

What Is Green Infrastructure?

By Scott Cullen, RCA #348

Introduction

The term green infrastructure is increasingly common in arboriculture and urban forestry discussions and practice. Arborists and urban foresters may, not surprisingly, understand the term in narrow reference to publicly owned street and park trees. The term is found in the arboriculture and urban forestry literature without definition (see, e.g., Dwyer and Childs 2003, McPherson 2007) as if the concept is widely and uniformly understood. To the contrary, many treatments of green infrastructure begin like these:

- “Green infrastructure means different things to different people depending on the context in which it is used. For example, some people refer to trees in urban areas as green infrastructure because of the ‘green’ benefits they provide, while others use green infrastructure to refer to engineered structures (such water treatment facilities or green roofs) that are designed to be environmentally friendly” (Benedict and McMahon 2002, p. 5).
- “...some believe that the phrase [green infrastructure] has undergone ‘definition creep’ and often means different things to different people” (Gross 2009).
- “‘Green infrastructure’ is a relatively new and flexible term, and it has been used differently in different contexts” (US EPA 2013b).

A review of the literature confirms that the meaning of green infrastructure varies widely by context and is in many

respects a subjective label. Since Consulting Arborists work in a range of contexts and with designers and managers having varied perspectives, it is essential for Consulting Arborists to identify the meaning of green infrastructure that is applicable to a particular discussion or arboricultural consulting assignment.

This article is not a technical tutorial on conserving, designing, building or maintaining green infrastructure. It is not about enumerating the real or perceived benefits of green infrastructure. Rather, it is intended to describe the general concept and related concepts and to distinguish categories of green infrastructure found in the literature and practice. This article identifies four distinct categories of green infrastructure, with variations among them:

- Conserved green space.
- Stormwater control measures.
- The urban forest.
- Green buildings and green building practices.

Before describing these categories in more detail, it is necessary to establish some concepts and terms.

What is Infrastructure?

With the basic assumption that green infrastructure is a form or subset of infrastructure, let’s start by understanding what infrastructure is. Literally it is the foundation or framework of things, the structure below (from the Latin *infra*). According to Wikipedia (2012): “Infra-

structure is basic physical and organizational structures needed for the operation of a society or enterprise, or the services and facilities necessary for an economy to function.”

Thus, the first distinction can be made between physical or “hard” infrastructure and organizational, institutional or “soft” infrastructure. The distinction between computer hardware and software is a useful analogy.

Hard infrastructure refers to physical assets, networks, structures or systems and this is reflected in many definitions, for example:

- “...‘hard’ infrastructure refers to the large physical networks necessary for the functioning of a modern industrial nation...” (Wikipedia 2012).
- “infrastructure: the human improvements, such as roads, bridges, and water and sewer lines to natural settings, that permit a city, state, or region to function” (SAF 2008).
- “infrastructure: the transport links, communications networks, sewage systems, energy plants and other facilities essential for the efficient functioning of a country and its economy. In corporate terms, the essential physical assets necessary to run a business, e.g., the cable laid by a pay-TV company” (FT 2012).
- “Bridges, roads, and tunnels [as examples]—what we know as hard infrastructure—are easy to grasp as the backbone of the city... the hard underpinnings that make cities work” (Iovine 2010).

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It is important to note that, in green industry jargon, **hardscape** (see, e.g., CTLA 2000, pp. 77-78; Costello and Jones 2003, p. 3; ISA 2013) refers to the non-plant or structural components of a landscape. Similarly, the so-called **built environment** (see, e.g., Roberts et al 2006, Johnston and Percival 2012) refers to human constructed environments and improvements. The built environment, however, is more broadly defined than hardscape and may include the entire built landscape. Younger et al (2008), for example, note that “Distinct from the natural environment, the built environment is comprised of manmade components of people’s surroundings, from small-scale settings (e.g., offices, houses, hospitals, shopping malls, and schools) to large-scale settings (e.g., neighborhoods, communities, and cities), as well as roads, sidewalks, green spaces, and connecting transit systems.” This might suggest that natural environments or plants in the built environment are “softscape.” Whether natural, naturalized, planted or constructed, however, they are hard or physical in nature. If treated as infrastructure, then as physical assets they are components of the hard or physical infrastructure.

