Proceedings of the Green Roof Infrastructure Workshop Held at NRC

Kuhn, M. E.; Liu, K. K. Y.; Marshall, S.

National Research Council Canada
Conseil national de recherches Canada

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Institute for Research in Construction
Institut de recherche en construction
IRC

GREEN ROOF INFRASTRUCTURE WORKSHOP

June 25, 2001
Ottawa

WORKSHOP PROCEEDINGS

Prepared For:

Canada Mortgage & Housing Corporation CMHC

National Research Council NRC

Environment Canada

Green Roofs for Healthy Cities Coalition

Prepared By:

Monica E. Kuhn, Architect
Karen Liu, NRC
Sandra Marshall, CMHC

INTRODUCTION

This report documents the proceedings of a workshop on Greenroof Infrastructure held at the NRC in Ottawa, Canada on June 25, 2001. The workshop was designed to provide architects, researchers, and policy makers with an introduction to the benefits, development, and design of green roofs, as well as an overview of current research projects, needs, and future opportunities, including a tour of NRC's new green roof research facility. It was hoped that the workshop would enable participants to meet, network, and share ideas with other people working or interested in the newly emerging field of green roof technology within North America.

This report is a record of the presentations made by speakers in the morning and the comments generated by three breakout sessions held in the afternoon, as well as background research in the form of appendices.

ACKNOWLEDGMENTS

This workshop was made possible by the National Research Council's (NRC) Institute for Research in Construction, in partnership with Environment Canada, Canada Mortgage and Housing Corporation, and the Green Roofs for Healthy Cities Coalition (The Cardinal Group Inc.). The generous support from our industrial sponsors, Hydrotech Membrane Corp. and Soprema Inc., are greatly appreciated.

Special thanks to the NRC for hosting the event at its research site in Ottawa, and to Karen Liu for all of her promotional and organizational support.

The workshop organizers would like to thank all of the people who contributed time and effort towards this project.

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TABLE OF CONTENTS

1.0 WORKSHOP OVERVIEW

Green roofs, or rooftop gardens, are receiving increasing attention in North America. They are a potential component of any strategy to address many of the environmental challenges facing our cities over the course of the next century. Green roofs can reduce urban heat island through evapotranspiration, which reduces the amount of heat that is radiated from the roofing membrane, thus reducing energy consumption for cooling, heat stress and the severity of smog episodes. Replacing impermeable surfaces with vegetation can reduce storm water runoff, and the plants and the soil act as filters, thus improving the quality of the runoff. By providing space for vegetation in urban areas, green roofs can increase wildlife habitat and play a role in preserving biodiversity.

The development of a market for green roofs would require that the workshop provide information about:

- green roof infrastructure implementation and their many benefits
- technical research on these benefits at the facility and aggregate level

The National Research Council of Canada (NRC), in partnership with Environment Canada, Canada Mortgage and Housing Corporation (CMHC), and Green Roofs for Healthy Cities, organized the Green Roof Infrastructure Workshop as an ICBEST pre-conference event on June 25, 2001. This workshop aimed to provide technical information on the implementation and benefits of green roofs, and offered an opportunity to discuss green roof research as well as to develop potential research collaborations. With the co-ordination with ICBEST, this workshop provided an opportunity for international participants to exchange information with Canadian colleagues on this exciting technology.

The objectives of the workshop were as follows:

- To introduce architects, developers, government officials and other interested parties to the design, implementation, marketing and benefits of green roofs.
- To profile NRC's Rooftop Garden Field Research Facility in Ottawa and other research on green roofs that are ongoing in North America and Europe.
- To provide an opportunity to continue to develop and refine the research protocols that were established at the University of Toronto workshop (2000) and to explore new research areas.
- To test a 'how to' basics in designing and marketing green roofs for the architectural profession and expand our knowledge on design for specific benefits.
- To establish an international network of interested parties on green roof design, implementation and research.

The primary audiences for this workshop were:

- Architects and developers interested in getting more information on green roofs.
- Domestic and international researchers who are interested in green roof research.
- Government officials involved in climate change, water quality, air pollution and city planning.

2.0 AGENDA

The workshop was designed in two parts. The morning sessions provided an introduction to green roofs and implementation information designed to accommodate the needs of architects. The afternoon sessions were focused on issues and opportunities related to green roof research at the facility and aggregate level, as well as related policy recommendations.

Time	Session	Notes
8:00-8:30	Registration	Coffee and Muffins
8:30 – 8:40	Welcome (NRC)	Ralph Paroli
8:40 – 8:55	Green Roof Introduction & Overview of Benefits	Steven Peck
8:55 – 9:25	Demystifying Green Roofs	Doug Pollard
9:25 – 10:45	Designing Green Roofs - Approaches, Key Issues, & Marketing to Clients; Q & A's	Monica Kuhn
10:45-11:00	Refreshment Break	Coffee and Juice
11:00 – 11:30	Landscaping Issues - Plants, Growing Medium, & Maintenance	Kaaren Pearce
11:30 – 12:15	NRC's Field Roofing Facility – Research and Tour	Karen Liu
12:00 – 2:00	Industrial Display of Green Roof Systems at Field Roofing Facility: • Soprema Inc. • Hydrotech Membrane Corp.	
12:15 – 1:15	Networking Lunch	At NRC - BBQ.
1:15 – 1:40	Overview of Research Needs and Activities	Brad Bass
1:20-4:00	3 Concurrent Sessions profiling research and asking: What do we know?; What needs more research?; Next steps in research?; Possible collaboration?	
	1. Aggregate Research - Urban Heat Island, Stormwater Modeling, & Air Quality	Brad Bass
	2. Facility Research – Toronto City Hall, Eastview Community Centre, & Penn State	Karen Liu David Beattie
	3. Policy Discussion – Policy instruments currently in place to encourage green roof infrastructure investment, how they work, & what more needs to be done	Steven Peck
4:00 - 4:15	Refreshment Break	Juice/Pop and Cookies
4:15 - 5:00	Closing Plenary	Steven W. Peck Brad Bass Karen Liu

3.0 MORNING SPEAKERS

3.1 GREENROOF INTRODUCTION & OVERVIEW OF BENEFITS - Steven Peck

Note: For more detailed information on the topics presented, please refer to Design Guidelines for Green Roofs, a report written by Monica Kuhn and Steven Peck for CMHC in Spring 2001. It can be downloaded at the CMHC web site:

English: http://www.cmhc-schl.gc.ca/en/imquaf/himu/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=32570
French: http://www.cmhc-schl.gc.ca/fr/amquablo/toenha/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=32572

Green Roofs: Infrastructure for the 21st Century

Green Roof Workshop - Ottawa
June 25, 2001

Steven Peck, President
Cardinal Group Inc.
Executive Director
Green Roofs for Healthy Cities
speck@cardinalgroup.ca

Our Goals

To foster the development of a multi-million $ market for green roof infrastructure in North America

- Share resources to develop market and new business opportunities.
- Address **technical performance** & **awareness** issues.
- Promote public investment?

Overview

- Green Roofs for Healthy Cities
- Market Drivers - 21st Century
- Public & Private Benefits
- Challenges to Widespread Market Penetration
- Conclusion

Our Activities

- Publish "Green Roof Infrastructure Monitor" smatheson@cardinalgroup.ca to subscribe.
- Free resources on our web site - www.greenroofs.ca
- Partner for demonstration projects - City Hall, Eastview and St. Patricks
- Promote and facilitate technical research - Researcher's Corner On-line.

