



SITE COMMISSIONING WHITE PAPER

U.S. GENERAL SERVICES ADMINISTRATION
PUBLIC BUILDINGS SERVICE
OFFICE OF THE CHIEF ARCHITECT

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SITE COMMISSIONING WHITE PAPER

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Front cover image credit: Nic Lehoux



LETTER FROM THE PROJECT SPONSOR

The infrastructure we build, and the combination of economic, environmental and cultural services that infrastructure provides, is 'evolutionary' by nature.

Therefore perhaps 'evolutionary infrastructure' is a more apt name to capture both our standard green infrastructure, that is often passive and relatively isolated, and the cyborg-like (natural and mechanical) site systems that are deeply intertwined with the performance characteristics of the high-performance architectural facilities we construct. Evolutionary infrastructure incorporates living organisms and man-made features, processes, and ideas that will, out of necessity, increasingly become the common design patterns and movements of our world.

Many entities across the globe are facing complex challenges; and a near universal need exists to achieve more with less, pursue greater return on investment, and pursue cross benefits wherever possible. Yet to date the field performance characteristics of the landscapes we build are seldom understood and the evolutionary infrastructure we construct has relied largely on predicative assumptions--- despite knowing that the field behavior of living landscape systems is deceptively complex, quite variable, and subject to maintenance regimes that are often less than ideal. And we must be reminded that in the world of living infrastructure such as this, "maintenance" does not equate to the simple idea of "maintaining performance," as it does with standard mechanical systems. Instead maintenance here, the system's care and feeding, is often the force multiplier required to minimally achieve, or occasionally exceed, the intended performance targets.

While historically the concept of Ecosystem Services provided the conceptual framework for the idea of developing green infrastructure, moving forward leveraging a well-established concept within the building industry, a concept known as Commissioning, may prove useful if we are to operationalize this thinking to an ever broader audience, reduce costs, increase benefits, deepen the interactions between dynamic systems, and elevate our collective ability to place greater primacy in those systems. This may well enable the paradigm to truly shift from "green" infrastructure as a back-up, or as a method for dealing with overages or "problems," to evolutionary infrastructure as the prime method for conceptualizing "opportunities." Commissioning site work, and the knowledge that process may bring, could enable us to design and manage with much greater precision, and move away from a future of relying on ever greater levels of force.

Please join me in reviewing the following paper which examines both the purpose of applying a measurement and verification framework in the context of constructing high-performing site work, and how that may be done.

Sincerely,

Christian Gabriel, RLA, ASLA
National Design Director for Landscape Architecture
U.S. General Services Administration

EXECUTIVE SUMMARY

Why is site commissioning necessary?

Achieving environmental, social, and financial resilience in the built environment requires a land development paradigm shift. Currently, conventional development practice presupposes that built sites function as intended—from managing stormwater to increasing employee retention—rather than testing and proving that performance goals are met. This lack of verification within the built environment can perpetuate ineffective and inefficient design, construction, and management practices. How can property owners gain assurance that their properties are functioning properly? How can they protect their investment in land development for the long term? *Site commissioning* offers a solution.

Site commissioning is a systematic process of verifying that systems within the built environment, beyond a building's skin, perform in accordance with design intent and the property owner's operational needs. Each site's unique performance benchmarks are established during a facility's pre-development planning phase, and then targeted during design, executed during construction, and verified with performance testing during site management. As one of the world's largest and most diversified public real estate organizations, the U.S. General Services Administration (GSA) must leverage site commissioning to assure that the agency's long-term investment in its extensive properties is protected using proven development and management practices. This approach becomes increasingly critical for GSA as:

- The agency continues to invest in long-lasting facilities through a build-to-own model, in which ineffective and inefficient implementation can have significant cost implications during a facility's lifetime;
- Facility owners demand that each built system delivers multiple benefits (e.g. a vegetated roof that manages stormwater, provides desirable views, and reduces the frequency of roof replacement);
- Facilities increasingly rely upon integrated site-building systems that must function properly to meet sustainability requirements and to utilize resources efficiently (e.g. air conditioning condensate harvesting and re-use for irrigation);
- Public properties are expected to provide vital ecosystem services (e.g. flood control) to help GSA steward tax dollars responsibly while adapting to climate change, mitigating risk management costs associated with extreme weather events, and protecting public health,

- safety, and welfare; and
- Capital budgets become less predictable and secure, thereby enhancing the urgency for durable sites that provide a return on investment and reduce the need for premature redevelopment.

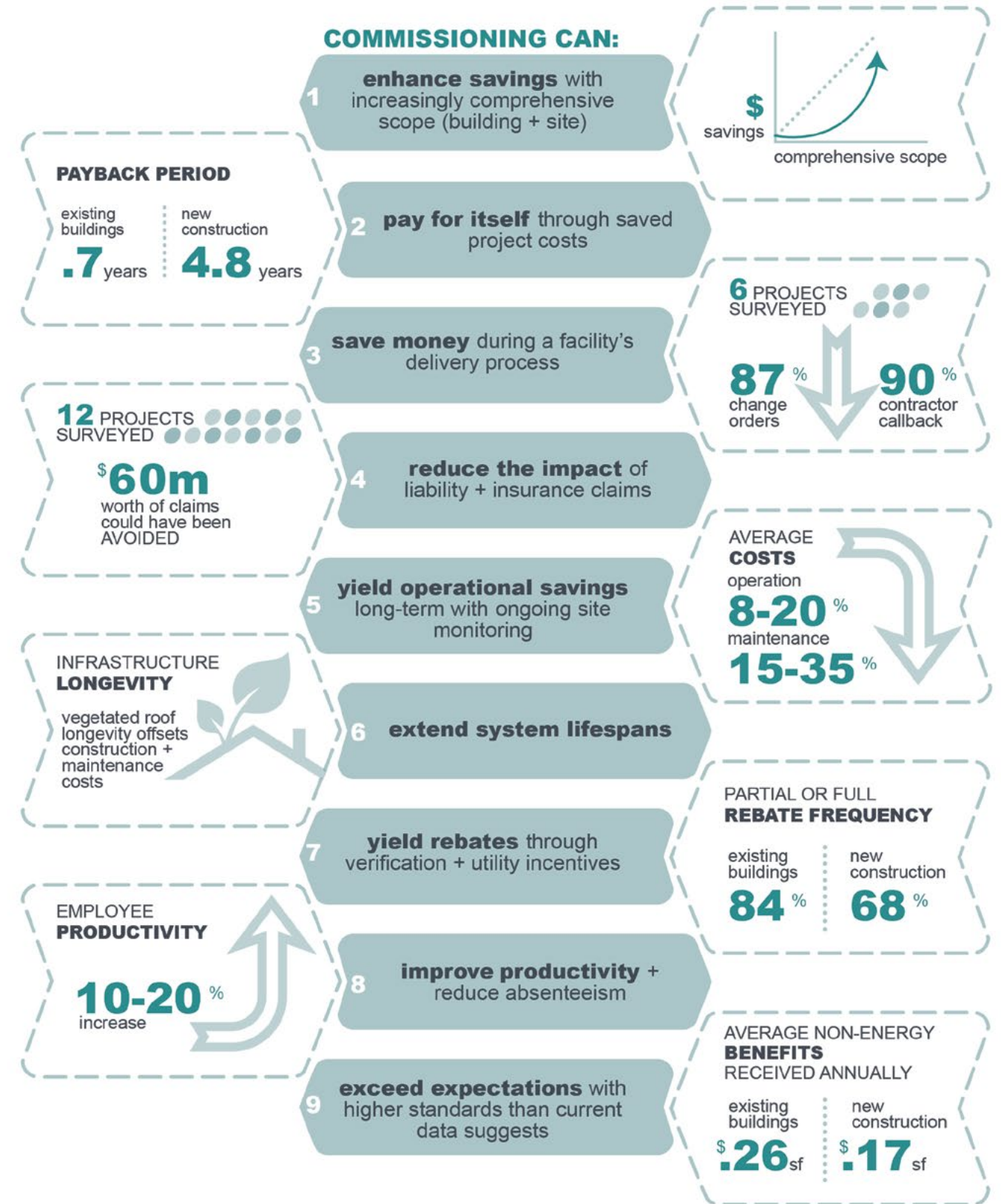
Site commissioning is an emerging practice, whereas an established, global industry exists for verifying the performance of buildings. GSA launched its first building commissioning program in 1995, and in 2006 expanded the effort's scope by adopting Total Building Commissioning for all new construction and major renovations. According to the largest meta-analysis of published building commissioning data, a facility's cost savings rise with increasingly comprehensive commissioning.¹ Expanding GSA's current commissioning program to include sites could therefore maximize the agency's capital investments, protect this investment through verification, and further enhance the agency's standard of national design excellence.

What is the value?

Implementing an agency-wide site commissioning process can help GSA protect its capital and operational investments by providing quality control, risk management, and assurance that sites are delivered to achieve each facility's unique performance goals. Studies suggest that commissioning can yield significant cost avoidance during design and construction (by detecting and resolving problems early in the project delivery process^{2,3}); during project turn-over (by reducing liability disputes^{4,5}); during occupancy (through energy⁶ and non-energy⁷ savings); and under management (through reduced trouble shooting and increased operational efficiency⁸). GSA owns and leases nearly 150,000 acres within 11 GSA regions, and in 2017, budgeted \$5 million for site management for the National Capital Region alone.⁹ Applying site commissioning's potential savings across just a fraction of this portfolio equates to lower facility life-cycle costs and direct savings for taxpayers.

Site commissioning is equally important in its ability to protect GSA's human capital investment, which is typically an employer's most valuable resource and greatest expenditure. The U.S. Department of Labor estimates that the average public sector absentee rate is 4%, or more than 83 hours per year, valued at

1 Mills (2011)
 2 Dorgan, et al. (2002)
 3 Altweis (2002)
 4 Nelson (1999)
 5 Alonso (2016)
 6 Mills (2011)
 7 Mills, et al. (2004)
 8 Ellis & Reilly (2015)
 9 Alonso (2017)



1 Mills (2011) | 4 Mills, et al. (2004) | 7 Mills (2011)
 2 Mills, et al. (2004), Mills (2011) | 5 Ellis & Reilly (2005) | 8 Lotturp, et al. (2015)
 3 Mills, et al. (2004) | 6 GSA (2011) | 9 SBW & Skumatz (2003)

Above: Nine financial benefits of commissioning

a \$2,502 average loss per employee in 2010 dollars.¹ For a facility with 1,000 employees, this rate equates to an annual loss of \$2.5 million. Studies suggest that the quality of the work environment, and specifically views of nature and access to fresh air, notably decreases absenteeism while increasing employee efficiency and retention by directly benefiting physical health and well-being.² Site commissioning offers a process for shepherding and verifying this critical link between goal setting, site design (i.e. spatial organization, site program, aesthetic quality), and a facility's triple bottom line performance.

Site commissioning would strengthen GSA's role as a national leader in sustainability, proving its dedication to excellence beyond the agency's existing commitments to Total Building Commissioning, LEED-certification, and SITES-certification. GSA's scale affords the agency the unique ability to create demand in the marketplace for site performance verification, professional training and certification, and increased accountability. As a result, the application of site commissioning across GSA's wide-ranging portfolio will advance the necessary land development paradigm shift on a national level.

What are the hurdles?

Realizing the benefits of site commissioning will require up-front investment. At the agency level, GSA will need to designate site commissioning personnel (including an administrative lead and regional liaisons), adopt digital tools, and develop a communications strategy to ensure successful

roll-out and management. At the facility level, site commissioning is likely to require additional costs during the following project delivery phases: 1) Planning / pre-design - by engaging the landscape architect and commissioning agent rather than waiting until the design phase, to maximize team integration and performance goal refinement; 2) Design - through increased landscape architect, commissioning agent, and owner scope; and 3) Construction - by investing in higher-quality materials and two years of intensive site management and monitoring that will vary with project scope, project complexity, and management personnel ability. Long-term operations will incur the cost of continual monitoring and periodic commissioning, but these expenditures are likely to be cost-neutral due to increased operating efficiencies and the reduced need for system remediation and replacement. Furthermore, costs are likely to decrease over time as established sites mature and as GSA builds and applies its knowledge base through an agency-wide, adaptive feedback loop.

Overcoming the current lack of professional expertise related to site commissioning, monitoring, and adaptive management, both within GSA and the broader design industry, is essential for success. The well-established building commissioning industry will need to supplement its expertise by hiring knowledgeable subject matter sub-consultants, specific to each project's needs, in order to deliver holistic commissioning of buildings and sites. Using each facility's request-for-proposal process to solicit these sub-consultants, as well as qualified site management personnel, will prove essential to meeting site performance goals long-term.

Lastly, sites contain biotic components (e.g. soil microbes, plants) that respond to management practices, weather events, and climatic fluctuations, while also changing over time with maturation. Relying upon these dynamic, living systems to provide facilities with critical services can be challenging as performance can vary from month-to-month, from season-to-season, and from young to mature growth. A successful site commissioning process must therefore anticipate performance trajectories and address under-performance before liability transfers at key points during a facility's life-cycle.

How would the process be implemented?

A successful, agency-wide site commissioning process must dovetail with GSA's existing Total Building Commissioning program, to build upon that which has already been vetted, implemented, and accepted. The process must also accommodate existing policies, executive orders, and GSA's project procurement and delivery processes, while complementing the Sustainable SITES Initiative (SITES), which GSA adopted in 2016. Site commissioning would be implemented at four nested scales—project, facility type, region, and agency—supported by a graduated roll-out strategy.

The process itself would ensure that each facility's unique performance goals are established and then provide an adaptable framework that informs performance metrics, temporal engagement, and monitoring schedules surrounding four core attributes (water, soil, vegetation, and materials) and three supporting attributes (human health and well-being, habitat, and climate). Like Total

Building Commissioning, site commissioning would be integrated in pre-planning, design, construction, and management phases of a project. An accessible, agency-wide adaptive feedback loop would then allow GSA to improve its practices over time and cultivate cumulative, institutional knowledge.

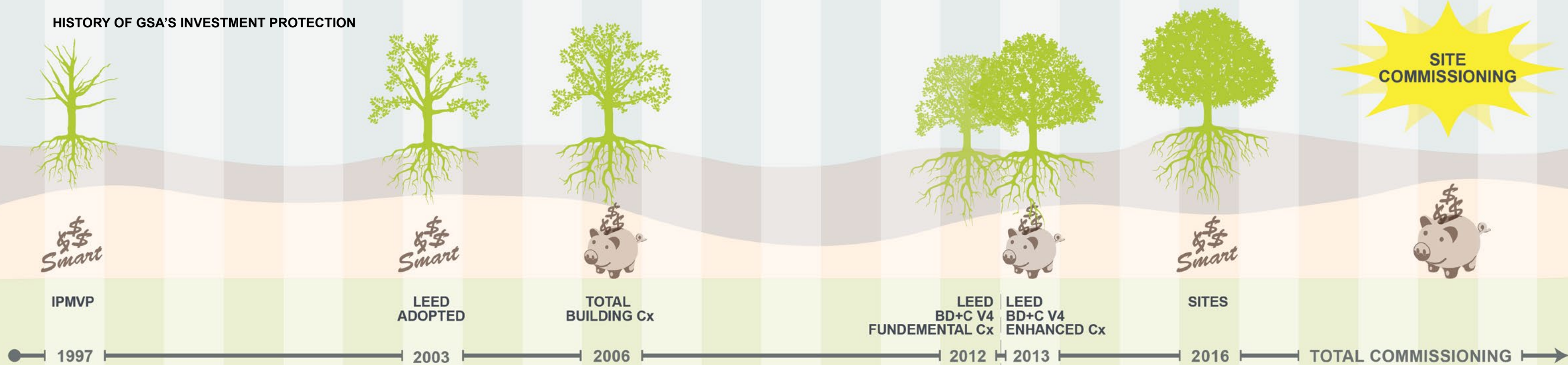
What does this document offer?

This white paper assesses the feasibility, and then details a strategy, for GSA to develop and implement an agency-wide site commissioning process for all new construction and major redevelopment. As one of the first publications to discuss the emerging practice of site commissioning, this white paper encapsulates a literature review of related subject matter (including building commissioning, site monitoring, and sustainability rating systems) and then envisions site commissioning's opportunities, constraints, costs, benefits, and relationship to industry-wide trends.

To supplement this analysis, this publication incorporates original research by the white paper's research team, which solicited input from 89 industry experts, organized into seven subject matter-specific working groups. Through participation in surveys and group interviews, these public sector, private sector, and academic experts provided critical input related to performance goals, monitoring methods, performance evaluation, and degree of support. The survey and interview results revealed statistically significant, cross-disciplinary support for GSA's adoption of a site commissioning process, thereby adding validity to the agency's pursuit. In response, this white paper proposes an actionable process framework and implementation strategy that is informed by the industry

¹ U.S. Department of Labor (2010)
² Terrapin Bright Green, LLC (2012)

HISTORY OF GSA'S INVESTMENT PROTECTION





What does this document recommend?

Front-end investment in high-quality facility planning, design, and construction, to achieve long-lasting facilities with reduced, long-term operational and replacement expenditures, improved worker productivity, and lower risk for liability and insurance claims.

Adopt an inclusive project development process (in which owner, designer, contractor, site manager, and commissioning agent work collaboratively) beginning during the planning / pre-design phase, to establish owner's triple bottom line benefits, craft performance goals, enhance team integration, and ensure buy-in.

Leverage ecosystem services by designing and managing site systems that further performance goals (e.g. habitat biodiversity and resilience), while recognizing that the performance of one system may affect the measurable performance of another.

Launch a 3-year pilot program, inclusive of diverse facility types and geographies, to test and fine-tune GSA's site commissioning process.

Split site maintenance into two phases: "early-stage management" to accommodate intensive care during plant establishment (years 0-2 after construction), followed by less intensive "long-term management." Finance the former with the facility's capital budget and the latter with the operational budget.

Anticipate performance trajectories to factor predictable changes in dynamic, living systems over time, particularly when integrated building / site systems drive a facility's operational performance.

Create an agency-wide information feedback loop that manages risk by improving GSA's land development and management processes, given the agency's build-to-own model.

Confirm true costs and benefits associated with site commissioning's added development and operations costs, and the agency's tangible and intangible benefits at the facility and regional scale.

Embrace a long-term outlook that accommodates fiscal fluctuation; climatic variability; programmatic flexibility, assessment, and adaption; and the time associated with creating an industry.



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Image credit: Andropogon Associates



1. INTRODUCTION

The Edith Green-Wendall Wyatt Federal Building, in Portland, OR, exemplifies how views of planting and access to site amenities can enhance the work environment. This LEED Platinum-certified renovation of a 1970s tower was commissioned through GSA's Total Building Commissioning program.

Image credit: Nic Lehoux

PROJECT BACKGROUND

The U.S. General Services Administration (GSA) is a proven leader in sustainability. The agency's adoption of cutting edge sustainability rating systems and commitment to performance benchmarks has—through demonstrated success and economies of scale—positively contributed to the current “green” movement within the design, manufacturing, and construction industries. This groundswell has largely centered around buildings. However, GSA's 2016 adoption of the Sustainable SITES Initiative (SITES) will broaden the discussion of sustainability to encompass land development. In recognition of GSA's sustainability leadership role, the agency is considering the development of a site commissioning process that could expand this sphere of influence to positively impact the site design, manufacturing, and construction industries while advancing progressive landscape stewardship practices.

At its core, *commissioning* is a process in which performance goals are established and then measured and verified over time. The versatile practice has been utilized for purposes ranging from the ancient Roman design of arches, to preparing naval ships for active service, to trouble-shooting problems on oil rigs. In the 1970s, commissioning of select building systems—such

as heating, ventilation, and air conditioning (HVAC)—gained popularity, largely due to life-cycle cost and warranty benefits. The concept of commissioning expanded in the late 1980s to include whole buildings, and in 1995, GSA initiated its own commissioning program with the publication of its first *Building Commissioning Guide*. Since this time, GSA's interest in commissioning has shifted from cost and warranties to the triple bottom line: people, planet, and profit.

The adoption of SITES, which establishes performance measures to assess the long-term impacts of land development on both environmental and human health, supports GSA's current triple bottom line approach to commissioning. A comprehensive site commissioning process would integrate the performance measures established in SITES (for water, soil, vegetation, materials, human health, and climate), along with habitat, with GSA's land development processes, from a facility's planning phase through long-term management.

As one of the world's largest and most diversified public real estate organizations, site commissioning offers GSA's decision makers an effective and efficient process for ensuring that the agency's extensive properties are performing as intended. The significance of these benefits is paramount in an era when sites must function as ecosystem services

INTENT: TO EXAMINE THE FEASIBILITY OF DEVELOPING + IMPLEMENTING A SITE COMMISSIONING PROCESS FOR GSA'S NEW CONSTRUCTION + MAJOR REDEVELOPMENTS

workhorses; building and site systems are becoming increasingly integrated; and capital budgets may become less predictable and secure. Furthermore, site commissioning offers a valuable adaptive feedback loop approach in which the successes and shortcomings of GSA's built projects can provide data for shaping future developments and managing risk.

This white paper examines the feasibility (*see chapters 2-3*) and offers a strategy (*see chapters 4-6*) for GSA to expand and develop its current, agency-wide Total Building Commissioning program to include sites for all new construction and major redevelopments. This white paper's primary objectives are to:

- Determine if site commissioning is feasible, cost effective, and desirable for GSA projects.
- Develop an expansive, actionable, and cost-effective model for site commissioning that

addresses site elements that relate to ecological services and other relevant factors (e.g. life safety, cost effective maintenance, first cost, and life cycle cost considerations).

- Develop a broad, site-focused list of commissioning elements that identify critical features and define the utility, the present feasibility, the commissioning method, and the net triple bottom line benefit of commissioning these elements.
- Identify strategies for “balancing” under-performing site systems, or minimizing the chances of under-performance.
- Identify a clear and concise “scope of services” for commissioning site elements, as well as an opinion on what type of commissioning agent would be most able to provide these unique services.

Image credit: James Steinkamp of James Steinkamp Photography



A satellite map of the United States with a yellow dashed line tracing a path across the country. Five white callout boxes with black text are overlaid on the map, each with a pointer directed towards the central United States. The boxes contain questions about site commissioning feasibility, model development, agent selection, system balancing, and identification of commissioning elements.

IS SITE COMMISSIONING **FEASIBLE,**
COST EFFECTIVE + DESIRABLE?

CAN AN EXPANSIVE, ACTIONABLE,
COST-EFFECTIVE **MODEL FOR**
COMMISSIONING BE DEVELOPED?

WHICH **COMMISSIONING AGENTS**
COULD PROVIDE THESE SERVICES?

CAN SITE SYSTEMS BE **“BALANCED”**
DURING POST-CONSTRUCTION
IF UNDER-PERFORMING?

WHICH BROAD SITE-FOCUSED
COMMISSIONING ELEMENTS
CAN BE IDENTIFIED?

DEFINING “SITE”

Sites are dynamic environments that encompass much more than “dirt and plants.” This white paper defines *site* as the complete area within a design-construction project’s defined boundaries, beyond the building extents. This includes all outdoor areas that are natural and constructed, vegetated and non-vegetated, on structure (i.e. vegetated roof) and off structure. The term *site* is synonymous with *landscape*.

Sites are, in part, living systems, teeming with microbial life and vegetation that respond to management practices, weather events, and climatic variation. Healthy sites provide ecosystem services (see *Ecosystem Services*, p. 16) and can be strategically designed, built, and managed to maximize the delivery of these services, even within dense, urban environments. Under the surface, constructed sites may support complex assemblies of native or engineered soils, geotextiles, stormwater storage materials, hydrologic conveyance infrastructure, irrigation components, reinforcement layers, structural footings, and utilities (e.g. electrical, telecom, gas). Above ground, sites may support roads, walkways, plazas, seating, walls, fencing, lighting, planting beds, rain gardens, bioswales, basins, and natural areas such as water bodies, wetlands, meadow, forest, plains, and desert.

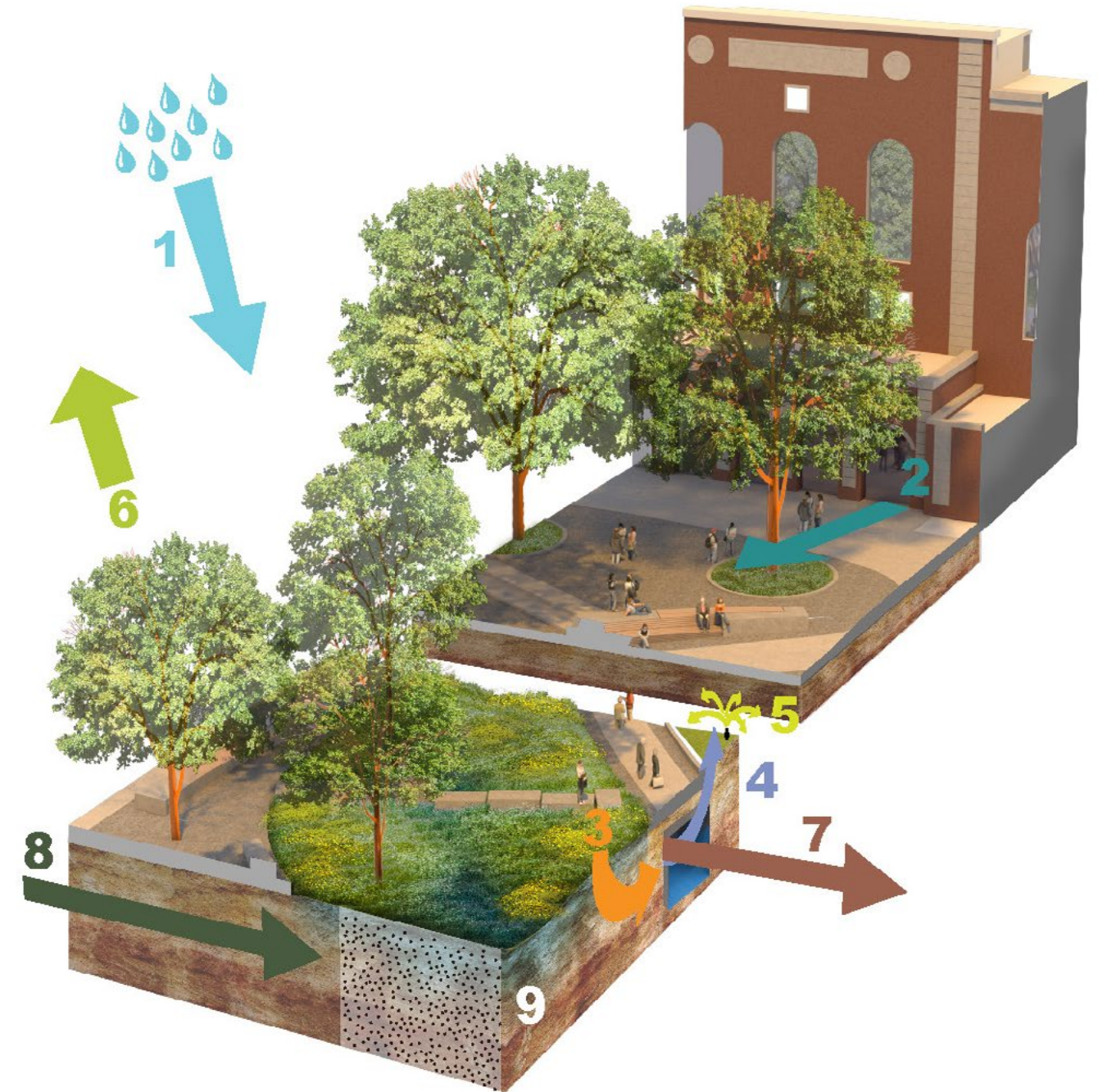
The design and management of sites supports green jobs and contributes to the economy. According to

a 2017 report, more than 64,000 people provide landscape design services within the U.S., an industry valued at \$5 billion per year.¹ The landscape care and maintenance services industry is even larger, with more than 1 million employees and annual revenues of \$83 billion, according to another 2017 report.²

The visual and functional divisions between site and buildings are becoming blurred within today’s progressive, sustainable design community. Visual integration of a site and the architecture within it is often achieved through topographic modification, material continuity, and strategic geometry of site features (e.g. plaza, seat wall, planting bed). Functional integration of site and architecture may involve building shading with plant material, connected hydrologic systems, and purposeful views of the site from within a building. When site and building design is integrated, the performance of site-building systems—such as a site irrigation system supplied by harvested roof runoff—may similarly become interdependent.

