RESEARCH REPORT

Latest Developments in Green Roofs in Quebec

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Latest Developments in Green Roofs in Quebec

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Executive Summary

This is a summary of the latest developments in green roofs in Quebec, serving to outline the very latest generation of technologies that are starting to prove themselves in the southern Quebec climate. In addition, this summary shows the link between green roofs (and greening in general) and the health and well-being of human beings in urban environments. The summary ends with fact sheets on 10 recent green roof projects in Quebec. These fact sheets include information on costs, technical and regulatory barriers encountered, and available solutions that were or could be incorporated into the projects, as well as scientific results and plant survival.

This document was drawn from a broader study on green roofs entitled **Toitures végétales : Implantation de toits verts en milieu institutionnel – Étude de cas : UQÀM**, a case study on the implementation of green roofs in institutional environments, published in April 2008 by the Verdis-toit committee of the Groupe de recherche d'intérêt public (GRIP), the public interest research group, of the Université du Québec à Montréal (UQÀM) and the Montreal Urban Ecology Centre (MUEC).

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Green roofs in Quebec

Modern green roofs first appeared in Quebec close to 15 years ago. Although they have aroused tremendous public interest, only modest progress has been achieved in Quebec's residential sector due to some irritants such as cost and weight. Most of the one hundred plus projects with green roofs involve institutional or commercial buildings. To reflect this reality, a publication entitled "*Toitures végétales: Implantation de toits verts en milieu institutionnel – Étude de Cas: UQAM*" focused mainly on public and commercial buildings. Nonetheless, the information contained in that study and this summary can be applied to the residential sector, particularly apartment buildings. With the advent of new technology that has made green roofs thinner and lighter, they could become more prevalent in Quebec homes.

New generation of green roofs in Quebec

A fifth generation of green roofs, which are far lighter and thinner than their predecessors, recently appeared in Quebec, as was predicted by the last two publications by the *Centre d'écologie urbaine* (Neremberg, 2005). These new products are between 5 and 10 cm thick (2 to 4 inches) and weigh between 40 and 90 kg/sq. m (8 to 18 lb./sq.ft.).

These roofs are more economical and since they weigh less, they can be installed on the roofs of existing buildings, which would normally require structural reinforcement, an onerous task. Most of these technologies were tested out in locations where winters are relatively harsh. Xeroflor and ELT, the technologies available in Quebec, were tested out in Umea, a city in Northern Sweden that is within the polar circle. In recent years, these ultra-light roofs have been successfully installed in various Canadian municipalities. Although a Quebec study did show that the minimum soil cover of 10 cm (4 inches) is required for plant life to survive in Quebec (Boivin, 2001), green roofs with thinner cover (5 and 7.5 or 2 to 3 inches) have survived the last two winters. This, however, is not sufficient to ensure viability, since the golden rule states that a product must last for three consecutive years to be considered viable.

Figure 1: Sedum roof – Xero Flor – the 2007 season

Figure 2: Sedum roof – Xero Flor – the 2008 season

The aspects of various ultralight roofs available in Quebec are similar from one supplier to another and resemble a thin carpet of growth. Some species of sedums, which are succulent slow-growth plants, generally come from alpine or arid environments and are selected for each product. Sedums possess several attractive characteristics, which make them the best suited for green roofs. For example, sedums are very resistant to heat fluctuations and can live a long time without water and survive in a thin soil cover, which effectively crowds out invasive plants.

Sedums are rather slow-growing plants, meaning they are less photosynthetically active. As a result, they do not rate as highly as several other plants in terms of carbon wells. As well, their ability to improve air quality by filtering out atmospheric pollutants is proportionately less than that of many other plants. Given their slower photorespiration and their lower shading effect on a growing medium, sedums are logically less able to reduce urban heat islands. Finally, these products do have respectable water retention capacity, which is slightly less than typical extensive 15-cm (6 in.) roofs.

Table 1: Comparison of green roof systems in Quebec

	Intensive	**Extensive (4th generation)**	**Extensive (5th generation)**
Soil cover thickness (high mineral content and light)	20 cm and over 8 in. and over	10 to 20 cm 4 to 8 inches	5 to 10 cm 2 to 4 inches
Weight (system deadweight only)	More than 220 kg/sq.m More than 45 lb./sq.ft.	90 to 220 sq.m 18 to 45 lb./sq.ft.	40 to 90 sq.m 8 to 18 sq.ft.
Cost of the green roof (materials and installation)	$160 sq.m and over $15/sq.ft and over	$110 to $160 sq.m $10 to $15/sq.ft.	$85 to $130 sq.m $8 to $12 sq.ft.

N.B.: Prices do not include potential structural reinforcements, roof rehabilitations or additions of an irrigation system, parapet walls and railings or any other changes to the roof.

The benefits of green roofs

The main arguments in favour of installing green roofs relate mainly to comfort and the cost-effectiveness for the owner. For example, they positively contribute to energy efficiency, protect and prolong the waterproof barrier or increase the value of a residence. However, plants, the main component of green roof, play a major role in cities. Whether growing on a roof or part of a landscaped area, they can significantly increase the quality of life of city-dwellers.

Green roofs, health and well-being

Discussions generally focus on the indirect benefits plants have on humans. Their ability to improve air quality, retain water and freshen the surrounding air receives much attention. However, plants have a major bearing on the health and well-being of humans merely by being present and visible.

Henri David Thoreau saw nature as essential to our mental and spiritual health, which makes a connection with nature necessary. Biologist Edward Wilson coined the term *biophilia* to explain humans' instinctive attraction to natural spaces. This affinity with nature is believed to be universal. Some studies have shown that, regardless of gender, age or culture, humans prefer a natural landscape to a built landscape (Newell, 1997). Moreover, the human eye sees green better than other colours and has adjusted to recognize more variations of green.

