ENVISIONING A MULTI-PURPOSE GREEN INFRASTRUCTURE APPROACH:
Strategies to Promote Health and Community Well-Being in Urban Environments

A thesis
submitted by

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ABSTRACT

The presence of nature in urban areas has great potential to influence health and community well-being. This thesis explores connections between green infrastructure and health and community well-being in urban areas, and presents a Guide to Green Infrastructure for Health and Community Well-being intended for planners and public health professionals. The Guide envisions how a multi-purpose green infrastructure approach could be used to affect three indicators of health and community well-being: urban microclimate and built environment, mental health, and social capital and community cohesion. It provides background information and evidence on green infrastructure and connections to health, suggests strategies for implementation, and includes suggested resources for further information. This thesis and Guide seek to raise awareness of broad potential benefits of green infrastructure and aim ultimately to promote green infrastructure as a viable strategy to improve health and community well-being and serve a functional purpose in the urban environment.

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Envisioning a Multi-purpose Green Infrastructure Approach:

Strategies to Promote Health and Community Well-being in Urban Environments

INTRODUCTION

Early urban planning was rooted in public health and intended to relieve poor living conditions common in the early industrial era (Frank, 2008). As urban development increased, planning and public health came to address increasingly disparate issues, and urban dwellers became progressively disconnected from the natural world. Through activities like filling, channelizing, regrading, and paving, cities work tirelessly to tame and contain formerly natural features and processes. These activities shape urban settings to suit human needs through regulation of natural processes and marginalization of natural systems. The Back Bay Fens in Boston, MA is one example; another is that of the Los Angeles River. Channelized for its entire 51 mile run through its' namesake California city, the Los Angeles River has essentially disappeared from view; visitors and residents of L.A. today rarely realize a river exists nearby. In combination with technological advancement in building design, nature-regulating urban infrastructure makes it possible for urban (and many rural) dwellers to now live without much knowledge of natural processes or need to engage with nature. In the past, conquest of and detachment from natural systems has been generally considered a triumph, an example of human engineering's potential to control nature. Conventional (grey) infrastructure has become the norm, piping wastewater and stormwater under cities, containing floodwaters, channeling rainfall through neighborhood streets. These systems are showing their limitations as storms worsen and population rises; pipes are increasingly too small to hold the necessary volumes of water. These insufficiencies in combination with the challenge of prohibitively expensive upgrades for

conventional infrastructure mean that cities are beginning to look at alternative, green, strategies to address stormwater management issues.

Along with issues of stormwater and wastewater management, paving cities has had additional consequences in other realms. Researchers in fields including environmental psychology and public health are increasingly coming to question what may be lost by the lack of regular contact with nature experienced by urban dwellers. For example, “what happens to our cognitive abilities, emotional states, and mental health if we are deprived of experience in nature?” (Bratman et *al.*, 2012, p. 120). In an effort to cope with rapid changes in industrialization and urbanization, “human, community and cultural well-being has suffered” (Maller, 2005, p. 46). In an article titled *Remaking American Environmentalism,* author Jenny Price remarks that “paving the major artery of the [L.A. River] watershed is in fact deeply implicated in L.A.’s increasingly notorious [environmental, social, and economic] troubles (2008, p. 547). Altering the river has “erased the most dominant natural system in the City,” “robbed people of the open space that is necessary for human health and well-being,” and “taken away the essential childhood experience of learning through observing nature” (LARRMP, 2007, p. 2.3).

To combat these environmental, physical, and social challenges, the City of Los Angeles developed a master plan for the river that aims, among other things, to build a more natural form of flood control to reduce reliance on conventional infrastructure to funnel stormwater to the ocean. Part of the plan is to expand parks and green space and employ low impact development (LID) techniques to encourage infiltration and increase capacity for natural stormwater management,

and to capture water where it falls. The L.A. River Master Plan includes techniques designed to mimic natural systems to improve health of the river, to provide opportunities for recreation and interaction with nature, and to help alleviate urban social and economic concerns. A similar approach was used in late 19th century Boston when Fredrick Law Olmstead designed the Back Bay Fens. Olmstead designed and engineered a natural system intended to control and absorb stormwater and to address public health concerns associated with flooding in the area (City of Boston, 2013). The resulting (green) infrastructure was not only functional, it provided a park-like landscape for recreation and enjoyment. Both Olmstead's plan and the L.A. River Master Plan employ techniques modeled after natural systems that reintegrate nature into the urban environment to provide infrastructural functions as well as aesthetic and recreational benefits to urban residents.

The purpose of this project and accompanying Guide to Green Infrastructure for Health and Community Well-being is to call attention to additional potential benefits of human-nature interaction and access to health and community well-being, and to promote a green infrastructure approach as a mechanism by which those benefits may be realized in an urban setting. Increasing evidence from recent studies shows relationships between human health and access to parks, open space, and natural environments. Unfortunately, these studies rely heavily on correlations and qualitative evidence. Formulating causal links between nature interaction and health remains problematic partially because of difficulties in creating sufficiently controlled experiments in nature; improvements to health shown in research may be complicated by the presence of confounding social,

physical, or other factors (Bowler *et al.*, 2010). Despite the lack of direct evidence, there is a long history of belief in the power of nature to encourage human health and overall well-being. Anthropological and evolutionary theories point to historical human connection with and dependence on nature for survival as evidence that humans are "therefore predisposed to resonate with these surroundings, consciously or not" (Bratman et *al.*, 2012, p.121). Nineteenth century naturalists including Henry David Thoreau, John Muir and Ralph Waldo Emerson professed the ability of the natural world to heal and inspire, beliefs then built mainly on intuition and personal experience. Parks of the era were created to provide recreational space, serve as 'green lungs' for the city, and to reduce crime and disease (Rodhe and Kendle, 1997 as cited in Maller et *al.*, 2005). Planners including Fredrick Law Olmstead recognized connections between public health and planning and saw that parks themselves could be designed and built to address specific urban issues.

Loss of natural areas, habitat fragmentation, degradation of water sources, and loss of beneficial ecosystem services are all consequences of past development and planning decisions, and contribute heavily to contemporary environmental, economic, and social stresses. Along with an increasing awareness of human activities' contributions to environmental and climate pressures is a growing desire for neighborhoods, cities, and countries to develop environmentally, economically, and socially sustainable solutions to these challenges. The holistic, comprehensive, strategic approach of green infrastructure offers strategies to counteract consequences of past haphazard development. Green infrastructure, defined most broadly as an "interconnected network of natural areas and other

open space that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wealth of benefits to people and wildlife," is gaining ground as an "ecological framework for environmental, social, and economic health" (Benedict and McMahon, 2006, p. 1). A green infrastructure approach is systematic and strategic; a process that encourages long-term planning, promotes strategic thinking, and encourages practices that are good for both nature and people. Encompassing a variety of forms and features, a green infrastructure approach can be applied in urban environments to reduce pressure on conventional infrastructure systems, to improve quantity and quality of green space, to boost habitat for urban species, and even to decrease building heating and cooling costs. Further, a holistic green infrastructure approach can improve land conservation and development planning efforts and provide social benefits to communities. Such multi-purpose green infrastructure provides environmental benefits and aids stormwater management while improving livability of the urban environment.

This Guide to Green Infrastructure for Health and Community Well-being, intended for planners and public health officials, calls attention to research on the benefits of nature interaction to mental health and community well-being, and illustrates how a green infrastructure approach can be used to achieve those benefits in an urban setting. It aims to translate a vision for multi-purpose green infrastructure into strategies to improve urban microclimate and built environment, promote mental health, and build social capital and community cohesion. The Guide demonstrates how green infrastructure can be integrated into ongoing municipal activities and priorities (e.g. sustainability, climate change

preparedness, water resource management) to achieve secondary benefits to communities and facilitate renewed collaboration between planning and public health. The Guide acknowledges and addresses potential barriers to implementation of a green infrastructure approach, emphasizes the importance of education and knowledge of local natural processes, and features a basic cost-benefit analysis. The final section of Suggested Resources showcases green infrastructure techniques, plans in cities across the U.S., and strategies for funding and implementation.

Focused intentionally on lesser-known potential benefits of nature interaction and green infrastructure, benefits to physical health are excluded from the Guide. Though perhaps correlated with green infrastructure networks, potential physical health benefits from increased activity as a result of improved green space and recreational opportunities is a separate issue. The exception is benefits to physical health resulting from improvements to the quality of the built environment (e.g. reduced asthma rates due to reduced airborne particulates or ozone, and reduced incidence of heat-related mortality due to cooler urban temperatures). References to health throughout the Guide therefore refer to mental health and to physical health in this narrow sense. Community well-being is a broad term; here it refers mainly to physical comfort of the built environment and to social capital, sense of community, and engagement of residents, businesses, employees, and others who inhabit the local community.

LITERATURE REVIEW

Humans remain dependent on natural processes, weather patterns, and the basic elements to live, despite whatever techniques we employ to engineer built and natural environments. Cities remain “built in nature, with nature, through nature, yet so often appear to be external and opposed to nature” (Keil and Graham, 1998, p. 102 as cited by Barlett, 2005). Boundaries of nature and culture have shifted over the last few hundred years, toward nature as wilderness, distinctly separate from the realm inhabited by humans (Rotenberg, 2005).This detachment means urban residents are increasingly unaware of the presence of nature around them, far less likely to regularly engage with nature in a meaningful way, and often uncomfortable experiencing nature outside human control. In essence humans “have become strangers to the natural world: our own world” (Bird, 2007, p. 4).

Public health officials know that protecting watersheds and eliminating air pollutants is essential to provide clean water, clean air, and to protect public health. In their article *The Powerful Link Between Conserving Land and Preserving Health,* Howard Frumkin and Richard Louv ask the question: “What about land? When we protect land, do we protect public health? (2007, p. 1). They argue that intuition, experience, and theory suggest yes. Although it is difficult to justify protecting nature for health based on intuition and theory alone, evidence shows that the quality of the spaces we inhabit has a significant impact on mental and physical health in addition to our overall well-being.

Built environment: effects on physical and mental health

Urban (and many rural) dwellers now face a continual stream of physical health hazards from exposure to air and waterborne chemicals, pollutants, and particulates; a negative consequence of inhabiting built environments. Vulnerable populations and those with low socio-economic status are often disproportionately affected by characteristics of the built environment (Younger et *al.,* 2008). Fueled by increasing pollutant and particulate emissions, the incidence of respiratory diseases in urban residents, such as asthma, is on the rise. Land use decisions, agricultural and industrial activities, building design, and transportation systems all affect environmental and human health. The way we structure our cities and living spaces plays a role as well. "Neighborhood design not only influences health by affecting physical activity, respiratory and cardiac health, injury risk, chronic disease risk, social connectedness and mental health, but… also adversely contribute[s] to global climate change" (Younger et *al.,* 2008, p. 517). Urban materials of concrete and dark asphalt hold and retain heat, increasing summer temperatures far beyond natural conditions. Called the urban heat island effect, this phenomenon contributes to increased heat-related morbidity and mortality in urban populations.

In addition to these risks to physical health, there is evidence that the built environment also has significant impact on mental health. Essential to human satisfaction, quality of life, and general well-being, good mental health is more than the absence of disease or disability; it enables people to achieve balance and to feel fulfilled, in control of their surroundings, and to cope with every day demands (Bird, 2007). The WHO European Declaration of Mental Health states

that “mental health and mental wellbeing are fundamental to the quality of life and productivity of individuals, families, communities and nations, enabling people to experience life as meaningful and to be creative and active citizens.” The Declaration contends that “there is no health without mental health” (Bird, 2007, p. 7). A report published by the Health Council of the Netherlands argues of a direct link to nature “through indicators for health and well-being,” and an indirect link, through which nature and environment “influence actions or mechanisms which in turn influence health” (2004, p. 15).

In *The Built Environment and Health,* Gary Evans compiles evidence of direct and indirect impacts of the built environment on mental health. Evans focuses on housing conditions, crowding, noise, and indoor air quality, and offers three hypothetical indirect pathways to explain impacts to mental health: personal control, social support, and restoration and recovery (2003). In another study, Galea *et al*. assess relationships between characteristics of the built environment and incidence of depression in New York City neighborhoods post-9/11. The analysis, based on a series of (mostly adverse) characteristics of respondents’ living environments, reveals living in a poor quality built environment to be associated with a greater likelihood of depression both in the past 6 months, and over respondents’ lifetimes (Galea *et al*., 2005). In his groundbreaking study *View through a Window*, Richard Ulrich investigated potential impacts of nature views on mental health in an effort to understand secondary impacts to physical health. Ulrich hypothesized that a “hospital window view [of trees] could influence a patient’s emotional state and might accordingly affect recovery” of hospital patients (1984, p. 420). The study found that patients with tree views had, on

average, shorter post-op stays, fewer negative comments on their condition from nurses, and need for fewer painkillers (Ulrich, 1984).

Theories of nature interaction

The most simplistic hypothesis of nature interaction health benefits is that nature "simply promotes health-enhancing behavior rather than having specific and direct benefits for health" (Bowler *et al.,* 2010, p. 9). While perhaps people who spend time in nature are more likely to be walking, playing sports, or participating in other activities beneficial to their health (therefore indirectly benefitting their health), evidence showing a positive effect after controlling for type of activity allows the authors to conclude that "this more simplistic hypothesis cannot fully account for the patterns observed" (Bowler *et al.,* 2010, 9). This indicates that something else is going on in the relationship between humans and the environment, something of which people may be consciously unaware. Three major theories link health with access to and experience in the natural environment: preferences for nature (biophilia), stress reduction theory (SRT), and attention restoration theory (ART) (Bratman *et al*., 2012; Bird, 2007; Groenewegen, 2006).