Sites, or their sub-systems, may be considered *high-performance* when meeting or exceeding baseline regulatory requirements, and also serving additional design and operational functions such as mitigating risk, adapting to environmental change, maximizing ecosystem services, contributing to social benefits, or providing a high cost-benefit.

¹ IBISWorld, NAICS 54132 (2017)
² IBISWorld, NAICS 56173 (2017)



Opposite: Hydraulic movement of an integrated site-building system that depends upon the constructed site’s above-ground and sub-surface components to manage stormwater.



2. CURRENT COMMISSIONING ENVIRONMENT

The expansion and modernization of the 55-acre Mariposa Land Port, in Nogales, AZ, demonstrates how commissioning can occur during the phased redevelopment of an active port. The LEED Gold-certified project relied upon building commissioning to meet the requirements of LEED 2.2 and achieve sustainability and security goals, without compromising safety.

Image credit: Bill Timmerman

CURRENT COMMISSIONING GAP

GSA has applied a Total Building Commissioning process to all of its new construction and major renovation projects since 2006. The agency adopted the National Conference on Building Commissioning's definition of Total Building Commissioning, which is a "systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel."¹ This definition recognizes the integrated nature of building systems performance—such as building envelope and automatic temperature control—which together influence sustainability, workplace productivity, and security. When these building systems are installed, calibrated, and monitored through a commissioning process, building owners tend to experience significant operations and maintenance savings.

When systems are bounded within the building, their evaluation is similarly contained. But how does the commissioning framework adapt to building systems that are integrated with the site? Design, particularly in urban settings, is by necessity shifting toward more integrated site-building solutions, in which stormwater runoff, building envelope performance, and even wastewater systems are addressed holistically, rather than relying on separate solutions for building and site. Unlike relatively static building systems, however, the site contains dynamic, vegetated, and soil systems that respond to climate, weather, and management.

Bridging the commissioning gap that surrounds dynamic, living site systems—by establishing performance standards, conducting monitoring, and calibrating the systems over time—presents a unique opportunity that stands to significantly affect GSA's triple bottom line.

SITE COMMISSIONING'S TRIPLE BOTTOM LINE BENEFITS

The triple bottom line is an accounting framework that assumes the true cost of doing business can be accurately understood only when social, environmental, and economic performance is measured. This concept of people, planet, and profit—or the "three Ps"—has been widely adopted by companies and organizations globally that aim to analyze their performance within a broader context by understanding their impact beyond financial profit. It's imperative that GSA understands that site commissioning can help the agency realize critical triple bottom line benefits, by shepherding goal development and verifying performance throughout a facility's lifetime. Monetization of these benefits is discussed later in this white paper (see *Ecosystem Services Valuation*, p. 26).

People: Depending on a facility owner's goals, site commissioning can help achieve increased employee health and well-being, productivity, satisfaction, and retention (from views of greenery and access to fresh air); improved safety and security (by reviewing and responding to incident reports); and educational benefit (from working in a sustainably designed environment).

Planet: Site commissioning can verify environmental performance, thereby meeting a facility's goals related to stormwater management, stewardship, wildlife habitat provision, carbon sequestration, and energy conservation.

Profit: Site commissioning can help lower a facility's life-cycle costs by protecting capital, operational, and human capital investment. Effective design, reduced construction errors, under-performance remediation prior to turn-over, efficient site management, and supported links between facility design and employee retention and productivity can result from the process' ability to manage risk and enhance quality control.

Many of site commissioning's triple bottom line benefits are interconnected. For example, views of a healthy landscape (planet) influence employee satisfaction and productivity (people), which in turn leads to less employee turnover and higher revenue (profit).² Similarly, a wisely designed stormwater management strategy can lead to water use savings and reduced stormwater fees. Recognizing this complex web of inter-related attributes is paramount to recognizing site commissioning's comprehensive benefits.



PEOPLE



PLANET



PROFIT



Top: Interdependent site-building systems;
Bottom: Site commissioning's triple bottom line benefits

1 General Services Administration (2016)

2 Terrapin Bright Green LLC (2012)

ECOSYSTEM SERVICES

services

- stormwater management
- heat island mitigation
- habitat provision
- resilience
- aquifer recharge
- biodiversity
- pollination
- nutrient cycling
- climate regulation
- air purification
- water purification
- carbon sequestration
- flood control
- erosion control
- pest control

regulating

- climate
- flood
- water quality
- disease...

to provide

- food
- clean water
- wood + fiber
- fuel...

social benefits

- aesthetic
- spiritual
- educational
- recreational...

CONSTITUENTS OF WELL-BEING



ECOSYSTEM SERVICES

The quality of human life relies upon ecosystem services that are provided by the natural and built environment. As populations continue to increase and urbanize, these services—from pollination to water cleansing to access to nature for all citizens—become increasingly important, yet more complex to sustain. Recently, a global trend has emerged involving the quantification of ecosystem services, which encompass both environmental and social services, and using the resulting data to guide land development decisions. This quantification helps convey, as well as advocate for, the multifaceted value of high-performing site systems. Additionally, the public policy decision-making process is strengthened by evaluating the challenges and opportunities of different development scenarios and their potential to contribute to ecosystem services.

Defining “Ecosystem Services”

Ecosystem services are generally categorized into four different groups: 1) Provisioning, which consists of goods delivered by ecosystems (e.g. food, water, wood, medicine); 2) Regulating, which captures ecosystem benefits (e.g. climate regulation, water purification, pollination, erosion control); 3) Cultural, which reflects the social benefits (e.g. tourism, recreation, spirituality); and 4) Supporting, which refers to ecological functions that sustain other services (e.g. biodiversity, habitat).^{1,2} Ecosystem service computer models, such as UFORE, i-Tree, and C-BAT, help quantify various measurable, direct benefits of ecosystem services (such as carbon sequestration in tons of CO₂ per year) while also estimating economic values (such as avoided costs). These tools help provide a more holistic perspective of the cost-benefit of different land development and management.

Why evaluate?

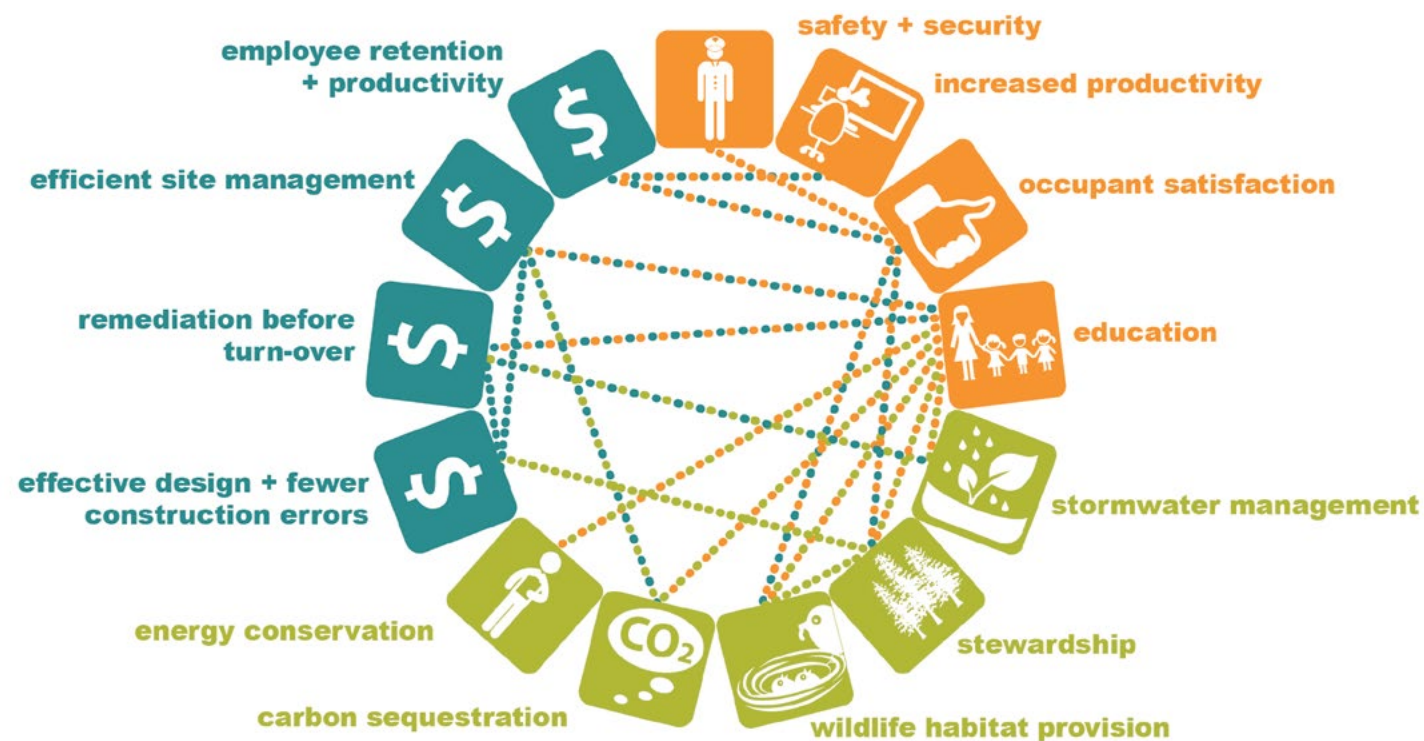
Assessing and quantifying ecosystem services is becoming common practice for large land owners across the world—from China to Latin America—and within the U.S. government, including the U.S. Forest Service and Department of Defense.³ These evaluations can be powerful decision making tools by helping to balance goals with a diverse group of stakeholder types, communicating the value of different landscape types and management regimens, and most importantly, helping land owners save money and support their unique institutional missions.

Applicability to GSA

Determining which ecosystem services to evaluate for any given site depends upon regional context, specific community needs, and goals. For example, GSA's needs for an urban courthouse in the rainy Pacific Northwest would differ from those of a port of entry in a southwest desert. Across all facilities, however, economic drivers (including cost avoidance and return on investment) offer the most convincing and influential support for fostering ecosystem services. These cost considerations within the built environment include:

- Decreased energy costs from cooling provided by vegetation during hot weather
- Water purification by natural systems, compared to energy-consuming mechanical or engineered systems
- Reduced healthcare costs resulting from improved employee health and well-being
- Reduced carbon tax payments through increased carbon sequestration
- Mitigation of emergency repair costs through protection from flooding and landslides
- Other risk avoidance and insurance claim reduction (for leased facilities) related to protection from extreme weather events
- Cost savings through increased durability of built systems, such as green roofs extending the life service of roofing material
- Reduced payment for goods that can be grown on site, such as edible food crops or site-milled lumber
- Enhanced social benefits, such as recreation, property values, increased worker productivity, job retention and aesthetics
- Increased workplace value through increased worker productivity and job retention by providing views and access to green space
- Increased property value from improved aesthetics
- Reduction of costs related to economic disservices, those ecosystem services that incur costs such as pests and disease, allergens, destruction of property, etc.⁴

These cost implications can inform a facility's goals and gain verification through site commissioning. The result will be data-driven proof of financial savings and increased protection of human health, safety, and welfare throughout the nation's natural and built environment.



¹ Millennium Ecosystem Assessment (2003)

² The Economics of Ecosystems and Biodiversity (2010)

³ Ma, et al. (2016)

⁴ Gómez-Baggerthun and Barton (2013)

Opposite (top): Ecosystem services and their influence on well-being;

Opposite (bottom): Site commissioning's interconnected triple bottom line benefits

International Performance Measurement + Verification Protocol (IPMVP)

IPMVP is an internationally-recognized compilation of best practices for verifying energy and water efficiency and cost savings. The Efficiency Valuation Organization publishes the reference document to increase investment in energy efficiency and renewable energy.

GSA's Total Building Commissioning

GSA's Total Building Commissioning process involves testing and verifying that all building systems perform in accordance with design intent and Owner's Project Requirements (OPR), from design to at least one year post-occupancy. A third party commissioning authority is typically engaged by the owner.

LEED BD+C v4

Leadership in Energy and Environmental Design (LEED) is a sustainability rating system for buildings, used by designers and consultants, developed and administered by the U.S. Green Building Council. LEED BD+C v4 is a version launched in 2012 with an expanded focus on metering and monitoring to track energy and water use and environmental quality during design, construction, and operations.

Sustainable SITES Initiative (SITES)

SITES is a point-based rating system used by designers, planners, and policy makers to develop sustainable landscapes. The SITES rating system is for land development projects with or without buildings to distinguish sustainable landscapes, measure their performance, and help quantify their value. It is administered by Green Business Certification Inc.

INDUSTRY-WIDE PERFORMANCE TRENDS

The American design, construction, and management industries demonstrate increasing commitment to the sustainability and performance of the built environment. This green building sector growth is both supported and driven by incentives, progressive regulation, and the adoption of an ever-increasing number of sustainability rating systems. Many of these rating systems have expanded in complexity over time, and in recent years some have moved away from relying upon design intent to evaluate sustainability and performance, towards a new model in which performance is tested and proven over time.

For example, Leadership in Energy and Environmental Design (LEED) is a rating system that, since its launch in 1998, has provided standardized methods for third-party verification of environmental performance in buildings. Sustained demand across market sectors has resulted in rating system diversification, which now supports five project types (e.g. interior design, neighborhood development, homes). To satisfy the

program's point system, LEED certification largely relies upon the completion of forms that document design decisions, such as material origin and anticipated stormwater performance. While this process fosters responsible use of resources, healthy living and work environments, reduced emissions, and lower operating costs, by 2010, several studies of non-GSA, LEED-certified buildings found that "up to a quarter of the buildings performed operationally below LEED energy codes and standards."¹ The 2012 launch of *LEED BC+D v4 Fundamental Commissioning and Verification* offered a solution to this under-performance quandary, by requiring the participation of a commissioning agent from design through 10-months post-occupancy. In 2013, a new *LEED BC+D v4 Enhanced Path 2: Enhanced Monitoring-Based Commissioning* offered the first opportunity in LEED's history for post-occupancy monitoring, and remediation of performance deficiencies, beyond the 10-month commissioning period.

GSA's commitment to high-performance buildings parallels these industry trends towards diversification,

¹ Richards (2012)

PROGRAM COMPARISON BY GSA'S DATE OF ADOPTION

PROGRAM	AGENT	ADOPTED	PHASE ENGAGEMENT					REQUIRED STEPS																					
			Pre-Design	Design	Construction	Post-Construction	Long-Term	Cx Authority Engagement	Owner's Project Reqs. Review	Basis of Design Review	Cx Plan +/or Specifications	Design Doc. Review	Submittal Review	Issues Log	Construction Checklist	Monitoring Methods	Site Visits + Meeting Min.	O&M Manual Review	Training	Recommissioning Manual	Performance Testing	O&M Manual Modification	Warranty Review	Test Result + Cx Reports	Post-occupancy Monitoring	Remediation			
International Performance Measurement + Verification Protocol	Qualified consultant beyond design team	1997- Vol 1 2000- Vol 3		X	-	X	-		X																				
GSA Total Building Commissioning	Qualified consultant beyond design team	2006	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
LEED BD+C V4 (Fundamental Commissioning + Verification)	Qualified employee or consultant	2012		X		X		X	X	X	X	X	X	X	X	X	X	X						X					
LEED BD+C V4 (Path 1: Enhanced Commissioning)	Qualified employee or consultant	2013		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
LEED BD+C V4 (Path 2: Enhanced + Monitoring-Based Commissioning)	Qualified employee or consultant	2013		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Sustainable SITES Initiative	Qualified consultant or design team	2016	X	X	X	X	X	X	X			X										X				X			

Opportunity to fill gap in owner training

Opportunity to fill gap in monitoring + remediation

X = Always required; -- = Sometimes required

IN RECENT YEARS, SOME RATING SYSTEMS HAVE MOVED AWAY FROM RELYING UPON DESIGN INTENT TO EVALUATE SUSTAINABILITY + PERFORMANCE, TOWARDS A NEW MODEL IN WHICH PERFORMANCE IS TESTED + PROVEN OVER TIME

performance verification, and general strengthening over time. In 2016, this commitment expanded to include site performance through GSA's adoption of the Facilities Standards for the Public Buildings Service (PBS-P100), which require that all new construction and significantly renovated projects achieve a minimum silver rating¹ through Sustainable SITES Initiative (SITES): the most comprehensive rating system for developing sustainable landscapes. SITES is a point-based system used by designers, developers, and policy-makers "to align land development and management with innovative sustainable design,"² and like other recent systems, the program requires post-occupancy monitoring.

of agent, phase engagement, required steps, owner's project requirements, engagement cost, and frequency additionally informs how a site commissioning process could potentially work in tandem with these previously-adopted programs, while filling certain gaps. The table includes examples of gaps that may be appropriately addressed by site commissioning, such as owner training and inclusion of maintenance requirements within the Owner's Project Requirements (OPR). The gaps within existing programs can serve as opportunities to build an even stronger site commissioning process, one which maximizes long-term performance and reduces remediation costs.

The table on the previous pages and below lists Total Building Commissioning, the International Performance Measurement and Verification Protocol (IPMVP), LEED BD+C v4, and SITES in chronological order based on each program's adoption by GSA. Comparing the programs in this way highlights similarities and discrepancies, while revealing nuanced shifts toward performance over time. This comparison

Comparing the GSA's previously adopted programs also underscores the project delivery coordination that's required to achieve multiple program benchmarks on a single project, particularly given the varied phases of engagement for each program. As the green building industry continues to diversify and become more rigorous, GSA's PM Guide (a comparative, organizational framework for the agency's many rating systems and performance benchmarks) will become increasingly useful.

¹ General Services Administration (2016)
² The Sustainable SITES Initiative (2017)

PROGRAM COMPARISON BY GSA'S DATE OF ADOPTION

PROGRAM	OWNER'S PROJECT REQUIREMENTS																			ENGAGEMENT COST			FREQUENCY
	Accessibility	Accoustics	Comfort	Constructability	Cost-Benefit	Design Excellence	Durability	Energy	Flexibility	Green Building / Materials	Health + Hygiene	Indoor Environment	Life Safety	Light	Maintenance	Security	Standards Integration	Structural Safety	Water	CxA Fees (% of Total Construction Cost)	Operations (% Annual Cost)	Maintenance (% Annual Cost)	Re-Cx (Months)
International Performance Measurement + Verification Protocol					X		X												X	Varies	Varies	Varies	Varies
GSA Total Building Commissioning	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		0.5-1.5 (PECI) 1.25-2.25 (NASFA)	(-) 8-20 (PECI)	(-) 15-35 (PECI)	36-60
LEED BD+C V4 (Fundamental Commissioning + Verification)							X	X				X							X	Unknown	Unknown	Unknown	10 (year 1)
LEED BD+C V4 (Path 1: Enhanced Commissioning)							X	X				X							X	Unknown	Unknown	Unknown	10 (year 1)
LEED BD+C V4 (Path 2: Enhanced + Monitoring-Based Commissioning)							X	X				X							X	Unknown	Unknown	Unknown	3 (year 1, then TBD)
Sustainable SITES Initiative										X	X			X					X	Unknown	Unknown	Unknown	Varies

Opportunity to fill gap in cost-benefit analysis

Opportunity to fill gap in maintenance requirements

Trend: increasing frequency

GSA'S CURRENT BUILDING COMMISSIONING PROCESS

To understand GSA's current building commissioning process, it's critical to first recognize the industry's four distinct commissioning types, which are largely defined by when the commissioning occurs relative to a project's lifetime. As shown in the chart on the following page, the first type, "commissioning," is applicable to new construction and major renovation projects. By definition it occurs once, either during construction or at substantial completion, and the evaluation method generally involves verification and functional performance monitoring. The second type, "recommissioning," involves periodic, functional performance monitoring and evaluation of a built project that was previously commissioned during construction or substantial completion. "Retro-commissioning" is a method of diagnostic and functional performance monitoring, generally of an older project, that occurs once to trouble-shoot a problem or periodically to establish a commissioning program. The last type, "continuous commissioning," relies upon regularly gathered or continuous feeds of data as part of an ongoing commissioning program for large, generally complex projects.¹

GSA requires building commissioning for all new construction and major renovations planned for 2006 or later, with scheduled recommissioning every 3 – 5 years (as defined by each project's OPR).² A limited retro-commissioning process is deployed for projects that received funding approval prior to 2005, in order to meet each project's performance objectives.³ This building commissioning process is intentionally integrated with GSA's project delivery procedures, from planning through post-construction. The following is adapted from GSA's Building Commissioning Guide:⁴

Planning: GSA's project manager is responsible for defining the commissioning scope, budget, and schedule within the project's feasibility study. Key to this is identifying the commissioning team, which typically includes GSA operations personnel, customer agency representatives, GSA technical experts, the design team (architect/engineer), construction team (manager/contractors), and commissioning agent. The OPR are then identified and documented, thereby providing critical performance benchmarks for the design and commissioning team moving forward. These decisions are captured within a preliminary commissioning plan that is periodically revisited.

Design: Building systems are designed with an

emphasis on meeting performance expectations, as defined by the OPR, from concept development to design documentation, and construction documentation. By the start of design documentation, the commissioning agent must be under contract (which is usually held by the construction manager), after which the agent will work closely with the design team. Additionally, performance verification tests and procedures will be incorporated into the contract documents, and the commissioning plan will be updated.

Construction: This phase begins with the review of submittals to ensure that performance parameters are met. Next, the commissioning agent prepares construction checklists that are maintained by the construction manager. As construction progresses, functional performance testing and documentation of each commissioned system provides baseline data that is critical to future recommissioning. Qualified instructors then train GSA operations and maintenance personnel in building system upkeep and adjustment. Before substantial completion, the team submits a Commissioning Record Document and Recommissioning Management Manual to the owner.

Post-Construction: To maintain expected system performance throughout the building's lifetime, this phase allows for continued adjustment and optimization. Deferred and seasonal testing occurs, and the commissioning agent submits a Final Commissioning Report. Lastly, the GSA project manager leads a final satisfaction review with the customer agency at one-year post-occupancy, and then the customer agency will recommission the facility.

APPLICABILITY TO SITES

A successful site commissioning process would integrate into GSA's well-established building commissioning program, rather than reinventing the wheel. Key to this process would be introducing a landscape architect along with the core design team during planning, to help refine the OPR and develop fully-integrated, site-building system solutions. This process would also involve broadening the OPR to include benchmarks for site performance, such as water use. Since living systems are inherently more dynamic than building systems, dedication to post-occupancy monitoring would be critical in verifying that the owners performance expectations are maintained during the project's lifetime. This white paper will explore the considerations surrounding an integrated site-building, or "Total Commissioning" process.

BUILDING COMMISSIONING TYPES

TYPE	APPLICATION	FREQUENCY	METHOD
Commissioning	New construction or major renovation	Once, during construction / substantial completion	Verification + functional performance monitoring
Recommissioning	Project that was commissioned during construction	Periodically, as part of the owner's O+M program	Functional performance monitoring
Retro-Commissioning	Old project with high operating expenses + frequent system failures	Once, to address a problem, or periodically to establish a program	Diagnostic + functional performance monitoring
Continuous Commissioning	Large, complex project with frequent tenant complaints	Periodically, as part of the owner's O+M program	Data monitoring + trending

Image adapted from Energy.gov.¹

HOW DOES **SITE COMMISSIONING** DOVETAIL INTO THIS PROCESS?

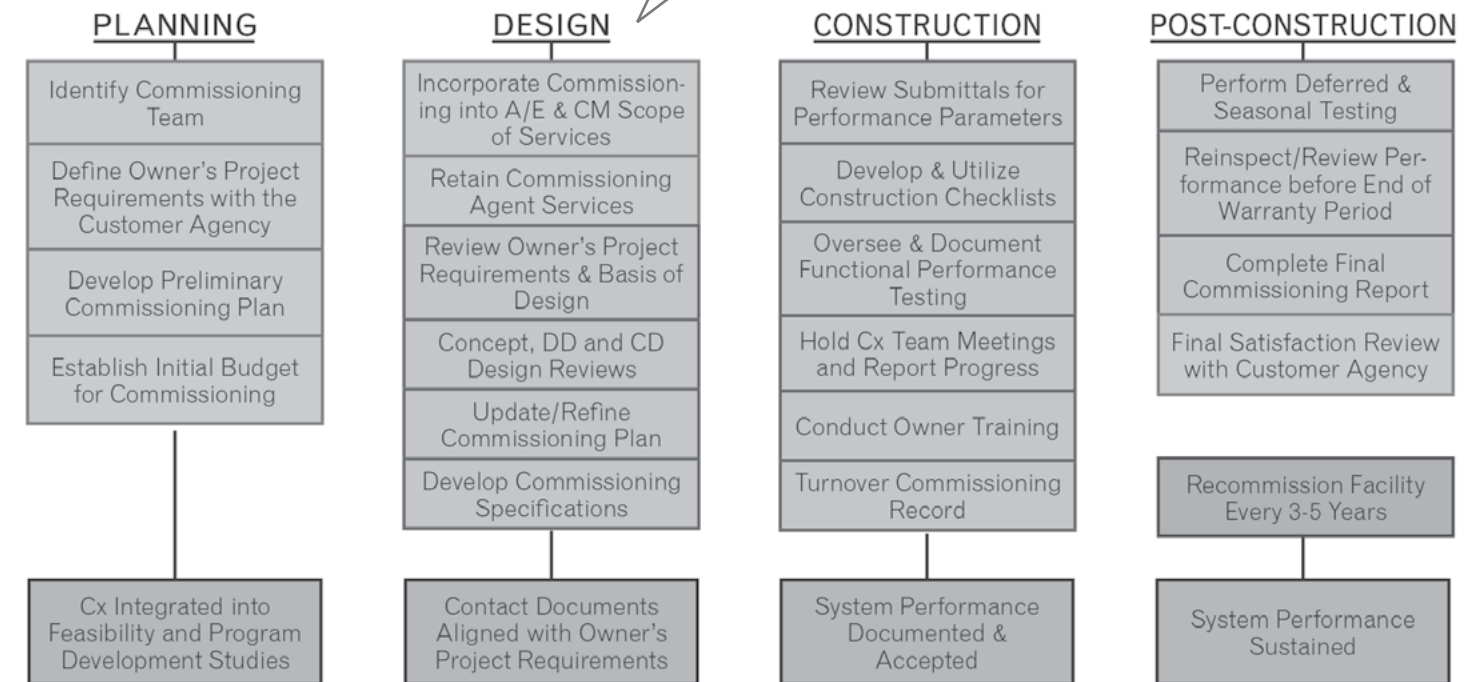


Image credit: GSA Building Commissioning Guide²

¹ Office of Energy Efficiency & Renewable Energy (2016)
² General Services Administration (2005)
³ General Services Administration (2005)
⁴ General Services Administration (2005)

¹ Office of Energy Efficiency & Renewable Energy (2016)
² U.S. General Services Administration, Public Buildings Service, Office of the Chief Architect (2005)



3. MAKING THE CASE

GSA's 32-acre U.S. Coast Guard Headquarters at Saint Elizabeths West Campus, in Washington D.C., demonstrates a high-performance approach to campus design that integrates building and site systems. This LEED Gold-certified redevelopment, completed in 2013, underwent a total building commissioning process.

