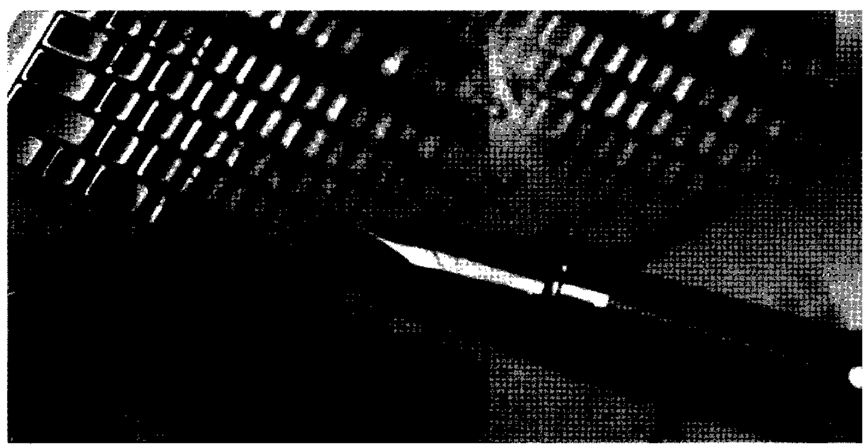
RESEARCH REPORT

GREENBACKS FROM GREEN ROOFS



CMHC SCHL

HOME TO CANADIANS

Canada

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) is the Government of Canada's national housing agency. We help Canadians gain access to a wide choice of quality, affordable homes.

Our mortgage loan insurance program has helped many Canadians realize their dream of owning a home. We provide financial assistance to help Canadians most in need to gain access to safe, affordable housing. Through our research, we encourage innovation in housing design and technology, community planning, housing choice and finance. We also work in partnership with industry and other Team Canada members to sell Canadian products and expertise in foreign markets, thereby creating jobs for Canadians here at home.

We offer a wide variety of information products to consumers and the housing industry to help them make informed purchasing and business decisions. With Canada's most comprehensive selection of information about housing and homes, we are Canada's largest publisher of housing information.

In everything that we do, we are helping to improve the quality of life for Canadians in communities across this country. We are helping Canadians live in safe, secure homes. CMHC is home to Canadians.

Canadians can easily access our information through retail outlets and CMHC's regional offices.

You can also reach us by phone at 1 800 668-2642
(outside Canada call (613) 748-2003)
By fax at 1 800 245-9274
(outside Canada (613) 748-2016)

To reach us online, visit our home page at www.cmhc-schl.gc.ca

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1 800 668-2642.

GREENBACKS FROM GREEN ROOFS: FORGING A NEW INDUSTRY IN CANADA

STATUS REPORT
ON
BENEFITS, BARRIERS AND OPPORTUNITIES FOR GREEN ROOF AND VERTICAL GARDEN TECHNOLOGY DIFFUSION

Prepared by:
Steven W. Peck
Chris Callaghan

P&A
Peck & Associates

Monica E. Kuhn, Architect
B.E.S., B. Arch., O. A.A.

and Brad Bass, PhD.
Environmental Adaptation Research Group, Environment Canada

Prepared for:

Canada Mortgage and Housing Corporation

March 1999

Table of Contents

This project was carried out with the assistance of a grant from Canada Mortgage and Housing Corporation under the terms of the *External Research Program* (CMHC File 6585-P085). The views expressed are those of the authors and do not represent the official views of the Corporation.

Acknowledgements

This research project was made possible by Canada Mortgage and Housing Corporation through its *External Research Program* and through the in kind support of Environment Canada, Environmental Adaptation Research Group. The report was prepared by Steven Peck, Principal, Peck & Associates; Monica E. Kuhn, Architect; Dr. Brad Bass, Environment Canada; and Chris Callaghan, Associate, Peck & Associates.

The project received valuable support and guidance from a Senior Advisory Team comprised of:

- Greg Allen, Principal, Allen Kani & Associates
- Frank Baxter, Vice President, Semple-Gooder Roofing Ltd.
- Sean Cosgrove, Consultant, Toronto Food Policy Council
- Dr. Roger Hansell, Associate Director, Institute for Environmental Studies, University of Toronto
- Evan Jones, Energy Analyst Specialist, Rose Technology Group
- Arnie Rose, Manager, Programs and Administration, City of Toronto Housing Division

The project advisor from Canada Mortgage and Housing Corporation was Susan Fisher.

The workshop component of the research was made possible through the support and efforts of a number of individuals and organizations:

- Debra Wright, Canada Mortgage and Housing Corporation; Jack Layton, Toronto City Councilor; and Marie-Anne Boivin, Soprema Inc. (Presenters)
- Anna Hercz, Senior Associate, Peck & Associates (Lead Facilitator)
- Stephanie Tencer and Karen Campbell, Research Associates, Peck & Associates
- Lauren Baker, Tracy Loverock, Michelle Rothman and Hayley Easto (Recorders)

Special thanks for their in-kind and/or financial sponsorship of the workshop to:

- Canada Mortgage and Housing Corporation
- Environment Canada
- Air & Waste Management Association
- Rooftop Gardens Resource Group
- Toronto Food Policy Council

Our appreciation is also extended to those who contributed their time to the interview process of this research and all of the workshop participants. Their contribution to the research has provided valuable data and insight.

Abstract

Peck & Associates prepared this report for Canada Mortgage and Housing Corporation (CMHC) through its External Research Program. Green roof and vertical garden technologies are very well established in many countries throughout Europe, yet remain in their infancy in Canada. This report provides a comprehensive review of the quantitative and qualitative benefits of green roof and vertical garden technologies and argues that most of these benefits are represented in the current market. The major barriers to the more rapid diffusion of these 'sustainable development' technologies are described and a number of initiatives are proposed to encourage the development of Canadian markets, including government policy and program support.

For further information about this report please contact:

Steven W. Peck, Principal, Peck & Associates
35-859 Millwood Road, Toronto, ON, Canada, M4G 1W7
Tel.: (416) 422-1977 Fax: (416) 422-2434
E-mail: speck@peck.ca
Website: www.peck.ca

Monica E. Kuhn, Architect, B.E.S., B. Arch., O.A.A.
14 Sackville Place, Toronto, ON, Canada, M4X 1A4
E-mail: rooftop@interlog.com

Brad Bass, PhD.
Environmental Adaptation Research Group, Environment Canada
33 Willcocks Street, Toronto, ON, Canada, M5S 3E8
Tel.: (416) 978-6285 Fax: (416) 978-3884
E-mail: brad.bass@ec.gc.ca

Susan Fisher, Researcher, Sustainable Planning and Regulation, CMHC, National Office
700 Montreal Road, Ottawa, ON, Canada, K1A 0P7
Tel.: (613) 748-2317 Fax: (613) 748-2402
E-mail: sfisher@cmhc-schl.gc.ca

Executive Summary

This report was prepared for Canada Mortgage and Housing Corporation (CMHC) through its *External Research Program*. It provides a comprehensive review of the quantitative and qualitative benefits of green roof and vertical garden technologies, examines barriers to their more rapid diffusion into Canadian markets and makes recommendations on overcoming these barriers.

Green Roofs and Vertical Gardens

There are two basic types of roof greening or green roof systems - extensive and intensive. Extensive green roofs are characterized by their low weight, low capital cost and low maintenance. Intensive green roofs are characterized by their increased weight and capital cost, intensive planting and higher maintenance requirements. Extensive and intensive green roofs are either accessible or inaccessible. Accessible green roofs are flat outdoor open spaces intended for use by people as gardens or terraces, while inaccessible roofs are only accessible for periodic maintenance. The term 'vertical garden' is used to define the growing of plants on, up or against the façade of a building.

Quantifiable and Qualitative Benefits

Green roof and vertical garden technologies offer an outstanding number of public and private benefits. Detailed quantitative information on most of the benefits listed below are presented in the body of the report. Green roof and vertical garden benefits include:

- Building owner economic benefits such as energy cost savings due to increased insulation, improved protection of the roof membrane that extends its life span, and sound insulation. Accessible green roofs can also improve property values.
- Community cost saving opportunities involving increased worker health, productivity and creativity and cost savings on infrastructure related to stormwater management.
- Air quality improvements from the mitigation of nitrous oxides, volatile organic compounds by plants; reductions in airbourne particulate matter.
- Greenhouse gas emission reductions from energy savings in buildings and the potential for adaptation to negative climate change impacts.
- Reductions in stormwater quantity and quality improvements.
- New employment opportunities for a wide range of professionals including suppliers and manufacturers of roofing membranes and related products, design and engineering professionals.
- Social benefits such as improved aesthetics; health and horticultural therapy; improved safety, and additional recreational opportunities.

Barriers to Green Roof and Vertical Garden Technology Diffusion

Architects, engineers, roofers, developers, manufacturers, policy makers and energy management consultants identified major barriers to technology diffusion at a November 1998 workshop held in Toronto, Canada. The major types of barriers are:

- *Lack of knowledge and awareness* - Although there are many benefits of these technologies, both quantitative and qualitative, they are not well known among the development industry, municipal officials or the general public.

- *Lack of incentives to implement* - In North America, there are virtually no government incentives in support of green roof technology diffusion, despite their many proven public and private benefits.

- *Costs-based Barriers* - More information needs to be assembled about the full range of 'traditional' and 'public' costs and benefits of these technologies in different applications. The current market does not recognize many of these benefits.

- *Technical Issues and Risks Associated with Uncertainty* - These types of barriers cover a wide spectrum including: lack of specialized products on the market; few examples of roof and vertical garden installations; and no industry technical standards for green roofs, which means no standards in building codes.

These barriers have resulted in a failure of the Canadian market to adopt these technologies, which are very well established in many countries in Europe. In Germany, for example, over 10 million square metres of green roofs were developed in 1996.

Overcoming Barriers – Towards A National Action Plan

The following recommendations form the basis of a National Action Plan to promote the more rapid diffusion of green roof and vertical garden technologies. Successful implementation will require partnerships among industry and government stakeholders.

Objective 1: Address Knowledge and Awareness Limitations
Compile a repository of green roof and vertical garden knowledge on the Internet integrating knowledge from all related fields and international data. Make this accessible to the public as well as to the 'how to' members of the industry and promote it accordingly.

Objective 2: Generate Awareness through High Profile Demonstration Projects
CMHC could establish a government co-sponsored design and implementation green roof and vertical garden technology demonstration competition in six major cities (i.e., Halifax, Ottawa, Montreal, Toronto, Edmonton and Vancouver).

Objective 3: Government Procurement Support for Technology Diffusion
Cities in each major census metropolitan area in Canada could be encouraged to develop a detailed plan to implement green roofs on their public properties, within the next three years. The federal and provincial governments could adopt green roof and vertical garden procurement policies. The federal government, through its *Federal Buildings Initiative* could demonstrate further leadership on climate change by setting aggressive, but realistic, targets for green roof and vertical garden installations.

Objective 4: Establish Direct Government Policy and Program Support
Such support has been critical to the establishment of green roof markets in Europe. Establish a financial incentive program of either grants or indirect subsidies to encourage implementation among private owners by reducing payback periods and associated economic uncertainties in order to overcome market failures.

Make it mandatory, through legislation, planning instruments or amendments to the building code, to fit new buildings with green roofs and/or vertical gardens.

Objective 5: Explore Additional Financial Incentives to Overcome Cost-based Barriers
Encourage insurance companies to investigate benefits that would reduce premiums, such as increased building envelope life span and energy efficiency and, establish partnerships with private sector to facilitate new approaches to performance-based contracting installation of green roofs and vertical gardens.

Objective 6: Reduce Technical Issues and Associated Uncertainty
Provide financial support for increased research by universities and other research institutions in order to fill the gaps in our technical and economic knowledge.

Create high standards for retrofitted and new green roofs and vertical gardens, focusing on the quality of materials and proper installation and ensure enforcement of these high standards.

Conclusion

Green roof and vertical garden technologies can simultaneously address a number of important economic, social and environmental challenges facing Canadian cities. They provide an outstanding number of public benefits in areas such as air quality improvement, reduction in greenhouse gases, stormwater quality and quantity improvements as well as long term economic benefits for building owners. In Europe, policy makers have established various measures to support the application of these technologies resulting in the formation of a new ‘green roof industry’. The many public benefits attainable from green roofs and vertical gardens present a strong case for federal, provincial and municipal government support of the proposed National Action Plan. Such support is fundamental to overcoming market barriers and thereby creating a viable market for these ‘sustainable development’ technologies across Canada.

Sommaire

Ce rapport a été préparé pour la Société canadienne d'hypothèques et de logement (SCHL) dans le cadre de son *Programme de subventions de recherche*. Il contient un examen complet des avantages qualitatifs et quantitatifs de la technologie des toits verts et des jardins verticaux, étudie les obstacles qui freinent une diffusion plus rapide de celles-ci sur les marchés canadiens et présente des recommandations pour lever ces obstacles.

Les toits verts et les jardins verticaux

il existe deux types de toits verts ou de systèmes de toits verts . extensifs et intensifs. Les toits verts extensifs se distinguent par leur légèreté, leur faible investissement initial et le peu d'entretien qu'ils nécessitent Les toits verts intensifs sont plus lourds, plus coûteux et comprennent une plantation et un entretien plus importants Ces deux types de toit vert sont soit accessibles, soit inaccessibles Les toits verts accessibles sont des espaces extérieurs ouverts qui ont une vocation de jardin ou de terrasse, tandis que les toits verts inaccessibles sont seulement accessibles pour un entretien périodique Le terme «jardin vertical » désigne la croissance des plantes sur ou contre la façade d'un bâtiment.

Avantages qualitatifs et quantitatifs

La technologie des toits verts et des jardins verticaux présente un très grand nombre d'avantages publics et privés Les renseignements quantitatifs détaillés sur la plupart des avantages présentés ci-après figurent dans le corps du rapport

- Augmentation des avantages économiques pour le propriétaire du bâtiment: économies d'énergie découlant d'une meilleure isolation, protection renforcée de la membrane du toit, ce qui en prolonge la durée de vie, et l'insonorisation. Les toits verts accessibles peuvent aussi augmenter la valeur foncière des bâtiments
- Possibilités d'économiser sur les frais collectifs employés en bonne santé, productivité et créativité, économies sur les coûts d'infrastructure reliés à la gestion des eaux pluviales,
- Meilleure qualité de l'air atténuation des oxydes nitreux, des composés organique volatiles par les plantes et réduction des poussières en suspension dans l'air,
- Réduction des émissions de gaz de serre découlant des économies d'énergie dans les bâtiments et possibilités d'adaptation aux effets négatifs des changements climatiques;
- Réduction des améliorations nécessaires de la qualité et de la quantité des eaux pluviales;
- Nouvelles occasions d'emploi pour un vaste éventail de professionnels (fabricants et fournisseurs de membranes de toit et de produits connexes; ingénieurs et concepteurs);
- Avantages sur le plan social meilleure esthétique, santé et thérapie par l'horticulture, plus grande sécurité et autres possibilités récréatives;

Obstacles à la diffusion de la technologie des toits verts et des jardins verticaux

Au cours d'un atelier tenu en novembre 1998 à Toronto, les architectes, ingénieurs, couvreurs, entrepreneurs, fabricants, décideurs et conseillers en gestion de l'énergie ont identifié d'importants obstacles à la diffusion de cette technologie, soit:

- *Ces technologies ne sont pas bien connues* Bien qu'elles présentent de nombreux avantages qualitatifs et quantitatifs, elles ne sont pas bien connues dans l'industrie de l'aménagement, parmi les élus municipaux et dans le grand public;
- *Manque d'incitatifs pour tamis en oeuvre* EnAmérique du Nord, les incitatifs gouvernementaux appuyant la diffusion de la technologie des toits verts sont pratiquement inexistants, malgré les nombreux avantages que celle-ci présente,
- *Obstacles d'ordre financier* Il est important de réunir plus de renseignements sur l'ensemble des coûts et avantages « traditionnels » et « publics »de ces technologies dans diverses applications Nombre de ces avantages ne sont pas reconnus sur le marché actuel
- *Questions techniques et risques associés à l'incertitude* Ces genres d'obstacles couvrent un vaste domaine, y compris manque de produits spécialisés sur le marché, peu d'exemples d'installations de toits verts et de jardins verticaux, absence de normes techniques dans l'industrie pour les toits verts, donc absence de normes dans les codes du bâtiment.

C'est à cause de ces obstacles que le marché canadien n'a pas adopté ladite technologie, qui est toutefois bien établie dans nombre de pays d'Europe. En Allemagne, par exemple, plus de 10 millions de mètres carrés de toit vert ont été installés en 1996.

Lever les obstacles : vers un plan d'action national

Les recommandations suivantes forment la base d'un plan d'action national pour stimuler une diffusion plus rapide de la technologie des toits verts et des jardins verticaux Unebonnemise en oeuvre exigera que l'industrie et les intervenants gouvernementaux travaillent en partenariat

Objectif 1 : Remédier à l'ignorance qui entoure ces technologies
Établir sur l'Internet un dépôt de données sur les toits verts et les jardins verticaux, intégrant des connaissances issues de tous les domaines connexes ainsi que des données internationales Rendre cette documentation accessible au public ainsi qu'aux exécutants de l'industrie et en faire la promotion en conséquence

Objectif 2: *Augmenter la sensibilisation à ces technologies par des projets de démonstration à grande visibilité*
La SCHL pourrait lancer, en coparrainage avec le gouvernement, un concours visant à démontrer la conception et la mise en oeuvre de la technologie des toits verts et des jardins verticaux dans six villes canadiennes (Halifax, Ottawa, Montréal, Toronto, Edmonton et Vancouver)

Objectif 3: Appui gouvernemental à l'approvisionnement pour la diffusion de la technologie
Les villes canadiennes situées dans chaque grande région métropolitaine de recensement pourraient être encouragées à établir un plan détaillé pour installer, dans les trois prochaines années, des toits verts sur leurs édifices publics Les gouvernements fédéral et provinciaux pourraient alors adopter des politiques d'approvisionnement pour cette technologie. Le gouvernement fédéral, à travers son Initiative fédérale dans le secteur du bâtiment, pourrait prendre un rôle de chef de file dans le domaine des changements climatiques en fixant des objectifs ambitieux mais réalisables pour l'installation de toits verts et de jardins verticaux

Objectif 4: Établir des politiques gouvernementales directes et un soutien de programme
Cet appui a été essentiel à l'établissement du marché des toits verts en Europe. Pour contrer les échecs de marché, il convient d'établir un programme de stimulation financière offrant des subventions directes ou indirectes pour encourager l'installation des toits verts chez les propriétaires privés en réduisant les périodes de paiement et les incertitudes économiques qui s'y rattachent

Imposer l'installation de toits verts et/ou de jardins verticaux sur les nouveaux bâtiments par la loi, les outils de planification ou des changements dans les codes du bâtiment

Objectif 5 : Étudier d'autres incitatifs pour lever les obstacles d'ordre financier
Encourager les compagnies d'assurances à examiner les avantages qui pourraient réduire les prîmes - augmentation de la durée de vie de l'enveloppe de bâtiment et l'efficacité énergétique des bâtiments, établir avec le secteur privé des partenariats favorisent les nouvelles approches pour l'installation rentable à contrat de toits verts et de jardins verticaux

Objectif 6: réduire les problèmes techniques et l'incertitude dont ils s'accompagnent
Soutien financièrement l'intensification des recherches dans les universités et d'autres établissements pour combler les lacunes dans les connaissances techniques économiques touchant les toits verts et les jardins verticaux

Établir des normes élevées pour les toits verts/jardins verticaux neufs ou installés après-coup en insistant sur la qualité des matériaux et la bonne installation, et veiller à ce que ces normes soient respectées

Conclusion

La technologie des toits verts et des jardins verticaux peut régler en même temps d'importants problèmes économiques, sociaux et écologiques qui se posent dans les villes canadiennes. lis présentent un grand nombre d'avantages publics dans des domaines tels que l'amélioration de la qualité de l'air, la réduction des gaz de serre, l'amélioration de la qualité et de la quantité des eaux pluviales, ainsi que des avantages économiques à long terme pour les propriétaires de bâtiments. En Europe, les décideurs ont établi diverses mesures pour appuyer la mise en oeuvre de ces technologies, ce qui a favorisé la naissance d'une nouvelle «industrie des toits verts ». Les nombreux avantages publics qu'on peut retirer des toits verts et des jardins verticaux constituent un dossier solide capable d'amener les gouvernements fédéral, provinciaux et municipaux à soutenir le plan d'action national proposé. Cet appui est fondamental pour lever les obstacles commerciaux et créer ainsi dans l'ensemble du Canada un marché visible pour ces technologies durables.