Green Roofs for Healthy Cities Coalition Members

- Flynn Roofing
- Soprema,
- Garland,
- Sheridan Nurseries,
- Elevated Landscape Technologies
- IRC Building Sciences,
- J+M, Landscape Architects

Establishing a Green Roof Industry in North America?

It's happened in Europe!

Is It Possible Here ?

21st Century Market Drivers

- Fiscal - Stretch Public $$ (infrastructure renewal)
- Quality Amenity Space/Strengthen Downtowns (aging/growing population)
- Air Quality - Human & Ecosystem Health (SMOG, particulates and toxins)
- Climate Change Impacts (severe storms/ heat waves, urban heat island effect)

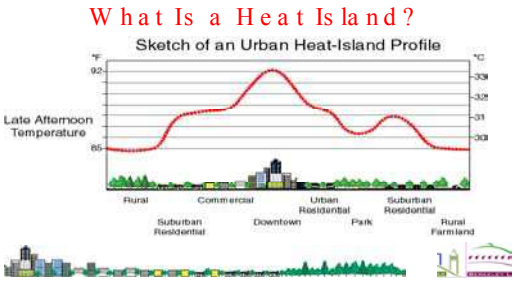
Public Benefits - A Basis for Investment

1. Improvement of Air Quality
   - reduce particulate matter
   - reduce smog precursors
2. Climate Change Mitigation
   - heating & cooling
   - sequestration CO_2 by plants
   - reduce urban heat island effect

21st Century Market Drivers

- Stormwater Quality - Quantity (flooding, erosion, pollution, recreation, fish habitat)
- Protection from Unstable Energy Costs
- Long Term - 25- 50 Years and More:
  - Food Security - (sprawl and loss of farmland - unsustainable production practices - water/soil fertility)
  - Lower Energy Material Throughput in Economy
  - Create Meaningful & Diverse Local Employment

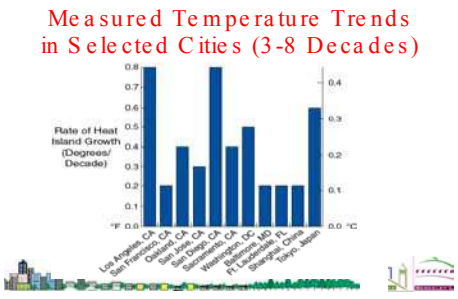
Public Benefits: Heat Island Mitigation



Green Roof Infrastructure: Addresses Challenges

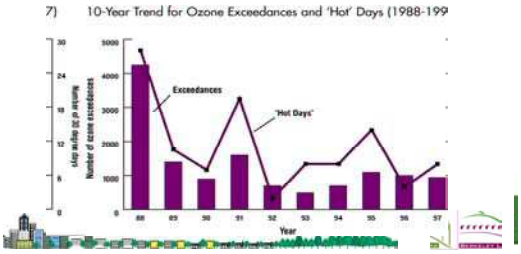
- Public Benefits - Typically City Wide or Aggregate
- Private Benefits - Building or Site Specific

Public Benefits: Cities are Getting Hotter



Public Benefits:
Hotter Cities = More Air Pollution

Ozone vs Temperature in Ontario



More Public Benefits of
Green Roof Infrastructure

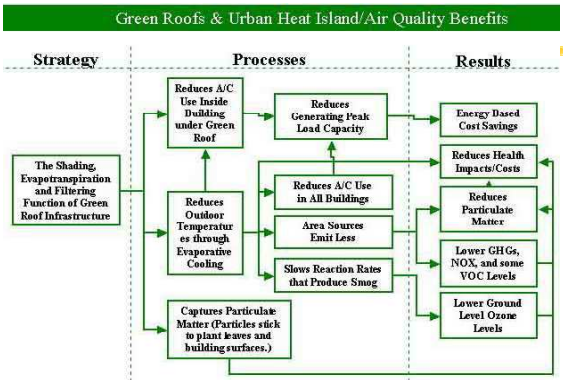
6. Aesthetic Improvements/Improve Public Spaces

7. Health Benefits (Hospitals)

8. Improved Safety (Safe spaces for seniors)

9. Recreation/Amenity Space

Reduce UHI = Cleaner Air & > Energy Use



More Public Benefits of
Green Roof Infrastructure

3. Climate Change Adaptation
   - improved stormwater retention (Floods)
   - reduce urban heat island effect (Heat Waves)

4. Stormwater Management (summer/winter)

5. Water Filtration & Quality Improvements (temperature, turbidity and pollutants)

Public Benefits
of Green Roof Infrastructure

10. Job Creation
(Direct Installation & Maintenance - New Uses of Wasted Space = ICI 6% tot. area of T.O-- Could be - urban agriculture production, industrial cooling, wedding pictures -)

11. Preservation of Habitat & Biodiversity (Island Habitat and Stepping Stone)

Private Benefits of Green Roof Infrastructure

1. Reduced Heating & Cooling Costs

2. Membrane Life Extension - x2 or more?

3. Indirect Economic Benefits - Amenity space for occupants/increased productivity/daycare play space at work etc.

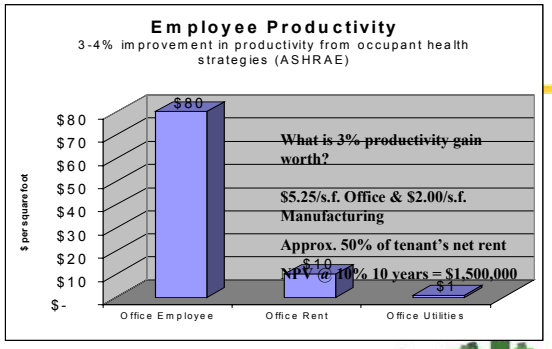
Selected Niche Markets For Green Roof Infrastructure

1. Multi Unit Buildings

2. Hospitals/Industrial With High Cooling Costs

3. Organizations with Social/Environmental Mandate

NO WIDESPREAD MARKET



Challenges to Widespread Market Penetration

- Quantification of public benefits in order to justify public direct or indirect investment/incentives
- Performance data (site and city-wide) for different systems in different climates
- Awareness raising/training

Private Benefits of Green Roof Infrastructure

4. Sound Insulation - airports, highways etc.

5. Increase Property Market Value
   - Private 'Roofpark' in condos

6. Direct Economic Benefits
- Lease space for Urban, Agricultural Production Special functions

- Roof space as 'last urban frontier' concept

7. Fire Retardation

Green Roofs for Healthy Cities- AWARENESS BUILDING

- Technical information available on-line: **www.greenroofs.ca**
- *Publish Green Roof Infrastructure Monitor* Free Journal - send e-mail to: **aysasept@cardinalgroup.ca**
- Public speaking events and reception - City Hall, June 13, 2001.

Bottom Line on Green Roof Infrastructure

- Public direct or indirect investment required for market transformation
- Much needed multi-faceted infrastructure for that will increasingly be driven by market forces.

Focus of Afternoon Discussions

- Examine current research efforts and way to expand it through joint projects.
- Examining opportunities for public policy support of green roof infrastructure.