Natural landscapes provide tranquility and possess healing properties to fight mental fatigue. In an urban environment, plants are said to reduce anger, anxiety, aggressiveness, fear and stress, among other things (Royal Commission on Environmental Pollution, 2004). It was even noted in clinical studies that exposure to natural landscapes for as little as five minutes had a major effect on blood pressure, heart rate, muscle tension and brain activity (Ulrick, 2002; Hartig, 2003).

Many people see stress as one of the greatest contributing factors to health problems in our modern society (Grahn and Stigsdotter, 2003). The relationship between the proximity of green spaces, the reduction of stress and the health of city-dwellers has been statistically shown in numerous epidemiology journals published in Sweden (Grahn and Stigsdotter, 2003), in the Netherlands (Mass, Verheij et al., 2006) and in England (Mitchell and Popham, 2006).

It has also been shown that concentration can be maintained more easily in natural environments and that cognitive recovery, attention, emotional stability and concentration are greater in a natural environment than in a city environment (Hartig, Evans et al., 2003; Kaplan and Kaplan, 1989).

According to the theories cited in Kaplan (1989) and Hartig (1996), there are believed to be two types of attention – direct and contemplative – which correspond to different regions of the brain. Direct attention is what we need to process and sort the information overload we are exposed to. Meanwhile, contemplative attention, which is stimulated by natural scenes, among other things, requires little energy, since humans assimilate them easily. Admiring a green space therefore enables areas of the brain controlling direct attention to rest (Kaplan and Kaplan, 1989, Hartig, Book et al., 1996).

Improved healing

Ulrich (1984) conducted a study in a Pennsylvania hospital on patients who had their gall bladder removed. They were grouped together according to their condition (age, smoker/non-smoker, etc.). Of this paring, one group of patients was assigned rooms looking out on a brick wall and another had a view of a tree grove.
The results were impressive: fewer doses of painkillers, shorter stays in hospital, fewer minor complications and better nurse evaluations of the conditions of patients whose rooms looked out onto trees. These findings were subsequently supported by other published reports (Hartig, Book et al., 1996; Herzong, Black et al., 1997).

This comes at a time when the population is aging and the health of seniors is a major concern. Armed with the knowledge that a sedentary lifestyle has much to do with increased mortality and morbidity, researchers have become interested in which type of environment contributes to fitness. A Japanese study team that followed citizens over a five-year period showed that there was a correlation between the prolonged longevity of seniors and the proximity of green and pedestrian spaces, regardless of the age, sex and socioeconomic status of the subjects. The integration of green spaces, including green roofs, in the landscapes of buildings where seniors live is one option to be given serious consideration, according to this study (Takano, Nakamura et al., 2002).

Air pollution

With the increase of vehicle traffic in the Montreal area (Bisson, 2005), the impact of air transportation and the presence of urban heat islands, air quality is becoming an increasing concern. Though it is not a direct source of mortality, poor air quality contributes to the advent of chronic respiratory disorders and very often represents an aggravating factor resulting in the deaths of those who are already struggling with respiratory problems. When the bill of the *Canadian Air Quality Act* (C-30) was tabled (it was taken from the *Canadian Environment Protection Act* (1999)), it was estimated that every dollar invested to improve air quality produced three dollars in health benefits (Drouin and King, 2007). According to research by the Montreal Public Health Branch, air pollution is believed to be responsible for:

- 1540 premature deaths (400 relating to spikes in pollution and 1140 to chronic exposure);
- Each increase of 10 micrograms of fine particulates per cubic metre of air beyond the 25 standard boosts the number of hospitalizations by about 1%;
- The increase in mortality in persons over 65, which is a reported 6.4% higher the day after a 12.5 µg/cu.m. increase in fine particulates.

(Drouin, Morency et al., 2006).

Plants as air purifiers

Vegetation in urban surroundings is known to filter suspended particles (some heavy metals) and reduce the formation of ozone (O_3), nitrous oxides (NOx) and sulfurous oxides (SOx) (Beckett, Freer-Smith et al., 1998; Jim and Chen, 2007). Some atmospheric pollutants can be **absorbed** directly by the plant metabolism and captured in their tissue, such as carbon dioxide (CO_2) during photosynthesis. Other pollutants such as NOx are **absorbed** by the plant throughout the year during sunny days (Fujii, Cha et al., 2005). Fine suspended particulates ($PM_{2.5}$, PM_{10}) are neutralized as they settle on the surface of urban materials, including trees. As air goes through the plants, it comes in contact with the large surface area of leaves covered with a protective coating known as a cuticule. This causes the fine particulates to stick to the leaves. Once stuck, the fine particulates are washed off to the ground during rain storms (Beckett, Freer-Smith et al., 1998; Dunnett and Kingbury, 2005). In urban settings, it has been calculated that 1.5 sq. m of uncut grass is able to capture 3 kg of suspended matter and provide enough oxygen for one person for one year (Banting, 2005).

Most research on the filtration of particles was done with trees. Little has been written about the contribution of green roofs and more research is required (Obendorfer, Lundholm et al., 2007). Nonetheless, it is estimated that if green roofs were installed on all of the available potential roofs in Toronto, some $2.5 million in health costs would be saved per year due to improved air quality (Banting, 2005).

Carbon well estimate

The American Public Power Association (APPA) has provided an interesting tool on its Website – the tree benefits estimator, which calculates CO_2 sequestration potential resulting from mature trees planted in urban and suburban settings, according to the age and species of trees. The calculator also estimates the amount of energy savings in kW/h, based on the distance, position and direction of trees with respect to the building. http://www.appanet.org/treeben/calculate.asp

Moreover, plants are known to sequester CO_2 in the air and use it for their growth through photosynthesis. For example, the Tree Canada Foundation estimates that an average tree normally absorbs 2.5 kg of CO_2 per year (Roulet and Freedman, 1999). Since a mature tree will sequester up to 1000 times more CO_2 than a small tree (Dagenais, 2007), it can be expected that the impact of an extensive green roof will be far less; nonetheless, it could help purify city air as part of a greening plan.

