal.qc.ca/portal/page?_pageid=6438,53833671&_dad=portal&_schema=PORTAL on March 20, 2012

2)Agricultural Innovation Program(Federal):

The Agricultural Innovation Program (AIP) is a $50 million initiative ending on March 31, 2013 designed to:

- accelerate the pace of innovation;
- facilitate the commercialization and adoption of innovative products, technologies, processes and/or services that will enhance economic growth, productivity and competitiveness of the Canadian agriculture, agri-food and agri-based products sector; and
- help the sector capture opportunities in domestic and global markets.

Maximum Funding and/or Support

- The maximum funding and/or support under both streams to any eligible recipient will not exceed $10 million over the life of AIP.
- Funding and/or support of up to $4 million per project will be considered under the Knowledge Creation and Transfer stream. This support is non-repayable.
- Funding of up to $10 million, or up to 50% of eligible costs per project will be considered under the Commercialization stream. This support is fully repayable.

AIP uses an open system where applications can be submitted for review at any point until the available program budget has been fully allocated. Applications are considered as soon as they are received and found to be complete. To be eligible for support, projects must be completed by March 31, 2013. Applications must be clear that this condition can be met.

Source: Agriculture and Agri-Food Canada. 2011. "Agricultural Innovation Program". Accessed at http://www4.agr.gc.ca/AAFC-AAC/displaafficher.do?id=1320767853009&lang=eng on March 20, 2012

3)TechnoClimat (provincial):

Program description
The Green technologies demonstration program aiming to reduce greenhouse gas emissions is a product of Measure 20 of the 2006-2012 Climate Change Action Plan (CCAP). This CCAP measure encourages the emergence and deployment of technologies that show strong potential for reducing GHG emissions in Québec.

Program objectives
The program focuses on reducing greenhouse gas emissions by:

- supporting the development of technologies that limit or reduce greenhouse gas emissions
- improving energy efficiency so as to reduce the consumption of fossil fuels
- replacing fuels and fossil fuels with renewable energy
- contributing to the development of Québec businesses and the creation of green technology jobs.

Component supporting the trial implementation of a technology
Specific objectives for this component

- Validate a GHG emission reduction technology in Québec
- Encourage the deployment of proven technologies in Québec that help reduce GHG emissions

Eligible clientele
Any legally constituted organization, enterprise or association that is established in Québec that wishes to use or market a proven GHG emission reduction technology that has weak market presence or no market presence in Québec.

Eligible projects
A product or process whose scale-up is complete and whose use in a commercial or industrial application serving to reduce GHG emissions is proven but has weak market presence or no market presence in Québec. Eligible projects must:
- involve the trial implementation and validation of performance characteristics or the compliance with a standard in order to establish the credibility of the technology as it is used in Québec; AND
- aim to reduce GHG emissions in Québec; AND
- present a strong potential for replication and marketing, as the case may require.

Clean technologies must be widely adopted to make the advantages of sustainable development a reality for Quebecers. Thus, the results of the technology's trial implementation must be released in pertinent market sectors in order to encourage its deployment.

Financial assistance
Financial assistance is limited to the lowest of the following amounts:
- 50 % of eligible expenses;
- $1M maximum per project;
- the amount requested by the applicant.

Financial assistance may take the form of a non-reimbursable contribution (grant).

Eligible expenses
Eligible expenses must be directly linked to the delivery of the trial implementation project. The greater part of the project's expenses must consist of studies or tests performed on the technology. Validation activities must be carried out by independent external resources established in Québec who have gained recognition in their field. If no resources possessing the required expertise are available, the tests may be performed outside the province of Québec.

These studies or tests aim to confirm the characteristics of a performance-based product or a product that complies with a standard or regulation. These activities must be performed after the completed and signed request is filed and include:

- professional fees and costs incurred within the scope of the project that pertain to evaluation and verification services (GHG emissions and energy performance) and to financial audit services;
- fees of the consultants required to carry out the project;
- the salary of each person working directly on the project as well as the mandatory fringe benefits pertaining to payroll;
- legal fees associated with securing a distribution agreement or a manufacturing license;
- costs of materials, equipment and supplies directly linked to the project;
- travelling and living expenses when directly linked to the project;
- for existing capital assets: the overrun of expenses and costs directly linked to the delivery and term of the project;
- for new capital assets: the amortization expenses, costs and value directly linked to the delivery and term of the project;

The Department reserves the right to review eligible expenses. The project must be accepted and the costs incurred must be recognized as eligible expenses by the Department within the scope of the agreement entered into with the applicant.

Non eligible expenses
The expenses not covered by eligible projects are R&D activities and costs related to the application for and acquisition of a patent.