SCHL CMHC

AU COEUR DE L'HABITATION

Canada

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le résumé à été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'addresse suivante :

Centre canadien de documentation sur l'habitation
Société canadienne d'hypothèques et de logement
700, chemin Montréal, bureau C1-200
Ottawa (Ontario)
K1A 0P7

Titre du rapport: ______________________________________

____

Je préfèrerais que ce rapport soit disponible en français.

NOM ______________________________________

ADRESSE______________________________________

rue App.

____

ville province Code postal

No de télephone ( ) ____________

1.0 Introduction

Finding practical and effective ways to implement sustainable development remains a significant challenge in our cities and smaller communities. Degraded air and water quality, climate change and chronic unemployment are all symptoms of unsustainable development. One way of achieving more sustainable forms of development in our cities is through an increase in the diffusion of green roof and vertical garden technologies on the roofs and walls of residential, institutional, industrial and commercial buildings throughout Canada.

Green roof and vertical garden technologies offer numerous economic, social and environmental benefits such as operational cost savings, greenhouse gas emission reduction, adaptation to climate change, air quality improvements, stormwater retention, water quality and quantity improvement, habitat provision, food production, employment opportunities, recreational opportunities and improved aesthetics. Despite these benefits and the widespread market penetration of green roofs in countries throughout Europe, the use of these technologies in Canada and North America remains in its infancy.

This study is a Canadian status report on green roof and vertical gardens. It was funded by Canada Mortgage and Housing Corporation's (CMHC's*) External Research Program* with in kind support from Environment Canada.

1.1 Research Objectives and Methodology

The objectives of this research were to:

- Review the status, quantitative and qualitative benefits and opportunities associated with green roof and vertical garden technology.
- Identify barriers to the more rapid implementation of green roof and vertical garden technology in Canada.
- Engage a variety of public and private stakeholders in a workshop to familiarize them with the concept and benefits of vertical and rooftop greening and gain information and insight from them.
- Develop recommendations to overcome the most important barriers to the diffusion of green roof and vertical garden technology in Canada.

The research involved a thorough literature review, interviews with ten individuals involved in green roof and vertical garden projects and a workshop with industry and government representatives. Early research on the technologies' benefits provided the background for a one-day workshop of industry and government stakeholders held in Toronto, Canada on November 24, 1998. Workshop participants identified barriers and made recommendations for improving the use of these 'sustainable development' technologies in Canada.

A Senior Advisory Team was also assembled to provide strategic advice and technical information for the project. The Advisory Team consisted of:

- Greg Allen, Principal, Allen Kani Associates
- Frank Baxter, Vice President, Semple-Gooder Roofing Ltd.
- Sean Cosgrove, Consultant, Toronto Food Policy Council
- Dr. Roger Hansell, Associate Director, Institute for Environmental Studies, University of Toronto
- Evan Jones, Energy Analyst Specialist, Rose Technology Group
- Arnie Rose, Manager, Programs and Administration, City of Toronto Housing Division

1.2 Overview of the Report

This report consists of four major sections. Section 2.0 gives a brief history of the development of these technologies in Europe and provides descriptions of the major types of green roofs and vertical gardens.

Section 3.0 provides a comprehensive review of the quantitative and qualitative benefits of these technologies, including statistical data representing the relationship between specific characteristics (soil depth), and benefits (stormwater retention capacity). Given that many of the benefits of these technologies are specific to the particular application, the data provided describes generic relationships that may be adapted to specific projects.

Section 4.0 of the report describes the major barriers to the more rapid diffusion of these technologies. Section 5.0 describes the major elements of a proposed National Action Plan designed to increase the market penetration of these technologies in cities throughout Canada.

The interview questionnaire is provided as Appendix I. Twelve case studies were developed and are included as Appendix II. A list of plants commonly used in green roof systems is included as Appendix III. A list of workshop participants is provided as Appendix IV.

2.0 History, Definitions and Applications

2.1 Early and Recent History

Green roofs and vertical gardens are not new phenomena. They have been considered standard construction practice in many countries for hundreds, if not thousand of years. This is mainly because of the excellent insulative qualities of the combined plant and soil layer (sod). In cold climates they help retain heat in the building, and in warm climates they help to keep the heat out.

Green roofs and vertical gardens can be traced back to the hanging gardens of Babylon and were known to exist in the Roman Empire, a response to population pressures in urban areas[1]. In Pompeii shopkeepers grew vines on their upstairs balconies, and the ancient historian Pliny wrote about trees being imported for green roofs[2]. The Romans also put trees on top of institutional buildings, such as the mausoleums of Augustus and Hadrian[3]. The Vikings layered the walls and roofs of their homes with turf to protect against wind and rain, and sometimes used seaweed to insulate roofs[4]. Canada claims several Viking and French examples of sod roofs, exported to Newfoundland and Nova Scotia.

During the Renaissance, steeply terraced gardens and green roofs were common in the city of Genoa[5]. Vertical gardens, in the form of hanging gardens also existed in pre-Columbian Mexico [6], India, and in some of the Spanish homes of 16th - 17th century Mexico[7]. In Russia, hanging gardens were favoured in the 17th century Kremlin, and in the 20th century, green roofs and hanging gardens grace homes in Tashkent, Tbilisi, and Dshanbe and even at the airport in St. Petersberg[8]. In 18th century France, vertical gardens were constructed for sake of aesthetics including Princ De Condé's 'sheared walls of greenery' that made up his outdoor dining room[9].

Two individuals associated with much of the thinking in contemporary architecture, Le Corbusier and Frank Lloyd Wright, made extensive use of green roofs. Le Corbusier envisioned urban areas with roads placed on roofs amid vegetation - his fifth point in *A New Architecture* was roof gardens[10]. He also included a green roof in the design of La Maison due Diable in 1913. Wright used rooftop and vertical gardens at Midway Gardens in Chicago, the Hollyhock House, the Cheney House, Falling Water, the Hillside Home School, and Horseshoe Inn, to name just a few of his projects. Green roofs were clearly a

---

1 (Farrar, 1996)
2 (Jashemski, 1979)
3 (Pieper, 1987)
4 (Donnelly, 1992)
5 (Gorse, 1983)
6 (Goode, 1986)
7 (Flower, 1937)
8 (Titova, 1990)
9 (De Lorme, 1996)
10 (Curtis, 1986)

natural outgrowth of his American Prairie School philosophy, which emphasized integrating a building's growth out of the landscape[11].

Viewed mainly as a folk or vernacular building practice until the middle of this century, recently the concepts of green roofs and vertical gardens have become widely adopted in Northern Europe; particularly in Germany, Switzerland, Austria, and Scandinavia. This renewed interest is due mainly to rising concerns regarding the degraded quality of the urban environment and the rapid decline of green space in intensely developed areas.

In the early 1960's terraced green roof technologies were developed and enhanced in many countries, particularly Switzerland and Germany. In the 1970's a significant amount of technical research on the different components of green roofing technology was carried out, including studies on root repelling agents, waterproof membranes, drainage, light-weight growing media and plants.

In Germany, the development of green roof markets expanded quickly in the 1980's, averaging 15-20% annual growth. By 1989, 1 million square metres of roofs were 'greened' in Germany. By 1996, this number had ballooned to 10 million square metres. This tremendous growth was stimulated largely by state legislation and municipal government grants of 35-40 Deutsch Marks per square metre of roof[12]. Other European states and cities have adopted similar types of support and policy, with several mid to large-size cities incorporating roof and vertical greening into their bylaws and planning regulations. Vienna, Austria provides subsidies and grants for green roof installations at three stages of the project - planning, installation and three years after installation to ensure proper maintenance and use. In Stuttgart, Germany, for example, a 1989 municipal by-law was passed requiring the installation of a grass roof on all flat-roofed industrial buildings[13]. A similar by-law was passed in the city of Mannheim, Germany. A key motivator in municipal government support for green roof implementation has been the benefit associated with improved stormwater quality and quantity management.

As a direct result of government policy and program support in Europe, a new industry has been created for plants and material suppliers, roofing professionals, installers and maintenance crews - the 'green roof industry'. In Germany, France, Austria, Norway, Switzerland and other European states, green roofs have become a commonly accepted feature in the construction industry and a welcome feature of the urban landscape.

[11] (Hoffman, 1995)
[12] (Boivin, 1992)
[13] (Johnston, 1996, p. 48)

2.2 Green Roof Definition

Green roof development involves the creation of 'contained' green space on top of a human-made structure. This green space could be below, at, or above grade, but in all cases the plants are not planted in the 'ground'. Green roofs using free-standing containers or planters should not be confused with the typical European green roof installation, which is applied as another layer of the roofing system. This green roof layering technology includes:

- The roof structure and perhaps some insulation.
- A waterproofing membrane, often with root repellent inserted in between or placed on top.
- A drainage layer, sometimes with built-in water reservoirs.
- A landscape or filter cloth to contain the roots and the soil.
- A specialized growing medium which may not include soil.
- The plants.

A barrier between the plants and any roof penetrations, parapet walls or flashing is crucial to prevent root penetration.

There are two basic types of green roof systems: extensive and intensive. Extensive green roofs are characterized by their low weight, low capital cost and minimal maintenance. The growing medium, typically made up of a mineral-based mix of sand, gravel, crushed brick, leica, peat, organic matter and some soil, varies in depth between 5-15 cm - a weight increase of 72.6-169.4 kg per m^2 [14]. Due to the shallowness of the soil and the extreme desert-like microclimate on many roofs, plants must be low and hardy, typically alpine, dryland or indigenous. Plants are watered and fertilized only until they are established and after the first year, maintenance consists of two or three visits a year for weeding of invasive tree and shrub species, mowing, safety and membrane inspections[15]. As a general rule, minimal technical expertise or practical experience is required for installation and maintenance[16].

Intensive green roofs are characterized by greater weight, higher capital costs, more plantings and higher maintenance requirements. The growing medium is soil-based, ranging in depth from 20-60 cm, with a weight increase of 290-967.7 kg per m^2. Due to increased soil depth, the plant selection is more diverse including trees and shrubs, which allows a more complex ecosystem to develop. Requirements for maintenance and watering are more demanding and ongoing than with an extensive green roof. Structural and landscaping consultation and an experienced installer are required[17]. The advantages and disadvantages of both major types of green roofs are summarized in Table 1.

---

[14] (Soprema Roofing Inc., 1996)
[15] (Thompson, 1998, p.49)
[16] (Johnston,1996, p. 54)
[17] (ibid.)

Table 1: Comparison of Extensive and Intensive Green Roof Systems

	Extensive Green Roof	Intensive Green Roof
Brief Description	• thin soil, little or no irrigation, stressful conditions for plants	• deep soil, irrigation system, more favorable conditions for plants
Advantages	• lightweight • suitable for large areas • suitable for roofs with 0-30º slope • low maintenance • often no need for irrigation and drainage systems • relatively little technical expertise needed • often suitable for retrofit projects • can leave vegetation to develop spontaneously • relatively inexpensive • looks more natural • easier for planning authority to demand green roofs be a condition of planning approvals	• greater diversity of plants and habitats • good insulation properties • can simulate a wildlife garden on the ground • can be made very attractive • often visually accessible • diverse utilization of roof (i.e., for recreation, growing food, as open space.)
Disadvantages	• more limited choice of plants • usually no access for recreation or other uses • unattractive to some, especially in winter	• greater weight loading on roof • need for irrigation and drainage systems hence, greater need for energy, water, materials, etc. • higher cost • more complex systems and expertise required

Source: adapted from Johnston, 1996, p. 54.

It should be noted that the advantages and disadvantages described in Table 1 provide generic information only. Each individual green roof system will likely be a combination of intensive and extensive, depending on factors such as:

- location;
- structural capacity of the building;
- budget;
- material availability; and,
- client and/or tenant needs.

There are other sub-classifications of green roofs which include: semi-intensive green roofs; earth sheltered buildings, where the earth covers all or part of the building; and hydroponic systems.

Green roof systems can be further classified as being either ‘accessible’ or ‘inaccessible’. An accessible green roof is a flat outdoor open space intended for use by people as a garden or terrace. These types of green roofs often involve surface planting, planter boxes, pathways, seating, water features, play areas and shade structures. Since these roofs are accessible by tenants, employees and/or the general public, certain safety requirements must be adhered to. These include exiting, occupant loads, guardrails and lighting. Accessible green roofs can provide an important social benefit to their users and increase the market value of the building.

An inaccessible green roof is only accessible for periodic maintenance. The green space can be viewed but not used, and as such, has no requirement for regulation stairs, guardrails or any other safety features. Inaccessible green roofs can be flat, curved or sloped up to 30ºC. Sloped and curved roofs need additional horizontal strapping to prevent slippage of the growing medium and plant layers when they become wet.

2.3 Vertical Garden Definition

The term ‘vertical garden’ is used to define the growing of plants on, up, or against the façade of a building. Strategies for vertical garden development include: planting ‘in the ground’ at grade; planting in planter boxes (at grade, attached to walls, on window ledges, balcony rails and as part of horizontal and vertical sun screens over windows, doors and glazed areas); and planting in a vertical hydroponic system. Suitable plants include a wide variety of perennial and annual vines as well as espaliered trees.

A vertical garden is essentially a living cladding system with many of the benefits of a green roof, and often without the added weight or cost implications. Vertical greening has more potential to impact the area per building, with greening of a building's façade encompassing four times the area of the roof. For a highrise building, this can increase to twenty times the area of the roof. In fact, vines can be trained to cover a low roof as well as the walls of a building.

On the other hand, vines and trees generally have an inherent height limit with perennials taking 2-3 years before they can begin to provide the coverage required to affect a measurable difference in temperature regulation and surrounding air quality[18]. To counter this, annual vines can be inter-planted at grade and at intermediary levels to provide full seasonal coverage while perennials are becoming established. Wind can also be a limiting factor in the effectiveness of vertical gardens, especially for plants and planter boxes located above eight stories.

[18] (Minke, 1982, p. 24)

Interior applications of the vertical garden concept, such as the living wall installations at Crown Life Insurance and Club Monaco in downtown Toronto, Canada, designed by Wolfgang Amelung, are bringing the benefits of improved air quality and greening into buildings.

2.4 New Buildings and Retrofits - Loading Capacity and Upgrading for Accessibility

Although green roof applications are fairly unique to the requirements of each project, there are several major application issues that must be addressed. The requirement for additional loading capacity is one of the main factors in determining both the viability and cost of a green roof (See Case Study J). If a green roof is part of the initial design of the building, the additional loads can be accommodated easily and at relatively minor costs (See Case Study I). If a green roof is installed on an existing building then the design is limited to the current carrying capacity of the roof unless the owner is prepared to upgrade the structure, which can be a significant investment.

Wet soil weighs approximately 100 lbs. per cubic foot (1,597 kg per cubic metre). In Ontario, Canada a typical residential roof is designed for a load of approximately 30-40 lbs. per square foot (146-195 kg per square metre), which does not include snow loading. If soil is used as the growing medium, the depth for planting is limited to less than 3" (7.6 cm). In Ontario, an accessible roof terrace or balcony must be designed for 100 lbs./sf (488 kg/m^2), which allows for less than 12" (30.5 cm) of soil. An extensive green roof is much lighter than an intensive green roof, with the lightest grass roof weighing as little as 11.2 lbs./sf (55 kg/m^2) including 2.36" (6 cm) of substrate[19].

The weight of soil has led to the development of various types of lightweight growing media. The green roof on the new library in Vancouver, British Columbia has a 14" (35.6 cm) layer of lightweight substrate made up of sand, pumice and compost. It weighs only 60 lbs./sf (292.6 kg/ m^2) when saturated and did not require structural upgrading beyond the standard requirements of Vancouver's building code[20] (See Case Study I).

On inverted roof applications, where the membrane is applied underneath the insulation and a layer of ballast, the growing medium/substrate can be directly substituted for the ballast - be it gravel or pavers, thereby gaining even more load-bearing capacity.

If the green roof is to be accessible to tenants, staff and/or the general public, it must comply with certain requirements of the building code, which in Ontario, include the following:

---

[19] (Minke, 1982, p. 35) *Please note*: All technical details provided will vary by region, building type and materials used. These figures are provided as generic examples only and ***should not*** be used for projects without expert advice and opinion. It should be further noted that the methods for calculating snow loads have changed in Ontario to approximately 22 lbs./sf, with higher loads only in specific areas subject to drifting and build-up, which leaves between 8 - 18 lbs./sf for a green roof system.
[20] (Thompson, 1998, p. 49)

- A continuous guard rail, 3.5 feet high.
- Adequate access and exiting, depending on roof size and number of occupants.
- Lighting, fire safety equipment, and a source of water.
- Structural integrity.

These elements are much easier and less expensive to include in the initial design of the building than after-the-fact.

2.5 Installation, Maintenance, and Upkeep

In green roof installations, the most crucial element is the roof membrane. Organic materials such as bitumen or bituminous roofing are not root-proof. However, this problem can be solved by placing a chemical or metal foil in between the layers and at the joint/seam lines. Parapets, edges, flashing and roof penetrations made by skylights, mechanical systems, vents and chimneys should be well protected with a gravel drainage layer and sometimes a weeping drain pipe.

Without greening, flat roofs are 50% more susceptible to damage after 5 years than slightly sloped roofs (e.g., 5% slope). This is because water tends to pool instead of running off. If the drainage layer isn't sufficient or if drainage routes become blocked, green roofs can cause some flat roofs to leak due to continuous contact with water or wet soil. With insufficient drainage, the plants will also be susceptible to the impact of wide degrees of variability in the moisture content of the soil. For example, with too much water, the soil can go sour and the plants can drown or rot[21].

On a roof, with a slope greater than 20º, the roofer needs to ensure that the sod or plant layer does not slip or slump through its own weight, especially when it becomes wet. This can be prevented through the installation of horizontal strapping, placed either under the membrane or loosely laid on top of the membrane (See Case Study A).

In vertical garden applications, vines require very little maintenance once established. Crop plants, such as beans, lettuce and escarole require the same level of maintenance as they would in a garden at grade. Since vertical gardens can be designed to keep plants from direct contact with a building's wall, no additional maintenance on the wall is required. Vines, which are often grown directly on the wall, will not damage a surface that is already in good condition. Rather, vertical gardens will actually reduce the damage caused by rapid temperature variations such as the freeze-thaw cycle, acid rain, ice accretion and pollution.

3.0 Quantifiable and Qualitative Benefits

Since Europe has been rapidly developing green roof and vertical garden technologies and practices for over 20 years, much of the technical information compiled in this report

[21] (Minke, 1982)

is from German, Austrian and British sources. Although Canadian climatic and economic conditions are similar to those of these countries, it should be noted that not all of the data presented in this section of the report is directly transferable and therefore should *only* be used as a guide. A number of Canadian case study examples have been compiled as Appendix II, however, much of the information provided in these case studies is qualitative, with little technical data.

Urban and suburban landscapes create imbalances in the natural ecosystem. These imbalances result, in large measure, from factors such as:

- concentrated human populations;
- the introduction of vast areas of hard, impermeable and reflective surfaces (areas which are also devoid of flora and fauna);
- the importation of energy and other resources from outside of the city; and,
- the creation of waste products which cannot be reintegrated into the ecosystem as a resource thereby resulting in water, soil and air pollution.

In most urban regions, resources such as carbon dioxide from vehicle emissions, rainwater and sunlight are often wasted or considered 'pollutants'. Through the reintroduction of plants on the walls and roofs of buildings, we can begin to rebuild some of the lost equilibrium in the urban ecosystem and utilize wasted resources (See Case Study G). The 'greening' of our urban regions can also help us better manage many of the wastes we generate in the air and water and thereby contribute to improved human and ecosystem health.