Biography: Steven Peck, the Cardinal Group & the Green Roofs for Healthy Cities Coalition

Steven Peck is an expert on public policy and the environment, particularly in the areas of technology development and diffusion, and urban sustainability. In 1996 he founded Peck & Associates to focus on developing and implementing policies and programs that yield both environmental and economic benefits. Since that time, he has completed major studies in areas such as: eco-efficiency and the software sector; barriers to the cross sectoral exchange of cleaner production technology; opportunities for eco-industrial networking in Canada; and how to establish an eco-fund to improve technology innovation among small to medium sized enterprises (SMEs).

Recently, Mr. Peck played a lead role in examining measures to stimulate technological innovation in Canada that will lead to greenhouse gas reductions for the Technology Table of the Climate Change Secretariat. He also wrote the SME chapter of the Industry Table's Foundation paper. In 1999, Mr. Peck and Monica Kuhn co-authored a study on green roof and vertical garden technologies for Canada Mortgage and Housing Corporation. As a result of this research, he founded Green Roofs for Healthy Cities, a coalition of businesses working to overcome barriers to green roof technology diffusion in Canada.

In June 1996 Mr. Peck and Dr. Ray Tomalty co-founded a peer reviewed electronic journal on urban sustainability called, "The New Urban Agenda". It includes articles on 'best practices' that address the root causes of unsustainable urban development. Peck and Tomalty are currently leading a major research project that is critically examining barriers to innovation in the development sector and identifying possible roles for the federal government to play in helping to stimulate innovation in this important sector.

Mr. Peck has an Honours B.A. degree from McGill University in Political Science & Economics.

3.2 GREEN ROOFS I DIDN'T KNOW I KNEW -The Green Roof Demystified
- Doug Pollard

Introduction:

When we decided that the Boyne River ecology centre should have and could only have a fully planted roof, I thought I would have to do a lot of research on how to build one.

And then it dawned on me one day that I had already done a lot of them without even thinking about it. Every parking garage of every high rise which extends beyond the edge of the building has one. It just happens to be at grade.

And then I remembered raised platforms with full plantings of trees and bushes and flowers in the middle of Toronto which we also did without thinking twice.

And then I remembered walking through Robson Square in Vancouver which has an elaborate green roof also at grade which most people regard as a park.

Admittedly conditions at higher levels get more extreme ...wind and solar exposure become more acute and species selection and planting techniques require more care. However the notion that plant life can be supported in a defined thickness of planting medium on an impenetrable structural layer without damage to the supporting structure remains a constant.

If the notion of a green roof makes you nervous start here with a grass roofed bird house. This is a design of Macolm Wells, an architect who has built countless earth roofed structures in the U.S for the last 40 years or so. In fact he has done virtually no other kind. He lives in a magnificent earth roof house on Cape Cod as well.

My Experience:

The Boyne River (Outdoor Education Centre of the Toronto Board of Education near Shelburne, Ontario) roof was done before I knew anything about the new more sophisticated systems now available. We used intuition and our experience with parking decks and so forth and we had no problems whatsoever other than with the skeptics.

This is what we did:

Explanation of system: EPDM sandwiched between two layers of rigid insulation to keep membrane protected but allow for drainage through open joints in upper layer, to keep water warm to allow for drainage during cool weather. 1 foot of mixed soil and granular, six inches each. Note:

- we used topsoil and gravel and granular - nothing new;
- in our case the weight of the material had very little effect on the truss design because of the inherent strength of the truss at the depth we wanted for other reasons;
- that the Soprema consultant who markets the Soprema system at first said EPDM would not last but upon examining our approach changed his mind and noted that we had extended the life of the membrane by isolating it from both thermal shock and UV degradation.
- curb not necessary but will explain later

It worked...in fact we produced huge icicles from our water spouts because it worked so well. We had to cut the spouts back because the icicles were growing so well and so fast thy extended four feet or more and then shot off. The board's lawyers (the client was the Toronto Board of

Education) were deathly afraid one of them would penetrate the offspring of someone in the legal profession and that would be the end.

When we did the roof the aforementioned legal brains were deathly afraid that the soil would slide off, once again, no doubt, onto the same legal offspring and they insisted we use a retention blanket off the sort you see along highway cut embankments.

This fear, by the way, was in spite of the fact that building was on a very stable slope which was many times steeper than the roof.

Our agenda for the Boyne was that we were going to avoid synthetic materials and most of these blankets are made of oil based petroleum.

So we set out to find a blanket made from natural materials and we found on made of straw glued together with natural resins and impregnated with wildflower seeds. (This took us a while and we finally made an arrangement for the supplier to visit the site. By this time the topsoil was already o the roof.)

When the supplier arrived and after he stopped smiling regard the very gentle slope we were dealing with and after he realized the overall agenda for this building he said that he could make us a blanket with indigenous seeds in it instead of the more generic seeds which were normally found in the off the shelf version. We said great. He said it will take him another few weeks to obtain the appropriate seeds, impregnate them into the blankets and deliver and install the now fully biodegradable indigenous wildflower seed impregnated blanket on the roof where it would decompose and by decomposing provide nutrition for the seeds which would grow and become the soil retention system.

While all this was going on we were obviously being observed from above by an apparently bemused creator because after a sudden rain shower this happened The roof sprouted by itself and the necessity for planting anything disappeared. We phoned the supplier, thanked him profusely and cancelled the order. WE never planted anything, everything which grows on this roof got there by itself either in the original soil, by wind or by bird or insect.

The growth on the roof is superior to that on the ground because solar exposure is better. We do have the wildflower blankets in swales at the back of the building and we can see the difference.

One of the other concerns we had when we were doing the roof was maintenance. We had on session with the maintenance staff about how they were supposed to mow the grass. They do not mow anything else on the 400 acre site and I thought they were joking. Besides since the leaf cover reflects about 30% of the sun you want it to be shaggy so it will cool the building.

Anyway I launched into a detailed dialogue about how to get three goats, tie them with different length ropes to the centre and how they would walk around in concentric circles munching away before I realised they were serious. When I told them not to mow they were relieved but still skeptical. If our budget had permitted perhaps I cold have cooked up a trip to Switzerland and sought out a few hundred year old shaggy grass roofs for examples.

I mentioned earlier the curb around the edge. This too was a result of the paranoia around soil slippage and we did concede to build the curb in order to control the noise we were getting. There are many many many grass roofs which exist happily without such a curb. In fact it was Malcolm Wells stated objective to build his roofs so the soil came to a knife edge point and he did it several times. Usually however soil has some thickness although not much.

How well does it work?

- The building has no mechanical systems at all.
- I have stood on the roof in suffocating heat practically unable to breath (to take slides and see how things were doing). Then I have gone into the building which was shut up tight in the peak of the heat to find it amazingly cool and comfortable.
- The earthy roof is a significant contributor to this non-mechanical cooling system since besides reflecting the sun as I mentioned it establishes a thermal lag effect whereby the soil must be warmed before the roof itself and the moisture in the soil removed through evaporation. This evaporation process requires heat which is drawn from the building shell thus cooling it. The lag is such that the actual roof membrane only begins warming up at the end of the day and very little heat actually ever gets onto the building itself. As night time temperatures fall the soil loses its gained heat and by morning conditions are such that the cycle can be repeated the next day.

