GREY TO GREEN

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Exploring Connections Between Green Infrastructure & Healthy & Resilient Communities

Steven W. Peck, GRP, Honorary ASLA, Chair, Green Infrastructure Ontario Coalition, Founder and President, Green Roofs for Healthy Cities

GREEN INFRASTRUCTURE FOUNDATION

Green Infrastructure ONTARIO COALITION

GREEN ROOFS FOR HEALTHY CITIES www.greenroofs.org

Introduction

Over the past two decades researchers have increased their understanding and begun to develop the tools for quantifying the multiple benefits of living green infrastructure. Living green infrastructure technologies cover a wide range of strategies from active and passive turf to trees, wetlands, bioswales, structural soils, green walls and green roofs.

Green infrastructure technologies are becoming recognized by engineers, designers, health care advocates, developers and policy makers world wide as proven and effective ways to solve multiple urban problems. Yet in North America, the many contributions of green infrastructure to our natural and built environments, as well as to human health, are not fully reflected in public policies pertaining to buildings, design practice, community planning or capital and operational investments in infrastructure.

The Green Infrastructure Ontario Coalition, in partnership with Green Roofs for Healthy Cities and the U.S.-based Green Infrastructure Foundation, works to strengthen public policies that develop and protect living green infrastructure, with a particular focus on the province of Ontario. [i]

This paper provides an overview of the literature that illustrates the connections between living green infrastructure and human health. Many of these topics will be more comprehensively presented and discussed during *Grey to Green: A Conference on the Economics of Green Infrastructure Focusing on Health,* which takes place August 25-26, 2014 in Toronto, Canada. This paper looks at living green infrastructure through the lens of health, largely human health, in an effort to raise awareness of these important benefits and to identify some opportunities for further research, public policy development and building design practice improvements.

Water, Water Everywhere...

When we engage in traditional urban development we change the hydrology of the landscape, largely by disrupting the natural cycles of water. Impervious surfaces do not allow stormwater in the form of rainwater and melt water to infiltrate soils or evaporate through vegetation. In a natural setting, vegetation captures and infiltrates stormwater with little as 10 percent runoff on the surface.

In the U.S., an estimated 10 trillion gallons a year of untreated stormwater runs off of buildings, roads and parking lots into waterways that are also sources of drinking water and flows of fresh water to beaches or wetlands.[ii]

This urban stormwater contains an unhealthy cocktail of contaminants

including bacteria, heavy metals, pesticides, organic materials, sediments, oils and grease. Polluted stormwater poses a serious threat to human and aquatic

Source: S. Peck

A natural storm and grey water treatment facility in San Francisco, SF Public Utility Commission.

health and is responsible for more than 20 percent of the beach advisories and closures in the United States.[iii]

With increasing amounts of green infrastructure in urban areas, stormwater is captured, stored and then slowly released, protecting water quality and reducing the strain on aging pipes, erosion controls, storage and treatment and other forms of water-related infrastructure. With sufficiently broad implementation, green infrastructure can reduce the size and cost or even eliminate single-purpose grey infrastructure, such as storage tanks, ponds and tunnels. In some jurisdictions, it can also help to reduce the high cost of pumping millions of gallons of stormwater from storage to treatment facilities.

In many older cities, stormwater from major rain events mixes directly with sanitary sewage, a phenomenon known as combined sewer overflow, because the two systems use the same pipes. When this occurs, stormwater becomes diluted sewage and picks up pathogenic bacteria, viruses and parasites, as well as cadmium, lead, zinc and various nutrients and debris. Thousands of people suffer from infections each year that are related to the contamination of stormwater flowing into receiving water bodies.[iv] The long term health effects from contaminated water are difficult to ascertain.

The continuing climate change-induced trend toward more intense periods of rainfall in many parts of the world has also placed additional stress on the capacity of our storm and sanitary sewer systems to deal with added volumes. The increasing frequency of intense storms is making the 100-year-storm event look a lot more like a 10-year-storm event. These storms and the resulting flooding contribute directly to

multi-billion record insurance claims across North America.

