Optimizing Urban Ecosystem Services: The Bullitt Center Case Study

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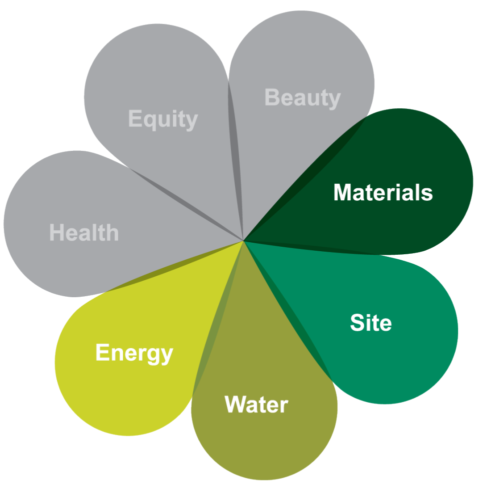
01 *Executive Summary*

The Bullitt Center Assessment Team was tasked with performing fundamental research on the ways green building and infrastructure features can produce, enhance, and transform urban ecosystem services benefits, using the Bullitt Center in Seattle, Washington, and the Living Building Challenge developed by the International Living Future Institute as key case studies. This research focuses on the distinct characteristics and modeling opportunities offered by ecosystem services in hybrid natural-technical systems (e.g., bioswales) operating in urban areas. Effectively harnessing these hybrid systems can allow us to move from the built environment as "disturbance" to a regenerative partner with living systems.

Key Findings

FIGURE 1

Value Created Over 250-Year Lifecycle of the Bullitt Center for Selected Building Features Using Social Price of Carbon ($200/Metric Ton)



= **$18,450,000**

over the lifecycle of the building,
Present Value with 4% discount rate

- As part of a broader qualitative and quantitative assessment of Bullitt Center green building features, functions, and ecosystem services provided, we have conducted a preliminary financial valuation of six important building strategies. As in all ecosystem service valuations, there are many different potential methodologies, and many detailed assumptions must be made to arrive at specific dollar figures. These assumptions should be made part of any communications strategy around these valuations, and should be carefully reviewed before releasing any specific figures. The results show that just a few features out of many available candidates suggest an additional value created comparable, and likely much larger than, any initial construction cost premium.
- This study assumes a 3% annual increase in carbon, electricity, water, wastewater treatment, and stormwater prices.

TABLE 2

Benefits by Feature

PETAL	Feature	Annual Benefit	Initial One-Time Benefit	Present Value Over Lifetime of Project Based on Different Discount Rates		
				8%	6%	4%
Site	01 Site Transportation Benefits	$32,005	$0	$640,000	$1,070,000	$2,930,000
Water	02 Rainwater Capture and Reuse	$9,665	$20,650	$210,000	$340,000	$910,000
Water	03 Composting Toilet	$7,450	$0	$150,000	$250,000	$680,000
Energy	04 Energy Efficiency	$112,027	$0	$2,240,000	$3,730,000	$10,270,000
Energy	05 Solar Array	$35,776	$0	$720,000	$1,190,000	$3,280,000
Materials	06 FSC Wood	$0	$368,824	$370,000	$370,000	$370,000
	TOTAL	**$196,922**	**$389,474**	**$4,330,000**	**$6,950,000**	**$18,450,000**

TABLE 3

Total Benefits as a Function of Discount Rate and Carbon Price

		Price of Carbon ($ per Metric Ton CO_2 Equivalent)		
		30	75	200
DISCOUNT RATE	10%	$1,470,000	$1,930,000	$3,200,000
	8%	$2,030,000	$2,630,000	$4,330,000
	6%	$3,320,000	$4,280,000	$6,950,000
	4%	$9,010,000	$11,510,000	$18,450,000

+ The Bullitt Center produces meaningful direct benefits (or avoided impacts) for over two-thirds of the twenty-two ecosystem services classified by the United Nations The Economics of Ecosystems and Biodiversity study.
+ These ecosystem services benefits vary significantly along space and time dimensions and many are difficult to measure.
+ The Bullitt Center provides a model for supporting and enhancing urban ecosystem services.
+ The language of ecosystem services has been critical in linking ecology and economics, but can be confusing to architects, engineers, planners, and others who have their own rich terminologies for talking about the interaction of the built environment and living systems. There is an excellent opportunity to make ecosystem services a daily working tool for built environment professionals.
+ Ecosystem services can be difficult to conceptualize at the individual building scale and are likely to become clearer and more effective when applied at the neighborhood or EcoDistrict scale.
+ Ecosystem services models need to be extended to effectively link together natural components with hybrid bio-technical components and purely technical components.
+ Ecosystem services models should become a two-way model, with the possibility of developed areas as regenerative contributors to other ecosystems rather than undifferentiated "urban zones" with zero ecological productivity.
+ Ecosystem services provide an important complement to the Living Building Challenge (LBC), with most LBC imperatives mapping naturally to one or more ecosystem services.

Recommended Next Steps

+ Undertake a comprehensive valuation and assessment of social and environmental benefits and costs of the Bullitt Center with accounting of amounts accruing to the general public vs. tenants vs. developer.
+ Share this case study widely and encourage replication on other buildings and EcoDistricts.
+ Work on communication strategies with the architecture, engineering, planning, landscape architecture, and allied communities to create a dialogue between ecosystem services and other design terminologies and frameworks.
+ Use the Bullitt Center as a lens to support the development of more comprehensive ways of linking together ecology and economics (ecosystem services) and design (ecological design, regenerative design, biomimicry) into a larger, more comprehensive approach (e.g., "regenerative economics").
+ Develop extensions to ecosystem services modeling tools so they can operate effectively with natural, hybrid natural-technical (ecologically engineered), and technical (engineered) systems.
+ Develop policy and market transformation initiatives that can provide better visibility into the FSC supply chain (e.g., woodlot → mill → distributor → building); offer opportunities to link orders to reduce shipping costs; support regional level coordination between general contractors preparing to order wood and FSC suppliers on a seasonal cycle; and integrate more flexible wood product dimensions that can allow FSC wood to be used in highly durable applications.
+ Conduct more detailed carbon storage and related ecosystem services (water, biodiversity, etc.) calculations that are tied to the specific forests where FSC wood is procured.
+ Formally submit this case study to the International Living Future Institute to initiate dialogue on how best to incorporate ecosystem services in Version 3.0 of the Living Building Challenge.