If you get concerns over extra costs for a green roof then suggest that the money be drawn from the cooling budget. By the way don't forget there is no operating budget required.

Bottom Line?

To me it's a no brainer. Nothing went wrong, everything went right. After 8 years I have not heard another word from the lawyers or the maintenance staff. The flowers continue to grow (some as high as six feet) the building continues to heat and cool itself, and the roof continues to provide an aesthetically pleasing breathing surface which is habitat to a number small birds and insects.

To me it is as natural as a golfer replacing the divot when he hacks up the golf course - when we make a scar on the earth's surface with a building we simply put back on top of it what we removed so that the balance of the ecosystem is maintained and so we can continue to benefit from that balance ..for free.

Would I do it again?..anytime I get (or make) a chance!

Biography: Doug Pollard, Senior Researcher, CMHC

For thirty years prior to joining CMHC in 1998 as a senior researcher in sustainable community planning, Doug maintained his own architectural practice in Toronto.

His practice focused on housing and small institutional projects demonstrating the potential for an intelligent use of land, resources, and finances, and optimizing opportunities for user participation in the design process. The work of his firm - including projects with green roofs - has been published in Canada, the US, and Europe, and has received several awards for sustainable design.

Doug has extended this architectural work in relation to the CMHC research work, which he manages. His current projects include the assessment of barriers to sustainable development in Canada, the development of user tools and participation methodologies, and the development of generic Canadian sustainable design guidelines.

Doug also chairs the National Housing Research Committee's working group on sustainable communities, which is exploring and developing the business case for sustainable development.

3.3 DESIGNING GREEN ROOFS - Monica Kuhn

1.0 Approaches & Key Issues

1.1 DEFINITION

- greenspace; created by adding layers on top of a traditional roofing system
- image of "slipping the building under a layer of soil and grass"
- not to be confused with a roof garden

1.2 LAYERS (definition and use)

- roof structure
- membrane, with insulation either above or below
- drainage layer
- filter / landscaping cloth
- growing medium
- plants

1.3 TYPES (definition, advantages vs disadvantages)

- extensive
- intensive
- mix of extensive and intensive

1.4 HISTORY / PRECEDENT

- cold climate applications - Scandinavia
- warm climate applications - Tanzania
- vernacular / folk architecture
- material necessity
- building as landscape
- environmental - current day suburban, urban, high tech, and folk

1.5 DESIGN CONSIDERATIONS

- Use - design for function; what is it supposed to do?
- Location - height, orientation, overlook, shadow, building type; every location is unique
- Consultants - who do you need to help you?; what questions do you need answered?
- Regulatory Approvals - permits, building codes, by-laws, planning acts
- Structure - most important determining factor; assume existing - new is easy; applicable loads
- Access & Exits
- Roofing - traditional vs inverted; new types of membranes; protection; leak detection
- Plants - it all depends on the depth of soil and the amount of maintenance & irrigation
- Construction / Installation - how to get it on the roof and by whom?
- Maintenance
- Insurance & Liability

2.0 Marketing to Clients / Selling the Concept

2.1 PRIVATE BENEFITS (Building Owner)

- energy savings
- roof membrane protection & lifespan extension

- sound insulation
- fire resistance
- amenity space / green space
- double value for price of one piece of land
- aesthetics
- horticultural therapy
- water cooling / mechanical system connection
- urban agriculture

2.2 PUBLIC BENEFITS (Tenants, Neighbors, and the General Public)

- mitigation of urban heat island effect
- storm water runoff reduction
- air & water cleaning
- creation of habitat

2.3 INCENTIVES (for Public Benefits)

Examples of European and potential / future North American

- tax credits
- utility / infrastructure credits
- density bonuses
- development approvals
- one time design and installation grants

Note: This was a presentation with slides / projected photographic images showing examples of green roofs from around the world. For more detailed information on the topics presented in point form above, please refer to Design Guidelines for Green Roofs, a report written by Monica Kuhn and Steven Peck for CMHC in Spring 2001. It can be downloaded at the CMHC web site:

English: http://www.cmhc-schl.gc.ca/en/imquaf/himu/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=32570
French: http://www.cmhc-schl.gc.ca/fr/amquablo/toenha/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=32572

Biography: Monica Kuhn

Monica Kuhn is an architect in Toronto. Her small practice, established in 1994, specializes in residential design, rooftop gardens, and urban greening.

She is one of the founding members of the Rooftop Gardens Resource Group, and acts as a technical consultant for The Green Roofs for Healthy Cities Coalition. Her writing on green roofs and rooftop gardens has been published by the Ontario Association of Architects and CMHC, among others.

Monica is a permaculture instructor and has taught and lectured in Canada and the Northern United States on sustainable design and urban greening issues.

3.4 LANDSCAPING ISSUES - Kaaren Pearce

1.0 Introductory Questions

The following is a list of general questions that establish the criteria for discussion about the specifics of a particular greenroof system:

- What is the space to be used for? (Views, esthetics, education, people/amenity space, storm water retention, heating and cooling effects, habitat, agriculture, etc.)
- What is the load bearing of the roof? (This will lead the design, as weight increases with soil depth and depth increases the variability of species available. Loads vary generally from 40-160 pounds per square foot.)
- What are the plant considerations? (Plants naturally found in Alpine, prairie or scree conditions are better suited to life on a rooftop.)
- What plant materials are available and where?
- What are the pros and cons of the specialized greenroof systems available?
- What are the pros and cons of the specialized soil mixes used in these systems?

2.0 Greenroof Maintenance

2.1 Qualifications of Maintainers

The personnel who are responsible for the establishment and maintenance of the greenroof should possess the following characteristics:

- formally trained in Horticulture or Agronomy
- a minimum of 15 years of practical experience in all aspects of horticulture
- extensive practical experience with perennial plants and specialty turf
- good taxonomy skills with ability to competently identify undesired species at various growth stages
- solid understanding of ecosystems and microclimates
- understanding of the various manufacturer's greenroof systems to prevent damage to any of these components during maintenance
- understanding of the basic components of an irrigation system

2.2 Maintenance Schedules

2.2.1 First Year Establishment

The greenroof should be established over a 21-week period beginning around May 24 running to about Oct 15.

- Weekly inspection of the entire greenspace is required for the first 8 weeks to ensure healthy root development. Replace, seed and top-dress as required. Fertilize if required. Remove undesired species. Check nozzles and spray patterns of irrigation system to ensure adequate moisture.
- Biweekly inspection of the entire greenspace for the next 8 weeks should include deadheading as required in addition to the items above. Fertilizing is not necessary during this period.
- Weekly inspection of the entire greenspace should be done for the final 5 weeks of the season. Weed as required, collect seed if desired, divide species if appropriate, adjust irrigation and wintering without adding undo weight! Maintain the greenspace as free of leaf litter as possible.

2.2.2 Established Extensive Systems

As a minimum, maintenance for an established greenroof should be conducted four times a year.

- Early spring -remove all leaf litter and any dead plant material, trim, divide, top-dress and seed if required. Weed out any germinating seeds from the fall. Prepare and check irrigation system for the season.
- Early summer -trim up early flowering plants, adjust irrigation, and weed.
- Early fall - weed, collect seed, and basic maintenance.
- Late fall -winterize irrigation and prep plants for winter ensuring that plants have adequate water in the soil to over-winter.