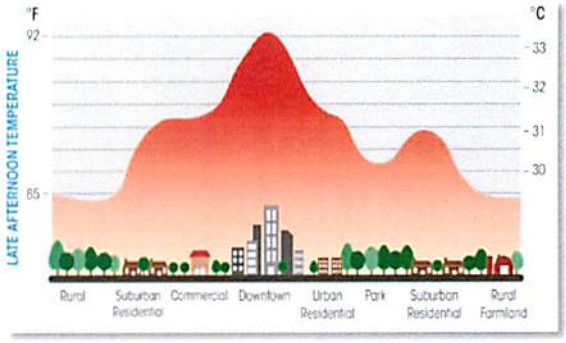
Green infrastructure can often be designed to maximize its ability to capture rainfall, thus mitigating some of the severity of flooding after a major storm event and reducing the occurrence of combined sewer overflow events, especially during periods of less intense rainfall. Plants and soils capture and retain stormwater, and micro-organisms are able to filter and metabolize a wide range of pollutants.

'Fire' On The Horizon

In addition to addressing stormwater challenges, green infrastructure also contributes to the cooling of our increasingly overheated urban regions. When the sun strikes the millions of square feet of dark roofs and miles of pavement that characterize typical urban growth, these surfaces transfer and reflect this heat to the atmosphere around it - a phenomenon called the urban heat island effect (UHI).

By using the sun's energy to turn water stored in plants (through transpiration) and soils (through evaporation) into water vapor rather than heat, green infrastructure transfers this energy away from surfaces and even cools the surrounding air.

According to the US EPA, cities of over one million people can be as much as 12°C (19°F) warmer than the surrounding countryside. Some large cities, such as Chicago, New York and Tokyo have recorded summer temperatures that are 14°C (22°F) higher than adjacent rural areas.



Source: EPA

Our urban regions are getting hotter—and overheated cities are unhealthy cities! Investing in green infrastructure saves electricity used for air conditioning and improves human health by cooling cities.

As cities continue to grow and add hard surfaces, they also get hotter. Recent atmospheric modeling projections for six major US urban regions by the US Environmental Protection Agency and Arizona State University indicate that urban growth under traditional development scenarios will result in 1-2°C of even higher temperatures in all regions, and more the 3°C in some.[v]

The cumulative cooling effects of a threshold level of green infrastructure in cities can actually reduce peak electricity

demand, which is driven largely by increased air conditioning and urban heat island stress. As temperatures rise, more and more people use air conditioners, more stress is placed on the electricity system, and more greenhouse gases are produced. An UHI modeling study by Environment Canada on the Annex neighborhood in downtown Toronto, demonstrated that when 25 percent of the area covered in trees was removed, the summer temperatures jumped by a remarkable 2°C. [vi] According to the US Environmental Protection Agency, a 1°F (0.6°C) reduction in the temperature of a city can reduce peak electricity demand by 1.5-2 percent.[vii] An unpublished Environment Canada study, found the UHI impact on energy use in Ontario is closer to a 4 percent increase in peak demand for every 1°C increase in temperatures.

Cooler cities mean less air pollution, from reduced demand for coal and gas fired electricity generation. Cooler cities have less particulate matter in the air, and less ground level ozone, which requires the right mix of heat, sunlight and airborne chemicals to form. Cooler cities also mean less heat related illnesses and premature mortality.

A study by Akbari in 2001, found that implementing strategies to mitigate the UHI effect in major U.S. cities could reduce air-conditioning energy use by about 20 percent, with the resulting savings on utility bills estimated to be $10 billion per year.[viii] Some types of green infrastructure, such as trees planted beside buildings, green walls and green roofs can also directly reduce energy consumption in buildings used for heating and cooling. This is accomplished by shading, providing wind breaks, evapotranspiration and even pre-cooling intake air which reduces air conditioning energy use. Green roofs also have the ability to improve the efficiency of solar panel energy production by keeping them cooler on hot summer days.

Source: S. Peck

Green walls, roofs and trees have been shown to reduce the energy required for air conditioning by shading units and cooling intake air and green roofs can improve the efficiency of solar panel energy production.

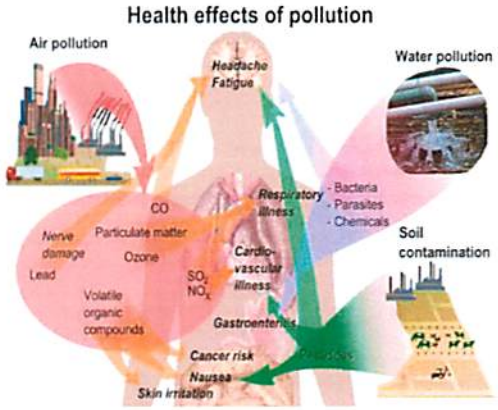
Green infrastructure can simultaneously address two major infrastructure challenges – stormwater management and mitigation of the UHI, providing the basis for water and energy utility cooperation. Yet, despite

growing evidence of the importance of reducing the UHI and its natural link to stormwater management, most water and energy utilities, and utility regulators do not work together, and have not implemented UHI mitigation programs. Senior levels of government need to re-evaluate traditional approaches to infrastructure spending and policies in order to take advantage of the multiple benefits of green infrastructure in helping our communities become more resilient in the face of extreme weather.