Biophilia "implies that humans hold a biological need for connection with nature on physical, mental, and social levels, and that this connection affects our personal well-being, productivity, and societal relationships" (Terrapin, 2012, p. 5). Viewing nature is a pleasurable experience that holds our attention and positively affects human neural activity. Coined by social psychologist Erich Fromm, and used initially by Edward O. Wilson in the 1980s (Terrapin, 2012), the term biophilia provides support and some explanation for arguments that humans

may respond powerfully to exposure to and interactions with natural environments. Bird contends that technology and cities cannot replace our need for contact with the natural world, arguing that our disconnection from nature has in fact led us to become strangers to our own world (2007, p. 4).

Both SRT and ART work to account for the restorative power of nature. Based in evolutionary history, stress reduction theory suggests that people experience an unconscious, psychologically positive response to natural elements when the body is stressed (Ulrich, 1983; Bratman, 2012). A series of studies designed to test human response to views of nature following a stress-inducing event or film indicate that views of nature have potential to reduce negative feelings (Ulrich, 1979) and improve mood (Hartig, 1991), reduce stress symptoms in prison inmates (Moore, 1981 as cited in Maller, 2005) and improve job satisfaction (Kaplan and Kaplan, 1989). Walks through a forest were found to lower cortisol (a stress hormone) and reduce blood pressure in participants, furthering support for the argument that nature contact has potential to reduce stress and benefit human health (Park, 2010 as cited in Terrapin, 2012). Another recent study tracked subjects' brain wave patterns during walks through natural and urban environments. Subjects consistently showed more activity, arousal, and frustration in busy urbanized areas "while traveling through the park, the walkers were mentally quieter" (Green, 2013). Attention restoration theory contends that exposure to nature encourages involuntary coherence and fascination, allowing the brain time to recover from fatigue and to renew its ability to focus intently (Kaplan and Kaplan, 1989 as cited in Bratman, 2012). Achieving this restorative environment requires both opportunity for effortless attention (fascination), and a

sense of pattern or organization in the experience (coherence) (Kaplan, 1983). Studies of nature contact for attention restoration have found evidence of potential for better test scores (Tennessen and Cimprich, 1995), enhanced attention performance of children with ADHD (Taylor and Kuo, 2009), and improved restorative qualities from dynamic window views of nature in comparison even to static screen views of nature (Kahn, 2008 as cited in Terrapin, 2012).

Additional benefits to health and well-being

Significant research has been done concerning potential benefits of nature interaction to human physical and mental health and well-being; the studies mentioned above are only examples. Additional benefits to human health from nature appearing in the literature include facilitation of social contact, encouragement of exercise, benefits to occupational health, improved child development, increased well-being and sense of purpose for adults, and reduced illness recovery time (Frumkin, 2010; Health Council of the Netherlands, 2004; Kaplan, 1995; Srinivasan *et al.,* 2003; Ulrich, 1983; Ulrich, 1981). Natural environments can facilitate learning and skill development, invoke a sense of 'oneness' with nature (Rodhe and Kendle, 1994), and create opportunities to dissolve prejudices toward and increase positive attitudes of neighbors (Lewis, 1990; Lewis, 1996).

Despite uncertainties in the extent of effects of nature on humans, anecdotal, theoretical, and empirical evidence combine to create substantial testimony that nature access promotes health and well-being. This testimony indicates that nature interaction is likely to benefit public health and makes a strong case for

improving health and function of nature in urban environments (Maller et *al.*, 2005). Through their socio-ecological approach, Maller et *al.* recognize that "not only is health itself holistic and multidisciplinary, but that a holistic or multidisciplinary approach is needed to promote and manage health successfully" (2005, p. 51). This approach requires collaboration, inventive new efforts, and a key role for natural spaces.

New opportunities: a green infrastructure approach

Federal water quality mandates, public health concerns, sustainable development, and urban revitalization are all fueling a shift toward holistic planning and a green infrastructure approach (McMahon, 2000). Green infrastructure provides an ideal opportunity for collaboration among planners, policy makers, landscape designers, and public health professionals, and techniques to improve environmental and human health together. The green infrastructure process aims to "promote a systematic and strategic approach to land conservation… encouraging land use planning and practices that are good for nature and people" (2006, p. 3). The concept elevates natural resources to be on par with conventional infrastructure, representing a radical shift in the ways communities think about and prioritize green space and environmental services.

> *The systems planning approach [of green infrastructure] focuses on creating a comprehensive, interrelated system of parks, recreational areas, open spaces, and greenways that: respond to locally-based needs, values, and conditions; provide an appealing and harmonious environment; and protect the integrity and quality of surrounding natural systems* (McMahon, 2000, p. 5).

This unique approach aims to simultaneously plan long-term for both conservation and development, and can be used to create a framework for future

expansion of both natural and built environments (McMahon, 2000). Such a framework provides a high level of predictability for both conservationists and developers, helps to eliminate controversies between interests, and ensures a consistent approach to planning. A long-term plan can also serve to direct development away from disaster-prone, environmentally sensitive, or other areas unsuitable for development.

Though often employed as a forward-thinking pre-development planning strategy, green infrastructure can be employed during site redevelopment, or adapted for use on small sites or individual lots. Installations of any size spaced thoughtfully throughout an urban area will create a network of natural areas and green spaces that inject green features, increase access, and improve environmental health of the entire area. Boston's Emerald Necklace, of which the Back Bay Fens is part, is an excellent example. In its design, Olmstead intentionally linked six parks in a string over 7 miles long (Emerald Necklace Conservancy, 2013). The system of parks, trails, and ponds provides recreational spaces, natural areas, and flood control over 1,200 total acres.

Highly adaptable and flexible, green infrastructure can be designed for and implemented on regional, neighborhood, and site-level scales. Planning at the neighborhood and site scales is perhaps most important when considering a green infrastructure approach to benefit health and well-being. Contemporary urban areas face constraints on capital and available space, especially where development is the common priority. Smaller-scale installations and low impact development (LID) techniques can effectively integrate green infrastructure into the existing urban landscape.

A subset of green infrastructure, LID practices imitate natural systems to filter stormwater, improve groundwater infiltration and recharge, and reduce flooding and peak stormwater flows. “By means of infiltration, evapotranspiration, and reuse of rainwater, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water” (EPA, 2007, p. iii). Techniques include green roofs (absorb stormwater), bioretention facilities (provide stormwater treatment and infiltration), permeable pavement (increase infiltration), storm sewer disconnection (reduce pressure on grey infrastructure), and more. Environmental benefits resulting from LID implementation include: pollutant reduction, protection of downstream water resources, groundwater recharge, water quality improvements, reduced incidence of combined sewer overflows, and riverine habitat improvements (EPA, 2007). Further, LID strategies bring a range of aesthetic, environmental, and economic benefits that conventional systems of pipes and tanks simply cannot.

Evidence that interaction with nature has significant potential to affect mental health and well-being argues for broad injection of green space into urban landscapes in all forms, from small planters to large green spaces. Microclimate in urban areas is influenced by building materials and building design; the composition and dark colored surfaces of the urban built environment result in temperatures far hotter than non-urban surroundings. The consequences of this effect include increased summer energy demand and energy costs, increased heat-related mortality, and heightened ozone pollution and associated asthma rates (EPA, 2013). Green strategies that increase urban tree cover help to

mitigate many of these impacts. Shading of sidewalks and streets moderates daytime temperatures, trees absorb pollutants and improve air quality, and both trees and green roofs can reduce energy demand. Creative strategies to green urban environment and improve streetscapes for bikers and pedestrians can also help build social capital and cohesion within communities. These approaches intend to foster safe, attractive neighborhoods where people are comfortable, physically and emotionally, spending time outside. Community gardens, tiny pocket parks, sidewalk benches, and landscaped common areas all create opportunities for interaction with nature and passersby. When implemented with the community in mind, these elements foster a sense of ownership over the space and enable creative, casual use.

The Guide to Green Infrastructure for Health and Community Well-being that follows is intended to start a conversation about how multi-purpose green infrastructure can provide broad benefits to urban residents. This Guide presents three indicators of health and community well-being that a green infrastructure approach has potential to positively affect: urban microclimate and built environment, mental health, and social capital and community cohesion. Green infrastructure provides an opportunity to address challenges to human and environmental health, but to do so, planners and public health professionals must be aware enough of the potential benefits and the process of a green infrastructure approach to promote it as a feasible option. Ultimately, the Guide aims to inspire planners and public health professionals to support and promote green infrastructure as a viable approach in their own communities.

METHODOLOGY

Drawing upon an in-depth review of the literature concerning nature interaction benefits to health and well-being and research on green infrastructure in practice, this thesis creates a Guide to Green Infrastructure for Health and Community Well-being for planners and public health professionals. Information gleaned from the literature review is used in combination with knowledge of green infrastructure techniques to illustrate how a green infrastructure approach could be used to simultaneously achieve comprehensive benefits to people and the environment. The Guide is intended to introduce the reader to the potential benefits of green infrastructure to health and well-being beyond those of stormwater management and environmental protection. The Guide aims to translate a vision for multi-purpose green infrastructure into strategies by which a green infrastructure approach can improve urban microclimate and built environment, benefit mental health, and build social capital and community cohesion. The hope is that urban planners and public health professionals will see the potential for green infrastructure to rebuild connections between urban dwellers and the natural world, and will understand the full range of potential benefits available through a green infrastructure approach. The Guide recommends strategies to incorporate green infrastructure for health and well-being into other municipal projects and priorities, and advocates for collaboration between planning and public health.

The Guide is structured as follows:

- Introduction and overview
- Key terms
- Background: Basics of green infrastructure and nature-health connections

- Implementation:
  - Adopting a green infrastructure approach
  - Indicators of health and well-being: Roles for, and visualizing green infrastructure
  - Recognizing and addressing obstacles to implementation
- Cost-benefit considerations
- Conclusions
- Suggested resources.

The literature review and research undertaken for the Guide in combination with feedback from planning practitioners on the Guide itself inform a section of next steps. These conclusions precede the Guide, and include suggestions for further research plus reflection on what makes a green infrastructure so important and so essential to pursue.

Input from the field

The structure and content of the Guide were shaped partially by feedback from four planning practitioners. Three planners (Tufts UEP alums) and one landscape architect provided constructive criticism and valuable feedback on the structure and contents of a draft version of the Guide. Feedback was positive: reviewers suggested working to clarify language and terms used and structuring the Guide to emphasize what to do and how to do it. Other suggestions were to include more visuals, summarize the implementation section, and to structure the document with a clear, easy to follow layout.

Following this process, the Guide was revised to highlight what planners, policy makers, landscape designers, and public health professionals need to know most. Key terms were clarified and defined. A section of Suggested Resources

was added, organized by area of interest. Photographs and images that best demonstrate strategies for multi-purpose green infrastructure were selected and described in detail. The Guide was condensed, and structured to more closely align with the three indicators of health and well-being, key elements of the story.

The feedback received was invaluable in developing the final product. It also served to confirm that the topics covered in the Guide are indeed practical for professionals who want to learn more about the potential of a green infrastructure approach.

REFLECTIONS AND RECOMMENDATIONS

Further research

Overcoming obstacles to green infrastructure implementation requires removal of legal and policy barriers, but also depends on establishment of quantified methods sufficient to indicate broad potential benefits of a green infrastructure approach (Dunn, 2010). When examined comparatively, green infrastructure shows huge advantages over conventional infrastructure in that it provides environmental, social, and economic benefits in addition to stormwater management. Many of these benefits (air filtration, urban heat mitigation, aesthetic improvement) persist even when it isn't raining. Conventional systems of pipes and tanks simply cannot provide the same. These benefits, unfortunately, are difficult to quantify and to track. The lack of quantitative and economic data on benefits of green infrastructure is a serious limitation to planners, public health professionals, and other municipal officials working to justify a green infrastructure approach to other departments, partner organizations, and the public.

As indicated by Kuppuswamy (2009) and others, what is needed is a basis on which to compare costs and benefits of green infrastructure with those of conventional infrastructure strategies (the business as usual scenario). From a planning and policy standpoint, conventional infrastructure has long been the norm. Because a conventional approach is so ingrained, promoting green infrastructure as a viable approach may require clarifying the scope and magnitude of benefits it offers. Enabling comparison between green and conventional infrastructure requires both strategies to be valued through similar

processes and presented in the same units. Clarifying these benefits will require creative research design and significant further research on benefits of nature interaction to health and well-being. Only by standardizing and broadening the assessment into a more holistic approach can the vastly different approaches be reasonably compared and the full range of costs and benefits be considered. A holistic approach would ideally calculate costs and benefits related to social well-being, environmental function and health, human mental and physical health, long-term operations and maintenance, social and environmental equity, energy consumption, and more. For example, a report prepared for the City of Philadelphia, PA compares dollar benefits of a green versus conventional approach to managing combined sewer overflows (CSOs). in a holistic way. The report examines a range of benefit categories and concludes that the "green infrastructure approach provide[s] a wide array of important environmental and social benefits to the community… not generally provided by the more traditional alternatives" (Stratus Consulting, 2009).

A consultant for the City of Portland, OR has created one approach to value benefits of green infrastructure that involves assigning metrics to a range of potential benefits of green infrastructure to health and community well-being. Potential benefits are divided into areas of health, energy and carbon sequestration, and community livability. Metrics such as respiratory symptoms, electricity usage, and crime correspond with one of the three benefits. Green infrastructure best management practices are then assessed for each metric in terms of the type and extent of potential benefits provided. Though many of the effects are categorized as 'uncertain' or 'possible positive,' this approach creates

a framework that could help target areas for future research, and provides knowledge areas for which data collectors and researchers can work to improve. If applied in a localized context, using a panel of community members, this approach could be an effective way to gain understanding of how a green infrastructure approach might affect the community, and where benefits could be greatest.