Modelling greening scenarios

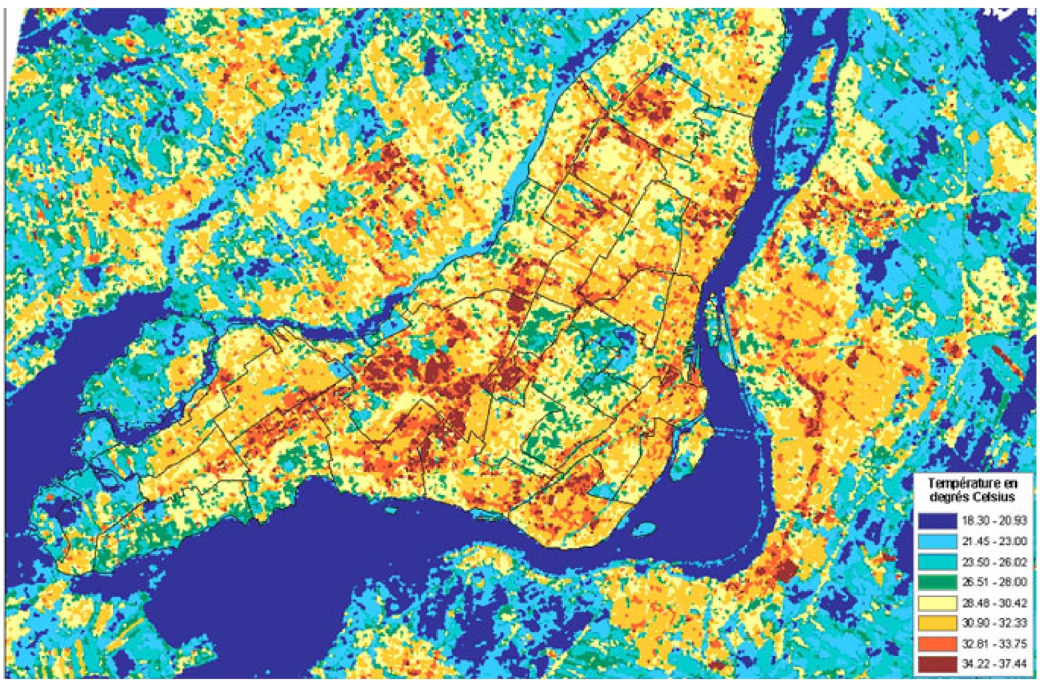
Originally developed by the USDA Forest Service Northeastern Regional Station, the UFORE (Urban Forest Effects) model was used by Toronto researchers to quantify the potential of various greening development scenarios. The various modules of the models analyze the impacts of depolluting the air of several contaminants based on various tree, bush, roof and green roof scenarios. The findings of the study indicate that green roofs reportedly play a significant role in the depollution of city air (Currie, 2005).

Urban heat islands

Heat islands are defined as urban areas with summer air or ground temperatures that are from 5°C to 10°C less than the immediate environment of the point where the measurement was taken (Lachance, 2005), resulting in higher night temperatures, more significant air hygrometry and greater concentration of suspended particulates and other atmospheric pollutants caused by reduced air circulation (Dunnet and Kingsbury, 2005).

The causes that are mainly cited are building density, reduced plant cover and evaporation surfaces, more paved surfaces for road and pedestrian traffic and more runoff surfaces. Materials in an urban environment (brick, concrete, stone, asphalt) have a rather low albedo value, which means they reflect little and absorb much of the sun's energy over and above their ability to store heat. This contributes greatly to the creation of urban heat islands (Guay, 2003).

Figure 3: Thermal representation of Montreal Island, Landsat 7ETM image, August 11, 2001



(Guay, 2003)

Impacts of urban heat islands on health

The presence of urban heat islands is conducive to the appearance of smog, drives up the concentration of pollutants in the air and contributes to the presence of mushrooms and molds in the air (Guay, 2003).

Smog and particulates

Smog is a mixture of atmospheric pollutants often seen as a yellowish fog that reduces visibility. Pollutants that cause smog consist mainly of fine particulates ($PM_{2.5}$ and PM_{10}) and ozone, specifically tropospheric ozone (O_3) that is measured at ground level. O_3 results from a photochemical reaction between nitrous oxides (NOx) and volatile organic compounds (VOC) that are largely produced by the industrial and transport sectors in Montreal. Heat is required for this reaction to occur, which explains why ozone levels in air are generally higher in the summer.

(Deny and Gaumont, 2007)

Smog

According to the Quebec Department of Health and Social Services (MSSSQ), the short-term effects of $PM_{2.5}$, PM_{10} and O_3 are numerous. They are believed to temporarily reduce breathing functions, cause more infections through the respiratory tract, increase the severity of asthma attacks, result in more visits to the emergency wards of hospitals and the number of hospitalizations, and increase the mortality rate of persons at risk, i.e., children, seniors and persons burdened with chronic health problems. Over the long term, they are believed to increase the incidence of asthma, diminish lung growth in children and raise the incidence of lung cancer (MSSSQ, 2008). One study even showed that particularly concentrated exposures to PM_{10} reportedly interferes with the development of newborn babies and could cause delayed growth such as reduced body or head size (Beckett, Freer-Smith et al., 1998).

Fine particulates ($PM_{2.5}$)

Fine particulates refer to airborne microscopic dust and droplets with a diameter of less than 2.5 micrometres. They consist mainly of sulfates, nitrates, carbon, organic substances and minerals from soil and metals. Fine particulates less than 2.5 µm penetrate deeply into and can collect in the respiratory tract. Brief exposure can cause coughing, irritations and bronchial inflammations. The effects of long periods of exposure, which are less documented than short-term effects, result in permanent impairment of lung functions and increased mortality rates due to cardiovascular disease and lung cancer. The nature of chemical substances that make up the particulates is a key factor any toxic effects they may have. The presence of polycyclic aromatic hydrocarbons (PAHs), dioxins and metals in the particulates explains their carcinogenic effects.

