Green Roof Infrastructure Network of BC

www.grinbc.org

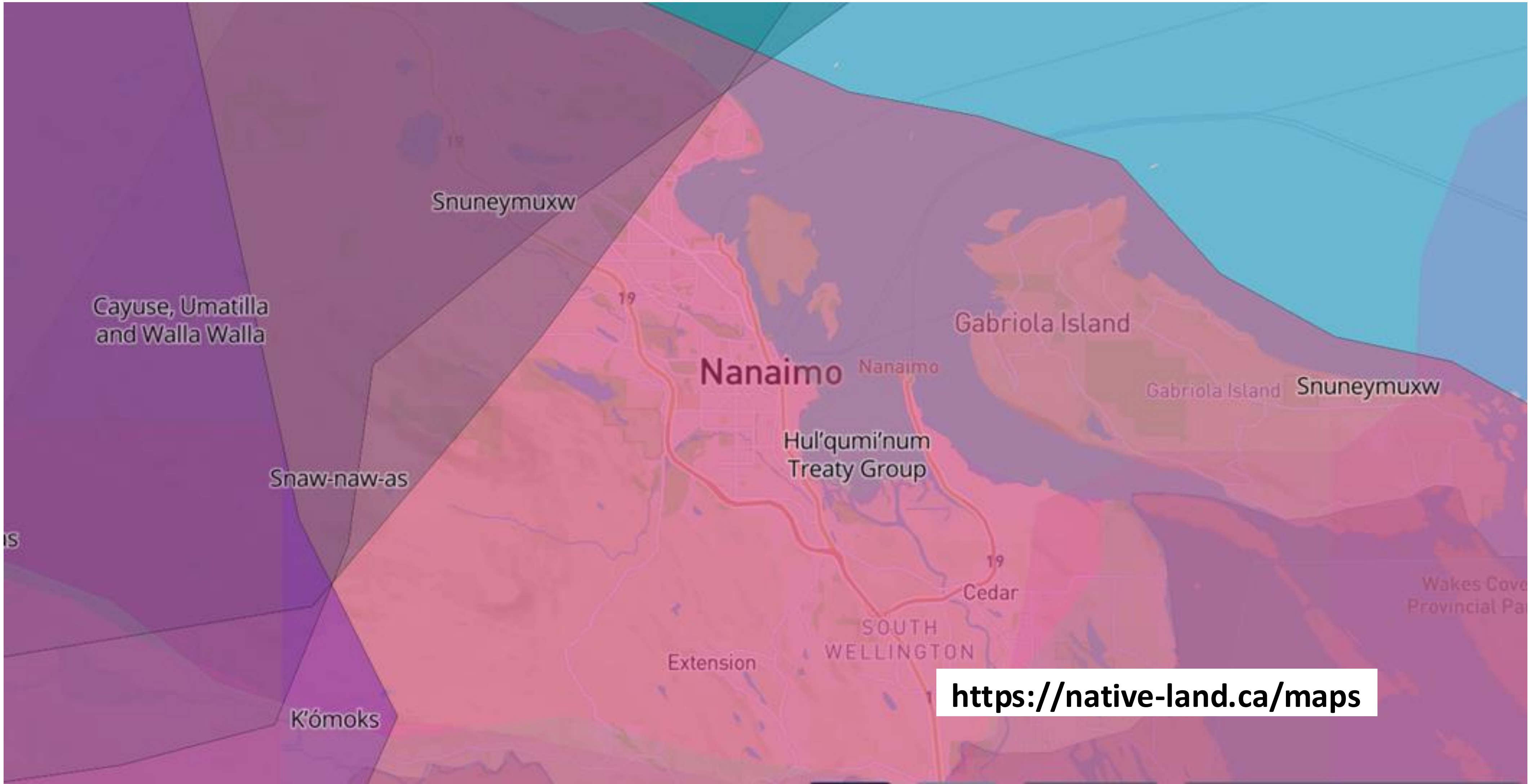
Climate projections and inspired policies: Aspirations for a healthy and resilient BC

Resilient Roofscapes for the 21st Century

2024 BC LAND SUMMIT COLLABORATIONS & CONNECTIONS

British Columbia Society of LANDSCAPE ARCHITECTS

Grateful to be on the unceded traditional territories of the Coast Salish people, and the ancestral lands of the Snuneymuxw, and the Hul’qumi’num Treaty Group.



https://native-land.ca/maps

Dr. Christine E. Thuring, GRIN Executive Director

With support from directors: Dr. Kathy Dunster, Dr. Karen Liu, Randy Sharp, Josh Stewart, Holly Horne

Climate projections and inspired policies: Aspirations for a healthy and resilient BC

Introduction

What is a resilient roofscape?

- Definition, Inspiration, Why aren't they everywhere?
- The problem with conventional roofs

Five roofing technologies that deliver resilience

What's holding us back?

Introduction: Who is GRIN?

GRIN (Green Roof Infrastructure Network) is an inter-disciplinary network of businesses, non-profits, researchers & community members united to advance the widespread implementation of green roofs in BC.

What we do:

- Green roof champions: cultivate and support
  - Advance policies, remove barriers
  - Fill information gaps
- Build allies
- Outreach and education
  - Tours
  - Presentations
  - White papers

June 6th is World Green Roof Day. Join us!

Get involved: join our mailing list.

Follow us on LinkedIn.

What is a resilient roofscape?

Resilience (/rəˈzilēəns/), noun

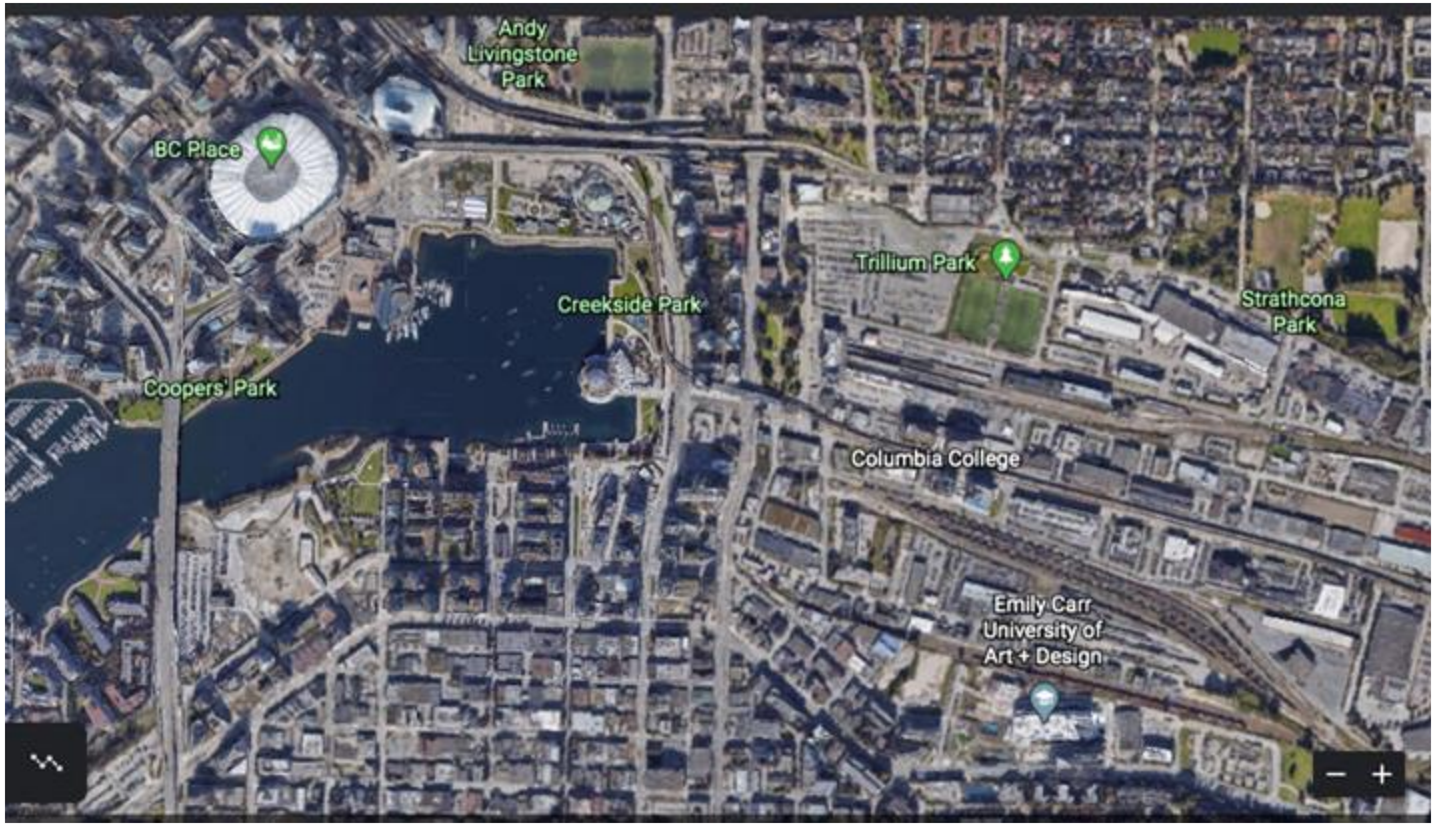
1. the capacity to withstand or to recover quickly from difficulties; toughness.
2. the ability of a substance or object to spring back into shape; elasticity (e.g., nylon)

Roofscape (ˈruːfˌskeɪp), noun

1. a view of the rooftops of a town, city, etc.

Why do we need resilient roofscapes?

The roofscape has impacts. Roofs occupy 20-30% of urban surfaces. Buildings account for 40% total energy consumption worldwide.



Not all roofs are created equal

The biggest impacts are caused by conventional roofs: flooding, drought, heat, GHG emissions, pollution, fire, health, etc.

The roofscape is expanding

Our population is growing (i.e., more roofs and infrastructure), while climate projections become more extreme.

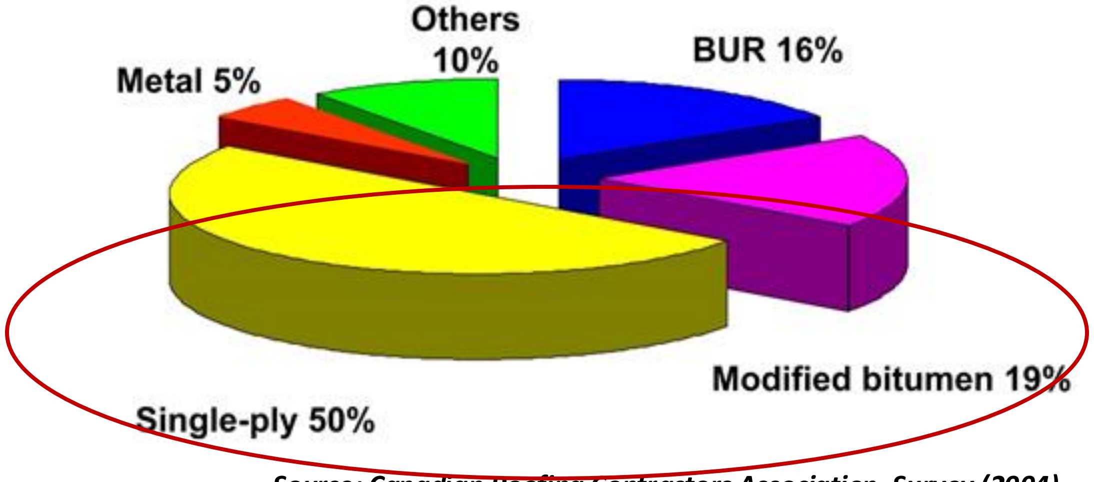
Excerpt from Climate Projections for the Okanagan Region (2020), p. 10.

The problem with conventional roofs

Conventional roofs have one function: waterproofing.

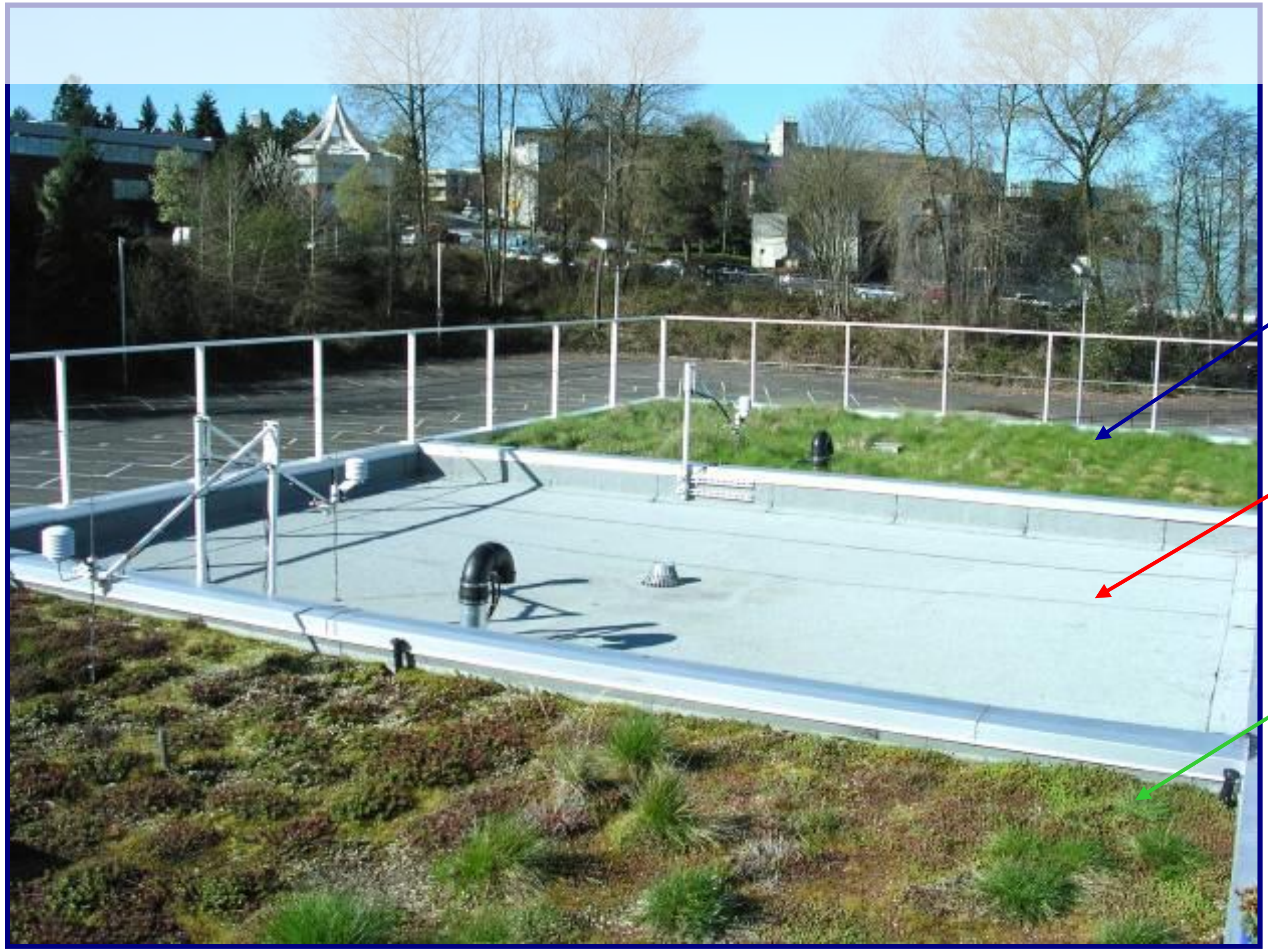
They are not resilient, break down quickly, and exacerbate urban and climate impacts, notably:

- **Energy** (demand/ consumption, GHG emissions, grid overload)
- **Membrane longevity** (waste production)
- **Water** (stormwater, flooding and groundwater depletion)
- **Urban Heat Island** (UHI)
- **Wildfire** (fire, embers, smoke)



Source: Canadian Roofing Contractors Association, Survey (2004)

We'll refer to data from BCIT's Green Roof Research Facility but focus on the reference roof's performance (2-ply SBS).