Roles for multi-purpose green infrastructure in social and environmental justice

Because of its flexibility and unique potential to affect environmental, economic, and social benefits, green infrastructure has potential to make serious contributions to environmental and social justice priorities. Neighborhoods of low socio-economic status are far too often most likely to be exposed to high levels of industrial pollutants and exposure to vehicular exhaust, and least likely to contain sufficient, clean parks and open space. Through a green infrastructure approach, planners and public health officials have an opportunity to reverse this trend, using vegetation and green spaces to combat rising asthma rates, childhood exposure to airborne pollutants, and high levels of impervious, paved surfaces.

Success of a green infrastructure approach for environmental and social justice requires directing initiatives to neighborhoods that lack access to green space, trees, and sufficient stormwater management infrastructure. Multi-purpose design will play a strong role in determining where and how green infrastructure can be integrated into the existing urban fabric. Schoolyards, empty lots, or other sites can be reconfigured, adding LID and green infrastructure elements to manage stormwater during rain events, improve health and well-being, and make neighborhoods more livable. Building green infrastructure in neighborhoods that

lack green space will do more than just add a green element; it will begin to address social and environmental injustices, and demonstrate to community members that the city is investing resources to make their urban environment healthy and livable.

Why green infrastructure?

The Guide that follows is not the first guide to green infrastructure. It does, however, examine potential benefits of a green infrastructure approach through a new lens, focusing on areas often overlooked in prior guides. This lens sheds light on benefits of green infrastructure beyond stormwater management in the hopes that planners and public health professionals will begin to see even more broadly how and why green infrastructure can benefit their communities.

Booming global population, continual development, climate change, and other stressors are increasing pressure on natural and man-made systems. Widespread paving and development have made cities highly impermeable environments, dependent on conventional infrastructure to move stormwater off of streets and sidewalks. This dependency makes cities especially vulnerable to flooding from large storm events, like those predicted to increase as climate change progresses. A green infrastructure approach provides strategies to manage rain where it falls, increasing natural capacity for stormwater control and absorption. These techniques can help prepare cities for increasing future unpredictability and reduce reliance on expensive, construction-intensive conventional stormwater control systems. Multi-purpose green infrastructure takes these techniques a step further, using creative design to bring a host of additional benefits to communities. This Guide demonstrates strategies to

improve urban microclimate and built environment, promote mental health, and build social capital and community cohesion – all through green infrastructure – ultimately increasing environmental health and human livability of our urban environments.

Guide to Green Infrastructure for Health and Community Well-being

INTRODUCTION

Cities work tirelessly to tame and contain natural features and processes. Activities like filling, channelizing, regrading, and paving shape urban environments to suit human needs, marginalize natural systems, and separate realms of urban and natural. In the past, human detachment from natural systems was seen as a triumph, an example of human engineering's power over nature. For example, in an effort to control flooding, a fifty-one mile portion of the Los Angeles River was channelized in concrete between 1938 and 1960. The river essentially disappeared from view; visitors and residents of Los Angeles now rarely realize a river exists in the City. In Los Angeles and beyond, loss of regular contact with nature that results from these activities has raised concerns of potential impacts to human mental and physical health may result. Further, rapid changes caused by industrialization and urbanization are implicated in a decline of "human, community and cultural well-being."[1] The good news is that green infrastructure, modeled after highly-effective natural systems, provides a holistic approach to combat these environmental, physical, and social challenges.

An expanding body of research indicates that access to and interaction with nature has potential to exert a significant influence on health and community well-being. Though quantitative evidence of a direct, causal relationship between nature interaction and health remains weak, evidence strongly suggests that facilitating access to nature in urban settings will benefit human health and

[1] Maller, C., Townsend, M., Pryor, A., Brown, P. and L. St Leger. (2005) Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations. Health Promotion International, 21, 45-54.

community well-being. Awareness of links between environmental health and human well-being has spread: Federal water quality mandates, public health concerns, and calls for sustainable development and urban revitalization are all fueling a shift toward holistic planning and a green infrastructure approach.[2] The L.A. River Master Plan, developed in 2007, incorporates engineered natural systems to increase capacity for natural stormwater management. The plan includes strategies to improve health of the river, increase opportunities for interaction with nature, and help alleviate urban social and economic concerns. By recognizing connections between environmental and human health, the plan aims to address both together. It is this ability of green infrastructure to improve environmental and human health together – an important advantage in policy and planning – that is the focus for this Guide.

Purpose of the Guide

In the broadest sense, green infrastructure refers to an interconnected network of green spaces and natural areas that "conserves natural ecosystem values and sustains clean air and water."[3] It is a systematic and strategic approach: a process that encourages long-term planning for conservation and development simultaneously, and encourages practices that are good for both nature and people. Green infrastructure provides ideal opportunities for collaboration among planners, policy makers, landscape designers, and public health professionals.

This Guide to Green Infrastructure for Health and Community Well-being calls attention to research on the benefits of nature interaction to mental health and

[2] McMahon, E. T. (2000) Green Infrastructure. Planning Commissioners Journal, 37, 4-7.
[3] McMahon, E. T. (2000) Green Infrastructure. Planning Commissioners Journal, 37, 4-7.

community well-being, and illustrates how a green infrastructure approach can be used to achieve those benefits in an urban setting. The Guide aims to translate a vision for multi-purpose green infrastructure into strategies to improve urban microclimate and built environment, promote mental health, and build social capital and community cohesion. Highly adaptable and flexible, green infrastructure can be designed for and implemented on regional, neighborhood, and site-level scales.

The Guide focuses intentionally on lesser-known potential benefits of nature interaction and green infrastructure; benefits to physical health, such as those from improved outdoor recreational opportunities, are excluded. Exceptions are physical health benefits resulting from improvements to the quality of the built environment. Examples include reduced asthma rates due to reduced airborne particulates or ozone, or reduced incidence of heat-related mortality due to cooler urban temperatures. References to health throughout the Guide therefore refer to mental health and to this narrow definition of physical health.

How is this guide different?

This is not the first guide to green infrastructure. Environmental planners, regional planning agencies, the EPA, and other organizations have produced a variety of general and site-specific tool kits and plans for green infrastructure. The Suggested Resources section of this Guide lists and links to some; these tool kits most commonly promote green infrastructure as a way to mitigate impacts of development, encourage strategic land conservation, improve wildlife habitat, absorb stormwater runoff, and reduce pressures on conventional

stormwater management systems. Some mention additional potential benefits in the form of cost savings, improved recreational opportunities, energy conservation, and health, but additional benefits are rarely the focus.

This Guide explores potential contributions of green infrastructure to areas often overlooked, specifically mental health and community well-being. A key function of local government is to ensure the health, safety and welfare of the community it serves. Green infrastructure provides an opportunity to address challenges to human and environmental health, but to do so, planners and public health professionals must be aware enough of the potential benefits and the process of a green infrastructure approach to promote it as a feasible option. This Guide presents three indicators of health and community well-being that a green infrastructure approach has potential to positively affect: urban microclimate and built environment, mental health, and social capital and community cohesion. These three indicators are central to ensuring health, safety and welfare of urban residents; here they create a structure for understanding why and how a green infrastructure approach can be implemented.

Overview of the Guide

The Guide that follows contains Key terms, Background, Multi-purpose Green Infrastructure Implementation, and Cost-benefit considerations.

Background includes information on the basics of green infrastructure and evidence of nature-health connections. Implementation is broken into a number of smaller parts: Adopting a Green Infrastructure Approach; Indicators of Health and Well-being: Roles for, and Visualizing Green Infrastructure; and Recognizing

and Addressing Obstacles to Implementation. The Indicators piece directly addresses how planners and public health professionals can use multi-purpose green infrastructure to improve urban microclimate and built environment, promote mental health, and build social capital and community cohesion. Intended to envision where and how multi-purpose green infrastructure can fit into urban environments, this piece should not be overlooked.

The Guide also includes Suggested Resources, at the end, to direct further reading.

KEY TERMS AND CONCEPTS

Community Well-being

Refers to physical comfort of the built environment. Also to social capital, sense of community, and engagement of community members: residents, businesses, employees, etc.

Green Infrastructure

An interconnected network of green spaces and natural areas that mimic natural systems to "conserve natural ecosystem values and sustain clean air and water."[4]

A systematic and strategic approach. A process that encourages long-term planning for conservation and development simultaneously, and encourages practices that are good for both nature and people.

Multi-purpose Green Infrastructure

Provides an environmental function (stormwater management, habitat improvement, etc.) and encourages urban livability and nature interaction (air filtration, usable green space, seating areas, nature trails, etc.).

Low Impact Development (LID)

Subset of green infrastructure. Imitates natural systems to manage stormwater and pollutants at the source, reducing pressure on conventional infrastructure and negative impacts to water bodies.

[4] Benedict, M. A. and E. T. McMahon (2006) Green Infrastructure: Linking Landscapes and Communities. Washington, DC: Island Press.

Microclimate

Localized climatic condition. Influenced by factors including temperature, humidity, wind, solar radiation. In an urban setting, conditions are further influenced by materials and form of the built environment.

Examples include: wind tunnels formed by long blocks of high buildings, increased ground-level temperatures caused by absorption and slow release of heat from paved surfaces (urban heat island).

Urban Heat Island effect

Annual mean temperatures up to 5.4°F higher in urban than surrounding rural areas.[5] Occurs because building materials and pavement heat up quicker and retain heat more effectively than the natural environment: temperatures of dry, exposed urban areas rise 50-90°F hotter than air; buildings and pavement release heat slowly; result in higher daytime and nighttime temperatures.

[5] EPA. (2013) Heat Island Effect. Available http://www.epa.gov/hiri/index.htm

BACKGROUND

Basics of green infrastructure

Green infrastructure is at once a network of green spaces, a systematic and strategic approach to planning, and a concept that prioritizes green space and environmental services. Designed as a system of hubs, links, and sites, a green infrastructure network is "planned and managed for its natural resource values and for the associated benefits it confers to human populations." A green infrastructure process promotes a thoughtful approach to land use, encourages planning for conservation and development simultaneously, and encourages "practices that are good for nature and people."[6] A green infrastructure approach elevates the significance of natural resources to be on par with conventional infrastructure. The concept represents a radical shift in the ways communities think about and prioritize green space and environmental services; it is an effort to plan for both conservation and development simultaneously.

The systems planning approach to green infrastructure "focuses on creating a comprehensive and interrelated system of parks, recreation areas, open spaces, and greenways" that protect environmental systems, incorporate local needs and conditions, and that are both visually pleasing and highly usable.[7] The emphasis on long-term planning provides a high level of predictability for both conservationists and developers, helping to eliminate controversies between interests and effectively directing development away from disaster-prone, environmentally sensitive, or other areas unsuitable for development. By

[6] Benedict, M. A. and E. T. McMahon (2006) Green Infrastructure: Linking Landscapes and Communities. Washington, DC: Island Press, p. 3

[7] McMahon, E. T. (2000) Green Infrastructure. Planning Commissioners Journal, 37, 4-7.

protecting biodiversity and allowing natural systems to function as intended, green infrastructure often reduces need for engineered solutions to flooding and other issues.

Significant flexibility in design and implementation means that a green infrastructure approach can be applied across all scales: from planning of green space networks at the regional level, to design of mixed-use neighborhoods, down to site-based strategies that mimic natural systems.

Green infrastructure for stormwater management (and more)

Low impact development (LID), a subset of green infrastructure, provides best management practices for stormwater management modeled on natural systems. These engineered natural systems capture rain where it falls, directing it out of sewer systems and back into the ground. Placed adjacent to sidewalks, parking lots and roads, even small rain gardens or bioretention installations (both LID features) filter pollutants from stormwater and inject green elements into previously impervious areas. By cleaning and returning more rainfall to the water table, LID improves local water quality and riparian habitat. Incorporating green infrastructure into stormwater management plans helps reduce infrastructure maintenance costs and ease financial pressures on cities facing stormwater infrastructure repairs.[8]

Increasing the overall amount of urban vegetation has additional benefits to people and the environment aside from stormwater improvement. Green roof systems absorb rainfall and help insulate buildings, reducing heating and cooling

[8] Winters, P., Piasecki, C. and R. Pirani. (2012) 9 Ways to Make Green Infrastructure Work. New York, NY: Regional Plan Association.

costs. Urban trees also absorb rain; additionally trees filter airborne pollutants and particulates, shade and cool the urban environment, and help mitigate climate change by storing greenhouse gases. Gardens and green spaces of all types boost habitat for urban species and aid biodiversity.

Potential for these benefits provides a compelling case for green infrastructure planning and implementation in all municipalities. Native plant species incorporated into green infrastructure plans reduce maintenance requirements, and increase habitat for local animal and insect populations.

Evidence of nature-health connections

Theories of anthropology and evolution point to the history of human connection and dependence on nature for survival as an indication that humans "are therefore predisposed to resonate with these surroundings, consciously or not."[9] No matter what strategies humans use to engineer and tame nature, we remain dependent on natural processes, weather patterns, and the basic elements for survival. Contemporary building design and engineering, however, have created urban environments in which residents are no longer required to engage with nature in a meaningful way. Urban dwellers often live with little to no recognition that natural processes are at work all around them. In a way, humans "have become strangers to the natural world: our own world."[10]

The form and quality of the spaces we inhabit has significant influence on our mental and physical health, and our overall well-being. Land use decisions,

[9] Bratman, G. N., Hamilton J. P. and C. G. Daily. (2012) The Impacts of Nature Experience on Human Cognitive Function and Mental Health. Annals of the New York Academy of Sciences, 1249, 118-136.