This section of the report provides a comprehensive review of the data on the environmental, social and economic benefits attainable through green roof and vertical garden technologies, often presented in the context of an urban ecosystem. Where data on benefits is unavailable or difficult to obtain, qualitative benefits are described.

3.1 Improvement of Air Quality

Urban areas tend to perpetuate their own air pollution. When the concrete, stone, glass and asphalt surfaces of roads, parking lots and buildings are heated during the summer months, vertical thermal air movements are created and the dust and dirt particles found on the ground and in the air are carried and spread.

A vertical garden will block the movement of dust and dirt particles along the sides of a building and filter them. A green roof will reduce the amount of energy available for heating, which decreases the tendency towards thermal air movement and will also filter the air moving across it. Airbourne particulates tend to get trapped in the leaves, branches and stem surface areas of plants and when it rains, they get washed into the soil/substrate below. Plants are also known to absorb gaseous pollutants through photosynthesis and sequester them in their leaves (which fall to the ground in autumn to create humus)[22].

Studies have shown that treed urban streets have only 10-15% of the total dust particles found on similar streets without trees[23]. In Frankfurt, Germany for example, a street without trees had an air pollution count of 10,000-20,000 dirt particles per litre of air and a treed street in the same neighborhood had an air pollution count of only 3,000 dirt particles per litre of air[24].

Using similar figures, it is assumed that a grass roof with 2,000 m^2 of unmowed grass (100 m^2 of leaf surface per m^2 of roof) could take 4,000 kg of dirt out of the air (2 kg per m^2 of roof). However, this estimate is probably high since the lower portion of the grass layer is too dense to be in direct contact with moving air. Even if the figures were cut to $1/10^{th}$ of what a forest could remove, the grass roof would still take out a significant amount, 0.2 kg of particles per m^2 every year[25].

This air cleansing quality of green roofs and vertical gardens has direct benefits for people who suffer from asthma and other breathing ailments, and directly decreases summer smog and other forms of air pollution. The widespread use of these technologies would also extend the life of all urban infrastructure that is susceptible to damage from air pollution.

3.2 Climate Change – Mitigation and Adaptation

At the Third Congress of Parties to the Framework Convention on Climate Change, held in Kyoto, Japan in December of 1997, an agreement known as the Kyoto Protocol, committed Canada to reducing greenhouse gas (GHG) emissions to 6% below 1990 levels between the years 2008 and 2012. Urban areas are a significant source of GHG emissions, with space/air conditioning playing a significant role in urban energy demand[26]. If widely implemented, green roof and vertical garden technologies can provide an effective and proven method for governments, companies and building owners to reduce these GHG emissions through direct shading of individual buildings, improving insulation values and reducing the Urban Heat Island Effect (Section 3.6).

Actual figures for energy cost savings are very difficult to standardize accurately since every building and installation is different. GHG emission reductions and associated cost savings depend on a number of factors such as:

- Specific siting of the building.
- Climate.

[22] (Minke, 1982, p. 11)
[23] (Johnston, 1996, p. 10)
[24] (Minke, 1982, p. 11)
[25] (ibid.)
[26] (Mercier, 1998)

- Choices of roofing materials and design.
- Insulation.
- Mechanical system.
- Thickness of growing medium.
- Primary sources of energy used to meet heating and cooling needs.
- Types of plants used.
- Extent of alternative functions of green roof, such as displacing the need for cooling towers and local food production.

Even though estimates of climate change mitigation specifically due to green roof and vertical garden installations are not readily available, the following examples provide some illustrative data:

- Approximately one-third of a home's basic thermal unit demand for heating in winter is created by wind. Even in an airtight home, wind chill makes the outside walls colder and reduces the effectiveness of the insulation. Protecting a house from wind can reduce the wind chill factor by 75% and cut the heating demand by 25%. Furthermore, every degree (F) of summer heat requires an additional 5-7% of cooling energy. Hence, a 10º F reduction in the outside air temperature achieved through the judicious arrangement of shade trees (green roofs and vertical gardens), can reduce energy consumption for air-conditioning by 50-70%[27].

- Canadian studies have shown that vines lower the inside temperatures as effectively as shade trees if allowed to grow on south or west walls[28]. Studies from Britain have also shown that over a one year period, energy costs for a conventional house can be reduced by as much as 25%. This is achieved through the reduction of wind penetration by, for example, careful perimeter planting of deciduous species of trees. These trees also provide summer shading and winter solar gain[29]. Similar results could be expected with a vertical garden.

With the successful diffusion of green roof and vertical garden technologies, Canadian communities will be better equipped to mitigate and adapt to climate change.

[27] (Gaudet, 1985, p. 24)
[28] (Gaudet, 1985, p. 29)
[29] (Johnston, 1996, p.14).

3.3 Temperature Regulation

Climate can be understood at four basic levels - climatic zones, regional climate, local climate and microclimate. 'Climatic zones' are defined as broad, geographic bands, affected primarily by large water bodies, land mass and distance from the equator. Most of Canada falls into the 'cool' or 'cool-temperate' zones, characterized by long, cold winters and hot, humid summers[30]. Significant changes to climatic zones, such as global warming, can occur only on a global scale.

Regional climate refers to the regional variations within climatic zones, with accompanying differences in annual temperatures, sunniness, snowfall, rainfall, wind, etc. Local climate occupies a smaller footprint. The Urban Heat Island Effect (discussed in 3.5) is an example of an anthropogenically produced local climate.

'Microclimates' are site-specific; for example, a rooftop will often have a different microclimate from the grade surrounding the building. Microclimate is directly influenced by a variety of elements on and around the site - land contour, vegetation, water, soil conditions, and buildings - which affect the site's sunniness, warmth or coolness, humidity, wind, snowdrift and runoff patterns and degree of wind chill. By manipulating these site elements, the microclimate of a site can be substantially change[31].

Much of the sun's energy falling upon a typical concrete, asphalt or hard surface is re-radiated as heat. Using a layer of vegetation to intercept the sunlight can reduce this heat. Of the sun's light energy that falls on a tree leaf, 2% is used in photosynthesis, 48% is passed through the leaf and stored in the plant's water system, 30% is transformed into heat (used in transpiration) and only 20% is reflected. Since a large amount of incident radiation on a plant canopy is used for evapo-transpiration, plants on vertical and horizontal surfaces are able to regulate wild temperature swings. On a warm summer day their absorption of energy lowers the temperature of the shaded surface and regulates humidity while at night and in the winter, they give off energy/heat. This can reduce the amount of sun-energy falling on a hot summer day by up to 90%[32]. In a city, the impact of evapo-transpiration and shading can significantly reduce the amount of heat that would otherwise be re-radiated by building and street surfaces.

3.4 Creation of Microclimates

Changing a site's microclimate through rooftop and vertical greening can have a complex and layered effect on urban climate. Roofs and walls create their own specific microclimate, quite different from surrounding conditions, both around the building and at grade.

[30] (Hoffman, 1995, p. 24)
[31] (Hoffman, 1995, p. 24)
[32] (Minke, 1982, pp. 11-12)

Depending on height, orientation and the location of surrounding buildings, the roof is subject to extreme temperature swings (hot during the day and cool at night), with constant exposure to sunlight and wind - a desert-like climate suitable only to specific types of plants. Although this can be tempered by additional irrigation and greater soil depth, a green roof is closer to an arid or alpine environment than it is to the surrounding environment at grade. This means that designers and installers must have a specialized knowledge of the flora and fauna best suited to these conditions. Once established, the green roof will have a noticeable impact on the heat gain and loss of the building beneath it, as well as the humidity, air quality and reflected heat in the surrounding neighbourhood. In conjunction with other green installations, the green roof will also play a role in altering the climate of the city as a whole. The same can be said for vertical gardens. One German source remarked that a 'healthy' urban climate could be achieved by greening only 5% of all roofs and walls within the city[33].

3.5 Plants and Building Insulation

The role of insulation and air/vapour barriers is to slow down the rate of heat transfer between the inside and outside of a building, which is a function of the difference between the inside and outside temperatures. Insulation mitigates the impact of this temperature differential. In the winter, insulation slows down the rate of heat transfer to the outside and in summer it slows down the rate of heat transfer to the inside. The greening of vertical and horizontal surfaces has long been used as a technique for insulating buildings through exterior temperature regulation. The insulation value of a building's 'skin' (façade and roof) can be increased in several ways:

- By trapping an air layer or 'pillow' within the plant mass, the building surface is cooled in summer and warmed in winter.
- By covering the building with vegetation, the summer heat is prevented from reaching the building's skin, and in the winter, the internal heat is either prevented from escaping, reflected or absorbed.
- Since wind decreases the energy efficiency of a building by 50%[34], a plant layer will act as a buffer that keeps wind from moving along a building surface.

With a vertical garden, the denser and thicker the plant layer on the façade, the more beneficial these effects. A 1.57" (4 cm) layer of standing air, trapped between an insulated wall and a 6.3" (16 cm) blanket of plants, can increase the R value of that wall by as much as 30%. Additionally, the better the existing R value of the wall the more effective the plants will be[35]. This strategy of increasing exterior insulation allows for R value upgrades and retrofits of existing under-insulated walls without the added cost of interior or traditional exterior insulation. The need to re-apply finish surface materials or

[33] (Minke, 1982, p. 7)
[34] (Minke, 1982, p. 14)
[35] (Minke, 1982, pp. 14 and 26)

cladding, the loss of space resulting from thicker walls and the interruption of usage during construction can all be avoided through the use of vertical gardens. In fact, insulation applied to the exterior of buildings is much more effective than interior insulation, especially during the summer months[36].

Ideally, if winter heat-loss is a concern, one should choose evergreen plants that do not lose their leaves during the winter months. However, on a protected southern or western exposure, this seasonal loss of foliage could serve as a passive solar technique. This would be advantageous since the lack of foliage would allow the sun to heat up the wall during the day. During the summer it is important to place vertical gardens on the southern and particularly western exposures, since they receive the largest amount of incoming solar energy. Installation of south and west-facing ‘green’ window shades can add significant insulation to buildings with large window exposure, since much of the summer heat gain is from the absorption of incoming solar energy by walls and other objects in a room. With plants shading the windows, the heat will not reach the interior (See Case Study E).

With a green roof, the insulation value is in both the plants and the growing medium. It is unclear which of the two has the most benefit since much depends on the depth of the growing medium and type of plants chosen[37]. An extensive application is much more effective as an insulator than an intensive one[38]. A layer of mixed grass performs better than a layer of limited-species grass, which in turn is better than a layer of low-growing sedum[39] (See Case Study A).

An 8” (20 cm) layer of substrate plus an 8 -16” (20-40 cm) layer of thick grass has a combined insulation value equivalent to 6” (15 cm) mineral wool insulation (R 20; RSI 0.14)[40]. Under a green roof, indoor temperatures (without cooling) were found to be at least 3-4ºC lower than hot outdoor temperatures between 25-30ºC[41]. In winter, a blanket of snow and fallen plant matter will also increase the building's insulation. If the dew point (point of condensation) can be located within the substrate layer instead of within the building, and if the roofing membrane is water but not vapour proof, one could theoretically eliminate the need for the traditional vapour barrier, resulting in reduced material and labour costs.

Green roofs can also play a role in pre-cooling the make-up air that is required by most mechanical systems. As the outdoor air temperature in the summer is often warmer than the exhausted, internal air it is replacing, the air needs to be pre-cooled before it is allowed into the building. A green roof and the strategic planting of specific vegetation to shade the intake valves will lower the air temperature at roof level, thereby reducing the make-up air temperature, the demands on air-conditioning equipment and result in net

[36] (Givoni, 1976)
[37] (Liesecke, 1989, p. 16)
[38] (Hooker, 1994, p. 3)
[39] (Minke, 1982, p. 34)
[40] (ibid.)
[41] (Liesecke, 1989, p. 18)

energy savings. It should also be noted that hydro costs incurred for summer cooling in Ontario are typically more expensive than those incurred for winter heating.

Although the benefit of roof greening as an insulator has been proven, the specific R values fluctuate depending on the amount of moisture in, and on, the growing medium (during the winter, after continuous rainfall, etc.). This fluctuation occurs to such an extent that German researchers have, as yet, been unable to provide standard and approved insulation ratings for green roof systems[42]. This has not, however, stopped them from promoting the insulating benefits of green roofs and vertical gardens.

3.6 Moderation of the Urban Heat Island Effect

The 'Urban Heat Island Effect' is a macroclimate caused by the difference in temperatures between a city and the surrounding countryside. This difference is mainly due to the expanse of hard and reflective surfaces in urban areas, which absorb incoming solar radiation and re-radiate it as sensible heat [43]. In the surrounding areas, there is a higher proportion of 'greened' surface area, which is able to absorb and transform this radiation into biomass and latent heat. Re-radiated heat, waste heat generated by industry, vehicles and mechanical equipment and increased levels of air pollution, have combined to raise urban temperature levels up to 8ºC warmer than their surroundings on warm summer evenings. And if estimates are correct, global warming will exacerbate the Urban Heat Island Effect by raising summer temperatures an additional 5ºC[44].

Higher urban temperatures increase the instability of the atmosphere, which in turn can increase the chance of rainfall and severe thunderstorms. The city of Cologne, Germany, for example, receives 27% more rainfall than surrounding areas[45]. In cities already plagued by overextended stormwater systems and combined sewage overflows, the problems caused by severe rainfall are likely to worsen with global climate change.

Higher temperatures also have a direct effect on air quality, since heated air stirs up dust and airbourne particulates as it rises. On a hot summer day, a typical insulated gravel-covered roof in middle Europe tends to heat up by 25ºC, to between 60º-80º C. This temperature increase means that a vertical column of moving air is created over each roof which, for 1,075 sf (100 m^2) of roof surface area, can be moving upwards at 0.5 m/sec. Studies have shown that there is no vertical thermal air movement over grass surfaces. These surfaces will not heat up to more than 25ºC.

Air movement along vertical heated surfaces is even greater than over horizontal surfaces. With strategic placement of vertical gardens, plants can create enough turbulence to break vertical air flow which cools the air at the same time it slows it down[46].

---

[42] (ibid.)
[43] (Johnston, 1996, p. 11)
[44] (Akbari, 1992, pp. 5-25)
[45] (Minke, 1982, pg. 11)
[46] (Minke, 1982, p. 12)

By changing wind energy into kinetic and heat energy, planted surfaces can also have a significant impact on local wind patterns - thereby reducing the detrimental effects of wind on a building.

3.7 Carbon Dioxide and Oxygen Exchange

Plants play a crucial role in the survival of life on our planet. Through the photosynthesis process, which takes place within green leaves and stems, plants convert carbon dioxide, water, and sunlight/energy (solar radiation) into oxygen and glucose. Plants supply humans and other animals with oxygen and food, and animals in turn, produce the carbon dioxide and manure required by the plants.

Studies have shown that one mature beech tree (80-100 years old), with a crown diameter of 15m, shades 170 m^2 of surface area, has a combined leaf surface area of 1,600 m^2 , and creates 1.71 kg of oxygen and 1.6 kg of glucose every hour (using 2.4 kg of carbon dioxide, 96 kg of water, and 25.5 kJ heat energy). This level of production equals the oxygen intake of 10 humans every hour[47].

One of the crucial elements in selecting plant types and densities is the green leaf and stem surface area available for photosynthesis. For example, 25 m^2 of leaf surface area produces 27 g of oxygen per hour during the day, which equals the amount of oxygen a human would require for the same time period. However, considering the effects of nature, night-time (no sunlight), and winter (no green leaves if using deciduous plants) 150 m^2 of leaf surface area would be required to balance the human intake of oxygen for one year[48].

For green roof applications:

- One m^2 of mowed lawn 3-5 cm high has a leaf surface area of 6-10 m^2.
- One m^2 of uncut meadow has a leaf surface area of up to 225 m^2.
- Assuming 1 m^2 of uncut grass roof, with a leaf surface area of 100 m^2, 1.5 m^2 would meet the yearly requirement of oxygen for one human.

For green wall/vertical garden applications:

- One m^2 of wall surface covered with dense 10-15 cm thick layer of wild grapevines has a leaf surface area 3-5 m^2.
- One m^2 of wall surface covered with a dense 25 cm thick layer of ivy has a leaf surface area 11.8 m^2.

Therefore an uncut grass roof produces 10-30 times the oxygen of a thickly covered wall of vines.

---

[47] (Minke, 1982, p. 10)
[48] (ibid.)

For comparison, the yearly requirement of oxygen for one human can be produced by:

- One tree with a 5 m diameter canopy.
- 1.5 m^2 of uncut grass, 0.4 m high.
- A densely planted greenhouse of 20 m^2.
- 30-40 m^2 of green parkland / mowed grass.
- 40 m^2 of dense, plant covered wall surface[49].

It should be noted that although the production of oxygen is an important contribution of urban greening, in evaluating this benefit it is necessary to take the following into consideration[50]:

- Plants only produce oxygen during the daytime; at night the process reverses so that they take in oxygen and give off carbon dioxide (however, there is still a net increase in oxygen).
- In the Canadian climate most plants are dormant during the winter and do not produce oxygen or carbon dioxide.
- The decomposition of organic matter on top of, and within, the growing medium also requires oxygen.
- In extensive green roof systems, where the plant/grass layer is allowed to dry up during the summer (i.e., no additional irrigation), the plants are unable to participate in photosynthesis.

On a global scale, some studies indicate that even with all of its industry, technology and the burning of fossil fuels, humanity has had little effect on the total amount of oxygen in the earth's atmosphere. Instead, these studies suggest that it is the quality of the air through the production of greenhouse gases, pollutants and air-borne particulate matter, that has been negatively affected by human activities.

By increasing the amount of biomass in an urban area, rooftop and vertical gardens can contribute to reducing the carbon dioxide levels produced by vehicles, industry, and mechanical systems, leading to improved air quality and reduced respiratory problems.

Stormwater Management

If the marketing strategies for green roof systems used by European firms are any indication, the most significant tangible benefit of green roofs is their ability to retain stormwater[51]. Engineering for urban development has traditionally focused on moving rainwater and melting snow away from buildings and roads as fast as possible. Since

[49] (Minke, 1982, p. 11)
[50] (Goode, 1986, p. 16)
[51] (North American Wetland Engineering Society, 1998)

much of the surface area in a city is either paved or covered with buildings, precipitation which otherwise would have infiltrated into the ground or been intercepted by vegetation, is diverted from the cities through constructed stormwater systems. For example, according to Toronto and Region Conservation Authority studies, approximately 25% of land area in new subdivisions in Canada are paved and non-porous. This non-porous landscape of urban areas and stormwater engineering to divert water has created a number of problems such as:

- The contamination of stormwater. As it runs off impermeable surfaces, it picks up particulates, pesticides, oil, grease, heavy metals, rubber and garbage from roads, driveway, parking lots, lawns, roofs and pavement before it reaches storm drains. In a number of cities, including Toronto, stormwater is the number one cause of water pollution in local rivers.

- Combined sewage overflows (CSO). As a safety and cost savings measure, many stormwater systems run parallel to a city's sewage system, overflowing into the sewage system if they cannot handle the volume of water during heavy rainfall or spring runoff. This is usually a problem in older urban areas. During a storm event, diluted raw sewage is discharged into the local streams and rivers, resulting in beach closures and other negative impacts.

- Drop in local water tables and the base flow of streams and rivers, with up to 95% of natural precipitation being immediately discharged into major bodies of receiving water rather than infiltrating into the ground[52].

- Increase in water temperatures, particularly during the summer that negatively impacts aquatic plants and animals and encourages algae blooms.

- Severe flooding, often resulting in loss of human life due to the high volume of run off.

- Erosion problems due to the turbidity of the stormwater and the sheer volume of runoff after a storm. This requires ongoing investment in infrastructure.