Image credit: Anice Hoachlander / Hoachlander Davis Photography

DIRECT SAVINGS

Building commissioning's cost-benefit analysis is relatively well studied by researchers, who largely agree that the process can pay for itself when applied to new construction.¹ The same level of rigor, however, has not yet been applied to site commissioning. In the absence of peer-reviewed literature on the subject, relevant information from building commissioning and ecosystem services valuation studies can inform a more thorough understanding of site commissioning's anticipated savings, costs, and payback. A general discussion of social, environmental, and financial benefits appears earlier in this white paper (see *Site Commissioning's Triple Bottom Line Benefits*, p. 13), whereas this section focuses specifically on monetized findings from the literature.

Facility Life-Cycle Cost Savings

Commissioning can protect capital and operational investments by providing quality control, risk management, and evidence-based assurance that facilities are delivered and managed to achieve intended performance goals. GSA owns and leases nearly 150,000 acres, which support approximately 9,600 buildings² and more than 25-acres of vegetated roofs³ nationwide. Multiplying the following savings—from planning through management—across just a fraction of this portfolio equates to significant cost avoidance for GSA, and direct savings for tax payers.

During a facility's planning phase, commissioning can help reduce a facility's life-cycle costs by supporting the development of goals that target material durability and system longevity. These goals can prove key in validating higher upfront investment in durable materials and systems, for the benefit of decreasing a facility's life-cycle costs. For example, a comprehensive 2011 study by GSA found that while vegetated roofs require increased construction and maintenance costs compared to non-vegetated roofs, the infrastructure's longevity offsets these expenditures.⁴ The study estimates the conservative payback of a typical vegetated roof to be 6.2 years in the U.S., based on the assumption that the average non-vegetated roof has a life expectancy of 17 and a vegetated roof extends the roof waterproofing's life to 40 years on average⁵ (due to protection from ultraviolet radiation and freeze-thaw). Vegetated roofs can provide additional financial benefits, such as downsizing stormwater management infrastructure elsewhere on the site and enhancing views for employees (see *Employee Retention and*

Performance, p. 26).

During design and construction, commissioning can be an effective tool in detecting and resolving problems, thereby avoiding unnecessary capital expenditures. One study found that commissioning resulted in cost savings of \$319,000, \$400,000, \$425,000, and \$500,000 in four newly-constructed, high-tech buildings by eliminating change orders, eliminating requests for information, properly selecting systems and system components, reducing contractor callbacks, and accelerating substantial completion dates.⁶ Another research effort that analyzed six buildings similarly found that commissioning reduced change orders by 87% and contractor callbacks by 90%.⁷ In fact, the largest meta-analysis of published building commissioning data, from 2011, suggests that the cost of commissioning new construction should be recovered through cost savings during project delivery alone.⁸

At the end of a facility's construction phase, if the general contractor turns over a *fully-functional* facility to its owner, liability disputes associated with inoperable systems and under-performance, as well as the cost of remediation, can be minimized. One commissioning expert provided expert testimony stating that claims in twelve buildings—totaling \$60 million—could have been avoided if commissioning was properly implemented.⁹ In 2016, a GSA Regional Horticulturist Team Lead corroborated this notion, for sites, when reporting that a lack of quality control surrounding site transfer from general contractor to owner, “has contributed to the turnover of failed systems in the form of inoperable cisterns, faulty irrigation systems and failed green roofs... [resulting in] added costs for GSA due to the need to replace, repair, and rebuild systems.”¹⁰ Commissioning sites in addition to buildings, through Total Commissioning, would likely minimize these failures and their remediation costs by turning over facilities only after meeting performance benchmarks. In fact, the data suggest that savings rise with increasingly comprehensive commissioning. The 2011 meta-analysis found that projects with a more comprehensive commissioning process attained nearly twice the overall median level of savings of all commissioned projects in the study, and five times the savings of the least-thorough commissioning projects.¹¹

The 2011 meta-analysis also found that once a facility is occupied, energy efficiency constitutes one of the primary quantifiable operational cost

savings of building commissioning.¹² The study found a 16% median energy savings for commissioned existing buildings and 13% for new construction, relative to non-commissioned buildings.¹³ A national study performed every four years by the federal Energy Information Administration found that LEED-certified buildings often exceed this performance, with the median energy use intensity (kBtu/sf/yr) for commercial and office buildings as 24% and 33%, respectively, lower than non-certified buildings of the same type.¹⁴ While energy benefits are explored in many studies, non-energy benefits are often the primary reason for commissioning projects, yet only a few of these benefits has been rigorously quantified. A 2003 study by SBW and Skumatz estimated that the average annual non-energy commissioning benefits were \$0.26 per square foot for existing buildings and \$0.17 per square foot for new construction.¹⁵ For most sites, these monetized, non-energy benefits would constitute the majority of total potential savings offered by commissioning.

The literature suggests that operations and maintenance training associated with site commissioning procedures (particularly during design and construction) may result in less troubleshooting during the first year of occupancy, as well as increased operational efficiency overall. One such study found that the average operating costs of commissioned buildings ranged from 8 – 20% below that of non-commissioned buildings, while maintenance costs, specifically for commissioned office buildings, resulted in 15 – 35% savings.¹⁶

Employee Retention + Performance

Human capital is typically an employer's most valuable resource. Using commissioning to shepherd and verify goals that protect employees, their productivity, and satisfaction is therefore the single most effective way that commissioning can impact an employer's bottom line. According to a 2010 BOMA report that used 2009 U.S. Department of Labor data, the majority of corporate square foot costs, nationally, are devoted to salaries (90.3%), while a relatively small amount is used for rent and mortgage (8.9%) and even less for energy (0.8%).¹⁷ Absenteeism is prevalent in all sectors, and in the public sector, the average absentee rate is 4% (or more than 83 hours per year) valued at a \$2,502 average loss per employee.¹⁸ For a facility with 1,000 employees, this rate equates to an annual loss of \$2.5 million. Studies indicate that views of nature and access to fresh air at the workplace decrease

absenteeism, while increasing employee efficiency and retention, by directly impacting physical health and well-being.¹⁹ Exposure to these elements—which can be achieved through biophilic design of sites and buildings—can lower blood pressure, improve stress recovery rates, enhance mental stamina and focus, improve cognitive functions, increase learning rates, and elevate mood, as demonstrated by case studies from the past 25 years.²⁰ A 2011 study by Elzeyadi found that the architecture of an administrative office building in Oregon accounted for a 10% variation in employees' sick leave, and that the quality of an employee's view was the number one predictor of absenteeism.²¹ Increased occupant productivity represents another cost benefit of site commissioning. One study related to commissioned buildings reported 10 – 20% higher worker productivity compared to non-commissioned buildings.²² A growing body of research suggests that views of a green outdoor environment improve worker productivity, and one study found the views to be a determinant of work ability and job satisfaction.²³ Providing effective biophilic design, programming, and view-sheds requires significant coordination between the site and building design; a more comprehensive commissioning approach can further this process by shepherding and verifying intertwined goals that impact human health and happiness, and in turn, the bottom line.

Municipality-Driven Savings

Local incentives throughout the U.S. offer opportunities for additional savings. Utility rebate programs, for example, increasingly provide incentives to verify and document improved performance. A 2011 study of commissioned projects nationwide found that partial or full utility rebates were received in 84% of existing building projects, and 68% of new construction.²⁴ Using commissioning to establish and verify goals that enhance a facility's environmental sustainability can result in additional savings from expedited regulatory approval and stormwater fee reductions, in cities such as Philadelphia, PA and Portland, OR. In Washington D.C., a project's Stormwater Retention Credits (SRCs) can be sold annually as a means of revenue (<https://doee.dc.gov/src>). A recent, GSA-funded study by the University of Maryland and the Landscape Architecture Foundation estimated that the GSA's U.S. Coast Guard Headquarters at St. Elizabeths West Campus will earn 89,667 SRCs based on green roof area and planted trees alone.²⁵ The implementation of carbon credit trading programs could yield similar financial benefit.

1 Mills (2011)
2 U.S. General Services Administration (2016)
3 U.S. General Services Administration (2011)
4 U.S. General Services Administration (2011)
5 U.S. General Services Administration (2011)

6 Dorgan, et al. (2002)
7 Altweis (2002)
8 Mills (2011)
9 Nelson (1999)
10 Alonso (2016)
11 Mills (2011)

12 Mills (2011)
13 Mills (2011)
14 Turner & Frankel (2008)
15 Mills, et al. (2004)
16 Ellis & Reilly (2015)
17 Terrapin Bright Green LLC (2012)
18 U.S. Department of Labor (2010)

19 Terrapin Bright Green LLC (2012)
20 Terrapin Bright Green LLC (2012)
21 Terrapin Bright Green LLC (2012)
22 Lottrup, et al. (2015)
23 NGA Campus East (2013)
24 Mills (2011)
25 Ellis & Reilly (2015)

INDIRECT SAVINGS

Ecosystem Services Valuation

By expanding GSA's commissioning program to sites, the agency could gain the additional benefits of verifying that sites support key ecosystem services. Ecosystem services offer value that is not directly or explicitly tied to existing markets. Instead, they provide significant secondary financial, social, and environmental benefits. These indirect benefits can take the form of avoided costs, replacement costs, factor income (added value to incomes), travel cost, hedonic pricing (indirect payment for goods or services), and contingent valuation (hypothetical alternative scenarios).¹ For example, a 2005 study found that municipalities across the United States have spent \$13-65 annually per tree, yet gained the added value of \$31-89 per tree (a \$1.37 to \$3.09 annual return per tree) due to indirect benefits such as avoided stormwater runoff, temperature regulation and energy savings, air purification, and property value increases.² Other indirect benefits of ecosystem services include: noise reduction, pollution removal, pollination, carbon dioxide reduction, promotion of cultural identity and social resilience, recreation, habitat, food supply, and avoided health, legal, and maintenance costs.

Risk Mitigation

Particularly relevant to the GSA's build-to-own model, site commissioning could help the agency reduce its avoided and replacement costs by verifying that sites have the resiliency and adaptive capacity to withstand often unpredictable weather-related events. Avoided costs in the realm of resiliency can thus be tied to reducing vulnerability and mitigating risk.³ These benefits include reducing the probability of and vulnerability to: landslides, storm surges, flooding, heat waves, drought, and pollutant exposure. In fact, some insurance companies recognize commissioning's propensity to manage risk, and a 2004 study reported that at least one insurer offered a 10% premium credit for participation in training related to commissioning.⁴

The value the site can provide in mitigating risk and reducing vulnerability is regionally specific, as not all sites are located in a coastal community, in landslide-prone areas, or in the arid southwest, for example.

1 deGroot, et al. (2002)
 2 McPherson, et al. (2005)
 3 Gómez-Baggethun & deGroot (2010)
 4 Mills, et al. (2004)

Although currently there is an "insurance value gap" in ecosystem service valuation data, there are some compelling studies that highlight the importance of the site in mitigating risk.⁵ A study conducted in Phoenix looking at the urban heat "riscscape" over 30 years of data found that vegetation provided 25 degrees Celsius of cooling on summer days, a significant economic, environmental, and social benefit to this community. However, the study also found that there are trade-offs with the benefits of vegetation, such as irrigation demand in this water-vulnerable community, highlighting the importance of choosing low-maintenance vegetation.⁶

The example of the "riscscape" study in Phoenix highlights that, although the secondary benefits of ecosystem services can be substantial, they must also be weighed with other considerations, such as ecosystem disservices (infrastructure damages, carbon emitted through management, allergies, irrigation demand, etc.). Another such example is the impact of trees on urban heat islands and carbon balance throughout different cities in the United States. Although trees are noted in numerous studies as being one of the most efficient means of reducing urban heat islands and avoiding carbon emissions and energy costs, a 2016 study found that from the nursery to disposal, planted trees can take 26 to 33 years to become carbon neutral.⁷ The range depends on the species and the intensity of maintenance (pruning practices can have the greatest impact on emissions). This study highlights that plant selection and management have a profound impact on ecosystem services and the significance of tree preservation.

The indirect benefits of ecosystem services at the site scale are an important factor in the value they have for the land owner, site user, and the general public. Furthermore their impacts are closely tied to all phases of project implementation, from pre-design and planning through management. For this reason, the indirect impacts of ecosystem services should be considered a significant parameter of a site commissioning framework in addition to direct benefits. Monitoring these services, particularly those closely tied to risk mitigation, should be a critical component of a site commissioning effort.

5 McPherson et al. (2005)
 6 Jenerette & Steganov (2011)
 7 Petri, et al. (2016)

COMMISSIONING COSTS

Direct Costs

According to the largest meta-analysis of published building commissioning data, from 2011, "the median normalized cost to deliver commissioning is \$0.30/ft² (\$2009 currencies) for existing buildings and \$1.16/ft² for new construction (or 0.4% of the overall construction cost)".¹ Predating this study, GSA's Building Commissioning Guide projected that commissioning budgets would vary by project type; as a percentage of construction cost, federal buildings and border stations could cost 0.5% to commission, more complex projects, like courthouses, 0.8 – 1.0%, and the most complex projects could exceed 1.0%.² Beyond the project type itself, variables that could sway the costs included phasing operations in a continuously operational facility; the depth and breadth of desired commissioning services; and types of systems slated for commissioning.

These same factors could similarly influence the cost of site commissioning, although project complexity and scale—rather than facility type (e.g. courthouse)—would more likely drive the overall commissioning budget. As site complexity and size increase, the overall cost of commissioning is also likely to increase. However, a caveat is that certain large site features (e.g. central stormwater wetland) may be less expensive to commission than multiple smaller elements (e.g. scattered stormwater wetlands) even if, in total, they equal the size of the large feature. GSA has observed this phenomenon with building commissioning, and the principle similarly applies to sites.

The primary components of commissioning costs relate to design fees, contractor costs, and commissioning agent fees. As a percentage of

1 Mills (2011)
 2 General Services Administration (2005)
 3 Portland Energy Conservation, Inc. (2002)

construction cost, the designer's commissioning scope (which typically includes meetings and document review) generally ranges from 0.01 – 0.03%; the contractor's scope (involving meetings, documentation, construction checklists, and testing assistance) often equals 0.05 – 0.375%; and the commissioning agent scope generally falls within 0.5 – 1.5%.³ For total building commissioning, however, the National Association of State Facilities Administrators suggests budgeting even more, 1.25 – 2.25%, for the commissioning agent's fee.⁴ Additionally, budgeting a slight amount for the owner to attend commissioning meetings, review documents, and attending trainings is often prudent. While these costs are specific to building commissioning, their relative magnitudes are applicable to site commissioning within the context of a site (rather than building) construction budget. For facilities with intensely integrated building and site systems, a blended rate may be appropriate for cost estimation.

Payback

Expenditures beyond a traditional construction budget are often difficult to justify. However, studies increasingly demonstrate that the benefit of commissioning outweighs the cost. In fact, a 2004 study prepared by the Lawrence Berkley National Laboratory found the median payback period for commissioning existing buildings to be only 0.7 years, and for new construction, 4.8 years.⁵ This assessment is based on energy savings alone, so the payback period could be even shorter if combined with non-energy related savings. It's important to note, however, that each facility's payback period will vary depending on the cost of both construction and commissioning.

4 National Assoc. of State Facilities Administrators (2012)
 5 Mills et al. (2004)
 6-8 Portland Energy Conservation, Inc. (2002)
 9 National Assoc. of State Facilities Administrators (2012)
 10 Amount estimated by this white paper's research team

TYPICAL BUILDING COMMISSIONING COSTS BY TEAM MEMBER

TEAM MEMBER	TYPICAL SCOPE	COMMISSIONING FEE (% of construction cost)	EXAMPLE OF FEE (\$20M construction cost)
Designer	Meetings, document review	0.03% - 0.05% ⁶	\$6,000 - 10,000
Contractor	Meetings, documentation, construction checklists, system testing assistance	0.05 - 0.375% ⁷	\$10,000 - 75,000
Commissioning Agent	Meetings, feasibility studies, document review, testing protocol development, system testing, documentation, coordination, owner training	0.5 - 2.25% ^{8,9}	\$100,000 - 450,000
Owner	Meetings, document review, training	0.05% ¹⁰	\$10,000

CASE STUDY MATRIX	1	2	3	4	5	6
		Edith Green-Wendall Wyatt Federal Building	Mariposa Land Port of Entry	Benjamin P. Grogan and Jerry L. Dove Federal Building	U.S. Coast Guard Headquarters at Saint Elizabeths	The Clark Art Institute (<i>non-GSA project</i>)
Project Statistics						
GSA District	Northwest 10	Pacific Rim 9	Southeast 4	Northeast 11	New England 1	Northeast 11
Facility Type	Office Building	Port of entry	Office Building	Campus	Campus	Park
Total Acreage	1-acre	55-acres	24-acres	32-acres	140-acres	3-acres
Project Delivery	Integrated delivery	Design-bid-build	Design-Build	Design-build	Design-bid-build	Design-bid-build
Completion	2013	2014	2014	2013	2014	2012
Development Method						
New Construction		X	X	X	X	
Renovation	X				X	
Redevelopment		X				X
Commissioning Type						
Commissioning	X	X	X	X	X	
Recommissioning					X	
Retro-Commissioning					X	
Continuous Commissioning	X			X		X
Commissioned Building Systems						
Automatic Controls*				X		
Building Envelope*			X	X		
Communications	X					
Plumbing*	X	X	X	X	X	
HVAC*		X	X	X		
Electrical*	X	X	X	X		
Safety + Security*		X	X	X		
Specialties*				X		
Commissioned Site Systems						
Automatic Controls					X	
Irrigation					X	X
Plumbing					X	
Soils						X
Stormwater				X	X	X
Vegetation				X		X
Wastewater					X	

* = System included in GSA's Building Commissioning Guide¹

1 General Services Administration (2005)

CASE STUDIES

GSA's scale provides the agency the unique opportunity to demonstrate good stewardship of both taxpayer dollars and natural resources within the built environment. The following case studies exemplify the way in which commissioning can be leveraged to achieve these critical goals. The case studies showcase commissioning impacts for projects across a diversity of geographic locations, facility types, land areas, and project delivery approaches to provide a representative survey of commissioned, recommissioned, and retro-commissioned projects. The selection weights building commissioning more heavily than site commissioning, which is appropriate since, to date, very few sites have been formally

commissioned. In fact, site commissioning is such a new process that established commissioning authorities are actively authoring site commissioning procedures. Nevertheless, this selection of projects addresses building, combined site-building, and site commissioning so as to demonstrate the full breadth of evaluative procedures deployed by property owners. Four government projects (case studies 1-4) and two non-government projects (case studies 5-6) are included.

These case studies, which will be referenced throughout this white paper, highlight reoccurring opportunities and challenges that have been historically endemic to the commissioning process:

Opportunities

- Partnering with an established, third party commissioning authority
- Adapting the OPR to each project's needs
- Understanding performance goals within varying geographies, including non-temperate climates
- Gaining operations and maintenance training during the commissioning process
- Understanding the performance of integrated site-building systems
- Experiencing enhanced, verified performance
- Using retro-commissioning to trouble-shoot post-occupancy system problems
- Maintaining the owner's commitment to performance
- Applying lessons learned to future development
- Simultaneously achieving LEED, SITES, and commissioning goals
- Developing site commissioning procedures and protocols from scratch
- Considering continuous commissioning for monitoring certain site sub-elements

Challenges

- Solidifying all commissioning tasks and schedules as early as possible
- Navigating each stakeholder's roles and responsibilities, including liability
- Developing site commissioning protocols and procedures from scratch
- Conducting site commissioning without an agent
- Occasionally allocating a facility's development budget for indirect project costs
- Accommodating late programmatic change requests
- Navigating a phased demolition process
- Switching commissioning agents during construction
- Navigating a phased turnover process
- Translating abundant construction commissioning data into a continuous commissioning process that integrates with established operations and maintenance programs

CASE STUDY 1

PROJECT: EDITH GREEN-WENDALL WYATT FEDERAL BUILDING
LOCATION: PORTLAND, OR
PERFORMANCE GOAL: LEED
CX AGENT: GLUMAC
DESIGNER: CUTLER ANDERSON ARCHITECTS / SERA ARCHITECTS / PLACE STUDIO



The Edith Green-Wendall Wyatt Federal Building exemplifies how the modernization of government office buildings, including those that are zero-lot-line, can achieve exceptional triple bottom line performance when paired with commissioning. The \$139 million renovation of this 18-story, LEED Platinum-certified, 1970s tower included replacing the building skin, mechanical, electrical, plumbing, and data systems. The facility received federal stimulus funding, and as such, was required to reach multiple energy saving benchmarks. The building now achieves 45% energy and 61% potable water use reductions¹ due to the new building skin, solar thermal panels, photovoltaics, automatic window shading devices, radiant heating and cooling, efficient lighting and plumbing fixtures, and a stormwater harvesting and re-use system that supplies toilet flushing and native landscape irrigation.

GSA retained Glumac, a third-party commissioning authority, from early in design to one year post-

occupancy. Tasks included design document review; functional performance testing; contractor training during system installation; and building tenant training on performance goals, facility features, and operational policies (which resulted in high occupant buy-in). The commissioning authority additionally engaged in continual discovery and communication with the project team. The team capitalized upon symbioses between commissioning and the facility's integrated project delivery approach by enhancing system design, construction, and operations, and reducing RFIs by more than 50% relative to comparable projects.²

Performance Outcomes: 1) 39% energy cost and 45% energy use reduction compared to ASHRAE/IESNA Standard 90.1-2007; 2) 61% potable water use reduction compared to pre-modernization conditions; 3) 50% reduction in RFIs relative to comparable projects.³

² Foreman & Lowen (2015)
³ Foreman & Lowen (2015)

¹ Foreman & Lowen (2015)

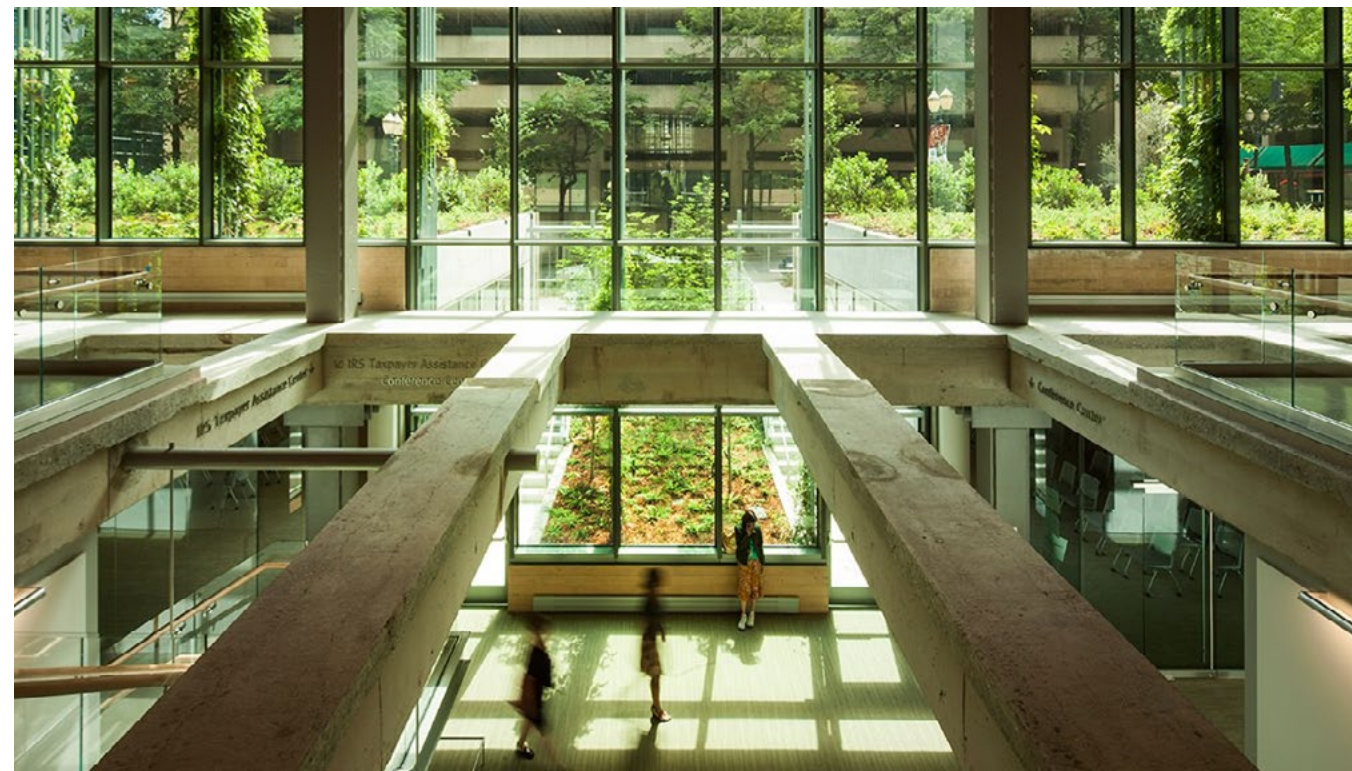


Image credit: Nic Lehoux

CASE STUDY 2

PROJECT: MARIPOSA LAND PORT OF ENTRY
LOCATION: NOGALES, AZ
PERFORMANCE GOAL: LEED 2.2
CX AGENT: COMMISSIONING CONCEPTS
DESIGNER: JONES STUDIO / CHRIS WINTERS & ASSOCIATES / ARC STUDIOS



The expansion and modernization of the Mariposa Land Port of Entry – one of the U.S.'s busiest land ports – demonstrates how commissioning can occur during the phased redevelopment of an active port. The 55-acre, \$187 million, LEED Gold-certified project involved the demolition of all existing buildings, acquisition of adjacent land, and construction of new facilities and integrated site amenities. Major constructed elements included buildings, inspection booths, loading docks, a hazmat area, vehicular parking, pedestrian gathering spaces, landscape plantings, water features, shade structures, and terraced embankments.

GSA retained Commissioning Concepts, a third-party agent, to perform commissioning during the design and construction phases to meet the LEED 2.2 requirements. The agent commissioned five building systems: HVAC, plumbing, lighting, electrical, and fire protection throughout the port of entry. This process included thorough design review followed by system

inspection, operational testing, and functional testing. Design elements that helped achieve the sustainability goals included significant use of photovoltaics, a solar domestic hot water system, advanced lighting, building automation system with diagnostics, and additional systems for future implementation aimed at assuring continued performance.¹ Additionally, the drought-tolerant, native landscape is irrigated with a non-commissioned, 1-million-gallon sub-grade cistern supplied by harvested rainwater from pavement and building roofs. Commissioning the cistern and other site elements would have holistically verified the project performance.