Tropospheric ozone

Tropospheric ozone is produced in large quantities by human activities such as transport, industries or heating. Ozone is an oxidant which, in large concentrations, irritates the nose, throat, skin and eyes. Short periods of exposure can cause coughing, headaches or respiratory difficulties due to restricted bronchi or bronchioles. Ozone could also weaken defence mechanisms, which can result in more infections.

MDDEPQ, 2002; Health Canada, 2006

Oppressive heat

Urban heat islands extend the frequency, duration and intensity of oppressive heat waves (Lachance, 2005). When exposed to heat islands, people stand a greater chance of suffering the effects of oppressive heat, in terms of morbidity and mortality (GIEC, 2001). For example, an oppressive heat wave that struck France in 2003 reportedly caused 15,000 fatalities, mainly seniors and women in particular (Besancenot, 2005).

Heat stress has direct and indirect effects on health. The most significant direct effects include dermatitis, edema in the extremities, heat cramps, fainting, insolation, exhaustion and heat strokes (Laplante and Roman, 2006; Auger and Houde, 2004). The indirect effects reach far more people and usually worsen an already chronic condition such as cardiovascular, cerebrovascular, respiratory, neurological and renal pathologies (Auger, Koastsky, 2002). Heat waves can also aggravate some chronic illnesses such as diabetes (Giguere and Gosselin, 2006) and expose to risk those taking medications such as tranquilizers, diuretics and anticholinergics, etc.

Eliminating heat islands

There are two main ways of reducing the effects of urban heat islands – increasing the reflectivity of materials used in the construction of infrastructures and increasing the surface area of green spaces. Since roofs account for a large portion of a city's surface area, using green roofs is an excellent way of countering heat islands, especially in densely populated areas such as downtowns, where the opportunities of plant life are normally limited. The City of Montreal sees green roofs as a way of combating heat islands first and foremost. However, no incentive policies are being planned in the near future in Montreal or in any other city in Quebec for that matter.

Recent green roof projects in Quebec

Despite the lack of support by municipalities and various levels of government, a host of green roof projects have sprung up in recent years in Quebec. On the following pages, we have presented a partial list of just some of the typical projects and have cited the motivations, choices of materials, experts, costs and technologies to carry out these projects.

Le Casse-tête

Date of completion: Summer of 2006

Promoter: Ron Rayside

Summary: Some of the major ecological objectives of this building include significantly reducing energy consumption and managing water and various materials responsibly. To achieve this first objective, a geothermal system, which both heats and air conditions the space, was installed. In addition, this building was constructed with exterior walls, windows and a roof that provide effective heat insulation. Low energy consumption is used. These installations have cut total energy consumption by at least half.

All of the plumbing systems come with water saving devices to reduce water consumption. The green roof cuts rain water runoff. In the next few years, reports will be produced regularly, showing energy and water consumption for each of the rental units and for the space occupied by Rayside Architectes.

The construction materials used have either been recycled or are produced locally or easily renewable. For example, the kitchen counters, moldings and furnishings are manufactured with straw panels. Hardwood floors come from certified forests. The balcony floors, the railings of parapet walls and the canopies are made of recycled plastic.

Choice of site: The roof was completely redeveloped. Both terrace portions were done and the remaining part was turned into a green roof.

Bearing capacity: 490 kg/sq.m (100 lbs./sq.ft.) of live load, 365 kg/sq.m (75 lbs./sq.ft.) of dead load.

Surface area: 166 sq.m (1800 sq.ft.).

System: Hydrotech's Garden Roof system was used for this project. A semi-intensive system with 200 mm of soil cover was installed and no permanent irrigation system is used.

Types of plants: Yellow cinquefoils around the perimeter of the roof and perennials: daylilies, groundcover and loosestrifes. A variety of fine herbs are planted each year.

Experts: Denis Gingras of Hydrotech, Aquatanche, a roofing contractor, and Rayside Architect.

Incentive measures: The aim is to create an interesting living and relaxation space for Rayside Architecte employees and the four tenants of the building. LEED credits for reducing heat islands and water runoff.

Costs: The project cost a total of $40,000, which includes $20,000 for the green roof.

Figure 4: Semi-intensive roof adjacent to the roof terrace

Figure 5: Example of possible green relief on rooftop arrangements

Société des alcools du Québec

Date of completion: Summer of 2007

Promoter: Société des alcools du Québec

Summary: The green roof design was prepared using the architectural specifications of the new building and reflects a willingness on the part of the SAQ to improve its environmental record. The provincial government encourages Quebec Crown corporations to adopt sustainable development action plans, and this roof is an integral part of the SAQ plan. Since this represents a first, the roof also serves as a pilot project, and its energy performance will be tested out over the coming years. No infrastructure has been provided for the access, which means the roof cannot be accessed for visits and maintenance. It can only be seen from certain offices in the building.

Choice of site: The SAQ was hoping to test the roof out on a new building. In addition, the relatively small surface area of the building means that the money invested in the pilot project is reasonable.

Bearing capacity: The bearing capacity of the steel structure was calculated based on the supplier`s recommendations for an extensive green roof.

Surface area: The green roof portion covers about 185 sq.m (2000 sq.ft.).

System: Soprema's SopraNature system with a concrete border, spacing with a parapet wall made of river stones, and a light soil cover 15 cm (6 inches) thick.

Types of plants: Plant seeds were included in the SopraflorX system cover, which mainly contained clover and chives.

Experts: Toits Vertige was retained to prepare the specifications for the installation of the green roof materials, the soil cover and the initial waterings.