6" Green Roof (150 mm)

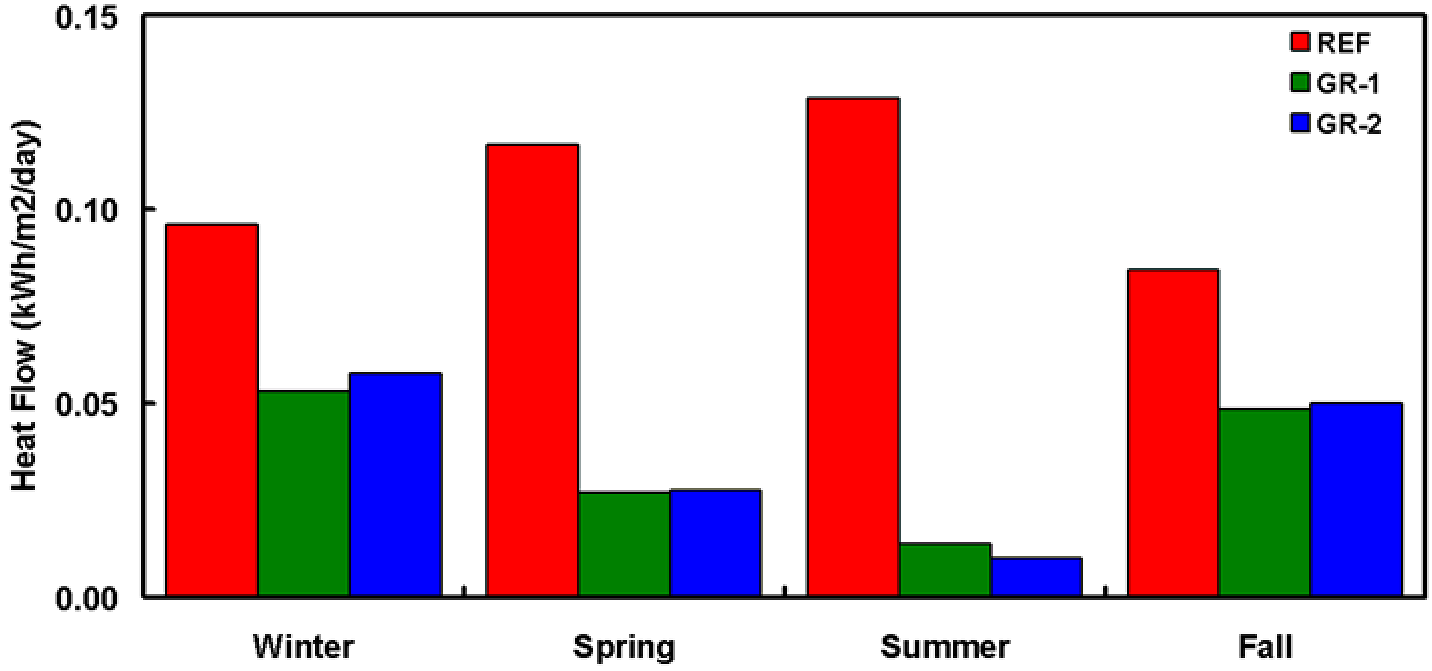
Conventional Roof (Reference)

3" Green Roof (75 mm)

Impact: Energy

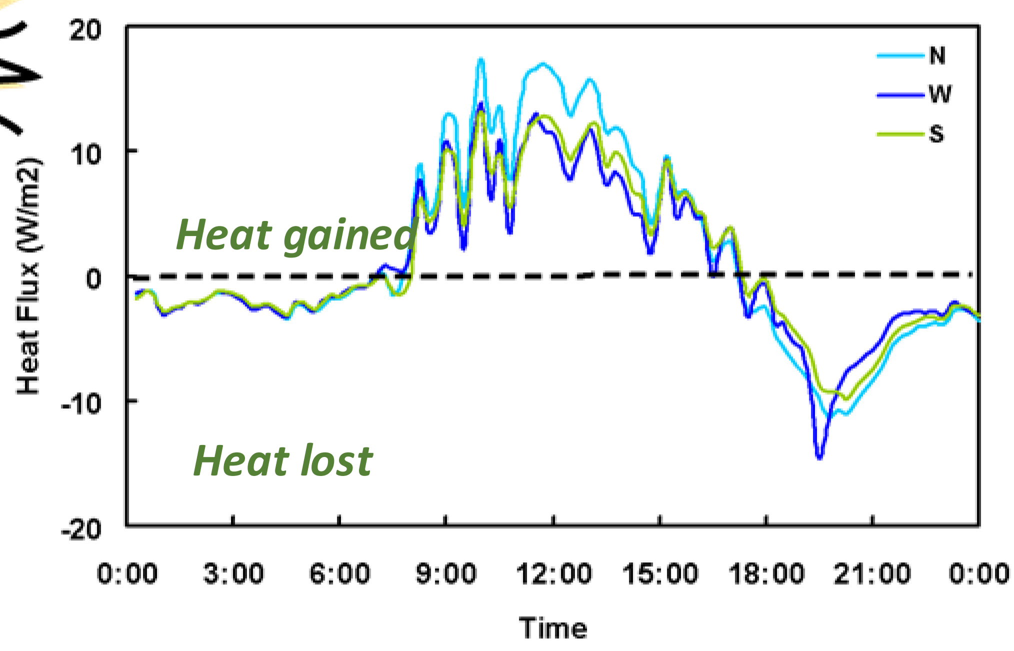
Conventional roofs allow heat flux (gain/ loss), which creates demand for space conditioning, which increases GHG emissions, exacerbates the urban heat island, impacts air quality, and can overload the grid.

Average Daily Heat Flow through 3 Roof Types (red: conventional)

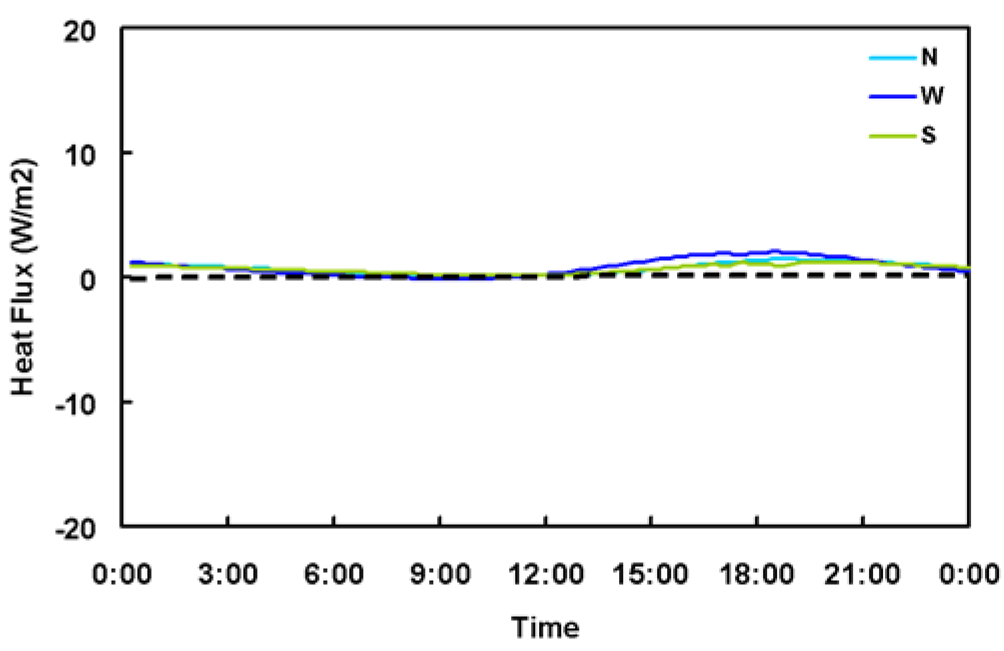


On a typical sunny summer day (August 1, 2005), the conventional roof lost heat (~1-3 W/ m^2) until 8am, when heat started entering the roof, peaking at ~17 W/ m^2 in the afternoon.

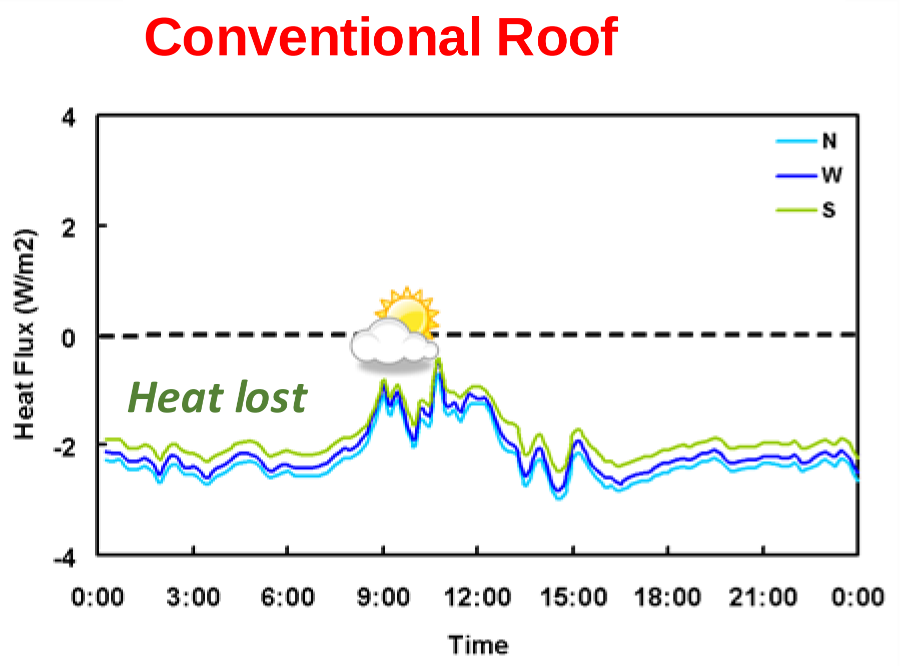
Conventional Roof

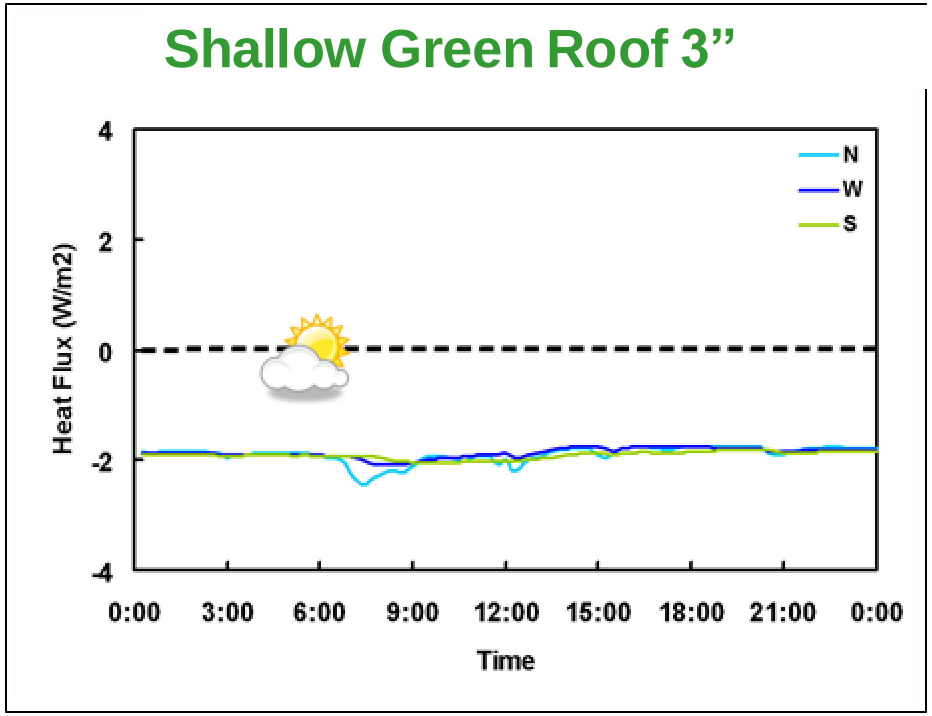


Shallow Green Roof 3”