- The sealing of the surface area of the land has contributed to a drop in local water tables and an increase in both end-of-pipe water temperatures and pollution levels, since the rainwater

One approach to solving some of these issues involves the enlargement or expansion of stormwater infrastructure, which can be a costly and disruptive process. Several cities, are commissioning consultants to study environmentally friendly, cost-effective alternatives to ‘end of pipe’ solutions that involve building large, temporary storage facilities. Other natural alternatives include the disconnecting of downspouts, increased use of swales adjacent to parking lots, constructed wetlands, rain barrels, cisterns, retention ponds and requiring the use of porous pavement. These solutions still require

[52] (Stifter, p. 156)

some level of associated inspection and maintenance, and in some cases, the cost of additional surface area at grade. Green roofs and vertical gardens can provide viable alternatives where, in older urban areas, there is often a lack of suitable land at grade to properly address alternative storm water management approaches (See Case Study J).

Many European cities, as well as several cities in the United States, now charge developers and building owners fees (in addition to property taxes) for hookup to the storm water system, based on the amount of discharge produced by the site. For example, in 1996, the State of Illinois passed a law that promotes the planting of buffer zones at grade, to reduce stormwater runoff, in return for a reduction in property taxes. There is also a gradual move in North America toward lot-level stormwater user fees, which are based on the degree of impermeable surfaces on a given site.

If sufficiently implemented in an urban area, green roof systems can help to improve stormwater management. Studies in Berlin show that green roofs absorb 75% of precipitation that falls on them, which translates into an immediate discharge reduction to 25% of normal levels[53]. In general, summer retention rates vary between 70-100% and winter retention between 40-50%, depending on factors such as substrate and vegetation depths, temperature, sun and wind. Runoff that does occur is also stretched out over several hours, thereby helping to reduce the risk of flash flooding[54] and the frequency of combined sewage overflow events. Most of the stormwater is stored by substrate and then taken up by plants, through which it is returned to the atmosphere through evapo-transpiration[55].

A grass covered green roof with an 8-16" (20-40 cm) thick layer of substrate can hold between 4-6" (10-15 cm) of water[56]. In Toronto, where the average rainfall event is 1.5" (4 cm), a green roof could certainly become a viable stormwater management option. A three month long summer study showed that an extensive roof with a 7 cm deep vegetation layer produced no runoff, while the soil surface at grade, without planting, produced 42% runoff and a gravel surface produced 68% runoff[57]. Tom Lipton, a landscape architect in Portland, Oregon, recently used his garage roof as a site for testing the stormwater reduction claims of green roof systems. With a mixed layer of sedum and grass on only 2″ of soil he found that the roof retained between up to 90% of all the rain that fell on it, becoming less effective only during continuous and heavy rainfall[58].

Vertical gardens interrupt rainfall and delay runoff to some extent, especially during heavy rainstorms with strong winds, where the rain is falling more horizontally than vertically. Statistics on the impact of vertical gardens on stormwater are not currently available.

---

[53] (ibid., p. 1)
[54] (Liesecke, 1989, p. 17)
[55] (ibid.)
[56] (Minke, 1982, p. 15)
[57] (Liesecke, 1989, p. 17)
[58] (Thompson, 1998, p. 50)

Most stormwater management represents a cost-based activity. If widely implemented, green roofs and vertical gardens provide new opportunities to address urban stormwater management in a manner that also results in other proven environmental and social benefits.

3.9 Water Filtration and Quality Improvement

Greened surfaces not only retain much of the precipitation that falls on them, they also moderate the temperature of the water and act as natural filters for any of the water that happens to runoff[59]. Heavy metals and nutrients carried by the rain end up being bound in the substrate instead of being discharged. Studies show that as much as 95% of cadmium, copper and lead, and 16% of zinc have been taken out of rainwater by green roof systems[60]. A residence designed by the engineering firm Allen Kani and Associates and located North West of Toronto has half of the house roofed in metal and the other half in grass, with each section draining into a separate cistern to capture runoff. Over the years the owners have found that the water coming off of the grass roof was much clearer and freer of organic matter, while the water coming off the metal roof brought with it debris and organic matter, which subsequently contaminated the cistern[61].

3.10 Other Water-based Benefits

In addition to the generic benefits from green roof systems, they can also be design to perform particular functions, which help to increase the return on investment for the building owner. For example, the use and reuse of water can be integrated into the design of a green roof system in a number of different ways.

- Ecover Inc., a manufacturer of biodegradable laundry products in Belgium, has a factory, built in 1992, with 2 acres of native grasses and wildflowers on its roof. Effluent produced by the factory is treated in an on-site sewage pond at grade and then filtered through the green roof, while at the same time acting as irrigation and nutrient source for the plants[62].

- In the new inner-city development of Block 103, Kreuzberg, Berlin, nearly 40% of the roofs have been greened and many of the façades have been planted with climbers and vertical gardens, including a unique ‘vertical swamp’, which cleans the building's grey water through a system of planters filled with swamp grasses and aquatic plants. Water is released in measured amounts from the roof into the top planter and then through a system of pipes and drains, is filtered through successive layers of grasses. Upon reaching ground level the cleansed water can be reused[63].

---

59 (North American Wetland Engineering, 1998)
60 (Johnston, 1996, p. 12)
61 (Allen, G. 1999. Personal Communication)
62 (Thompson, 1998, p. 49)
63 (Johnston, 1996, p. 75-6)

- The Possman Cider Cooling and Storage Facility in Frankfurt, Germany uses a water-based heat exchange system to cool the building. The green roof was designed as a marsh with rain and roof water collected in an underground cistern pumped through the building to collect heat, run through the vegetation layer on the roof for cooling and filtration and then recycled back into the cistern[64] (See Case Study H).

- Roofs can also be used as water collectors and storage "cisterns" by using a floating layer of plants to decrease evaporation and act as a filter. By recycling the stored rainwater, whether in the building or on the site, companies like Possman eliminate the need to purchase water from other sources and consequently, are able to realize cost savings[65].

3.11 Sound Insulation

Soil, plants, and the trapped layer of air between the plants and the building surface can be used to insulate for sound[66]. Sound waves produced by machinery, traffic and airplanes can be absorbed, reflected and deflected. The substrate tends to block lower frequencies while the plants block higher frequencies. Tests have shown that a 5” (12 cm) layer of substrate can reduce sound by 40 dB; 8” (20 cm) can reduce sound by 46 dB[67] (with some reductions as high as 50 dB)[68].

The ‘white’ noise produced by the wind moving through the branches and leaves of vertical gardens can also play a positive role in enhancing an individual’s psychological well-being[69].

3.12 Building Envelope Protection and Life Extension

Green roofs have been proven to protect the roofing membrane against ultra-violet (UV) radiation, extreme temperature fluctuations and puncture or physical damage from recreation or maintenance[70]. The second 'Building Failure/Damage Report' issued by the German government in 1988, identifies roof greening as a solution to flat roof membrane failure[71]. For example, a London Department store installed a roof membrane under a planting in 1938 and 50 years later, the membrane was still in excellent condition. This is in a climate where most flat roofs have an average life span of between 10-15 years[72].

---

64 (Franke, 1994)
65 (Johnston, 1996, p. 12)
66 (North American Wetland Engineering, 1998)
67 (Minke, 1982, p. 15)
68 (Hooker, 1994, p. 3)
69 (Minke, 1982, p. 15)
70 (Liesecke,1989, p. 18)
71 (Liesecke,1989, p. 19)
72 (Johnston, 1996, p. 49)

On a roof, temperatures can swing from minus 20º-80ºC over the course of a day. A 4" (10 cm) thick green roof layer can reduce this range in temperature from 10º-30ºC, thus ensuring less expansion and contraction stress on the roof membrane, which in turn reduces cracking and aging[73]. The longer life-span decreases the need for re-roofing and the amount of waste material bound for landfill, both of which are direct cost savings for the building owner. Reducing building waste also helps to conserve municipal landfill capacity (See Case Studies H & L).

It is a misconception that vertical gardens will damage the wall they are covering; as long as the original cladding is in good repair, even vines that cling with their roots will not threaten the integrity of the wall. If the façade is not in good shape or has not been properly installed, vines can be trained to grow up a trellis (or another structure) that is kept separate from the wall itself or on a bottom-hinged system, which can be pivoted towards the ground while keeping the plants intact. These systems are ideal if periodic maintenance of the cladding is required. Vertical gardens actually protect the exterior finishes and masonry from UV radiation, driving rain and the wear and tear caused by moisture and temperature differentials. A façade can heat up to 60ºC and then cool to minus 10ºC with a layer of plants, temperatures will only fluctuate between 30º and 5ºC [74]. Plants will also increase the 'seal' or air tightness of doors, windows, and cladding by decreasing the effect of wind pressure[75].

3.13 Aesthetic Improvements

Urban greening has long been promoted as an easy and effective strategy for beautifying the built environment. Studies have shown that from earliest recorded times, Western cultures have conditioned their citizens to appreciate nature and to have negative associations with cities and their aesthetic[76].

A layer of plants can enhance good design or disguise bad design[77]. Plants can add visual interest to plain walls and roofs, soften industrial and commercial properties[78] and allow a new building to blend in better with rural or suburban surroundings. The new public library in Vancouver, Canada was designed with a green roof specifically to offer a better view to the residents of the surrounding office towers[79] (See Case Study I). Similarly, the new Mountain Equipment Co-operative green roof in Toronto, Canada will provide a much better view for the neighbouring hotel complex (See Case Study J).

3.14 General Health Benefits and Horticultural Therapy

---

[73] (Liesecke,1989, p. 49)
[74] (Minke, 1982, p. 18)
[75] (Minke, 1982, p. 25)
[76] (Ulrich, 1992, p. 95)
[77] (Johnston, 1996, p. 32)
[78] (Liesecke, 1989, p.13)
[79] (Thompson, 1998, p. 49)

The belief that contact with trees, shrubs, grasses and flowers fosters psychological well-being and reduces the stress of urban living dates back to ancient cities like Cairo, Mesopotamia and Rome. More recently, visual contact with vegetation has been proven to result in direct health benefits. Psychological studies have confirmed these beliefs by clearly demonstrating that the restorative effect of natural scenery holds the viewers' attention, diverts their awareness away from themselves and from worrisome thoughts and elicits a meditation-like state[80]. Swedish studies on brain wave activity also indicate that views of natural settings elicit a wakeful and relaxed state characterized by a decreased heart rate and a quicker stress recovery time[81].

A 1984, Pennsylvania-based study was conducted on the restorative effect of natural views in surgical patients. The study involved patients in the same hospital undergoing the same operation. Half the patients looked out onto a brick wall and the other half onto a landscaped courtyard. The study showed that the patients with the garden view had shorter post-operative hospital stays, fewer negative evaluation comments from the nurses and took less pain medication[82].

Windowless rooms or rooms with little or no visual access to the outdoors, are disliked and cause stress, especially in the workplace and in healthcare facilities. Studies conducted in 1982 and 1985 showed that prison inmates whose cells look out over farmlands and forests were less likely to report for a sick call than those whose cells looked out onto walls, buildings, or other inmates[83].

People living in high-density developments are known to be less susceptible to illness if they have a balcony or terrace garden[84]. This is partly due to the additional oxygen, air filtration and humidity control supplied by plants. Trees in a park setting can filter out up to 85% of airbourne particulates, with the leaves of climbing plants providing an equally large surface area capable of filtering out dust, pollutants and possibly even viruses. Additionally, there are therapeutic benefits from the act of caring for plants. The variety of sounds, smells, colors and movement provided by plants, although not quantifiable, can add significantly to human health and well being.

Based on these proven psychological and physical benefits, Kassel, Germany launched a public campaign in 1993 to encourage people to grow climbing plants. Similar actions have also been taken in Munich, Berlin and Frankfurt[85].

3.15 Improved Safety

A garden or amenity space on a roof is often considered safer than one located at grade for the following reasons:

---

[80] (Ulrich, 1992, pp. 96 and 4)
[81] (Ulrich, 1992, p. 99)
[82] (Ulrich, 1984)
[83] (Ulrich, 1992, p. 101)
[84] (Johnston, 1996, p. 27)
[85] (Johnston, 1996, p. 33)

- There is less likelihood of assault or vandalism because access to the roof is usually restricted to building tenants or employees.
- The public services and utilities that may hamper garden installation or digging on the ground do not exist on the roof.
- Pollution levels on the roof are lower than at street level.
- Soil quality, including contamination through heavy metals, hydrocarbons, and the use of pesticides and herbicides, can be controlled since everything has to be sourced and then brought up to the roof (this is of particular relevance if the green roof is being used for food production).

3.16 Recreation/Amenity Space

Studies show that leisure activities in natural settings such as gardens and parks are important for helping people cope with stress and in meeting other non-stress-related needs[86]. Green roofs and vertical gardens can help to address the lack of green space in many urban areas. Due to a lack of urban green space, many urban dwellers flee to the cottage, the country house or move to the suburbs at the first opportunity[87].

The benefits of active gardening have long been known. In Montreal, Quebec, the city funds a community gardening program. Other cities have seen rapidly growing interest in community gardening over the past five years.

Many urban dwellers consider the roofs and walls of buildings as a city's greatest untapped resource. Finding new ways to utilize roof and wall space can generate added economic impetus and make cities more livable by providing significant amounts of accessible outdoor recreation or amenity space close to work and home. Over time, the widespread applications of green roofs may even help to stem the exodus from urban areas to the suburban fringe (Case Studies B, C, D, K, L).

Greening is often the only legal and also one of the least expensive ways that an individual tenant can personalize or change the exterior of their building, apartment unit or exterior living space.

3.17 Community Building

Persons planning, organizing and maintaining a communal garden or outdoor space confirm that the process can only succeed if the surrounding community gives its support. Without continuous use, maintenance, communication, labour, funding and goodwill these projects do not succeed. However, when they do work, the results are very inspiring (See Case Study B).

---

[86] (Ulrich, 1992, p. 98)
[87] (Stifter, 1997, p. 156)

Apartment buildings, although densely populated, seldom become 'communities' unless the residents are able to rally around a common goal or against a common problem. The creation of shared gardens, like the green roof on top of the Mary Lambert-Swale housing project in Toronto (See Case Study D), allows residents to feel ownership of their building and meet neighbours in a relaxed setting. The propensity of apartment dwellers to grow plants on their balconies attests to the potential for vertical gardens to help build communities.

3.18 Economic Benefits

There are a number of different types of economic benefits, several of which have already been discussed throughout Section 3 of this report. The nature and scale of economic benefits vary by project and jurisdiction, and are shared among building owners, operators and the general public.

Typical economic benefits and opportunities for building owners that implement green roofs and vertical gardens include:

- Increase in the R-value of the walls and roof of the building, resulting in energy cost savings related to space heating and cooling and leading to reductions in greenhouse gas emissions.

- Protection of the roof membrane and the wall cladding, which results in a longer material life span, decreased maintenance and associated savings in replacement costs. Green roofs and vertical gardens have been proven to protect the roofing membrane and cladding against UV radiation, extreme temperature fluctuations and puncture or physical damage from recreation or maintenance.

- Increase in stormwater management may offset these costs elsewhere in a development by, for example, reducing the need for stormwater management ponds or reducing fees where lot level stormwater user fees apply. In most European cities residents must pay a fee, tax or service charge for hooking up to the stormwater system. In Germany however, residents with green roofs receive discounted rates[88].

- Increase in property values - American and British studies show that good tree cover increases the value of a home by 6-15%. Vertical gardens and green roofs offer very similar visual and environmental benefits. Urban beautification will also have an impact on tourism and the way visitors view the city (Case Studies J & K).

- Provision of outdoor amenity space and aesthetic appeal can directly increase the value and marketability of a property (e.g. private gardens on the top of downtown condominiums) (See Case Study C).

---

[88] (ibid.)

- Provision of a business-related function, such as the cooling of water used in industrial processes (See Case Study H). The cleansing of wastewater and the growing of herbs and other urban agricultural products are less commonly realized as benefits but can add economic value to underutilized roofs and walls. Similarly, the implementation of gardens by hospitals can improve patient recovery rates, which translates into cost savings in health care. Noise reduction benefits can also help offset additional costs for buildings where noise control is an issue.

Standard cost savings realized through the greening of a roof or wall are often immediate in terms of reduced space heating and cooling costs, but pay back periods are typically medium to long-term. Cost savings are however, difficult to estimate accurately and vary considerably between projects. Installation of a green roof or vertical garden requires an up-front capital investment, especially in a retrofit situation. However, this initial expense can be returned through long-term cost savings[89]. If the concept is included at the beginning of the design phase for a new building, a green roof can be installed at little or no extra capital cost[90]. For example, the green roof component of the new administrative building for the Chancellor of Germany was only 0.1% of its total cost[91]. For developers or turn-key operators, who are looking to build and sell quickly, even this extra expense can be seen as a barrier, unless they are convinced that the property will become more marketable.

The life cycle costs would be moderately increased by the maintenance of the garden, but would be decreased by the extended durability and minimized maintenance of the building envelope[92], as well as the savings in energy costs. Although costing is site and roof specific, some rough figures are provided below:

- An extensive green roof is 50-80% cheaper than an intensive green roof[93].

- According to 1987 pricing in Britain, a simple do-it-yourself green roof installation can cost around $5.11 per sf/$55 per sm; a professionally designed and installed green roof can cost $12 per sf/$130 per sm, which is three times the cost of an average flat roof[94].

- A Soprema *Sopranature* green roof on an existing roof can cost between $5.00 and $10.00 psf for supply and installation add $3.00 psf to include a special waterproof membrane[95].

[89] (Johnston, 1996, p. 12)
[90] (Johnston, 1996, p. 71)
[91] (Johnston, 1996, p. 72)
[92] (Hooker, 1994, p. 3)
[93] (Johnston, 1996, p. 72)
[94] (ibid.)
[95] (Rouyer, 1998)

Additional data shows that if the extra load bearing capacity, the railings, the root protection and the greening layers are included from the very beginning, they can end up costing less than 0.5% of the total building cost[96]. Unfortunately, similar cost estimates are not yet available for vertical gardens. Additional cost-based barriers and opportunities to overcome them are discussed in Sections 4.0 and 5.0. A green roof or a vertical garden becomes even more viable where the price of land, or the lack of available adjacent land, prevents the creation of garden or green space at grade[97]. Marketing studies have shown that people place a high value on green space. By providing green space, developers, building owners and companies are often more effective at attracting and retaining buyers and tenants and keeping qualified and motivated staff[98] (See Case Study C).

The following points summarize some of the major economic benefits for the community-at-large:

- Job creation in design, growing, manufacturing, installation and ongoing maintenance.
- Increased livability of cities, including overall worker productivity and creativity.
- Various air quality improvements that have a direct impact on human health and well being.
- The ability to retain and treat stormwater runoff, which if sufficient, can help decrease capital and operational expenditures on related urban infrastructure.
- Reductions in operation expenses of publicly-owned buildings such as schools, hospitals and offices.
- The benefits of passive and active experiences with nature and vegetation decrease the need for health care services[99].

Green roofs and vertical gardens can be located in courtyards, on terraces, balconies, rooftops and parking garages and will increase property values. This makes them accessible to people in offices and multi-family residential buildings and doubles or stacks the function of the property - two uses for the price of one (See Case Study L)!

Despite the numerous economic benefits from these technologies, additional quantitative information on the economic benefits for installations in Canada is required. A method of evaluating these benefits for a variety of different applications needs to be developed.

---

[96] (Stifter, 1997, p. 158)
[97] (Liesecke, 1989p. 13)
[98] (Johnston, 1996, p. 12)
[99] (Ulrich, 1992, p. 101)

3.19 Job Creation

The job creation potential of green roof technologies is significant as has been demonstrated in Europe. The recent growth of the green roof industry in Europe has been remarkable, with an average annual growth in the German green roof industry of between 15-20% since 1982. With one million m^2 of extensive grass roofs under construction in (West) Germany as early as 1989 and over 10 million m^2 completed in 1996, the impact on the market and job opportunities has been experienced by many sectors. Green roof installations can create and enhance the following job markets:

- Suppliers and manufacturers of roof membranes and root repellent layers.
- Suppliers and manufacturers of drainage layers, landscaping cloth, curbs, irrigation systems and other specialty products.
- Suppliers and manufacturers of substrate, light-weight soils and amendments.
- Wholesale and retail nurseries specializing in plants specifically for green roof and vertical garden applications (vines, sod with wildflowers or alpine/succulent varieties, soil and seed/plant sprout mixes, seeded erosion blankets, etc.).
- Designers, roof consultants and engineering professionals.
- Contractors and landscapers.
- Companies supplying maintenance contracts.