Incentive measures: Energy efficiency is a key part of the project. Thermometers were included to determine the quantifiable benefits of green roofs in terms of heat insulation costs in the summer and the winter. The building`s central heating system can also remotely monitor building temperatures to compile data and analyze it more easily. In addition, other Crown corporations could derive some benefit from these analyses, as they are portable. Since air conditioning is important when it comes to conserving wine, the appeal of green roofs is greater, as the demand for air conditioning during peak periods is less. In addition, the system proved to be effective.

Costs: The green roof cost $25,000, or approximately $135/sq. m ($12.5/sq. ft).

Maintenance: No maintenance or access is provided

Figure 6: Extensive green roof covered with clover

Photo by Trois Vertige Inc.

Maison de la culture Côte-des-Neiges-Notre-Dame-de-Grace

Date of completion: October 2006, official opening in June 2007

Promoter: The Côte-des-Neiges-Notre-Dame-de-Grace borough

Summary: This was the first time a green roof had ever been installed on a municipal roof in Montreal. The original roof dated back to 1982, and replacement was imminent. A feasibility study was performed to evaluate the possibility of installing a garden, and a expert structural assessment was performed to determine the roof's ability to support the green roof.

Choice of site: The municipal building was chosen due to the accessibility of the terrace (which was kept closed in the summer because it was too hot), the panoramic view afforded by the roof and the flat surface area of the roof.

Bearing capacity: The analysis showed additional bearing capacity of about 122 kg/sq.m (25 lb./sq.ft.).

Surface area: Of the 960 sq. m (10,300 sq. ft.) in total, 250 sq. m (2700 sq. ft.) were turned into a semi-intensive garden.

System: Soprema's SopraNature system Ultralight soil cover 6 inches thick from Compost-Quebec to overcome the low bearing capacity. Automated subirrigation system with electronic humidity detection.

Types of plants: The development includes several varieties of resistant perennials. The decorative aspect is important, as the roof acts as a garden. A budget was set aside for regular maintenance. Nine pots containing vines were installed at heights to green the upper portions of the building. A slabbed terrace accessible to the public was also fitted up with a pergola, flower boxes of annuals and climbing roses.

Experts: A mixed team consisting of members of the City of Montreal Buildings Section and a few specialists from the CDN-NDG borough.

Incentive measures: Several objectives were behind the completion of this project, including environmental aspects that are undeniable. The development of expertise and a place of learning for City professionals is another factor. Nonetheless, public access and the teaching aspect are keys to this project that is located in the heart of the neighbourhood in the building housing the Maison de la culture and the library. In addition to spaces to include sculptures in the development of the garden, locations were set up where the public can get information on green roofs and the environment with:

- Explanatory signs;
- A video on installing a green roof;

- Information activities for young people;
- A special collection of reference books on green roofs at the library

Costs: Redoing the roof cost $175,000 alone, and the green roof system, including the plants, pots and irrigation system cost $110,000. The entire project came in at an estimated $680,000, with the remainder going toward the installation of parapet walls, the pergola, concrete slabs for the terrace, masonry work, plumbing and electricity, contingencies and other expenses.

Maintenance: $4,000 has been set aside for horticultural maintenance.

Figure 7: The garden on the extensive roof portion

Figure 8: Greening of the terrace portion of the roof

Centre Culture et environnement Frédéric Back

Date of completion: October 2005

Promoter: *Vivre en ville, le Regroupement québécois pour le développement urbain, rural et villageois viable*[1]

Summary: In keeping with its interest in innovative construction techniques and new types of urban development, *Vivre en ville* went ahead with this project to assess the actual benefits of green roofs to demonstrate their viability in a northern climate. The installation of vegetation walls, which is included in the *Programme de végétalisation de bâtiments*[2], was also tried out. All details of the project along with an analysis of the repercussions and a financial quantification of the effects of this vegetation initiative, are available in a complete report available at *Vivre en Ville* (Vivre en Ville, 2006).

Choice of site: The entire roof of the Centre Frédéric Back (two different levels), i.e., both buildings that make up the centre.

Bearing capacity: The bearing capacity was rather low, i.e., 19 pounds per sq. ft., which represented a major constraint.

Surface area: 720 sq. m (7,750 sq. ft.)

System: Soprema`s Sopranature system with a soil cover of between 10 and 15 cm (4 to 6 in.). The roof comes with a subirrigation system and an automatic humidity detector. Probes were installed to analyze the heat fluctuations of the roof and to check water retention capacity. A section of the roof was reinforced to hold a thicker organic soil cover that is also home to a vegetable garden. A staircase was installed to reach the terrace that was fitted up as a meal and rest area adjacent to the green roof. At the time of our visit, two tree pots were put in to hold small trees that will provide some shade on the terrace.

Types of plants: Several varieties of sedums and rustic perennials were planted. A natural dynamic took hold, as some plants became predominant in certain areas, depending on the variations of sun and wind exposure.

Experts: A technical committee made up of numerous specialists was created for the project, including Marie-Anne Boivin, the Sopranature development coordinator with Soprema. The project was coordinated by Véronique Jampierre and supervised by Jérôme Vaillancourt, the person in charge of *Vivre en ville*.

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[1] Unofficial translation : Living in the City – the Quebec Group for Urban, Rural and Viable Village Development
[2] Unofficial translation: Building Vegetalization Program

Incentive measures: *Vivre en ville* described the project, which was conducted with experimental and educational intentions in mind, as follows:

- Experiment with the installation of two roofs and a vegetation wall on the same building in a northern climate;
- Measure the increased energy efficiency of the building envelope;
- Measure the runoff water retention capacity;
- Demonstrate the feasibility and advantages of both plant cover techniques in the Quebec housing market and in the institutional and public building renovation and maintenance sector;
- Create public awareness and expand the circle of its partners;
- Emphasize the relevance of and need for broadening this approach to residential, commercial, industrial, municipal and institutional buildings in the same region;
- Demonstrate the collective benefits that can only be measured on a broader scale.