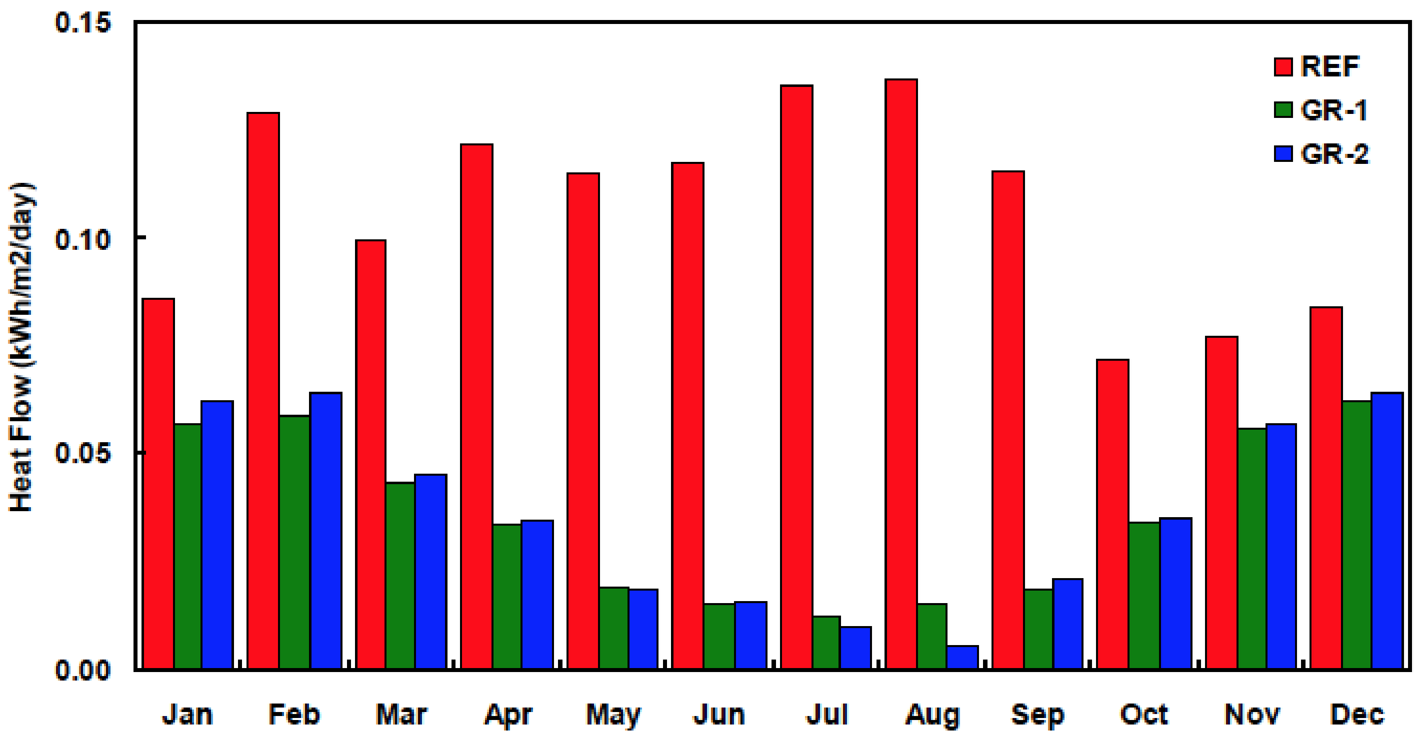


Even on a typical overcast winter day (January 30, 2005), conventional roofs allow heat through.



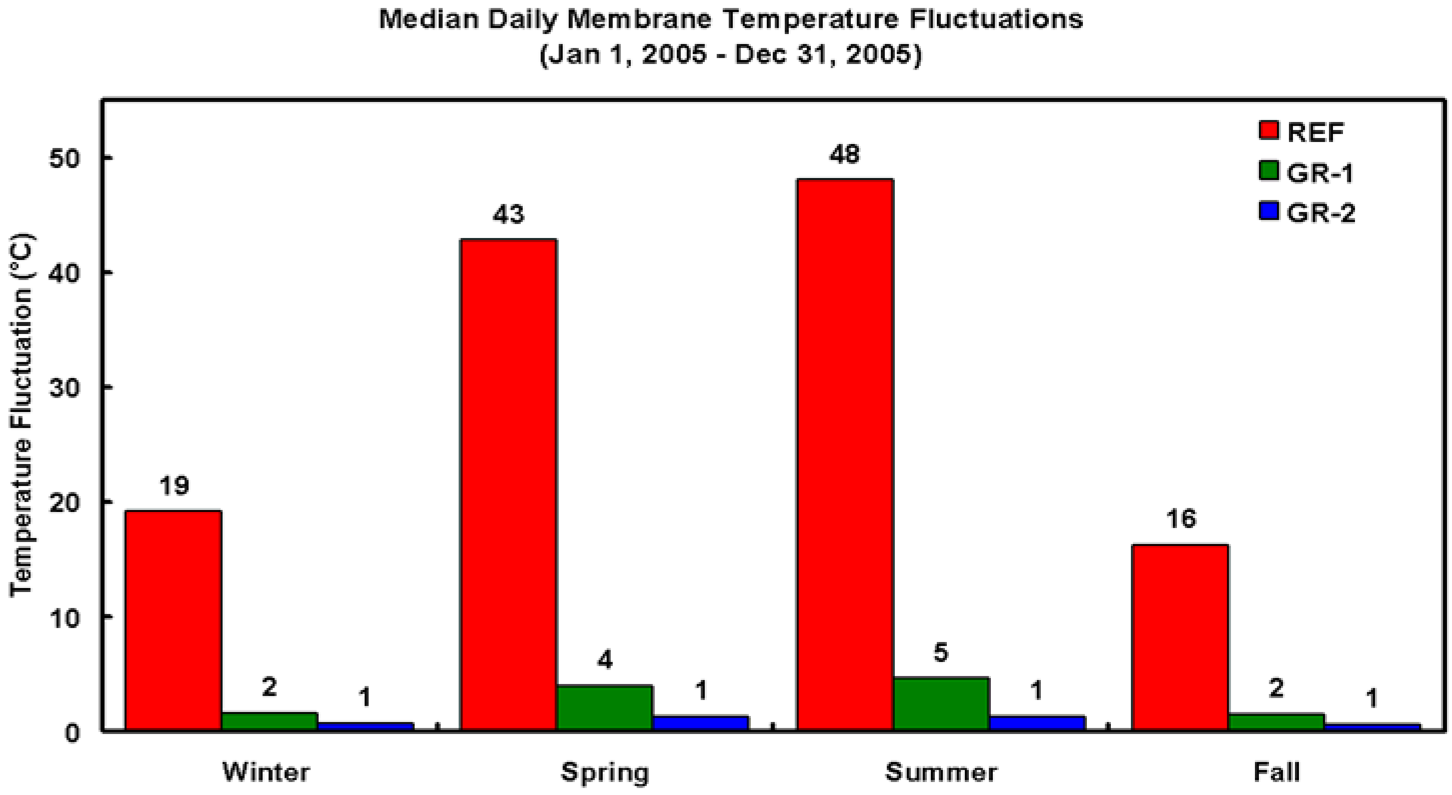


Heat flux through conventional roofs correspond closely with outdoor temperatures, i.e., low energy efficiency, especially air-conditioning. **Significant disruptions to the electrical grid concurrent with an extreme heat event can be a fatal combination.**



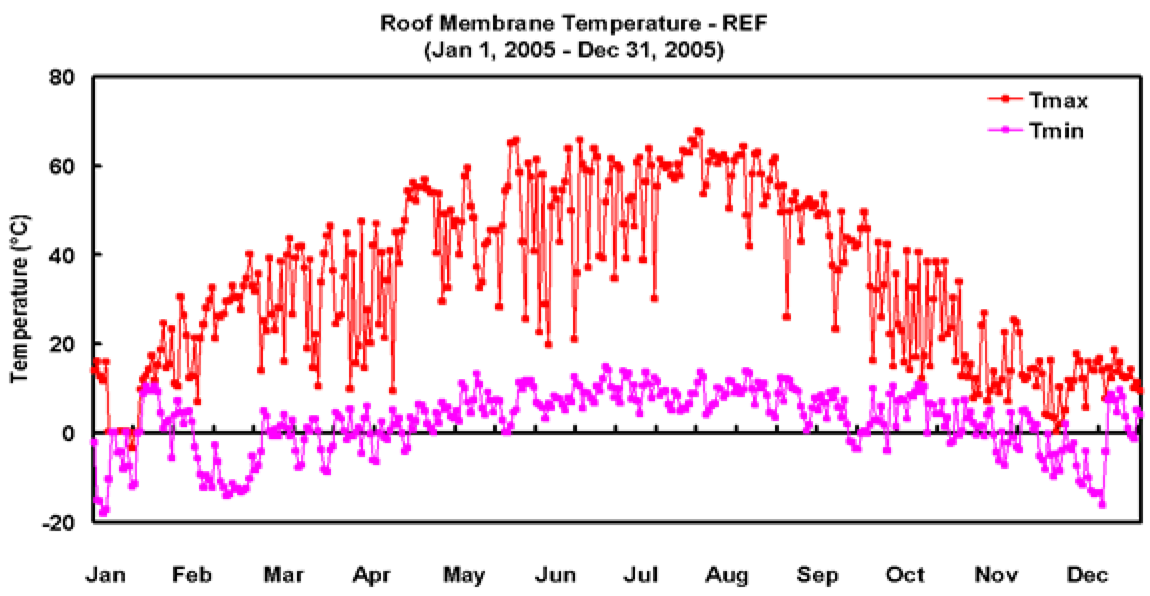
Impact: Waste production (unprotected membranes)

Being exposed to the sun, elements and **extreme temperature fluctuations,** conventional roofs have an average lifespan of 10-15 years.

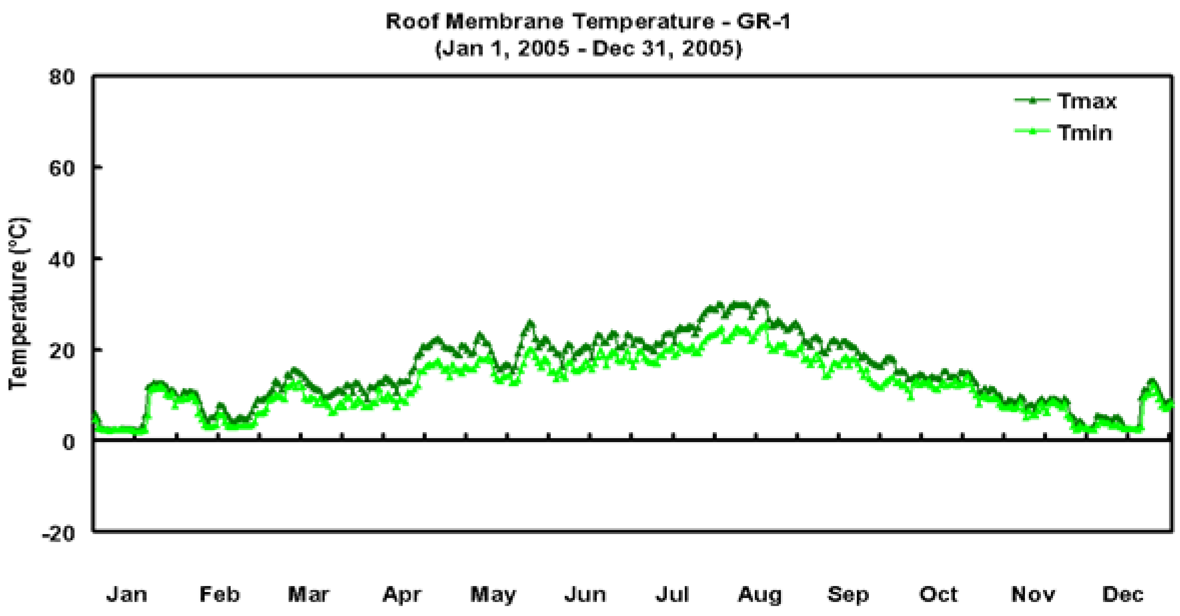


Protected membranes last 2-3 times longer.

Conventional Roof, 2005



Extensive Green Roof (3”), 2005



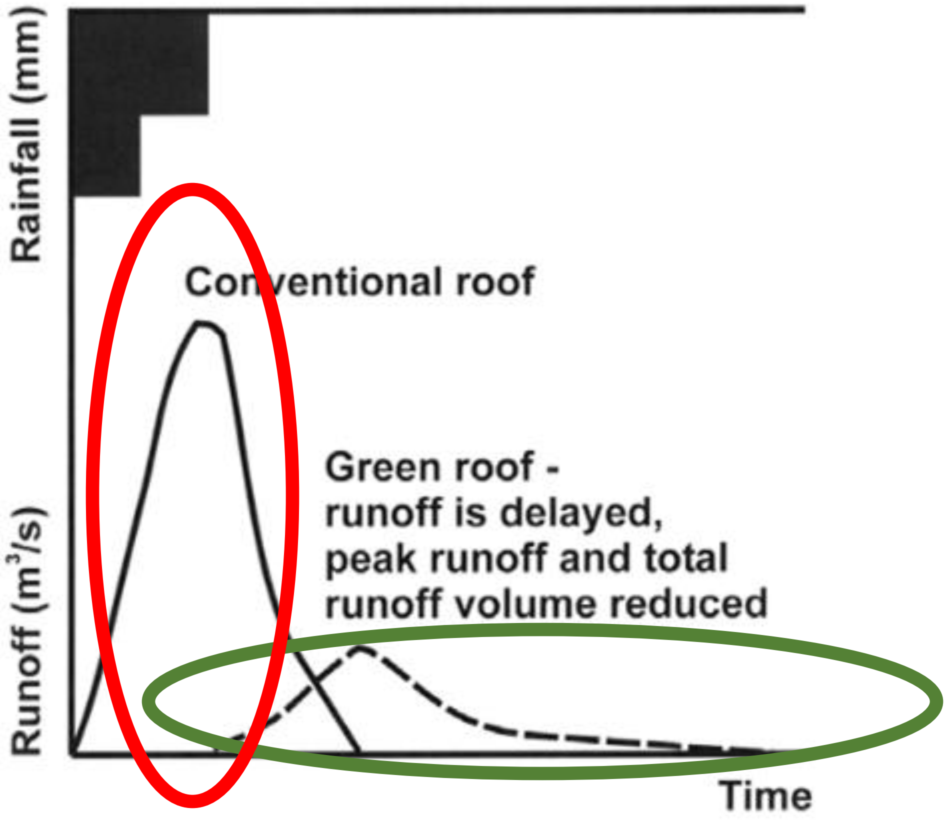
Membrane durability under green roofs exceeds 50 years (US General Services Administration, 2011). Swiss observations suggest over 100 years. (Soprema will provide a Canadian example next.)