[10] Bird, W. (2007) Natural Thinking: Investigating the links between the Natural Environment, Biodiversity and Health. United Kingdom: Royal Society for the Protection of Birds, 1st Edition, p. 4

agricultural and industrial activities, building design, and transportation systems all potentially affect environmental and human health. For example, incidence of asthma and respiratory disease in urban residents is growing, likely fueled by increasing pollutant and particulate emissions. Neighborhood design influences social connectedness and mental health by enabling or inhibiting opportunities for contact with neighbors, nature, and the world outside our homes. Housing conditions, crowding, noise, and indoor air quality all impact mental health: research correlates living in a poor quality built environment with a greater likelihood of depression.[11]

The practice of promoting positive mental and physical health through nature exposure and interaction is not new. Restorative gardens were incorporated into hospital settings as early as the Middle Ages,[12] and many 19th century parks were installed for recreational space, to provide 'green lungs' for cities, and to reduce crime and disease.[13] Strategies to bring nature into the urban, human realm were intended to rebuild human connections to the natural world in the face of increasingly distinct spheres of nature and culture. At the time, these efforts were based mainly on broad beliefs that the presence of trees, light, and air would improve health and reduce disease. Recent studies show evidence of potential for nature interaction to reduce negative feelings,[14] improve mood,[15]

[11] Galea, S., Ahern, J., Rudenstine, S., Wallace, Z., and D. Vlahov (2005) Urban Built Env and Depression: A Multilevel Analysis. Journal of Epidemiology and Community Health, 59, 822-827.

[12] Bratman, G. N., Hamilton J. P. and C. G. Daily. (2012) The Impacts of Nature Experience on Human Cognitive Function and Mental Health. Annals of the New York Academy of Sciences, 1249, 118-136.

[13] Maller, C., Townsend, M., Pryor, A., Brown, P. and L. St Leger. (2005) Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations. Health Promotion International, 21, 45-54.

[14] Ulrich, R. S. (1979) Visual Landscapes and Psychological Well-being. Landscape Research, 4, 17-19.

[15] Hartig, T., Mang, M. and G. W. Evans. (1991) Restorative Effects of Natural Environment Experiences. Environmental Behavior, 23, 3-26.

reduce stress,[16,17] and increase job satisfaction.[18] Other research indicates potential for nature contact to promote mental restoration and improve concentration,[19] facilitate social contact,[20] and create opportunities to dissolve prejudices toward neighbors.[21]

In spite of these studies, the extent of relationships between nature and health remain unclear. Creating sufficiently controlled experiments in nature is difficult because of the high variability of natural systems. It is therefore problematic to determine whether improvements to health shown in research are solely the result of interaction with nature, or whether confounding social, physical, or other factors played a role. [22]

Implications of research for green infrastructure

Despite the uncertainty, anecdotal, theoretical, and empirical evidence combine to form a substantial testimony that nature access promotes health and well-being. [23] Together with knowledge that low impact development and a green infrastructure approach can benefit environmental health and function, this testimony suggests that incorporating strategies that encourage nature

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[16] Kuppuswamy, H. (2009) Improving Health in Cities Using Green Infrastructure: A Review. *FORUM Ejournal*, 9, 63-76.

[17] Maller, C., Townsend, M., Pryor, A., Brown, P. and L. St Leger. (2005) Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations. Health Promotion International, 21, 45-54.

[18] Kaplan, R. and S. Kaplan. (1989) The Experience of Nature: A Psychological Perspective. New York, NY: Cambridge University Press.

[19] Terrapin Bright Green. (2012) The Economics of Biophilia: Why Designing with Nature in Mind Makes Financial Sense. New York, NY: Terrapin Bright Green LLC.

[20] Frumkin, H. (2010) Nature Contact: A Health Benefit? In Frumkin, H. (ed.), Environmental Health: From Global to Local, 2nd ed. San Francisco, CA: Jossey-Bass.

[21] Lewis, C. A. (1990) Gardening as a Healing Process. In Francis M. and Hester, R. T., Jr (eds.) The Meaning of Gardens: Idea, Place and Action. Cambridge, MA: MIT Press, 244-251.

[22] Bowler, D. E., Buyung-Ali, L. M., Knight, T. M. and A. S. Pullin. (2010) A Systematic Review of Evidence for the Added Benefits to Health of Exposure to Natural Environments. BMC Public Health, 10, 456.

[23] Maller, C., Townsend, M., Pryor, A., Brown, P. and L. St Leger. (2005) Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations. Health Promotion International, 21, 45-54.

interaction into larger municipal projects and plans has high potential to benefit health and community well-being. In this way, green infrastructure is a ‘no regrets’ approach: highly likely to improve human health and well-being, but at least guaranteed to bolster environmental function and health in our urban environments.

IMPLEMENTATION: **adopting a green infrastructure approach**

Every community is different, and is therefore likely to use green infrastructure in some unique way that works to address its specific social and environmental challenges. In some communities, an opportunistic site-by-site approach to green infrastructure may be most effective; others may plan for large-scale green infrastructure implementation, incorporating its techniques into larger master plans and broader municipal efforts. There is no single, best way for a green infrastructure approach to be applied. It is important for planners, public health professionals, and others to keep in mind that green infrastructure can be adapted for use in any community, on any scale. The strategies discussed here are meant as starting points to implementation, suggestions for how multi-purpose green infrastructure can look and how it can benefit communities. Where, how, and to what extent green infrastructure is employed is determined by each community on a case-by-case basis.

To be seen as a viable strategy to address urban challenges to health and well-being, green infrastructure must be universally understood as a flexible, adaptable, reliable, inexpensive, long-term, practical approach. Planners, public health professionals and others must recognize where green infrastructure can be integrated into ongoing municipal projects and initiatives, and continually promote its use. This section explores general strategies for implementation of green infrastructure in an urban context, then concentrates on three areas – urban microclimate and built environment, mental health, and social capital – all indicators of health and well-being. These indicators typically receive minimal attention in guides to green infrastructure, but have high potential to be improved

through a green infrastructure approach. This section therefore provides essential knowledge for planners and public health professionals.

Integration into ongoing municipal initiatives

A green infrastructure approach can help local governments accomplish key goals in planning, transportation, economic development, water quality, land conservation, and other areas. Successful programs often leverage the broad benefits of multi-purpose green infrastructure by adapting green techniques to fit individual agency and department needs. A transit department, for example, could incorporate native species or vegetated stormwater filtration systems in street improvements such as curb bump outs or sidewalk planters; a planning department could use a green infrastructure approach to promote efficient land use while obtaining economic benefits from development projects. [24]

Green infrastructure provides a prime opportunity for cross-department collaboration. If departments and agencies work together to justify, plan, and request funding for new green infrastructure projects, they will strengthen the case for a holistic green infrastructure approach and promote broad use of multi-purpose green infrastructure techniques. Initiatives that promote green space and public health together are already underway across the globe. The Healthy Parks Healthy People initiative in Victoria, Australia takes a holistic approach to parks, people and nature, "actively seeking health and nature connections that reflect community diversity within the broader ecological, economic, and social

[24] EPA. (2010) Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. EPA-841-F-10-004. Washington, DC: US EPA Office of Wetlands, Oceans and Watersheds.

landscape."[25] New York, NY has begun "to re-imagine what the public space outside of parks can be, as well as design sustainable, high-performance open spaces that have the potential to enhance ecosystems."[26] The city recognizes the need to insert green infrastructure and new public spaces into existing infrastructure; its new Parks and Public space initiatives aim to:

- Open underutilized spaces, such as schoolyards and streets, as part-time parks/public spaces;
- Upgrade existing sites by expanding hours and improving facilities;
- Activate the streetscape and re-imagine the public realm;
- Create a network of green corridors; and
- View streets as "vital public spaces… and as ecological assets."

A number of U.S. cities are designing and implementing green infrastructure-specific plans and initiatives. Philadelphia, PA signed the Green City, Clean Waters plan in June, 2011. The 25-year plan, developed by the Philadelphia Water Department, aims to "manage stormwater with innovative green infrastructure" and "to provide a clear pathway to a sustainable future while strengthening the utility, broadening its mission, and complying with environmental laws and regulations."[27] In 2010, New York, NY released the NYC Green Infrastructure Plan, intended to further commitments made in PlaNYC and its Sustainable Stormwater Management Plan. The Green Infrastructure Plan "provides a detailed framework and implementation plan to meet the twin goals of better water quality in New York Harbor and a livable and sustainable New York

[25] Campbell, C. (2013) Health in Victoria, Australia. In 'Nature of Cities' blog. Available http://www.thenatureofcities.com/2013/03/20/working-beyond-park-boundaries-to-benefit-public-health-in-victoria-australia/

[26] City of New York. (2011) PlaNYC, update April 2011. New York, NY: Office of Mayor Michael R. Bloomberg, p. 34

[27] PWD (Philadelphia Water Department). (2013) Green City, Clean Waters: What We're Doing. Available http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan [Accessed 5/14/2013].

City."[28] Portland, OR launched the Grey to Green initiative in 2008 to "improve water quality, air quality, wildlife habitat and neighborhood livability."[29] The $55 million initiative, supported in part by public and private partnerships, is working to plant yard and street trees, construct green streets, control invasive species, replace culverts, install green roofs, protect open spaces, and re-vegetate natural areas.

The adaptive and flexible nature of green infrastructure make it ideal for implementation in cities with a range of urban landscapes, funding structures, and municipal priorities. This high adaptability means green infrastructure can be employed throughout cities, not just in areas with large open spaces. Because it delivers broad benefits, green infrastructure is an excellent tool to address social and environmental justice concerns. Far too often, neighborhoods of low socio-economic status are also most likely to be experience high levels of industrial pollutants and vehicle exhaust, and least likely to contain adequate, safe, usable parks and green spaces. Such deficiencies further disadvantage residents and contribute to asthma incidence, poor mental health, obesity risk, and other health problems. When implemented thoughtfully, trees, green spaces, and functional natural systems can combat these trends and contribute to social and environmental justice.

[28] City of New York. (2010) NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways. New York, NY: Office of Mayor Michael R. Bloomberg.

[29] City of Portland. (2013) Environmental Services: What is Grey to Green? Available http://www.portlandoregon.gov/bes/article/321331 [Accessed 5/14/2013].

Promoting use of green infrastructure

Green infrastructure is a new approach to planning, health, and stormwater management for many communities. Offering incentives to developers, businesses, or homeowners is one way to increase awareness and use of a green infrastructure approach, especially in stormwater management. The EPA Municipal Handbook, *Managing Wet Weather with Green Infrastructure* offers detailed information on potential incentives including:

- Stormwater fee discounts
- Expedited permitting
- Grants
- Rebates and installation financing, and
- Awards and recognition programs.[30]

These mechanisms, of course, apply mainly to new and redevelopment projects; existing buildings and infrastructure are likely exempt. To address issues of stormwater control and management in a more proactive way, cities may need to develop creative strategies that encourage parcel owners and occupants to retrofit existing sites for green infrastructure even in the absence of development. Municipalities are currently experiencing success with rebate and installation financing models for solar energy panels; perhaps implementation of broader green infrastructure techniques could be promoted and supported in a similar way. Indeed, subsidized rain barrel programs intended to promote rainwater capture and reuse have already occurred in Oakland, CA, Philadelphia, PA, Syracuse, NY, and other cities.

[30] EPA. (2009) Managing Wet Weather with Green Infrastructure: Municipal Handbook: Incentive Mechanisms. EPA-833-F-09-001. Washington, DC: US EPA.

A variety of green infrastructure tool kits and plans address additional topics, including site prioritization and selection, regulatory methods and funding mechanisms, best management practices, regulatory land use controls, incentive mechanisms, economics and cost analysis, strategic outcomes and benefits, and more. A selection of tool kits and plans are included in the Suggested Resources section of this Guide.

IMPLEMENTATION: **indicators of health and well-being: roles for, and visualizing green infrastructure**

A green infrastructure approach has potential to positively affect urban microclimate and built environment, mental health, and social capital and community cohesion. When the urban environment is physically comfortable, residents are more likely to spend time outside and to reap the benefits of clean air and shaded streets. Nature views and experiences promote positive moods and reductions in stress, helping improve mental health. The presence of multi-use outdoor spaces, neighborhood gardens, and green areas increases opportunity for casual interactions among neighbors, can break down cultural and social barriers, and enhance knowledge of and interaction with nature.

An individual or community's level of comfort in the urban environment, degree of mental health, and amount of social capital are all indicators of health and well-being. For this Guide, three indicators with high potential to be affected by a green infrastructure approach were selected for focus: urban microclimate and built environment, mental health, and social capital and community cohesion. A strong argument can be made linking the presence of nature to the status of each of these indicators, making them ideal areas for improvement through a green infrastructure approach. Ensuring a comfortable built environment, high degree of mental health, and safe, engaged community are key priorities for local governments, and therefore prime opportunities to integrate a green infrastructure approach into ongoing municipal projects and plans.

For each indicator, common related urban challenges are identified. Suggestions are then provided, based in a green infrastructure approach, for ways to mitigate

and alleviate these hazards to health and community well-being. Finally, images with descriptions are shown to visualize how these multi-purpose installations could function in various communities.

1: Urban microclimate and built environment

The built environment's traditional combination of extensive pavement and concrete, little shade, and relative lack of vegetation creates cities that can be oppressively hot, windy and dirty. In many urban and suburban environments, automobiles, industries, and housing developments have been prioritized in planning, consequently limiting usability and comfort at the pedestrian scale. In many cases, sidewalk availability is limited, or sidewalks are impractically placed. These conditions make cities uncomfortable places to walk and be outside, and may create conditions hazardous to health. Children and individuals living and working near highways, industrial sites, pollutant emitters, and highly paved areas are especially vulnerable to respiratory risks from ozone and airborne pollutants and particulates, or mortality risks from hotter sustained temperatures. Far too often, people most at risk are also those with the least power to avoid known hazardous conditions.

Mitigating these effects requires that planners and public health professionals minimize the urban heat island effect (where buildings retain heat more efficiently than the surrounding environment, resulting in increased urban temperatures – see Key Terms and Concepts), improve indoor and outdoor air quality, and improve the overall comfort level of the built environment.

Roles for green infrastructure

Installing vegetation to green the landscape, improve livability of the built environment, and encourage use of outdoor spaces are the best ways to affect urban microclimate through a green infrastructure approach.