(*Vivre en ville, 2006)*

Costs: Given that *Vivre en ville* was pursuing experimental and innovative goals, it was able to secure the cooperation of several organizations: the *Agence d'efficacité énergétique, the Fonds en efficacité énergétique du Québec, la Ville de Québec, the Fonds d'habitation municipal vert, les Caisses populaires Desjardins, Chantier Jeunesse,* the Canada Mortgage and Housing Corporation (CMHC) and several volunteers. The project cost $295,453, and it is estimated that the green roof accounted for $167,830, i.e., $21.64 a square foot.

Maintenance: The vegetation was left to its own devices. Frequent scientific and professional follow-up.

Scientific results

Energy efficiency

Two methods were used to assess energy savings. The electricity saved by not installing an air conditioning system was calculated, and the heat resistance of the green roof was assessed. It was determined that the green roof saves about 10,000 kWh per year in air conditioning. It was also determined that the insulation potential of the green roof was more associated with its capacity to absorb radiation rather than its ability to reduce heat flow from outside to inside the building. This finding solidly supports the findings of Liu and Baskaran, who showed that green roofs are more effective in the summer than in the winter in northern climates, i.e., they are effective in reducing the impact of solar radiation but are ineffective heat insulators in the winter (Liu and Baskaran, 2003; Liu, 2005).

Reduction of greenhouse gases

Since hydroelectricity in Quebec creates little greenhouse gases (1kWh produces 0.022 kg of CO equivalent), the impact of the green roof produces is rather modest on this score. However, a 10,000 kWh reduction does avoid releasing 330 kg of CO_2 equivalent into the atmosphere.

Secondly, if we use Leucopoa kingie, a plant that consumes CO_2 at a rate similar to that of the plants on the roof, as a yardstick, the project is believed to have sequestered about 5,757kg of CO_2 over a 105-day period (summer).

Air quality

Plants are known for their filtering capacity. Given the 720 sq. m of plant surface and assuming 0.2 kg of suspended fine particulates absorbed per square metre of vegetation per year, the roof potentially filters 144 kg of dust particles every year.

Water retention potential

For 2005, the green roofs water retention potential was an estimated 100% for 4 to 8 mm of rainfall and 98% for 8 to 12 mm. During the heaviest downpour of the year when 18 mm fell, the system retained 98% of the water. Only 161 of the 8,272 litres of rainfall turned into runoff over a three-day period. These findings far exceed industry data, especially since the substrate was only 10 cm thick on average over the course of this project.

Figure 9: Example of a natural aspect development on an extensive system

Université de Montréal: École d'architecture de paysage[3]

Date of completion: Fall of 2004

Promoter: Faculté de l'aménagement[4]

Summary: Originally a small terrace of a religious institution, the green roof was installed as a result of a development competition organized by the planning faculty. The modest project drew on participation of volunteers, and its vocation is primarily educational and experimental. Though the terrace is readily accessible, regulatory restrictions prevent the public from gaining easy access to the roof. Nonetheless, the site does have some good potential in terms of any student initiative.

Choice of site: This terrace could be readily fitted up, as it is near faculty premises, is visible from inside the building and can be accessed easily.

Bearing capacity: The terrace was designed to support heavy loads and was previously used by occupants as a terrace.

Surface area: 150 sq. m (1600 sq. ft.)

System: Hydrotech system with 150 to 200 of soil cover and an irrigation system.

Types of plants: The original development included several species of perennials, including some varieties of speargrass. Some plants died because of the difficult conditions posed by the positioning of the roof, particularly the strong prevailing wind. As a result, spontaneous vegetation appeared, and one student identified 40 different species.

Experts: The Faculté de l'aménagement, Professor Ron Williams and Denis Gingras, a sales representative with Hydrotech.

Incentive measures: The incentive was probably experimental, but the initial motivations of the project were uncertain, since the project's creator is now retired. The space will likely be used for educational purposes, e.g., for flora identification and botany courses, given the wide range of indigenous plants that can be seen there.

Costs: This roof was built thanks to donations and subsidies.

Maintenance: No maintenance is being considered.

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[3] Unofficial translation = Landscape Architecture School
[4] Unofficial translation = Planning faculty

Figure 10: Green roof in May

Figure 11: Green roof in August

Collège de Rosemont

Date of completion: 2007

Promoter: Collège de Rosemont

Summary: The Collège de Rosemont has been following a stringent environmental and sustainable development policy since 1996. It employs an environmental technician and gives environment management courses, mainly through the person behind the college's green roof project. The Collège's environmental vision has earned it several awards and certificates in the area of residual waste management, energy efficiency and horticultural beautification. The installation of a green roof dovetails with this vision. In addition to the green roof, a reflective roof was put in to reduce the Collège's contribution to the effect of the urban heat island.

Choice of site: The roofs of the sections now sporting a green roof have reached the end of their useful life and had to be redone. Given they were highly visible from the library, their ease of access and the protection afforded by buildings surrounding these roofs, the choice was an easy one. The reflective roof was installed on a roof that also had to be redone but on a floor where the roof could not be seen. This choice was made, in part, due to the fact reflective roofs get dirtier faster and throw off too much glare on sunny days.

Bearing capacity: The bearing capacity of the green roof is substantial, since the building is shaped in such a way that it accumulates huge amounts of snow. Moreover, the green roof system chosen added little weight (75 kg/sq.m or 15 lb./sq.ft.).

Surface area: The green roof covers 930 sq. m (10,000 sq. ft.)

System: The Xero Flor system with three layers of felt-covered absorbent carpets for the green roof. A PVC Sanafil PVC membrane was chosen for the reflective roof.

Types of plants: About 8 varieties of sedums.

Experts: Les Toits Vertige was chosen to install the system.