3.0 Considerations

3.1 Irrigation

If the budget is available, sensors can be used to maintain the balance between the air pockets and available water to the roots. They will control the system based on moisture content instead of the use of a timer or manual control. This is the most efficient method and will save on water costs.

Irrigation on extensive systems is not required but is recommended. It can be used during periods of low rainfall to ensure protection of the plant investment. If it is not in place the options can be cumbersome.

3.2 Fertilization

Fertilization for extensive systems should not be an annual requirement; perhaps every 3-4 years. For intensive or semi-intensive gardens a recommended fertilizer should be specified. A landscape company will likely use what is on hand or the cheapest available. Granular varieties if not watered in or broadcast on dry growing medium can burn roots and leaves. The same concern exists if a liquid application is used in high temperatures as the roots are thirsty and they "suck up" the moisture quickly. Natural fertilizers such as fish emulsion or compost tea are good alternatives to commercial fertilizers. As most of the species used on extensive rooftops are not heavy feeders and would rather live on poor soil it is suggested that fertilization be used on intensive and urban agriculture rooftops, keeping the use on extensive systems light.

3.3 Pest Control

Pest control requirement is minimal. Use of herbicides and pesticides should be avoided and used only in a crisis situation.

3.4 Weeds

Most common landscape weeds will also be a nuisance factor on the rooftop. They tend to grow in cycles. Early spring weeds prefer cooler conditions and tend to go dormant or die in the heat. Others do not actively grow until the average air temperature goes up in late spring and summer. Maintenance scheduling should be done to catch the majority of these at certain times of the year. The most damaging of the weed found on rooftops will be trees, wind-borne species in general. The maintenance schedule should include a time frame to enable removal of the seedlings at the appropriate time.

3.5 Roof Repair

If roof repair under the planted area should be required, first identify the limits of the area and devise a complete plan for the process before beginning. Discussions with the roofer are important here and will not likely need to involve the Architect or general contractor. The aim is to minimize damage to root structures. For example, if a 2'x2' area requires repair, a plywood sheet with small

folding legs could be used to slide the lifted area on to and set aside. Soaked burlap should be placed under the lifted roof area to help retain moisture. If possible the plants should be lifted and returned during the cooler part of the day and be sheltered from wind in particular. The time the lifted section is isolated should be minimized and returned as soon as possible.

3.6 Warranty

The installer of the system should be offering a warranty. To maintain a valid warranty the maintenance contractor must fill out a report at the end of each month verifying activities conducted. This report includes dates of inspection, personnel involved, activities performed, notes on growing conditions and adjustments made or required. The report is to be signed by the maintenance contractor, the maintenance personnel and verified by an appropriate person responsible for the building where the greenspace is installed.

A complete maintenance manual is the best way to ensure ultimate care. Using the design or architectural drawings, the areas of low, medium, and high maintenance can be identified with defined schedules for each. The Landscape Architect or designer should be able to provide general cultural notes of the species on the roof. This can be as simple as a plant list or as comprehensive as a booklet or report, with pictures, general horticultural information, division times, diseases and insects that specific plants may be susceptible to. A manual could also include the most common undesirable species with pictures of these weeds in different stages of growth and include chemical and cultural control methods.

Biography: Kaaren Pearce

Kaaren Pearce has been active in the Horticulture field for 18 years and has an extensive background in Landscape Design. Since 1999, she has become known and respected as a specialist in the field of green roof technology. Kaaren has been invited to speak on and conduct workshops in green roofs, landscape design, naturalizations, horticultural therapy, plant pathology, pruning techniques, and arboriculture by a wide variety of organizations.

Elevated Landscape Technologies (ELT), founded by Kaaren Pearce, is a federally incorporated company focused on the creation and conversion of spaces into environmentally and socially healthy areas. The company specializes in green roof systems for residential, commercial, institutional, and industrial facilities. ELT provides complete service for horticultural therapy gardens, both above and at ground level, and naturalization of school grounds, including related curriculum development.

4.0 NRC'S FIELD ROOFING FACILITY – Research and Tour

National Research Council Canada | Conseil national de recherches Canada

NRC·CNRC

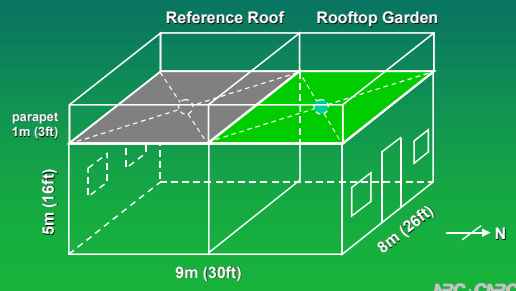
NRC's Rooftop Garden
Field Research Facility

Karen Liu
Institute for Research in Construction (IRC)

Canada

construction IRC

Field Roofing Facility (FRF)



NRC·CNRC

Barriers to Technology Diffusion

*4 Major Barriers**

- technical issues
- lack of knowledge / awareness
- lack of incentives to implement
- cost - based barriers

* Greenbacks from Green Roofs - Steven Peck and Brad Bass, 1999

NRC·CNRC

What Do We Monitor ?

- Temperature profile
- Heat flow
- Solar reflectance
- Soil moisture content
- Relative humidity
- Storm water retention

NRC·CNRC

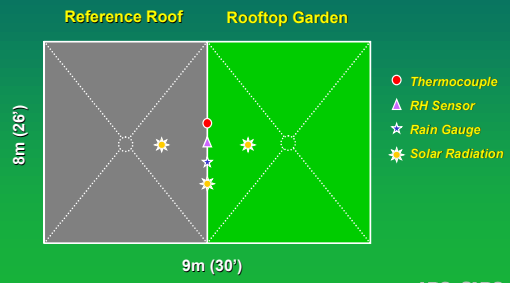
Rooftop Garden Consortium

National Research Council
Institute for Research in Construction

Government Organizations	Roofing Associations	Roofing Manufacturers
Climate Change Action Fund (CCAF)	Canadian Roofing Contractors Association (CRCA)	Bakor
Environment Canada	Roofing Consultants Institute (RCI)	EMCO
Oak Ridge National Laboratory (ORNL)		Garland
Public Works Government Services Canada (PWGSC)		Hydrotech
		IKO
		Soprema
		Tremco