When installed as a series of small, relatively inexpensive sites and links, green infrastructure creates networks of functional green space. Trees and green plants intercept and absorb potentially harmful pollutants in the air, reducing incidence of asthma, lung disease, and respiratory infections.[31] Increased urban tree cover reduces the amount of solar radiation that hits pavement and buildings, moderating the urban heat island effect and reducing risk of heat-related mortality.[32] Proper siting of trees to shade buildings reduces energy needs in summer; green roofs insulate year-round with a similar effect. Urban vegetated areas and green roofs absorb rainwater where it falls, controlling runoff and lessening pressure on existing conventional infrastructure systems.

While enhancing neighborhood aesthetics, sidewalk greening projects and enhanced tree pits designed as bioretention features filter stormwater and improve infiltration back into the ground. Similarly, vegetated curb bump-outs intercept stormwater while calming traffic and improving street safety. To reduce time and money required for implementation, green infrastructure improvements may easily be undertaken simultaneously with other street infrastructure projects. PlaNYC, New York City's 2011 plan for 'A greener, greater New York' advocates for an improved view of streets as "vital public spaces, promoters of mobility by a variety of modes, and as ecological assets."[33]

Privately owned public spaces, amenities often installed as a condition of bonus development rights on a site, also have potential to provide usable green space

[31] Entrix, Inc. (2010) Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits. Portland, OR: ENTRIX, Inc.

[32] EPA. (2008) Reducing Urban Heat Islands: Compendium of Strategies. Washington, DC: US EPA Climate Protection Partnership Division. Available http://www.epa.gov/heatisland/resources/compendium.htm [Accessed 5/21/2013].

[33] City of New York. (2011) PlaNYC, update April 2011. New York, NY: Office of Mayor Michael R. Bloomberg.

and seating areas to the public.[34] One overwhelming benefit of the private ownership model is that maintenance is the responsibility of the developer. The spaces may also be interspersed throughout commercial and residential areas. To ensure public usability, however, requirements of accessibility and functionality of these privately owned spaces must be carefully thought out. Policies may be written to require seating, vegetated stormwater filters, or native plants as primary components of these spaces.

Objectives, strategies and examples

Prioritize pedestrian usability and develop streets as ecological assets

To improve pedestrian safety and comfort, improve street aesthetics, reduce negative effects to health from air pollution, encourage use of streets and sidewalks, increase everyday contacts with nature, moderate urban heat island effect, improve stormwater management and absorb rainwater where it falls.

- Plan urban infrastructure at the human, pedestrian scale
- Install public seating areas alongside enhanced tree pits, rain-fed sidewalk planters, and other green elements to encourage use
- Install vegetated bioretention features and enhanced tree pits (Figure 1) to absorb, filter stormwater, reduce flooding
- Incorporate green features into traffic calming elements (e.g. bump outs, medians, etc.) (Figure 2)
- Increase overall tree cover and vegetation

[34] New York City Department of City Planning. (2013) Privately Owned Public Space. Available http://www.nyc.gov/html/dcp/html/pops/pops.shtml [Accessed 5/21/2013].

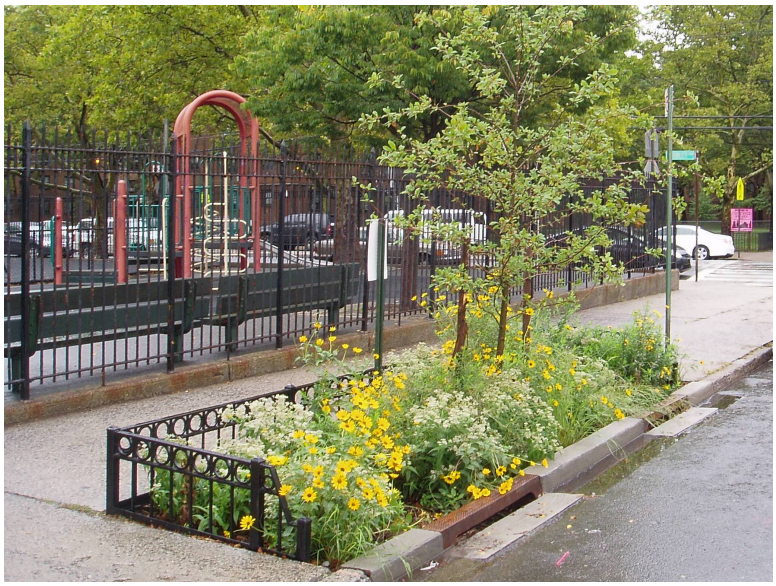

Fig. 1
Enhanced tree pit, Autumn Ave, Brooklyn NY

- Features: Enhanced tree pit also contains flowers and shrubs.
- Functions: Absorbs, filters stormwater; flowers add visual interest; once grown, tree will shade the sidewalk.

Source: NYC Department of Environmental Protection, http://switchboard.nrdc.org/blogs/plehner/new_york_city_commits_to_green.html

Fig. 2
Curb extension at SW 4th Ave and College St, Portland OR

- Features: Vegetated bump out: curb cuts direct water into the vegetated system; narrows road.
- Functions: Replaces pavement with stormwater-absorbing and filtering vegetation; calms traffic, reduces pedestrian crossing distance.

Source: The Intertwine Alliance, http://theintertwine.org/adventures/storming-downtown-portland

Encourage vegetation of public spaces and roofs

To increase total amount of green space, create networks of sites and green spaces, improve urban aesthetics, reduce urban heat island effect, improve building heating and cooling efficiency, absorb rainwater where it falls.

- Expand sidewalk tree pits; plant additional native species, flowers, and shrubs adjacent to street trees
- Plant street trees to shade exposed building fronts
- Consider installing multi-use vegetated green roofs (Figure 3) on buildings with large roof surface area
- Incentivize or require usable green infrastructure in privately owned public spaces (spaces built by private developers in exchange for additional development rights, open to the public)
- Find creative ways to inject green space, such as vegetated walls (Figure 4)

Fig. 3
Intensive green roof, Phipps Conservatory, Pittsburgh PA

- Features: Vegetated green roof containing a variety of plants including edibles; includes paths and open space.
- Functions: Reduces stormwater runoff (volume and pollutants); insulates building, reduces urban heat island effect; provides demonstration gardens and backdrop for events.[35]

Source: http://media.tumblr.com/tumblr_m7h2d7UdU81rsaob2.jpg

[35] Phipps Conservatory, Center for Sustainable Landscapes. 2013. http://phipps.conservatory.org/project-green-heart/green-heart-at-phipps/center-for-sustainable-landscapes.aspx [Accessed 7/7/2013].

Fig. 4
Vegetated wall, Quai Branley Museum, Paris France

- Features: Mur Végétal (Vertical Garden) vegetated wall
- Functions: Visual interest to passers-by; absorbs sunlight: cool building and sidewalk, reduce heat island effect.

Source: Patrick Blanc, http://www.verticalgardenpatrickblanc.com/realisations/paris/quai-branly-museum

2: Mental health

The WHO European declaration of mental health states “There is no health without mental health” and that “mental health and mental wellbeing are fundamental to the quality of life and productivity of individuals, families, communities and nations, enabling people to experience life as meaningful and to be creative and active citizens.”[36] Research indicates that poor housing conditions are correlated with poor mental health and affect levels of personal control, social support, and restoration from stress and fatigue.[37] Crowding, noise, and insufficient daylight in indoor environments are all potential contributors to poor mental health. In a study of incidence of depression, living in a poor quality built environment was linked with a greater likelihood of depression in both the short and long term.[38] Children living in crowded homes may experience greater social isolation and lower mental health scores,[39] while noise pollution from roadways can result in increased stress and/or elevated blood pressure.

Humans have been deeply engaged with and dependent on nature for survival for the majority of our history. With this fact in mind, it is unsurprising that highly engineered urban environments provide little relief from stress and the strains of everyday life. Aside from suggestions of an innate human preference for nature (biophilia), two major theories make an effort to explain the links between the natural environment and restorative benefits to health. Stress reduction theory

[36] Bird, W. (2007) Natural Thinking: Investigating the links between the Natural Environment, Biodiversity and Health. United Kingdom: Royal Society for the Protection of Birds, 1st Edition, p. 7

[37] Evans, G. W. (2003) The Built Environment and Mental Health. Journal of Urban Health: Bulletin of the New York Academy of Medicine, 80, 536-555.

[38] Galea, S., Ahern, J., Rudenstine, S., Wallace, Z., and D. Vlahov (2005) Urban Built Env and Depression: A Multilevel Analysis. Journal of Epidemiology and Community Health, 59, 822-827.

[39] Evans, G. W., Lercher, P., and W. W. Kofler. (2002) Crowding and Children's Mental Health: The Role of House Type. Journal of Environmental Psychology, 22, 221-231.

(SRT), asserts a deep psychologically positive response to nature when the body is stressed,[40] while attention restoration theory (ART) argues that restorative natural environments allow our brains to relax and recharge.[41]

Mitigating effects of the built environment requires planners, landscape designers, and public health professionals to work together to minimize oppressive characteristics of poor quality built environments and design cities that promote a positive mental state.

Roles for green infrastructure

Though much of our time is spent indoors, green infrastructure has a role to play in promoting positive mental health. Evidence from recent research indicates that views of trees may enhance attention performance in children with attention deficit hyperactivity disorder (ADHD),[42] reduce mental fatigue of residents in public housing units,[43] and improve relaxation, positivity and coping in hospital patients.[44] Additional research supports links among views of trees, mental health, and physical recovery from surgery. In his famous study, Richard Ulrich hypothesized that a "hospital window view [of trees] could influence a patient's emotional state and might accordingly affect recovery."[45] The study found that patients with tree views, on average, had shorter post-op stays, fewer negative

[40] Ulrich, R.S. (1981) Natural versus Urban Scenes. Environmental Behavior, 13, 523-556.

[41] Kaplan, S. (1995) The Restorative Benefits of Nature: Toward an Integrative Framework. Journal of Environmental Psychology, 15, 169-182.

[42] Taylor, A. and F. E. Kuo. (2009) Children with Attention Defecits Concentrate Better After Walk in the Park. Journal of Attention Deficit Disorders, 12, 402.

[43] Kuo, F. E. and W. C. Sullivan. (2001) Environment and Crime in the Inner City: Does Vegetation Reduce Crime? Environment and Behavior, 33, 343-367.

[44] Cooper Marcus, C. and M. Barnes. (1995) Gardens in Health Care Facilities: Uses, Therapeutic Benefits, and Design Considerations. Martinez, CA: The Center of Health Design.

[45] Ulrich, R. S. (1984) View Through a Window May Influence Recovery from Surgery. Science, 224, 420, p. 420

comments on their condition from nurses, and need for fewer painkillers. Together with evidence that characteristics of the built environment influence mental health, these results create a strong argument for increasing tree views and green spaces in urban environments.

Even in cities, where nature is inherently constructed and anthropocentric, benefits to mental health from nature access can occur when conditions are right. Achieving these positive effects requires

- space sufficient to get away from daily tasks or concerns,
- a coherent location rich with things to see and experience,
- opportunity for effortless fascination, and
- compatibility with needs for restoration and relaxation.[46]

By increasing opportunities for everyday views of and contact with nature, projects will maximize potential benefits to mental health. One strategy is to improve views of dynamic nature from housing developments, schools, and workplaces. Another is to increase vegetation along recreation trails, in and outside buildings, and along streets. Plants and greenery add interest and a natural element, and promote opportunities for mental restoration through effortless fascination. Some redesign of older parks and plazas to install smaller outdoor rooms, secluded niches within parks and green spaces, can facilitate quiet relaxation and mental restoration. Elevated green roofs provide places to 'get away' and encourage interaction with natural spaces.

[46] Bird, W. (2007) Natural Thinking: Investigating the links between the Natural Environment, Biodiversity and Health. United Kingdom: Royal Society for the Protection of Birds, 1st Edition, p.35

Objectives, strategies, and examples

Increase opportunities for everyday views of and contact with nature

To improve employee/student performance and enhance focus, reduce sick time, reduce ADHD symptoms and medication costs, facilitate mental restoration and stress reduction, improve knowledge of nature.

- Renovate office/school buildings to maximize outdoor nature views
- Increase plant installations and vegetation in- and outside buildings (Figure 5)
- Create incentives for developers to provide usable green space for building occupants and the public
- Green playgrounds and schoolyards (Figure 6); increase playground/outdoor activity time for grade school students
- Incorporate local nature education modules into curriculum at all levels

Fig. 5
Carroll Street MTA Plaza, Brooklyn NY

- Features: Public plaza adjacent Carroll St subway entrance; planters contain drought tolerant grasses and flowering perennials.
- Functions: Buffer private and public space; planters capture stormwater, provide passive recreational space, add visual interest.

Source: Future Green Studio, http://futuregreenstudio.com/portfolio/project/carroll-street-mta-plaza/

Fig. 6
Herron Park playground, Philadelphia PA

- Features: Permeable pavement basketball court, rain garden, improved plantings.
- Functions: Reduces runoff, increases infiltration; incorporates natural elements into unique play setting; once grown, trees will provide shade.

Source: Grounds for Change, http://www.gfcactivatingland.org/media/uploads/cache/images/large/Herron_01.jpg

Create vegetated spaces designed for fascination

To promote mental restoration and stress reduction, facilitate effortless attention and encourage users to 'get away.'

- Design indoor and outdoor spaces for multiple purposes and users, e.g. active/passive, groups/individuals, etc.
- Vary seating types and arrangements
- Aim to create coherent, richly designed spaces with numerous focal points
- Incorporate unique, distinctive features (plants, water features, path designs, etc.)

Fig. 7
Liz Christy Community Garden, Manhattan NY

- Features: Lower East Side garden adjacent to busy streets; includes walking paths, seating areas, fish pond; maintained by volunteer Gardeners.
- Functions: Plants absorb rainwater; design allows space for mental restoration, bird watching, nature education, passive recreation.