Soft infrastructure, by contrast, refers to institutions and organizational structures or systems. The distinction is reflected in other definitions, for example:

- “‘soft’ infrastructure refers to all the institutions which are required to maintain the economic, health, and cultural and social standards of a country, such as the financial system, the education system, the health care system, the system of government, and law enforcement, as well as emergency services” (Wikipedia 2012).
- “the three basic institutions—the requisite soft infrastructure—of a market economy are the legal system, the

accounting system, and the cultural attitudes” (Niskanen 1991).

- “Soft infrastructure is something else altogether. Immaterial, expansively informational, and slippery...with none of the steel beams, soaring trusses, and hulking pipes we associate with the hard underpinnings that make cities work” (Iovine 2010).

While this hard-physical vs. soft-immaterial distinction may seem basic and hard to blur, even it varies in practice. For example: “The idea of soft infrastructure is to use techniques from nature and ecology to improve resiliency...Among

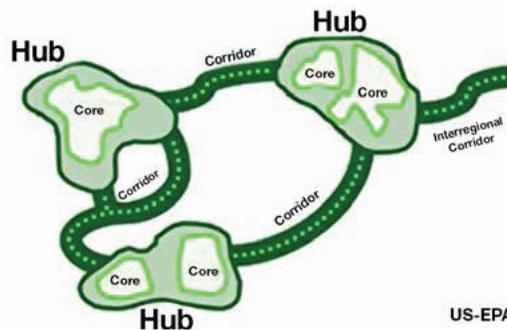


Figure 1. Networked green infrastructure. (US EPA 2013a)

the techniques it proposed were restoring and enlarging wetlands, creating reefs and archipelagoes of artificial islands and seeding oyster beds” (Anon. 2012). This use obviously describes constructed or enhanced physical forms but characterizes them as “soft,” apparently to contrast them to architectural forms like flood gates, levees or seawalls.

Combined hard and soft infrastructure. Much of our infrastructure is obviously composed of both hard and soft elements. A legal system is composed of both hard infrastructure like government offices, courthouses, police stations and correctional facilities and the soft infrastructure of government and laws. An educational system is composed of both the hard infrastructure of educational offices, school and university buildings and research facilities and the soft infra-

structure of curriculum, teaching, testing and credentialing. A health care system is composed of both the hard infrastructure of hospitals, medical buildings and nursing homes and soft infrastructure such as administration, clinical professions and health insurance.

People as infrastructure. It is also obvious that people—fire fighters, police officers and teachers to name a few examples—are essential to the creation and operation of our hard and soft infrastructure. The question arises of whether those people are infrastructure. They might be described as **personal infrastructure**, but some economists consider all people working or available to work in an economy or society as personal infrastructure or human capital (see, e.g., Torrisi 2009). It might seem logical to categorize people as **human infrastructure**, but that label has been used to collectively describe the hard, soft and personal infrastructure dedicated to caring for people: “...education, health service, care for the elderly and disabled” (Benedict and MacMahon 2002, p.6).

Other characteristics of infrastructure. Two other infrastructure characteristics will distinguish some of the meanings or uses of green infrastructure.

Infrastructure is often described as **networks** or components of physically interconnected networks. The obvious examples are highways, railroads and various utility networks. Many other components of infrastructure are, however, physically discrete. Examples include courthouses, hospitals, police stations and schools. Networked green infrastructure is described as composed of “hubs and links” (e.g., Benedict and MacMahon 2002, pp.7-8) or “cores and corridors” (e.g., Firehock 2010). Greenways, trails or other corridors can connect green spaces, that would otherwise be isolated, into a network.