Performance Outcomes: 1) 35% of energy cost reduction compared to ASHRAE 90.1-2004; 2) 100% potable water use reduction for irrigation; 3) 38% domestic water use reduction; 4) 97% construction waste diversion from the landfill.²

¹ State of Arizona, State Procurement Office (2016)
² GreenIdeas Building Science Consultants (2017)



Image credit: Bill Timmerman

CASE STUDY 3

PROJECT: BENJAMIN P. GROGAN AND JERRY L. DOVE FEDERAL BUILDING
LOCATION: MIRAMAR, FL
PERFORMANCE GOAL: LEED; SITES PILOT PROJECT
CX AGENT: JACOBS ENGINEERING GROUP
DESIGNER: GENSLER / KRUECK + SEXTON ARCHITECTS / CURTIS + ROGERS DESIGN STUDIO



The Benjamin P. Grogan and Jerry L. Dove Federal Building transcends the goals of GSA's Design Excellence Program while demonstrating an elegant solution to self-evaluated building system performance optimization. The \$194 million, 20-acre south Florida site contains two office buildings and a parking structure, bordered primarily by two courtyards and restored wetlands. The LEED Platinum-certified office complex, which was developed through GSA's Design Excellence Program and meets the agency's PBS-P100 guidelines, emphasizes daylighting, views, walkability, energy efficiency, and enhanced security. High-performance design features include sunscreens, photovoltaics (which meet 20% of the complex's energy demand), stormwater and greywater harvesting (which reduce water consumption by 95%), and wildlife-friendly lighting.

GSA retained Jacobs Engineering Group for construction management and total building commissioning services. In addition to this formal

process, the design-engineering team self-evaluated building system performance from schematic design through construction, to ensure system performance. Building information modeling (BIM) informed the project's thermal performance and mechanical-electrical-plumbing coordination, while also functioning as a design-assist tool during fabrication of custom elements, such as the building skin. Through this process, the mechanical, electrical, plumbing, building skin, and HVAC systems were evaluated and optimized. No record of formal site commissioning can be located, although post-occupancy site monitoring will need to occur as a requisite of the project's SITES Pilot Project-certification

Performance Outcomes: 1) 20% of energy demand provided by photovoltaics; 2) 95% reduction in water consumption.



Image credit: Taylor Lednum

CASE STUDY 4

PROJECT: U.S. COAST GUARD HEADQUARTERS AT SAINT ELIZABETHS WEST CAMPUS
LOCATION: WASHINGTON, D.C.
PERFORMANCE GOAL: LEED 2.2 ENHANCED CX
CX AGENT: RD3, INC. / UNIVERSITY OF MARYLAND
DESIGNER: PERKINS + WILL / WDG ARCHITECTURE, PLLC / ANDROPOGON ASSOCIATES / HOK



The U.S. Coast Guard Headquarters exemplifies how commissioning multiple buildings within a large, federal campus can successfully fold into the LEED-certification process. As the U.S.'s largest federal LEED 2.2 Gold-certified project and the GSA's largest construction project in history, this 32-acre, \$646 million development contains a headquarters building built into a sloping hillside, a parking garage, central utility plant, and visitor processing center. The buildings support 12.8-acres of green roof, which together with at-grade wet ponds, bio-swales, and step pools, provide an integrated site-building stormwater strategy that harvests, treats, and re-uses site and building stormwater. Energy-efficient mechanical and electrical systems additionally enhance the development's performance.

The building commissioning agent retained by GSA is not known, although records do indicate that the headquarters building and central utility plant were fully commissioned. A commissioning process was

used for all building systems,¹ as pursuant to LEED 2.2 Enhanced Commissioning. Site performance was evaluated under a separate GSA-sponsored effort: a Landscape Architecture Foundation Landscape Performance Case Study Investigation, conducted by the University of Maryland. This year-long investigation, akin to a retro-commissioning process, examined the site's social, environmental, and economic impacts.² The study evaluated site stormwater and vegetation system performance. Pursuing an integrated site-building commissioning process would have served as a valuable learning experience, but perhaps too complex an effort for a development of this size.

Performance Outcomes: 1) 1.7-inches of rainwater managed within 9.2-acres of vegetated roofs; 2) 14.5° cooler than buildings with non-vegetated roofs during peak heat; 3) 88% occupant satisfaction.³

¹ General Services Administration (n.d.)
² Ellis & Reilly (2015)
³ Ellis & Reilly (2015)



Image credit: Andropogon Associates

CASE STUDY 5

PROJECT: THE CLARK ART INSTITUTE
LOCATION: WILLIAMSTOWN, MA
PERFORMANCE GOAL: LEED 2.2 ENHANCED CX
CX AGENT: ARAMARK ENGINEERING & ASSET SOLUTIONS
DESIGNER: TADEO ANDO ARCHITECTS / GENSLER / REED HILDERBRAND



The Clark Art Institute deployed one of the first, formal site commissioning processes in the U.S. during a comprehensive campus renewal. Core to the 140-acre pastoral campus, is the Clark Center—a visitor exhibition and conference center with an underground physical plant building, parking, rain gardens, and meadow—which received LEED 2.2 Gold-certification in 2016. As part of a coinciding campus-wide stormwater management strategy, the Clark Center’s water systems are fully integrated with the surrounding site through a network of water collection and re-use systems. A one-acre, tiered reflecting pool that flanks the Clark Center is central to this strategy. Foundation water and roof runoff feed the reflecting pool, which in turn supplies the site’s irrigation, gray water use for building plumbing, and cooling tower systems.¹

site commissioning became necessary. Initially, the project’s landscape architect, Reed Hilderbrand, aimed to self-perform the site commissioning, but through trial and error realized the advantage to engaging a certified, third party commissioning agent. The project’s acting building commissioning agent, Aramark, was therefore retained for site commissioning during construction. As the company’s foray into site commissioning, the agent authored testing protocols and procedures for each relevant system: stormwater management, gray water and irrigation, water feature pumping, water feature treatment, and automatic controls.² After substantial completion, the owner retained the agent for retro-commissioning services to trouble-shoot a repeatedly clogging reflecting pool purifier.

LEED 2.2 Enhanced Commissioning requires verification of building system performance, but since the building and site systems were fully integrated,

Performance Outcomes: 1) Fully-functioning stormwater, gray water, irrigation, and water feature systems.

¹ The Clark (2016)

² Kramer (2013)

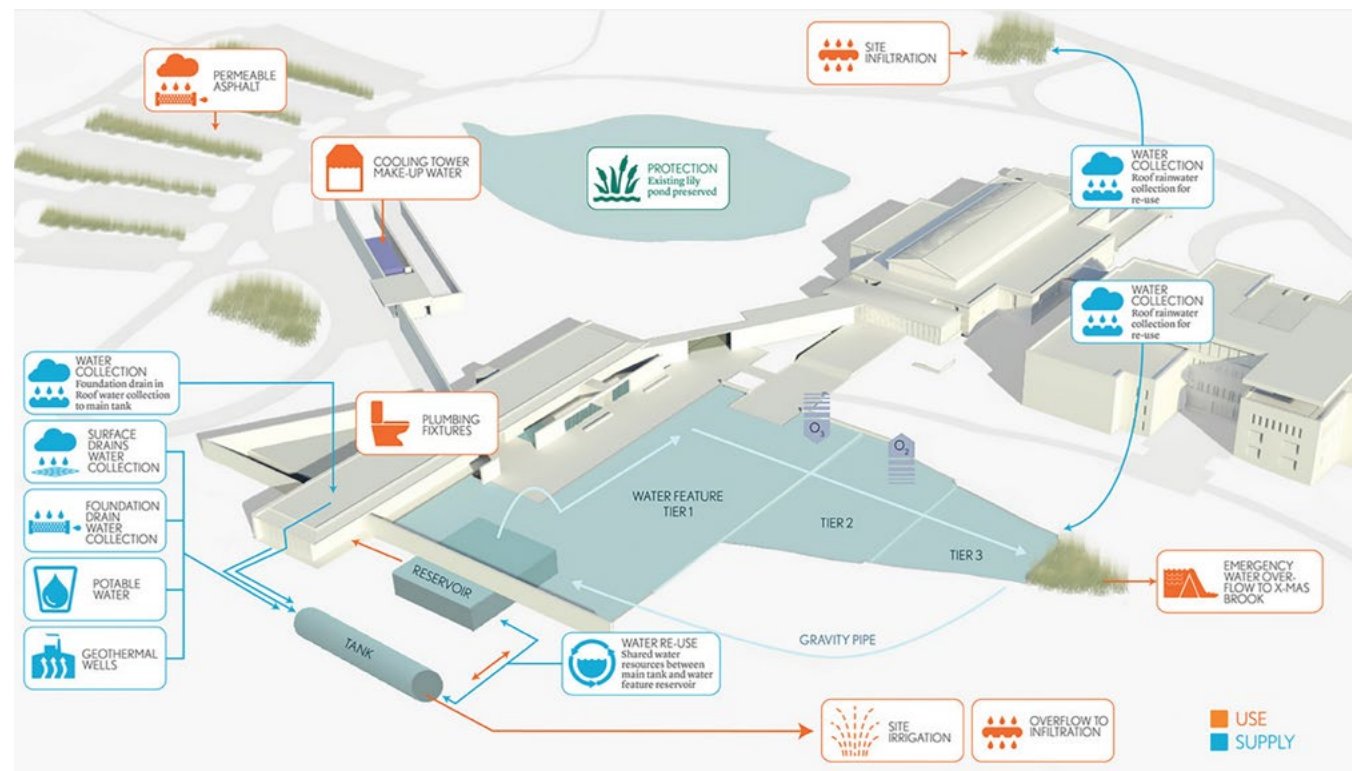


Image credit: courtesy of Gensler

CASE STUDY 6

PROJECT: SHOEMAKER GREEN
LOCATION: PHILADELPHIA, PA
PERFORMANCE GOAL: SUSTAINABLE SITES INITIATIVE PILOT PROJECT
CX AGENT: SELF-EVALUATED (ANDROPOGON ASSOCIATES / UNIVERSITY OF PENNSYLVANIA)
DESIGNER: ANDROPOGON ASSOCIATES



Shoemaker Green has supported one of the most comprehensive site monitoring programs of any constructed landscape to date. This 2.75-acre, publicly accessible, greenspace at the University of Pennsylvania contains a bioretention rain garden, large green with sub-grade stormwater storage, planting beds, tree trenches, permeable pavement, and a stormwater capture and re-use cistern that supplies a site irrigation system. Due to inconsistent urban fill composition and infiltration rates, this greyfield redevelopment is fully lined, thereby functioning hydrologically like a non-infiltrating green roof. Shoemaker Green’s design is optimized to manage stormwater from the site and surrounding rooftops; provide viable native plant and animal habitats; demonstrate sustainable land management strategies; and support large crowd of people.

and academic researchers conducted monitoring site visits multiple times per year to collect certain data, while relying upon continuous monitoring equipment and software for other data types. Monitoring and evaluation has targeted water (quality, quantity, plant transpiration rates); soil (compaction, infiltration, biology, moisture, pH, organic matter); plants (vigor, species suitability); and human use (occupancy, behavior).¹

While a formal commissioning process was not utilized, the comprehensive monitoring program exhibited more regularity and detail than would likely be typical of a standardized site commissioning program.

To meet the university’s research goals and SITE-certification performance monitoring requirements, university and design team personnel initiated a robust, five-year monitoring program. The design

Performance Outcomes: 1) 3x more rainwater managed than regulatory models predicted, due to soil storage capacity and plant transpiration; 2) Irrigation programming error detected and resolved.

¹ McCoy & Mandel (2017)

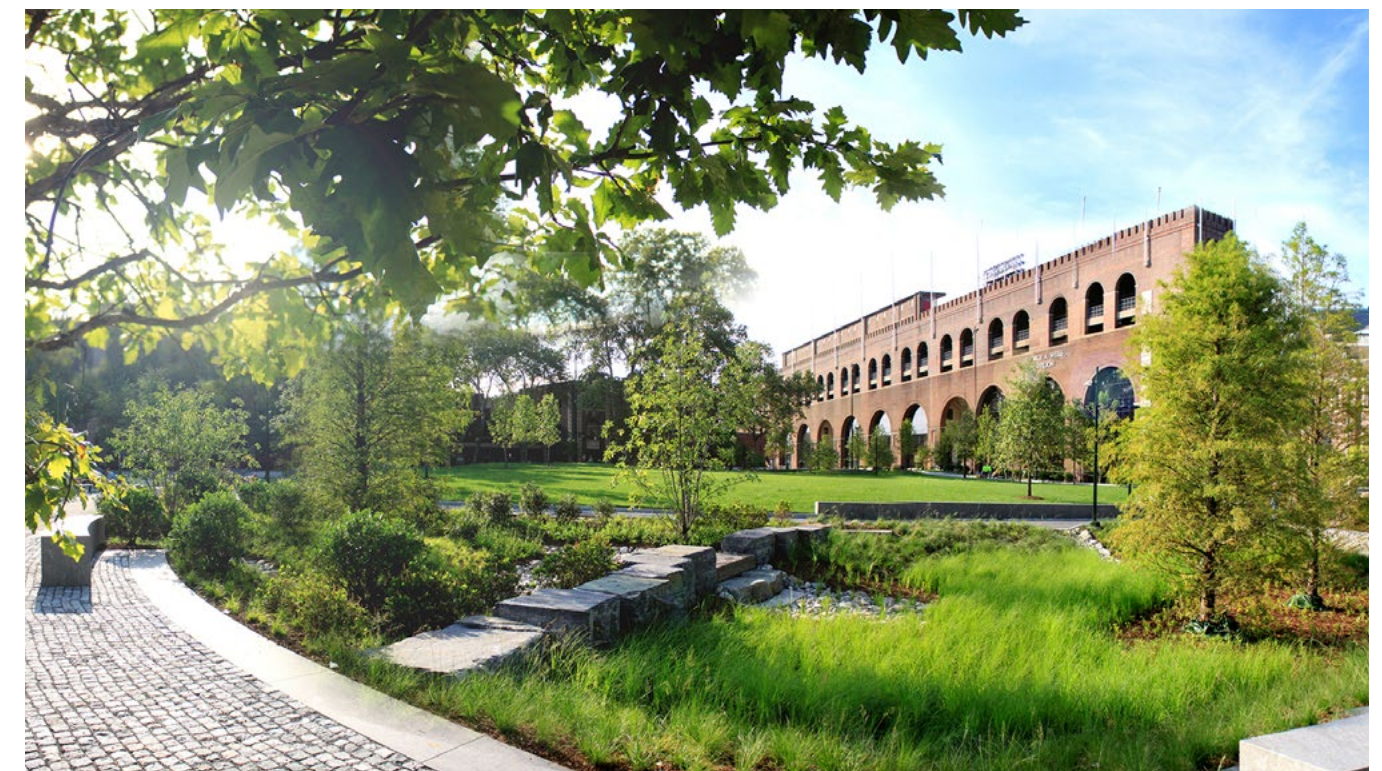


Image credit: Andropogon Associates

WORKING GROUP INPUT

Analysis of existing information (including opportunities, constraints, costs, benefits, industry trends, GSA's existing commissioning framework, and case studies) did not provide the white paper's research team with enough information to recommend whether GSA should pursue a site commissioning process. The research team therefore solicited input from 89 industry experts—organized into seven subject matter-specific working groups (see *appendix A*)—through participation in surveys and group interviews (see *Appendix B*). The subject matter areas were informed by the SITES sections (see *Potential Site Commissioning Metrics, p. 41*), thereby maximizing compatibility with GSA's recent, agency-wide SITES-certification adoption.

GSA Sees Payback in Quality Design

According to several working group members who are employed by GSA, the agency now builds, operates, and occupies durable facilities that are expected to last 50 - 100 years. Some of these facilities, such as border stations, are operational 24 hours a day, 365 days a year. Members from multiple working groups stressed that given this build-to-own model and operational requirement, life-cycle costs are paramount to an owner's value decision, particularly given lost revenue associated with shutting down facilities under repair. Many working group members therefore advocate for higher up-front costs (from planning / pre-design through construction) with the goal of optimizing a facility's life-cycle expenditures. This approach is challenging under the realities of current budgetary cycles, but poses a necessary step in supporting long-lasting facilities that rely upon high-performance, integrated building / site systems.

Overcoming Barriers

Two specific barriers to high-performance site system implementation stand out, across the working groups. The first barrier, client justification, is the most significant obstacle to overcome during a project's planning / pre-design phase. The second barrier,

lack of "knowledge, training, or integration" must be overcome during all other project phases from design through post-warranty maintenance. Multiple working group members suggested that an inclusive project delivery process—in which owner, designer, contractor, maintenance and operations personnel, and commissioning agent work collaboratively—that starts as early as possible could minimize these hurdles. More specifically, if each party across disciplines understands the owner's performance goals and the implications of design decisions and maintenance strategies in achieving those goals, the chance of meeting the goals increases.

Lastly, several working group members noted the value of an information feedback loop, to improve the land development and management processes over time, particularly since GSA owns and operates so many facilities and continues to develop new ones.

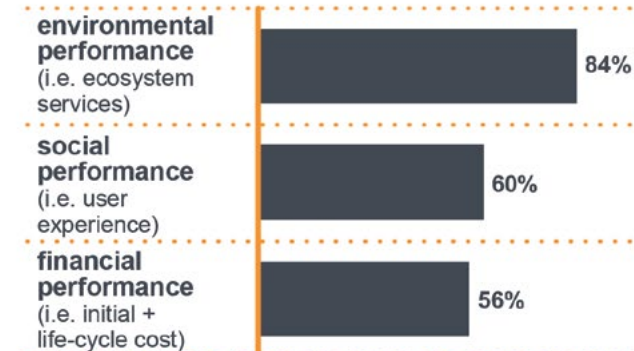
The following sections of this white paper offer an actionable path forward, aimed at providing GSA with a strategy to refine, implement, test, and further refine a site commissioning process that dovetails with the agency's existing building commissioning program.

Support for Site Commissioning

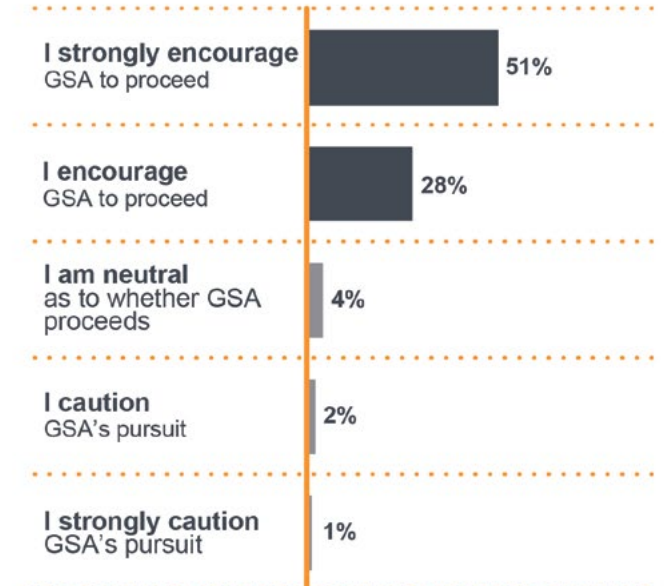
The survey and interview results revealed statistically significant, cross-disciplinary support for GSA's adoption of a site commissioning process. Based on the 89 person sample size, the majority of working group members believe that a commissioning process for high-performance site systems would benefit GSA by positively impacting a facility's environmental performance (i.e. ecosystem services), social performance (i.e. user experience), and financial performance (i.e. initial and life-cycle cost), respectively. After weighing the pros and cons, 79% of working group members either "strongly encourage" or "encourage" GSA to pursue a site commissioning process for all new construction and major redevelopments.

THE SURVEY + INTERVIEW RESULTS REVEALED STATISTICALLY SIGNIFICANT, CROSS-DISCIPLINARY SUPPORT FOR GSA'S ADOPTION OF A SITE COMMISSIONING PROCESS

A COMMISSIONING PROCESS FOR HIGH-PERFORMANCE SITE SYSTEMS WOULD LIKELY IMPACT:



HOW DO YOU RECOMMEND GSA PROCEEDS IN PURSUING A SITE COMMISSIONING PROGRAM?



Above: Anticipated triple bottom line benefits and degree of support for GSA's adoption of a site commissioning process. Data source: All working group surveys, administered by Andropogon Associates (n = 89)



4. PROCESS FRAMEWORK

Shoemaker Green—a 2.75-acre greenspace at the University of Pennsylvania, in Philadelphia, PA—exemplifies how strategic redevelopment within a tight, urban site can yield an ecologically valuable, high-performing landscape. The SITES-certified project supports a five-year site monitoring study aimed at addressing the knowledge gap between science and policy by informing new engineering models, advocating for progressive regulations, and advancing sustainable site design.

Image credit: Andropogon Associates

POTENTIAL SITE COMMISSIONING METRICS

Measuring performance is essential in determining whether specific design and operational goals are being achieved. *Assessment metrics* are standards of measurement that provide a means for quantifying or qualifying performance, which can then be evaluated against benchmarks that are established during pre-development. Some benchmarks may apply agency-wide or to a certain geographic region or facility type. Others may be entirely site specific.

For example, water use serves as a relevant agency-wide commissioning metric for GSA because the agency is embarking on an ambitious net-zero water development approach, which will elevate the need for GSA facility owners to know exactly how site-building stormwater and wastewater systems are performing throughout a facility's lifetime. After verifying that a facility is designed and constructed to achieve net-zero water, commissioning will verify whether the hydrologic goal is being met. Any shortcomings present opportunities for remediation. This could include re-examining the site's monitoring equipment functionality, built system (e.g. rain garden) condition,

and management practices. Perhaps a rainwater harvesting and re-use irrigation system was improperly programmed, resulting in the system turning on when the soil is already saturated. Resolving problems like these would result in improved hydrologic performance during the next monitoring or commissioning period, while also conserving natural resources. Site commissioning assessment metrics can therefore serve to strengthen established regulatory, design excellence, and rating system requirements to ensure that each site performs as intended by the facility owner's OPR.

and effort to measure and evaluate, but are equally important to support.

The Site Commissioning Assessment Metrics Chart (see p. 43) lists the seven attributes (e.g. water), which each consist of performance metrics (e.g. water use) and general examples of data types (e.g. volume). The chart includes three performance tiers with a 1-3 star rating system, much like the PBS-P100. The chart proposes phase engagement for each metric, to illustrate when each metric would be most effectively integrated into the project-delivery process, from pre-design through long-term post occupancy. Monitoring frequency for each metric is additionally proposed.

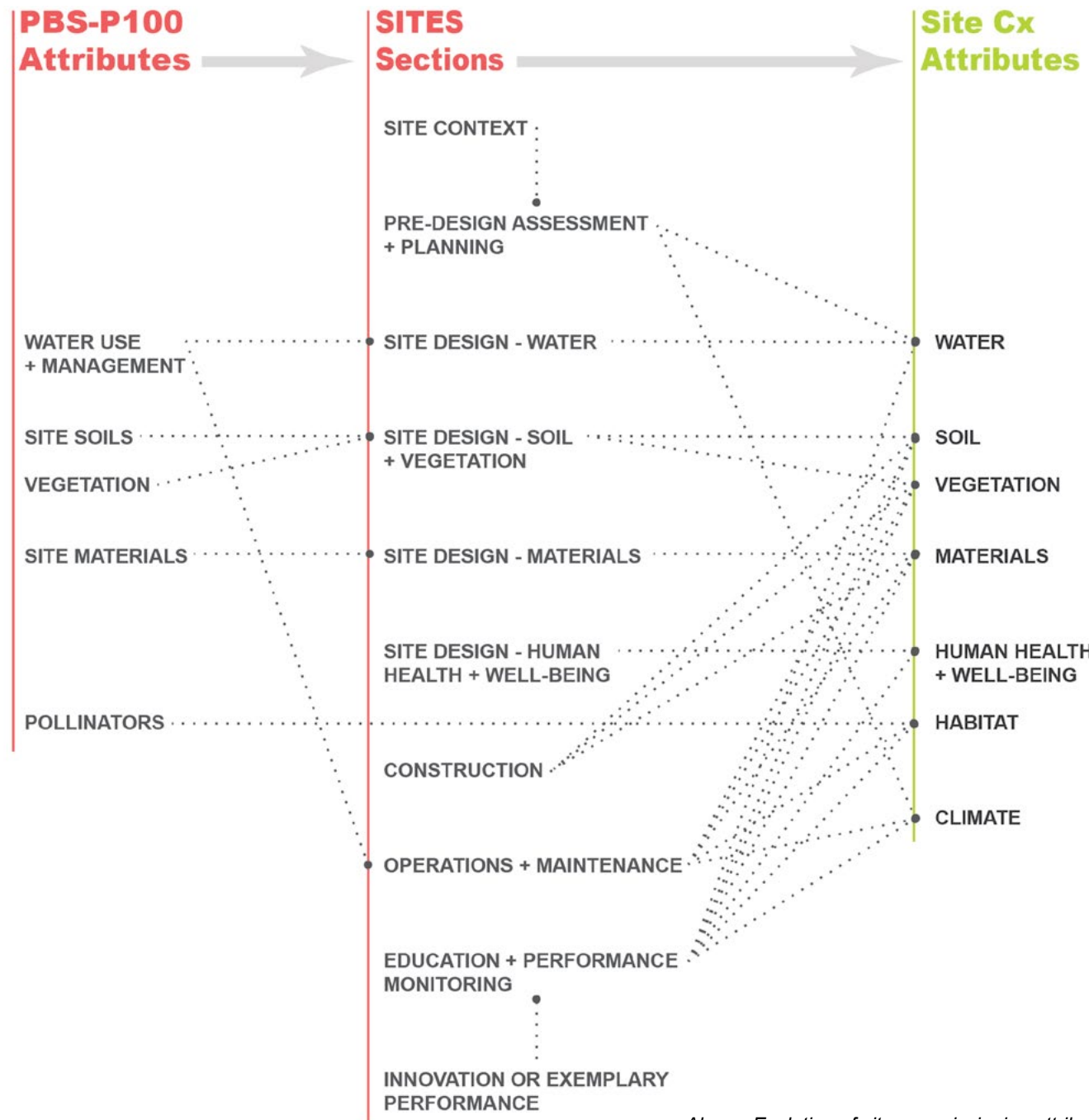
Tier 1: Basic level of required site performance that contains only core attributes. Includes metrics that are already adopted by GSA through existing requirements and/or likely to result in direct financial savings.

Tier 2: Optional, enhanced level of site performance that builds upon Tier 1 requirements with metrics that require more resources to assess.