Source: Hannah Kohut

Fig. 8
Tanner Springs Park, Portland OR

- Features: Stormwater runoff-fed pond and wetlands, wall of recycled railroad tracks, seating/performance areas; maintained by Friends of Tanner Springs.
- Functions: Space for exploration and recreation; habitat for urban birds and wildlife; collects, filters, and uses stormwater runoff.

Source: Mark Houck, http://www.thenatureofcities.com/2013/05/29/size-doesnt-matter-really/

3: Social capital and community cohesion

Urbanization and engineering of the built environment have altered the way people interact with nature and also shifted patterns of human interaction within communities. Increasing reliance on technology for entertainment, loss of locally owned businesses, and reductions in public green space mean fewer opportunities for casual interaction with immediate neighbors. Costs to communities from weak social networks can be serious. During Chicago's 1995 heat wave, hundreds of people, many elderly, died alone in their homes as casualties of social isolation.[47] In Los Angeles, "paving the major artery of the [L.A. River] watershed is in fact deeply implicated in L.A.'s increasingly notorious [environmental, social, and economic] troubles.[48] Altering the river has "erased the most dominant natural system in the City," "robbed people of the open space that is necessary for human health and well-being," and "taken away the essential childhood experience of learning through observing nature."[49]

In efforts to "resist some of the environmentally and socially destructive effects of contemporary industrial culture and economic globalization" a diverse range of urban grassroots groups are already using nature to restore a sense of place and bring communities back together.[50] Planners and policy makers can help reverse trends of social isolation and mitigate impacts of the built environment on social

[47] Klinenberg, E. (2002) Heat Wave: A Social Autopsy of Disaster in Chicago. Chicago, IL: University of Chicago Press.

[48] Price, J. (2008) Remaking American Environmentalism: On the Banks of the L.A. River. Environmental History, 13, 536-555, p. 547

[49] City of Los Angeles. (2007) Los Angeles River Revitalization Master Plan. Los Angeles, CA: Department of Public Works, Bureau of Engineering, p. 2.3

[50] Barlett, P. F. (2005) Introduction. In Barlett, P. F. (ed.), Urban Place: Reconnecting with the Natural World. Cambridge, MA: The MIT Press, p. 1

structures by creating public spaces and opportunities for people to meet and interact.

Roles for green infrastructure

A green infrastructure approach has potential to encourage community engagement, improve neighborly activity and socialization, and create vital outdoor common spaces.[51] Many components of green infrastructure, such as parks and green space, contribute significantly to community livability, sense of place, and unique local character. Research indicates a relationship between green space, a sense of safety, and the social cohesion of neighborhoods. Additionally, "enhanced [neighborhood] permeability and accessibility" cultivated by green infrastructure helps reduce perceptions of crime, encouraging use of outdoor natural spaces.[52]

Networks of even small green infrastructure sites and installations have potential to improve community aesthetics and to begin addressing issues of equity in access to nature. Lower income neighborhoods often lack tree cover and park space; green infrastructure in the form of enhanced tree pits, rain gardens, and sidewalk planter boxes green the landscape while improving natural capacity for stormwater management. In neighborhoods that lack parks or park space, community gardens can fill some of the void, providing green spaces for social interaction and passive recreation. Community gardens accommodate residents of all ages and provide space for local food production and opportunities for hands-on learning.

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[51] Groenewegen, P. P., van den Berg, A. E., de Vries, S., and R. A. Verheij. (2006) Vitamin G: effects of green space on health, well-being, and social safety. BMC Public Health, 6, 149.

[52] LUC (Land Use Consultants). (2009) Green Infrastructure Guidance. Sheffield, UK: Natural England, p. 30

Objectives, strategies, and examples

Facilitate opportunities for casual interaction with neighbors and nature

To promote neighborhood social networks, increase contact with and knowledge of local nature, encourage breakdown of social stereotypes.

- Create outdoor, vegetated spaces designed for socialization
- Support multiple uses of existing sites, such as schoolyards, parks, sidewalks
- Devote resources (funding, land, planning and design assistance, etc.) to neighborhoods for establishment and/or maintenance of parks, community gardens, and other outdoor public spaces
- Empower community groups to maintain green infrastructure sites, by training master gardeners or caretakers
- Invite community members to participate in green infrastructure visioning and planning
- Remove policy barriers limiting use of vacant lots to allow gardening or other public use
- Provide signage adjacent to vegetated stormwater management systems, native plant installations, and other innovative sites

Fig. 9
Castro Plaza, San Francisco CA

- Features: Enclosed seating area; large concrete planters with variety of wind and drought-resistant vegetation; maintained by Castro/Upper Market Community Benefit District.
- Functions: Part of San Francisco pavement to parks program: reclaimed part of busy intersection for human use; space for community interaction/social gathering.

Source: Seth Boor, http://sfpavementtoparks.sfplanning.org/castro_commons.htm

Fig. 10
P-Patch community garden, Seattle WA

- Features: Community garden plots; open space resource for all community members.
- Functions: Land dedicated for growing food, flowers, plants; community gathering place; space for recreational and therapeutic activities.[53]

Source: Flickr/Padraic, http://www.flickr.com/photos/padraics_travels/2179832732/

[53] Seattle Department of Neighborhoods, P-Patch Community Gardening Program. 2013. http://www.seattle.gov/neighborhoods/ppatch/gardening.htm [Accessed 7/7/2013].

IMPLEMENTATION: **recognizing and addressing obstacles**

Challenges for green infrastructure implementation may be policy-based, or social and cultural in nature. They may concern site aesthetics or knowledge of natural systems, involve planning, collaboration, or management, or relate to securing space or funding. It is important that anyone involved in green infrastructure planning and implementation be able to anticipate potential obstacles and think ahead of time about how to address those challenges.

Space, funding, and policy constraints

In highly urbanized environments, inexpensive open space is rare or nearly nonexistent. Some areas may be almost entirely paved, complicating tree planting and city greening efforts. Former industrial sites may provide space, but are frequently contaminated; remediation is expensive. City budgets are universally stretched thin, making it critical for planners and public health professionals to identify green infrastructure's multiple benefits and to prove it's non-traditional techniques worthwhile financially. Policy barriers may be another issue: city zoning regulations and legislation simply may unintentionally prohibit unconventional green infrastructure installations. When considering a green infrastructure approach it is essential to recognize and evaluate potential logistical and policy constraints in the early stages of the planning process. In the face of space, funding, and policy constraints, it is necessary for planners and public health professionals to:

Site green infrastructure projects creatively

- Open space in highly urbanized areas is minimal
- Integrate green infrastructure installations into existing urban landscapes
- Optimize use of unconventional sites: slivers of open space, abandoned rail right-of-ways, former industrial sites, etc.
- Work with landowners to site projects on private land or in privately-owned public spaces

Maximize potential benefits to health and community well-being

- Residents of socio-economically disadvantaged areas often lack green space and access to nature
- Use green infrastructure to address issues of environmental equity
- Install green infrastructure in an effort to increase opportunities for nature access and education

Work collaboratively and resourcefully to find funding

- Municipal budgets are tight, may not accommodate non-traditional infrastructure and green spaces
- Capitalize on multi-disciplinary nature of green infrastructure benefits to encourage installation and maintenance funding by multiple local departments (public health, environmental conservation, water resources management, etc.)
- Combine green infrastructure with other ongoing municipal projects
- Increase incentives for private action/implementation

Identify and remove policy barriers

- Green infrastructure installations may be blocked unintentionally by zoning codes and/or policies
- Quantify costs and benefits where possible to promote acceptance by policy makers and the public
- Adjust existing zoning codes/building requirements and legal structures to facilitate green solutions; for example, allow residents to disconnect downspouts from storm systems to improve groundwater recharge rates

The importance of education

The challenge for cities is to encourage deep awareness of nature and foster stewardship in populations who may feel they have little connection with the natural world. Children and adults who have minimal experience with nature may be unaware of the natural processes going on around them and may feel uncomfortable outside. Detachment from nature reduces the likelihood that people will recognize important contributions of natural systems to their health and well-being, and may decrease their willingness to support a green infrastructure approach in cities.

Campaigns to increase familiarity with local natural history and environmental systems help connect urban dwellers with the natural world and encourage stewardship of the environment. Education about local nature (plants, animals, natural systems) familiarizes residents with the look of native plants, reduces unease of the natural world, and contributes to positive attitudes toward urban wildlife. Programs that facilitate a walking culture, bring plants and nature views into work environments, and reduce hours spent indoors at school and work are ambitious, yet effective ways to encourage human-nature interaction and awareness of the natural environment. Cultivating even basic awareness of nature promotes informed decision making and long-term community investment in environmental health and function.

In his book *Biophilic Cities,* Timothy Beatley recommends approaches "to nurture deep knowledge about and care for place through everyday life and living" within communities.[54] To do so, he suggests that cities and neighborhoods:

Make learning about community and place fun: people must want to participate

- Create unique and fun activities, able "to compete with many other life diversions"

Take advantage of opportune times for education: when new residents arrive, or when children are young

- Display unique natural features and "situate the street and neighborhood… in its original natural context" on community maps
- Develop fun, active, educational nature/natural history programs for children

Urge residents to learn about local natural history

- Run a "short course about the nature, natural history, and ecology of the community and region"
- Require a 'caring for place'-type certificate of all new homeowners/residents
- Perhaps mandate participation, similar to receiving a driver's license

Support activity mentorship programs

- Establish mentor programs (for biking, walking, gardening, etc.), match those with knowledge with those who want to learn
- Designed to provide tips and guidance, encourage interaction and get people outside.

Shifts in attitude brought about by increased environmental awareness have an additional benefit: community support and commitment sends a clear message in favor of green infrastructure and sustainable strategies. Community members who feel connected to nature are likely to encourage municipal action and financial support for green infrastructure, and to inspire others to do the same.

[54] Beatley, T. (2011) Biophilic Cities: Integrating Nature into Urban Design and Planning. Washington, DC: Island Press, p. 139

Working with communities and cultivating support

Community support and participation "ultimately dictates the success or failure of an urban greening program."[55] Indeed, municipal green infrastructure planning requires a long-term community commitment to ensure continued support through inevitable changes in political leadership. Without community input on a project, planners can only assume what residents want; when they are wrong, green spaces may go unused. It is therefore essential that planners and designers engage the public early and often in the green infrastructure implementation process. Part of this includes education: the why, where, and how of natural systems and green infrastructure.

Planners, policy makers and public health professionals must help community members first understand influences of natural systems on the urban environment. They can then promote green infrastructure's benefits for stormwater management, human health and well-being, and environmental quality, and cultivate support for a green infrastructure approach.

In the process of green infrastructure implementation it is essential that planners and site designers:

Avoid a total top-down approach

- Unwanted, or inappropriately designed sites may not be used as intended, or at all; defeating their purpose
- Engage community members early and often in site planning and design: assemble stakeholders, involve community in project visioning/planning processes, incorporate ideas into plans and designs

[55] Yang, J., Zhao, L., Mcbride, J. and P. Gong. (2009) Can you see green? Assessing the visibility of urban forests in cities. Landscape and Urban Planning, 91, 97-104.

Overcome aesthetic unfamiliarity of native plants, green infrastructure systems

- Native plants and less-manicured landscapes may look ‘unkempt’ and unfamiliar to community members
- Actively increase awareness about landscaping choices through signs, brochures, news articles, word of mouth

Address issues of fear and perceived safety

- Fear of nature or unfamiliar urban wildlife, and concerns about personal safety in parks may reduce support for green infrastructure
- Introduce community members to local nature and the purpose of green infrastructure: minimize concerns, facilitate positive opinions of natural systems

It is essential to engage community members early and often in the green infrastructure planning process. This process is not only good practice, it will ensure that multi-purpose sites are appropriate for the needs of the community. Taking time to build support and enthusiasm will ensure that green infrastructure systems receive strong support and ongoing stewardship from the community.

COST-BENEFIT CONSIDERATIONS

Cost is an important concern in any municipal project or initiative. Funds are limited, so projects that promise positive economic returns or clear use value to the community are most likely to garner support. Initiatives that deliver broad benefits are positioned to be funded by multiple sources, and backed by diverse groups. Green infrastructure has potential to be funded and implemented by municipal departments that address a range of issues: stormwater management, to parks and recreation, public health, and community economic development, for example.

Many of the benefits to health and community well-being that this Guide promotes are difficult to quantify in economic terms. In a stormwater management context, the inability to easily compare conventional and green infrastructure costs and control volumes means that a green infrastructure approach is not often even considered. To combat this problem, clarification of the scope and scale of green infrastructure benefits is needed. Interdisciplinary research and development of a standardized, holistic assessment for both green and conventional infrastructure is necessary to enable the approaches to be reasonably compared.[56] A holistic assessment tool will magnify the weaknesses of a conventional infrastructure approach and help put sustainability planning and green infrastructure on par with development and other traditional planning concerns.

[56] Kuppuswamy, H. (2009) Improving Health in Cities Using Green Infrastructure: A Review. *FORUM Ejournal*, 9, 63-76.

In urban areas, economic costs due to changes in the natural environment are presently valued in a number of ways. Health Impact Assessments (HIA) take a holistic approach to value the costs and benefits to health of proposed policies. Impacts to productivity at the industry, individual, or natural system level may be measured on economic terms: loss of work time due to dangerous air pollutant levels is one example. Though difficult to value economically, impacts to ecosystem health and function may, at least, be stated qualitatively. Finally, users' Willingness To Pay (WTP) for health/existence of natural areas is one potential way to uncover some sense of the value humans place on natural systems.[57] Though each have their flaws, frameworks for these approaches can assist cost-benefit valuation of green infrastructure systems. As understanding of green infrastructure function and processes increase, communities may develop alternative ways to economically value the benefits of green systems.

A full cost and benefit analysis of green infrastructure is beyond the scope of this Guide. For links to documents that explore these issues in-depth, see Suggested Resources.