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Scale describes spatial size or distribution. Gross (2009), for example, notes “When using the term ‘green infrastructure’...resource managers may be referring to anything from a street-side rain garden to a statewide land conservation network.” A site scale, street-side bioswale rain garden is not likely to be physically connected to a network.

Origin of Green Infrastructure

The term green infrastructure is often traced to the early 1990s but it is not clear when it was first used or by whom. Secondary sources are conflicting and not clearly verifiable. Gross (2009) suggests that the term was “Coined by...McMahon...in a May, 1999 report of the President’s Council on Sustainable Development...” Firehock (2010) acknowledges McMahon’s significant contributions but suggests that “The term itself was first coined in Florida in 1994 in a report to the governor on land conservation strategies...” In that primary source (MacKay and Reed 1994, p.3) MacKay states “Just as we carefully plan the infrastructure our communities need to support the people who live there—the roads, water and electricity—so must we begin to plan and manage Florida’s green infrastructure” and alludes to a green infrastructure mission of the Florida Greenways Project which was undertaken in 1991. There is no documentation, however, of a 1991 usage of “green infrastructure” (personal communication, Florida Office of Greenways and Trails staff). In the same period, Rowntree et al (1994) also used the term in an urban forest context: “Vegetation is part of the region’s infrastructure, woven into a complex network of power lines, roads, aqueducts, and sewers...green infrastructure...” No source is cited and co-authors McPherson and Nowak (personal communications) suggest that the term was already sufficiently established in the vernacular that citation was not necessary. The term was reportedly in use by the State of Maryland during this same early 1990s period (Benedict and

McMahon 2002, p. 8; personal communication, Mike Galvin, RCA #432).

While it might be interesting and tidy to credit an original source, the important point is that the term green infrastructure came into use in the early 1990s to characterize particular classes of assets or resources.

Why Green Infrastructure?

The next question is why the term emerged. Green infrastructure was used to depart from the traditional concept of green spaces, greenways and urban forests in at least three ways. Benedict and McMahon (2002, p. 7) describe them well:

- **Necessity.** “Whereas green space is often viewed as something that is nice to have, the term green infrastructure implies something that we must have. Protecting and restoring our nation’s natural life support system is a necessity, not an amenity.”
- **Sustainability.** “Whereas green space is often viewed as self-sustaining, the term green infrastructure implies something that must be actively maintained and at times restored.” Many sources note that green infrastructure must be planned for and managed.
- **Connectivity.** “Whereas green space is often thought of as isolated parks, recreation sites or natural areas, the term green infrastructure emphasizes interconnected systems...”

Necessity is the essential characteristic of infrastructure that applies to all green infrastructure. The need to manage for sustainability applies to all green infrastructure but the level of management required varies from intensive in the urban built environment to minimal in wildland green spaces. These two char-

Green Infrastructure is often abbreviated as GI. That usage is avoided in this article because of potential confusion with Gray Infrastructure.

acteristics support the allocation of financial resources to the planning, acquisition, conservation, management and maintenance of green infrastructure, and this is a key motivation for applying the label.

The characteristic of physical connectivity in networks is essential in some green infrastructure contexts and immaterial in others.

In the 20 odd years since the term emerged, it has been applied to different things in different ways and it is as much an element of branding and marketing as it is of physical characteristics.

The Infrastructure Color Palette

Color is an intuitively descriptive way to distinguish some types of infrastructure.

Green infrastructure. Green is obviously descriptive of vegetation or vegetated habitats and varied types of green infrastructure are described in the following section. Once in use, the term green infrastructure was quickly compared and contrasted to gray infrastructure. Both are infrastructure but they are materially different.

Gray infrastructure. Gray is descriptive of construction materials in the built environment such as concrete, steel and stone. Gray (also called “general”) infrastructure includes networked systems like highways, roads, sidewalks, utility lines, sanitary and storm sewers and potable water lines, and discrete structures like buildings or seawalls (see, e.g., Benedict and McMahon 2002, p. 7; Costello and Jones 2003, p. 3; Sustainable Cities Institute 2010).