Although an industry for vertical gardens does not yet exist, similar employment benefits may be expected particularly for container based or hydroponic systems.

In addition to the employment generated through the implementation and maintenance of green roofs and vertical gardens, there is great potential for producing high quality food in urban areas. Although in its infancy in North America, many cities of the developing world have realized this potential and grow significant amounts of food for local consumption[100].

Green roofs and vertical gardens can help facilitate significant local agricultural production in urban and suburban areas. There are numerous benefits associated with increasing local food production:

- Increased access to food by everyone, including lower income, inner-city communities.
- Fresher produce.

[100] Smit, 1995)

- Decreased travel and environmental costs, such as greenhouse gases generated by long range transportation and cooling requirements.

- Local economic opportunity in growing, processing and distribution.

- Improved control of soil, fertilizers and pesticides.

Vertical gardens can be used to grow fruit (on espaliered trees), grapes and climbing vegetables (such as squash, tomatoes, beans and some types of leafy greens). Green roofs can produce a variety of fruits, grains and vegetables (either in containers or as field crops). By placing a portion of the roof under glass (with greenhouses or coldframes), food production can also extend into the winter season and could be combined with water collection, treatment or filtering systems for the building[101].

Since 1995, a firm called Annex Organics has grown organically certified food on an experimental 1,000 square foot roof garden in downtown Toronto. In 1997, using a hybrid hydroponic system, they grew approximately 500 lbs. of saleable tomatoes. These were sold at $2.00 /lb. ($0.50-$0.75 above the market price of other organic tomatoes) and the business grossed about $1.00 /square foot[102] (See Case Study G).

From May-September 1998, an experimental hydroponic green roof at the University of Toronto, Faculty of Environmental Studies approximately 2 x 1.5 m in size, produced 1,200 hot peppers (6 different varieties), 100 cherry tomatoes and 40 large tomatoes[103].

Hydroponic designs are lightweight and do not require a traditional growing medium. In one such design the plants are grown in containers suspended above the roof. A water-nutrient solution and air are pumped to the roots through separate tubes. This system eliminates the need for soil or other growth mediums that retain large amounts of water. The water-nutrient solution is recycled, requiring a change at infrequent intervals that depend on the specific plant. A similar hydroponic design can be adapted for vertical gardens as well (See Case Study F). Another variant of this design is to leave the roots exposed to the air and to apply the water-nutrient solution as a mist. This however is problematic in an outdoor application, as evaporation of the liquid will result in subsequent over-concentration of the nutrients. These designs are suitable for food crops such as tomatoes, peppers, lettuce and escarole.
A single concord grapevine covering the front façade of a small, south-facing, semi-detached house in Cabbagetown, Toronto has been producing 3 bushel-baskets of juice grapes for the last 3 years. The grapevine is 5 years old and was installed primarily to shade the house from the summer sun[104].

The yields from these technologies depend considerably on the climate and the growing media used. The use of green roofs and vertical gardens to produce high quality food

[101] (Johnston, 1996, p. 49)
[102] (Loverock, 1998)
[103] (Bass, 1998)
[104] (Smith, 1997)

locally in North America is still in its infancy. However, these and other alternative uses of wasted building space hold tremendous promise through the application of rooftop and vertical garden technologies.

3.20 Preservation of Habitat and Biodiversity

Habitat is defined as the "specific surroundings within which an organism, species or community lives. The surroundings include physical factors such as temperature, moisture, and light together with biological factors such as the presence of food or predator organisms".[105] With ongoing suburbanization, buildings, lawns and pavement are replacing natural habitats such as meadows and wetlands. This causes plants, animals and insects to adapt, find other locations to live, become extirpated or in some cases, extinct. Green roofs and vertical gardens can be designed as acceptable alternative habitats although they should never be considered as substitutes for natural habitat or as a justification to destroy natural habitat at grade[106] (Case Studies A, C, J).

In Europe, two types of green roof habitats have been defined and implemented as part of a larger system of wildlife corridors in urban areas:

- A stepping-stone habitat connects natural isolated habitat pockets with each other. It is important to remember that this connection can be by air only (nesting and migrating birds, insects, air-borne seeds) since the height difference prevents most animals and plants from reaching the roofs.

- An 'island' habitat that remains isolated from habitat at grade. This type of habitat would be home to specific plant varieties whose seeds are not spread by air or over short distances.

Green roofs are also specifically designed to mimic endangered ecosystems/habitats, including the prairie grasslands of the midwest United States[107], the rocky alvars of Manitoulin Island and the Great Lakes Region in Canada[108]. In Germany, 20% of all endangered plants are arid/semi-arid grassland plants, conditions specific to an extensive green roof installation. Dryness, heat, frost and lack of oxygen are rooftop conditions that are very similar to the dry grassland ecosystem which have been seriously degraded by fertilizing, irrigation and other forms of human interference.

Extensive green roofs, because of their lack of human intervention, are more protected and can become home to sensitive plants that easily damage by walking and to bird species that only nest on the ground. Since the soil on an inaccessible green roof is also less likely to be disturbed, it becomes a safer habitat for insects as well. The deeper the soil the more insect diversity the green roof will support.

---

[105] (Stevenson and Wyman, Ed., 1991)
[106] (Johnston, 1996, p. 49)
[107] (North American Wetland Engineering, 1998)
[108] (Reid, 1996)

The animals and invertebrates found on a green roof tend to be highly mobile, not only because they have to be able to reach the roof in the first place, but because the varying and intense temperature and moisture levels force them to move from one location to the next[109]. American studies show that butterflies will visit gardens as high as 20 stories high[110]; bees have been found on the 23rd floor; and birds fly up to the 19th floor. Birds, including a falcon, regularly alight and even nest on the Ecover factory green roof in Belgium.

Vertical gardens can also create important habitat for birds and insects. Birds eat insects as well as the berries and fruits produced by certain vertical garden plants. Insects however, typically will not migrate into buildings since the interior environment does not offer the food they would find outside.

Conclusion

Green roof and vertical garden technologies offer a wide range of social, environmental and economic benefits for building owners, building residents and the general public. These technologies are specifically useful for urban and suburban applications where they simultaneously address many of the most pressing environmental problems facing these areas.

Some of these benefits are well proven and result from all projects; others are project specific by nature. Community-wide benefits such as improved stormwater management and reductions in airbourne particulate matter will likely require the widespread adoption of these technologies. Other benefits such as moderation of the Urban Heat Island Effect are still not well understood and will require further research and investigation. Much less is known about the quantifiable benefits of vertical garden technologies than green roof technologies.

Despite the efforts of a number of firms, Canadians have been slow to embrace green roof and vertical garden technologies. As a result, communities have yet to exploit the many economic, human health and ecosystem advantages they can confer. Section 4.0 of this report describes a number of reasons for the lack of market penetration for these 'sustainable development' technologies. Section 5.0 presents a proposed National Action Plan to help overcome these barriers.

4.0 Barriers to Green Roof and Vertical Garden Technology Diffusion

All new technologies face barriers to market entry such as lack of pilot projects, uncertainties over costs and benefits and unfamiliarity among users and clients. Even though green roof and vertical garden technology is proven and well established in Europe, barriers to market entry in North America have prevented their widespread

[109] (Johnston, 1996, p. 69)
[110] (Johnston, 1996, p. 49)

diffusion. With the exception approximately 20 examples, green roofs are not very well utilized in Canada.

At a workshop held in Toronto, Canada on November 24, 1998, over sixty participants, primarily from industry, identified and prioritized many of the barriers to green roof implementation. These barriers are structured into four main categories with some overlap. Each category is discussed below in greater detail:

- Lack of Knowledge and Awareness
- Lack of Incentives to Implement
- Cost-based Barriers
- Technical Issues and Risks Associated with Uncertainty

4.1 Lack of Knowledge and Awareness

It may be surprising to some that the concepts of green roofs and vertical gardens, so widespread in Europe, are still relatively unknown in North America. Here, vines are often planted indiscriminately, without the knowledge of their various benefits. Roof greening techniques are most frequently applied at grade locations (i.e., on top of an underground parking garage or a shopping concourse), where they often go unnoticed because the public, seeing a landscaped space, assumes that there is nothing but soil beneath their feet. Hence, the many benefits of rooftop and vertical greening, both quantifiable and qualitative, are not well known among the development industry, professionals, politicians and the general public.

There are four main groups of stakeholders who require additional knowledge on the subject of green roofs and vertical garden technology:

- *Policy Makers*. Politicians and staff at all levels of government, but municipalities in particular need knowledge about both the traditional and social costs and benefits of green roofs (social, environmental and economic as discussed in Section 3.0). This includes such things as:

    - ♦ Creation of a 'new industry' resulting in jobs for suppliers of green roof materials and a variety of green roof 'experts' such as landscape architects, architects, roofers, builders, gardeners, etc.
    - ♦ Possibility of local food production (See Case Study G).
    - ♦ Stormwater quality and quantity improvements.
    - ♦ Costs and benefits of various policy and program opportunities to promote implementation.
    - ♦ The reaction of stakeholders (public, building owners, building industry) to government policy and program measures that support and promote the use of these technologies.

    - ♦ The role of green roofs and vertical gardens in meeting Canada's commitment to reduce greenhouse gas emissions and in adapting urban areas to climate change.

- *How-to Professionals.* The North American construction industry is not very well integrated - every task requires a different sub trade, often a different union and sometimes a different contract and warranty period. Green roofs and vertical gardens may require that bricklayers, roofers, framers, landscapers and mechanical contractors work together to create the final product. Each layer of the system is dependent on the one below it, so each sub trade must know the requirements demanded by the next sub trade in the process as well as the desired outcome. In Europe, companies like Soprema Inc. have overcome this problem by creating 'turn-key' companies that implement the complete project. 'How-to' professionals require:

    - ♦ Information on plants, seed mixes, products and vendors.
    - ♦ Case examples to show potential clients.
    - ♦ Better knowledge on data, costing, finance, performance and other technical parameters.
    - ♦ Better knowledge about the cost savings for building owners, maintenance expenses, etc. (See Section 4.3).

- *Researchers*. Researchers need to be familiar with the existing body of knowledge so they can make contributions such as:

    - ♦ Detailed energy savings information from different types of applications, growing media and plants.
    - ♦ Detailed information on stormwater benefits and the benefits in aggregate.
    - ♦ Modeling economic benefits from different applications.
    - ♦ Large scale benefits, such as reducing greenhouse gases by reducing the Urban Heat Island Effect and reducing stormwater runoff.
    - ♦ Climatological and ecological studies of green roofs and vertical gardens and comparisons to similar environments found in nature.

- *General Public*. Knowledge about many public benefits of green roofs will help create a political demand for government incentives as well as demand for residential, commercial and industrial applications. For this to happen, the public requires knowledge about the many broad benefits of green roofs and vertical gardens as well as the economic benefits. This can help create a political demand for government incentives as well as increased demand for residential applications. Benefits that need to be communicated to this group include:

    - ♦ Improved stormwater management.
    - ♦ Improved air quality (i.e., particulates).
    - ♦ Reduction of greenhouse gases.
    - ♦ More amenity/recreational space.

- Better local food production.
- Jobs/employment opportunities.
- Aesthetic benefits.

Soprema Inc., in comparing its marketing strategies for Canada and Europe, found that Canadians appear to value aesthetics and want 'instant' results. In contrast, Europeans value environmental benefits, encourage the diversity of 'weeds' in their plant mixtures and are prepared to wait for up to 2 years to allow the garden to establish itself.

A common complaint is that vertical gardening takes a long time before results are seen. While the green roof can become green over the course of one year, vertical gardening vines generally take 2-3 years to establish themselves, before they will begin to grow enough to make a difference. This can be solved by using older plants, inter-planting annual climbers, fastening containers to the wall[111] or using a hydroponic system.

The lack of information about the characteristics of the different types of green roof and vertical garden systems leads some to believe that the installation will require constant and costly maintenance. Common questions about maintenance include:

- Will the garden cause the roof to leak?
- Will the roots penetrate the roofing membrane?
- Will the grass have to be cut?
- Will the containers fall off the wall?
- Will the vines have to be pruned?
- Will an irrigation system be required?
- What are the nutrient concentrations in a hydroponic system?

These inquiries can all be addressed with available information. For example, green roofs are designed to capture and drain water; this function will not change with a green roof as long as drainage paths are kept clear and the membrane is not damaged during installation of the garden. Typically, the substrate including the plants and roots, are separated from the membrane by the drainage layer and from the parapet and any roof penetrations, by a barrier of gravel. This makes it very difficult for the roots to do any damage. As well, a root barrier is placed between the membrane layers for extra security.

With extensive systems, maintenance involves a first season of irrigation and monitoring to ensure that the plants get established, after which the garden should require no more than 2 or 3 inspections per year with no additional watering. Accessible, intensive systems require more care. Some vines will require pruning and training once a year. Grass on green roofs can be cut or left to grow, depending on the aesthetic desires of the owner. Building owners should be reminded that every system within their buildings including the roofing membrane itself, requires ongoing, periodic maintenance and a green roof or vertical garden will be no different.

[111] (Minke, 1982, p. 24)

In addition to the lack of available information, there are also misconceptions about these technologies. The most common misconception about vertical gardening is that the vines will damage the wall they are climbing on. This is true only if the wall or the material joints are already in poor condition[112] and in this case, the same greening effect can be achieved by choosing a vine that doesn't cling directly to the building. For example, a vine can wrap around or attach itself to a trellis-like screen or structure.

One issue that cannot be adequately addressed at this time is the extension of vertical garden designs above eight stories on high-rise residential or office buildings, as the building's microclimate is expected to change with elevation. Different plants might be better suited to these heights due to changes in temperature and wind speed. In addition to the plants, the structure that supports the plants would also have to be designed to account for the higher wind speeds at these heights. At this time there are too few examples of these types of vertical gardens to assess which plants and designs are best suited for different heights.

Toronto's *Rooftop Gardens Resource Group*, a volunteer organization established in 1993 to promote green roofs, has noted a steady increase in the number of inquiries for information coming from locations around the world about the theoretical and the practical applications of this form of urban greening. However, much of the existing information, particularly quantitative data, is not easily accessible or even available in English.

4.2 Lack of Incentives to Implement

The development of a 'green roof industry' in Europe is largely the result of legislation passed in Germany in 1989 requiring new developments to install green roof systems. A number of similar legislative developments at the state level as well as financial incentives by municipal governments such as Mannheim, Germany, create markets for these technologies among new and existing buildings. The City of Mannheim passed a by-law in 1988 that requires developers to install green roofs on most new and renovated industrial, retail, commercial and some residential developments in the downtown core. The by-law applies to roofs or rooftop parking lots that are greater than 20 m^2, are flat or have less than a 10º slope. The by-law provides developers with increased height and density allowances to compensate for the added costs of green roofs[113].

In North America, there are virtually no government incentives to support green roof technology diffusion, despite their many proven public benefits. Major types of potential government support identified during the workshop include:

- Research and demonstration projects.
- Grants and subsidies for implementation.
- Green roof/vertical garden procurement policies for publicly owned buildings.
- Legislation, by-laws and building codes requiring installations.

[112] (Minke, 1982, p. 18 and Cutler, 1992, p. 13)
[113] (Overtveld, 1990, p. 4)

Reasons for the lack of government support were also identified during the workshop. These include:

- Lack of easily accessible information about the social, environmental and economic benefits.

- The benefits are long-term while the capital costs are up-front, which is a strong disincentive for those who would otherwise invest in green roofs.

- Many of the economic benefits (e.g. operations) are not necessarily accrued by the initial developers or investors, or are public in their nature.

- There is no readily available information on local success stories.

- Many social benefits will result from widespread application, particularly in cities, but these are not captured in the current market place (hence, the need for government market stimulus).

Once appropriate government incentives are in place, the industry will be able to implement projects and work to overcome other barriers.

4.3 Cost-based Barriers

More information needs to be assembled about the full range of 'traditional' and 'public' costs and benefits. The lack of detailed information about benefits is exacerbated by the lack of information about associated costs. Unless green roofs and vertical gardens are part of a new project at its initial design stage, they are much more difficult to sell to potential clients. In the case studies described in Appendix II, most building owners/managers have not monitored or tracked the resulting financial benefits.

Different types of installation costs include upfront capital costs, maintenance costs and lifecycle costs (i.e., roof replacement might cost more when it has to be done with a garden). The lack of cost and benefits data establishes a number of interrelated barriers to implementation centred on the economics of the technology and the marketplace:

- There is a lack of understanding about direct, tangible and long-term economic benefits. This means that the costs appear to be much higher than they actually are and the market fails to drive implementation. Moreover, there are disincentives to market acceptance of long-term benefits - the average homeowner moves every five years, and governments, as major property owners, often now tender on the basis of price alone.

- The technology often requires maintenance costs to be built into the original budget (almost all gardens require some level of maintenance). Maintenance budgets are commonly the first to be cut when operations budgets become restricted.

- Long-term maintenance costs should be small, especially since damage to the building envelope will be reduced, but these exact costs are not known. Long-term maintenance also requires effort and initiative on the part of the building owner/manager.

- Green roofs and vertical gardens represent 'new territory' with respect to industry insurance and liability issues. Issues here concern weight, drainage, interior damages from roots, damage to walls and liability to personal injury.

- Additional up front design costs may be incurred – consultants and structural engineers will be needed. This can provide a strong deterrence for 'turn key' developers who are unlikely to reap the 'downstream' operational cost saving benefits.

- Additional infrastructure costs may be required (i.e., railings to allow public access to green roofs).

The lack of 'full-cost accounting' of externalities such as air and stormwater pollution in the market place is seen as a barrier since market forces alone will not drive the widespread implementation of these technologies that generate important benefits in each of these areas.

There is also a perceived unwillingness of decision-makers to enter long-term investments that often yield the greatest degree of public benefit. Due to pressures on public finances, government procurement is shifting to short term, bottom line driven decision making while quality, longevity and innovation are sacrificed.

4.4 Technical Issues and Risks Associated with Uncertainty

The fourth category of barriers has to do with technical issues and the associated uncertainties that result. Available technical data has not been tested in the North American climate - except for Soprema Inc., which has tested its *Sopranature* product line through the Horticultural Research Centre at Laval University, Quebec since 1994[114]. Soprema Inc. is a leader in Canada with respect to developing and marketing a fully integrated green roofing system.

Funding for research, unless sponsored by industry stakeholders, has been difficult to access. The multi-disciplinary nature of the subject has often prevented application to specific funding sources. It is interesting to note that the construction industry has the

[114] (Rouyer, 1998)

lowest budget for research and development of any sector compared to its employment and revenue contributions.

Due to the lack of knowledge in the marketplace, designers must constantly 'reinvent the wheel' by sourcing off-the-shelf products and making assumptions about load bearing capacity and the compatibility between different layers of material, plants and water[115]. Because the products and materials that are available were not specifically designed for rooftop or vertical applications, it is difficult to provide the warranty or guarantee that institutional and commercial clients often request.

Additional technical barriers were discussed at the workshop – many of which reflected the high degree of 'on-the-ground' knowledge among workshop participants. These included:

- The lack of specialized products on the market as well as the lack of built examples of green roof and vertical garden installations creates an understandable lack of client confidence in both the designer and the concept.

- The cost of specialized products can also be prohibitive. Soprema Inc. has found that due to transportation costs, some of the major mineral components of their growing medium are 10-15 times more expensive in Canada than in Europe. Attempts to replace these natural raw materials with secondary recycled byproducts from local industry have not been successful.