Incentive measures: The environmental value of green roofs is in total synch with the institution's vision. The esthetics of the green roof also had a bearing on the decision, since the entire roof can be seen from inside the building.

Costs: The green roof components cost about a third of the overall cost of redoing the roof. A white roof costs an estimated 20% more than a standard roof.

Maintenance: Entretien Indigo and Xeroflor are doing follow-up as part of a case study

Figure 12: Roof adjacent to the College's library

Figure 13: Roof of sedums in 2007 in year one (left) and 2008 in year two (right)

Polytechnique: Pavillon Lassonde

Date of completion: Inauguration in October 2005

Promoter: École Polytechnique de Montréal

Summary: The project's green roof is integrated with the new building that has received the LEED Gold certification. Several technologies were put to use to earn this prestigious rating, including the heat recovery from the main chimney of the former building and the rainwater retention basins. All of the technologies used are available on the market and have nothing to do with research being done at Polytechnique.

Choice of site: Visibility and accessibility played a key role in the choice of the site. Two separate areas were fitted up – a portion of the terrace accessible to the public and a roof visible from the library.

Bearing capacity: The bearing capacity was calculated in the building design, i.e., at least 145 kg/sq.m (30 lb./sq.ft) for the Hydrotech system.

Surface area: 800 sq. m (8600 sq. ft.)

System: Hydrotech's Garden Roof system contains 150 mm of soil cover, and the formula is prepared by Savaria. The roof is not irrigated to save water, which earns a further LEED credit.

Types of plants: The base is carpeted with clover, and spontaneous vegetation has popped up in the plant bed.

Experts: Michel Rose, the Property Manager at Polytechnique, spearheaded the project team. Denis Gingras, a Hydrotech representative, assisted with the installation of the green roof. Three architectural firms took part in the project: Menkes Shooner Dagenais Letourneux, Saia Barbarese and Desnoyers Mercure et associés.

Incentive measures: LEED credits for scaling down runoff water and reducing the impact on heat islands.

Maintenance: Development left to its own devices.

Figure 14: Extensive green roof on the terrace overlooking Montreal

Figure 15: Portion of the roof visible from inside the library

McGill University: Francesco Bellini Life Sciences Complex

Date of completion: 2008

Promoter: McGill University

Summary: The green roof is part of the new Francesco Bellini Life Sciences Complex at McGill University. The research centre will rank among the largest in Eastern Canada and is promoting interdisciplinary collaborations. The project is seeking the LEED Silver designation.

Choice of site: The green roof, which is located by the McIntyre Pavillon Medical Sciences Building and along the side of the mountain, is visible from the Mount Royal Park lookout and the windows of the McIntyre Tower.

Bearing capacity: The bearing capacity was calculated in the building design, i.e., at least 145 kg/sq.m (30 lb./sq.ft.) for the Hydrotech extensive system.

Surface area: 700 sq. m (7500 sq. ft.)

System: The Hydrotech system contains 150 mm of mineralized soil cover. The roof comes with a drop-by-drop irrigation system to save water while ensuring plant growth all summer.

Types of plants: Sedums

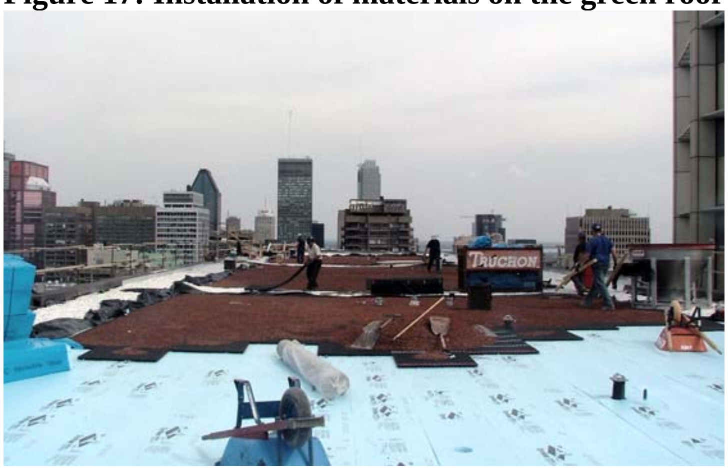
Experts: Claude Cormier, Architectes paysagistes Inc., Provencher Roy + Associés architectes, Diamond and Schmitt Architects Inc. and Hydrotech.

Incentive measures: LEED credits for reducing runoff and reducing the impact on heat islands.

Costs: $100,000 budget.

Figure 16: Roof covered with soil cover prior to vegetalization

Figure 17: Installation of materials on the green roof



Université Laval : Pavillon Charles-de Koninck

Date of completion: 2005 and 2006

Promoter: Université Laval

Summary: A new building was erected in an area surrounded by the buildings of the Pavillon Charles-de Koninck and provides an excellent view of all of the offices on the upper floors of the Pavillon. Two terraces surrounded by plant beds were fitted up at the base of the building. Technically speaking, these terraces are green roofs, as the materials used for drainage are the same as for green roofs. The plant beds are located over the classrooms. The university's landscaping staff, which did the planting and prepared the floral design, is looking after these new green spaces.

Choice of site: The idea of a green roof was proposed in the architectural specifications. The space where the new building sits was a vacant area where several plants grew. An attempt was made to maintain this proximity between the green spaces and users of the premises. The ground-level terraces had reached the end of their useful life.

Bearing capacity: The bearing capacity of the steel structure of the new building has been calculated to support 150 kg/sq.m (30 lb./sq/ft.) over and above the standard loads.

Surface area: The roofs of the new building and the connections with the Pavillon cover a surface area of 500 sq. m (5300 sq. ft.) . A green roof measuring 615 sq. m (6600 sq.ft.) was installed at ground level, one half of which was paved, which means the green roof covers 800 sq.m (8600 sq.ft.) in total.