Blue infrastructure. Blue is descriptive of water. Oceans, lakes, rivers and

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streams, for instance, are traditionally shown on maps in blue. The term blue infrastructure is sometimes used to distinguish environments and systems associated with water.

- **Natural environments.** Some uses of blue infrastructure refer to ecosystems, habitats or landforms dominated by water. They may be described broadly as “aquatic” whether they are freshwater, brackish or marine habitats. [McCall \(2012\)](#), for example, notes “Each region of our State—from the forested mountains in the West to the coastal plains in the East—is home to unique portions of...blue infrastructure.” Some uses focus on coastal or “nearshore” environments (see, e.g., [Garman et al 2008](#), [Edwards et al 2013](#)) and others describe inland water resources (see, e.g., [SBPC 2011](#)).
- **Built environments.** Man made environmental features like artificial reefs (see, e.g., [Harris 2009](#), [SIT 2011](#), [Anon. 2012](#)) can easily be characterized as blue infrastructure.
- **Built infrastructure.** Some uses of blue infrastructure refer to the components of the constructed infrastructure dedicated to water including both potable water supply and storm and sanitary sewer systems (see, e.g., [SBPC 2011](#)). Some uses may focus on water reuse (see, e.g., [Bargmann et al 2011](#)). These constructed systems might otherwise be considered gray infrastructure.

To complicate the color palette, constructed roof-top stormwater management might all be described as blue infrastructure, but purely mechanical detention systems are called “blue roofs” while systems that incorporate growing plant media are called “green roofs” ([NYC-DEP 2012a](#)). Green roofs, however, frequently appear in catalogues of green infrastructure. In the context of climate adaptation, “white roofs” use high reflectivity to reduce thermal energy absorption ([Foster et al 2011](#)). Simi-

larly, water re-use jargon distinguishes brown or black (containing high levels of organic waste such as fecal matter and urine), gray (other domestic waste) and white (fresh) water ([Ecoshift 2012](#)), but blue infrastructure might handle any of those waters.

What Is Green Infrastructure?

With that foundation laid, we can more meaningfully answer the question: What is green infrastructure?

Green infrastructure—a broad concept. Some definitions of green infrastructure are broad and all-encompassing. For example:

- “Green infrastructure can be considered a conceptual framework for understanding the ‘valuable services nature provides the human environment.’ At the national or regional level, interconnected networks of park systems and wildlife corridors preserve ecological function and create a balance between built and natural environments. At the urban level, parks and urban forestry are central to reducing energy usage costs and creating clean, temperate air. Lastly, green roofs, walls, and other techniques within or on buildings bring a range of benefits, including reduced energy consumption and dramatically decreased stormwater runoff. At all scales, green infrastructure provides real ecological, economic, and social benefits” ([ASLA 2011](#)).
- “Green infrastructure is defined by a range of natural and built systems that can occur at the regional, community, and site scales” ([NOAA 2009](#)).
- “Green infrastructure...may be defined as the system of land, natural resources, and natural habitats that collectively comprise a community’s underlying ecosystem” ([Sustainable Cities Institute 2010](#)).
- “Although there is no commonly accepted or authoritative definition in the UK, ‘green infrastructure’ refers

to the combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services” ([Forest Research 2010](#)).

There are variations even in such broad definitions, principally whether green infrastructure includes both natural and built or only natural elements. [Firehock \(2010\)](#) suggests that this “confusion” started in 2007 when the US-EPA labeled built engineered structures for stormwater management as green infrastructure. This neglects the fact that natural appearing green spaces such as parks are often designed and built.