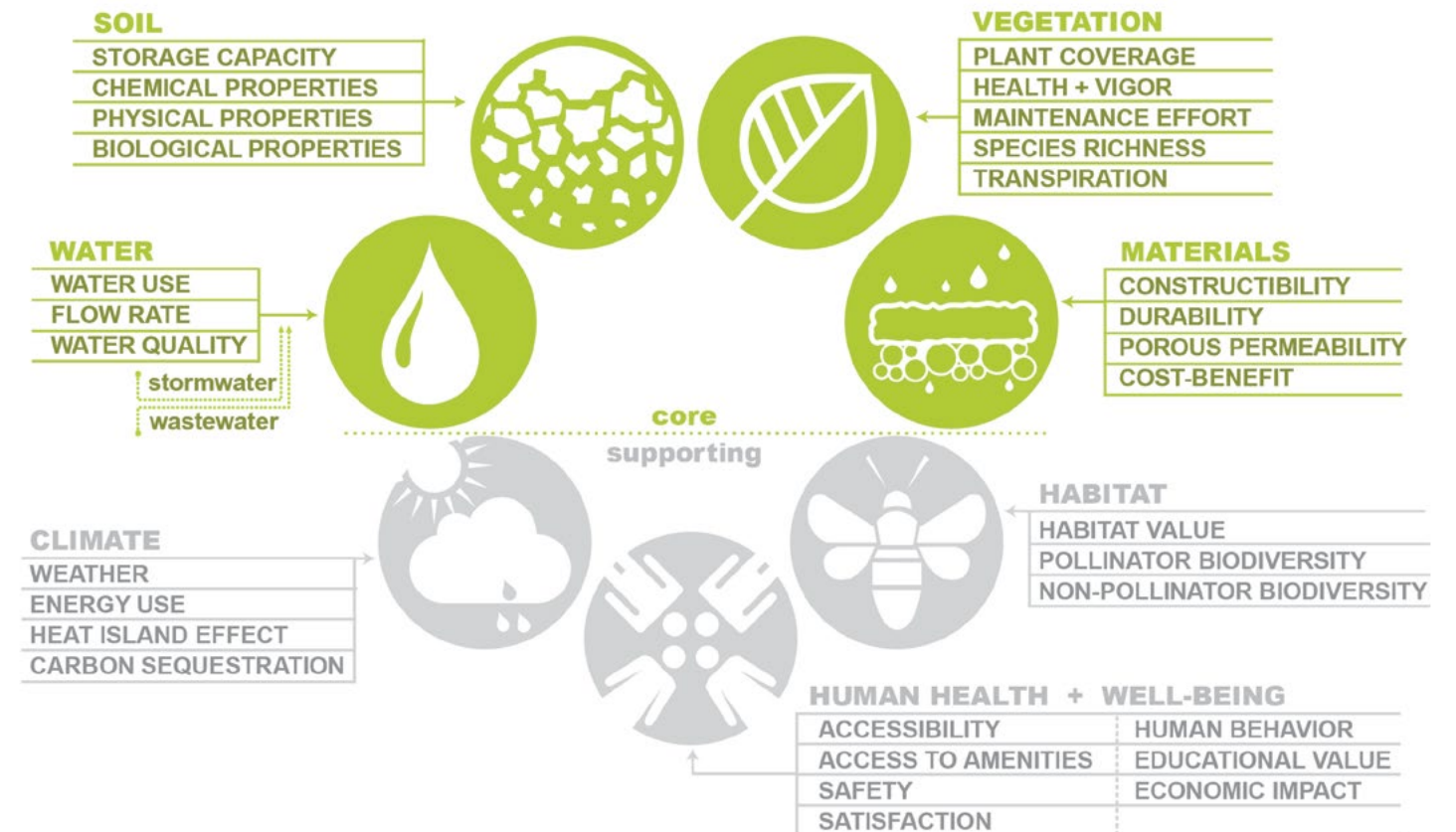
Tier 3: Optional, comprehensive level of site performance that builds upon Tier 2 to provide a detailed, holistic understanding of site functioning.








To determine which assessment metrics are most applicable to site commissioning, this white paper's research team built upon existing performance frameworks, most notably the five PBS-P100 landscape performance attributes and the ten SITES v2 sections.¹ Synthesizing and reorganizing these existing frameworks resulted in seven site commissioning attributes (see p. 41). Shown below in green are the "core attributes"—water, soil, vegetation, and materials—which are relatively easy and cost effective to monitor and evaluate using common technology and skill sets. In yellow are the "supporting attributes"—habitat, human health and well-being, and climate—which require more sophisticated expertise

¹ Sustainable SITES Initiative (2014)



Above: Evolution of site commissioning attributes;
Opposite: Site commissioning attributes diagram



SITE COMMISSIONING ASSESSMENT METRICS CHART	DATA TYPES	PERFORMANCE LEVEL			PHASE ENGAGEMENT					MONITORING FREQUENCY*				
		★	★★	★★★	Planning / Pre-Design	Design	Construction	Substantial Completion	Post-Construction	Only during construction	Only at end of warranty	Annually	Quarterly	Continuously
		Tier 1	Tier 2	Tier 3										
	General Examples													
	Water													
	Water Use	X	X	X	X	X			X					X
	Flow Rate		X	X					X					X
	Water Quality			X					X			X		
	Soil													
	Storage Capacity	X	X	X		X			X	X				
	Chemical Properties	X	X	X		X			X		X			
	Physical Properties		X	X		X	X		X		X			
	Biological Properties			X		X			X	X				
	Vegetation													
	Plant Coverage	X	X	X		X	X	X	X		X			
	Health + Vigor	X	X	X			X		X			X		
	Maintenance Effort	X	X	X	X	X			X		X			
	Species Richness		X	X		X	X		X		X			
	Transpiration			X					X			X		
	Materials													
	Constructability	X	X	X		X	X	X		X				
	Durability	X	X	X		X			X		X			
	Porous Pavement Permeability		X	X		X		X	X		X			
	Cost-Benefit			X		X			X	X				
	Habitat													
	Habitat Value		X	X	X	X			X		X			
	Pollinator Biodiversity		X	X					X		X			
	Non-pollinator Biodiversity			X					X		X			
	Human Health + Well-Being													
	Accessibility		X	X		X			X		X			
	Access to Amenities		X	X	X	X			X		X			
	Safety		X	X					X		X			
	Satisfaction		X	X					X		X			
	Human Behavior			X		X			X		X			
	Educational Value			X		X			X		X			
	Local Economic Impact			X	X	X	X	X	X		X			
	Climate													
	Weather		X	X					X					X
	Energy Use		X	X	X	X	X	X	X			X		
	Heat Island Effect		X	X	X	X			X		X			
	Carbon Sequestration			X	X	X			X		X			

* = Frequencies recommended by Working Groups to gain basic performance data that balances cost, accuracy + usefulness

CATEGORIZING SITE “SYSTEMS”

Site systems are often interdependent, meaning that the performance of one system may affect the measurable performance of another. In fact, when this white paper’s working groups (see Appendix B) were asked, via survey, to what degree the performance of one type of high-performance site system (e.g. those related to water) are typically interdependent with others (e.g. those related to vegetation) within facilities that contain integrated building / site systems, participants reported that all system influence one another, to a degree of more than 50%, regardless of type. Across all working groups, high-performance water systems were reported to be the most interdependent system type, at 80%:

High-Performance Site System Type	Interdependence to Other Site Systems
Water	80%
Vegetation	71%
Climate	66%
Soil	64%
Human Health & Well-Being	62%
Habitat	61%
Materials	54%

This finding underscores the complexity of site systems, and the difficulty involved with separating and categorizing them into units that can be individually commissioned. Despite this complexity, dividing site systems into “commissionable” units is critical in developing an actionable site commissioning process.

Commissioning System Components

When Working Group participants were asked which characteristic *they* would use to define the units, 40% said that performance goal (e.g. all elements that contribute to achieving a single performance goal), and 32% said that system component (e.g. plaza, rain garden, green roof) should be the defining variable. Due to the inherent complexities associated with categorizing units by performance goal, the white paper’s research team recommends that GSA rely upon system component as the commissioning unit. Performance data from each system component could then be measured against the facility’s overarching performance goals.

Performance Trajectory

Unlike building systems that remain relatively static over time, living site systems are, by definition, in a constant state of flux. In addition to short-term

variation, many site features increase in performance over time, when managed appropriately. For example, if kept free of invasive species, a floodplain forest will typically manage more stormwater (through transpiration), sequester more carbon, and increase in habitat value over time. GSA’s site commissioning process should therefore anticipate specific performance trajectories and build these assumptions into each facility’s commissioning plan. Required maintenance and operations resources are similarly likely to change over time. For vegetated systems, the most attention is required during the critical establishment period, which is typically until 2 – 3 years after planting.

Data Collection Schedule

GSA’s site commissioning process should aim, at a minimum, to gain the most basic, meaningful performance data possible, that is, the data that reveals fundamental performance efficiencies and indicates problems. Facility’s owners and/or tenants who seek to integrate more comprehensive monitoring initiatives should be encouraged to do so, but for the sake of program-wide cost efficiency and ease of execution throughout a facility’s lifetime, basic monitoring should be the required default. Monitoring frequency varies for each performance metric (see *Site Commissioning Assessment Metrics Chart*, p. 43). For example, basic monitoring of a soil’s storage capacity is most effectively measured during construction only, while chemical and physical properties should be measured annually.¹ For hydrologic systems, water quality should be measured quarterly, while flow rate requires continual monitoring.² Each facility’s design and management team should establish the monitoring methods that will be used to assess each metric. The range of methods could include secondary data source review (e.g. for weather data), field observation / inspection, low-cost field tests, portable equipment field tests, in-situ equipment monitoring, and laboratory analysis. Continual monitoring typically requires in-situ equipment, which should be integrated into the project’s design.

Commissioning Schedule

When paired with adaptive management, site monitoring is a continual process that achieves performance measurement, performance verification, and calibration of under-performing systems. By contrast, site commissioning and recommissioning function as periodic data analysis and formal reporting efforts (like a third party audit) that occur at intervals predetermined by the facility’s commissioning plan.

¹ Mandel & McCoy (2017e)

² Mandel & McCoy (2017g)

This distinction differs significantly from building commissioning, wherein a relatively static system (e.g. heating, ventilation, and air conditioning (HVAC)) can be examined during a commissioning inspection every 3 – 5 years, and then calibrated as needed at that time. Living site systems are unique in that they do not have “on / off switches.” Their change is constant, and waiting several years to remediate under-performance can devastate the system’s long-term functioning and the performance of interdependent systems. Sites therefore require a two-pronged approach, in which monitoring / adaptive management and commissioning function as complementary processes aimed at achieving a unified goal.

The white paper’s research team therefore recommends the following commissioning schedule approach, during which time monitoring and adaptive management would occur continually:

Commissioning begins during the planning / pre-design phase and ends two years after construction completion, which is the length of a standard plant establishment period and aligned with the turnover from “early stage management”³ to “long-term management”⁴ contractor

Recommissioning occurs every 3 – 5 years after the initial recommissioning, concurrent with the facility’s established building commissioning schedule.

³ Mandel & McCoy (2017f)

⁴ Mandel & McCoy (2017f)

SAMPLE MONITORING / COMMISSIONING SCHEDULE (★★ performance level)



INTEGRATION INTO GSA'S CURRENT BUILDING COMMISSIONING PROCESS

GSA's site commissioning process must dovetail into the agency's existing Total Building Commissioning process, thereby building on what has already been vetted, implemented, and accepted. The diagram below offers recommended actions specific to site commissioning (shown in red) inserted into GSA's existing commissioning process (shown in gray - for a detailed description see *GSA's Existing Building Commissioning Process*, p. 21). The number associated with each chronological action keys into the following pages of this white paper, which illustrate how site commissioning could plug into three project delivery models that GSA regularly deploys: design-bid-build, design-build, and integrated project delivery.

The most critical moments for site commissioning during each delivery phase (regardless of project delivery model) are client justification and goal setting; design, construction, and management team member hiring; and project turnover. Here are the detailed concepts and critical moments during each delivery phase, regardless of project delivery model, that are unique to site commissioning. SITES credits embedded in the process (see *Appendix C*) are shown in brackets:

Planning / Pre-Design

#1: Successful site commissioning requires an inclusive project delivery process, in which owner, designer, contractor, maintenance and operations personnel, and commissioning agent work collaboratively, starting as early as possible. This means that GSA's project manager should identify *and retain* the project team – architect / engineer (A/E), landscape architect, construction management agent (CM), and commissioning agent (CxA) – during the facility's planning / pre-design phase. During the hiring process, the project manager should secure site commissioning understanding and buy-in from the team, as well as from facility user representatives.

#2: The team must then work together to inform the owner about the implications of potential facility performance requirements, as "owner interest" is one of the most significant hurdles to implementing high-performance site systems (see *Appendix B*). Once the owner's project requirements (OPR) are established, the chance of meeting those goals increases as each party across disciplines understands how design decisions and maintenance strategies impact those goals. [P2.1, P2.2, P2.3, C2.4]

Design

#7: When updating the commissioning plan during this phase, the team should incorporate the anticipated performance trajectory for each feature (see *Categorizing Site Systems*, p. 45). [P4.1, P4.2, P4.3]

#8: Concurrent with design development and construction documentation, the design and management team must develop monitoring methods and plan accordingly for any monitoring equipment slated for integration into the site. [P9.3]

#9: The commissioning specification language that is produced next, should be incorporated into Division 1, and then referenced in all relevant specification sections. Development of clear, well-documented operations procedures should be developed, so that changes in management personnel do not impact system performance.

Construction

#15: To catch operational deficiencies before project turnover (thereby managing liability), sites systems and monitoring equipment should be tested *and remediated* before submission of the commissioning record. [P7.3, P8.1]

Post-Construction

#17: Unlike GSA's Total Building Commissioning protocol, which calls for commissioning completion at a minimum of one year after construction, sites will require two years, to accommodate plant establishment and seasonal changes, and align with warranties and the Early-Stage Management period. During this time continual monitoring and adaptive management will guide the maturing site along the performance trajectories defined in the OPR. The management during this phase should be included in

the facility's capitol budget to ensure proper execution. [P8.1, C8.4]

#19: Remediation of operational deficiencies will ensure system performance before project turnover to the long-term management party.

#22: Long-term management party training at the end of the Early-Stage Management period will provide supplementary, hands-on knowledge exchange.

Long-Term Management

#23: While not included in GSA's Total Building Commissioning process, this phase is critical for the long-term performance of living site systems. During this phase, the monitoring schedule will continue as in the previous phase, but the adaptive management should be less intensive and included in the facility's operations budget.

#24: A two-pronged approach of monitoring / adaptive management and commissioning will formalize a process for identifying, reporting, and remediating site system performance deficiencies.

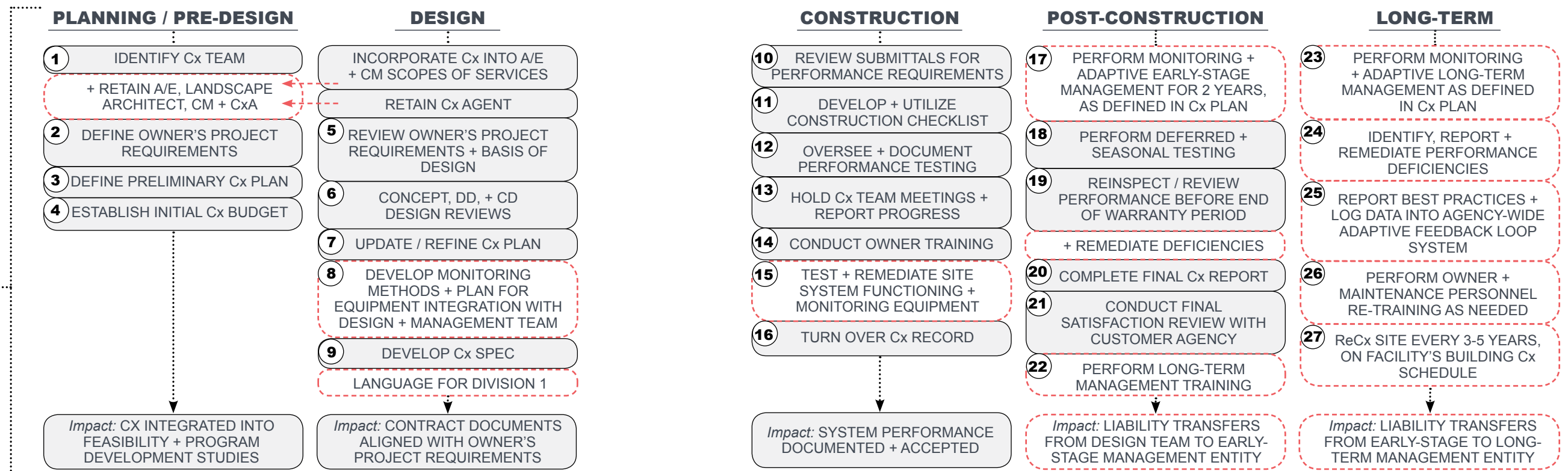
#25: Logging data and lessons learned into an agency-wide adaptive feedback loop system will improve best practices over time and aid in life-cycle analysis, particularly since GSA owns and operates so many facilities and continues to develop new ones. [C9.1]

#27: During this phase, the site should be recommissioned on the same schedule as the facility's buildings (every 3 – 5 years).

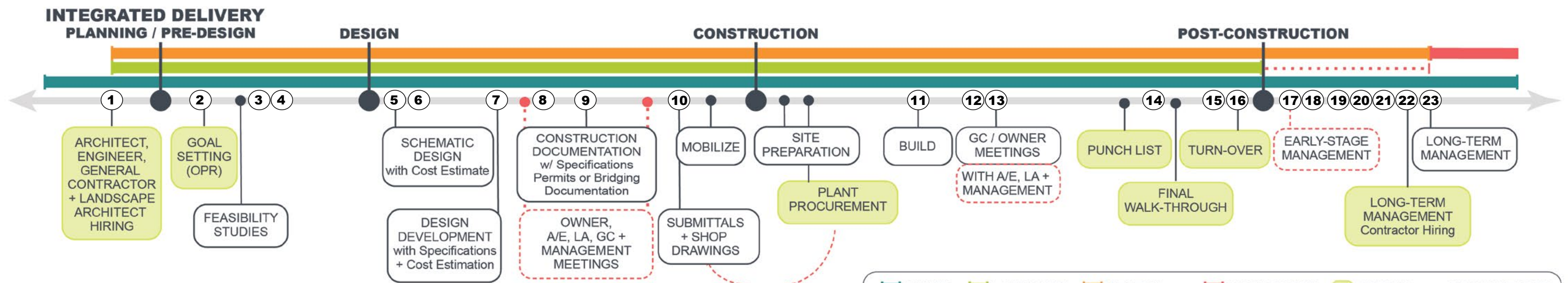
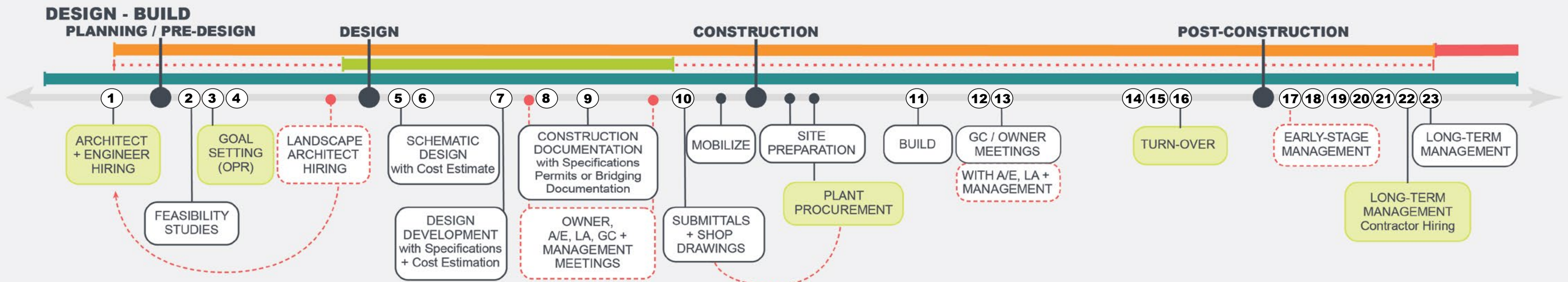
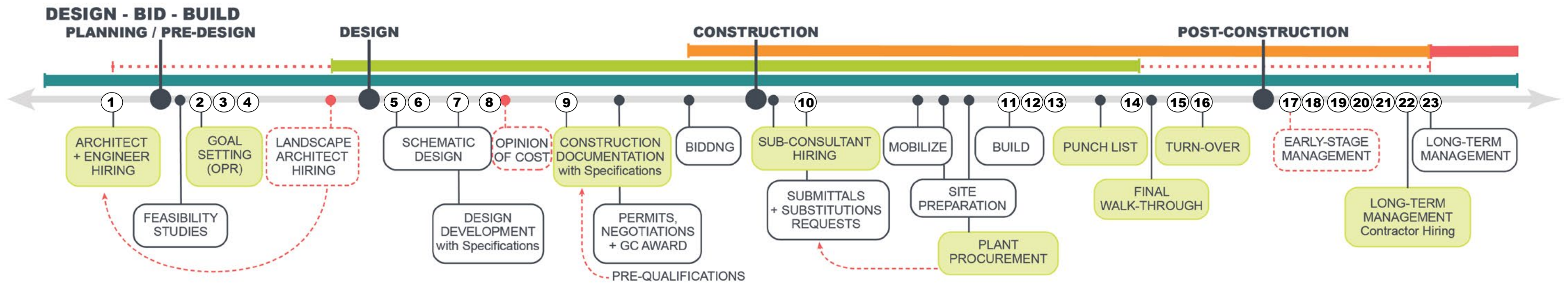
PROCUREMENT PROCESS

- COMMUNITY PLANNING
- PROSPECTUS DEVELOPMENT STUDY
- PROJECT AUTHORIZATION
- PROJECT DEVELOPMENT
- PROJECT EXECUTION

LEGEND
 — CURRENT PROCESS
 --- RECOMMENDED CHANGE



Above: Site commissioning integrated into GSA's current commissioning process (see p. 24)





QUALIFICATIONS-BASED PROCESS FOR HIRING COMMISSIONING PROFESSIONALS

Since site commissioning is an emerging practice, site commissioning agents (abbreviated here as “SCxA”) do not formally exist. How, then, could GSA apply a qualifications-based process to hiring those who will commission the agency’s sites? Who fills this void? As with LEED and SITES, the necessary skills, knowledge, training, and ultimately, professional certification programs for site commissioning will likely be adopted within the marketplace over time to meet increasing project needs and owner demand. GSA’s adoption of site commissioning could kick-start a similar type of marketplace, for site commissioning professionals.

The white paper’s research team therefore recommend a two-step approach to hiring third-party commissioning professionals, based on this projected marketplace development. A sample scope of services for these site commissioning agents is provided in *Appendix D*.

Initial Approach: During the initial process roll-out (see *Process Implementation*, p. 54) GSA should solicit a building commissioning agent that has, or could readily acquire, the expertise needed to commission the facility’s site. Potential professionals with relevant expertise could include horticulturists, field researchers, civil engineers, or other site performance subject matter experts. Multiple contributors would likely be required to address the breadth of site commissioning attributes (e.g. water, plants, materials, human health and

well-being) within a given facility. It’s most likely that these professionals would be contracted to the building commissioning firm as sub-consultants until demand for site commissioning grows enough to support in-house positions. For example, the building commissioning industry relied upon building skin sub-consultants for approximately 17 years before experiencing sufficient demand to bring them in-house as employees, which has occurred only recently.¹ Contracting site commissioning professionals under the building commissioning umbrella could provide an opportunity for established building commissioning processes to adapt to the unique needs of sites. The approach would be additionally beneficial in streamlining the communication for the commissioning of integrated building / site systems, when compared to commissioning the building and site through two distinct contractual entities.

Long-Term Approach: Once the site commissioning marketplace begins to develop, which based on existing precedents could take 5² – 15³ years, GSA should craft requests for qualifications (RFQs) and requests for proposals (RFPs) that solicit either building commissioning firms with in-house site commissioning professionals; or site commissioning firms. The RFQs, in particular, should request qualifications based on the agent’s previous site commissioning experience and any SCxA certification that may exist at that time. Additionally, when hiring site commissioning professionals, GSA should feel confident that the entity will remain in existence for the duration of the facility’s design life in order to maintain continuity. These requirements will result in higher-quality commissioning services and better performing facilities, while creating marketplace demand within the site commissioning marketplace.

¹ King (2017)
² Kelly (2017)
³ King (2017)



5. PROCESS IMPLEMENTATION

In Albuquerque, New Mexico's high desert, the 4.4-acre Pete V. Domenici U.S. Courthouse plaza renovation demonstrates ecological, economic, and cultural sustainability within the region's challenging climate. The public space, designed by Rios Clementi Hale Studio, relies upon elements including drought-tolerant plantings, harvested rainwater, and an efficient landscape irrigation system, to reduce the site's potable water use by more than 75% of its pre-redevelopment rate. In 2013 this Sustainable SITES Initiative Pilot Project became GSA's first SITES-certified facility.

Image: courtesy of GSA

NESTED SCALES OF IMPLEMENTATION

The implementation of GSA's site commissioning process will occur at four levels, or nested scales, from project to agency level:

Project Scale: At the individual project level, GSA will integrate site commissioning into the agency's established procurement and Total Building Commissioning processes (see *Integration into GSA's Existing Building Commissioning Process*, p. 47). Key milestones will include: 1) Owner buy-in and goal setting / OPR development; 2) Design documentation with emphases on delivery team communication, interdisciplinary collaboration, performance-based specifications, and meeting the OPR; 3) Construction with strategies in place for plant procurement,¹ soil protection,² and acceptable performance-based material substitutions;³ and 4) Adaptive management, monitoring, and repair or calibration of under-performing site features.

Facility Type Scale: GSA's site commissioning process must respond to the unique spatial and performative needs of the agency's six facility types: office building, land port of entry, courthouse,

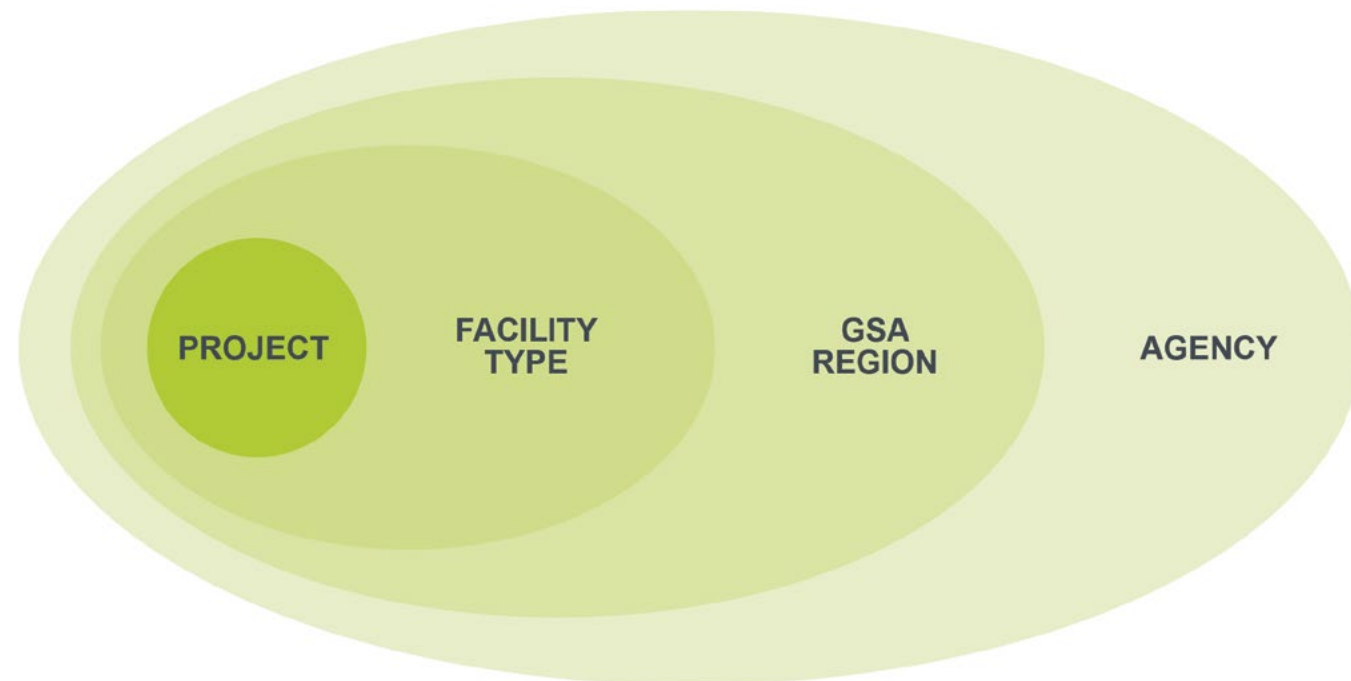
laboratory, post office, and data processing center. The expectations of those typologies that typically occupy large, spacious campuses (e.g. land port of entry), for example, must be approached differently than those found in zero-lot-line urban sites (e.g. courthouse).