It is also true that communities may not require more quantification than is provided here to see the value of a green infrastructure approach. Major cities across the U.S. including Los Angeles CA, New York NY, Philadelphia PA, and Portland OR are already using green infrastructure to address environmental and social concerns. These cities are incorporating green infrastructure strategies without waiting for all the data on costs and benefits. This suggests that while further quantification may allow better comparison of green and conventional

[57] Dixon, J. A. and M. M. Hufschmidt (1986) Economic Valuation Techniques for the Environment: A Case Study Workbook. Baltimore, MD: Johns Hopkins University Press.

infrastructure, it is not required before cities will get on board with new, green infrastructure strategies to improve environmental and physical health.

General cost comparisons: conventional vs. green infrastructure

Cost analyses of green in comparison to conventional infrastructure often focus highly on stormwater management. Low impact development (LID) is perhaps the most commonly applied type of green infrastructure, but this focus may also relate to the comparative ease in measuring costs of LID development, construction, and maintenance, and volumes of water managed. Low impact development strategies (bioinfiltration systems, street tree plantings, and green roofs, for example) are integral to many of the multi-purpose green infrastructure strategies envisioned in this Guide.

The EPA and others have worked to summarize costs and benefits of green infrastructure projects in comparison to conventional. An EPA report titled *Reducing Stormwater costs through Low Impact Development (LID) Strategies and Practices* compares known costs of LID with those of conventional grey infrastructure. The report monetizes costs of 17 projects and indicates overall "that applying LID techniques can reduce project costs and improve environmental performance."[58] Within the 12 true cost and modeled case studies, LID project costs ranged from 15-80% lower than costs for conventional infrastructure. The report concludes that additional research is needed to quantify environmental benefits and avoided costs resulting from a green infrastructure approach. The authors also conclude that additional research should be done to monetize cost reductions from improved environmental performance, decreased

[58] EPA. (2007) Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. EPA-841-F-07-006. Washington, DC: US EPA Nonpoint Source Control Branch, p. i

long-term operations and maintenance costs and/or infrastructure replacement costs.[59]

A report from American Rivers entitled *Banking on Green* uses information from a survey conducted by the American Society of Landscape Architects to analyze green infrastructure project costs. The survey compiled data on green infrastructure projects in 43 states and addressed project type, funding, support, and cost, receiving 479 responses. Of those, 50.7% were retrofit and 18.6% were redevelopment projects. Use of green infrastructure reduced costs in 44.1% of projects, had no influence to cost in 31.4% of projects, and increased costs in 24.5%. *Banking on Green* builds on current knowledge and evidence to demonstrate that green infrastructure can:

- be cost-effective
- increase energy efficiency and reduce energy costs
- reduce economic impacts associated with flood events, and
- protect public health and reduce illness-related costs.[60]

Cost comparisons in New York, NY and Philadelphia, PA

The Department of Environmental Protection in New York, NY recently undertook a cost comparison analysis to determine the most cost-effective approach to manage stormwater and reduce pollutants in the City's waterways. To do so, the Department compared a grey infrastructure strategy with a grey-and-green infrastructure strategy; results are show below (Figure 11). Both scenarios

[59] EPA. (2009) Managing Wet Weather with Green Infrastructure: Municipal Handbook: Incentive Mechanisms. EPA-833-F-09-001. Washington, DC: US EPA, p. 27

[60] Odefey, J., Detwiler, S., Rousseau, S., Trice, A., Blackwell, R., O'Hara, K., Buckley, M., Souhlas, T., Brown, S., and P. Raviprakash. (2012) Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. United States: American Rivers, American Society of Landscape Architects, ECONorthwest, Water Environment Federation.

assume that the $2.9 billion invested for grey infrastructure currently under construction will remain so. This makes $2.9 billion the base cost in both scenarios. To achieve comparable stormwater management, the all-grey strategy would require an additional $3.9 billion investment over 20 years, while the green strategy would cost an additional $2.4 billion. This translates to savings of $1.5 billion through the green approach.

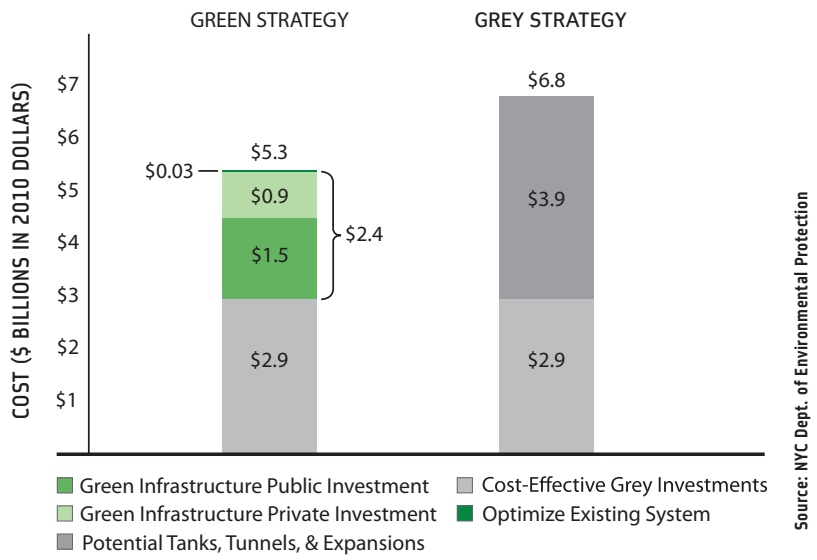

Fig. 11
Citywide Costs of CSO Control Scenarios, New York NY
Source: PlaNYC, originally from NYC DEP

Perhaps most importantly the analysis notes:

> *significant sustainability benefits of the Green Strategy – which are not available through the Grey Strategy – would begin to accrue immediately and build over time, in contrast to tanks, tunnels, and expansions, which provide only water quality benefits at the end of a decades-long design and construction period.*[61]

[61] City of New York. (2010) NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways. New York, NY: Office of Mayor Michael R. Bloomberg.

This point is an essential argument for green infrastructure. In addition to its high flexibility and adaptability, green infrastructure projects deliver immediate, ongoing stormwater management and other benefits to people and the environment. Many benefits to health and community well-being from green infrastructure installations (e.g. parks/open space, air filtration, heat island reduction) are available even when it's not raining. In contrast, conventional infrastructure is designed only to channel and contain stormwater, functions available only once a lengthy, highly disruptive, period of construction is complete. Conventional infrastructure is also unlikely to contribute aesthetic value to communities, another important consideration.

A 2009 report prepared for the City of Philadelphia Water Department analyzed potential of LID technology, in comparison to conventional infrastructure, to reduce waterway pollution resulting from combined sewer overflow events. In cities with combined sewer and stormwater piping systems, large storm events occasionally trigger release of excess stormwater and raw sewage into waterways. Named combined sewer overflow (CSO), these events prevent backups into treatment plants and neighborhoods, but pollute local waterways instead. In Philadelphia, CSO events pollute the Delaware and Schuylkill Rivers, two major rivers that drain together to Delaware Bay. The EPA now mandates that cities limit overflows and comply with the Clean Water Act. Many cities invest heavily in conventional pipe and tank systems to contain excess stormwater and reach compliance. Water quality requirements continue to tighten, however, cities such as Philadelphia and New York are beginning to explore alternative strategies to deal with the CSOs.

The green scenarios for Philadelphia proposed in the 2009 report include an LID component ranging from 25%- 100%; the grey approach requires construction of a 30 foot diameter stormwater storage tunnel. Results of the report show "the LID-based green infrastructure approaches provide a wide array of important environmental and social benefits to the community, and that these benefits are not generally provided by the more traditional [grey] alternatives."[62] The report monetizes this range of benefits, shown below (Figure 12), concluding the City will see cumulative benefits of $2.84 billion through 2049 from the 50% LID option versus $122 million from construction of the 30' storage tunnel option.

Table S.2. City-wide present value benefits of key CSO options: Cumulative through 2049 (2009 million USD)

Benefit categories	50% LID option	30' Tunnel option[a]
Increased recreational opportunities	$524.5	
Improved aesthetics/property value (50%)	$574.7	
Reduction in heat stress mortality	$1,057.6	
Water quality/aquatic habitat enhancement	$336.4	$189.0
Wetland services	$1.6	
Social costs avoided by green collar jobs	$124.9	
Air quality improvements from trees	$131.0	
Energy savings/usage	$33.7	$(2.5)
Reduced (increased) damage from SO_2 and NO_x emissions	$46.3	$(45.2)
Reduced (increased) damage from CO_2 emissions	$21.2	$(5.9)
Disruption costs from construction and maintenance	$(5.6)	$(13.4)
Total	**$2,846.4**	**$122.0**

a. 28' Tunnel option in Delaware River Watershed.

Fig. 12
Comparison of benefits, LID to conventional approach, Philadelphia PA
Source: Stratus Consulting, 2009

Aside from the stark dollar amount difference in benefit value between the options, a number of benefits are missing from the 30' tunnel option. The conventional option provides only a water quality benefit; the 50% LID option

[62] Stratus Consulting. (2009) A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds. Boulder, CO: Stratus Consulting.

provides a water quality benefit in addition to increased recreational opportunities, improved aesthetics, reduced heat-related mortality, wetland services, improved air quality, and avoided social costs. When considered holistically, the LID option is a clear winner.

Data on cost of green infrastructure design and implementation will only increase as more cities incorporate engineered natural systems and a green infrastructure approach into their stormwater management plans. Development of holistic evaluation methods that compare green and conventional infrastructure will demonstrate what is missing from a conventional approach, and provide support for green infrastructure strategies to improve social environmental health.

CONCLUSIONS

By exploring potential benefits of multi-purpose green infrastructure to health and well-being, this Guide envisions new ways to improve urban microclimate and built environment, promote mental health, and build social capital and community cohesion. In comparison with conventional infrastructure systems, green infrastructure provides a host of benefits that pipes and tanks do not, and has the added feature of providing immediate, ongoing benefits to people and the environment, even when it's not raining. Cities across the U.S. are already realizing the potential of a green infrastructure approach and renewing natural systems in an effort to improve human and environmental health. Philadelphia, PA's Green City Clean Waters Program now uses green infrastructure, in addition to conventional, to manage stormwater and control CSO events triggered by large storms. The Grey to Green initiative in Portland OR invests in green systems to improve water quality, air quality, wildlife habitat and neighborhood livability. In 2010, New York, NY published a Green Infrastructure Plan as an addendum to its PlaNYC that outlines specific, green infrastructure-based strategies to achieve clean waterways. These cities and others are setting an example for how green infrastructure can be conceived and implemented to address specific environmental and human health concerns and leading the way for other cities to join.

So why hasn't every community adopted a green infrastructure approach? The truth is that despite increasing evidence, uncertainties remain. Volumes of stormwater controlled in a single system of concrete are easier to measure, and perhaps more certain, than in a dispersed system of vegetated sites. Many of the

benefits green infrastructure provides are difficult to track and to quantify, reducing ability to easily compare benefits of green and conventional infrastructure systems.

The most important message from this Guide is that green infrastructure has potential to provide far more than stormwater management. In its flexibility and adaptability, a green infrastructure approach designed to bring multiple uses and services also delivers additional benefits of health and well-being to communities and their residents. These qualities make a strong case for green infrastructure's adoption – for reasons beyond stormwater management – and showcase green infrastructure as a powerful tool for planners and public health professionals.

SUGGESTED RESOURCES

More about green infrastructure

Biophilic Cities: Integrating Nature into Urban Design and Planning, Timothy Beatley.
Island Press, 2010.
Outlines essential elements of biophilic cities, reviews emerging practice of biophilic design and planning, provides examples from cities around the world.

Green Infrastructure, Edward T. McMahon.
Planning Commissioners Journal, Winter 2000.
Catalogs trends influencing shift to a green infrastructure approach, plus key elements of design, major benefits, and strategies for communities.

Green Infrastructure: A Landscape Approach, David Rouse and Ignacio Bunster-Ossa.
APA Planning Advisory Service, 2013.
Report details broad benefits of GI, presents six principles for successful projects, and includes detailed case studies.

Green infrastructure for cities: The spatial dimension, J. Ahern.
In *Cities of the Future,* IWA Publishing, 2007.
Explores strategies to spatially organize green infrastructure in cities to support ecological and cultural functions.

Research on green infrastructure benefits

Green Infrastructure: Linking Landscapes and Communities, Mark A. Benedict and Edward T. McMahon.
Island Press, 2006.
Includes chapters on the GI approach, benefits, basics of design, management and stewardship, and detailed tips for building support and making it happen.

Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations, Cecily Maller et *al.*
Health Promotion International, Dec 2005.
Summarizes empirical, theoretical, and anecdotal evidence on human health benefits of contact with nature, includes recommendations for further research and collaboration.

Improving Health in Cities Using Green Infrastructure: a Review, Hemavathy Kuppuswamy.
FORUM E-journal, Dec 2009.
Reviews green infrastructure and the evidence that supports its multiple benefits.

Natural Thinking, William Bird.
Royal Society for the Protection of Birds, 2007.
Investigates links between the natural environment and mental health and wellbeing through theories and significant research-based evidence.

Siting Green Infrastructure: Legal and Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities, Alexandra D. Dunn
Environmental Affairs Law Review, 2010.
Catalogs additional potential benefits of GI to urban poor not frequently discussed (water/air quality, safety, green jobs, food security), and argues that achieving these requires removal of legal and policy barriers.

Vitamin G: effects of green space on health, well-being and social safety, Peter P. Groenewegen, et *al*.
BMC Public Health, June 2006.
Combines existing land use and health survey data and new survey data to investigate effects of green space in the living environment on health, well-being and social safety.

Green infrastructure implementation and tool kits

9 Ways to Make Green Infrastructure Work for Towns and Cities, Regional Plan Association.
http://www.rpa.org/library/pdf/RPA-9-Ways-to-Make-Green-Infrastructure-Work.pdf
Highly visual guide presents 9 strategies in 3 categories: Securing the Space, Finding the Funding, Rethinking Management; includes case studies for each.