An internet or library search on “green infrastructure,” however, is as likely to find a narrow and specific definition as a broad one. The searcher might be given the impression that such a specific definition is the only, best or preferred definition, especially if the source seems authoritative. The more specific definitions are sometimes described as “implementation strategies” or “practices” of the broader green infrastructure concepts. This article identified four distinct categories of green infrastructure with variations. These categories may be clearly bounded or may overlap.

Green infrastructure—conserved green space. This category was probably the first usage, as noted in the preceding origins section. It came out of and continues to be used in conservation and land use planning. It is sometimes associated with “smart growth” and “anti-sprawl” efforts. It is the least specific of the categories and may incorporate goals and objectives from the more specific ones. Some examples are:

- “Green infrastructure is the term applied to undeveloped lands with high value for their environmental and open space functions. Green infrastructure most commonly refers to forest sys-

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- tems...[but] green infrastructure concepts are still applicable to grasslands or mixed shrub landscapes” (Outen 2009).
- “...green infrastructure is defined as *an interconnected network of green space* [emphasis in the original]...Green infrastructure is ‘smart’ conservation... because it looks at conservation values and actions in concert with land development...Other conservation approaches typically are undertaken in isolation from—or even in opposition to—development. This monograph introduces green infrastructure as a strategic approach...” (Benedict and McMahon 2002, p. 5).
 - [We define] “...green infrastructure as the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, forest preserves and native plant vegetation, that provide wildlife habitat, natural drainage, recreational opportunities and help to sustain our Nation’s cities...” (U.S. Conference of Mayors 2006).
 - “Just as we plan networks of roads, we can plan networks of open spaces and natural resources that connect communities and regions. This is our green infrastructure.” (The Conservation Fund 2013).
 - “Green infrastructure is the network of open space, airsheds, watersheds, woodlands, wildlife habitat, parks, and other natural areas that provides many vital services that sustain life and enrich the quality of life (PCSD 1999, p. 64).

Green infrastructure—stormwater management. Many sources describe green infrastructure in the specific context of managing stormwater (that is, the water generated by rain or snowmelt on ‘impervious surfaces’ (such as roads, sidewalks, parking lots, and buildings) or wet weather. Green infrastructure, in this context, is contrasted to the gray infrastructure of stormwater or combined sewer pipes and water treatment plants. (SUNY-ESF 2102) Green infrastructure, in this context, is a type of Stormwater

Control Measure (SCM), (see NRC 2009, pp. 145) or an element of Water Sensitive Urban Design (WSUD, Melbourne Water 2013).

Much of the emphasis is on so called “site-scale” green infrastructure including bioswales, green roofs and rain gardens, but parks, urban forests and other green spaces may be included under this umbrella.

- “Green Infrastructure: Systems that mimic natural processes in order to infiltrate, evaporate, and/or reuse stormwater. Green infrastructure uses soils, topography, and vegetation in a way that minimizes the impacts of anthropogenic disturbance and maintains the pre-development hydrology and water quality of urban environments” (SUNY-ESF 2102).
- “Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water” (US EPA 2012).
- “...green infrastructure—including bioswales, green roofs, and subsurface detention systems—to control stormwater from impervious spaces such as roofs and sidewalks ...can reduce more CSOs [combined sewer overflows] at less cost than second-tier ‘grey’ infrastructure” (NYC-DEP 2012b).
- “Green infrastructure is an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly” (Latham 2012).

A closely related concept is **low impact development (LID)**. Some examples are:

- “Green Infrastructure and Low Impact Development practices (we use these

terms interchangeably) produce a range of economic and social benefits in conjunction with managing storm water” (Wise et al 2010).

- “Low impact development is an approach to land development, or redevelopment, that works with nature to manage stormwater as close to its source as possible... Recently, this term has come to be used interchangeably with the term ‘site-scale green infrastructure practices’” (NOAA 2009).
- “LID is an approach to land development...that works with nature to manage stormwater as close to its source as possible... LID can be applied to new development, redevelopment, or as retrofits to existing development... Green infrastructure can be used at a wide range of landscape scales...to support the principles of LID” (US EPA 2013b, see also US EPA 2000).