Source	Membrane lifetime (years)	
	Green	Black
GRHC Life Cycle Cost Calculator	40	17
LBNL Research	29	14
Fraunhofer Institute	40	15
European Federation of Green Roof Associations	60	30
Mann, G. (2002) *Approaches to object-related cost-benefit analysis*	50	25
Single Ply Systems & Glass, GAF Materials Corp, SBS/TPO average	n/a	14
AOC Dirksen Green Roof Study	50	17

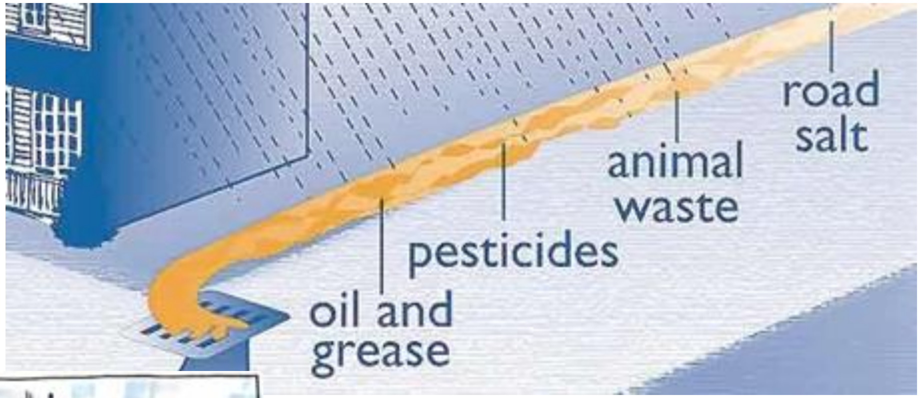
https://www.gsa.gov/governmentwide-initiatives/federal-highperformance-green-buildings/resource-library/integrative-strategies/green-roofs

Impact: Water

1) stormwater runoff, 2) pollution, and 3) groundwater depletion



Source: Stovin et al. 2012. J.Hydrology

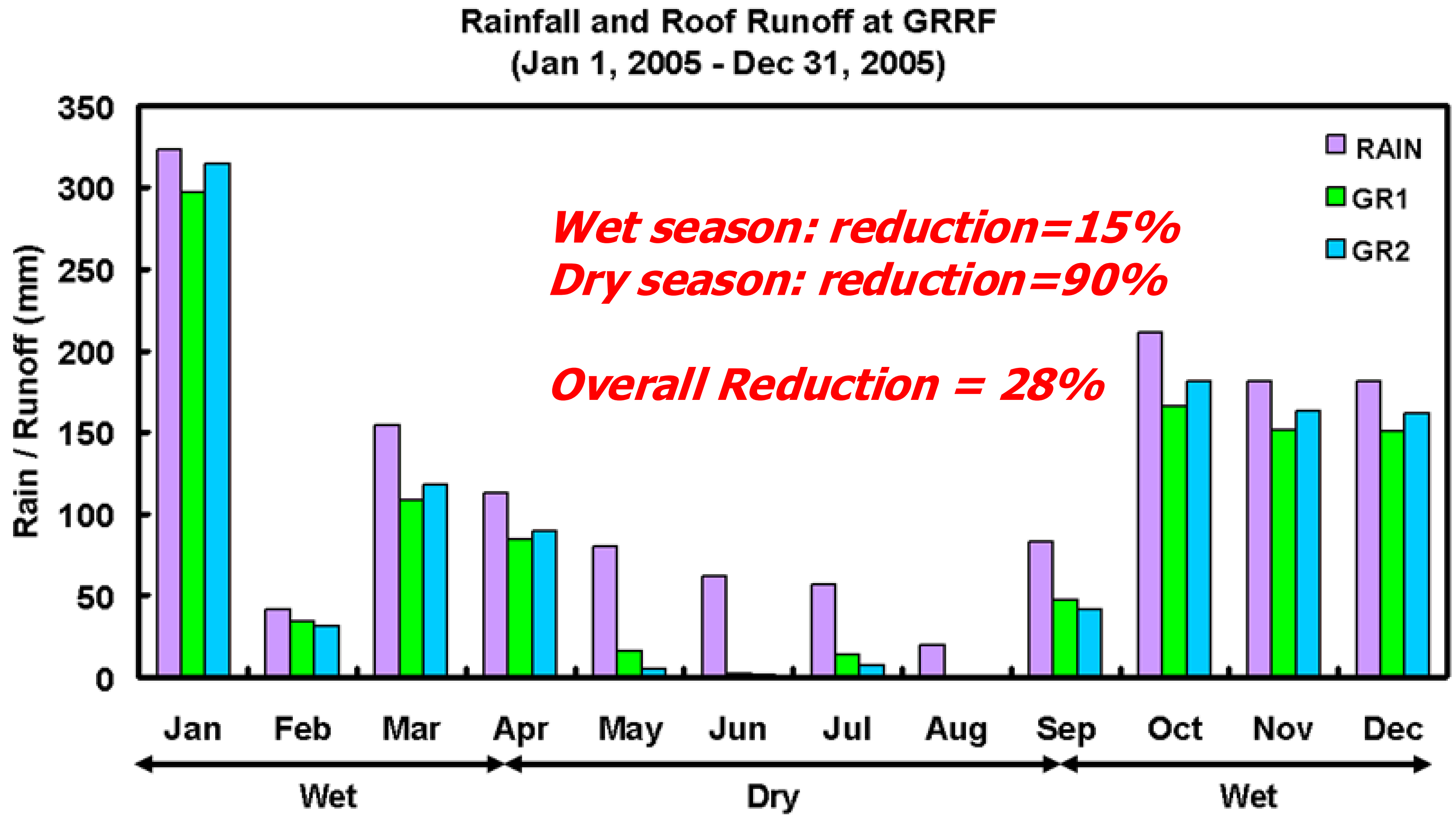


Source: Rain City Strategy

Mercedes HQ (Germany) is a zero-discharge site and receives stormwater credits.

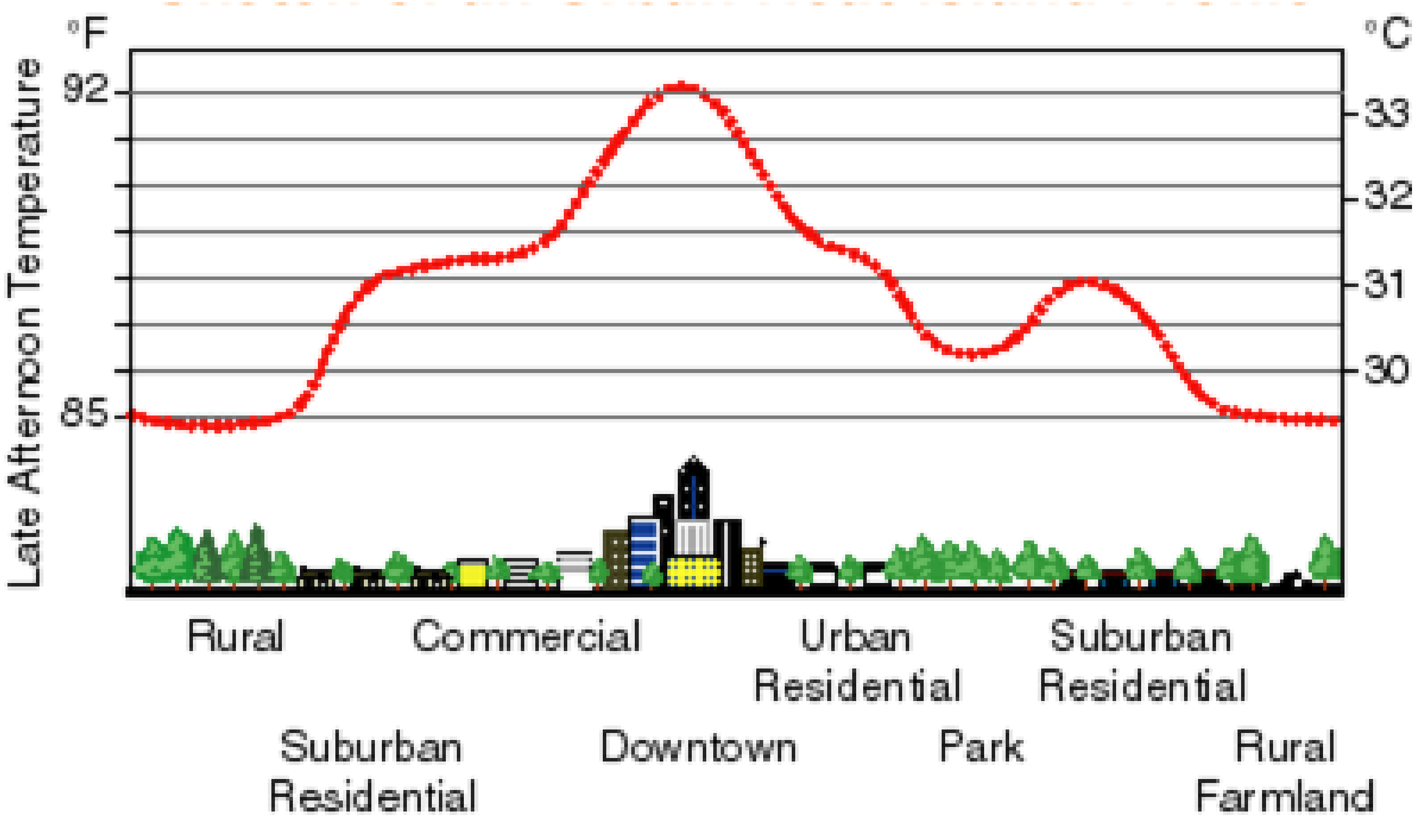
Source: Jörg Breuning

[Even with its wet season, green roofs in coastal BC reduce stormwater runoff by 28% annually (90% in the dry season).]



Impact: Urban Heat Island (UHI)

Heat from the sun is retained, absorbed, and re-radiated by dark and hard building materials (e.g., rooftops) creating an urban heat island.



Impact: Wildfire

Some bitumen roofs are Class A fire-rated, but bituminous and asphalt-based surfaces are flammable. Once ignited, they can act as a fuel source, contributing to the spread of fire. Their smoke can create respiratory hazards and reduce visibility, complicating firefighting efforts. (Green roofs suppress fire).

Source: Sippakorn Yamkasikorn

Five technologies that deliver resilience

Roofs cover considerable, but under-used, area. This is prime real estate to improve the conditions of the built environment.

Top 5:

1) **Vegetated (green) roofs**
2) **Solar PV**
3) **Vegetated Solar PV roofs**
4) **Blue roofs**
5) **Cool roofs**

1. Vegetated (green) roofs

Green roofs are protective roofing assemblies on top of the waterproofing. Extensive GRs don't require irrigation like intensive systems, however it's good for establishment (and fire protection).

"It's too expensive" NOT to install green roofs!

As a protection layer, extensive green roofs are economical with 5-6 year return on investment; 1 year for roof gardens. They are multi-functional with numerous co-benefits, often simultaneous.

PUBLIC	PRIVATE	
Waste diversion	Aesthetic improvement	New amenity spaces and property value
Reduction of the urban heat island (UHI) effect	Energy efficiency	Blockage of electromagnetic radiation
Improved air quality	Stormwater management: quality and quantity	Noise reduction
Increased biodiversity	Integrated water management	Marketability
Educational opportunities	Increased membrane durability	Improved human health and well-being
Local job creation	Fire retardation	Urban agriculture
	Enhanced photovoltaic performance	

Avling Brewery Rooftop Farm,
Source: Danette Steel

Source: Dane Sabey

2. Solar PV (photovoltaics)

Solar energy via photovoltaics (PV) has become the cheapest form of electricity in most parts of the world. PV panel prices hit record lows in late 2023 (but Canada puts high tariffs on imports). Rooftop solar panels are a cost-effective means of increasing renewable energy generation, compared to solar farms.


Source: kindelmedia

3. Vegetated Solar PV roofs

Combining GRs with PV enhances the performance of both: pure synergy! Integrated installations are common in Europe, after decades of research and development. Several manufacturers offer integrated systems (see ZinCo's presentation).

Source: Christine Thuring

Vegetated Solar PV roofs: what says the science?

The results are consistent and unequivocal: compared to PV panels over black, gravel, and cool roofs, **PV panels always produce more energy output when located over a green roof**.

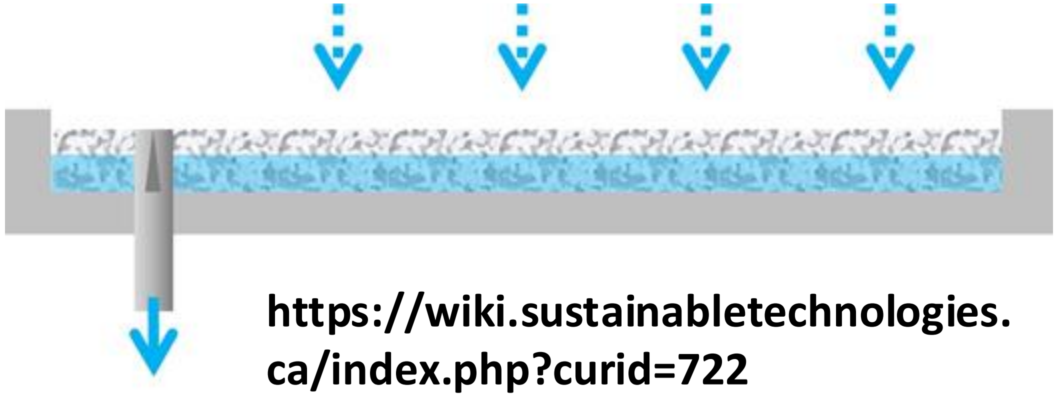
Alshayeb & Chang, 2016;
Cavadini & Cook, 2021;
Guzmán-Sánchez et al., 2018;
Maurer, Lienert, & Cook, 2023

4. Blue roofs

Preceded by green roof and flow control roof drain systems, **blue roofs are innovations for flood/ drought resilience and adaptation.**

Captured & stored water has public and private benefits:

- non-potable uses (reducing consumption of potable water);
- evaporative cooling (reduce need for AC, mitigate urban heat);
- regulate & control rooftop runoff;
- restore the hydrological cycle.



https://wiki.sustainabletechnologies.ca/index.php?curid=722

5. Cool Roofs

Buildings with radiative coatings roofs use less air conditioning because they reflect thermal heat from the sun away, into space. [*This technology is better suited for warmer climates and southern cities, but is presented here for good measure.*]

Cool roofs: what says the science?

For places with cold winters, cool roofs “will cost the building owner a significant amount of money due to the heating penalty (or negative effect on energy costs)” (Goodman, 2014).

With respect to the other technologies, cool roofs rank the lowest due to their singular benefits Maurer *et al.* (2023).

Maintenance-wise, cool roofs require similar attention as green roofs if they are to perform as intended.

What’s holding us back?

Political will & leadership are essential (new developments and projects benefit from guidance). Needless barriers must be removed. Market & industry require investment and support.

Policy levers and programs are invaluable:

- Mandates – Laws & Regulations
- Funding – Grant, Rebate, Subsidy
- Tax Credit/Abatement
- Stormwater Fee Credit
- Density/Floor Area Ratio Bonus
- Green Area Factor
- Residential Stewardship Programs
- Procurement

GR Policies/ programs in Canada

City of Toronto GR Bylaw & Eco-Roof Incentive Program

- All new buildings with gross floor area (GF) over 2,000 m^2 **MUST** install a GR covering **20-60% of the roof area** (depending on GFA)
- Penalty for non-compliance: $200/$m^2$
- **Eco-Roof Incentive Program:** Buildings not subjected to GR Bylaw can receive $100/$m^2$ for GR installed, up to $1,000 for a structural assessment

Gatineau GR Bylaw

- **20% GR cover** on all new buildings larger than 2,000 m^2

Saint-Laurent Montreal

- **New or roof replacement** of flat or low-pitched roofs (slope <2:12 or 16.7%) MUST either be green roof or light (cool) roof to mitigate Urban Heat Island.