EPA Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with GI, EPA-841-F-10-004, EPA Office of Wetlands, Oceans, Watersheds.
http://www.epa.gov/owow/NPS/lid/gi_case_studies_2010.pdf
Covers regulatory framework, local GI policies, policy implementation: barriers, lessons learned, realities; plus 12 case studies.

Great Parks We Can Learn From, Project for Public Spaces.
http://www.pps.org/reference/six-parks-we-can-all-learn-from/
Features six truly outstanding parks, plus nine strategies to help parks achieve their full potential.

Green Infrastructure Toolkit, Atlanta Regional Commission.
http://documents.atlantaregional.com/Land%20Use/lu_greenspace_toolkit_1009.pdf

Provides information specific to implementation in Georgia, but also many suggestions and steps for implementation.

Guidelines and Performance Benchmarks 2009, Sustainable Sites Initiative.
http://www.sustainablesites.org/report/
Presents LEED-like Guidelines and Performance Benchmarks for measuring site sustainability; program currently in pilot phase.

Managing Wet Weather with Green Infrastructure: Municipal Handbook, *Incentive Mechanisms, EPA-833-F-09-001,* U.S. EPA
http://water.epa.gov/infrastructure/greeninfrastructure/gi_policy.cfm
Describes potential incentives that municipalities can offer to encourage implementation of GI techniques.

Municipal green infrastructure plans

Lancaster, PA: *City of Lancaster Green Infrastructure Plan*.
http://www.cityoflancasterpa.com/lancastercity/cwp/view.asp?A=1189&Q=650765

New York, NY: *NYC Green Infrastructure Plan*.
http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml

New York, NY: *PlaNYC, Update April 2011*.
http://www.nyc.gov/html/planyc2030/html/publications/publications.shtml
Section on Parks and Public Space describes many creative initiatives and multi-use approaches to improving use and function of public spaces.

Philadelphia, PA: *Green City, Clean Waters*
http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan

Portland, OR: *Grey to Green Initiative*.
http://www.portlandoregon.gov/bes/47203

Green infrastructure cost analyses

A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds.
Stratus Consulting Inc., Aug 2009.
Presents a triple bottom line assessment of all-grey and green-and-grey alternatives for controlling combined sewer overflows in Philadelphia, PA.

Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide.
American Rivers, ASLA, ECONorthwest, Water Environment Federation, 2012.
Focuses on economic impacts of stormwater runoff, presents GI as effective, cost-effective counter-approach.

The Economics of Biophilia: Why Designing with Nature in Mind Makes Financial Sense.
Terrapin Bright Green LLC, 2012.
Details range of benefits and economic advantages of biophilia, plus strategies for biophilic design.

Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits.
Center for Neighborhood Technology, 2010.
Reviews current methods, tools, case studies of valuation to define a framework for assessing economic benefits of low impact development strategies.

Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits.
ENTRIX Inc., Feb 2010.
Provides expert review and quantitative cost estimates of social and economic benefits of green infrastructure.

The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits.
Center for Neighborhood Technology, 2010.
Guides valuation of benefits in eight areas: Water, Energy, Air Quality, Climate Change, Urban Heat Island, Community Livability, Habitat Improvement, Public Education.

<u>Other links</u>
EPA Green Infrastructure Resources
http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm
Lots and lots of resources, case studies, and example projects.

End of guide.

REFERENCES

Ahern, J. (2007) Green Infrastructure for Cities: The Spatial Dimension. In Cities of the Future: Toward Integrated Sustainable Water and Landscape Management (Novotny, V. and P. Brown). London, UK: IWA Publishing.

Barlett, P. F. (2005) Introduction. In Barlett, P. F. (ed.), Urban Place: Reconnecting with the Natural World. Cambridge, MA: The MIT Press.

Beatley, T. (2011) Biophilic Cities: Integrating Nature into Urban Design and Planning. Washington, DC: Island Press.

Benedict, M. A. and E. T. McMahon (2006) Green Infrastructure: Linking Landscapes and Communities. Washington, DC: Island Press.

Benedict, M. A. and E. T. McMahon. (2001) Green Infrastructure: Smart Conservation for the 21st Century. Sprawl Watch Clearinghouse Monograph Series. Washington, DC: Sprawl Watch Clearinghouse.

Bird, W. (2007) Natural Thinking: Investigating the links between the Natural Environment, Biodiversity and Health. United Kingdom: Royal Society for the Protection of Birds, 1st Edition.

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M. and A. S. Pullin. (2010) A Systematic Review of Evidence for the Added Benefits to Health of Exposure to Natural Environments. BMC Public Health, 10, 456.

Bratman, G. N., Hamilton J. P. and C. G. Daily. (2012) The Impacts of Nature Experience on Human Cognitive Function and Mental Health. Annals of the New York Academy of Sciences, 1249, 118-136.

Campbell, C. (2013) Health in Victoria, Australia. In 'Nature of Cities' blog. Available http://www.thenatureofcities.com/2013/03/20/working-beyond-park-boundaries-to-benefit-public-health-in-victoria-australia/

City of Boston. (2013) Back Bay Fens. Available http://www.cityofboston.gov/parks/emerald/back_bay_fens.asp

City of Los Angeles. (2007) Los Angeles River Revitalization Master Plan. Los Angeles, CA: Department of Public Works, Bureau of Engineering.

City of New York. (2010) NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways. New York, NY: Office of Mayor Michael R. Bloomberg.

City of New York. (2011) PlaNYC, update April 2011. New York, NY: Office of Mayor Michael R. Bloomberg.

City of Portland. (2013) Environmental Services: What is Grey to Green? Available http://www.portlandoregon.gov/bes/article/321331 [Accessed 5/14/2013].

Cooper Marcus, C. and M. Barnes. (1995) Gardens in Health Care Facilities: Uses, Therapeutic Benefits, and Design Considerations. Martinez, CA: The Center of Health Design.

Dixon, J. A. and M. M. Hufschmidt (1986) Economic Valuation Techniques for the Environment: A Case Study Workbook. Baltimore, MD: Johns Hopkins University Press.

Dunn, A. D. (2010). Siting green infrastructure: Legal and policy solutions to alleviate urban poverty and promote healthy communities. Environmental Affairs Law Review. 37, 41-66.

Emerald Necklace Conservancy. (2013) Back Bay Fens. Available http://www.emeraldnecklace.org/park-overview/back-bay-fens/

Entrix, Inc. (2010) Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits. Portland, OR: ENTRIX, Inc.

EPA. (2007) Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. EPA-841-F-07-006. Washington, DC: US EPA Nonpoint Source Control Branch.

EPA. (2008) Reducing Urban Heat Islands: Compendium of Strategies. Washington, DC: US EPA Climate Protection Partnership Division. Available http://www.epa.gov/heatisland/resources/compendium.htm [Accessed 5/21/2013].

EPA. (2009) Managing Wet Weather with Green Infrastructure: Municipal Handbook: Incentive Mechanisms. EPA-833-F-09-001. Washington, DC: US EPA.

EPA. (2010) Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. EPA-841-F-10-004. Washington, DC: US EPA Office of Wetlands, Oceans and Watersheds.

EPA. (2013) Heat Island Effect. Available http://www.epa.gov/hiri/index.htm

Evans, G. W. (2003) The Built Environment and Mental Health. Journal of Urban Health: Bulletin of the New York Academy of Medicine, 80, 536-555.

Evans, G. W., Lercher, P., and W. W. Kofler. (2002) Crowding and Children's Mental Health: The Role of House Type. Journal of Environmental Psychology, 22, 221-231.

Frank, L. D. and S. Kavage. (2008) Urban Planning and Public Health: A Story of Separation and Reconnection. Journal of Public Health Management Practice, 14, 214-220.

Frumkin, H. (2010) Nature Contact: A Health Benefit? In Frumkin, H. (ed.), Environmental Health: From Global to Local, 2nd ed. San Francisco, CA: Jossey-Bass.

Frumkin, H. and R. Louv. (2007) The Powerful Link Between Conserving Land and Preserving Health. Washington, DC: Land Trust Alliance, Special Anniversary Report.

Galea, S., Ahern, J., Rudenstine, S., Wallace, Z., and D. Vlahov (2005) Urban Built Env and Depression: A Multilevel Analysis. Journal of Epidemiology and Community Health, 59, 822-827.

Green, J. (2013) New Research: Parks Alleviate Brain Fatigue. In 'The Dirt' blog. Available http://dirt.asla.org/2013/04/02/new-research-nature-helps-with-brain-fatigue/

Groenewegen, P. P., van den Berg, A. E., de Vries, S., and R. A. Verheij. (2006) Vitamin G: effects of green space on health, well-being, and social safety. BMC Public Health, 6, 149.

Hartig, T., Mang, M. and G. W. Evans. (1991) Restorative Effects of Natural Environment Experiences. Environmental Behavior, 23, 3-26.

Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment. (2004) Nature and Health: The Influence of nature on social, psychological and physical well-being (Part 1 of a two-part study). The Hague: Health Council of the Netherlands and RMNO. Available http://www.gezondheidsraad.nl/sites/default/files/Nature%20and%20health.pdf

Kaplan, R. (1983) Impact of Urban Nature: A Theoretical Analysis. Urban Ecology, 8, 189-197.

Kaplan, R. and S. Kaplan. (1989) The Experience of Nature: A Psychological Perspective. New York, NY: Cambridge University Press.

Kaplan, S. (1995) The Restorative Benefits of Nature: Toward an Integrative Framework. Journal of Environmental Psychology, 15, 169-182.

Klinenberg, E. (2002) Heat Wave: A Social Autopsy of Disaster in Chicago. Chicago, IL: University of Chicago Press.

Kuo, F. E. and W. C. Sullivan. (2001) Environment and Crime in the Inner City: Does Vegetation Reduce Crime? Environment and Behavior, 33, 343-367.

Kuppuswamy, H. (2009) Improving Health in Cities Using Green Infrastructure: A Review. *FORUM Ejournal*, 9, 63-76.

Lewis, C. A. (1990) Gardening as a Healing Process. In Francis M. and Hester, R. T., Jr (eds.) The Meaning of Gardens: Idea, Place and Action. Cambridge, MA: MIT Press, 244-251.

Lewis, C. A. (1996) Green Nature/Human Nature: The Meaning of Plants in our Lives. Champaign, IL: University of Illinois Press.

LUC (Land Use Consultants). (2009) Green Infrastructure Guidance. Sheffield, UK: Natural England.

Maller, C., Townsend, M., Pryor, A., Brown, P. and L. St Leger. (2005) Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations. Health Promotion International, 21, 45-54.

McMahon, E. T. (2000) Green Infrastructure. Planning Commissioners Journal, 37, 4-7.

New York City Department of City Planning. (2013) Privately Owned Public Space. Available http://www.nyc.gov/html/dcp/html/pops/pops.shtml [Accessed 5/21/2013].

Odefey, J., Detwiler, S., Rousseau, S., Trice, A., Blackwell, R., O'Hara, K., Buckley, M., Souhlas, T., Brown, S., and P. Raviprakash. (2012) Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. United States: American Rivers, American Society of Landscape Architects, ECONorthwest, Water Environment Federation.

Price, J. (2008) Remaking American Environmentalism: On the Banks of the L.A. River. Environmental History, 13, 536-555.

PWD (Philadelphia Water Department). (2013) Green City, Clean Waters: What We're Doing. Available http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan [Accessed 5/14/2013].

Rotenberg, R. (2005) On the Sublime in Nature in Cities. In Barlett, P. F. (ed.), Urban Place: Reconnecting with the Natural World. Cambridge, MA: MIT Press.

Srinivasan, S., O'Fallon, L. R. and A. Dearry. (2003) Creating Health Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health. American Journal of Public Health, 93, 1446-1450.

SSI (Sustainable Sites Initiative). (2009) Guidelines and Performance Benchmarks, 2009. Available http://www.sustainablesites.org/products/

Stratus Consulting. (2009) A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds. Boulder, CO: Stratus Consulting.

Sullivan, W. C., Kuo, F. E. and S. F. Depooter. (2004) The Fruit of Urban Nature: Vital Neighborhood Spaces. Environment and Behavior, 36, 678-700.

Taylor, A. and F. E. Kuo. (2009) Children with Attention Defecits Concentrate Better After Walk in the Park. Journal of Attention Deficit Disorders, 12, 402.

Tennessen, C. M. and B. Cimprich. (1995) Views to Nature: Effects on Attention. Journal of Environmental Psychology, 15, 77-85.

Terrapin Bright Green. (2012) The Economics of Biophilia: Why Designing with Nature in Mind Makes Financial Sense. New York, NY: Terrapin Bright Green LLC.

Ulrich, R. S. (1979) Visual Landscapes and Psychological Well-being. Landscape Research, 4, 17-19.

Ulrich, R. S. (1984) View Through a Window May Influence Recovery from Surgery. Science, 224, 420.

Ulrich, R.S. (1981) Natural versus Urban Scenes. Environmental Behavior, 13, 523-556.

Winters, P., Piasecki, C. and R. Pirani. (2012) 9 Ways to Make Green Infrastructure Work. New York, NY: Regional Plan Association.

Wolf, K. L. (2003) Ergonomics of the City: Green Infrastructure and Social Benefits. In C. Kollin (ed.), Engineering Green: Proceedings of the 11th National Urban Forest Conference. Washington, DC: American Forests.

Yang, J., Zhao, L., Mcbride, J. and P. Gong. (2009) Can you see green? Assessing the visibility of urban forests in cities. Landscape and Urban Planning, 91, 97-104.

Younger, M., Morrow-Almeida, H. R., Vindigni, S. M. and A. L. Dannenberg (2008) The Built Environment, Climate Change, and Health: Opportunities for Co-Benefits. American Journal of Preventative Medicine, 35, 517.