Regional Scale: At a broader level, GSA's site commissioning process should be based on the region in which a facility is located. The 50 U.S. states fall into 11 GSA regions, each of which contains its own performative needs based on geography and climate. For example, GSA's Pacific Rim region (AZ, CA, NV, HI) might emphasize water conservation, whereas the New England region (CT, ME, MA, NH, RI, VT) might stress ice and snow management. Independent of these divisions, the country can be subdivided into the U.S. Environmental Protection Agency's *ecoregions* (ecologically similar regions).⁴ The latter organization contains more meaningful distinctions from an ecological perspective, while the former is more practical in terms of agency management and tracking.

Agency Scale: Agency-wide implementation will require an administrative program lead that collaborates with regional-level liaisons in order to gain feedback from each project. GSA's existing regional horticultural team leads could qualify for these positions.

¹ Vegetation Working Group (2017)
² Soil Working Group (2017)
³ Materials Working Group (2017)

⁴ U.S. Environmental Protection Agency (2016)



Above: Four nested scales of site commissioning implementation

GRADUATED ROLL-OUT STRATEGY

GSA's site commissioning process should be implemented in stages, to provide opportunity for initial testing, adaptive feedback, buy-in, and continual improvement over time. The white paper's research team therefore recommends the launch of a three-year pilot program, as was successfully executed during the implementation of SITES, followed by the fully-formulated process launch. Also recommended is a formal reevaluation of the process every 10 years to work out any "kinks" that may arise as the process develops. Here is the recommended graduated roll-out time line:

Years 1-3

- Appoint GSA's site commissioning program lead
- Coordinate proposed roll-out strategy with GSA's Total Building Commissioning program lead/ liaison
- Test roll-out at the project level
- Select pilot projects from planned project portfolio prioritizing facility type and regional diversity
- Encourage owners to pursue ★ performance level rating (see *Site Commissioning Assessment Metrics Chart*, p. 43)
- Organize feedback around facility type and region to gain data about cause and effect

Years 4-6

- Refine the site commissioning process framework based on lessons learned from pilot projects
- Adapt to unique needs of each facility type
- Adapt to unique needs of each GSA region
- Transition from pilot to fully-formulated process
- Increase opportunities for higher-performing facilities by launching paths for ★★ and ★★★ performance level ratings (see *Site Commissioning Assessment Metrics Chart*, p. 43)

Years 7+

- Continue to expand portfolio of building / site commissioned facilities
- Create reward system for highest-performing facilities and associated design and implementation teams
- Advance process through adaptive feedback (see *Adaptive Feedback Loop*, p. 59)
- Reevaluate the process every 10 years



Image credit: Andropogon Associates

REQUIRED RESOURCES

What would it take for GSA to refine and implement a site commissioning process for all new construction and substantial renovations? Here are some of the required resources, which all depend upon the a long-term financial commitment by the federal government:

- **Personnel**, including an administrative program lead (at the federal level); regional liaisons; and staff dedicated to process implementation, operations, communications, and compliance.
- **Digital tools** such as: 1) A decision tree to lead project teams through critical decisions and scenarios from planning through long-term management; 2) Integrated project management software that tracks tasks, progress, schedule, and communication, such as through Proliance Construction Management Software, Newforma, Procore, or Synchro Software; 3) An agency-wide monitoring database that centralizes real-time field data and provides an outlet for data synthesis to easily distill trends; and 4) An online platform for design and management teams to access

performance trends (searchable by site feature type and size, facility type, and region) to make informed decisions while advancing GSA projects.

- **Communications strategy** that emphasizes the process' triple bottom line benefits. A web presence for public outreach and prospective consultants is critical to this effort, and should be considered as an addition to GSA's existing "Landscape Architecture" web page (www.gsa.gov/portal/category/101730) and also linked to on the agency's "Commissioning" web page (www.gsa.gov/portal/category/21063). Additionally, promoting the site commissioning process through GSA's existing social media platforms (Facebook, Twitter, Youtube, Instagram, Pinterest, and blog) could effectively and economically increase public awareness and receptiveness to the process, as could creating an award category for projects that demonstrate excellence in site commissioning.
- **Time and Dedication** are required to successfully implement and sustain a site commissioning process. GSA's established Total Building Commissioning program shows the agency's potential for this commitment.

PARTNERSHIPS + BUY-IN

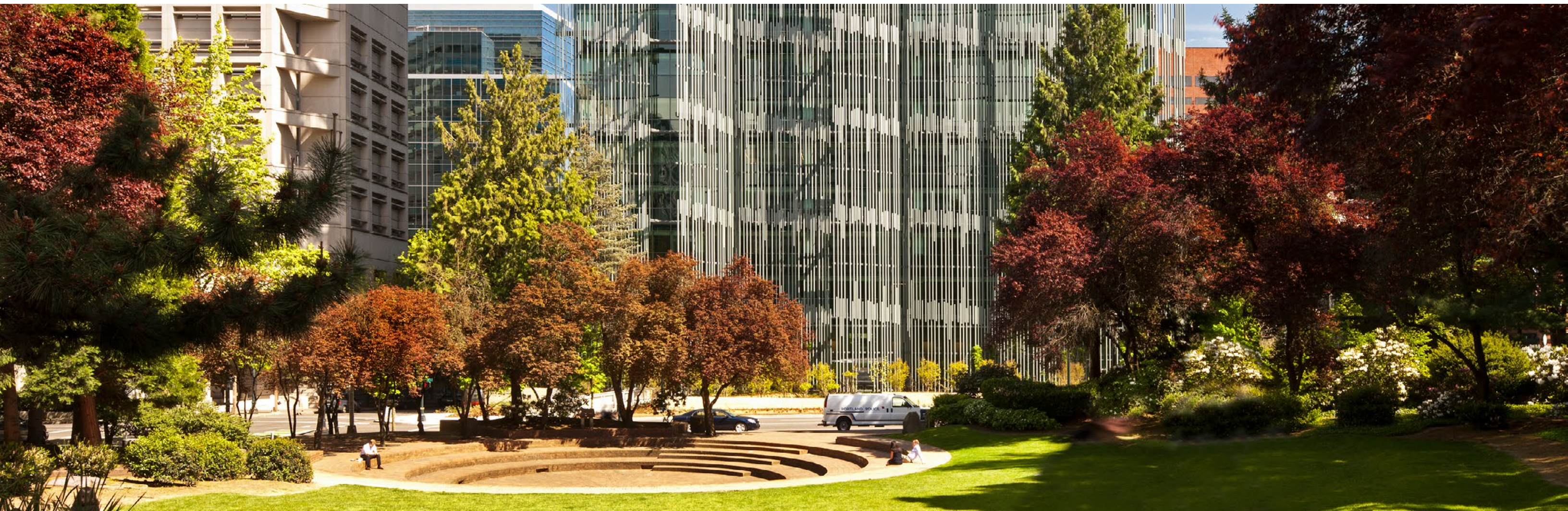
A site commissioning process will never be implemented without public sector buy-in by GSA and other relevant federal agencies. Key to this buy-in is a commitment to process development, execution, and management. Additionally, a commitment to awarding projects to the most qualified design teams, site management companies, and commissioning agents (*see Qualifications-Based Process for Hiring Commissioning Professionals, p. 52*) would further solidify the process' success while benefiting the quality of information provided during the duration of the pilot program (*see Graduated Roll-Out Strategy, p. 56*).

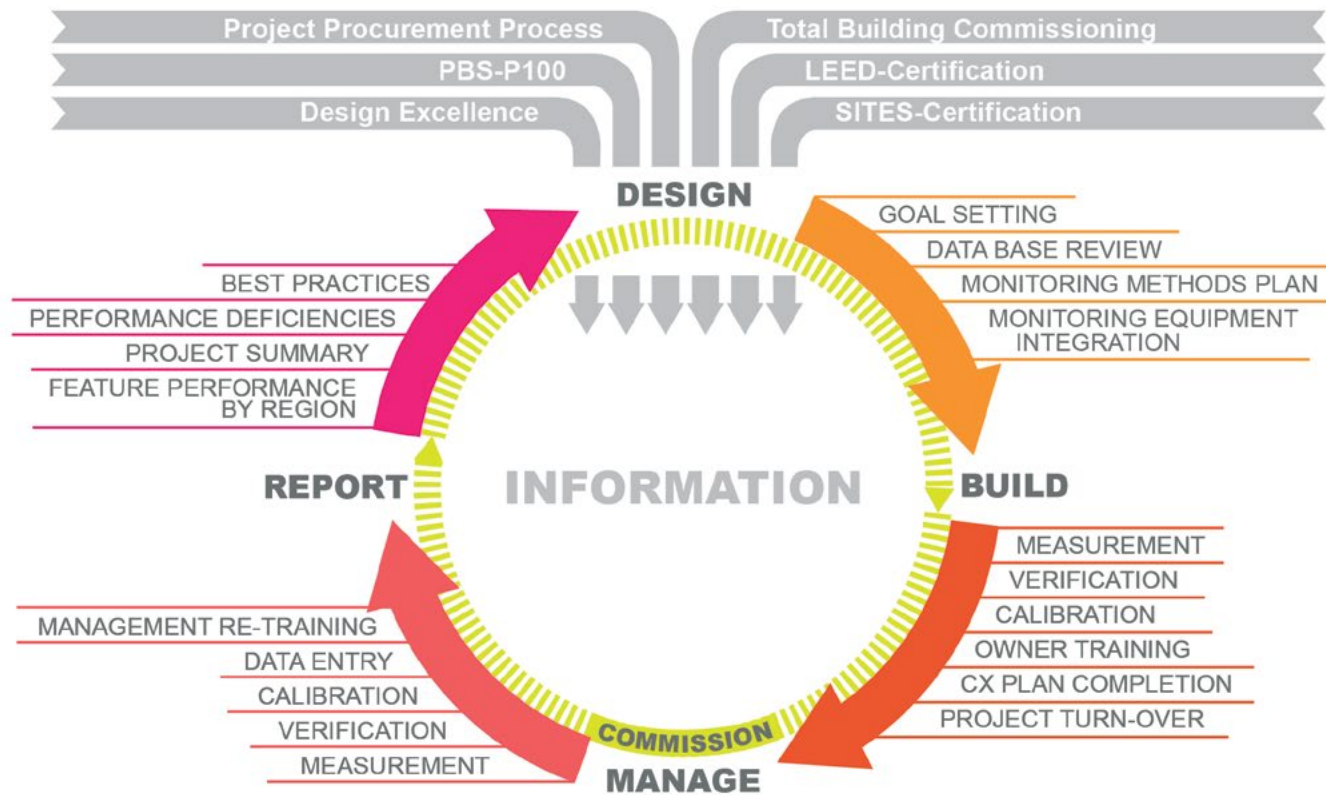
From the private sector, successful implementation requires industry buy-in of both the concept of site commissioning and GSA's program requirements. To achieve this, industry members must perceive a clear benefit to exposing their companies to the inherent risk associated with engaging in something new. This perceived benefit would most likely be financial, whereby companies pursue projects due to their

large scale and the opportunity for repeat business with GSA. Of equal importance is GSA's ability to establish a clear strategy for managing liability. Site commissioning will uncover performance deficiencies (e.g. a rain garden that manages less water than intended), so design, construction, site management, and commissioning professionals must understand and agree to GSA's strategy for remediating under-performance (e.g. reconstructing the rain garden with different soil types) that minimizes finger pointing and associated lawsuits.

Strategic partnerships with academia and non-profits will additionally foster the process' successful implementation. These entities would be the likely candidates for developing site commissioning training programs, continuing education classes, and ultimately, a trade organization that offers professional certification. Precedents for this type of industry trajectory with professional certification exist for building commissioning (The Building Commissioning Association), LEED (U.S. Green Building Council), and SITES (Green Business Certification Inc.).

Image credit: Nic Lehoux





Above: Adaptive feedback loop

ADAPTIVE FEEDBACK LOOP

Development of an accessible, agency-wide adaptive feedback loop will allow GSA to cultivate cumulative, institutional knowledge. This organizational approach to collecting and disseminating information at all four nested scales of site commissioning must respond to the agency's existing project procurement process, design and construction programs (e.g. Design Excellence, Total Building Commissioning), and standards (e.g. PBS-P100, LEED, SITES). It could take the form of a database or other digital interface that is compatible with GSA's existing Building Automated Systems software.

Commissioning then becomes a tool that integrates the adaptive feedback loop into each project's design, construction, management, and reporting practices. The feedback loop is inherently cyclical, meaning that information gleaned from the successes and failures of one project directly informs decisions made during the implementation and management of the next. The process can additionally help to refine the project team composition and the assessment metrics over time.

Design: When establishing a new facility's OPR, owners can review the initial goals and actual performance of operational facilities as documented in the database. Design and management teams can similarly reference monitoring methods plans and equipment integration strategies from previous projects, so mistakes are not repeated. The team's actions and results then enter into the feedback loop to benefit future projects.

Build: During construction, measurement, verification, and calibration, data enters the feedback loop. This information is then accessible to the facility's commissioning agent and becomes available for owner training. A centralized record of this

information helps reduce liability disputes after project turnover from designer to early-stage management entity to long-term management entity.

Manage: A facility experiences adaptive management and monitoring for most of its life-cycle. Measurement, verification, calibration, and data entry into the feedback loop are therefore essential, as is learning from approaches used in the past. Management and monitoring information must be accessible to the facility's commissioning agent and available for management re-training in case of employee turnover.

Report: In addition to inputting detailed project information (i.e. performance goals, monitoring methods, equipment integration strategies, and data) into the feedback loop, a granular summary of each project should be submitted. The summary should reflect what worked and what didn't during each project phase and how decisions influenced the OPR. These summaries should be readily accessible by GSA and the design and management teams to quickly reference best practices, typical performance efficiencies, and how features can be expected to perform based on composition, scale, facility type, and region.

This approach suggests a paradigm shift, in which project delivery is no longer viewed as a linear process, but rather a cyclical one that increasingly breeds better performing projects over time. Nested feedback domains for individual projects, facility types, GSA regions, and the whole agency would further benefit GSA's knowledge base. Eventually, additional feedback loops for the design, product manufacturing, construction, and stewardship industries could also spin off to benefit the greater good. *This* is how GSA positively impacts people, planet, and profit at an unprecedented scale of influence.



6. NEXT STEPS

GSA's 32-acre U.S. Coast Guard Headquarters at Saint Elizabeths West Campus, in Washington D.C., demonstrates a high-performance approach to campus design that integrates building and site systems. This LEED Gold-certified redevelopment, completed in 2013, underwent a total building commissioning process.

Image credit: James Steinkamp of James Steinkamp Photography

ACTION ITEMS

The following seven steps can lead GSA to successfully implementing the site commissioning process outlined in this white paper:

- 1. Re-frame GSA's commissioning program** as Total Commissioning by integrating the site commissioning process into the agency's current Total Building Commissioning program (see p. 47)
- 2. Launch a pilot program** by identifying planned facilities with diverse geographies, facility types, and project delivery methods, and adjusting the graduated roll-out time line (see p. 56)
- 3. Allocate resources** for process development that support personnel, digital tool development and management, and communications (see p. 57)
- 4. Secure buy-in** from public and private sector entities while cultivating partnerships (see p. 58)
- 5. Create adaptive feedback loop** with an accessible interface that allows GSA to cultivate cumulative, institutional knowledge related to site commissioning (see p. 59)
- 6. Promote site commissioning** to provide design and commissioning professionals an opportunity to understand the subject matter (see p. 57)
- 7. Reevaluate** while remaining flexible by learning from successes and failures, to foster the success of this brand new industry (see p. 56)

OPEN QUESTIONS

The following questions are for GSA's consideration while refining and implementing the agency's site commissioning process:

- What type of database or other digital interface would most effectively be deployed to support the adaptive feedback loop?
- Is there a benefit to accessible, real-time data?
- How would design, construction, and management team members gain information access and data entry training for the adaptive feedback loop?
- Should site performance data and/or findings be made available to the public, since they will be derived with taxpayer dollars?
- Should site commissioning-related innovation be encouraged and / or rewarded?

Image credit: courtesy of Millicent Harvey





7. APPENDICES

GSA's 32-acre U.S. Coast Guard Headquarters at Saint Elizabeths West Campus, in Washington D.C., demonstrates a high-performance approach to campus design that integrates building and site systems. This LEED Gold-certified redevelopment, completed in 2013, underwent a total building commissioning process.

Image credit: Andropogon Associates

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B | INDUSTRY EXPERT INPUT

INDUSTRY EXPERT SELECTION PROCESS

After conducting a literature review, the white paper’s research team and GSA project sponsor identified 141 industry thought leaders that hold expertise related to each of the Site Commissioning Attribute categories: Water, Soil, Vegetation, Materials, Habitat, Human Health and Well-Being, and Climate. Each of these individuals was approved by GSA, and then invited via email to join a specific “design, construction, and stewardship working group.” Eighty-nine participants (63% of those initially invited) joined the working groups, each of which consisted of 11 to 15 members. Each working group contained representatives from governmental organizations, non-governmental organizations, academic institutions, and professional companies, in order to capture a representative cross-section of stakeholder input for each subject area.

SURVEY METHODS

The research team developed and administered an online survey specific to each working group, which was completed by all 89 members. The survey goals were to:

- Confirm which metrics are most critical in evaluating site performance through a commissioning process
- Identify hurdles within the design-construction-management process that cause site performance to diverge from intended goals
- Gain exposure to unfamiliar nuances of commissioning issues and relevant processes
- Gauge multi-industry support for site commissioning

Questions within each survey addressed: 1) general performance goals; 2) technical performance goals; 3) monitoring methods; 4) performance evaluation; and 5) survey wrap-up (to solicit information about the survey participant’s general experience, level of support for GSA’s adoption of a site commissioning process, and willingness to participate in follow-up communication). Questions within the first four categories were discipline-specific, while the remaining questions were identical across all surveys. These questions that spanned surveys were designed to solicit broad, multi-disciplinary feedback with a larger sample size than any individual survey, and thus, more statistically significant results. By contrast, discipline-specific questions were designed to solicit in-depth responses aimed at tapping into each participant’s expertise. In order of declining frequency, questions were asked as multiple choice, short answer, and ranking. Consequently, both quantitative and qualitative data were collected.

Results were analyzed automatically by the online

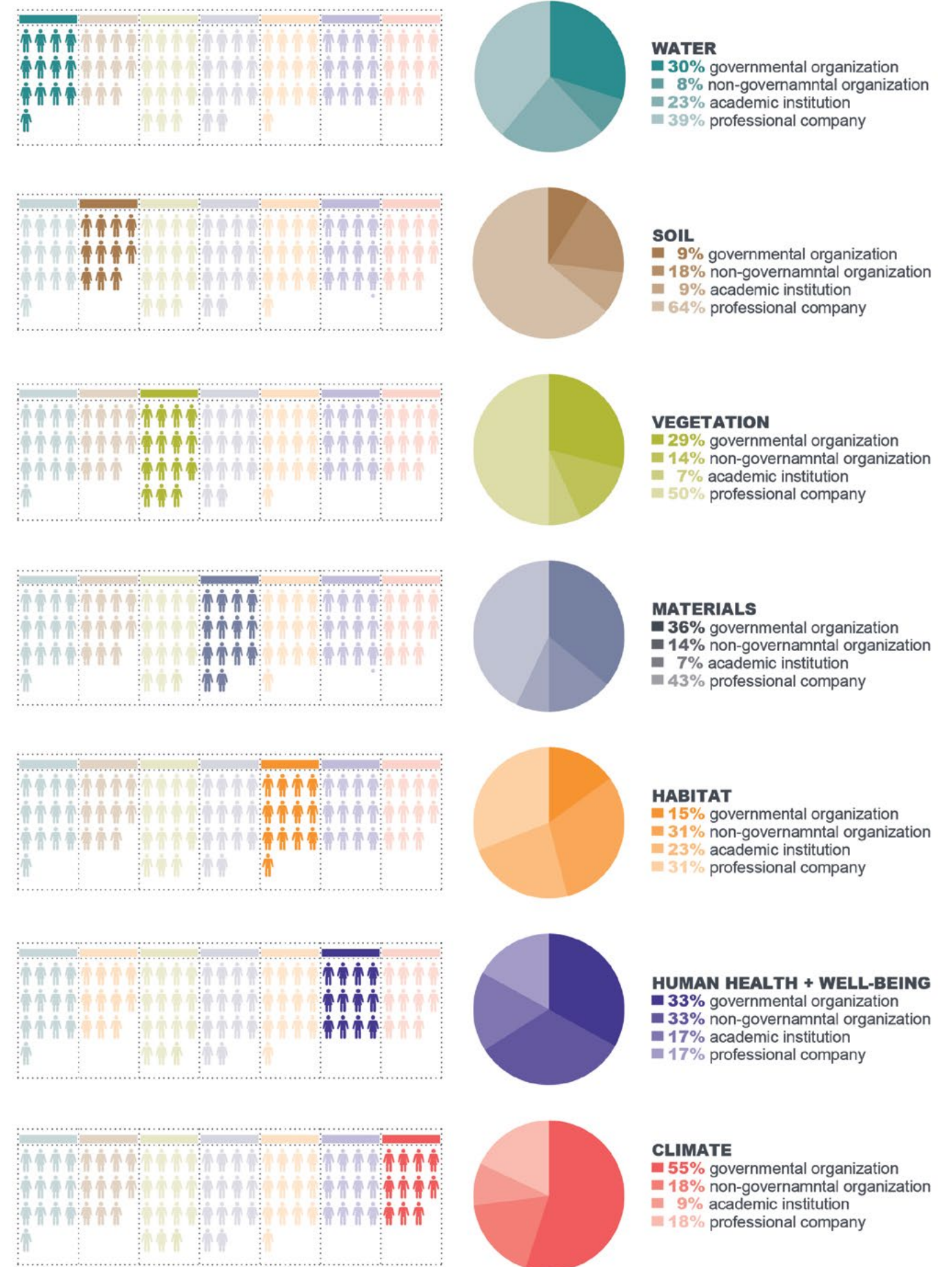
survey program, SurveyMonkey (www.surveymonkey.com). The research team then reviewed and analyzed the data further to extract the most significant trends and discrepancies between answers within each working group survey. Graphs and charts were created during this analysis and used to formulate discussion questions for each working group conference call (see “Interview Methods” below). A selection of these graphs and charts appear in this appendix.

INTERVIEW METHODS

Upon completion of the surveys, the research team and GSA project sponsor conducted and recorded semi-structured group interviews, via conference call, with each working group. These 90-minute discussions (plus one additional 60-minute call with the Materials group due to low attendance during the scheduled meeting) served to review and validate survey result findings and facilitate discussion between experts. Questions focused on the value of commissioning, optimizing goals, overcoming barriers, material sourcing, performance monitoring, cross-disciplinary analysis, and feedback loops.

Not all working group members were available to or interested in participating in the calls, and so those who did not attend were sent the presentation and discussion questions from each conference call and offered the opportunity to provide responses via email. Comments made during the calls and in follow-up emails were manually analyzed and summarized by the research team. The following number of working group members participated in each group interview:

Working Group	Membership (No.)	Group Interview Participation (No.)
Water	13	6 (46%)
Soil	11	8 (73%)
Vegetation	15	11 (73%)
Materials	14	11 (79%)
Habitat	13	9 (69%)
Human Health & Well-Being	12	7 (58%)
Climate	11	6 (55%)
Total	89	58 (65%)



Opposite: Working group survey participants by sector

RESULTS: WATER WORKING GROUP

The Water Working Group survey indicated that when implementing high-performance, total water systems within a facility, “client interest” is the most significant barrier to overcome during a facility’s planning / pre-design phase, while a lack of “knowledge, training, or integration” poses the greatest challenge during construction through post-warranty maintenance. The group expressed that these obstacles are important to overcome due to certain cost-benefit aspects of high-performance water systems, most notably: 1) Ecological, flood, landslide, and drought resilience; and 2) Irrigation reduction. When monitoring high-performance systems and balancing cost, accuracy and usefulness, 83% of survey participants reported that water use is the easiest parameter to measure, while water quality was listed as most difficult. One member predicted that water quality monitoring will become easier over time, and presumably more affordable, as technology improves.

Interview participants acknowledged the complexities of total water systems and largely attributed the obstacles surrounding their implementation and long-term performance to poor knowledge

transfer. Participants noted that cumulative change orders during construction can jeopardize system performance, and that high-performance systems that aren’t installed correctly experience an increased risk of abandonment. Similarly, maintenance personnel that don’t understand the system’s inner-workings may abandon the system (e.g. complex irrigation program) for a simpler, although much less efficient solution.

Recommended Solutions

- Tailor each facility’s performance goals to accommodate regional variability in water needs
- Acknowledge savings that can result from using total-water features (e.g. constructed wetland) to achieve multiple goals
- Increase communication between landscape architect, civil engineer, and MEP engineer
- Engage site manager and maintenance personnel throughout the design process
- Coordinate the site’s soils and irrigation strategies
- Require a high-performance total water system maintenance plan within the contract documents
- Solicit highly-trained installation contractors
- Advocate for local regulations that incentivize green stormwater infrastructure

RESULTS: SOIL WORKING GROUP

According to the survey participants’ experience, the most commonly occurring obstacle to high-performance soil system implementation involves failing to further or reinforce a facility’s soil management plan during construction, which occurs 32% of the time. The results also indicated that construction activities overly compact the soil 30% of the time, and a soil management plan is not prepared during design 29% of the time. Interview comments stressed that soil compaction and/or a lack of soil management planning can significantly impact a facility’s long-term stormwater management capabilities, plant performance, irrigation demand, and habitat value. In fact, a significant number of survey participants reported that a site commissioning process for high-performance soil systems would positively impact a facility’s environmental (88%), social (64%), and financial performance (73%). Additionally, multiple participants noted the performance and financial value of protecting and/or restoring the existing, native soil profile whenever possible and appropriate to the site’s intended use, as opposed to importing natural or engineered soils.