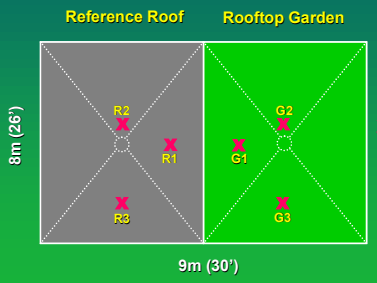
NRC·CNRC

Measurement Locations - Outdoor



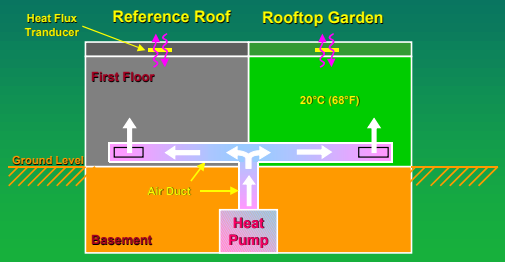
NRC·CNRC

Measurement Areas - Roofing Systems



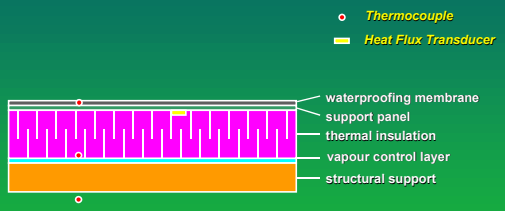
NRC·CNRC

Energy Efficiency



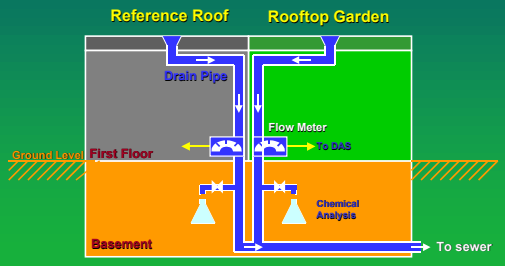
NRC·CNRC

Instrumentation of Reference Roof



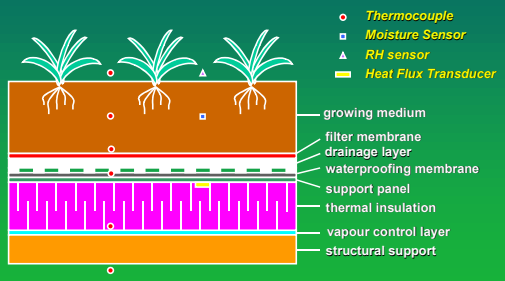
NRC·CNRC

Storm Water Retention



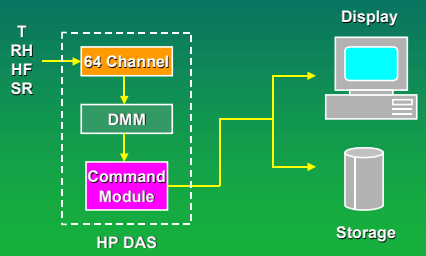
NRC·CNRC

Instrumentation of Rooftop Garden



NRC·CNRC

Data Acquisition System



NRC·CNRC

Tour of NRC's Field Roofing Facility

Biography: Karen Liu, NRC, Institute for Research in Construction

Dr. Karen Liu is a research officer with the Building Envelope and Structure Program at the Institute for Research in Construction (IRC), National Research Council Canada (NRC). She has more than 10 years of research and development experience in polymers and composite materials. Her current research interests at IRC/NRC include environmental effects on the durability of construction materials, chemical and mechanical characterization of roofing components, and thermal performance of rooftop gardens. She has initiated the Rooftop Garden Consortium at the NRC/IRC and established a field research facility on the NRC campus to systematically study the energy efficiency and environmental benefits of rooftop gardens. Dr. Karen Liu received her Ph.D. from the Department of Chemical Engineering and Applied Chemistry at the University of Toronto, Canada.

5.0 AFTERNOON BREAKOUT SESSIONS

This section contains notes from the afternoon breakout sessions' discussions.

5.1 GREEN ROOF INFRASTRUCTURE WORKSHOP

Breakout Group No.1 - Aggregate Research

Chair: Brad Bass, Environment Canada

Presentation: Urban Heat Island - Brad Bass, Environment Canada

Slide #1- Elevated temperatures of cities are due to:
reduction of vegetation cover in the city
large amount of impervious surfaces such as roof tops, asphalt roads
thus the release of waste heat into the atmosphere

Slide #2 – Display of Surface energy Budget
Q = H+ LE + G
H = Heat Flux
LE = Sensible Heat Flux
G = Storage of Heat

Slide #3-5 These slides graphically depicted the mean, minimum and maximum temperatures of Toronto as compared to London and St. Catherines. They illustrated that the rising difference in temperature between Toronto and the other urban centres is mainly due to the larger roof top area, road surface, number of vehicles on the road, and the removal of vegetation from Toronto area.

Slide #6- An IR photograph from space shuttle showing the heat islands of Toronto and surrounding area. Toronto is a hotter than other surrounding cities, including the rural area around it. The downtown is significantly hotter than urban parts of the city, radiating more heat back into the environment.

Slide #7- Thermal cross section of Toronto
It illustrates temperature increasing from residential area to the downtown core.
There were two small dips in the graph depicting the lower temperature of the green belt in Toronto, then the increase in temperature closer to the downtown core.

Slide #8 – Map of land use in Toronto
It depicts the green canopy cover in Toronto (1996) and the potential improvement for urban reforestation. Unfortunately at this time we cannot calculate the total square footage of rooftops vs green.

Summary

- Green roofs are cooler than non green roofs
- Vegetation and white surfaces (walls) will reduce urban heat island.

- Hard data or numbers showing the energy savings of green roof vs standard roof can convince building manufactures the savings in heating/cooling cost. There are other environmental impacts of a green roof such as improving air quality and reducing roof run off.

Comments:

Matt Carr, American Hydrotech
To complement Brad's IR slide on Toronto, depicting the thermal gradients in the Toronto area; Matt Carr displayed a slide showing the thermal imaging of downtown Atlanta GA. He stated that due to urban sprawl, the temperature of the urban heat island has increased 3 times in the last 10 years.

David Schryer, University of Toronto (Chemical engineering student involved in the study of Chemical movement in cities)
The pollution in cities are generated mainly from automobile, public transportation, compounds released by BBQ's, which result in approximately 1000 deaths / year in Toronto. His research studies revealed that chemicals found on walls and windows can be washed off, which can be transferred into the soil. Vegetation tends to absorb more chemicals, through the "wax" part of the plant, which then breaks down the particulate.

Further discussion had revealed that Japanese research has been studying the effect of TiO_2 on surfaces and its relationship on the breakdown of chemicals. Germany has been collecting rain water from roof top garden and collecting the rain water in a cistern. Since the rain water is filtered through the soil, this grey water is then reused to water plants, flush toilets, etc.

Summary:

- We need quantifiable data on chemical compounds being absorbed by plants, and the quantity and quality of the storm water run off.
- It is necessary to convince property owners on the storm water management benefits of green roofs. Germany has tax incentive programs to promote installation of green roofs. In North America, government agencies have to recognize the benefits of green roof through provision of financial incentives.

Discussions:

1. What are the effects of a prolonged rain on a rooftop garden and on the runoff?
For prolonged rains, as in England, the green roof will absorb the water, which will impede the initial flow of the storm water into the sewer. When the rooftop garden becomes saturated with water, the storm water flow should be the same as the storm water flow from a non-rooftop garden.

2. How does thermal mass of growing medium work?
Growing medium absorbs heat during the day and then releases the heat back into the environment at night. Shading of the roof by trees will reduce the buildup of heat. Evapotranspiration of water from the growing medium helps with cooling. Factors to be

considered are soil porosity, depth of soil, water retention of the soil. There is very little data on this subject in North America, apparently Germany has lots of data on this subject.

3. What is the winter and summer performance of a green roof?
The temperature fluctuations experienced by the membrane on a green roof are lower than those of the reference roof in the summer. The green roof helps keep the roof membrane cooler in the summer, protecting it from UV, thus extending its life. The green roof tends to moderate the temperature of the roof membrane to approximately 20°C, while the membrane temperature of the reference roof goes up to 60°C. The green roof also moderates the daily temperature fluctuations the membrane experienced in the winter, but to a lesser extent.
It will be beneficial to show computer modeling performed by engineers and architects, showing an energy efficient building with and without green roof.