Halifax Regional Centre Land Use By-Law

- Soft landscape is required on any main building with a flat roof or flat-roofed addition within selected zones in the city, on **no less than 40%** of the combined portions of the roof that are flat.

GR Policies/ programs in Canada

Port Coquitlam GR Bylaw

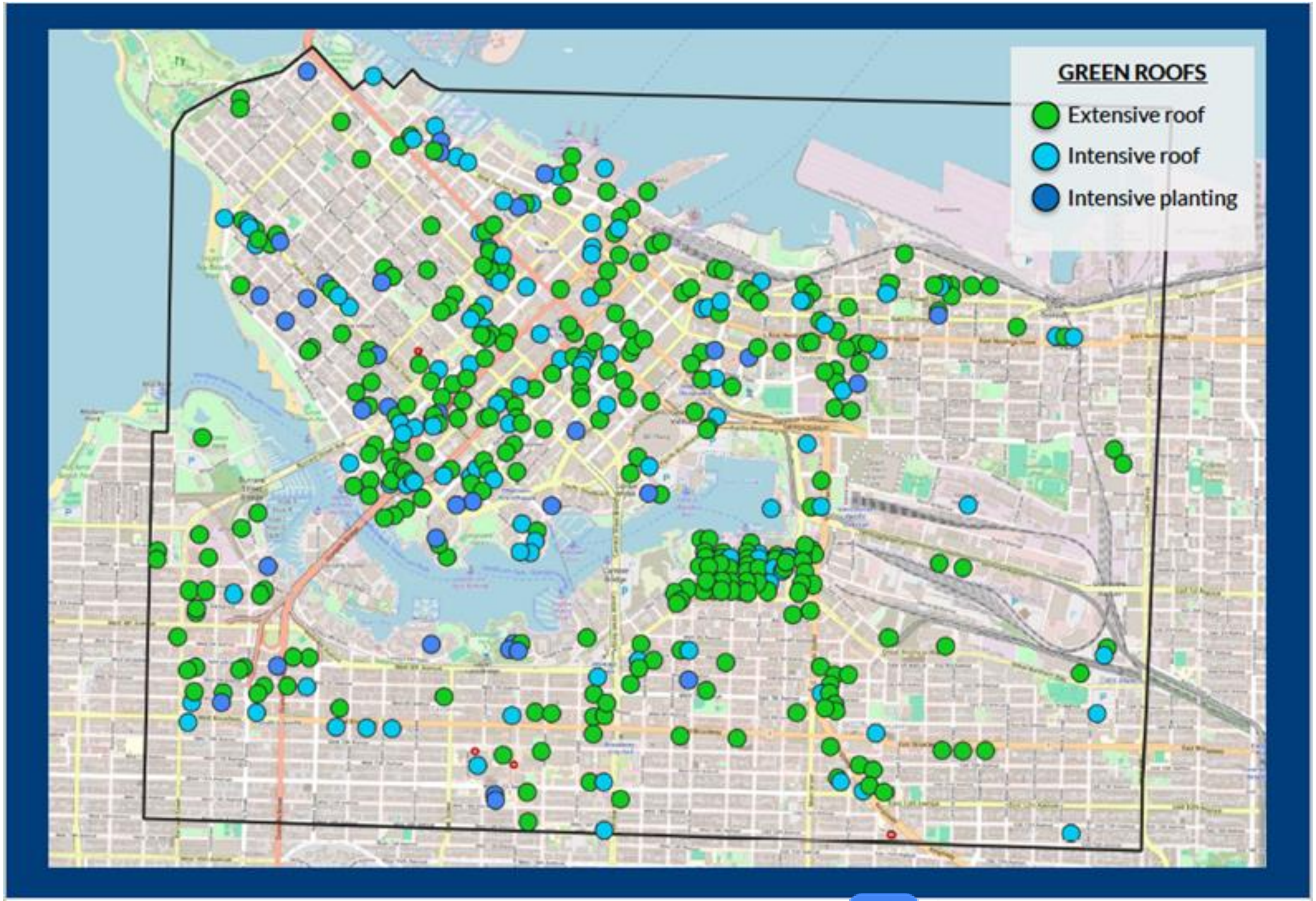
- All new commercial & industrial buildings >5,000 m^2 must install a GR covering **> 75% of roof area**

Richmond GR Bylaw

- All new industrial or office buildings >2,000 m^2 outside city centre must install a GR covering **>75% of the roof area** or LEED silver certified

Mandates work!

(Spot Vancouver Olympic Village!)



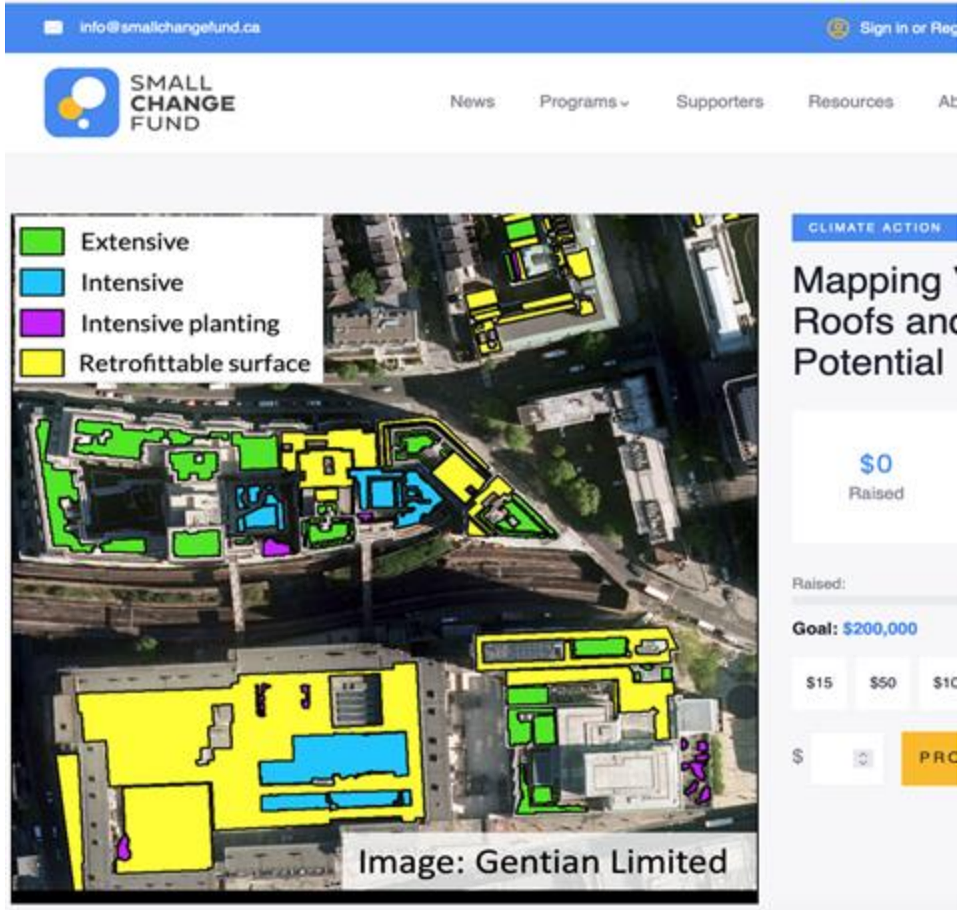
SMALL CHANGE FUND
Bring your change here.
gentian

To identify risks/ opportunities/ low-hanging fruit for BC towns and cities, **GRIN is fundraising to generate maps** (May 16 launch.) https://smallchangefund.ca/project/mapping-green-infrastructure

High resolution, current satellite imagery with analysis:

- Green roof identification
- Green roof retrofit
- Trees and canopy
- Tree Count
- Private Garden
- Habitat mapping for urban areas

We're starting with 15 km^2 of the City of Vancouver.

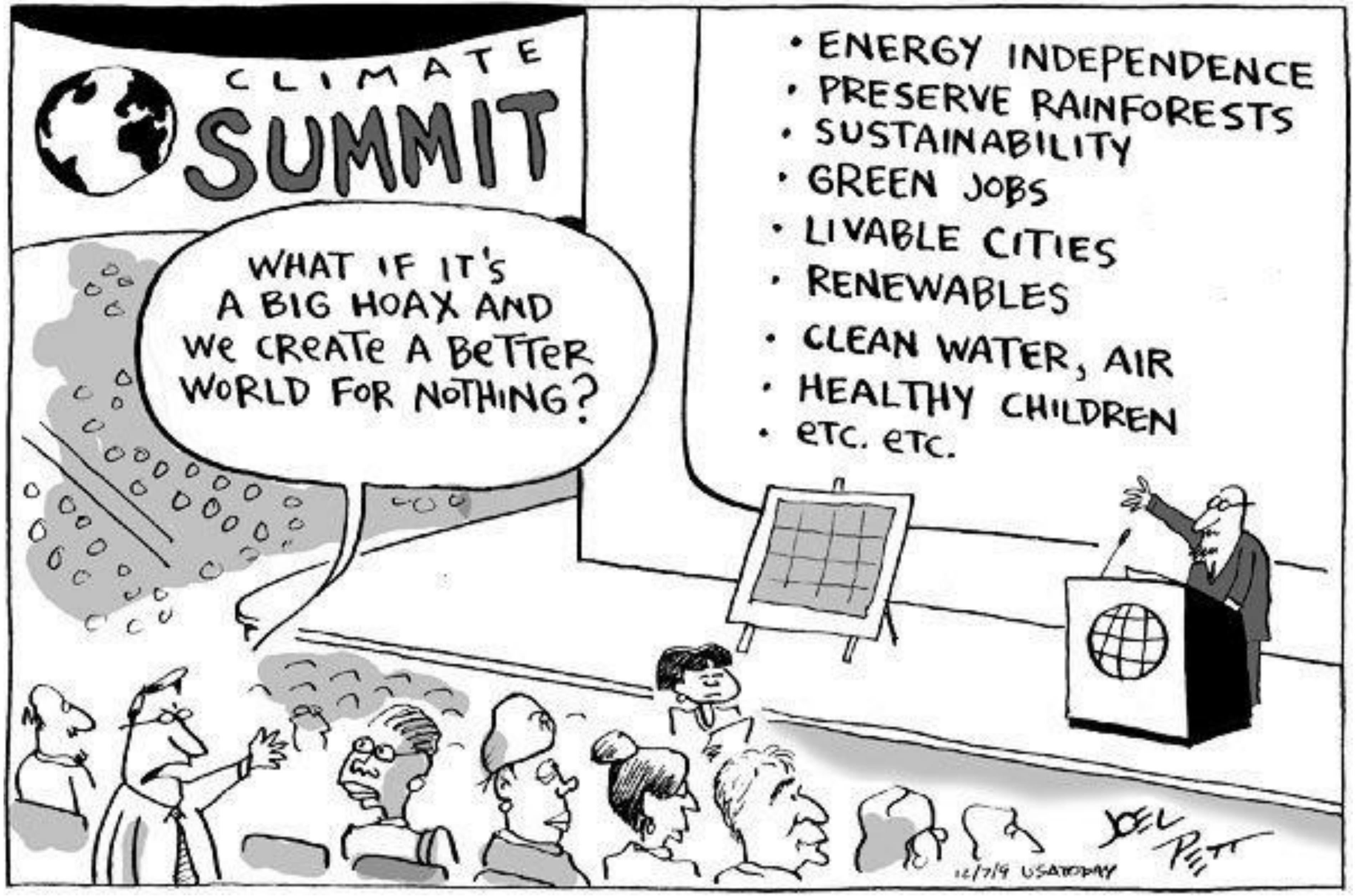


Investment and support for market and industry

To prepare for Zero Carbon 2050 or UN Sustainable Development Goals, the green roof industry and market require investment and support.


Source: Gingko Sustainability


Source: NLSM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WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• etc. etc.
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Let's Work Together!

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Optimizing Environmental Benefits of Green Roofs Through Integrated Photovoltaic & Water Management

Photo Courtesy of ZinCo GmbH

Resilient Roofscapes for the 21st Century

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GRIN British Columbia

Importance of Renewable Energy

- Renewable energy often approached from the perspective of financial return, rather than resilience

- Economies of scale and widespread adoption of technologies have resulted in competitive and efficient market, lower overall costs to acquire

- Renewable energies are an investment in our overall resilience and independence from the grid

- THE GRID IS A MESS

Photo Courtesy of Sponge Microgrids Inc.

Photovoltaic System Types Common to Canada

Non-penetrative ballast system on roof.

Aluminum racking fastened through roof deck

Ground mounted system on concrete foundations

PV & Green Roofs Fighting for Space

Trade-off

- Situational decision that involves diminishing returns in one set, with in return gains for other set

- There is a constant tradeoff in roof design;
    - Do I design my roof to maximize energy production and forgo stormwater, bio-diversity and useable benefit?
    - Do I maximize my stormwater capture at roof level inception and forgo potential energy independence and resilience?