- Although gardening has become a popular hobby, most gardeners have little or no experience with the specific techniques for designing and maintaining the types of 'gardens' grown on roofs and walls. This is further inhibited by the lack of specific plants or seed mixes available for purchase. In Europe, there are nurseries that specialize in supplying plant stock, sod, sprouts and seed mixes that are grown and marketed specifically for green roof applications. In North America, installers are not able to purchase plants as part of a prefabricated roofing system and therefore take what the nurseries have in stock and pay higher prices. Alternatively, they order the plant quantities required for a roof a year in advance. Direct seeding of a garden, although cheaper per plant, requires more initial maintenance and irrigation.

- To date, the only companies in North America supplying products and services specifically for green roof installations are:

    - ♦ Soprema Roofing, Quebec, Canada (subsidiary of a French parent company), designing, manufacturing and installing the Sopranature complete green roof package, with warrantee.
    - ♦ North American Wetland Engineering (NAWE), Minnesota, USA, importing the German ReNatur product line.

---

[115] (Goode, 1986, p. 51). A roof greening manual in English, written by Landscape Architect Theodore Osmondson entitled*, Green Roofs: History, Design, and Construction* is waiting to be published in California.

- ♦ Roxul Insulation, Ontario, Canada, importing the Danish firm Grodania's Grodan rockwool growing medium.
- ♦ Hydrotech Membrane Corporation, Canada, importing the German firm Zinco's drainage system.
- ♦ The Garland Company Inc., importing systems from Europe.

Other firms, such as architects and landscape architects provide the required consulting services and there are a few landscaping companies familiar with installation techniques.

- Four-season aesthetics – some types of green roofs may look worse than bare roofs in winter.

- Difficulties in managing maintenance effectively. Improper maintenance can cause roof damage (i.e., tree and woody plant seedlings establishing themselves on a roof that was meant only for groundcover).

- Consultants who design green roofs may not be around after it is built, causing liability and warranty concerns among clients.

- The gardens require trained maintenance staff, especially during the first few years. A failure in maintenance will result in an unsuccessful garden, which can be perceived as a failure in the technology. Most of the problems and system failures in green roof systems are caused by faulty installations, damage during installation or maintenance, improper drainage or neglect (e.g. tree and woody plant seedlings establish themselves on a roof that was meant only for groundcover).

- There are no industry technical standards for green roofs or vertical gardens, which means there are no standards in building codes or warranty assurances.

- If a green roof is to be accessible to tenants, staff or the general public, it must comply with certain requirements of the building code. These elements are much easier to include in the initial design of the building than after the fact.

- It can be technically difficult and risky to adapt existing roofs to carry the weight of a garden, particularly if structural requirements are not well known. There may also be unknowns related to:

  - ♦ Fire hazards.
  - ♦ Relationship to other buildings (shading, wind, microclimate etc.).
  - ♦ Effect of green roofs (pollen, leaves and dirt) on mechanical units.
  - ♦ Effect of vertical gardens on the cladding.
  - ♦ Maintenance requirements and costs.

This may or may not be a problem for vertical gardens, but there are not enough examples to make a general statement.

Conclusion

Many of these barriers represent fairly standard challenges facing the adoption of new technologies. Fortunately, much of the technical, policy and market-based information on green roofs is available in Europe and can be adapted to Canada.

Difficulties in identifying the costs and benefits of green roofs and vertical gardens are perhaps the most difficult challenge. Tangible economic benefits are difficult to quantify and guarantee. The significant environmental and social benefits attainable, in the absence of government policy, do not find expression in the market place.

Recommendations on how to overcome many of the barriers discussed in this section are presented as a proposed National Action Plan in Section 5.0.

5.0 Generating Opportunity – Towards A National Action Plan

The following recommendations are based on our research and the input generated from the workshop participants. They form the basis of a proposed National Action Plan to promote the more rapid diffusion of green roof and vertical garden technologies in Canada. These recommendations are directed at a variety of industry and federal, provincial and municipal government stakeholders. The recommendations are based on the fact that these technologies provide proven and outstanding, public and private, economic, social and environmental benefits and the realization that current market conditions are insufficient to effectively promote their diffusion.

With the appropriate level of government support and industry/government partnerships, green roof and vertical garden technologies can help initiate substantial progress in achieving sustainable development throughout Canadian cities. These technologies can also help to address Canada’s international commitments to reduce greenhouse gases that result in climate change. Moreover, the diffusion of green roof and vertical garden technologies will help Canadian urban and suburban areas begin adapting to the negative impacts of climate change and atmospheric variability.

The National Action Plan is designed to address the four major types of barriers described in Section 4 and represents a synthesis of the workshop findings and our research. Implementation of these recommendations will require partnerships and shared information and resources among industry and government stakeholders.

5.1 Addressing Knowledge and Awareness Barriers

Compile a repository of green roof and vertical garden knowledge on the Internet, integrating all professional fields and international data. Make it available to the public as well as to the 'how to' members of the industry and promote it accordingly. Informational resources should cover elements such as:

- Climatic and ecological theory, technical data, costing, finance opportunities and performance indicators.
- Data on the full 'bottom-line' and public value of green roofs directed to building owners and to the general public.
- Detailed case studies and examples, wherever they exist.

Lead implementers for this initiative could be industry representatives such as manufacturers, architects, engineers, builders, university researchers and all orders of government.

5.2 Generating Awareness through High Profile Demonstration Projects

CMHC could work to establish a government co-sponsored design and implementation green roof and vertical garden demonstration competition - The *National Green Roof and Vertical Garden Design, Implementation and Monitoring Competition* in six major cities (e.g. Halifax, Ottawa, Montreal, Toronto, Edmonton and Vancouver). The competition should be a partnership between local, provincial and federal government agencies wherever possible.

Contestants could be required to design green roofs and vertical gardens for both new and existing buildings. These might involve two publicly and two privately owned buildings in each city. Each project should be built and monitored in addition to being designed. Designs that minimize up-front capital costs should be a key criterion of success. Additional criteria for selecting buildings and winning submissions should include:

- Projects should be awarded on a competitive basis.
- Each project should be marketable (i.e., these projects should be chosen on the basis that they can be replicated – financially and technically – in other niche market segments).
- Projects should result in multi-functional benefits including a mix of societal (i.e., climate change/stormwater) and personal (roof membrane life extension, cooling and energy cost savings).
- Projects should be in high profile locations in each city.
- Several projects should be accessible to the public, government and industry representatives.
- Projects should involve monitoring of benefits, performance evaluation and maintenance.

This competition would raise awareness, galvanize interest among the private sector and improve awareness and technical know-how. It could be implemented in the fall of 2000, in time for year 2001 implementation across Canada.

The competition would provide a ‘test’ market for industry representatives, data for the research community, harness creative energy and provide full-scale, high profile demonstration projects in major cities resulting in better market awareness for these technologies. The competition would also help to develop a better understanding of the costs and benefits related to a variety of applications and provide technical data in a variety of climatic conditions.

This competition could be implemented by all orders of government in partnership with the private sector. The contestants would be teams of roofers, designers, engineers, financiers, landscapers and landscape architects, energy service companies, nurseries, roofing consultants and manufacturers.

5.3 Government Procurement Support for Technology Diffusion

One important type of government support for these technologies is through procurement. Each major census metropolitan area in Canada could develop a detailed plan to implement green roofs on their properties within the next three years. For example, the City of Toronto owns approximately 1,700 buildings. If the City of Toronto committed to 'greening' 20% of all city owned rooftops or walls in three to five years, and the remainder where technically feasible in ten years, the result would be a stimulated market for these technologies and significant public economic, social and environmental benefits. Each plan should include best estimates of costs and future benefits in areas such as adaptation to climate change, job creation, stormwater management, air quality improvement, greenhouse gas reduction, etc.

The federal and provincial governments could also adopt green roof procurement policies. For example, the federal government through its *Federal Buildings Initiative* can demonstrate leadership on climate change by setting aggressive but realistic targets for green roof and vertical garden installations. The costs of government procurement projects can be reduced by 'bundling' projects together to achieve economies of scale and by focusing on retrofitting buildings that already require new roofs.

5.4 Establishing Direct Government Policy and Program Support

As in Europe, policy and program support will be required to stimulate widespread technology application, particularly among existing buildings. There are two programs that could be adopted from Europe:

- Establish a financial incentive program of grants or indirect subsidies to encourage implementation by reducing payback periods and associated economic uncertainties. Government investment will make up for the market failure to acknowledge the significant social and environmental benefits (air quality, amenity space, climate change, biodiversity, water quality, etc.).

- Make it mandatory through legislation, planning instruments or amendments to the building code to fit new buildings with green roofs and vertical gardens. This would create a strong market for green roof and vertical garden technologies, as was the case in Germany. It should be noted that a requirement for vertical gardens would be unique to Canada.

These two measures could be implemented at the municipal government level with support from provincial and federal governments.

5.5 Exploring Additional Financial Incentives to Overcome Cost-based Barriers

Encourage insurance companies to investigate benefits that would reduce premiums, such as increased roof life span and energy efficiency. Insurance companies could be encouraged to look into these types of incentives for building owners.

Establish partnerships with private sector to facilitate performance-based contracting installation of green roofs and vertical gardens. The cost savings generated would be used to finance the implementation of the projects. This could involve industry-government partnerships, perhaps between the Canadian Association of Energy Services Companies and Natural Resources Canada.

5.6 Technical Issues and Associated Uncertainty

Some technical issues can be addressed through The *National Green Roof and Vertical Garden Design, Implementation and Monitoring Competition*. Other issues will likely require more focused scientific research and analysis, such as the benefits of green roofs and vertical gardens in ameliorating the Urban Heat Island Effect and other longer-term benefits. Two possible programs to encourage research are:

- The provision of financial support for increased research by universities and other research institutions focused on filling the gaps in our technical and economic knowledge. Lead implementing stakeholders could be the provincial ministries of the environment and energy, and the federal government with Environment Canada, CMHC and National Research Council in partnership with universities and other research organizations.

- The creation of high standards for retrofitted or new green roofs and vertical gardens that focus on high quality of materials and installation, and ensure enforcement of these standards. This could involve the establishment of a rating system for suppliers and building companies to encourage accountability for quality and to reassure potential buyers of past success.

These programs would likely involve partnerships between the building industry, government and standards setting bodies such as the Standards Council of Canada and the Canadian Standards Association.

Conclusion

Green roof and vertical garden technologies provide solutions that support Canada's effort to reduce GHG emissions and sustainable development by simultaneously improving human and ecosystem health while yielding economic benefits. Despite the many social, economic and environmental benefits of these technologies and their widespread use throughout Europe, Canadians have been slow to implement them.

This report provides a comprehensive review of the quantitative and qualitative benefits of green roof and vertical garden technologies and the barriers to technology diffusion that must be overcome to fully exploit these benefits. The proposed National Action Plan provides a series of recommended initiatives based on our research and the input of over sixty workshop participants. The National Action Plan, if implemented, will generate a new industry in Canada with multiple spin-off benefits that will improve the health and liveability of our urban environments.

Green roof and vertical garden technologies provide an outstanding array of public benefits in areas such as air quality improvement, reduction of greenhouse gases, water quality and quantity improvements and economic benefits for building owners. These proven benefits present a strong case for federal, provincial and municipal government policy and program support to create a stronger, more viable market for these technologies throughout Canada.

References

1. Akbari, H., Davis, S., Huang, J., Liu, P., and Taha, H.; "The Urban Heat Island: Causes and Impacts"; in *Cooling our Communities*, Lawrence Berkeley Laboratory Report LBL-31587, 1992, pp. 5-25.

2. Bass, Brad; Personal Communication; Environmental Adaptation Research Group, Environment Canada, November 1998.

3. Boivin, Marie-Anne; "Geld vom staat fur gurne dacher"; DZ, December 1992, in *Presentation Abstract – Greenbacks from Green Roofs: Forging A New Industry In Canada*, Workshop Program, Peck & Associates, November 1998.

4. Curtis, William J.R.; *Le Corbusier: Ideas and Forms*; Paidon Press, Oxford, 1986.

5. Cutler, K.; *Vines, Harrowsmith Gardener's Guide*; Camden House Publishing, Vermont, 1992.

6. De Lorme, Eleanor; *Garden Pavilions and the 18th Century French Court*; Antique Collector's Club, Suffolk, 1996.

7. Donnelly, Marian; *Architecture in the Scandinavian Countries*; The MIT Press, Cambridge, MA, 1992.

8. Farrar, Linda; *Gardens of Italy and the Western Provinces of the Roman Empire from the 4th Century BC to the 4th Century AD*; BAR International Series No. 650, 1996.

9. Flower, W.P.; "Mexican Motif: Casa Alvarado"; *in Bulletin of the Pan American Union*, No. 71; 1937, pp. 316-324.

10. Franke, W.; "Dachwiese fuer Kuehlwasser"; in *Kraut & Rueben*, August 1994, pp. 25 –27.

11. Gaudet, C.; "Sunspots, Landscaping for Energy Efficiency"; in *Harrowsmith* Volume X:1, No. 61, June/July 1985, pp. 20-33.

12. Givoni, B.; *Man, Climate, and Nature*, 2nd Edition; Van Nostrand Reinhold, New York, 1976.

13. Goode, Patrick; entry for "Mexico" in *The Oxford Companion to Gardens*; Oxford University Press, 1986, p. 371.

14. Gorse, George L.; "Genoese Renaissance Villas: A Typological Introduction; in *Journal of Garden History*, Volume 3, No. 4, 1983, pp. 255-289.

15. Hoffman, David; *Understanding Frank Lloyd Wright's Architecture*; Dover Publications, New York, NY, 1995.

16. Hooker, J. and Hendriks, N.; "The Green Roofs of Europe"; presented by The International Waterproofing Association at The 107th Annual Convention and Exhibit of the National Roofing Contractors Association, San Francisco, CA, 1994.

17. Jashemski, Wilhelmina Feemster; *The Gardens of Pompeii: Herculaneum and the Villas Destroyed by Vesuvius*; Aristide D. Caragzas, New Rochelle, NY, Volume I and II, Appendices, 1979.

18. Johnston, J. and Newton, J; *Building Green, A Guide for Using Plants on Roofs, Walls and Pavements*; The London Ecology Unit, London, 1996.

19. Liesecke, H-J., Krupka, B., Brueggemann, H.; *Grundlagen der Dachbegruenung, Zur Planung, Ausfuhrung und Unterhaltung von Extensivbegruenungen und Einfachen Intensivbegruenungen*; Patzer Verlag, Berlin - Hannover, 1989.

20. Loverock, T. ; Personal Communication; Annex Organics, November 1998.

21. Mercier, G.; "Energy Sector"; in *Canada Country Study: Climate Impacts and Adaptation*, Environment Canada, 1998.

22. Minke, G. und Witter, G.; *Haeuser mit Gruenem Pelz, Ein Handbuch zur Hausbegruenung*; Verlag Dieter Fricke GmbH, Frankfurt, 1982.

23. North American Wetland Engineering, P.A.; "Ecology, Construction, and Benefits"; in *ReNature/NAWE Green Roof Product Literature*, Minnesota, May 18, 1998.

24. Overtveld, J.C.; "The Application of "Green Roof" Legislation to the City of Ottawa Official Plan"; Paper prepared for the University of Ottawa, Faculty of Law, April 1990.

25. Pieper, Jan; "The Nature of Hanging Gardens"; in *Daidalos* #23, March 15, 1987, pp. 94-109.

26. Reid, R.; "Habitat for the Hardy"; in *Seasons*, Federation of Ontario Naturalists, Autumn 1996, pp. 14 – 22.

27. Rouyer, C.; Newspaper Article/Interview with Marie-Anne Boivin of Soprema Roofing; *The Montreal Gazette*, Montreal, Quebec, July 1998.

28. Smit, Jack; *Urban Agriculture*; UNAP, New York, NY, 1995. In Hundertwasser, F.; *For a More Human Architecture in Harmony with Nature, Hundertwasser Architecture*; Benedikt Taschen Verlag GmbH, Cologne, 1997.

29. Smith, C.; "How to Eat, Drink, and Keep Cool"; in *The Toronto Star*, Saturday, July 5, 1997; p. C5.

30. Soprema Roofing Inc.; Promotional brochure *on the "Sopranature System"*; Quebec City, Quebec, 1996.

31. Stevenson, L. H. and B. Wyman. 1991. *The Facts on File Dictionary of Environmental Science*. Facts on File, Inc: New York

32. Stifter, R.; "Greenery on the Roof: a Futuristic, Ecological Building Method"; in Hundertwasser, F., *For a More Human Architecture in Harmony with Nature, Hundertwasser Architecture*, Benedikt Taschen Verlag GmbH, Cologne, 1997, pp. 156 – 158.

33. Thompson, Wm.; "Grass-Roofs Movement"; in *Landscape Architecture, The Magazine of the American Society of Landscape Architects*, May 1998, Volume 88, No. 6, pp. 47 – 51.

34. Titova, N.; "Rooftop Gardens"; in *Science in the USSR*, No. 5, September-October 1990, pp. 20-25.

35. Ulrich, R.S. and Parsons, R.; "Influences of Passive Experiences with Plants on Individual Well-being and Health"; in *The Role of Horticulture in Human Well-being and Social Development*, Chapter 15, Timber Press Inc., 1992.

36. Ulrich, R.S.; "View from a Window May Influence Recovery from Surgery"; in *Science*, Volume 224, April 1984, pp. 420-21.

Appendix I

QUESTIONNAIRE for GREEN ROOF and VERTICAL GARDEN RESEARCH/CASE STUDIES

1. Name of the contact gardener.

2. Address of the green roof.

3. Name of the building owner (including Housing Co-op, Non-Profit Housing Group, etc.).

4. Is the garden part of a new building OR the retrofit of an existing building?

5. Date of green roof construction/installation and date of original building construction (if the two were completed at different times).

6. Who were the consultants for the green roof?

   - Architect
   - Landscape Architect
   - Structural Engineer
   - Mechanical Engineer
   - Were there any non-technical, resource people/groups involved in the development of the green roof?

7. Who was the contractor/installer? Did anyone donate "sweat equity", labour or materials to the project?

8. Please describe the green roof in terms of type, location, size /area, height, orientation, amenities, use, number of people/occupant load capacity and loading capacity.

9. How much did the green roof cost? Please identify any "sweat equity", donations and in-kind resources

   - Labour and materials for garden
   - Building or structural upgrade, if required
   - Ongoing maintenance

10. What materials were used in the green roof? (soil type, plants, containers, insulation, drainage, etc.)

11. What were the initial reasons (expectations) for installing the green roof? (environmental, energy related, cost saving, promotional, social/community, food production) Has the garden taken on any new meaning or benefit to its users and the owner?

12. What were the barriers to green roof installation, if any? (technical issues, availability, material cost, regulatory approvals, etc.)

13. Did you experience any reluctance or objections on the part of building owners, building managers, neighbors, building officials, or tenants over the installation of a green roof? What were the reasons given?

14. Based on your original expectations (refer to Question 11), was / is the project a success? How? Can this success be quantified? How? Who is benefiting from any cost savings?

15. Describe the ongoing maintenance and use of the green roof? Who maintains the garden and how is this maintenance paid for?

16. If you had the chance to design and install another green roof, what would you do differently, knowing what you know now?

Appendix II

Case Study Overviews of Green Roof and Vertical Garden Projects

Case Study A: The Boyne River Ecology Centre

Classification:	Institutional
Overview:	Green roof is a part of the design of an earth-sheltered ecology centre used for educational purposes. The green roof is inaccessible, covered with wildflowers and grass, and designed for earth and snow loading. The costs of construction were minimal - local top soil was used, no containers were required and all plants were either in the soil already or transported by wind, insect or bird (nothing was cultivated). Gravel is used on the roof to aid drainage. There is no cost associated with the ongoing maintenance of the green roof since it is all natural.
Location:	Shelbourne, Ontario
Owner:	Toronto Board of Education
Construction:	Building and green roof constructed in 1993.
Partners:	Structural and Mechanical Engineer- Allen Kani & Associates.
Drivers:	The green roof was initially constructed in order to provide habitat for flora and fauna, to provide additional cooling for the building and maintain the breathing surface of the earth.
Barriers:	Cost and regulatory approvals did not prove to be a barrier in this case. A Board of legal advisors, however, would not endorse access to the green roof by students without the installation of numerous safety devices (i.e. guard rails) and as a result, the school opted to make the green roof inaccessible. Because the roof is sloped, there was talk of installing retention blankets to address concerns about soil slides. This matter was resolved when the roof sprouted and the roots made the retention blanket redundant.
Cost:	Unknown.
Benefits:	The green roof has provided many benefits. It keeps the building cool (the building does not require any air conditioning in the summer), and it helps to educate 5,000 visitors each year on the topic of green roofs. The green roof has also provided a superior habitat for indigenous species (due to improved solar access) and the grass and wildflowers are more plentiful on the roof than at grade.
Changes:	In the future the garden may be changed to allow people to access the green roof so that they could get a closer look at it.