Source: Resources Naturelles et Faune Quebec. "Technoclimat--One Program: 2 Components". Available at http://www.efficaciteenergetique.mrnf.gouv.qc.ca/en/technological-innovations/technoclimat/un-programme-en-2-volets on March 20,2012

4) SR&ED (Tax Credit) (Fedearal):

The Canadian Scientific Research and Experimental Development Tax Incentive Program (SR&ED or SRED) provides support in the form of tax credits and/or refunds, to corporations, partnerships or individuals who conduct scientific research or experimental development in Canada. The SR&ED program gives claimants cash refunds and/or tax credits for their expenditures on eligible R&D work done in Canada.

Who qualifies?
Generally, a Canadian-controlled private corporation (CCPC) can earn an investment tax credit (ITC) of 35% up to the first $3 million of qualified expenditures for SR&ED carried out in Canada, and 20% on any excess amount. Other Canadian corporations, proprietorships, partnerships, and trusts can earn an ITC of 20% of qualified expenditures for SR&ED carried out in Canada.

Generally, a CCPC with a taxable income in the immediately preceding year that does not exceed the qualifying income limit may receive a portion of the ITC earned as a refund, after applying these tax credits against taxes payable.

The ITC earned by a Canadian corporation that is not a CCPC is non-refundable, but may be used to reduce any taxes payable. The ITC earned by a proprietorship or certain trusts may be partially refunded after applying these tax credits against taxes payable.

What kind of projects qualify?
To qualify for the SR&ED program, work must advance the understanding of scientific relations or technologies, address scientific or technological uncertainty, and incorporate a systematic investigation by qualified personnel.

Work that qualifies for SR&ED tax credits includes:
- experimental development to achieve technological advancement to create new materials, devices, products, or processes, or improve existing ones;
- applied research to advance scientific knowledge with a specific practical application in view;
- basic research to advance scientific knowledge without a specific practical application in view; and
- support work in engineering, design, operations research, mathematical analysis, computer program ming, data collection, testing, or psychological research, but only if the work is commensurate with, and directly supports, the eligible experimental development, or applied or basic research.

The following activities are not eligible for benefits under the program:

- social science and humanities research;
- commercial production of a new or improved material, device, or product, or the commercial use of a new or improved process;
- style changes;
- market research or sales promotion;
- quality control or routine testing of materials, devices, products, or processes;
- routine data collection;
- prospecting, exploring, or drilling for or producing minerals, petroleum, or natural gas; and
- development based solely on design or routine engineering practice.

Source: Canada Revenue Agency. "Scientific Research and Experimental Development (SR&ED) Tax Incentive Program: Support for your R&D in Canada". Accessed at http://www.cra-arc.gc.ca/txcrdt/sred-rsde/menu-eng.html on March 20, 2012

5)IRAP (Federal)

The National Research Council-Industrial Research Assistance Program (NRC-IRAP) is Canada's premier innovation assistance program for small and medium-sized enterprises (SMEs). It is a vital component of the NRC, a cornerstone in Canada's innovation system, regarded world-wide as one of the best programs of its kind.

Our Program Goals

- Support small and medium-sized enterprise innovation.
- Strengthen technology-based communities.
- Increase our client reach.

Our Strategic Objectives

- Provide support to small and medium-sized enterprises in Canada in the development and commercialization of technologies.
- Collaborate in initiatives within regional and national organizations that support the development and commercialization of technologies by small and medium-sized enterprises.

Research and Technology Development Activities

The National Research Council of Canada Industrial Research Assistance Program (NRC-IRAP) provides financial support to qualified small and medium-sized enterprises in Canada to help them develop technologies for competitive advantage. NRC-IRAP operates on a shared-risk model, providing cost-shared financial assistance for research and development projects that meet both the firm and project assessment criteria.

Financial support for firms

Financial support may be provided for an eligible research and development project, supporting a portion of salary and contractor costs associated with the project.

Eligibility criteria

To be eligible for financial assistance, your business must:

- Be a small and medium-sized enterprise in Canada, incorporated and profit-oriented
- Have 500 or less full-time equivalent employees
- Have the objective to grow and generate profits through development and commercialization of innovative, technology-driven new or improved products, services, or processes in Canada

The potential client must contact one of our Industrial Technology Advisors who work directly with many of our smaller clients to develop a technical proposal. Larger companies often come to the program with a clear technical proposal already in mind.

In order to be considered for possible financial support, both the firm and the project are assessed by NRC-IRAP. Specifically, the due diligence process assesses:

1. the business and management capabilities of the firm and the company's potential to achieve the expected results and outcomes associated with the proposed project;
2. the financial capabilities of the firm and its plan to commercialize the developed technologies; and
3. the technical aspects of the project and its potential impact on the firm.

Based on a combination of the recommendation of project merit and available funding, a Contribution Agreement is generated, which details the project objectives and activities being funded, as well as the conditions of contribution, the expected results and conditions for payment.

Source: National Research Council Canada (2012). "NRC Industrial Research Assistance Program" Available at http://www.nrc-cnrc.gc.ca/eng/ibp/irap.html on March 20,2012