02 *Background on Project*

BACKGROUND ON PROJECT

The Bullitt Center is a six-story, fifty-thousand-square-foot office building located in the Capitol Hill neighborhood of Seattle, Washington. The building serves as the headquarters for its owner, the Bullitt Foundation, while also hosting a range of innovative organizations including the International Living Future Institute and the University of Washington's Integrated Design Lab. The Bullitt Center was designed to meet the rigorous requirements of the Living Building Challenge Standard 2.1,[1] which requires that a building be net zero energy, net zero water, use non-toxic materials, provide a net increase of functional ecosystem area, enhance human health, contribute to social equity, and emphasize beauty. The Bullitt Center opened on Earth Day 2013, and is anticipated to be the world's first infill, multi-story Living Building (certification pending). The Bullitt Center, designed by Miller Hull Partnership, was named the global Sustainable Building of the Year for 2013 by World Architecture News.[2]

The Bullitt Center relied on an Integrated Design Process, with key team members including:

Schuchart—General Contractor, Core & Shell

Miller Hull Partnership—Architect

Point32—Development Partner

PAE Consulting Engineers—MEP Engineering

Foushee—General Contract, Tenant Improvements

Luma Lighting Design—Lighting

2020 Engineering—Water Systems

Berger Partnership—Landscape Architecture

The Bullitt Foundation and other organizations are supporting a comprehensive research program to document the economic, ecological, and social benefits of the Bullitt Center in order to accelerate opportunities for replication. This research includes both design intent and rigorous post-occupancy analysis. The Bullitt Center's unprecedented ecological performance suggests new avenues of research and inquiry that explicitly link the built environment and ecosystem services.

In order to address the ecosystem services benefits of the Bullitt Center, the Bullitt Center Assessment Team (BCAT) was formed in August 2012. The BCAT team originally included Ecotrust (nonprofit and team lead), Autopoiesis LLC (for-profit), and Parametrix (for-profit), with all three organizations based in Portland, Oregon, and possessing deep expertise in the intersection of the built environment and ecosystem services. BCAT received a scoping grant from the Bullitt Foundation and conducted an initial analysis from October 2012 to January 2013 of how best to approach an unprecedented detailed case study of key ecosystem services reflected in a specific building.[3]

BCAT subsequently received a second grant from the Bullitt Foundation supporting the work documented in this report. This work was conducted from April 2013 to February 2014, with Parametrix replaced by EcoMetrix Solutions Group partway through the grant. BCAT employed a wide range of research methods, including hosting two large, interdisciplinary charrettes on the themes of the project with regional experts (see Appendices 1 and 2); interviews with project team members, researchers, building material vendors, and others; analysis of project design documents and narratives; a literature review of urban ecosystem services and related topics; and application of the methods of ecological economics to measure and value selected ecosystem services.

BCAT would like to acknowledge the contributions of the following individuals in the research process:

+ All participants in the two charrettes;
+ Bullitt Foundation staff including Steven Whitney, Neelima Shah, Denis Hayes, and Amy Solomon for overall grant guidance and key introductions;
+ 2020 Engineering staff including Mark Buehrer and Colleen Mitchell for detailed discussions on the Bullitt Center water systems;

[1] See http://living-future.org/lbc.

[2] See http://www.wantoday.com/sustainability_4_2013/mailer.html.

[3] Cowan, Stuart, Brent Davies, Noah Enelow, Kevin Halsey, Carolyn Holland, and Kathryn Langstaff. 2013. *Understanding Ecosystem Services in the Built Environment: The Bullitt Center.* Portland, OR: Ecotrust.

- Biomimicry Puget Sound principals Jennifer Barnes and Alexandra Ramsden for helpful peer reviews and insights from a biomimicry perspective;
- University of Washington, Department of Architecture Integrated Design Lab staff, with critically important data provided by Robert B. Peña;
- Point32 Sustainability Program Manager Joe David, who offered helpful insights on the development process;
- International Living Future Institute staff including Executive Director Richard Graves;
- Economics of Change project team including Jason Twill, Richard Graves, and Theddi Wright Chappell;
- University of Washington, Department of Architecture Assistant Professor Kathrina Simonen, for early Lifecycle Analysis results for the Bullitt Center and Research Assistant Professor Heather Burpee for the Bullitt Center transportation survey;
- Miller Hull architect Steve Doub, AIA for assistance with Bullitt Center renderings and Lifecycle Analysis; and
- Wood brokers and suppliers for the Bullitt Center.

This case study is intended to contribute to a long-term dialogue about how to fully integrate ecosystem services and the built environment. We hope that it will be of value to ongoing Bullitt Center research efforts, as well as for similar studies of other high performance green buildings and Living Buildings.

03 *Linking Ecosystem Services and the Built Environment*

Human communities have always recognized their profound interdependence with ecosystems. Plato, writing twenty-five hundred years ago, observed that deforestation led to soil loss and decrease in available groundwater (drying springs). George Perkins Marsh established strong connections between human activities and the behavior of ecosystems in his seminal book *The Earth as Modified by Human Activity* in 1874. The term "ecosystem services" was coined by Paul and Anne Ehrlich in 1981 to specifically emphasize the role of ecosystems in providing fundamental life support systems (food, water, air, etc.) to the human species.[4] The term gained popularity in the 1990s with the emergence of ecological economics and rigorous attempts to estimate the equivalent monetary value of ecosystem services.[5]

Based on earlier classification systems, the authoritative Millennium Ecosystem Assessment recognized four classes of ecosystem services:[6]

+ Supporting (e.g., nutrient cycling, soil formation, and primary production)
+ Provisioning (e.g., food, fresh water, wood fiber, and fuel)
+ Regulating (e.g., climate regulation, flood and disease regulation, and water purification)
+ Cultural (e.g., aesthetic, spiritual, educational, and recreational)

Ecosystem services classification systems and frameworks continue to evolve along with our understanding of the complex linkages between natural systems, societies, and economies. However, they currently share these characteristics:

1. Modeled after the activities of "pristine" wild ecosystems or relatively undisturbed large-scale rural areas
2. Typically modeled at a relatively large scale (one to one thousand kilometers) rather than a fine-grained (one to one hundred meters) urban site or building scale
3. Focused on a "one-way" flow of services from natural systems to individuals and societies, rather than a dialogue between people and nature in which buildings, infrastructure, manufacturing processes, and other human activities may also magnify, enhance, mimic, and generate ecosystem services within a single biosphere-scale system
4. Designed to measure, without double counting, specific streams of benefits to individuals and communities that can be aggregated over ecosystem service type, time, and space to produce a unified measure of equivalent monetary value, the "total economic value"
5. Grounded in the terminology and science of both ecology and economics, which are often incompatible with the terminology and frameworks of architecture, urban and regional planning, engineering, landscape architecture, interior design, and other design professions

The Bullitt Center was designed to meet the most advanced green building certification program in the world: The Living Building Challenge 2.1. According to the LBC, "Nothing less than a sea change in building, infrastructure, and community design is required. Indeed, this focus needs to be the great work of our generation. We must remake our cities, towns, neighborhoods, homes and offices, and all the spaces and infrastructure in-between. This is part of the necessary process of reinventing our relationship with the natural world—reestablishing ourselves not separate from, but 'part and parcel with creation.'"[7]

[4] Ehrlich, P. R. and A. H. Ehrlich. 1981. Extinction: *The Causes and Consequences of the Disappearance of Species*. New York: Random House.

[5] Costanza, Robert et al. 1997. "The Value of the World's Ecosystem Services and Natural Capital." Nature, Vol. 387, pp. 253-259.

[6] Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press.

[7] International Living Future Institute. 2012. *Living Building Challenge 2.1: A Visionary Path to a Restorative Future.* Seattle: International Living Future Institute.

LINKING ECOSYSTEM SERVICES AND THE BUILT ENVIRONMENT

As our project team has wrestled with the question of the types and magnitudes of ecosystem services directly and indirectly (through avoided impacts) generated by the Bullitt Center, we have come to realize that *the Bullitt Center can provide a dynamic new approach to understanding and optimizing ecosystem services in built environments*. This approach extends the ecosystem services characteristics described above in the follow ways:

1. Modeled with a *flexible matrix of wild ecosystems, rural ecosystems, urban green spaces, and built environment* (buildings + infrastructure)
2. If needed, can be modeled at the s*cale of a few blocks, a district, or a neighborhood* to capture the fine-grained detail of the built environment, which can change significantly within tens of meters
3. *Integrated model of ecosystems and built environment* working together to magnify, enhance, mimic, and generate ecosystem services, using typical landscape attributes for ecosystems, "bio-technical attributes" for designed natural-technical hybrid features like bio-swales, and "technical attributes" for conventionally engineered features like roads
4. Designed to provide reasonable order of magnitude estimates of ecosystem services flows in order to *provide decision support across a wide range of benefits and values* tailored and prioritized by specific communities (e.g., levels of key ecosystem services like food production and water provisioning; resiliency; human health, etc.)
5. Grounded in the terminology, frameworks, and software tools of architecture, urban and regional planning, engineering, landscape architecture, etc. so that *design and planning professionals can measure and optimize ecosystem services as part of their normal workflow*
6. Designed to use *regionally appropriate materials* that are sourced in a way that enhances regional ecosystems, economies, and quality of life

When people think about ecosystem services, they often picture a wilderness landscape with clean rivers flowing through healthy forests. This landscape is producing food, medicinal herbs, fiber, clean air, and clean water among other important services that humans depend on for survival and quality of life. However, we seldom think about the extent to which these same benefits are, or are not, being produced within urban areas and the built environment.

There are significant consequences to ignoring the potential for the built environment to produce and deliver ecosystem service benefits. Removing nature from an urban landscape, or failing to maintain that urban landscape in harmony with the ecosystem that encompasses it, reduces the resilience and sustainability of those communities. With an ever-increasing majority of people living in urban areas, the role of ecosystem services production within urban boundaries cannot be ignored. The ability of these urban areas to provide quality of life over time is inextricably linked to our ability to integrate ecosystem services into our urban planning and design practices.

Accordingly, promoting ecosystem services within the urban context is critical to improving the human condition and ensuring the ongoing vitality of our communities. But understanding the role and need for ecosystem services in urban areas is a nuanced issue that requires us to move beyond simplistic models that create a dichotomy of nature versus human development, or ecological functions versus technology. In an urban context we cannot draw a bright line between "natural" and "human."

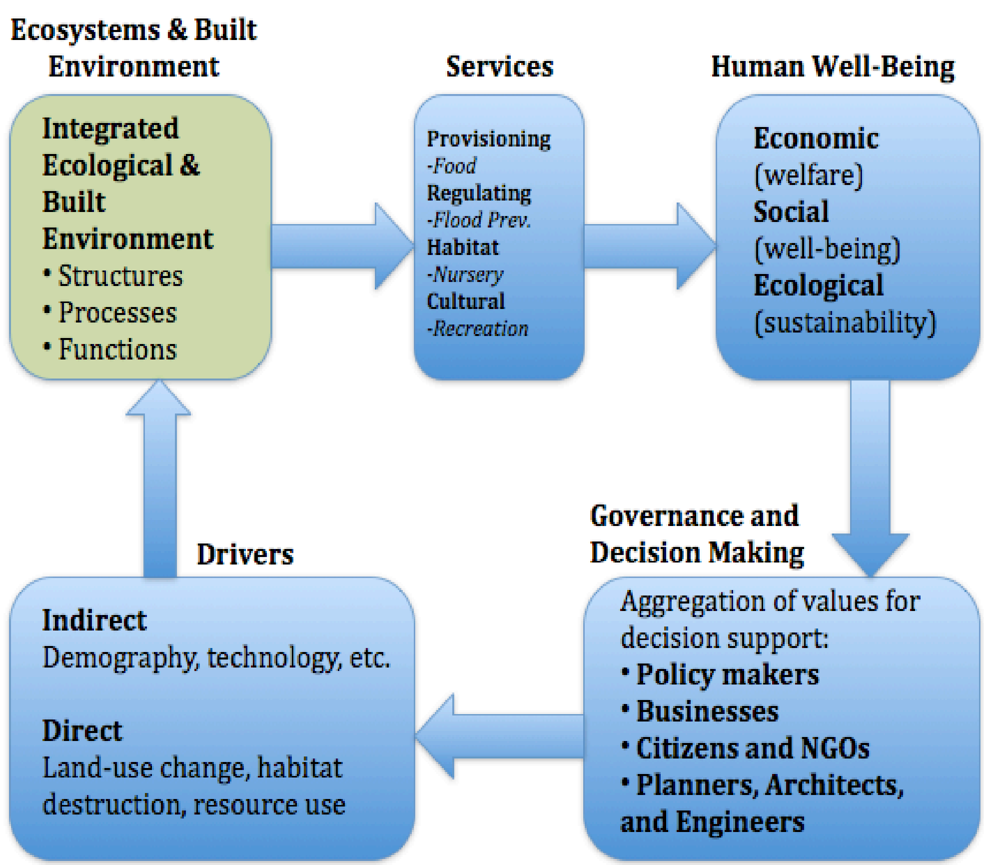
The graphic below shows how our proposed extended framework for ecosystems services can function in a coherent cycle:

- *Ecosystems & Built Environment* together provide integrated structures, process, and functions which generate . . .
- Ecosystems services providing a wide range of . . .
- Benefits and Values for human well-being that inform comprehensive . . .
- Governance, decision making, and design taking into account ecosystem services . . .
- That diminish negative drivers and enhance positive drivers for . . .
- *Ecosystems & Built Environment* . . .

This cycle is adapted from that of the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity sponsored by the United Nations.[8] It explicitly expands "Ecosystems & Biodiversity" to "Ecosystems & Built Environment" in the green box in the upper left corner and emphasizes the decision making role of planners, architects, engineers, and allied professionals.

FIGURE 4

The Economics of Ecosystems and Biodiversity Conceptual Framework for Linking Ecosystems and Human Well-Being (Expanded to Include Ecosystems & Built Environment)



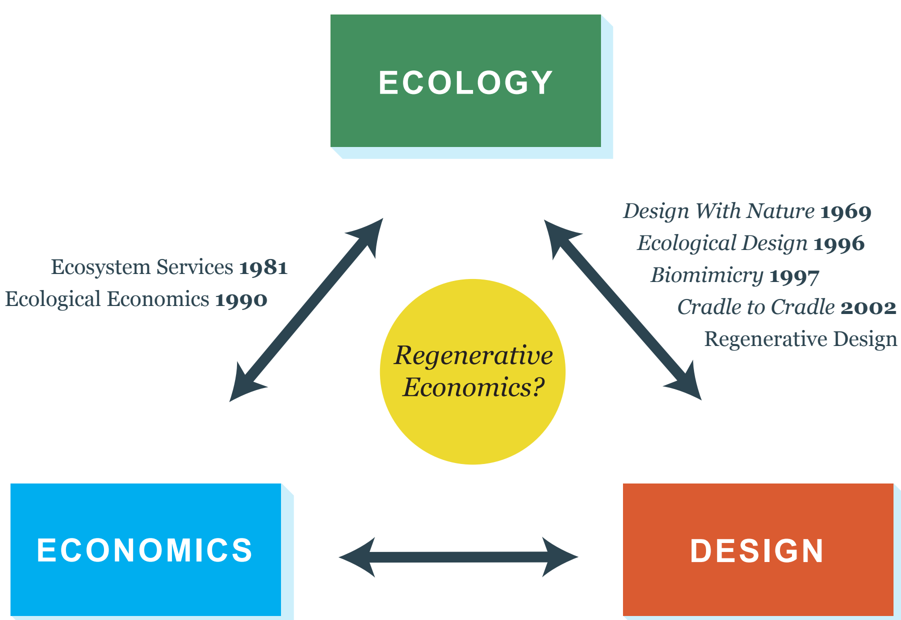
[8] Kumar, Pushpam. 2012. *The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations.* New York: Routlege. See page 21.

The ecosystem services framework was developed as a way to translate the multi-scale, intergenerational, complex, whole systems dynamics of ecosystems into a suite of specific services (of value to the human species) suitable for economic analysis. Ecosystem services are a bridge between ecology and economics, but their inherent complexity (temporal, spatial, nonlinear) continues to make measurement and valuation a challenge, suggesting complementary qualitative approaches may also be beneficial.

For several decades now, an alternative approach has been underway to actively design with living systems, in dialogue with nature. This tradition is focused on working with nonlinear living systems in their full complexity rather than filtering them through an economic valuation lens. Architects, planners, engineers, landscape architects and other designers have developed a rich set of frameworks, metaphors, and terms of art to understand the interaction of the built environment and living systems. This dialogue between ecology and design provides another rich lens with which to view the Bullitt Center. Ecosystem services can become another helpful tool for designers grappling with living systems, but a fair amount of translation will be required in order for the concept to be widely and usefully applied. The Bullitt Center itself can play a key role in this dialogue, providing a vivid example of ecosystem services being supported by and flowing through a building. The full integration of ecology, economics, and design currently remains out of reach. Perhaps the Bullitt Center is an early example of this integration in action, a form of "regenerative economics"?

FIGURE 5

The Economics of Ecosystems and Biodiversity Conceptual Framework for Linking Ecosystems and Human Well-Being (Expanded to Include Ecosystems & Built Environment)[9]



[9] See McHarg, Ian. 1969. *Design With Nature*. Garden City, NY: Natural History Press; Van der Ryn, Sim and Stuart Cowan. 1996. *Ecological Design*. Washington, DC: Island Press; Benyus, Janine. 1997. *Biomimicry: Innovation Inspired by Nature*. New York: William Morrow; Braungart, Michael and William McDonough. 2002. *Crade to Cradle: Remaking the Way We Make Things*. New York: North Point Press; Kellert, Stephen R., Judith H. Heerwagen, and Martin L. Mador. 2008. *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*. Hoboken, NJ: John Wiley & Sons. For regenerative design, see the work of Bill Reed and colleagues.