Human Health & Well-Being

Managing stormwater and reducing the urban heat island are two important benefits that translate directly into saving dollars and cents. Cooler cities use less electricity and less stormwater running off of our streets and buildings means less water pollution and cleanup of waterways, swimming beaches and aquatic ecosystems.

In addition to these benefits, research shows that living green infrastructure can make important direct and indirect contributions to our physical and mental health and well-being – another potentially huge category of savings. The amount of research on human health is growing rapidly and already demonstrates benefits in a number of areas that have implications on how we think about designing 'infrastructure' and buildings, and how we plan, regulate and invest in community development. Here are a few of the many additional ways that green infrastructure has positive health impacts.



Source: Wikipedia

Common pollution sources and typical health impacts.

Breathe, breathe in the air...

Cleaning contaminants out of the air is one of the most important factors in preventing respiratory disease. Outdoor air pollution, sometimes originating from hundreds of miles away, consists of particulate matter (PM 2.5 and PM 10), ground level ozone, nitrous and sulphur dioxide (SO_2) that have direct links to respiratory illness and premature death. Fine particulates penetrate deep into our airways, sulphates become embedded in lung tissue and ground level ozone directly results in lung inflammation.

Source: S. Peck

Research shows urban forests clean pollutants from the air and also contribute directly to our mental well-being.

Poor air quality annually costs the Canadian health care system nearly $5.7 billion directly, in costs to hospitalize people, and $6.7 billion in indirect expenses associated with disability and premature deaths.[ix] According to a 2013 study in the US, air pollution largely from transportation and power generation, causes 200,000 premature deaths annually.[x]

Plants contribute to better air quality through their ability to catch particulate matter on rough leafy surfaces as the air passes over. Plants also metabolize certain types of chemical pollution, such as benzene and carbon dioxide.

Toronto's urban forest, for example, with approximately 10 million trees, removes over 1,400 metric tonnes of air pollutants annually.[xi] In a study of the effects of 50 million trees in the Chicago area, researchers estimated 9.8 tonnes of particulates, 4 tonnes of SO_2, and 11.9 tonnes of ozone were removed daily.[xii]

Put simply, more vegetation contributes to better air quality for everyone.

The big C...

Air pollution, such as PM10 (which refers to particulate matter less than 10 microns in diameter), is known to carry carcinogens deep into human lungs. That's because particles are in part, small enough to bypass defenses in lung tissue.

Vegetation removes PM10 from the air that passes over leaves, with different rates of capture depending on factors such as leaf and branch structure.[xiii]

Another important cancer prevention benefit, provided specifically by trees, is shading. Trees prevent or reduce ultraviolet radiation from the sun, a cause of skin cancer, from striking one's skin. Tree cover also allows people to stay outdoors longer, without worrying about over exposure to harmful radiation.

Some tree species produce essential oils called *phytoncides*, which when inhaled, improve mental well-being and may even have a preventative effect on cancer development.

Source: G. Yang

Before and after – a green infrastructure makeover. Urban forests and green walls capture air pollutants which help to reduce respiratory illnesses.

Conversely, some tree species may contribute to poor air quality, such as oaks which emit volatile organic compounds (VOCs) that may contribute to the formation of ground level ozone. Other types of trees, such as evergreens, are better at removing particulate matter. This illustrates that there are important cost and benefit tradeoffs with the use of different types of green infrastructure plant species. These tradeoffs need to be fully understood when green infrastructure is being designed for specific health purposes.

Just do it...

When physical activity is low, more people suffer from coronary artery disease, stroke, high blood pressure, cancer and diabetes. In Canada, the direct health care costs associated with low levels of physical activity were estimated at $2.1 billion in 1999.