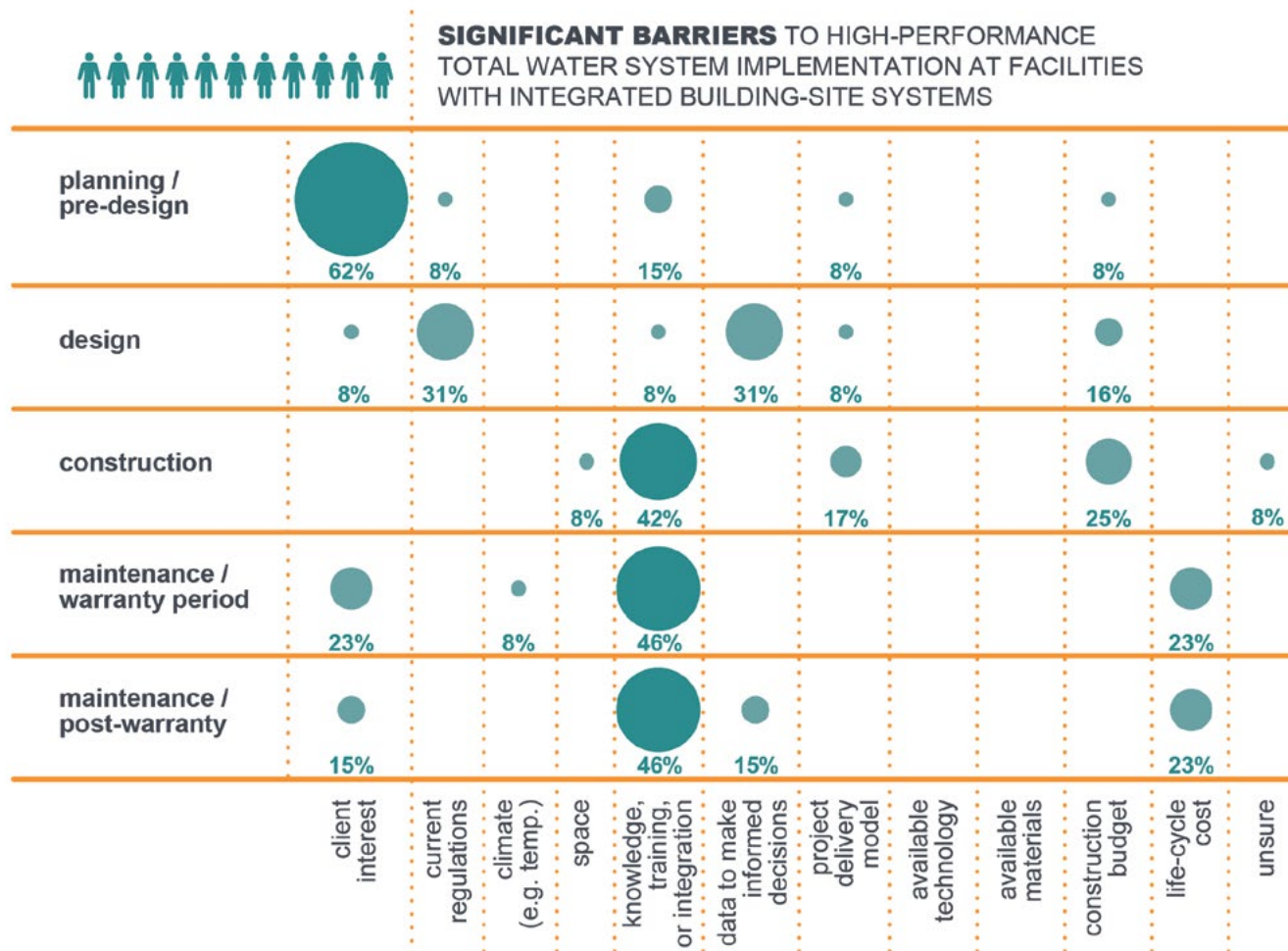
Problems related to construction, as articulated during the interview, can be largely attributed to a lack of:

- 1) Communication between the construction trades;

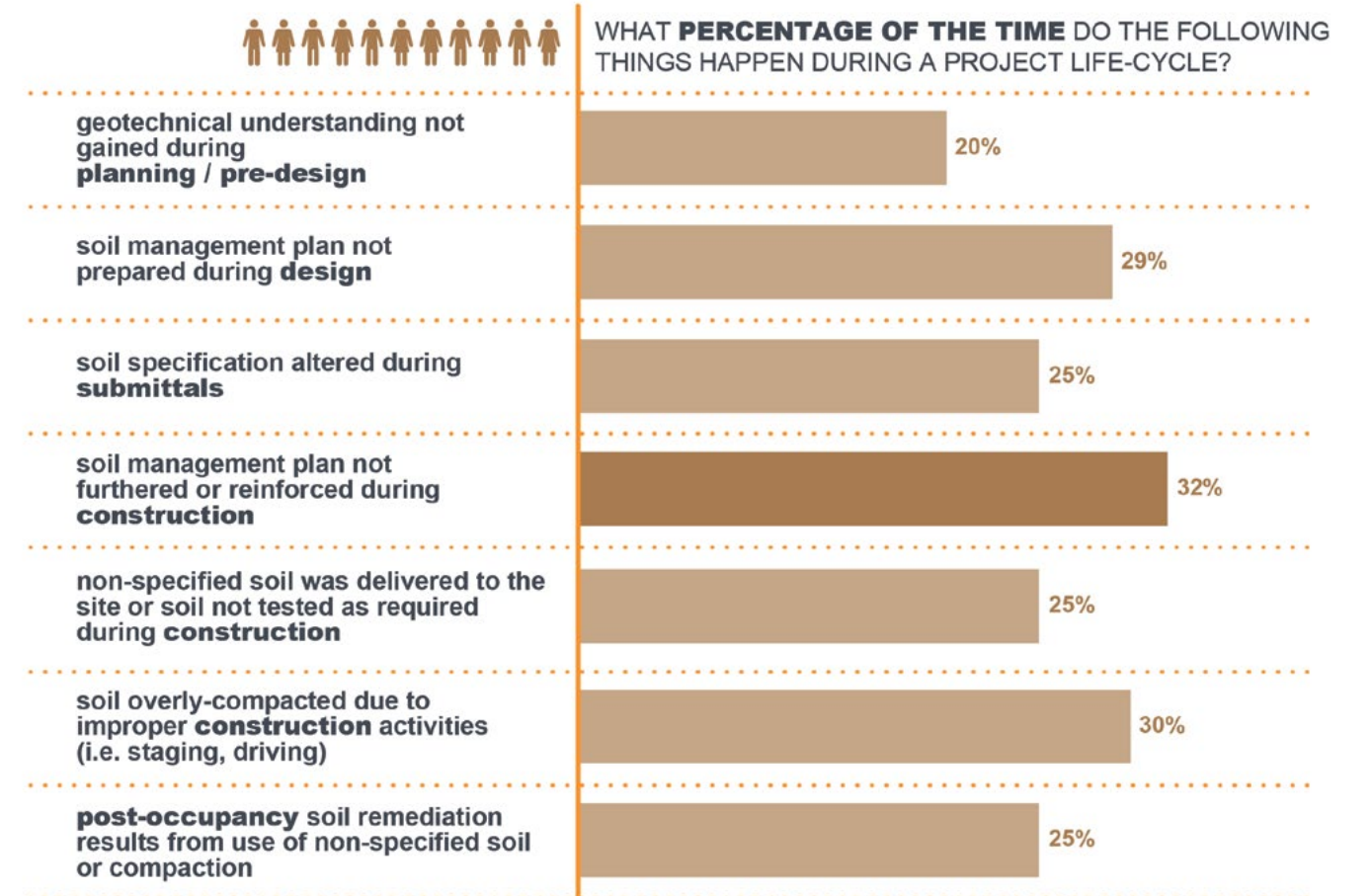
- 2) Poor understanding of the performative services that healthy soil systems provide; and
- 3) Lack of construction standards related to soil. Part of this disconnect may result from the traditional placement of soil management plan requirements in “Division 32 - Exterior Improvements” of the specifications, which is primarily read by the landscape contractor, but may not be reviewed by other trades who drive heavy machinery on the construction site.

Recommended Solutions

- Map existing site hydrology and soil drainage by *redoximorphic features* before construction
- Preserve and/or restore existing, native soil profile whenever possible and appropriate
- Require the preparation, implementation, and enforcement of a soil management plan
- Include the soil management plan requirement in “Division 01 - General Requirements” of the specifications so trades beyond the landscape contractor read the information
- Tailor soil specifications to meet performance goals
- Allow for material substitutions / flexibility through performance requirements in specifications
- Enforce soil-related rules, regulations, and metrics
- Anticipate changing performance over time



Data source: Water Working Group survey, administered by Andropogon Associates (n = 13)



Data source: Soil Working Group survey, administered by Andropogon Associates (n = 11)

RESULTS: VEGETATION WORKING GROUP

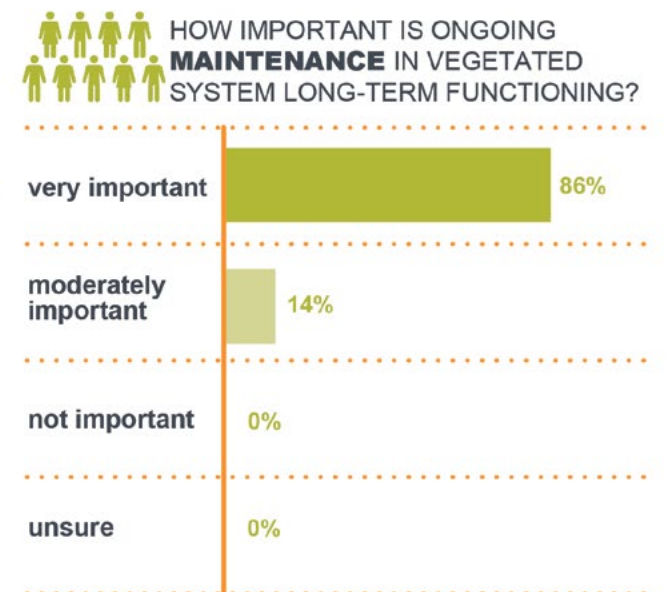
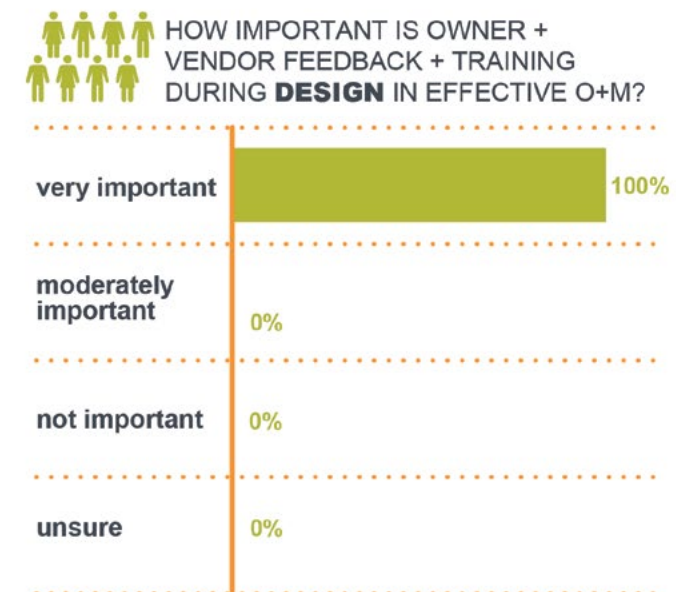
The survey data show that overwhelmingly, design and maintenance are the critical moments for influencing long-term vegetated system performance. Selecting native or adapted, site-appropriate plant species during the design phase is critical to a facility's ability to provide native pollinator habitat, provide bird habitat, and minimize long-term maintenance costs according to 89%, 86%, and 61% of survey participants, respectively. During submittals and construction, however, the data show that contract growing requirements are often not considered or followed, and that plant species, sizes, or spacing is often changed, thereby implementing a planting design that differs from what was intended. After construction, a lack of knowledge and training poses barriers to vegetated system performance 50% of the time during a project's pre-warranty and post-warranty maintenance phases. Problems may be exacerbated when a facility's installation and management personnel differ.

Interview participants noted that problems during the design phase often result when landscape architects are not knowledgeable about high-performance vegetated systems, not cognizant of plant availability, or not in-tune with the owner's level of maintenance expectations. At the same time, the owner often needs to be educated about true maintenance costs by the landscape architect and management personnel, during the design phase. Participants noted that owner buy-in is essential to a vegetated system's success, and that more maintenance is generally required during the first two years of establishment (termed "early stage management") compared to the extended system's life (termed "long-term management"). During the maintenance, or management, phases, most

problems arise due to a lack of personnel knowledge and training. Sometimes this is paired with more maintenance effort (i.e. mowing, pruning) than needed.

Recommended Solutions

- Solicit knowledgeable designers, construction sub-contractors, and site management personnel
- Engage the site manager and/or site management personnel throughout the design process
- Require native or adapted, site-appropriate plants
- Utilize conservation and restoration ecology principles whenever possible, and incorporate each site's existing, native seed bank into the design when possible
- Ensure the owner and landscape architect share expectations of anticipated maintenance effort
- Factor the true cost of early-stage management (years 1-2) into facility's capital budget
- Factor the true cost of long-term management (years 3+) into facility's operational budget
- Hold a pre-bid contractor's meeting to convey the design intent and performance expectations
- Move contract growing submittal requirement earlier in the submittals process
- Ensure best practices during soil preparation and planting
- Understand that plant species dominance and relationships change over time
- Collect monitoring data in centralized, real-time database
- Leverage site commissioning to ensure vegetated system performance at construction completion (i.e. project turnover)
- Retain the designer for periodic, post-construction site visits to validate design intent



Data source: Vegetation Working Group survey, administered by Andropogon Associates (n = 14)

RESULTS: MATERIALS WORKING GROUP

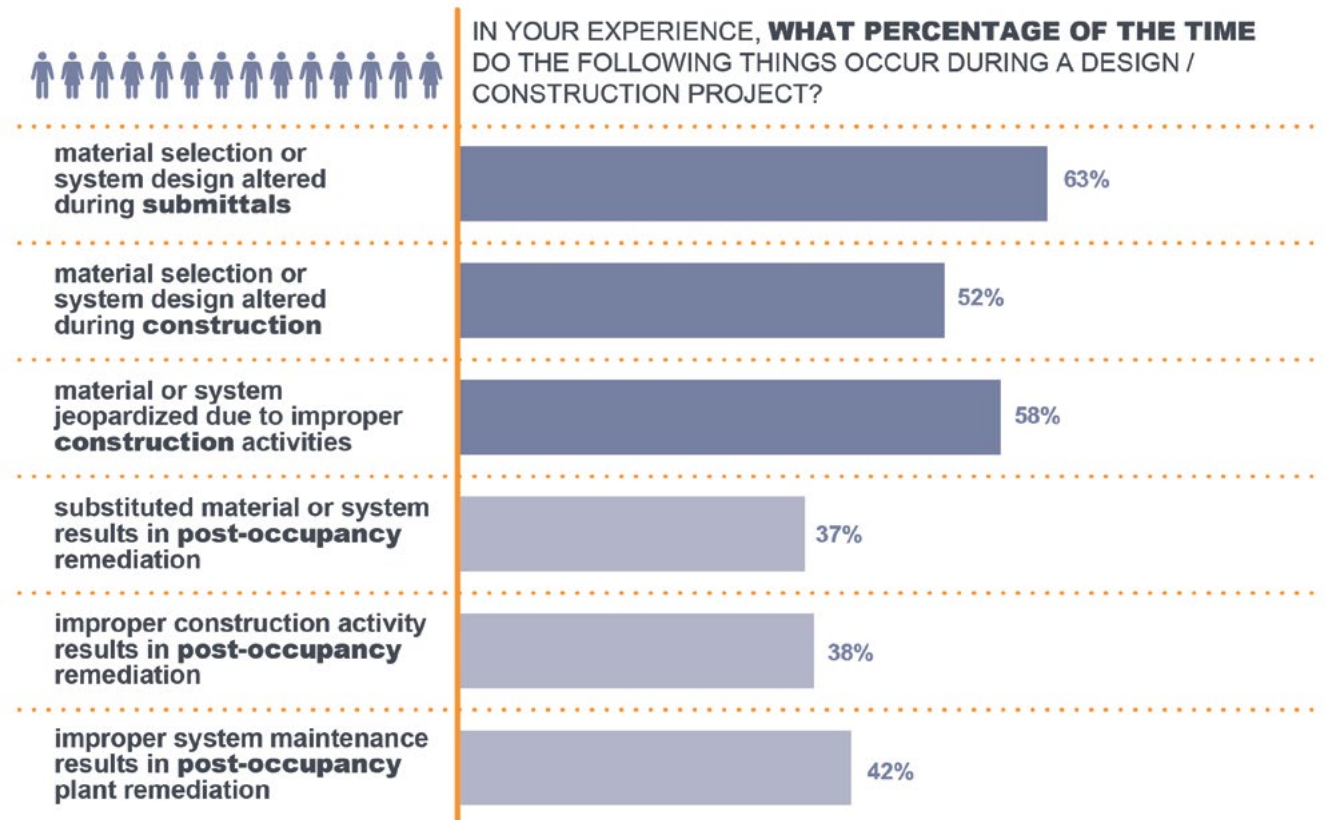
The survey found that "durability" is the most important performance goal for high-performance material systems, and yet, "material durability and material life-cycle value" are commonly overlooked from design through maintenance. Compounding the problem is a high rate of material and system alteration that occurs 63% of the time during submittals and 52% of the time during construction (according to the survey participants' experience), which can impact intended material and system performance. Furthermore, materials or systems are jeopardized due to improper construction activities 58% of the time.

Core to these problems, as articulated during the group's two interviews, are: 1) The added upfront cost of durable, high-value products; 2) A lack of contractor and sub-contractor training related to high-performance materials and systems; and 3) Low owner, designer, contractor, and site manager understanding of how material and system selection, and the quality of their installation and maintenance, impact long-term system performance. As a result, substitutions are common for the benefit of lowering upfront costs, at the expense of material and system performance throughout the facility's life-cycle. This scenario is particularly problematic and costly for build-to-own facilities, like those of GSA, because the owner is invested for the long-haul (as opposed to

build-to-sell).

Recommended Solutions

- Pursue inclusive project delivery processes in which owner, designer, contractor, maintenance and operations personnel, and commissioning agent understand performance goals and work collaboratively, starting as early as possible
- Clearly articulate project goals and budgets early in design to avoid value engineering that negatively impacts performance
- Include life-cycle and accurately projected maintenance costs in material selection process
- Anticipate type and level of use and let owner determine maintenance effort upfront
- Encourage designer-manufacturer communication regarding performance goals, early during design
- Build performance expectations and under-performance consequences into specifications
- Emphasize performance requirements of suitable substitutions in specifications
- Include sub-contractor pre-qualification and pre-construction requirements in specifications and submittals
- Leverage site commissioning process to increase performance feedback and general communication between owners, designers, operations and maintenance personnel, and manufacturers



Data source: Materials Working Group survey, administered by Andropogon Associates (n = 14)

RESULTS: HABITAT WORKING GROUP

Participants agreed that the use of native plants is very important in achieving multiple habitat performance goals, including the support of “native animal health at multiple trophic levels” and “system resilience.” The survey and interview data indicated that site selection, construction, and maintenance are the critical moments for influencing these and other measures of habitat performance. However, in the group’s experience, habitat goals are jeopardized due to improper construction activities and improper maintenance activities 71% and 77% of the time, respectively.

Interview participants noted that some of the most common obstacles during construction are soil compaction, the availability of native seed and plant material (particularly local ecotypes), plant species substitutions, plant size and spacing alterations, and planting within appropriate seasonal windows. The data suggest that knowledge and training pose significant barriers to habitat performance during the facility’s pre-warranty and post-warranty maintenance phases. Additionally, GSA, as an institution, has prioritized pollinator habitat (which is typically expressed as meadow) due to an executive order that requires the provision of pollinator habitat at federal facilities. Several participants objected to this prioritization, noting that habitat needs vary by region, and that high-quality habitat for other organisms, ranging from soil microorganisms to mammals and

birds, is equally important to ecosystem integrity.

Recommended Solutions

- Consider habitat scale and on/off-site connectivity opportunities when selecting each facility’s location
- Tailor each facility’s performance goals to prioritize regional habitat needs
- Conserve and/or restore existing habitat and water systems whenever possible
- Include scientists (e.g. ecologist, biologist, geomorphologist) as needed, and knowledgeable landscape architects on the facility’s design team
- Expand pollinator habitat typology to include appropriate woodland and scrub-shrub habitats, which also serve other types of indigenous species
- Establish sequenced performance metrics, or trajectories, rather than focusing on optimization immediately after construction
- Incorporate monitoring costs into facility’s operational budget
- Require baseline habitat assessments, including landscape ecology studies, soil and hydrologic analysis, along with flora and fauna surveys
- Provide interpretive signage
- Plan and allow for plant community succession
- Employ maintenance personnel knowledgeable in wildlife and ecological systems
- Practice adaptive management

RESULTS: HUMAN HEALTH & WELL-BEING WORKING GROUP

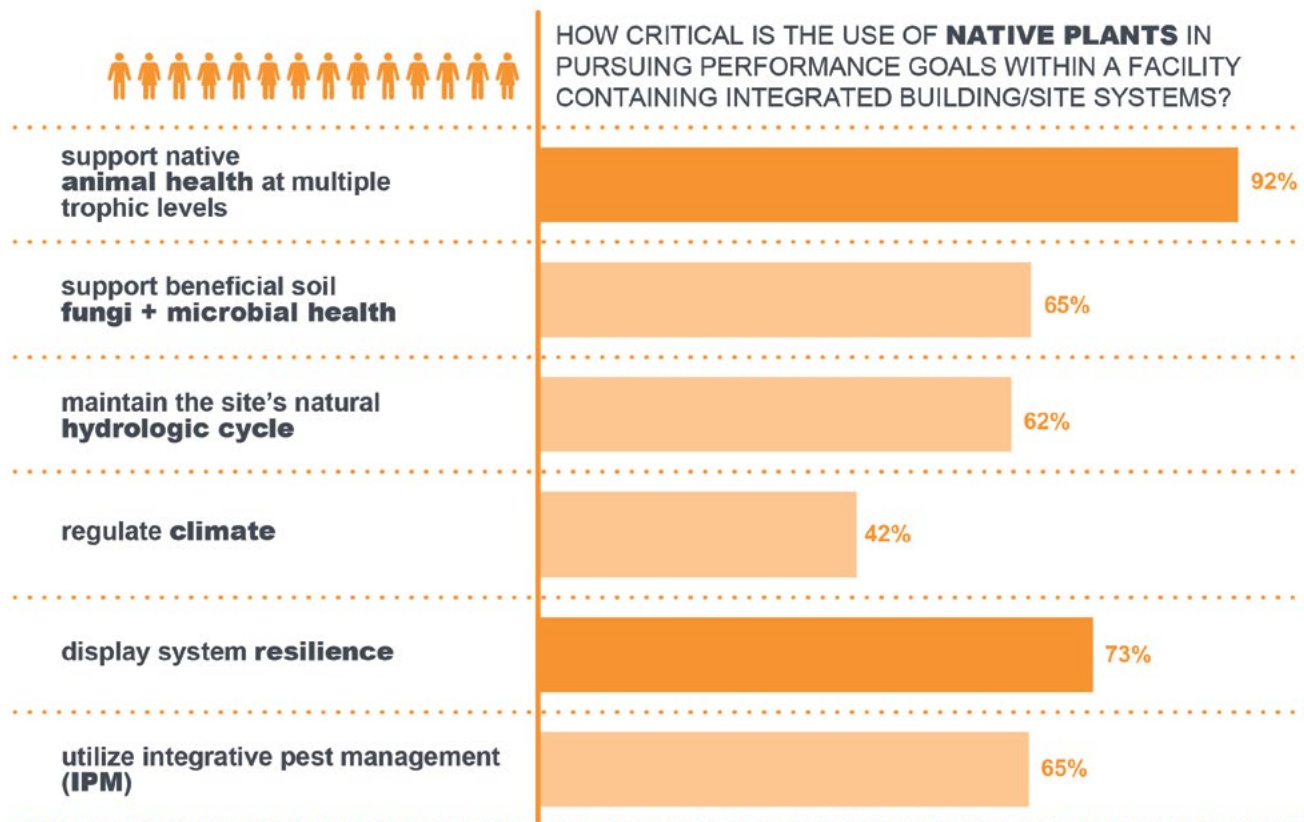
The survey found that “views of vegetation from indoors” and “access to outdoor space” are the most highly influential variables to human health and well-being in the workplace. When facilities fail to meet these and other human health and well-being goals, survey participants reported that “increased absenteeism and worker health problems” pose the greatest financial risk to employers. According to the survey, the most significant barriers to implementing systems that support these human health and well-being performance goals are “client interest,” during a facility’s planning / pre-design phase, and lack of “knowledge, training, or integration,” during every other project phase (except for construction) through post-warranty maintenance.

Several working group members noted that these problems frequently result when stakeholder engagement is overlooked and clear human health and well-being goals are not established early enough in a facility’s planning process. When performance goals are effectively distilled and documented, achieving them may require interdisciplinary coordination, particularly between the architecture

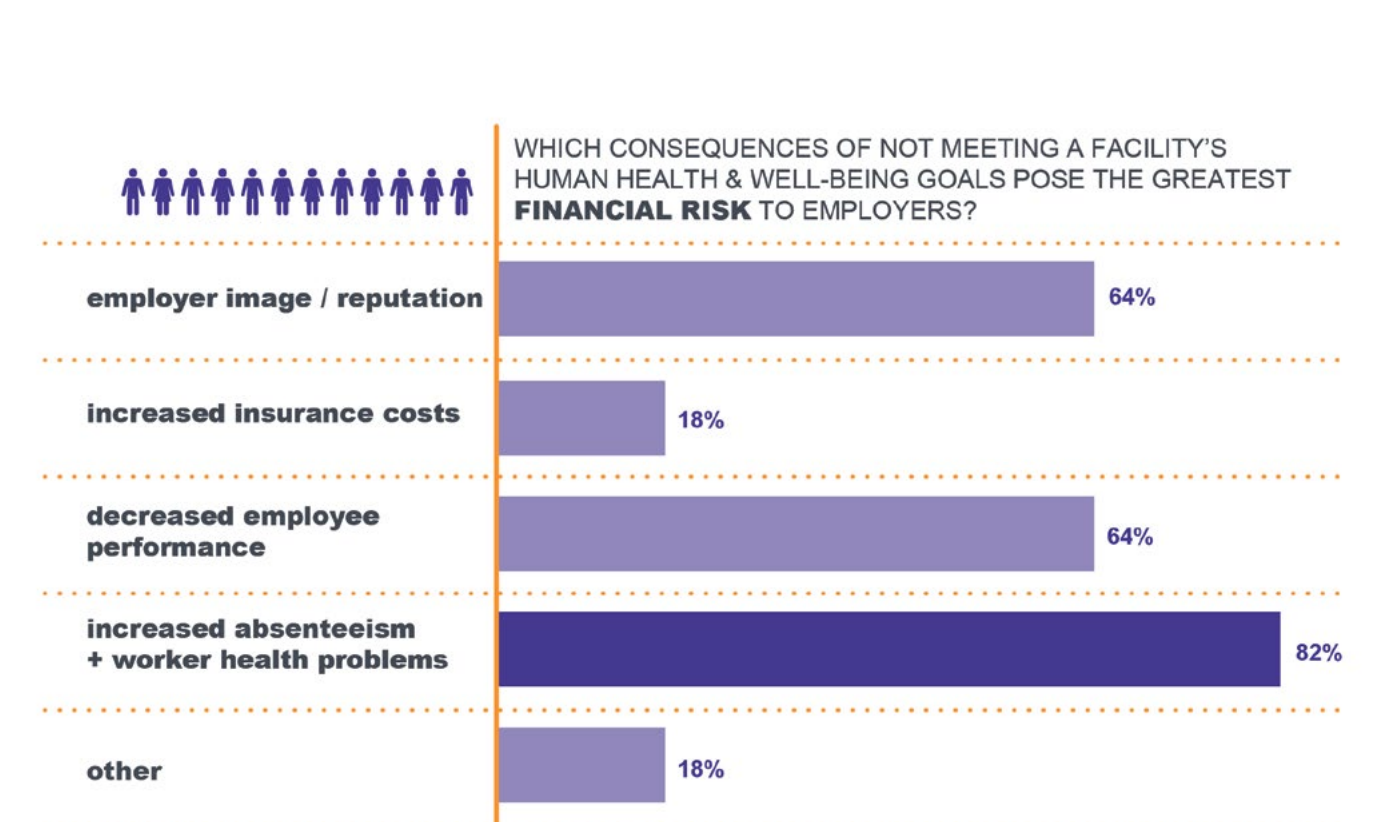
/ landscape architecture / engineering team. Additionally, the goals should function as the basis of accountability in performance from a facility’s design through post-warranty maintenance phase.