Case Study B: Conservation Co-operative Homes Inc.

Classification: Multi-Unit Residential

Overview: Green roof provides greenspace and amenities for members of a housing co-operative. Two green roofs are accessed from 4th floor corridors (located above apartments). One faces south and has almost full east and west exposure. The other faces west and has almost full east and south exposure. The area for each green roof is 43.5 m^2 and therefore the capacity is about 45 people per deck. The green roof contains rain barrels that collect water from the 4th floor and are then used for irrigation. As well, each green roof has an enclosed storage area (accessible from outside), to store patio tables, chairs and gardening tools. In addition to the green roof, built-in planter boxes were designed. Many residents have installed lattice screens or planted vines (vertical gardening) to supplement the planter boxes and provide more privacy.

Location: Ottawa, Ontario

Owner: Conservation Co-operative Homes Inc.

Construction: New building and green roof in 1995.

Partners: Architect- Cole & Associates Architects Inc.,
Landscape Architects- Lashley & Associates,
Structural Engineer- Aston Engineering,
Mechanical Engineer- Leslie Jones & Associates.
The Co-op Board was also involved in the development phase.

Drivers: The green roof was constructed to provide pleasant, additional outdoor amenity space for tenants.

Barriers: High material costs as well as having to provide barrier-free access to residents (which drove up the cost) were barriers - both of which were overcome.

Cost: Costs for building and structural upgrades are not known.

Benefits: Benefits include hobby gardening, food production, and an enhanced sense of community among co-op residents. Some residents use their planters to grow mini-vegetable gardens and others grow flowers.

Changes: The green roof could be more centrally located (i.e. accessed from 2nd floor in a 4 story building). It could also be smaller and more intimate.

Case Study C: Luxury Condominium Building

Classification:	Multi- Unit Residential
Overview:	Green roof is built over many levels and can be viewed and accessed by all occupants of an upscale condominium complex. The green roof is 15,000 square feet in area and is only accessible to the 70 residents. The green roof cascades over 3 stories and is completely enclosed at all sides. It contains a bridge, waterfall, full grown trees (evergreen and deciduous), flowers, a pond, benches at various elevated terraces and a growing medium consisting of one metre of soil.
Location:	Toronto, Ontario
Owner:	Private condominium corporation.
Construction:	Retrofit of existing building built in late 1920's. The green roof was constructed in early 1980's.
Partners:	Confidential.
Drivers:	Main reason was to create 'an oasis' in the middle of the urban 'concrete jungle'.
Barriers:	There is a theatre under the garden and therefore the noise from the waterfall was an issue. This was resolved with the use of sound insulation. Also, massive weight transfer structures were designed to support loading in specific places.
Cost:	Costs were kept confidential by the contractor. Maintenance is paid for out of condominium fees (the costs are unknown).
Benefits:	The residents love the green roof. Quantified success lies in the fact that real estate values have benefited-units in the building start at $500,000. Additionally, birds are attracted to the garden.
Changes:	Nothing would be done differently.

Case Study D: Mary Lambert-Swale Green Roof, Homes First Society

Classification:	Multi-Unit Residential
Overview:	An accessible and intensive green roof located on the 10th floor of a multi-unit residential building. The green roof is 4,250 square feet and faces all four directions. It is used for gardening, BBQ's, sun bathing, composting and sitting. The green roof can support 100 lbs. psf and 60 people. The green roof was built using cedar planters lined with insulation and filter cloth and contains triple mix soil, vegetables, fruit trees, berry bushes and vines, ornamental annuals and perennials.
Location:	Toronto, Ontario
Owner:	Homes First Society
Construction:	The original roof terrace was part of a new building (built in 1994) and the garden component on the terrace was installed one year after construction of the building was completed.
Partners:	Architect - Monica E. Kuhn, Architect. Structural Engineer - Halsall & Associates. Carpentry and Co-ordination- Blue Tree Building. Non-technical resource people included the tenants and the staff of Homes First Society.
Drivers:	To provide private green space for the tenants.
Barriers:	None.
Cost:	Labour and materials required for the green roof cost $16,000.00. Ongoing maintenance of the green roof is provided by tenant volunteer labour and major maintenance expenditures are paid for by the owner.
Benefits:	Each year more tenants use the green roof (tenants have formed a gardening group) and more perennials get planted. Birds and insects are now found on the roof. The success has not been quantified, except that the roof terrace is used and vandalism has decreased after the first year.
Changes:	Lower costs by not using western red cedar and do some surface planting (i.e. put a lawn on the roof).

Case Study E: University of Toronto Vertical Garden

Classification:	Institutional
Overview:	Temporary vertical garden constructed as a part of an academic experiment to learn more about vertical gardens and their application. It was constructed on the Sir Daniel Wilson Residence, which is located on campus. The garden was installed in the summer of 1996 and was removed before students returned in the fall. Three planter boxes were situated beneath three windows on the west side of the building. The plants were trained to climb fishing line, which was attached to a curtain rod, allowing the plants to be moved into place over the window in the afternoon. The plants used were scarlet runner beans, sunflowers and morning glories. *President's Choice* soil and wooden planting boxes were also utilized.
Location:	Toronto, Ontario
Owner:	University of Toronto
Construction:	The vertical garden was installed in June 1996 and the building was constructed in the 1960's.
Partners:	Brad Bass, Environment Canada and Monica Mucka, Student constructed the garden. Roger Hansell, Professor donated the planter boxes, the support braces and the soil.
Drivers:	The project was intended to measure the effects of vertical gardens on evaporative cooling and to promote the use of vertical gardens.
Barriers:	The facilities management department were concerned that the planter boxes might damage the masonry (no damage occurred).
Cost:	Labour and materials for the garden were $350. Ongoing maintenance, including labour for the summer was $440.
Benefits:	The vertical garden was successful in that the evaporative cooling was significant. The evaporative cooling was quantified in terms of temperature, which was measured with an infrared thermometer. It was not successful as a promotional vehicle. No additional benefits have been quantified.
Changes:	Since the original design, better ways to incorporate plants into a window shade have been found. These new designs would also require different plants.

Case Study F: Franz Schryer Vertical Garden

Classification:	Single Unit Residential
Overview:	Vertical garden installed by a resident in his own home. The vertical garden is located on a fence and on the walls of a tool shed. It is composed of 5-foot long vinyl posts, with five small planters inserted at regular intervals. Water is pumped up to the first planter and waters each plant in turn until reaching the bottom. The water contains a nutrient solution and receives sufficient aeration as it moves through the system. The plants currently used are flowers. Soil, peat moss, perlite, vinyl planters and vermiculite are also used.
Location:	Toronto, Ontario
Owner:	Franz Schryer
Construction:	The vertical garden, built in 1988, was a retrofit installed on a home built in 1875.
Partners:	Franz Schryer constructed the vertical garden on his own.
Drivers:	To gain personal enjoyment in designing and installing a hydroponic garden in a limited space. Also the opportunity to grow greens such as lettuce and escarol.
Barriers:	As the garden was first being installed there were many technical problems, the most persistent of which was insect 'pests'. Companion planting (garlic and African marigolds) and other biological controls, such as ladybugs now handle the most common pests (white flies and aphids).
Cost:	Labour and materials for the garden cost $100 (pump) and the vinyl cost $4/unit. Ongoing maintenance is infrequent and entails very little expense.
Benefits:	The quantification of food production has not been done in any formal manner, although the amount of lettuce produced was more than sufficient for the family of eight.
Changes:	The current vinyl posts are square. The next ones will be circular because it is faster and easier to cut the holes in the vinyl because less precision is required.

Case Study G: Field to Table Green Roof

Classification:	Commercial
Overview:	The green roof is operated by Annex Organics, which uses it to grow vegetables that are sold to local residents and businesses as part of its *Field to Table* program. The green roof is 4000 square feet and accessible. It is located on a 30-foot high building, has a southern orientation, a 25-30 psf loading capacity and access to water. The green roof consists of 2 systems. System 1 is a passive hydroponic system that has a 5 mL plastic covering and uses wood, fish emulsion (nutrients), tar paper to cover troughs and soil potting mix. System 2 uses traditional planters and planting mix.
Location:	Toronto, Ontario
Owner:	Building owned by the Province of Ontario and is managed by the City of Toronto.
Construction:	The green roof was installed in 1997 as a retrofit on an old warehouse building which was converted into offices and a food production facility.
Partners:	Landscape Architect- Monica Kuhn. Installation was completed by 3 Field to Table partners and various volunteer labourers.
Drivers:	The green roof was installed primarily for the purpose of food production. Secondary drivers were the cooling effect on the building, increased CO_2 sequestration, CO_2 emission reductions and wanting more urban greenery.
Barriers:	There was difficulty accessing the appropriate space for experimental purposes, accessing financial resources, working with the design constraints of building (loading and design constraints), overcoming skepticism relating to its economic and social benefits and obtaining relevant information. There were also a few concerns about the safety of the roof.
Cost:	Installation materials cost $500, labour was $1200 and maintenance costs are $2400 per year.
Benefits:	Food production has not lived up to expectations. There are plans to make the green roof a profit centre by 1999.
Changes:	Invest more money in equipment to establish more permanency. Also, test potential configurations on smaller scales in order to determine the most productive agricultural system.

Case Study H: ***Gruendack fuer Kuehlwasser***
(Roofmeadow for water cooling)

Classification:	Industrial
Overview:	The green roof is located on a German apple cider factory. The installation has two layers of roofing paper with a layer of copper and warm water from the building's cooling system for the purpose of heat exchange (rain water is gathered on the roof, drained into an underground 200,000 cistern, pumped throughout the system to collect heat and is dumped onto the roof through a perforated pipe, and the water cools from 31 to 28 degrees Celsius). Vegetation is comprised of swamp and marsh plants with shallow root balls (plants clean the water and feed from it).
Location:	Frankfurt, Germany
Owner:	Possman Cider Factory and Storage Facility
Construction:	Both the building and green roofs were built in 1990.
Partners:	Unknown.
Drivers:	Water and plants were intended to keep roof insulated, protect roofing and provide a cheaper and more effective means of water cooling.
Barriers:	Installers could not use a deep soil layer because of the structural capacity of the roof and the high cost of structural upgrades (estimated at 150,000 to 170,000 DM).
Cost:	The plants cost less than 40,000 DM. Ongoing maintenance costs are unknown.
Benefits:	In 2-3 years, the savings in cooling towers and electricity costs (estimated to be 12,000 DM per year) paid for the plants.
Changes:	Unknown.

Case Study I: Vancouver Public Library Green Roof

Classification:	Institutional
Overview:	This extensive green roof is located on the Vancouver Public Library and can be viewed from surrounding downtown office towers. The green roof is located on top the 7-storey library building and is approximately 2400 m^2. The green roof is inaccessible and is oriented toward the city and the harbour to the north. The roof is planted with green and blue/green tufted fescues. The lightweight growing medium is composed of reconstituted vegetable waste, sand and pumice. The green roof consists of *Omni* soils, four different types of grass and four different types of trees.
Location:	Vancouver, British Columbia
Owner:	City of Vancouver
Construction:	Building and green roof were constructed in 1995.
Partners:	Architects- Moshe Safdie and Associates and Downs Archambault & Partners. Landscape Architect- Cornelia Hahn Oberlander. Landscape Contractor- Jackway Landscaping.
Drivers:	Environmental and aesthetic purposes.
Barriers:	None.
Cost:	Total cost of Library green roof was approximately $250,000. There were no donations or in-kind resources.
Benefits:	The green roof was a great success. This success, however, has not been quantified.
Changes:	Nothing different would be done.

Case Study J: Mountain Equipment Co-op Green Roof

Classification: Commercial

Overview: This inaccessible green roof garden is located on downtown corporate headquarters of the Mountain Equipment Co-op. The green roof area is 903 m^2 around a skylight located on the second floor of the building. The roof has full sun exposure and has a load capacity of 40 psf. The green roof uses Soprema SOPRADRAIN PSE for drainage, a Soprema SOPRAFILTRE filter, and Soprema SOPRAFLOR-X growing medium. The vegetation is a wild flower meadow mix of sunflower seeds and perennial plants (contained in 4-inch pots, plantation at a density of 14 plants/m^2).

Location: Toronto, Ontario

Owner: Mountain Equipment Co-op.

Construction: Installation of the green roof took place in May 1998 and the building was constructed during Fall 1997- Winter 1998.

Partners: Architect- Stone Kohn McQuire Vogt (SKMV) Architects
Landscape Architect- Ferris + Quinn with recommendations from Marie-Anne Boivin of Soprema Inc.
Structural Engineer - Read Jones Christopherson Ltd.
Mechanical Engineer - Keen Engineering Co. Ltd.
Landscape Contractor - Top Nature.

Drivers: There were a number of items included in the building program that had no quantifiable economic benefit, but in the mind of the owner they contributed to social and community leadership. The owner wanted the building to create discussion and debate about environmental issues and the green roof has contributed to this.

Barriers: Cost and impact on the building were the major deterrents. The costs were substantial because structural redesign was required to accommodate the addition of the garden. Accessibility, or lack thereof, was a cost saving issue since the roof structure would have had to be further upgraded to accommodate live loads.

Cost: Labour and materials cost $115,000 and the structural upgrade cost $55,000.

Benefits: The green roof has environmental and wider use community benefits. It may also have some cost benefit due to thermal inertia caused by the growing medium. The garden is a success in the adaptation and establishment of the vegetation and wildlife (birds, butterflies, insects, etc.). Additionally, it has been of interest to others who are now considering green roofs on their own projects, such as the City of Toronto and Metro Hall. Local developers are also viewing the green roof as an example of what they can undertake, considering similar initiatives.

Changes: Include green roof in original design scope to cut costs. Design to provide limited access.

Case Study K: Cooperative d'habitation Chloé – Green Roof

Classification:	Multi-unit Residential
Overview:	This accessible green roof is located on a 16-unit apartment building. The green roof is accessible from the third floor and is 80 m^2. A wood deck with picnic tables and benches surround the green roof terrace. The roof has a direct view on the sunset upon the Laurentian mountains. The green roof is on a flat, ventilated roof (0-5º slope) with a loading capacity of 170 kg/m^2. The rooftop is landscaped with a garden of succulents, ground covers, bulbs and herbs. The green roof utilizes Soprema SOPRADRAIN PSE for drainage, a Soprema SOPRAFILTRE filter, and the growing medium is Soprema SOPRAFLOR-X. It is manually irrigated only during dry periods. A weeding was done once a month during the first year and slow release fertilization is applied once a year, in spring.
Location:	Quebec City, Quebec
Owner:	Coopérative d'habitation Chloé
Construction:	The building was constructedaround 1850 and the green roof was constructed in 1997.
Partners:	Architect - Jacky Deschênes. Landscape Contractor - Top Nature. Designers - Jacky Deschênes and Marie-Ann Boivin.
Drivers:	Aesthetic, environmental and to provide new access to a rooftop that was not used before. It was designed to create an accessible terrace for people living in the co-op (which is located on a main commercial street with no green spaces in the surrounding area).
Barriers:	None.
Cost:	Cost was $5,650 including all the material, plants and installation.
Benefits:	The residents enjoy the use of the green roof.
Changes:	Nothing would be done differently.

Case Study L: Copropriétés Manrêse – Green Roof

Classification:	Multi-Unit Residential
Overview:	Accessible green roof located on an open parking garage of a 12-duplex development. The flat area is 215 m^2 and on a concrete structure with load capacity of 130 kg/m^2. The green roof utilizes Soprema SOPRADRAIN PSE for drainage, a Soprema SOPRAFILTRE filter, and the growing medium is Soprema SOPRAFLOR-X. The vegetation is a wild flower meadow mix with sunflower seeds and perennial plants, contained in 4-inch pots at a density of 14 plants per m^2.
Location:	Quebec City, Quebec
Owner:	Copropriétés Manrêse
Construction:	The green roof, installed in October 1996, was a retrofit on an existing building.
Partners:	Architect - Mario Laffont, La Clinique d'architecture de Quebec. Landscape Architect - Michel Martin. Landscape Contractor - JAMO Paysagiste.
Drivers:	Waterproofing repair and enhancing the visual appearance of the existing terrace.
Barriers:	None.
Cost:	Approximately $11,000 all inclusive.
Benefits:	The ground cover on the landscaped terrace has been shown on television news as a prototype for greening spaces over parking garages.
Changes:	Nothing would be done differently.