The American Heart Association reports that the rates of adult and childhood obesity continue to rise and that this costs employers an average of $3,000 per person annually, and even more if that person is obese.[xiv]

Source: S. Peck

A new park on the roof of Toronto City Hall reduces the urban heat island and promotes better human health. The Grey to Green Conference reception will be at this location.

Green infrastructure creates environments that facilitate play, from turf in playgrounds to trees for climbing. Accessible green roofs and walls provide new gardening and

recreational opportunities on underutilized surfaces in our cities. Parks with trails through natural areas provide important recreational infrastructure.

Providing children with nearby opportunities for natural playgrounds and unstructured play is an important strategy for combating the rise in sedentary lifestyles. Our children are spending excessive amounts of time sitting in front of their computer screens. Too many children are more inactive now than ever and the future costs of this will be staggering.

No laughing matter... mental health

It's well-known that one of the worst forms of punishment in a prison setting is to be put into the 'box', where you have no contact with people or the natural world. Many areas within our urban centers are like the box, virtually devoid of vegetation. Studies show that contact with nature can reduce stress, a major contributing factor for depression, impaired immune systems and infections. A recent study conducted by Ian Alcock of the University of Exeter tracked 1,000 participants for over five years. He found that green spaces in cities, such as parks and gardens, contributed to the long-term mental health of communities. In the study, people who moved to densely-built or grey areas suffered a decline in mental health.[xv]

The Green Infrastructure Foundation, in partnership with Horticultural Trades Association and the Ontario Parks Association is running a pilot project called the Green Infrastructure Charrette which brings together designers and community members to redesign neighbourhoods with green infrastructure. After designs are completed they are subjected to a detailed cost-benefit matrix in order to gain a better understanding of the many benefits of green infrastructure investment at the local and regional level.

Teach a man to fish...

Having a job contributes considerably to supporting our health and well-being. Green infrastructure projects tend to be more labor-intensive than traditional forms of infrastructure. So for each dollar invested, more employment is generated.

Source: V. Javet

Green infrastructure investments create a wide range of employment opportunities from designers to manufacturers to installation and maintenance workers.

Recent research shows that investments in green infrastructure provide jobs in both cities and in rural areas, where many of the materials used in green infrastructure projects come from.

City of Toronto research indicates that for every $170,000 to $520,000 invested in green roofs, a year of employment is created for one person based on the direct labor related to design and installation.[xvi]

The indirect labor associated with green infrastructure components – such as growing plants, manufacturing roof systems and blending growing media provides additional employment, often in rural economies. Green infrastructure creates opportunities for ongoing employment in urban areas from annual maintenance.

Additional employment can also be generated if green infrastructure is used to produce local food, which has its own health benefits from improved access to fresh, local food.

For example, community gardens facilitate active recreation, resilient local economies, better food quality and community building.

Source: S. Peck

Asian pears growing on a skyscraper roof garden in Battery Park City, New York provide recreational and food value.

Rooftop food production can supply fresh produce year-round to restaurants while utilizing their compost and wasted heat and spaces. Community orchards help unite communities while supplying fresh fruits and nuts. The more food we produce locally, the more money stays and circulates in the local economy, rather than being exported to pay for produce from thousands of miles away.

Way beyond aesthetics...

The American biologist, Edward O. Wilson is credited with formulating the "Biophilia Hypothesis," which argues that humans share an innate attraction to nature and it is this level of connectivity with nature that directly affects our mental and physical

well-being. Bill Browning, a veteran green building designer, researcher and analyst, has studied the many benefits that result from integrating nature into the building design process. Among these are:

- reduced illness and absenteeism,
- better employee retention,
- faster healing rates for hospital patients,
- better classroom learning rates,
- improved retail sales from greener streets and natural lighting and,
- reduced levels of crime and violence.

Source: S. Peck

Honey production on an accessible and viewable green roof at Terrapin's Headquarters, in NYC provides tasty treats and improves employee productivity. Employee costs are often 112 times as much as energy costs, so designing for improved health can pay big dividends.

Bill Browning, a keynote speaker at *Grey to Green: A Conference on the Economics of Green Infrastructure Focusing on Health*, argues that given that public and private organizations on average pay 112 times as much for the people in their workplaces as the energy used by their buildings, there is a strong economic rationale to include natural/biophilic design elements in the workplace.[xvii]

Source: Drew School. GRHC Awards of Excellence Winner, 2013

Even seeing green infrastructure can result in healthier office workers, reducing absenteeism and improving bottom line productivity.