System: Soprema's Sopranature Prairie system was installed with the drop-by-drop subirrigation system for the roof portion. The soil cover is about 15 cm (6 inches) thick.

Types of plants: Several varieties of perennials were used for decorative purposes. The plants were chosen based on the expertise of Ms. Boivin and the horticultural knowledge of university employees.

Experts: Kevin McInless of Lemay & Michaud, Marie-Anne Boivin, a Soprema representative, and the Université Laval Maintenance Department.

Incentive measures: The major motivation behind the project was its decorative aspect. In spite of a limited selection of plants that can be used on a green roof due to extreme weather conditions, the employees nonetheless created an attractive, dynamic and resistant layout. Considerations regarding the effect of flowers on heat islands and soil dampproofing also encouraged the project's creators.

Costs: It cost about $71,000 for all of the materials and the soil cover. The plants were purchased and grown in part by the university's maintenance department.

Maintenance: The green roof is part of the developments to be maintained just as the other plant beds are.

Figure 48: Terrace made of green roof materials

Figure 195: Mass development on an extensive roof

Charlesbourg Library

Date of completion: Inauguration in October 2006

Promoter: Ville de Québec

Summary: The green roof of the library is part of the building expansion project. The promoter staged a competition for the new section, which Croft Pelletier won with its green design. The roof is accessible to members of the public who can walk around or relax on the large grassy surface. When this green roof was being constructed, it was the largest accessible and usable roof of its kind in North America.

Bearing capacity: Since it was a new structure, the bearing capacity of the roof was designed to handle the added weight of materials, soil cover, plants and people walking about.

Surface area: About 1800 sq. m (19,400 sq. ft.)

System: Sopranature. The Highland system was used because of the sloping roof. The system comes with an integrated subirrigation system. It is similar to the standard garden system, aside from the fact that the type of drain used maximizes water retention on inclines.

Types of plants: A mixture of seeds consisting of varieties of speargrass, sedums, a few perennials and fescues was used. They provide a natural look and require little maintenance.

Experts: Eric Pelletier of Croft Pelletier architectes put together the plans and Marie-Anne Boivin of Soprema provided her assistance during the green roof installation phase.

Incentive measures: One of the most important aspects for the firm was integrating the building into its environment. The vegetation chosen is reminiscent of what surrounds the site. Energy savings are another important item, since the building is low with a wide roof expanse. This optimizes the green roof's air conditioning performance. Other major considerations were the creation of a public area and the excellent view of the St. Lawrence River.

Costs: It cost an estimated $110 sq.m ($10 sq.ft.) for the green roof. The project architect mentioned that the roof cost two and one-half times more than a regular roof, but given that its useful life is two to three times that of a roof and that less air cooling capacity is needed, it is a cost-effective investment (Asselin, 2006). Moreover, the 21 geothermical wells produce an estimated energy saving of 52% in the new building.

Maintenance: Like a grassy public space.

Figure 206: Green roof with a sloping prairie look

Institut de technologie agroalimentaire (ITA): St. Hyacinthe Campus

Date of completion: November 2006. The roof was officially inaugurated in the fall of 2007, at the same time ITA joined the *Cégep Vert du Québec*.

Promoter: The Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ)

Summary: Two students who have now graduated, Brigitte Lavoie and Valérie Simard, presented the project to professors of the Institut. The timing of the project was good, since the idea was put forward at a time when steps were being taken to redo a section of the building. In addition, the project received the support of the Institut's administration and MAPAQ officials, whose passion for the project moved the project along at a pace beyond all expectations.

Choice of site: The location of the roof was based on accessibility, visibility and energy efficiency. The roof that was chosen is over a room reputed to be (but not quantified) as the hottest in the summer. The green roof is adjacent to the library premises which have large windows. The panoramic view of the green roof from inside is ideal. The roof could already be accessed from the roof, which made it easy to prepare and maintain.

Bearing capacity: The analysis determined that the roof could bear about 150 kg./sq.m (30 lbs./sq.ft.), which is enough for a light extensive roof with special soil cover.

Surface area: About 630 sq. m (6785 sq. ft.) of flat roof was fitted up. A semi-intensive green roof was installed on the portion visible from inside the building and an intensive roof with a grassy surface on the other section.

System: Soprema's Sopranature system was installed over the entire surface with a 15-cm (6-inch) soil cover. The grassy surface is not irrigated, but water intakes were provided for watering when there is a drought. The semi-intensive section has an automated subirrigation system.

Types of plants: The semi-intensive part contains a wide variety of perennials and a few small bushes, which were selected by those members of the ITA teaching staff with expertise in botany. The plants were also selected in keeping with a willingness to test out certain plants and develop some expertise in selecting plants for green roofs in Quebec. The grassy part consists of a mixture of other speargrass and fescues.

Experts: The project was supervised by Manon Tardif, a professor at the ITA; and René-Paul Debord, foreman for the Physical Resources Branch. They were assisted by Marie-Anne Boivin, Sopranature`s development coordinator.

Incentive measures: Three major objectives were developed:

- Make the building more comfortable and more ecological by improving its energy efficiency;
- Give future students in horticulture and landscaping an opportunity to become familiar with this new technology;
- Implement a technological transfer and research program relating to the choice of plants for green roofs.

Costs: There was very little cost due to the fact ITA has expertise in horticulture, partnerships with local nurseries and a professor of horticulture with 25 to 30 students to look after developing the project. In addition, the project received assistance from the Gaz Métropolitain Energy Efficiency Fund, which covered about 50% of the cost. The only expenses incurred related to the structural analysis, materials and the irrigation system. The total pre-subsidy cost of the project was $48,204.55 or $10.75 sq.ft. With the subsidy, the cost dropped to $25,657.05 or $5.75/sq.ft. for the entire project, which was paid by MAPAQ.

Maintenance: By ITA professors and volunteer students

Figure 71: Grassy portion of the extensive green roof

Figure 82: Development viewed from inside the building

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