TABLE 6

Translating Ecosystem Services into Existing Design Frameworks and Terminology

Ecosystem Service	Living Building Challenge Petal: Imperatives that Most Strongly Support or Are Supported by This Ecosystem Service	Terminology Used by Architects, Engineers, Planners, Landscape Architects, and Other Designers
Provisioning Services		
* Solar Energy and Related Renewable Energy Sources (in most cases not technically classified as an ecosystem service)	07 Energy: Net Zero Energy	Renewable Energy, Solar Energy, Wind Energy, Geothermal Energy, Energy Efficiency, Geothermal Exchange (Geoexchange), Carbon Emissions
1. Food (e.g., fish, game, fruit)	02 Site: Urban Agriculture	Sustainable Agriculture, Urban Farming, Community Gardens, Biodynamic, Organic Agriculture, Permaculture, Urban Gleaning
2. Water (e.g., for drinking irrigation, cooling)	05 Water: Net Zero Water	Rainwater Catchment, Potable Water, Greywater Reuse
3. Raw Materials (e.g., fiber, timber, fuel wood, fodder, fertilizer)	11 Materials: Red List 12 Materials: Embodied Carbon Footprint 13 Materials: Responsible Industry 14 Materials: Appropriate Sourcing 15 Materials: Conservation + Reuse	Non-Toxic Materials, Local or Regional Materials, Recycled or Recyclable Materials, Cradle to Cradle, Technical Nutrients, Biological Nutrients, Biogeochemical Cycling, Renewable Materials, Low Embodied Energy Materials, FSC Certified, Third-Party Certified (Declare, Just, etc.)
4. Genetic Resources (e.g., for crop improvement and medicinal services)	03 Site: Habitat Exchange	Specialized use only for Plant Breeding Facility
5. Medicinal Resources (e.g., biochemical products, models, and test-organisms)	02 Site: Urban Agriculture	Specialized use only for Medicinal Gardens; Medicinal Herbs; Wildcrafting in urban areas
6. Ornamental Resources (e.g., artisan work, decorative plants, pet animals, fashion)	02 Site: Urban Agriculture	Landscaping with Native Plants; Wildcrafting in urban areas
Regulating Ecosystem Services		
7. Air Quality Regulation (e.g., capturing dust, chemicals, etc.)	08 Health: Civilized Environment 09 Health: Healthy Air	Indoor Air Quality, Regional Air Quality, Public Health Impacts (e.g., Asthma)
8. Climate Regulation (carbon sequestration, influence of vegetation on rainfall, local climate influence, etc.)	12 Materials: Embodied Carbon Footprint 07 Energy: Net Zero Energy	Carbon Emissions, Carbon Sequestration, Carbon Storage, Bioclimatic Design, Passive Solar Design

Ecosystem Service	Living Building Challenge Petal: Imperatives that Most Strongly Support or Are Supported by This Ecosystem Service	Terminology Used by Architects, Engineers, Planners, Landscape Architects, and Other Designers
9. Moderation of Extreme Events (e.g., storm protection and flood prevention)	01 Site: Limits to Growth	Site Constraints (e.g., floodplain, seismic, geotechnical)
10. Regulation of Water Flows (e.g., natural drainage, irrigation, and drought prevention)	06 Water: Ecological Water Flow	Ecological Stormwater Management, Ecological Wastewater Treatment, Stormwater, Greywater, Blackwater
11. Waste Treatment (especially water purification)	06 Water: Ecological Water Flow	
12. Erosion Prevention	01 Site: Limits to Growth	Erosion Prevention
13. Maintenance of Soil Fertility (incl. soil formation) and nutrient cycling	02 Site: Urban Agriculture 03 Site: Habitat Exchange	Nutrient Cycling
14. Pollination	02 Site: Urban Agriculture 03 Site: Habitat Exchange	Butterfly Gardens, Habitat Gardens
15. Biological Control (e.g., dispersal, pest and disease control)	02 Site: Urban Agriculture 03 Site: Habitat Exchange	Natural Pest Control, Integrated Pest Management
Habitat Services		
16. Maintenance of Lifecycles of Migratory Species (including nursery service)	01 Site: Limits to Growth 03 Site: Habitat Exchange	Migratory Species
17. Maintenance of Genetic Diversity	01 Site: Limits to Growth 03 Site: Habitat Exchange	Biodiversity
Cultural and Amenity Services		
18. Aesthetic Information (Beauty)	19 Beauty: Beauty + Spirit 10 Health: Biophilia 16 Equity: Human Scale + Humane Places	Beauty, Wholeness, Biophilia
19. Opportunities for Recreation and Tourism	19 Beauty: Beauty + Spirit 20 Beauty: Inspiration + Education 10 Health: Biophilia	Ecotourism, Recreation
20. Inspiration for Culture, Art, and Design	19 Beauty: Beauty + Spirit 20 Beauty: Inspiration + Education 10 Health: Biophilia	Biomimicry, Biophilia, Regenerative Design, Sustainable Design, Ecological Design, Green Buildings
21. Spiritual Experience	19 Beauty: Beauty + Spirit 10 Health: Biophilia	Spirit, Sacred Architecture, Sacred Geometry
22. Information for Cognitive Development [Learning and Pedagogy]	20 Beauty: Inspiration + Education	Ecological Literacy, Avoiding Nature Deficit Disorder

From a technical perspective, one of the lessons from this case study is that the standard model of ecosystem services flow (illustrated below), needs to be supplemented. Along with landscape attributes typical of wild, rural, and urban ecosystems, we also need to consider attributes corresponding to hybrid natural-technical systems (e.g., bioswales) and purely technical systems (e.g., impervious surface). This suggests the kind of conceptual models used to model ecosystem services (see Figure 7 below) can be extended to incorporate both hybrid natural-technical systems and technical systems.

FIGURE 7

Standard Model of Ecosystem Services Generation: From Landscape Attributes → Functions → Services → Value