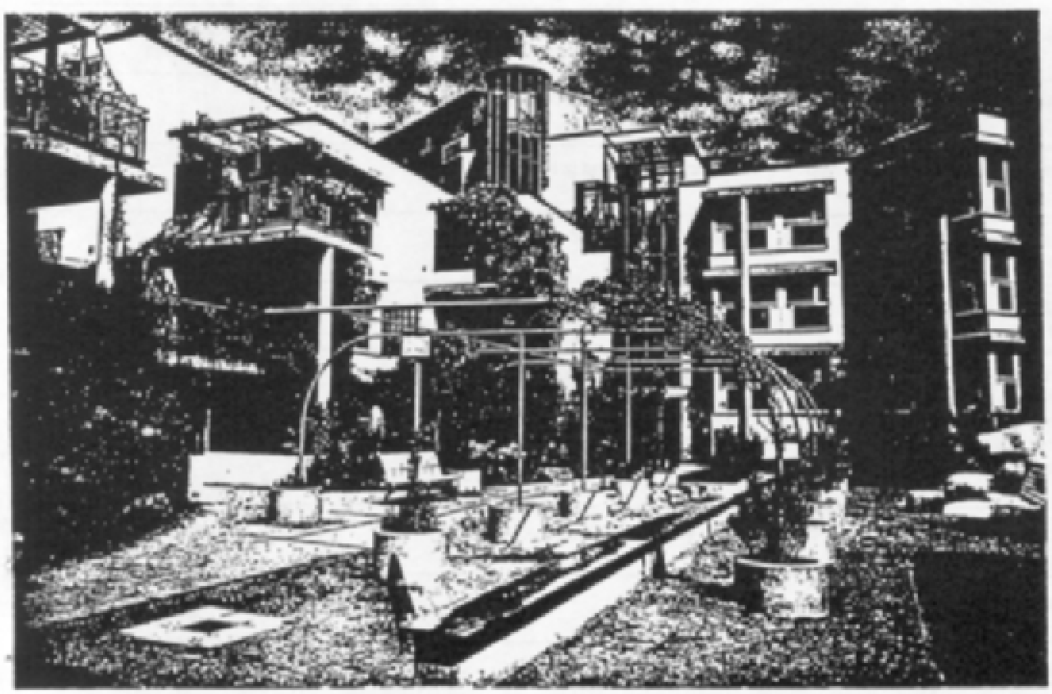
Appendix III

Plant List

TABLE 3: A Selection of Plants Suitable for Walls

		D DECIDUOUS E EVERGREEN A ANNUAL	ASPECT N Bold = preferred Light = tolerates	E	S	W	MAX HT mtrs	GROWTH RATE	SOIL	NATIVE/ EXOTIC	WILDLIFE NOTES
SELF-CLINGING CLIMBERS (Generally no support needed. May need support on very smooth walls)	Ivy *Hedera helix*	E	N	E	S	W	30	Slow	Most, rich	N	Excellent wildlife plant. Good nesting site for robins and wrens, and hibernating butterflies – esp. brimstone. Nectar and pollen for bees and hoverflies.
	Virginia Creeper *Parthenocissus quinquefolia*	D	N	E	S	W	15	Average	Any	E	Useful for nesting birds if grown on a trellis. Provides nectar and pollen for bees. May attract nesting spotted flycatcher.
	Boston Ivy *Parthenocissus tricuspidata*	D	N	E	S	W	15	Fast	Any	E	
	Climbing Hydrangea *Hydrangea petiolaris*	D	N	E		W	15	Average	Moist, loamy	E	Good for nesting birds and produces nectar for bees and other insects
	Euonymus *Euonymus fortunei vars.*	E	N	E		W	5	Slow	Any	E	
TWINING CLIMBERS (Support needed. Thin steel wires, roughened plastic lines or timber battens running vertically will suffice for some species. Others will need a good network of wire or wooden trellis-work.)	Russian Vine *Polygonum bauldschianicum*	D	N	E	S	W	30	Fast	Any moist	E	Good for nesting birds.
	Honeysuckle (Woodbine) *Lonicera periclymenum*	D		E	S	W	5	Average	Good loam	N	Must be kept bushy for nesting birds. Excellent for insects, especially moths, due to night-scented flowers. Bark from older stems used by nesting birds. Berries eaten by birds.
	Honeysuckle (others) *Lonicera spp.*	Mainly D Some E	N	E	S	W	6	Average	Good rich	E	Several varieties are useful nectar and seed plants. Evergreen honeysuckle trained up a trellis makes a good bird roosting site.
	Old Man's Beard *Clematis vitalba*	D		E	S	W	10	Fast	Prefers alkaline	N	Seeds for birds. Nesting sites. Nectar for insects.
	Clematis (others) *Clematis spp.*	Mainly D Some E		E		W	10	Fast	Various	E	Useful nectar and/or seed providers. Useful for nesting sites if trained thickly on a trellis.
	Common Hop *Humulus lupulus*	D		E	S	W	6	Fast	Rich moist	N	Good for bees.
	Dutchman's Pipe *Aristolochia spp.*	D	N		S	W	10	Average	Most	E	
	Jasmine *Jasminum officinale*	D		E		W	9	Fast	Well-drained	E	Night-scented, attracting moths and other night-flying insects.
	Vine *Vitis spp.*	D		E	S	W	20	Average/fast	Rich, loamy, moist	E	Provides fruit for birds and nectar and pollen for bees.
	Wisteria *Wisteria spp*	D		E	S	W	18	Average	Rich, moist, loam	E	Excellent nectar and pollen for bees. Can be used by nesting birds.
	Trumpet Vine *Campsis radicans*	D		E	S	W	12	Slow	Rich, well-drained	E	
	Passion Flower *Passiflora caerulea*	D		E	S	W	8	Fast	Any	E	Nectar and pollen for bees.
	Sweet Pea *Lathyrus odoratus*	A			S	W	2	Fast	Rich, well-drained with chalk	E	
	Nasturtium *Tropaeolum spp*	Mainly A		E	S	W	2	Fast	Poor	E	Nectar/pollen for bees and beetles. Seeds eaten by birds and small mammals. Food plant of small and large white butterflies.

RAMBLING SHRUBS (Not true climbers but can be trained on wide-meshed grid structures or by tying to wall)	Brambie *Rubus fruiticosus*	E	N E S W		Average	Most, but likes acid	N	Provides pollen for bees and nectar for bees and butterflies Berries for birds and small mammals Night-scented and attracts moths
	Winter Jasmine *Jasminum nudiflorum*	D	N S W	5	Average	Most	E	
	Dogrose *Rosa canina*	D	E S W	3	Average	Good, cultivated	N	Night-scented for moths Nectar for insects, rosehips for birds and small mammals Good nesting cover for birds.
	Climbing rose *Rosa spp*	D	E S W	5	Average	Most	E	Excellent nectar for bees. Rosehips as above Nesting cover for birds
	California Lilac *Ceanothus spp*	E	S W	3	Average	Light, well-drained	E	Nectar and pollen for bees Nesting sites for birds
	Forsythia *Forsythia suspensa*	D	N E S W	4	Average	Most	E	Nesting sites for birds, as above
	Cotoneaster *Cotoneaster spp*	Mainly D Some E	N E	3-6	Slow	Any	E	Thick growth may be used by nesting blackbirds and thrushes Berries for birds, especially blackbirds, and small mammals Nectar and pollen for bees
	Firethorn *e g Pyracantha atalantiodes*	E	E S W	5	Slow	Most, esp fertile, well-drained	E	Good for nesting birds e g thrushes, and provides nectar and pollen for bees and berries for birds, particularly blackbirds
WALL FRUITS (Can be trained to cover walls through espalier technique)	Apple, cherry, quince, pear, currant, gooseberry, apricot, fig, grape, peaches etc	Various	Various	3	Slow	Various	N E	Strong branches can provide good nest sites Fruit eaten by birds and insects Nectar and pollen for bees



Above: Vegetation gives colour and texture to the walls of this apartment block

Left: *Climbers used to great effect in a green courtyard for a new housing estate in Berlin.*

TABLE 4: A Selection of Plants Suitable for Extensive Green Roofs

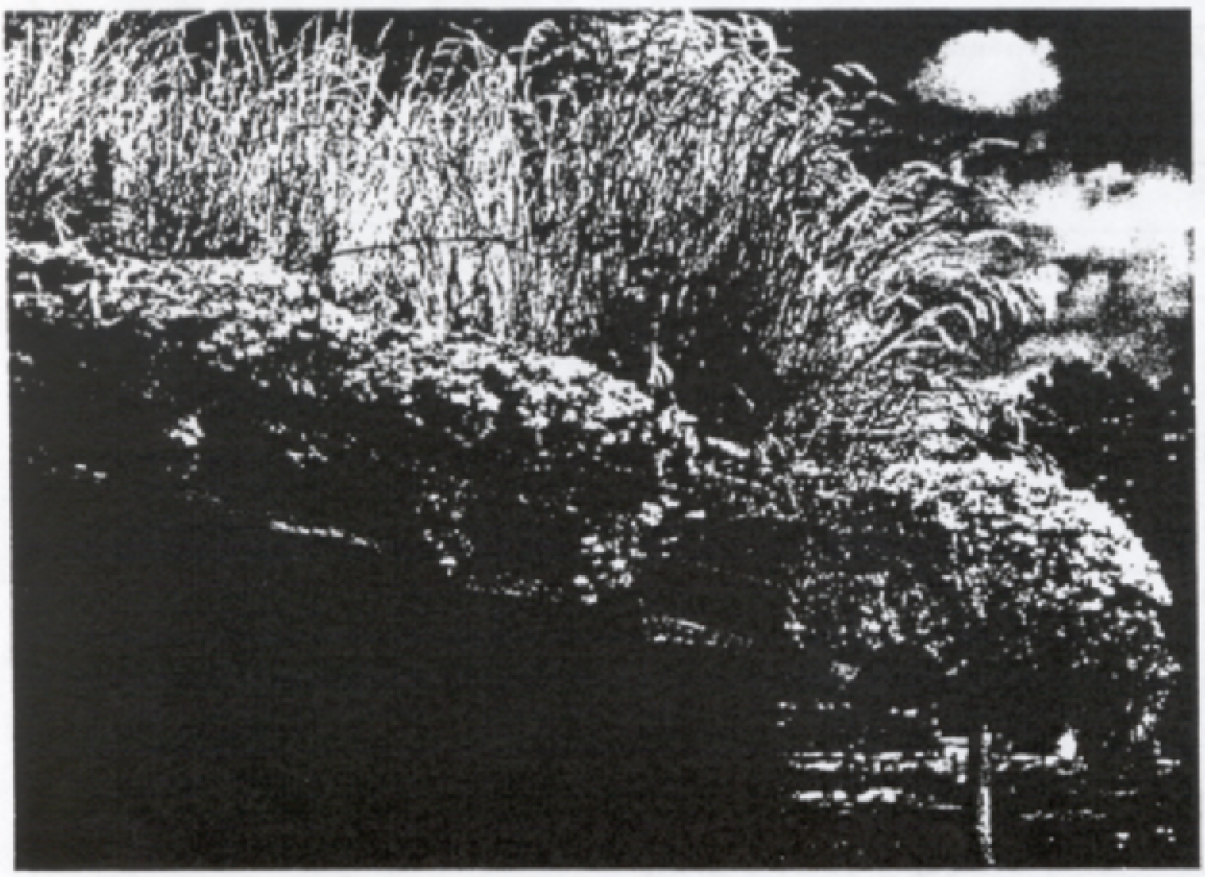
NAME	HT (CM)	CULTIVATION SOIL	S / Ps / Sh	NATURAL HABITAT	WILDLIFE NOTES
HERBS					
ROCK PLANTS					
White Stonecrop *Sedum album*	5-10	Poor, dry, well-drained, prefers alkaline	S	Rocky places, walls and sea cliffs	Attracts bees
Biting Stonecrop *Sedum acre*	2-10	Poor, dry, well-drained, acid or alkaline	S	Rocky and sandy places, dry grassland, dunes, beaches, walls, railway tracks	Attracts bees
Reflexed Stonecrop *Sedum reflexum*	5-10	Poor, dry, well-drained	S	Walls, rocks, dry banks	Attracts bees
Tasteless Stonecrop *Sedum sexangulare*	5	Poor, dry, well-drained	S	Old walls	Attracts bees
Hen-and-chickens Houseleek *Jovibarba sobolifera*	5	Well-drained, prefers acid	S	Sandy and grassy places	
Common Houseleek *Sempervivum tectorum*	10	Well-drained	S	Grassy and rocky places, screes, walls and roofs	
Wild Thyme *Thymus serpyllum*	20	Poor, well-drained, prefers alkaline	S	Sandy heaths, dry grassland	Attracts bees and provides nectar for butterflies
Common Wild Thyme *Thymus drucei*	20	Poor, well-drained, prefers alkaline	S	Dry grassland, heaths, dunes, rocks	Nectar for bees and butterflies
Chives *Allium schoenoprasum*	20-30	Loamy, netural to alkaline	S/Ps	Grassy and rocky places, limestone	Attracts bees
Golden Alyssum *Alyssum saxatile*	10	Well-drained	S	Rocky habitats, walls and embankments	Attracts bees and provides nectar for butterflies
Snow-in-Summer *Cerastium tormentosum*	10-20	Well-drained	S	Grassy and rocky places, banks and walls	
Mountain Alison *Alyssum montanum*	5-15	Well-drained	S	Rocky places and gravels	
Mountain Avens *Dryas octopetula*	5-20	Well-drained, poor, alkaline	S	Limestone or basic rocks	
Purple Saxifrage *Saxifraga oppositifolia*	5-10	Well-drained, poor, alkaline	S/Ps	Rocks and cliffs, often limestone	Attracts bees
Meadow Saxifrage *Saxifraga granulata*	5-30	Well-drained, neutral or alkaline	S	Meadows, road verges, rocky places	
Common Rockrose *Helianthemum nummularium*	5-30	Well-drained, poor, alkaline	S	Dry meadows, banks and rocky habitats	Nectar for bees and butterflies
Red Valerian *Centranthus ruber*	30-80	Well-drained, poor, neutral to alkaline	S	Old walls, cliffs, rocks, wasteland	Nectar for bees and butterflies
Lavender *Lavendula augustifolia*	50	Well-drained, alkaline	S	Rocky slopes	Nectar for bees and butterflies
ROCK/GRASSLAND PLANTS					
Hoary Cinquefoil *Potentilla argentea*	10-40	Well-drained	S/Ps	Dry, sandy grasslands and rocky/stony places	Nectar for bees and butterflies

Thrift *Armeria maritima*	10-20	Most. Well-drained, slightly acid to alkaline	S/Ps	Cliffs, salt marshes, mountain ledges, dry grassland	Nectar for bees and butterflies
Sheep's-bit *Jasione montana*	5-30	Well-drained, acid, sandy, stony	S/Ps	Cliffs, dry grasslands, heaths, dunes	Nectar for bees and butterflies
Bloody Cranesbill *Geranium sanguineum*	10-40	Well-drained, alkaline	S/Ps	Dry rocky or sandy places, grassland and open woods	Nectar for bees
Fine-leaved Sandwort *Minuartia hybrida*	5-20	Well-drained, sandy	S	Walls, dry stony grassland	
Wall Germander *Teucrium chamaedrys*	10-20	Well-drained	S/Ps	Chalk grassland, walls, rocky places	
Toadflax *Linaria vulgaris*	30-80	Most well-drained, neutral to alkaline	S/Ps	Fields, rocky and waste places	Nectar for bees and butterflies
Mouse-ear Hawkweed *Hieracium pilosella*	5-20	Well-drained	S	Grassland, heaths, wasteland and rock outcrops/scree	Nectar for bees and butterflies
Common Centaury *Centaurium erythraea*	10-40	Well-drained, dry	Ps	Roadsides, wasteground, rock outcrops and cliffs	
Wild Carrot *Daucus carota*	30-60	Well-drained, dry, alkaline	S	Grassland, roadsides, rock outcrops and cliffs	Attracts a variety of insects
GRASSLAND PLANTS					
Yellow Chamomile *Anthemis tinctoria*	50	Well-drained	S	Arable land, roadsides, wasteland	Nectar for bees
Thyme-leaved Sandwort *Arenaria serpyllifolia*	3-20	Well-drained, alkaline	S	Arable land, wasteland, chalk, grassland	
Maiden Pink *Dianthus deltoides*	10-50	Well-drained	S	Dry grassland	
Mullein *Verbascum thapsus*	30-200	Mostly well-drained	S	Wasteland, dry banks	Nectar for bees Mullein moth caterpillar feeds on leaves
Common Fumitory *Fumaria officinalis*	20	Well-drained, moderately acidic to alkaline	S	Arable fields, esp on chalk and sand, wasteground	
Perforate St. John's Wort *Hypericum perforatum*	30-90	Most well-drained, neutral to alkaline	S/Ps	Roadsides, hedgebanks, grassland, esp on chalk and sand	Nectar for bees and butterflies
Common Mallow *Malva sylvestris*	45-90	Well-drained, dry	Ps	Roadsides, wasteground, hedgebanks	Nectar for bees and butterflies Food for painted lady caterpillar
Yarrow *Achillea millefolium*	10-50	Well-drained	S/Ps	Roadsides, grassland	Nectar for bees and butterflies
Wild Mignonette *Reseda lutea*	30-75	Well-drained, alkaline	S	Wasteland, grassland	Nectar for bees and butterflies
Bird's-foot Trefoil *Lotus corniculatus*	10-40	Most well-drained, except very acid	S	Grassland, roadsides	Nectar for bees and butterflies Food for various moth and butterfly caterpillars
Bladder Campion *Silene vulgaris*	25-90	Well-drained	S/Ps	Roadsides, open ground, hedgebanks, esp. on chalk and sand	Nectar for butterflies
GRASSES/SEDGES					
Common Bent *Agrostis capillaris*	10-70	Poor, dry, acid, sands to clay	S/Ps/Sh	Dry acid grasslands, wastground, heath	
Creeping Bent *Agrostis stolonifera*	8-40	Most. Light or heavy, dry or wet	S/Ps	Widespread Grassland, roadsides, cliffs, wasteland	

TABLE 4: A Selection of Plants Suitable for Extensive Green Roofs (cont.)

NAME	HT (CM)	CULTIVATION		NATURAL HABITAT	WILDLIFE NOTES
		SOIL	S / Ps / Sh		
Upright Brome *Bromus erectus*	40-100	Well-drained, alkaline	S	Wasteland, roadsides, chalk grassland	
Sheep's Fescue *Festuca ovina*	5-60	Well-drained, poor, acid to alkaline	S/Ps	Dry grassland	
Red Fescue *Festuca rubra*	20-60	Well-drained, chalky, gravelly or sandy soils	S/Ps	Dry grassland, roadsides and wasteground	
Yorkshire Fog *Holcus lanatus*	20-100	Most.	S/Ps	Rough grassland, wasteland	Caterpillar food plant for skipper butterflies
Smooth Meadow-grass *Poa pratensis*	10-90	Well-drained, sandy, gravelly and loamy	S/Ps	Meadows, roadsides, walls, wasteland	Caterpillar food plant for meadow brown and gatekeeper butterflies
Crested Dog's-tail *Cynosurus cristatus*	15-75	Well-drained, esp chalk	S/Ps	Grassland on acid and basic soils	
Yellow Oat-grass *Trisetum flavescens*	20-50	Well-drained	S/Ps	Widespread in meadows and grasslands, esp calcareous	
Annual Meadow-grass *Poa annua*	5-30	Most	S/Ps/Sh	Bare and disturbed ground	

NOTES: S = sun Ps = partial sun Sh = shade Not all the plants listed are native to Britain, and in addition some have very limited natural distributions Absence of entry under "wildlife notes" does not imply absence of value to wildlife



A detail of the roof edge shows brilliant yellow sedum in full flower

Appendix IV

Workshop Participants

Name	***Organization***
Greg Allen	Allen Kani Associates
Lauren Baker	Annex Organics
A. Baskaran	National Research Council of Canada
Brad Bass	Environment Canada
Gineette Battikha	Beak International Services
Frank Baxter	Semple-Gooder Roofing Limited
William R. Bean	Garland Canada Inc.
Dietrich Boecker	Architect
Marie-Anne Boivin	Soprema Inc.
Charles Boulos	Garland Canada Inc.

Name	***Organization***
Murray Boyce	Toronto Parks and Recreation
Richard Brault	Studio Innova Inc.
Chris Callaghan	Peck & Associates
Karen Campbell	Peck & Associates
George Challies	Soprema
Darlene Conway	The Toronto and Region Conservation Authority
Sean Cosgrove	Toronto Food Policy Council
Trevor Dick	Toronto Economic Development Corporation
Hayley Easto	University of Toronto, Division of the Environment
Heinrich C. Feistner	City of Toronto/Energy Efficiency Office
Andria Giles	Mountain Equipment Co-op

Name	*Organization*
Roger Hansell	Institute for Environmental Studies, University of Toronto
Jane Hayes	Toronto Parks and Recreaton
Anna Hercz	Peck & Associates
Ruedi Hofer	PMA Landscape Architects
Ed Horner	Mountain Equipment Co-op
Christina Idziak	Friends of the Earth
Terry Johnson	Hydrotech Membrane Corporation
Evan Jones	Rose Technology Group
Angela Jonkman	The Toronto and Region Conservation Authority
Janis Kravis	Architect
Monica Kuhn	Architect

Name	***Organization***
Kurt Kulakowsky	Garland Canada Inc.
Brian R. Lambert	The Garland Company, Inc.
Anne Lesperance	Mountain Equipment Co-op
Nina-Marie Lister	Zawadzki Armin Stevens Architects, Inc.
Mary Jane Lovering	Vertechs Design Inc.
Tracy Loverock	Annex Organics
Jamie McFadyen	
Terry McGlade	Perennial Gardens Corporation
Clarissa Morawski	CM Consulting
Ted Munn	Institute for Environmental Studies
Alex Murray	York University

Name	Organization
Elizabeth Ohi	Ontario Association of Architects
Steven Peck	Peck & Associates
Glenda Poole	University of Toronto, Division of the Environment
Angela Poto	City of Toronto, Energy Efficiency Office
Arnie Rose	City of Toronto Housing Division, Community and Neighbourhoods Division
Michelle Rothman	
Marilyn Roy	Toronto Bay Initiative
David Schryer	
Franciscus Schryer	
Paul Sheehey	Tremco Ltd.
John Sugden	Arcadia Housing Co-operative Inc.

Name	Organization
Egils Tannis	Egils Tannis Architect
Stephanie Tencer	Peck & Associates
Nikki Vecchiola	City of Toronto Works
Bardi Vorster	Individual Landscapes
Martin Wade	Martin Wade Landscape Architects Ltd.
Elisabeth Whitelaw	Cornelia Hahn Oberlander Landscape Architect
Cathy Wiley	Mountain Equipment Co-op
Debra Wright	Canada Mortgage & Housing Corporation
Sue Zielinski	Transportation Options, City of Toronto