Next Steps

At the community scale, green infrastructure can deliver preventative health care benefits that translate into reduced expenditures for health care, longer life spans and better quality of life. More interdisciplinary research is needed to better understand the full extent of these

benefits and help practitioners and policy makers better quantify them.

Policy regulators that govern urban water management, energy and land use should be encouraged to work together to address the urban heat island effect *and* stormwater management so that we can improve the resiliency of communities and maximize the effectiveness of scarce public dollars. If the public had a real choice in the matter, do you think they would invest in a new power or water treatment plant in a remote location, or in green infrastructure spread throughout their own community?

Detailed research is also needed to better understand the health contribution of specific plant species used in green infrastructure projects, and any tradeoffs that may exist.

At the building scale, these health benefits can translate into better workplace performance and recurring bottom line revenues for employers. Designers need to better understand these benefits, and have access to regionally specific performance metrics so they can illustrate the full range of economic benefits provided by using green infrastructure, and convince more building owners to implement it.

At *Grey to Green: A Conference on the Economics of Green Infrastructure Focusing on Health* in Toronto, August 25-26, 2014, local and international experts will focus on these and other health-related dimensions of green infrastructure. The conference will provide a unique opportunity for sharing the most recent research, case studies and policy developments that recognize the multiple links between human, economic and ecosystem health and green infrastructure in our communities and our workplaces. The conference will also be a catalyst for even more interdisciplinary research to inform planning and design practice. It will encourage better public policies that promote the use of green infrastructure and protect existing green infrastructure assets.

Conclusion

With society facing rapidly-escalating public and private health care costs, multi-billion dollar infrastructure deficits, extreme weather events ranging from heat waves to floods and ice storms, broad support for living green infrastructure provides a unique opportunity to achieve multiple dividends and address multiple needs in our communities. We need to rapidly adopt new thinking about what constitutes 'infrastructure' and how green infrastructure investment can complement traditional grey infrastructure to derive the maximum public benefits from the billions of tax dollars invested in grey infrastructure each year.

Resources

See: www.greytogreenconference.org for more information about the conference and to register.

www.greeninfrastructureontario.org for more information about GIO Coalition.

www.greenroofs.org for more information about Green Roofs for Healthy Cities.

www.greeninfrastructurefoundation.org for more information on the Green Infrastructure Foundation.

The *Living Architecture Monitor*, North America's green roof and wall magazine: www.livingarchitecturemonitor.com

Green Cities: Good Health www.greenhealth.washington.edu

End Notes

[i] www.greeninfrastructureontario.org

[ii] Natural Resources Defense Council, "Rooftops to Rivers II", 2011, pg. 5. www.nrdc.org

[iii] NRDC "Rooftops to Rivers" www.nrdc.org

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[v] "Urban Adaptation can roll back warming of emerging megapolitan regions" http://www.pnas.org/content/early/2014/02/04/1322280111

[vi] Personal communication, Dr. Brad Bass, March 1, 2014.

[vii] www.epa.gov/heatisland/resources/pdf/BasicsCompendium.pdf

[viii] Akbari, H., Pomerantz, M., & Taha, H. "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas," *Solar Energy* 1 Jan., 2001: 295-310.

[ix] For health cost impact data see: "A Healthy Dose of Green: A prescription for a healthy population", Trees Ontario. www.treesontario.ca

[x] http://journalistsresource.org/studies/environment /pollution-environment/health-effects-costs-air-pollution-research-roundup#

[xi] For Toronto Forestry data: http://www1.toronto.ca/staticfiles/City%20Of%20Toronto/Parks%20Forestry%20&%20Recreation/Urban%20Forestry/Files/pdf/B/backgroundfile-55258.pdf

[xii] "A Healthy Dose of Green" op. cit., pg. 10.

[xiii] www.unidue.de/imperia/md/content/geographie/klimatologie/104_on_the_reduction_of_urban_particle_concentration.pdf

[xiv] www.heart.org

[xv] Alcock 2013. www.eurekalert.org/multimedia/pub/66766.php?from=257330

[xvi] City of Toronto http://www1.toronto.ca/static_files/economic_development_and_culture/docs/Sectors_Reports/ecoroof_challengesopportunities.pdf

[xvii] "The Economics of Biophilia" Browning B., et al. http://www.terrapinbrightgreen.com/downloads/The%20Economics%20of%20Biophilia_Terrapin%20Bright%20Green%202012e.pdf

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