Photo Courtesy of ZInCo International

Integrated Systems: Bio-solar Roofs

- Utilizes green roof substrate/vegetaion as necessary ballast for PV panels

- Vegetation grows continuously across roof

- Given sq.m of roof can capture solar energy, manage rainfall, increase bio-diversity, cool ambient air temperature, increase fire resilience of building, increase thermal properties

Resilient Roofscapes for the 21st Century

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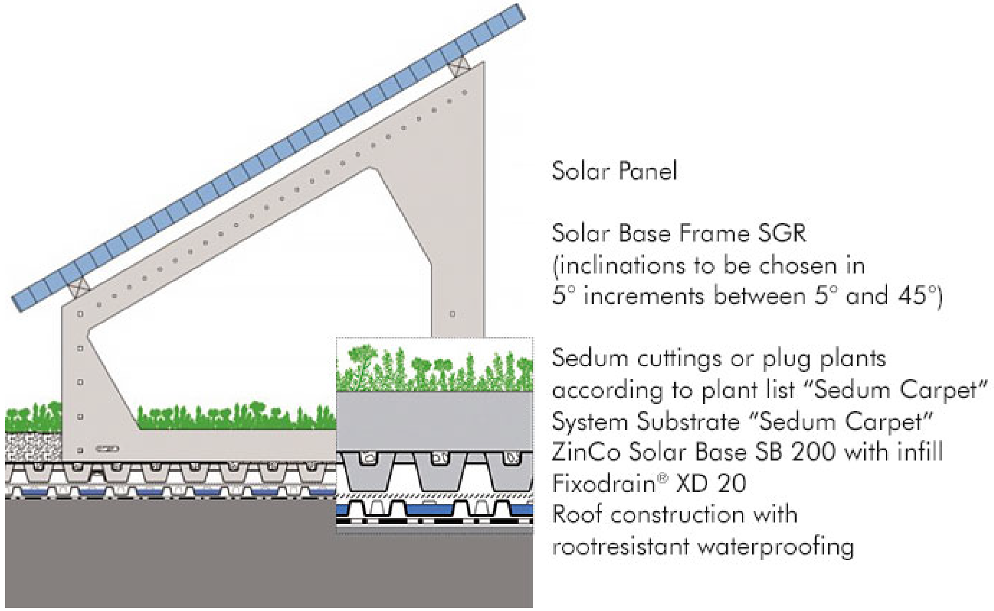
Integrated Systems: Bio-solar Roofs

GR-PV System Prior to Substrate

FLL Substrate – Necessary for Uplift



Cross Section of GR & PV Assembly

Initial Bio-solar Research: Germany Late 2000s

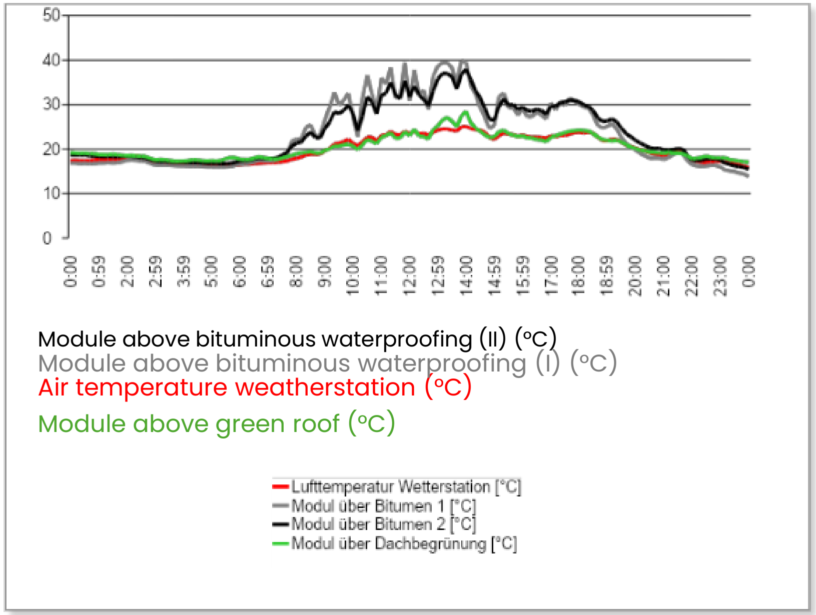
Temperature Sensors Placed in Three Scenarios

Sensor I: solar module applied above a green roof

Sensor II: solar module applied above a bituminous waterproofing (with distance)

Sensor II: solar module applied above a bituminous waterproofing (no distance)

Measured Values July 6th 2009: 25 Degree Day



Results

- Average temperature of panel 6°C higher than ambient temperature
- PV panel exhibited almost ideal temperature to ambient air temperature above green roof
- Efficiency of PV panel decreases 0.5% per degree above ambient air temperature
- Inclusion of GR under PV: Potential 5% Efficiency Gain in high heat of day

Resilient Roofscapes for the 21st Century

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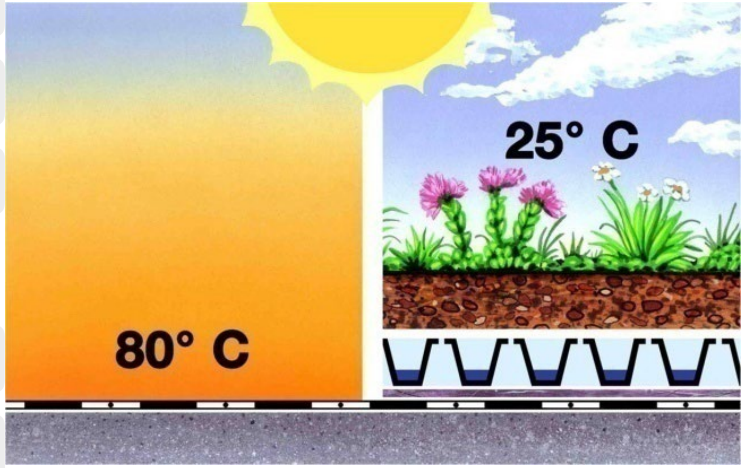
Higher Efficiency through Cooling Effect



The temperature differences vary drastically on naked, gravelled or green roofs. The temperature differences result in increasing temperatures of the surrounding air (contributing to Urban Heat Island Effect)

Maximum surface temperatures on flat roofs:
Unprotected waterproofing depending on the colour above 80°C
with Gravel **up to 60°C**
with **Green Roof ca. 25°C**

Bio-Solar Research: Globally Adopted

Suspended solar array research, GRIT Lab U of T

Green Roof and Photovoltaic Panel Integration: Effects on plant and arthropod diversity and electricity production (Schindler et. Al, 2018 – Israel)

- PV panel enhanced flowering time of perennials & growth of sedums were enhanced with shade from panels

Measuring Effect of PV Performance of Photovoltaic Panels in Combined Systems (Ogaili, 2015, Portland)

- Results showed highest achievable PV performance was with integrated PV and green roof system

Ogaili & Sailor (2016) quantified effective heat transfer coefficient of green roof; first time GR effect was embedded into model physics

Studies across the globe exhibit results varying from 3% to 6% efficiency gains, though some produced lower in colder climates (1.7%)

Bi-facial Panels – Future of Bio-solar projects

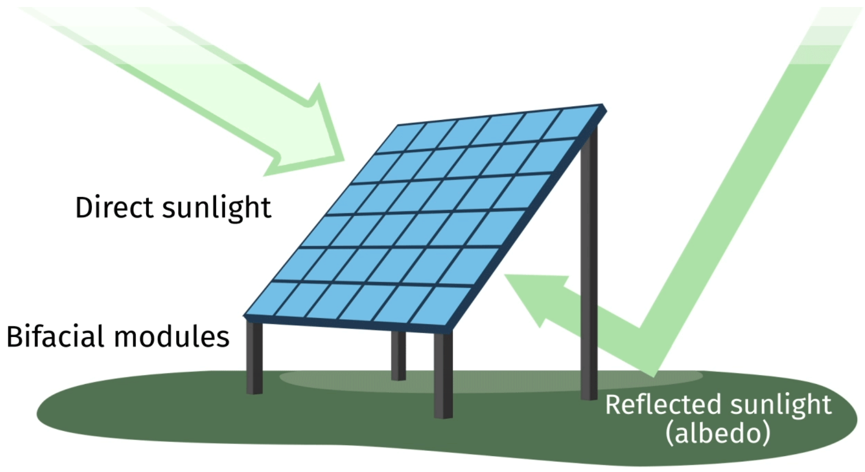
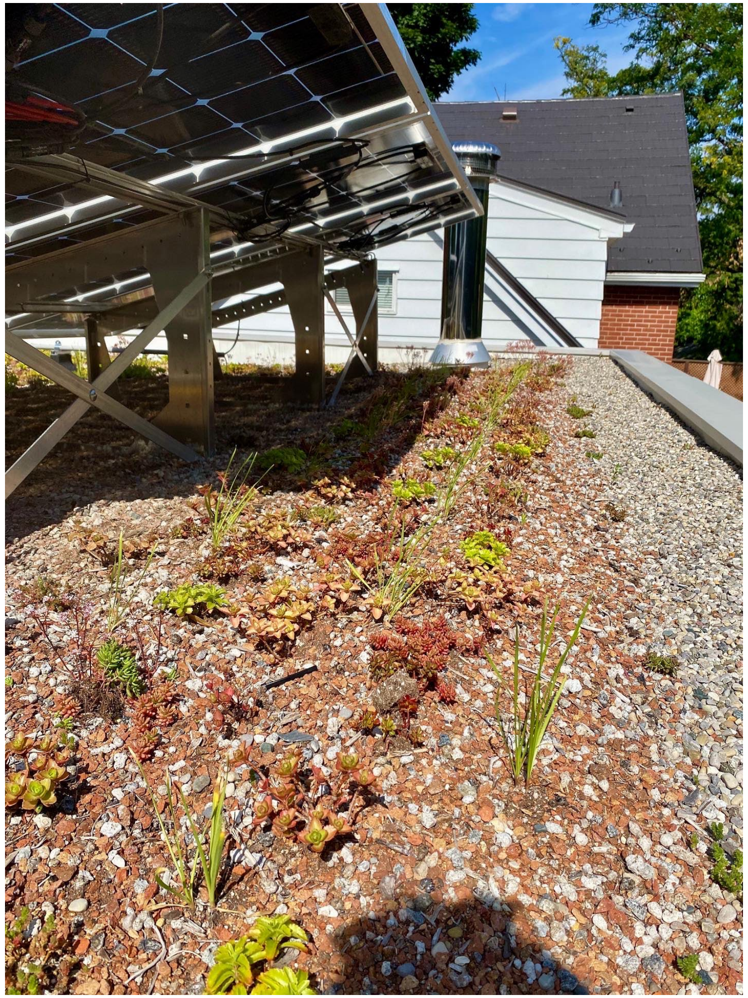


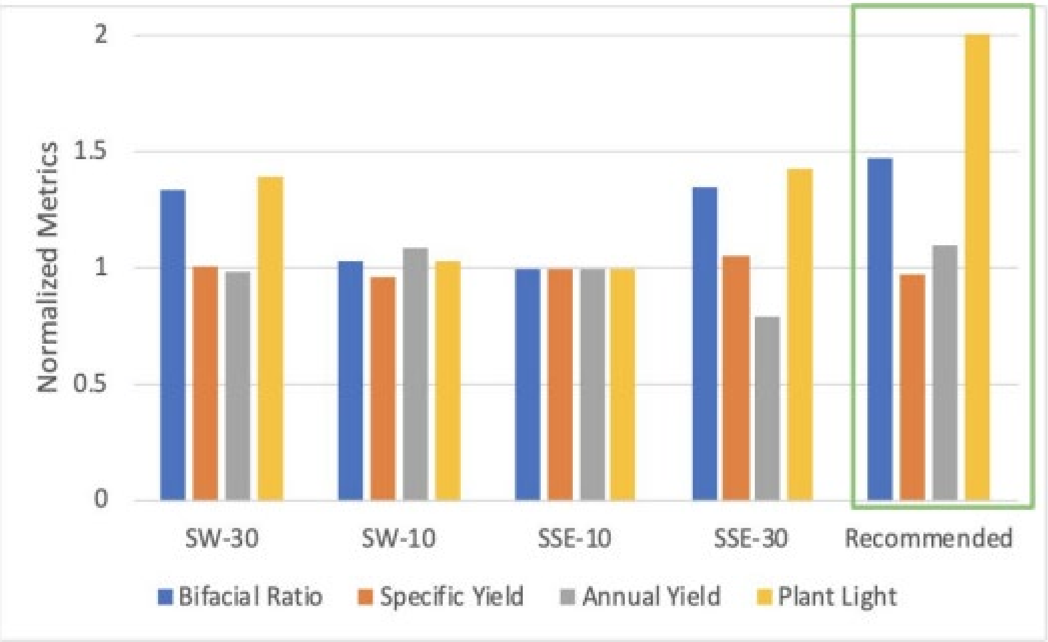
Image courtesy of CBC



Bi-facial Solar Panels

- Produce power from both sides of the panel; reflected light from ground is captured on back side of panel
- Semi-transparent film; allows more light through for reflection
- Economies of scale have reduced costs substantially; returns on power are hard to discredit – this is the only type of panel we specify

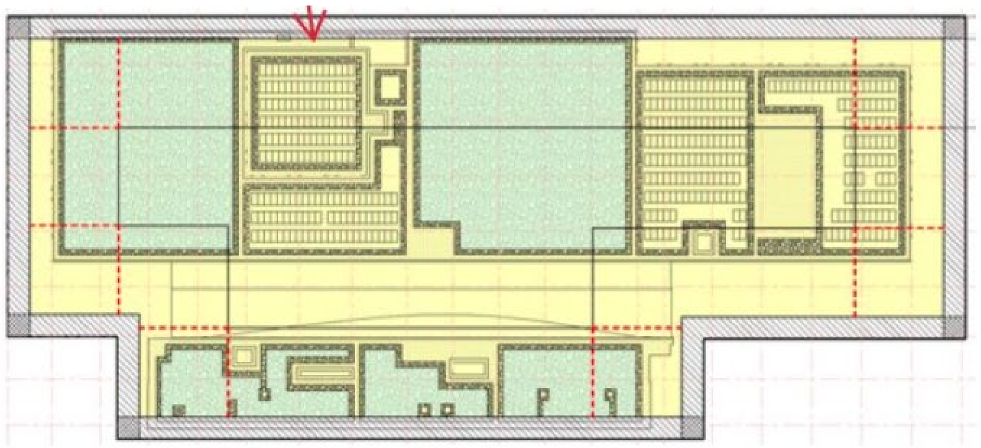
Bi-Facial Solar Panels & Green Roofs – Maximizing Productivity & ROI

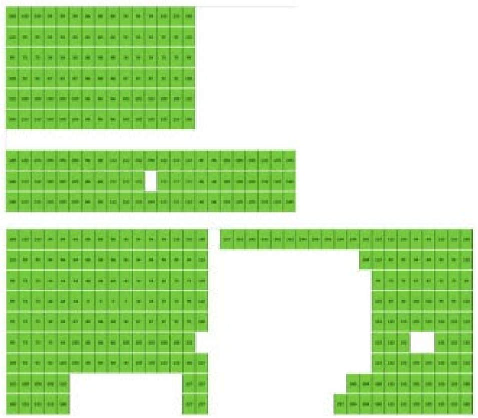


Sample Energy Model for Canadian Project
Courtesy of Sponge Microgrids Inc

- Distributed ballast of GR allows for higher resistance to wind uplift; enables higher tilt on panel and increased production
    - Lower tilt assemblies typically employed for wind uplift restraints
- Higher tilt, high albedo from plants and bi-facial gain produce highest production yield in our modelling for projects

Bi-facial & GR Systems: Optimization of Space and Roof Designs





- BC's largest GR/PV under design currently – 131 MWh/year
- Combination of 10% increase in heat transfer of green roof with 5% increase of annual capacity, and bi-facial panels, resulted in smaller solar system overall
- Reduced costs by minimizing areas, optimizing efficiency of overall system

- We don't necessarily want larger PV systems, we want smarter ones
- Energy modelling, winduplift and green roof system enable smaller, more optimized systems for generating power