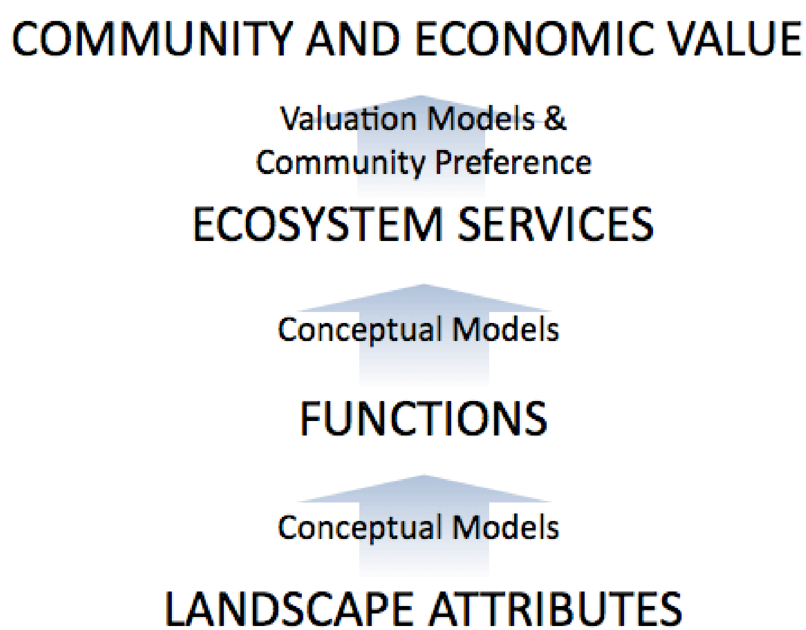
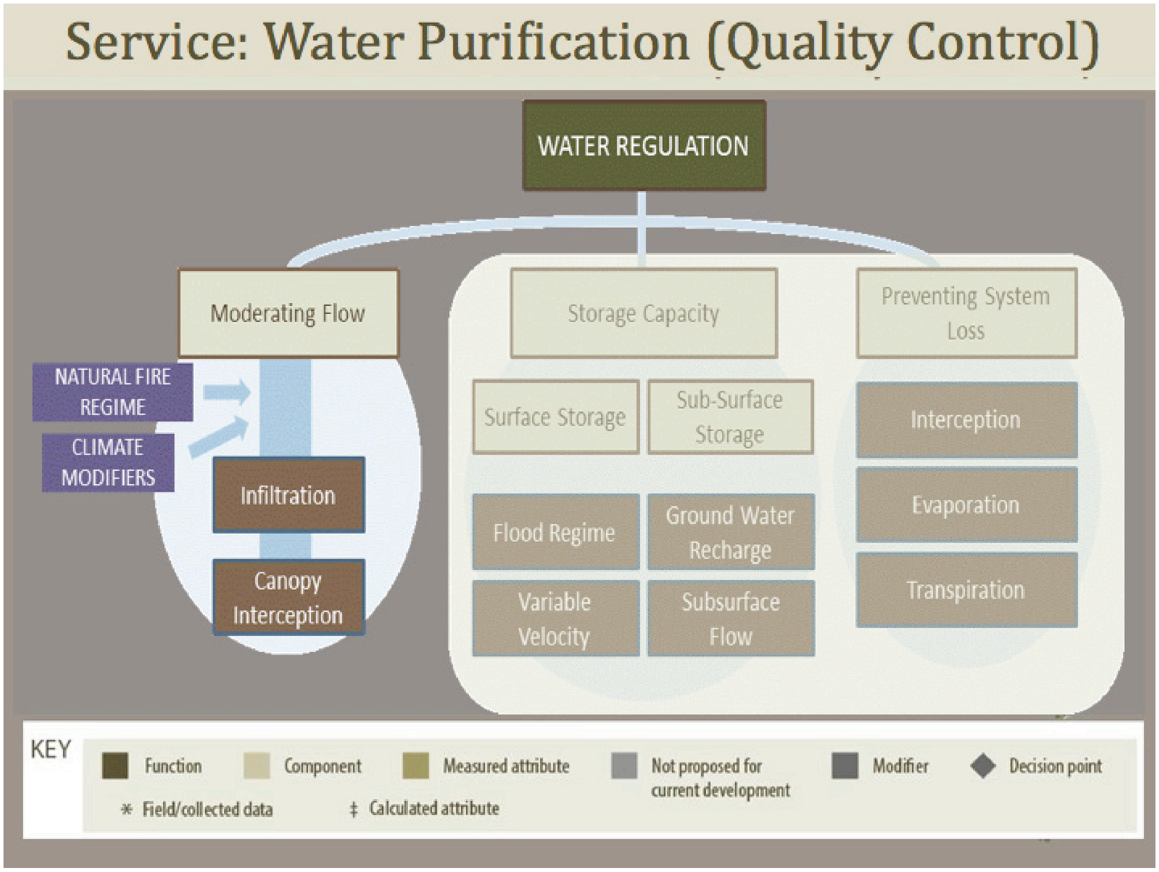


FIGURE 8

Example of a Concept Model for Water-Related Ecosystem Services[10]



An urban context requires us to understand the concept of "ecosystem services" in a nuanced manner—not as a bright line dichotomy of natural versus man-made. There is a spectrum that runs from purely natural to completely man-made that passes through many interim points. This spectrum encompasses a number of concepts, including blending of natural and non-natural elements within a building or design and mimicking or simulating natural processes. As one of us wrote in *Ecological Design* in 1996:

> Ecological design begins with the particularities of place— the climate, topography, soils, water, plants and animals, flows of energy and materials, and other factors. The task is to integrate the design with these conditions in a way that respects the health of the place. The design works when it articulates new relationships within a context that preserves the relevant ecological structure.[11]

[10] This ecosystem services concept model is used with permission of EcoMetrix Solutions Group.

[11] Van der Ryn, Sim and Stuart Cowan. 1996. *Ecological Design*. Washington, DC: Island Press. See page 72.

Biomimicry, the simulation of naturally occurring processes by human design, is a key property of living buildings that is relevant to the question of urban ecosystem services. Approaches that mimic or simulate natural processes may seem like a departure from typical ecosystem services analysis, which has focused largely on wholly natural areas and natural processes and the incentives that exist to preserve or restore those natural areas and processes. Along these lines there have been many studies that evaluate the benefits to home prices of proximity to parks or open space. For many, the presence of these natural areas within our cityscape is the focus of urban ecosystem services. However, while parks and open space are an important part of the urban ecosystem services equation, they are not the full story.

In a typical urban context there is often an integrated mix of nature and technology. For instance, a curb-cut vegetated stormwater swale is a careful mix of technology and natural processes. This vegetated swale is one of many such features in the Portland Green Streets program.

Does the fact that this vegetated area is part of an engineered facility, built into an urban street network, make it any less of an ecosystem service provider? Such a narrow focus would be much too limiting if we are trying to optimize[12] the performance of our urban areas. While parks and open space are important, creating sustainable cities will require us to think well beyond such a limited view of urban ecosystem services.

While the field of ecosystem services is relatively nascent—particularly as it relates to urban areas, there are other fields of study that have made great progress in thinking about the relationship between ecology and urban design. There have been more than fifty years of inquiry in the fields of ecological design, biomimicry,[13] regenerative design,[14] historical ecology,[15] and biophilia.[16] These disciplines provide important perspectives for how we evaluate the ecological performance of a city. This includes all aspects of the urban environment, not just parks and open spaces, but the built environment as well.