There is no concrete data in North America on this subject.

Suggestion: try and find a comparable building with and without a green roof. Record the energy consumption of the two buildings.

Suggestion: monitor the energy of a building without a green roof for a year. Build a green roof on it and monitor it again for another year.

Conclusions:

Green roofs work. They reduce storm water runoff, heating and cooling costs, prolong roof membrane life, improve air quality and when used extensively in an urban area, they can help to reduce the Urban Heat Island effects.

However there are some drawbacks:

At the moment there is not enough hard data in North America to show the positive aspects of rooftop gardens. It is necessary to convince building manufactures and property owners to justify the capital cost of building a rooftop garden.

Another concern from the property owners is the pay pack period for the capital costs.

Local or federal government bodies should give incentives through tax breaks to have property owners to establish a rooftop garden.

PARTICIPANTS
Breakout Group No.1 - Aggregate Research

Chair: Brad Bass, Environment Canada

Name	**Organization**
Pierre Avard	PWGSC
Matthew Carr	Hydrotech
Joe Edmonds	PWGSC
Susan Fisher	CMHC
Murray Gallant	PWGSC
Tom Jarrett	PWGSC
Gary Johnson	BC Building Corporation
Brian LeVoguer	Henry Company
Donald Macdonald	PWGSC
Rodney McDonald	CIER
David Schryer	U of T
Sybil Stymiest	PWGSC
Mansoor Suteir	PWGSC
Simon Taylor	Pin/Matthews Architects
Christine Ward	PWGSC
Sylvia Welke	
Scott Wylie	Hydrotech

Biography: Brad Bass, Environment Canada

Dr. Brad Bass is a member of the Adaptation and Impact Research Group, an Environment Canada Research Group with a mandate to examine the impacts of atmospheric change and strategies for adaptation to a changing atmosphere. Dr. Bass is co-located in the Institute for Environmental Studies at the University of Toronto. His primary research interests include the use of ecological engineering, such as green roofs and vertical gardens, to adapt urban areas to extreme and anomalous weather events and other aspects of atmospheric change, the impact of climate change on the energy sector and the characteristics of adaptable systems. He has published several articles on ecological adaptation to atmospheric change, climate scenarios and decision making under uncertainty. This work has appeared as reports, articles in journals and chapters in books.

GREEN ROOF INFRASTRUCTURE WORKSHOP
Breakout Group No.2 - Facility Research

Chair: Karen Liu, National Research Canada

Presentations:

1. Rooftop Garden Research - Potential Projects - by Karen Liu, National Research Council, Institute for Research in Construction

Dr. Karen Liu described the research plan for two potential field monitoring projects at the Toronto City Hall and Eastview Community Centre in Toronto. The main features of the two sites and the monitoring plans were described.

Toronto Centre Hall:

- High visibility demonstration site on top of the public library
- Accessible by public
- 8 different plots, 2 green roof systems
- Re-cover project
- Protected membrane system
- Different soil depth in different plots
- Parameters to be monitored
  - Temperature profile
  - Heat flow
  - Soil moisture content
  - Relative humidity
  - Solar radiation

Eastview Community Centre:

- Over large gym, high roof to wall ratio
- Inaccessible
- 2 green roof systems
- Re-roofing project
- Conventional roofing system
- Minimum weight design with shallow soil
- Parameters to be monitored:
  - Temperature profile
  - Heat flow
  - Soil moisture content
  - Solar reflectance
  - Relative humidity
  - Storm water retention

Other potential green roof projects of interest:

- To monitor green roofs in different cities across Canada.
- To study the effects of different components (soil depth and types, plant types, configuration of garden components) in a green roof system as to maximize specific benefits such as energy efficiency, stormwater retention and runoff quality.
- To study the benefits of green roofs in sloped roof of residential housing and to develop light weight growing medium, special anchoring system and low cost, easy-to-install components for residential housing applications.

2. Penn State: Green Roof a Bumper Crop - David Beattie, Penn State University

Professor David Beattie described his green roof research project with PEPP panels on test beds on a roof at Penn State. He showed that the sedum acted as a natural air conditioner. Using an infrared gun, he recorded that while the ambient temperature was 90° F, the gravel reached 119° F, the PEPP at 145° F and the sedum at 82°F. He is planning on establishing and monitoring green roofs on several small portable houses at Penn State.

He stated that there is no reliable statistical data of energy savings to measure the cost/benefit ratio to make specific assertions or declarations, and a quote from Dr. W. Kolb in Germany concurred with that. It is necessary to look at how to sell the green roof to customers, which Germany has done well. Plants are an important component in green roof and they should be studied further.

Discussions:

Comparison of conventional and protected / inverted roofing systems

- installation of green roofs on conventional roofing system and protected membrane system
- need to test both inverted roofs and conventional roofs
- vapor barrier in convention roofs is almost impossible to achieve in real world: best experience with inverted roofs
- the use of one over the other system depends on the environment and service conditions the roof is being subjected to
- both systems worked well when installed properly
- conventional roofs are commonly installed in Canada and have worked well

Can green roof be put on existing roofs?

- should be inspected/tested first to ensure that the existing roof is in good shape

Leakage in green roofs is more difficult to locate and more expensive to repair. Considerations should be taken to prevent and detect leaks.

- perform flooding test before green roof installation to check membrane continuity
- compartmentalize the roof for easy identification/location of leakage
- incorporate leak detection devices into roofing system
- need to plan for leakage/failure in green roof system

Are universities in Canada interested in green roof research?

- U of T is collaborating with NRC on this project
- UBC are considering similar research
- Funding issue is a problem

Any field data from other cities for comparison?

- the climate is very different across North America.
- the Ottawa site is the first research facility
- the Toronto sites will be used for field monitoring
- BC: Use of BCIT's facility
- Winnipeg: Red River College

Suggestion: Karen Liu can provide the instrumentation knowledge and compile data from different sites across Canada

Roofing membranes?

- roofing membrane is the waterproofing layer in a green roof system. Special attentions / considerations should be paid in selecting the roofing membrane.
- Canadian manufacturers generally provide a 10-year warranty for roofing membranes used in green roof systems
- membrane quality is important as future repair can be costly - and choose higher quality products and obtain longer warranty
- use reliable, high quality of roofing membranes which have been tested
- depending on the green roof system configuration, the incorporation of a root repellent in the membrane may be required to prevent roof penetration
- installation of membrane is also important – skilled and experienced labor ensures high quality job.

Existing research?