Vertical Bi-Facial Solar& GR: The Future

Vertical Bi-Facial Installation Switzerland, Photo Courtesy of Over Easy Solar

Image courtesy of ZinCo GmbH

- Initial pilot project in Oslo exhibited a 30% higher power output compared to conventional array in winter of 2022. Extremely promising results
- Provides longer exposure to UV rays and eliminates reduced PV performance due to snow
- Higher resistance to wind uplift do to vertical configuration, easier access for maintenance, more light for vegetation

Agrivoltaics: Integration of Food Production & PV Systems

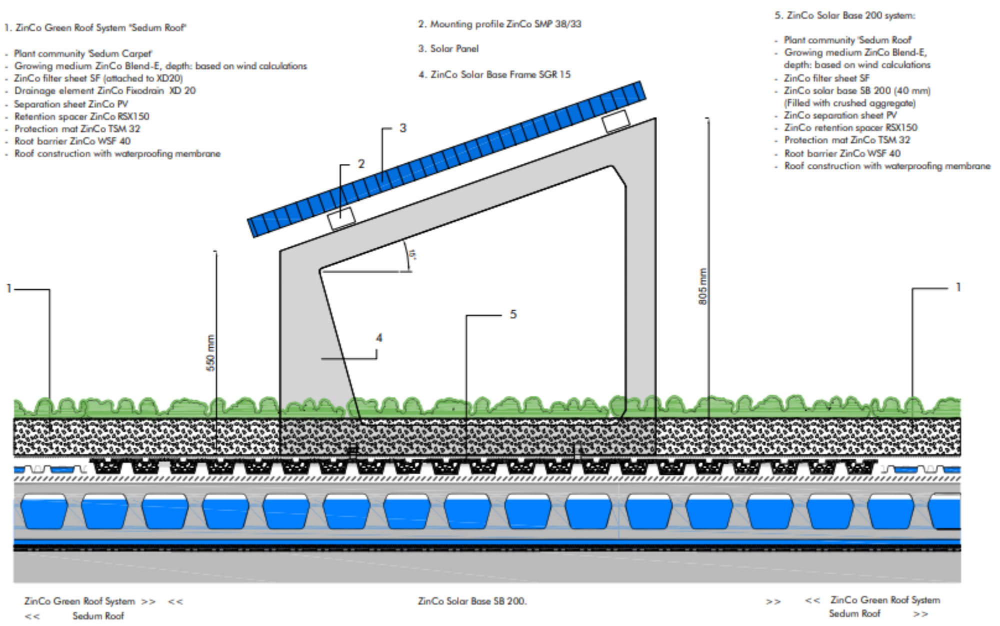
Colorado State University Studying the effects of vegetable production and PV panels in simulated green roof module. Photo courtesy of CSU.

Riverdale Hub Toronto, arguably first green roof and PV in Canada that integrated Agriculture

- Ground level studies have showcased the PV performance enhanced by vegetables beneath, vegetables inherently have a much higher ET rate compared to traditional green roof species

- Colorada State University, Professor Jennifer Bousselot, at the fore front of researching rooftop Agrivoltaics

Stormwater Management &Photovoltaics: Green Roofs Make This Happen



Combined Blue Roof Detention Systm w/ PV Green Roof

- Static stormwater management parameters of GRs (initial abstraction & retention capacity) can be coupled with predictable release rates w/ detention designed roofs
- Blue roofs do not need to seem as scary as they are; water is temporarily detained
  - Roofs will not turn into swamps..

Controlled Outflow & Actively Controlled Drains: Of course Europe Uses This!

Image courtesy of Blue Green Platform

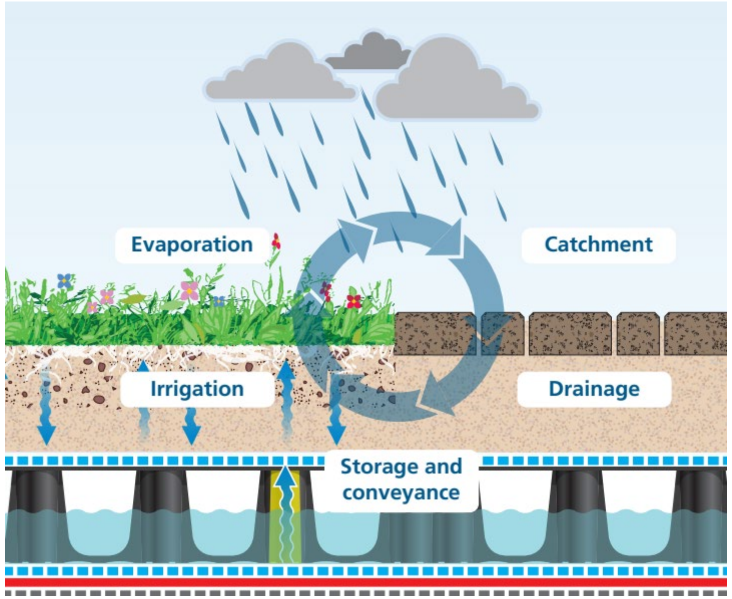


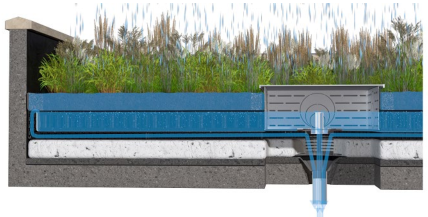
Image courtesy of Blue Green Platform

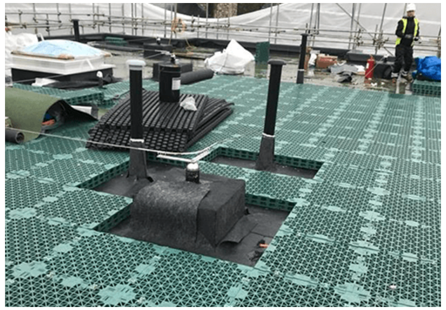
Project Smart Roof 2.0

- Combined 80 mm detention system installed under all vegetation & hardscaping
- Water sensors around roof communicated with drain when to release water, based on rain events, and when to hold water for plants (maximum detention period – 30mm of water)
- Incredible results
  - Blue roof evaporated 2.3 times standard green roof
  - Temperature diffierence between conventional roof; up to 40 degrees
  - Additional water capacity
    - Supported diverse species better
    - More days cooling temperature

Zurn Run-off limiter – Typical

ZinCo Adjustable Run off limiter





Opportunities for Greater Hydrological Benefit

1) Run-off Limiters
   - Frequently used on conventional roofs, rarely used in combination with green roof
   - Predicable and mechanical control of roof discharge

2) Detention / Retention Systems
   - Create permanent voiding for water storage, either temporarily or until evaporated

3) Native Perennials & Grasses
   - Powerful stormwater tools that evaporate higher amounts of water in projects needing to re-use retained stormwater

Green Roofs: Where We Will Go

Image courtesy of Over Easy Solar

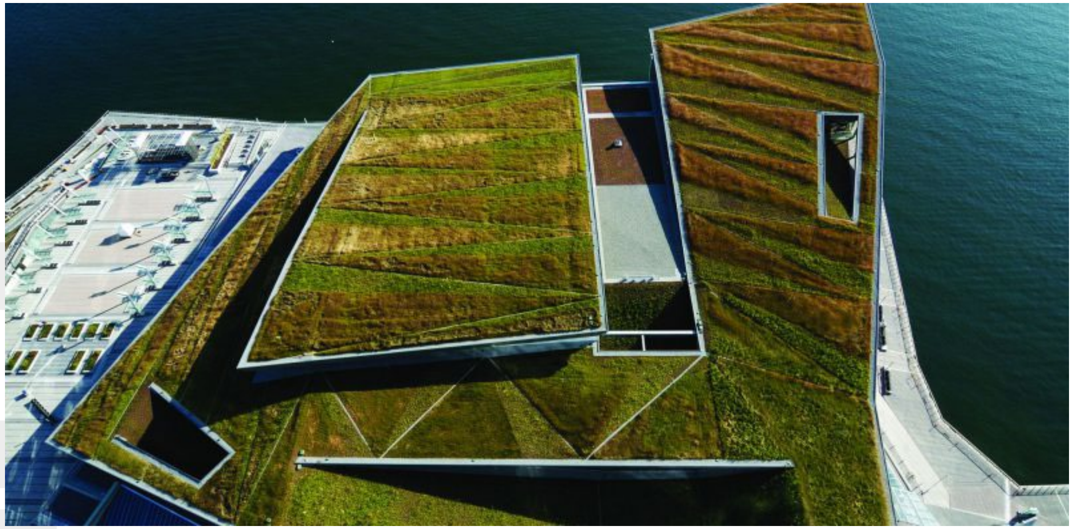


Image Courtesy of Premium Soils

- Smarter pairing of system offerings
  - Integrated PV systems based on optimized layouts, and reducing long term operational costs of a sustainably built building
  - Integrated water management systems in sync with natural weather, actively managing rainfall from point of inception to relase into stormwater systems
  - Vegetation of green roof will be more diverse, resilient and productive in terms of water capture storage and re-use
  - Productive green spaces for food production (Urban Ag)

Green Roofs: The Water – Energy – Food Nexus

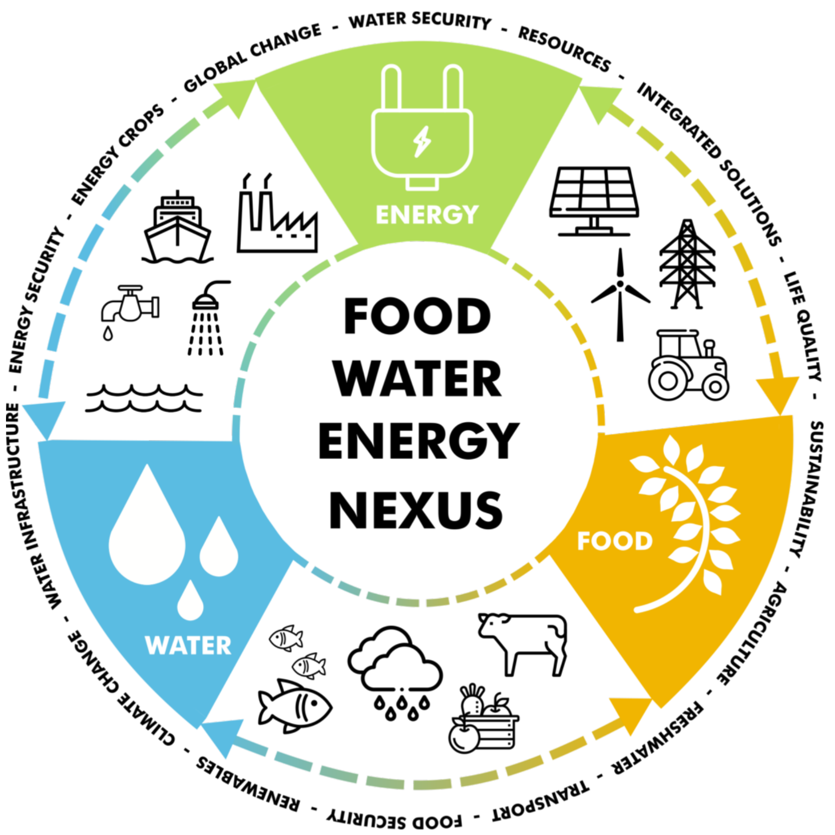


Image courtesy of Sustainable Urbanization Global Initiative

- On any given project, the green roof can be adapted to increase societal / environmental impact with the design tools the green roof industry has in their tool box
- Water – Energy – Food Nexus
  - Green roofs need to be approached with a nexus approach too; does my green roof have any affect on theses three nexuses?
  - If it doesn't, time to re-design
  - Thoughtful designs have long term impacts

1090 West Pender, Vancouver, BC

Thank you!

Green Roof contribution to Fire resistance and Waterproofing Longevity

Roxanne Miller - SOPRANATURE Director

What is a sustainable building?

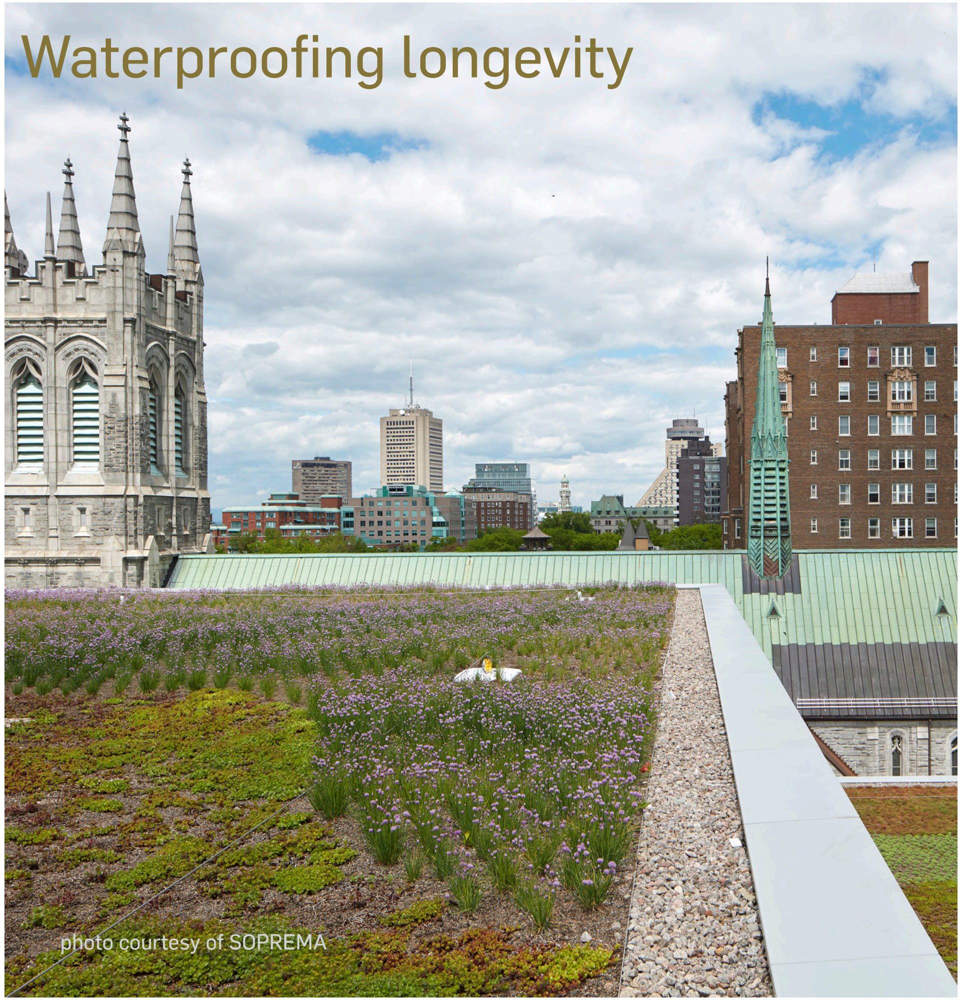
photo courtesy of SOPREMA

What is a resilient building?

photo courtesy of SOPREMA

How can GR contribute?