By expanding our understanding of ecosystem services to incorporate learning from these other disciplines, our thinking around urban ecosystem services can be greatly enhanced. However, an ecosystem services framework remains the appropriate approach for assessing urban planning and design decisions. The concept of ecosystem services provides a critical component that is otherwise missing from these other disciplines. An ecosystem services approach helps us understand the consequences of landscape changes for ecological, social, and economic conditions. This not only helps us shape more resilient, healthy, and sustainable cities, but by framing the interaction of ecological, social, and economic systems within a human value context, it also helps answer the important question of why we need or should want these outcomes. While this may seem trivial, it is the failure to understand these consequences or to be able to answer questions around the true cost of our approaches that too often leads to unsustainable, or sub-optimal solutions to our urban planning and design decisions.

Accordingly, the focus of our effort is to develop an analysis framework built around an ecosystem services approach. However, the ecosystem services framework must incorporate the important findings from other disciplines such as ecological design, biomimicry, regenerative design, historical ecology, and biophilia. Through this process we can move from a simplistic view of ecosystem services as being natural versus human, to a more nuanced perspective of ecosystem services existing on a spectrum. The spectrum needs to encompass all states from completely natural to purely technological that is entirely divorced from ecological processes.

[12] In this instance, "optimizing" refers to the ability for an urban area to best balance high density levels with low levels of externalities outside the urban area, as well as providing high resilience and quality of life within the urban center.

[13] Jenine Benyus. 2002. *Biomimicry.* New York, NY: William Morrow Paperbacks.

[14] John Tilman Lyle. 1996. *Regenerative Design for Sustainable Development.* New York: Wiley. See also the work of Bill Reed.

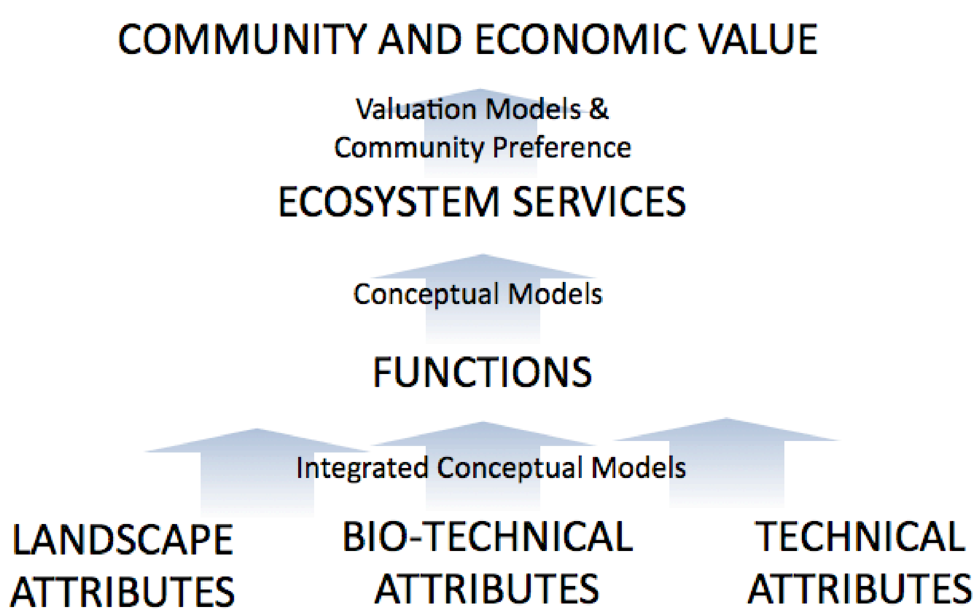
[15] Dave Egan and Evelyn A. Howell. 2005. T*he Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems.* Washington, DC: Island Press.

[16] Stephen R. Kellert, Judith Heerwagen, and Martin Mador. 2008. *Biophilic Design.* New York, NY: Wiley.

In the context of an ecosystem services analysis of the Bullitt Center, we should not focus just on the natural elements within or around the building, but instead on whether the performance of the building as a whole creates a properly functioning ecological condition. In doing so we see the building using a mix of technology and natural processes, or ecological design, that enables it to accomplish the objectives identified by the Biomimicry Puget Sound "greenprint." Rainfall that is captured from the roof is cycled through a treatment process. A portion of this water is stored for future use and a portion is diverted to the stormwater system. As the water is used within the building, greywater is sent to the green roof areas where it maintains the vegetation, eventually evaporating or transpiring into the atmosphere. This mix of natural processes and technology allows the building to control stormwater in a fashion that replicates natural outcomes.

FIGURE 9

Expanded Model of Ecosystem Services Generation: Wider Range of Attributes on a Technical Spectrum



In this example technology and natural processes are integrated and working together to provide the desired ecological performance. This mix of nature and technology, guided by historical ecology, biomimicry, and the Living Building Challenge imperatives allow the building to achieve “optimized performance” by balancing the objectives of resilience, density, quality of life, and minimal off-site externalities.

The Bullitt Center is an ideal case study for developing and refining an approach for optimizing urban planning and design outcomes. The Living Building Challenge introduces an explicit consideration of restorative design—honoring and enhancing ecosystem functionality—at scales from buildings to districts to regions. For instance, the LBC requirement for land exchange to offset site use for building can be grouped according to greatest ecosystem benefit upstream. Like buying a “brick” for a community public plaza, the land “offset” can be aggregated to optimize the healthy functioning of the most critical habitats in the geographical watershed of the building.

The principles of ecological design are exemplified in the Bullitt Center. For instance, the principle of scale-linking enables us to design urban infrastructure at multiple scales that encompass site, neighborhood, district, region, and watersheds in an inextricably linked manner embedded in biogeochemical cycles whose functions enhance all living systems in the geographical area. The building is designed to renew different systems at different timescales. This temporal component of ecosystem services production is critical for providing urban systems resiliency and dynamism, allowing greater complexity to be achieved through distributed systems (e.g., energy generation, rainwater storage, etc.). Living Buildings, including the Bullitt Center, are ideal candidates for regional Federal Emergency Management Agency (FEMA) relief sites, and are potentially eligible for modest ongoing FEMA funding to serve in this role.