While some language is obviously borrowed across sources, LID is variably applied to green infrastructure scales. LID is variously considered interchangeable with green infrastructure or a green infrastructure practice or implementation. Or, conversely, it may be considered that green infrastructure is an LID practice or implementation. When LID is limited to stormwater management (as in these examples), then it seems most accurate to say that green infrastructure practices are one LID implementation strategy and that some gray infrastructure practices such as permeable paving are another LID implementation strategy. While most often found applied to stormwater management, LID is easily associated conceptually with conservation and planning (preceding) and green building (following) categories of green infrastructure.

Green infrastructure—the urban forest. Arborists and urban foresters increasingly describe and manage urban forests as green infrastructure. The usage is frequently found in the literature (see, e.g.,

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Dwyer and Childs 2003, McPherson 2007, Schwab 2009). Consulting Arborists are generally familiar with this category, so elaboration is beyond the scope of this article, which is intended to put this category in the broader green infrastructure context.

It is interesting to note the attention given to so called “tree-infrastructure conflicts” (see e.g., McPherson and Peper 1995, Coder 1998, Costello and Jones, 2003). If we effectively treat trees and urban forests as green infrastructure then we will talk about complementing and integrating gray and green infrastructure rather than about conflicts.

Green infrastructure—“green building.” Green building is a widely discussed concept. According to [Wikipedia \(2013\)](#) “green building practices aim to reduce the environmental impact of buildings...” Consulting Arborists may be familiar with the U.S. Green Building Council’s LEED (Leadership in Energy and Environmental Design) program ([USGBC 2013](#)) and the related Sustainable Sites Initiative ([SSI 2013](#)).

When green building incorporates green infrastructure practices such as bioswales or green roofs the green infrastructure label is properly applied. When gray infrastructure incorporates “green” or environmentally desirable features that do not include living plants, however, green infrastructure is a misnomer. A new light rail station, for example, is obviously infrastructure. If it is constructed largely of locally sourced, recycled, natural materials, is energy efficient and obtains its energy from “alternative” sources, it may qualify as a green building but is not properly green infrastructure.

While found less frequently in the literature there is discussion of green infrastructure for climate adaptation. This is less a category or type of green infra-

structure than an objective that can utilize any of the more distinct categories (see e.g., Foster et al 2011, University of Melbourne 2013).

Conclusion

Green infrastructure is a term with many meanings and is not confined to urban forests. Many authoritative sources give specific definitions that vary from or exclude others. This article explores various meanings and applications of green infrastructure and underlying and related concepts to identify four distinct categories of green infrastructure. This article brushes the surface of some current sources and is not exhaustive. The meanings are evolving and proliferating constantly.

If an arboricultural consulting assignment involves green infrastructure, a Consulting Arborist must identify the specific meaning that applies and should independently consult current sources. Among the things to confirm are:

- Is the green infrastructure hard (physical, such as trees) or soft (organizational, such as a tree inventory)?
- What is the green infrastructure (e.g., trees, parks, greenways, rain gardens)?
- Is the green infrastructure the objective (e.g., an urban forest for all its benefits) or a practice to achieve another primary objective (e.g., a bioswale to manage storm water)?
- What is the scale of the green infrastructure (e.g., one or more site scale bioswales or a statewide trails network)?
- Does the green infrastructure complement or conflict with gray infrastructure in the project area?
- In the specific context, does the green infrastructure have an alternative or confusing label (e.g., blue infrastructure, softscape, soft infrastructure)?

As with any arboricultural consulting assignment, preparation, research and communication with the client or other stakeholders are essential.

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Scott Cullen, RCA #348, has been involved in various aspects of arboriculture since 1971 and is a full time consultant in the metropolitan New York area. He is a licensed real estate broker, has a masters degree in real estate development and often works at the professional interface among land use planning, development, arboriculture and urban forestry. 🌿

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