Recommended Solutions

- Leverage site commissioning to encourage owner investment in physical spaces that are designed to decrease worker absenteeism, reduce health problems, and enhance worker performance
- Identify simple, measurable goals that can be monitored by non-scientists
- Focus on quantitative metrics to prove value
- Hold regular, interdisciplinary team meetings throughout the design process
- Design above the baseline (ADA-compliance) through a “human-centered design” approach
- Document performance goals related to specific design elements to protect elements and goals from value engineering
- Bring attention to the value of each human space
- Consider expanding GSA’s existing indoor user satisfaction surveys to the outdoors, as an informative qualitative metric



Data source: Habitat Working Group survey, administered by Andropogon Associates (n = 13)



Data source: Human Health & Well-Being Working Group survey, administered by Andropogon Associates (n = 12)

RESULTS: CLIMATE WORKING GROUP

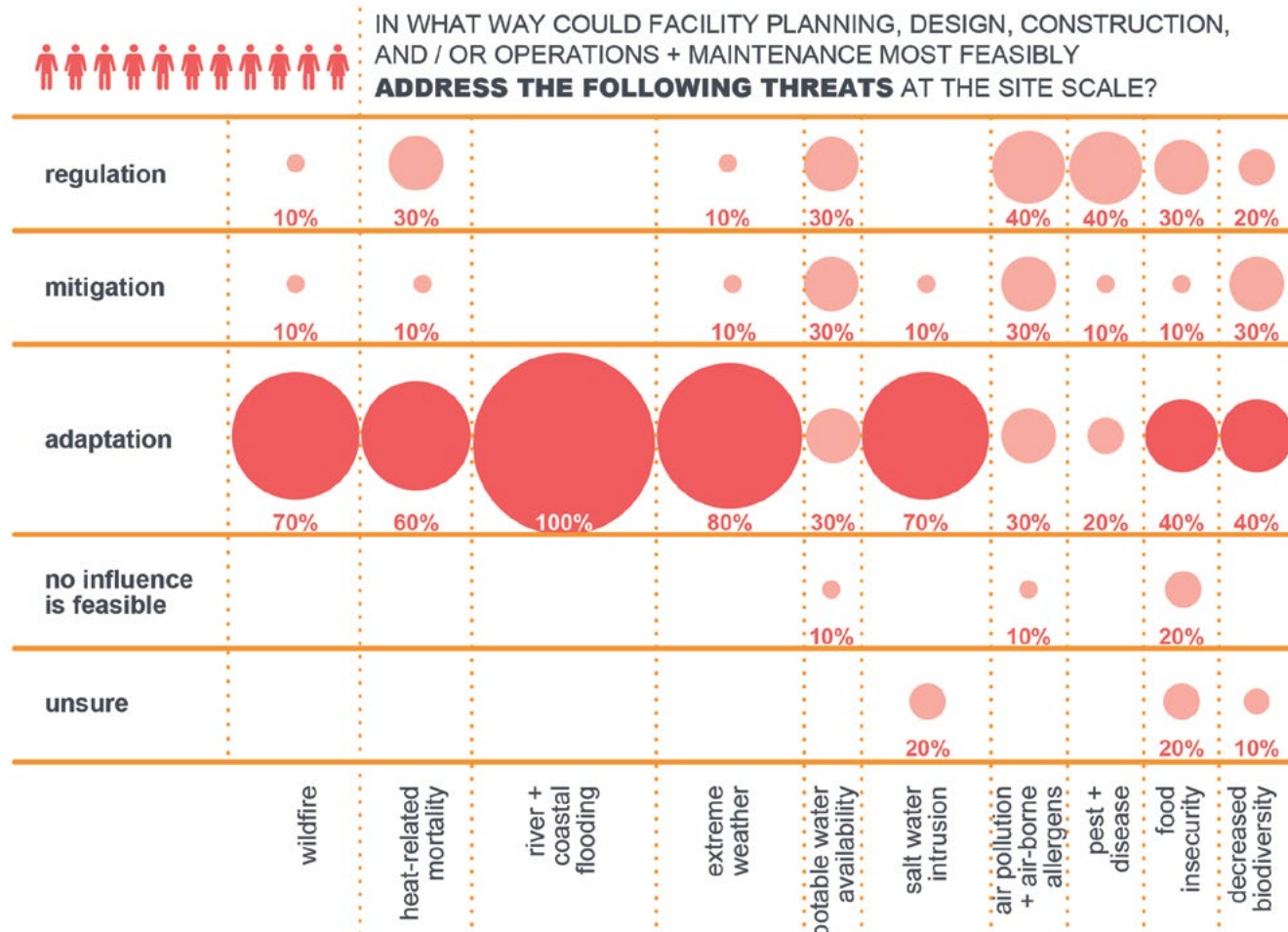
The survey data revealed strong agreement between working group members that facility planning, design, construction, and operations and maintenance can most feasibly be used to address threats of climate change through “adaptation.” In particular, adaptation to wildfire, heat-related mortality, river and coastal flooding, extreme weather events, and salt water intrusion. Multiple survey responses and interview comments noted that one of site commissioning’s greatest potential values would be to reduce facility owners’ and occupants’ risk and vulnerability associated with these effects of climate change. Although, “client interest” was found to pose one of the most significant barriers to the implementation of high-performance systems that support climate issues.

When considering adaptation to climate change, (particularly for facilities like ports of entry, which may expand but will not move) many group members agreed that facilities should be planned, designed, and built to withstand 50 - 100 years of climate-related stresses and extremes. They recognize that this is difficult, though, given the unpredictability of extreme weather events and the propensity for site system performance to change over time. Lastly

the survey data suggested that only a researcher or commissioning professional is capable of assessing performance data and adjusting a maintenance regime related to carbon sequestration, vegetation and soil system resiliency, and prevalence of pests and disease, which can be challenging within a facility’s budgetary realities.

Recommended Solutions

- Focus on climate change adaptation during design
- Demonstrate important adaptations for each region
- Accommodate anticipated environmental stress and system performance fluctuations into system design and operations
- Carefully cite buildings to manage facility’s risk
- Embed automated monitoring systems into sites
- Involve maintenance personnel in site monitoring
- Use each facility to build knowledge about performance changes in each system over time, so performance is more predictable on future projects
- Deconstruct assumptions about building / site integration and consider innovative technologies
- Use commissioning to enhance site adaptiveness to climate change related stresses



Data source: Climate Working Group survey, administered by Andropogon Associates (n = 10)

C | SITES CREDITS EMBEDDED WITHIN SITE COMMISSIONING

Relevant Prerequisites + Credits	Value
Section 1: SITE CONTEXT	N/A
Section 2: PRE-DESIGN ASSESSMENT + PLANNING	
Pre-Design Prerequisite 2.1 : Use an integrative design process	Required
Pre-Design Prerequisite 2.2 : Conduct a pre-design site assessment	Required
Pre-Design Prerequisite 2.3 : Designate and communicate Vegetation and Soil Protection Zones	Required
Pre-Design Credit 2.4 : Engage users and stakeholders	3 points
Section 3: SITE DESIGN—Water	N/A
Section 4: SITE DESIGN—Soil + Vegetation	
Soil+Veg Prerequisite 4.1 : Create and communicate a soil management plan	Required
Soil+Veg Prerequisite 4.2 : Control and manage invasive plants	Required
Soil+Veg Prerequisite 4.3 : Use appropriate plants	Required
Section 5: SITE DESIGN—Materials Selection	N/A
Section 6: SITE DESIGN—Human Health + Well-Being	N/A
Section 7: CONSTRUCTION	
Construction Prerequisite 7.3 : Restore soils disturbed during construction	Required
Section 8: OPERATIONS + MAINTENANCE	
O+M Prerequisite 8.1 : Plan for sustainable site maintenance	Required
O+M Credit 8.4 : Minimize pesticide and fertilizer use	4 - 5 points
Section 9: EDUCATION + PERFORMANCE MONITORING	
Education Credit 9.1 : Promote sustainability awareness and education	3 - 4 points
Education Credit 9.3 : Plan to monitor and report site performance	4 points
Section 10: INNOVATION OR EXEMPLARY PERFORMANCE	N/A

In 2016, GSA adopted the Sustainable SITES Initiative (SITES) for all new construction and major redevelopments by embedding the requirement in its PBS-P100 (see *Project Background*, p. 5). SITES contains prerequisites, which must be completed to gain SITES-certification, and credits, which can be selectively earned to contribute to varying certification levels. Eight of these prerequisites and four credits (for a maximum total of 16 points) are embedded within the site commissioning processes outlined in this white paper. These prerequisites and credits can guide the OPR development, help shape the project scope, and integrate seamlessly into the site commissioning process (see *Integration into GSA’s Current building commissioning process*, p. 45).

D | SAMPLE SCOPE OF SERVICES FOR SITE COMMISSIONING AGENTS

Site Commissioning Agent (SCxA) Responsibilities

1. The SCxA is the Owner's commissioning consultant and a member of the Commissioning Team. The SCxA advises the Owner and Commissioning Team on issues involving the site commissioning process and its intended results. The SCxA direct the site commissioning process in accordance with the project commissioning specifications to provide long-term performance and maintainability of the systems included in the scope of work.-
2. The SCxA is authorized and obligated to advise the Owner of issues involving the design, construction materials, construction methods, system start up, testing protocols, data analysis, adjusting and balancing, and other activities that are required to maximize system performance and maintainability.
3. The SCxA is authorized and obligated to make recommendations to the Owner regarding the acceptance, modification, rejection of materials (with agreement by the Design Team), construction procedures, schedules, tests, reports or other items pertaining to the systems within the site commissioning scope of work.
4. The SCxA is not authorized to change contract documents, schedules, costs, or scopes of work for any parties contracted on the project. The SCxA is not empowered to direct any contractor, subcontractor or person on the project to make required changes in the work, materials used, or construction methods utilized in completing their scope of work. Directives for corrective action will come through the contract chain of command as dictated by the contracts for the project.

Site Commissioning Activities

1. Planning / Pre-Design Phase

- a. Attend a pre-commissioning meeting with the Owner, Commissioning Team, and Design Team to review the commissioning process.
- b. Maintain and update a commissioning issues log.
- c. Review the Owner's Project Requirements (OPR) document and the current Basis of Design (BOD) document for consistency for elements related to the project's site systems and integrated site-building systems.
- d. Direct and document site commissioning meeting(s) with the Owner and site managers.
- e. Prepare site system and integrated site-building system portions of the Preliminary Commissioning Plan, including standard pre-functional checklists.
- f. Identify potential subject matter expertise (i.e. soils, hydrology, ecology etc.) based on the project's OPR goals.
- g. Assist the Owner in development of commissioning budget.
- h. Review feasibility and design studies related to site commissioning goals and provide feedback to the Commissioning Team, Design Team, and Owner.

2. Design Phase

- a. Attend design meetings as requested by the Owner.
- b. Review drawings and specifications related to the site commissioning scope of the project at the Schematic Design, Design Development, and Construction Documentation submissions and provide feedback to the Design Team and Owner. Reviews shall occur at interim and final submissions.

- c. Determine if the drawings and specifications provide sufficient instrumentation, test and access ports, and specified responsibility in order to provide a complete, commissionable project.
- d. Update and refine the site systems and integrated site-building system-specific portions of the project's commissioning plan and pre-functional checklist to describe the organization and activities of the Commissioning Team. This plan shall describe responsibilities, lines of communication, reports and specific commissioning activities, schedules, and reports.
- e. Develop site commissioning specification language for Division 1.
- f. Review the project's Adaptive Management Plan with the Owner and contractor who will manage the site.

3. Construction Phase

- a. Plan Review: The Design Team and General Contractor shall forward copies of plans, specifications and submittals for review by the SCxA for possible conflicts, site deficiencies, ability to be tested and balanced, ability to be commissioned and coordination between disciplines.
- b. Schedules: Assist the Commissioning Team and General Contractor in developing commissioning schedules and checklists (see Site Commissioning Metrics Chart, p. 41)
- c. Field Installation Verification (FIV): Provide construction FIV for site systems and integrated site-building systems, and a pre-functional check sheet matrix (see Site Commissioning Metrics Chart, p. 41). Submit any concerns or deficiencies through a daily field report and the commissioning issues log.
- d. Commissioning Meetings: Attend on-site commissioning meetings as required to complete and coordinate the site commissioning process.
- e. Control Point to Point Tests: The startup verification report tests include complete point-to-point tests of automatic control systems and electronic site management systems (e.g. irrigation and water harvesting systems). Prior to this test, the controls contractor shall complete the installation and conduct a self-test and calibration of each point on the system. A team consisting of the SCxA, the controls contractor and possibly an Owners representative shall verify the system point-to-point test. Each point shall be verified as to its operational status and correct mapping, and recorded on the startup verification report test form. These point-to-point tests may be concurrent with parties performing the point to point verification together.
- f. Test & Balance verification: Work with the TAB firm to verify that the work is performed using the methodology described in the procedural standard (e.g. NIST, ASTM) and is in line with the design intent. The TAB firm must provide current calibration certificates for instrumentation used in the TAB work.
- g. Functional Performance Tests (FPT): Develop FPT required to be performed with the responsible contractor who provided the site being tested for systems included in the scope of work. The contractor shall demonstrate under CxA direction to verify that the site materials and installation are compliant with the design.
- h. Preliminary O&M Manuals: Each contractor and vendor must submit maintenance manuals early in the construction process (directly following approval of submittals). These documents are required to develop commissioning procedures for FPT tests.
- i. Final O&M Manuals and As-Built Drawings: Upon the completion of startup/functional testing verification report tests, O&M manuals and As Built Drawings shall be finalized to "As Built" condition and supplied to the GC. These manuals shall be reviewed by the CxA in conjunction with the A/E firms for use in the Owner training seminar.
- j. Owner Training: This training session shall be presented by the design professionals, installing contractors, and equipment suppliers. The CxA shall participate.
- k. Final Commissioning Report: Provide the site system and integrated site-building system portions of a final commissioning report to the Commissioning Team, which shall include commissioning communication, test results, FIV check sheets, and FPT reports.

E | SAMPLE FIELD OBSERVATION FORM - BIRDS

4. Post-Construction Phase

- a. Review the project's Adaptive Management Plan with the Owner and contractor who will manage the site.
- b. Post Occupancy Performance Verification: Coordinate and schedule the post occupancy performance verification activities for the site. These tests will be a measure of performance during the occupied period. Review the testing results that are provided by the management personnel who are responsible for maintaining the systems. At the completion of post occupancy tests, publish a site commissioning report addendum to document the performance verification tests.
- c. Cost Events: If multiple tests prove to be failures (e.g. the same test fails more than once), and the contractor fails to provide proper corrective measures thus causing added testing attempts, then the contractor will incur the added time as a cost event charge for retesting of the system.
- d. Prepare the site system and site-building system-specific portions of the final commissioning report to the Commissioning Team, for submission to the Owner.
- e. Participate in a lessons learned meeting with the Owner.
- f. Conduct Long-Term Management contractor training.

5. Long-Term Phase

- a. Recommission site on the building commissioning schedule, every 3 to 5 years.
- b. Prepare the site system and site-building system-specific portions of the final commissioning report to the Commissioning Team, for submission to the Owner.
- c. Conduct owner and management personnel re-training as needed.

Bird field data sheet

Page 1 of 2

Survey area _____ **Date:** _____
Team Number _____ **Team Leader** _____ **Site number:** _____
Location and description *(brief description using landmarks, photograph number, etc. so site can be located again)*

Project Name _____ **AMG Zone** _____
Project scale _____ **Easting** _____
(6 digits; should be recorded mid-point along transect)
Latitude _____ **Northing** _____
(7 digits; should be recorded mid-point along transect)

Start time (24 hour) _____

Temperature at start (write in Celsius) _____

Finish time (24 hour) _____

Temperature at finish (write in Celsius) _____

Wind speed (tick)	Moon (tick)	Rain (tick)	
<input type="radio"/> 1. Calm <input type="radio"/> 2. light, leaves rustle <input type="radio"/> 3. Moderate, branches move <input type="radio"/> 4. Strong, tops of trees move	<input type="radio"/> 1. No moon <input type="radio"/> 2. less than or equal to 1-4 moon <input type="radio"/> 3. less than or equal to 1/2 moon <input type="radio"/> 4. less than or equal to 3/4 moon <input type="radio"/> 5. between 3/4 and full moon <input type="radio"/> 6. full moon	<input type="radio"/> 1. dry <input type="radio"/> 2. light drizzle <input type="radio"/> 3. constant drizzle <input type="radio"/> 4. heavy rain <input type="radio"/> 5. mist, fog or heavy haze	Cloud cover (in percentage of sky) _____

Bird field data sheet

area _____
 number _____
 Team Leader _____

Area Location Observer	Start time (24 hrs)	Finish time (24 hrs)	Bird species code	Bird name	Observation type	Number of individual		
						0 - 15 metres	15 - 30 metres	30 m

SAMPLE FIELD OBSERVATION FORM - POLLINATORS

POLLINATOR MONITORING DATA SHEET Date: 6 / 15 / 2009 **MORNING OBSERVATION PERIOD**

INSTRUCTIONS: Fill in the date and requested times, and circle the relevant weather-related information. For the "Habitat changes..." section, fill in all of the habitat changes and other anomalies (i.e. heavy precipitation, high winds, temperature extremes, etc.) since the last time you observed bees at this site. In the table, fill in the "Floral Resource" column with the flower species you are observing (i.e. type, cultivar, etc.); for each species, count the total number of plants ("# Plants") and count the number of bees visiting each floral resource for ten (10) minutes per species; record the number of plants you actually made your bee counts from ("# Obs. "). If you cannot determine which group a bee belongs to, record the bee in the "Other" column and note whether you could tell it was not a honey bee or bumble bee in the "Observational Notes" section at the bottom of the page, along with any additional comments. Please record additional blooming species at the bottom of the other side of this datasheet, under "Additional Blooming Plants".

Location: Department of Agriculture Observation Start Time: 9 : 00 End Time: 11 : 30

Weather: Temp: 50 / 60s / 70s / 80s / 90s / 100+ Wind: Still / Light Breeze / Windy / Gusty Sky: Clear / Partly Cloudy / Mostly Cloudy / Overcast

Habitat changes since the last observation/collection date:
There was a lot of rain at the end of May (about 2.25 inches) - the plants really perked up. The first week of June it was very warm (highs in the low 90s), but it has cooled off this week. A lawn tractor cut down a few of the plants on one end of the garden...

Floral Resource (Genus species)	# Plants/ # Obs.	Honey Bees	Bumble Bees	Large Carpenter Bees	Hairy Leg Bees	Large Dark Bees	Small Dark Bees	Green Sweat Bees	Metallic Hairy Belly Bees	Dark Hairy Belly Bees	Cuckoo Bees	Other - Describe in Notes
<i>Megacynus</i> X	3 / 3	1	2	1			9	4		3		
<i>Thymus</i> X	4 / 3		4			1	13	8			1	
<i>Monarda 'Fireball'</i>	8 / 5	2	8			2	3	3				
<i>Chinacea</i> sp.	5 / 5		3		1		4	11			1	
<i>Isclapias tuberosa</i>	10 / 4	2	6	1		1	2	6		1		
<i>Agastache</i> X	20 / 11		1			3	11	3				
<i>Felicitus annuus</i>	6 / 3	4	4			2	9	8				
<i>Lymphotrichum novae-angliae</i>	12 / 9	1	2		1		8	7				

Feel free to use tally marks or write the final number. If you use tallies, please write the final total for each bee species on each plant species and circle it.

Observational Notes:
Activity increased as temperature increased.
Some of the bees were already loaded with pollen before we started. The dandelions in the grass surrounding the garden seem to be quite attractive.

SAMPLE FIELD OBSERVATION FORM - INSECTS

Insect Order Richness (No. of Individuals)

Time: 3:05 PM - 3:20 PM

Temperature: 93°F, light wind from south

Scientific Name	Common Name
Blattodea	Cockroaches and termites
Coleoptera	Beetles
Dermaptera	Earwigs
Diptera	Flies
Embiidina	Webspinners
Ephemeroptera	Mayflies
Hemiptera	True bugs, cicadas, hoppers, aphids, allies
Hymenoptera	Ants, bees, wasps, sawflies
Lepidoptera	Butterflies, moths
Mantodea	Mantids
Mecoptera	Scorpionflies, hangingflies, allies
Megaloptera	Alderflies, dobsonflies, fishflies
Microcoryphia	Bristletails
Neuroptera	Antlions, owlflies, lacewings, mantidflies, allies
Notoptera	Rock crawlers
Odonata	Dragonflies, damselflies
Orthoptera	Grasshoppers, crickets, katydids
Phasmida	Walkingsticks
Plecoptera	Stoneflies
Psocodea	Barklice, booklice, parasitic lice
Raphidioptera	Snakeflies
Siphonaptera	Fleas
Strepsiptera	Twisted-winged insects
Thysanoptera	Thrips
Trichoptera	Caddisflies
Zoraptera	Zorapterans
Zygentoma	Silverfish

8/15/16		
Plot A	Plot B	Plot C
5	4	5
5	7	10
1	9	2

Source: Andropogon Associates

F | ADDITIONAL RESOURCES

ASHRAE, Standard 202-2013: Commissioning Process for Buildings and Systems - www.ashrae.org/resources--publications/bookstore/commissioning-essentials

Berkeley Lab, Measurement and Verification Portal - <http://mnv.lbl.gov/keyMnVDocs/ipmvp>

Building Commissioning Association - www.bcxa.org

Efficiency Valuation Organization - <http://evo-world.org/en>

GSA Commissioning Program - www.gsa.gov/portal/category/21064

GSA PBS-P100 - www.gsa.gov/portal/content/104821

GSA SF Tool, Landscaping Services - <https://sftool.gov/greenprocurement/green-services/3/landscaping-services>

International Living Future Institute - <http://living-future.org/lbc>

Landscape Architecture Foundation - <http://lafoundation.org>

Leadership in Energy and Environmental Design (LEED) - www.usgbc.org/leed

National Institute of Building Sciences, Whole Building Design Guide - www.wbdg.org/project/buildingcomm.php

Project BudBurst - http://budburst.org/phenology_climatechange

Sustainable SITES Initiative - www.sustainable-sites.org

The Economics of Biophilia - www.terrabinbrightgreen.com/reports/the-economics-of-biophilia/

Universal Floristic Quality Assessment (FQA) Calculator - <http://universalfqa.org/about>

USA National Phenology Network - <https://www.usanpn.org/data/spring>

U.S. Environmental Protection Agency Ecoregions - www.epa.gov/eco-research/ecoregions

G | GLOSSARY

Adaptive management: iterative approach to improving operations and maintenance by systematically learning from past decisions and outcomes

Appropriate plant: species adapted to a project's site conditions, climate, and design intent

Blackwater: water that contains the waste of humans, animals, or food

Climate: average weather within an area over a period of time

Climate mitigation: actions that reduce contributing factors of climate change

Climate adaptation: actions that minimize or prevent negative impacts of climate change

Climate regulation (global): maintaining the balance of atmospheric gases at historic levels, maintaining healthy air quality, and/or sequestering carbon

Climate regulation (site/local): maintaining local temperatures, precipitation levels, and humidity, through shading, evapotranspiration, and/or windbreaks

Commissioning (Cx): systematic process of assuring, by verification and documentation, that built systems perform in accordance with design intent and the owner's operational needs

Commissioning agent (CxA): qualified member of the project team that plans, coordinates, and oversees the commissioning process, including functional performance testing and performance verification

Commissioning plan: living document that describes a facility's commissioning process, including schedules, responsibilities, documentation requirements, and communication structures

Continuous commissioning: systematic process that relies upon regularly gathered or continuous feeds of data as part of an ongoing commissioning program for large, generally complex projects

Cultivar: sub-species of a straight plant species bred for a particular trait

Design-bid-build: project delivery method in which design services are provided, the project is bid by contractors, and then a contractor is awarded and provides construction services

Design-build: project delivery method in which a contractor provides both design and construction services

Ecoregion: ecologically-similar regions, as defined geographically by the U.S. Environmental Protection Agency

Ecosystem service: any positive, direct or indirect benefit that wildlife or ecosystems provides to people

Ecotype: genetically distinct geographic variety of a species that is adapted to local conditions

Early-stage management: intensive site maintenance during the first 2-3 years after construction, generally corresponding to the plant establishment period

Functional performance testing: evaluation of a built system's function and operation relative to the OPR, based on direct observation and/or monitoring after completion of construction checklists

Greywater: domestic wastewater that does not contain the waste of humans, animals, or food

Integrated building/site systems: open- or closed-loop features that support one another for operation

Integrated project delivery (IPD): project delivery method that engages members of the project team throughout the entire process, who traditionally occupy one segment of the process

International Performance Measurement and Verification Protocol (IPMVP): an internationally-recognized compilation of best practices protocol for verifying energy and water efficiency and cost savings

Landscape: *see Site*

Landscape performance: a measure of the effectiveness with which landscape solutions fulfill their intended purpose and contribute to sustainability¹

Leadership in Energy and Environmental Design (LEED): is a sustainability rating system for buildings, used by designers and consultants, developed and administered by the U.S. Green Building Council

Long-term management: less intensive site maintenance after a project's 2-3 year early-stage management period

Native plant: species that naturally occurs with a project site's U.S. Environmental Protection Agency Ecoregion Level III designation

Owner's project requirements (OPR): documented performance outcomes, established by a project's owner, that form the basis from which design, construction, acceptance and operational decisions are made during the commissioning process

PBS-P100: GSA Public Building Service's facility standards for the Public Buildings Service, which establishes design standards for the agency's new buildings and renovations

Performance metric: measurement type that provides a means for quantifying or qualifying performance

Recommissioning: systematic process that involves periodic, functional performance monitoring and evaluation of a built project that was previously commissioned during construction or substantial completion

Redoximorphic features: soil discoloration indicating that the soil has been saturated and anaerobic

Retro-commissioning: systematic process that involves diagnostic and functional performance monitoring, generally of an older project, that occurs once to trouble-shoot a problem or periodically to establish a commissioning program

Total building commissioning: systematic process that involves testing and verifying that all building systems perform in accordance with design intent and OPR, from design to at least one year post-occupancy

Triple bottom line: accounting framework that assumes the true cost of doing business can be accurately understood only when social, environmental, and economic performance is measured

Site: area within the defined boundaries of a design-construction project that includes all vegetated and non-vegetated areas beyond the building extents

Site Commissioning (SCx): systematic process of assuring, by verification and documentation, that built site systems perform in accordance with design intent and the owner's operational needs

Site Commissioning Agent (SCxA): qualified sub-consultant to or employee of the CxA that plans, coordinates, and oversees the commissioning process related to a facility's site

Stormwater: rainwater or snow melt

Sustainable SITES Initiative (SITES): point-based rating system used by designers, planners, and policy makers to develop sustainable landscapes that was created by the American Society of Landscape Architects, The Lady Bird Johnson Wildflower Center at The University of Texas at Austin, and the U.S. Botanic Garden, and is administered by Green Business Certification Inc.

Total water: all potable and collected water that is brought to or originates on a facility's site

Wastewater: water that has been used for domestic or industrial purposes and contains dissolved or suspended waste materials

Zero-lot-line: form of development in which the building(s) extend to or very close to the property line

¹ Landscape Architecture Foundation (2017)

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