- Europe has more experience in green roof research than North America. We can learn from their research and development.
- Problem: most German literature has not been translated in English. Funding for translation is required
- Dr. Walter Kolb from Germany is experienced with green roof research; current German FLL test for membrane: 5 year duration, long and expensive
- France also has extensive green roof experience
- an institute in Switzerland is doing research in green roofs

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PARTICIPANTS
Breakout Group No.2 - Facility Research

Chair: Karen Liu, National Research Canada

Name	**Organization**
David Beattie	Penn State University
Guido R Capolino	Chetwynd Systems Inc
George Challies	Soprema (Toronto)
Julia De Nardo	Penn State University
Pat Done	Government of Manitoba
John English	BC Institute of Technology
Kevin Grasty	Halsall Associates Ltd.
Roman Halitzki	Roman Halitzki Architecture and Design
Ken Klassen	NRCan (Winnipeg)
Hulya Kus	University of Gavle (Sweden)
Maria Lipowiec-Kepka	PWGSC
Michael Marton	M. Marton Eng
Kaaren Pearce	ELT
Doug Pollard	CMHC
Michael Rich	
Ed Snodgrass	Emory Knoll Farms
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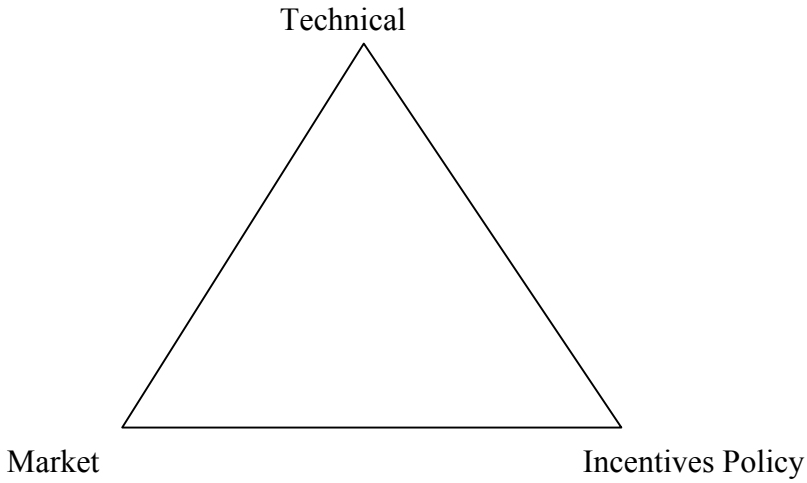
Dana Turnbull	
Allan Wingfield	Colbond Inc
Kevin Wong	CRC

GREEN ROOF INFRASTRUCTURE WORKSHOP
Breakout Group No.3 - Policy

Chair: Steven Peck, Green Roofs for Healthy Cities



- Realistic Policy – Global, Continental, National, Local
- Density Housing (Portland Oregon) saw reductions
- Leader in sustainable community, design, and planning

Context
- Validation, cost / benefit analysis
- Regulations – Density Housing
- Tax incentives / Disincentives
- Subsidies - such as Direct (Grants) and indirect
- Moral situation
- Carbon tax credits have (prove reductions in consumption and emissions).
- Public policy (internal clients)
- Market drivers – manufactures dictate need to educate and promote.
- Practice dedication – a credit (2%- 5%) – local
- Climate Change Action Fund
- NMS – Green Roof?
- SD strategies Federal departments.

Need to convince private sector that the cost benefit exists to support green roof initiatives, e.g. through government self regulating / directing policy

Inverted roof data already exists and is applicable to extensive roof on a new building.

What about major market potential? e.g. renovation of existing buildings with nominal structural capacity

How to create Incentives

How to promote or even require green roofs on new buildings where there is little or no cost?

- Sewer surcharge
- Trend anticipated - differential cost benefits are being collected but not yet available
- Take advantage of corporations utilize consultants advising on return profits, including long term benefits of operational aspects, employee benefits and overall cost benefits and qualitative benefits of green roof.
- Savings/incentives, long and short term.
- Clarify so those architects can "sell" to client to be specific about cooling and heating.
- Sound attenuation, etc. – give a ratio and variation
- Data existing in Germany and is mandated that 1'10 flat roofs – primarily industrial
- Portland Oregon also has incentives, why not here?
- Toronto has trials underway. What are those trials?
- Portland took a political stand and self directed to be a model sustainable community. Political support for green roof type, initiatives and incentives. Favor and interest is growing so timing is perfect for data collection and marketing, to quantify qualitative claims.
- Coalition: does not actively support a requirement for green roof but would encourage any or all incentive development
- Support partnering trials with local government
- Supplier needs better support to sell market – validation to transfer through to client.

How do partners grow and sell this market? by…

Where ASHRAE- American Society of Heating Refrigeration Air Conditioning Energy (European Market is built for Centuries, North Americans is built for warranties)

We need to point out long term and cumulative effects of not using sustainable design approaches (costs are enormous)

Need to respond to initiatives from manufactures / suppliers a clearing house for new ideas and products and sharing of individual project design ideas and results.

Don't forget fundamental resistance to be overcome and traditional practicability, who would rather not change roof design. Thinking and are concerned with possible loss of revenue from a new way of doing things.

Barriers to be overcome maybe broken down by employing existing professional and manufacturing associations pyramidal growth recommended –allies.

Don't pick one venue, but pick best ones, e.g.: institutions used as demo projects

Government to lobby for policy and regulatory supports- identify which departments and What targets #'s, and, What benefits, What Criteria, What defines Success
E.g.: Public Works- Largest real estate Property holder

Tap into their existing programs – C2000

RAIC –Sustainable building committee- national education and promotion
Ally – with other current environmental associations and commercial groups with "green" banners – tap into their network

Monica Kuhn- Who will do these things?

Summary

We need to

- link projects with partners ; create demonstration projects for data collection; US Organizations - PE, ASHARS, ANSI, NRCA, SPRI, BOMA, APPA. Hospitals, Schools, ORNL, DOE, GSA, HUD; Canadian Organizations -
- look for politically ready cities
- look for existing incentives to build or tap into and organizations
- collect an inventory of existing green roofs and those that would be good candidates
- create an assessment that would be good candidate
- create an assessment profile
- assist consultants and manufactures / suppliers to promote/sell this design solution
- promote public accessibility

PARTICIPANTS
Breakout Group No.3 - Policy

Chair: Steven Peck, Green Roofs for Healthy Cities

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Marta Mulkins	PWGSC
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Don Taylor	Bakor
Robert Venasse	Soprema

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Matt Carr	American Hydrotech
George Challies	Soprema
Julia De Nardo	Penn State University
Patrick Done	Government of Canada
Joe Edmonds	Public Works & Government Services Canada
John English	British Colombia Institute of Technology
Alexandre Ferland	Parks Canada
Susan Fisher	Canada Mortgage and Housing Corporation
Murray Gallant	Public Works & Government Services Canada
Denis Gingras	Hydrotech
Kevin Grasty	Halsall Associates Limited
Roman Halitzki	Roman Halitzki Architecture and design
Tom Jarrett	Public Works & Government Services Canada
Gary Johnson	BC Building Corporation
Peter Kalinger	Canadian Roofing Contractors Association
Regina Katsman	Institute for Research in Construction / NRCC
Ken Klassen	Natural Resources Canada
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Mansoor Suteir	Public Works & Government Services Canada
Don Taylor	Bakor Inc.
Simon Taylor	Pin/Matthews Architects
Maria K. Terrence	DFAIT
Gabriel Thibault	Composts du Québec Inc.
Stephen Thornton	Thorton Consulting
Dana Turnbull	
Robert Venasse	Soprema
Christine Ward	Public Works & Government Services Canada
Sylvia Welke	
Allan Wingfield	Colbond Inc.
Kevin Wong	Communications Research Centre
Scott Wylie	Hydrotech