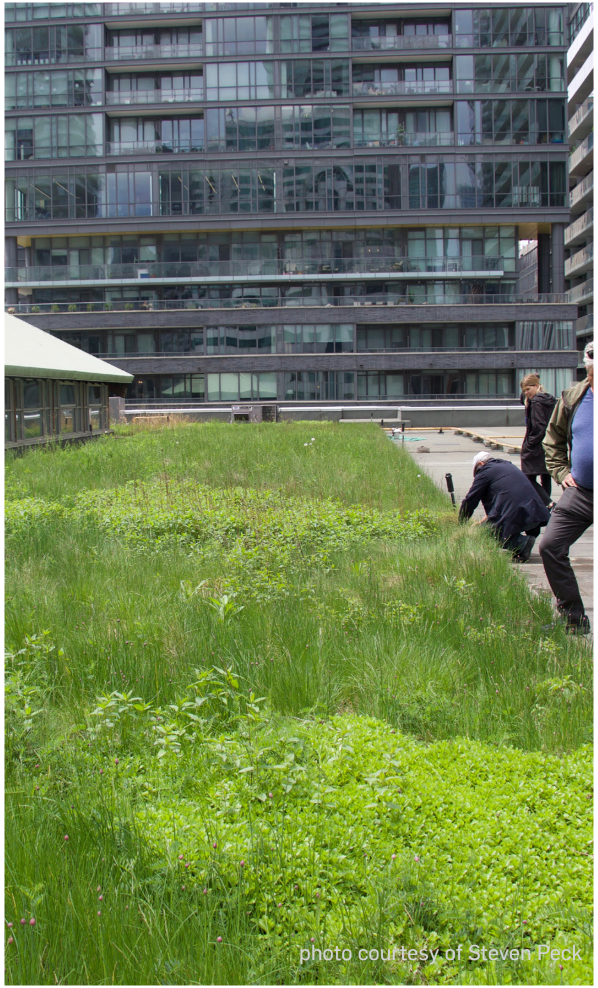
The GREEN ROOF - Two lenses of observation



Waterproofing longevity - The MEC Case Study

photo courtesy of Steven Peck

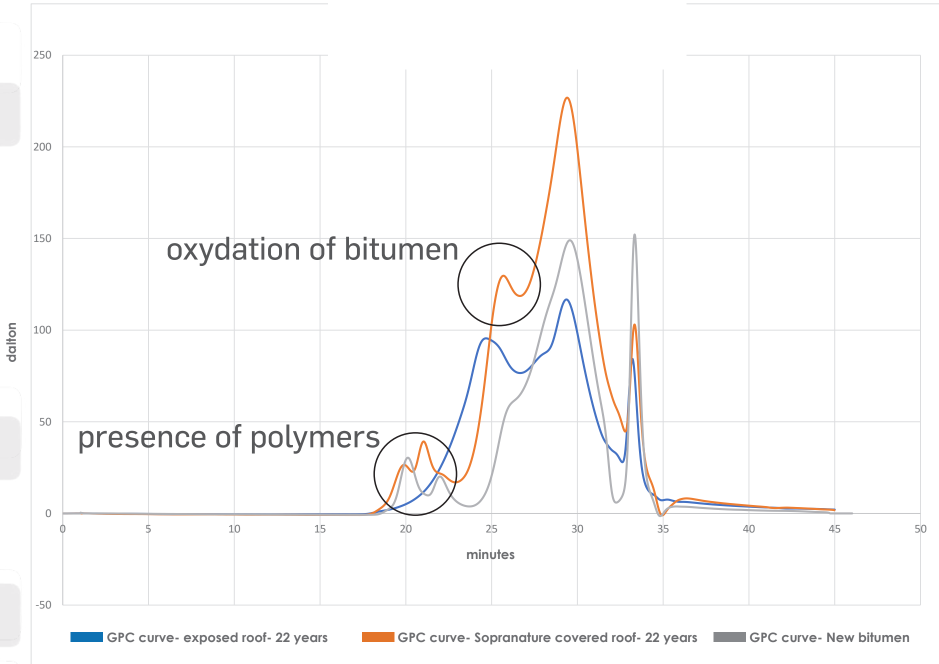
The roof 1998-2019



The test - 2019

The results

GPC curves comparaison

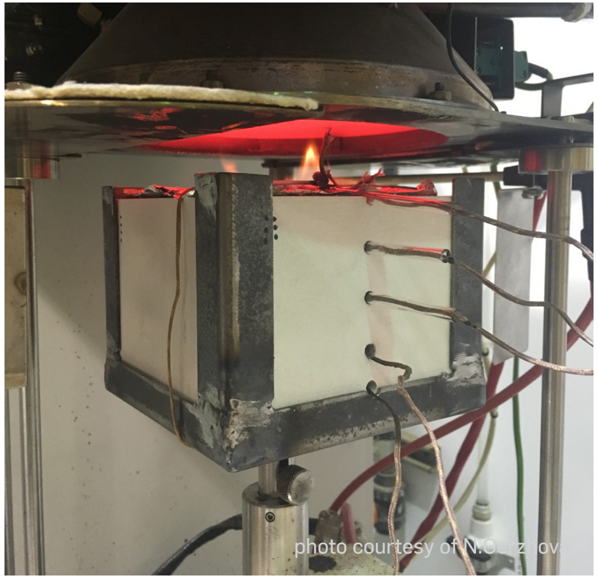


Fire Safety - a GR contribution

photo courtesy of Soprema

How to test the fire hazard?

- determine the growing media **thermal parameters**
- analyse **fire propagation** throughout the GR system
- establish the **combustible properties** of a GR system
- analyse **fire risk** for adjacent buildings



Thermal parameters of the growing media

Difference between GR media and soil

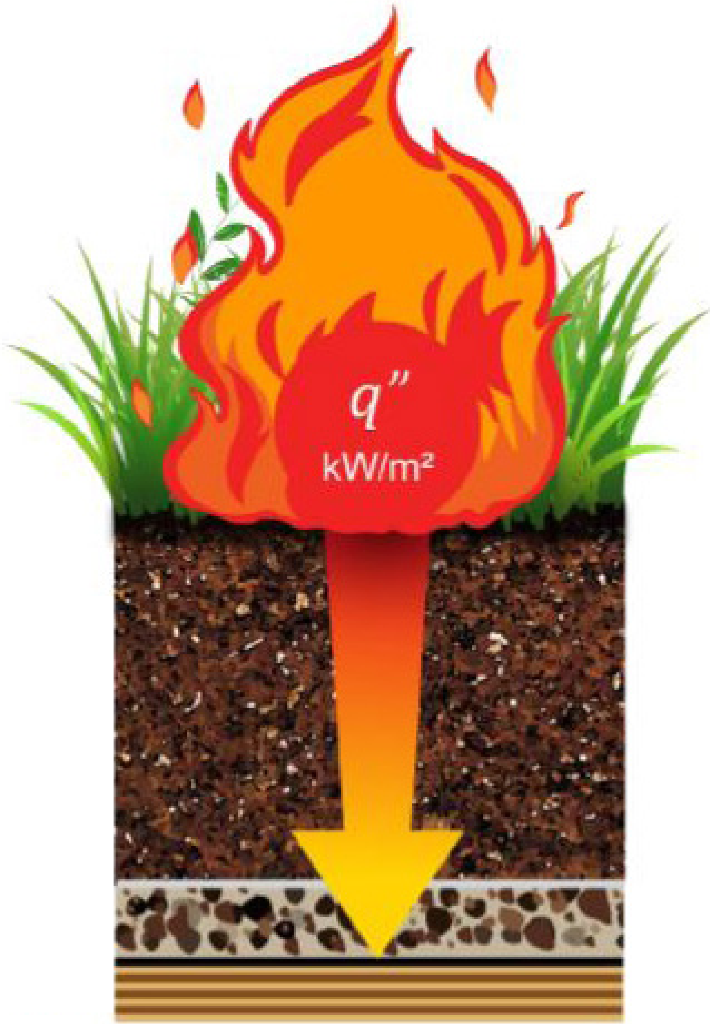
- particle size
- organic content
- water retention and drainage capacity
- density

* GR GM's properties make them suitable for other types of green infrastuctures

Parameters that affect the conductivity are:

- temperature
- thermal conductivity of solid particles
- thermal propagation between the particles
- organic content reaction to heat

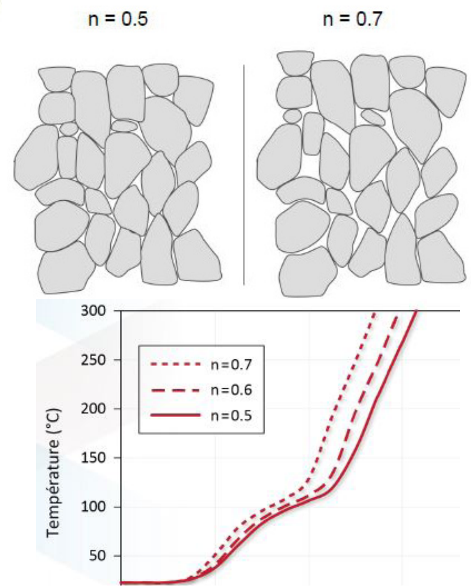
Fire propagation throughout an extensive green roof system

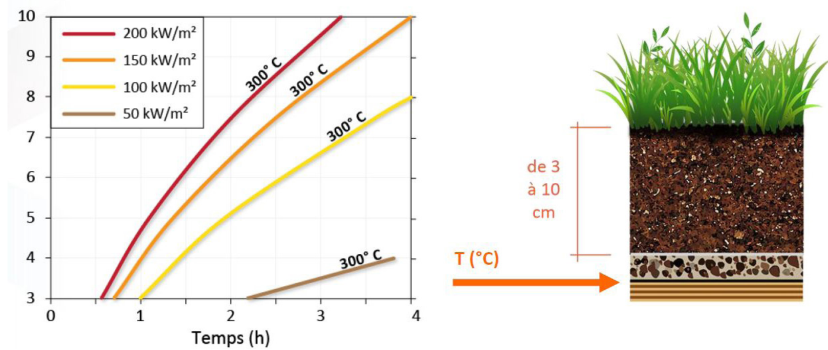


Parameters that affect the propagation speed are:

- porosity of the GM
- thickness of GM
- thermal charge (amount of heat applied)
- type of roof deck (wood, gypsum, steel)

effect of porosity on thermal propagation





effect of thickness of GM thermal propagation

Flammability properties of an extensive green roof

parameters that affect the flamability are:

- ignition time
- combustible charge
- moisture content

organic content

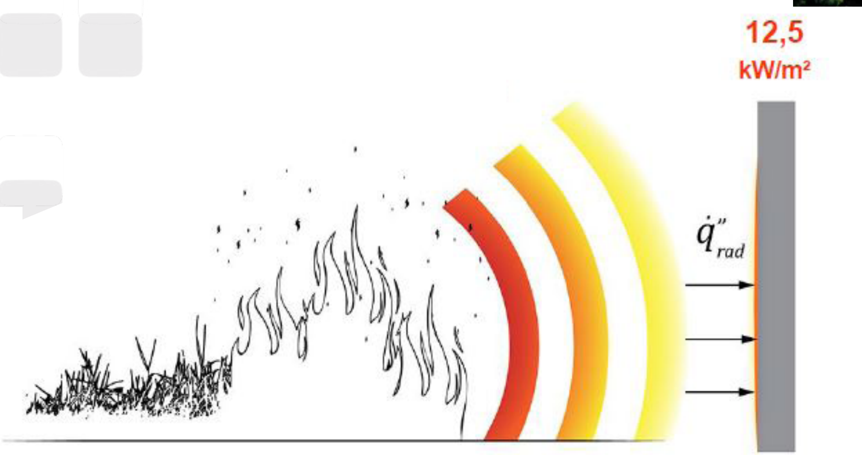
living herbacious species

dead and dry vegetation

Fire hazard of green roof for adjacent buildings

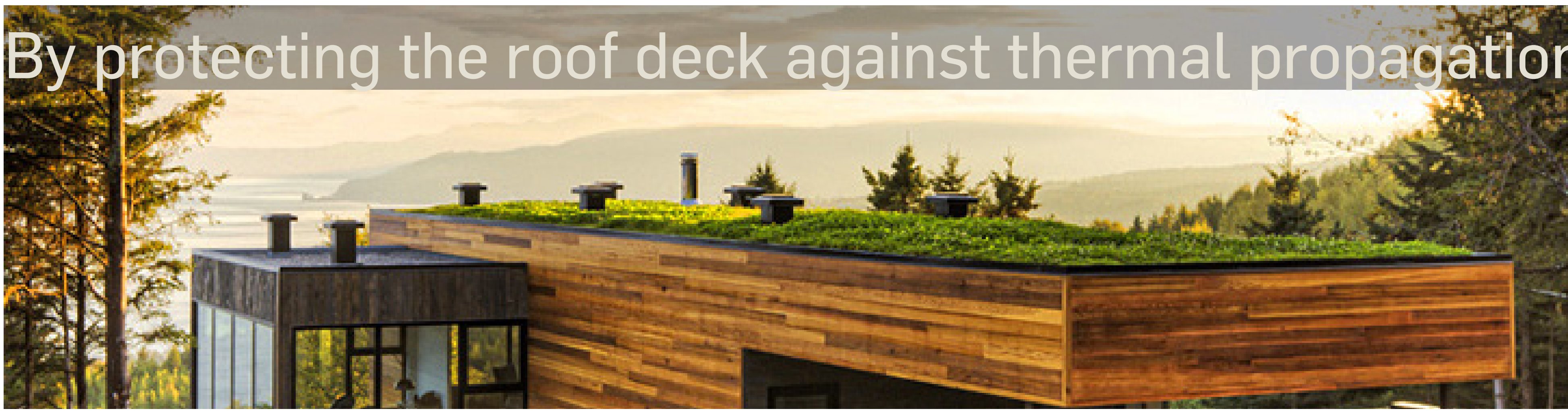
parameters that affect the fire hazard are:

- wind
- type and state of vegetation
- humidity level



Hornby Island, 1994. The Shingle Spit resort, designed by Arthur Erickson, burnt to the ground, save the ones covered by green roofs.

How can GR contribute to a resilient roofscape?



Thank you

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photo courtesy of C. Thuring