3.1 Optimizing Urban Ecosystem Services

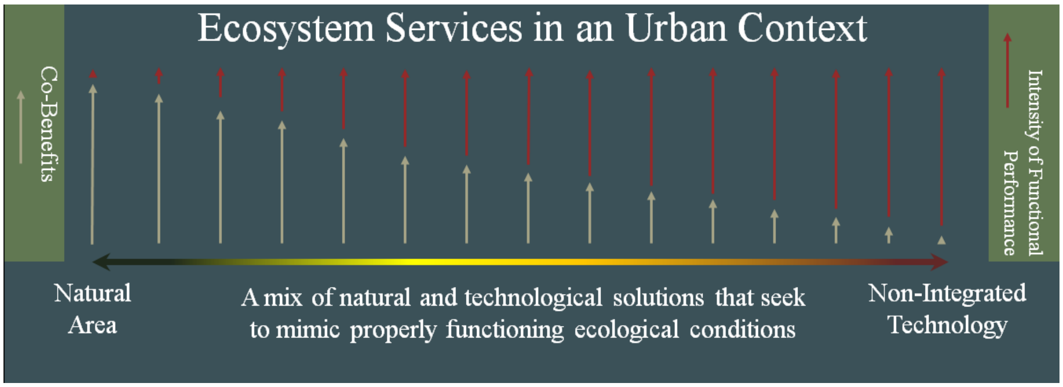
In the previous section, we touched on the importance of understanding ecosystem services as a spectrum that runs from completely natural to purely technological solutions. In this section we identify the ramifications associated with where our chosen solutions fall within the spectrum. In particular, this section identifies an important consequence of natural versus technological performance, and then identifies how that affects community resilience, population density, quality of life, and likelihood of externalities.

A) As we move down the spectrum from purely natural to purely technology based, there is typically an increase in the efficiency of functional performance but a loss in the number of functions performed.

We can understand this concept through a simple example of a wetland that provides filtering and purification of water within the basin in which it is located. Compare that wetland with a water quality treatment facility. A treatment facility of a given footprint is able to treat a much greater volume of water than an equivalent area of wetland. However, the wetland is also providing numerous co-benefits, such as functions associated with nutrient cycling, climate regulation, and biodiversity support, to name just a few (see Figure 10).

FIGURE 10

Functional Performance Along the Natural to Technological Spectrum



This premise suggests that whenever our urban design incorporates natural elements, we preserve some aspect of the performance of important ecological functions, which we rely on for survival and quality of life. However, in an urban context, we are not always able to rely on natural processes to provide the level of service needed.

When looked at from this perspective, the ecosystem services spectrum describes a trade-off that we make every time we make an urban design decision. The trade-off is between a comprehensive but lower level of performance of functions spread across the landscape or a targeted high level of performance of specific functions in particular locations. This trade-off in turn affects the outcome of our efforts to achieve our optimization goals of density, resilience, quality of life, and minimizing externalities. While we reap significant benefits by moving our design to the left on the spectrum (effectively integrating more natural elements), we also give up some desired outcomes by doing so. We will describe the trade-offs we experience in more detail in the sections that follow.

B) As we move from reliance on ecosystem services toward reliance on centralized technology solutions, we introduce a greater level of fragility into our urban areas.

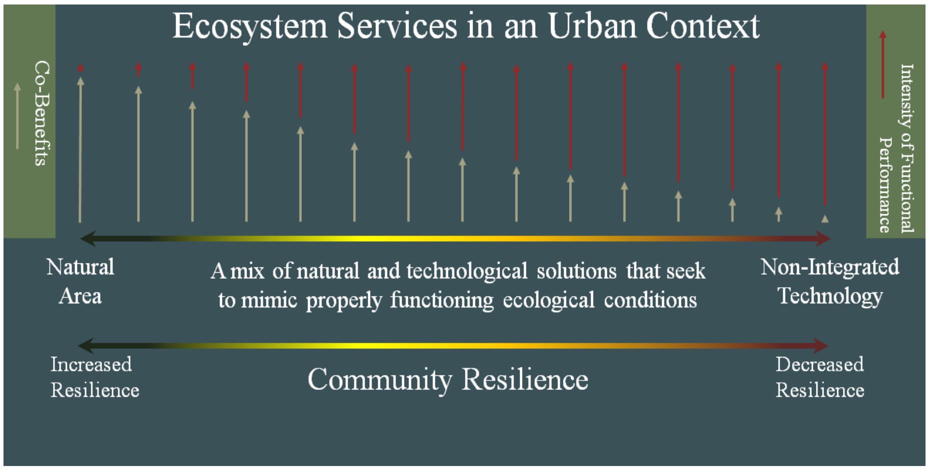
Currently, most urban areas have some level of centralized hard infrastructure associated with energy delivery, water utilities (including drinking water and wastewater), natural hazard protection (levees, dams, etc.), and transportation. As an example, if all of the drinking water for an urban area comes from a single drinking water treatment and conveyance system and that system fails, all of the population is without water. On the other hand, if stormwater capture and treatment were ubiquitously integrated into building design, then failure of a single system would not be catastrophic, but could be absorbed by the community.

The benefit of distributed service production for community resilience extends to all of the provisioning services. For example, industrialized food production can provide massive amounts of food, very cheaply. However, dependence on industrial agriculture can significantly reduce a city's resilience.[17] Backyard gardens, community gardens, roof-top gardens, and other forms of urban food production decrease our dependence on industrial agriculture, increasing community resilience and improving ecological conditions. Figure 11 below illustrates the general relationship between community resilience and the ecosystem services spectrum.

[17] A recent report for Whatcom County determined that "[I]f transportation were to become interrupted, local grocers would be limited to the food that they have on hand. This is likely to be only one to three days worth of food." Vincent, A., C. Philips, M. Hoss, C. Desmond, R. Green, J. Lowes-Ditch. 2008. *Issues in Emergency Food Distribution for Whatcom County, WA*. Page 25. Institute for Global and Community Resilience Report. Given these numbers, if the grocery store is your only source of food, then your food security is low.

FIGURE 11

Change in Community Resilience Along the Natural to Technological Spectrum



The concept expressed in Figure 11 could as easily apply to energy, sanitation, wastewater, or any other provisioning service. However, there are many considerations that go into deciding on the best solution for service production. We have developed our utilities and other provisioning services as centralized systems for a reason. Centralization can reduce the costs of providing services through efficiencies in shared infrastructure. These efficiencies also allow us to produce greater quantities of the provisioning benefit than we could otherwise. Accordingly, even within this one factor there is a trade-off between resilience and cost that we must consider. The optimal solution for a given area will require careful application to avoid undesirable disruption of existing systems. Like wildlands, when urban systems are designed with multilayered ecological design solutions, they too can reach efficiencies that are nonlinear and more robust. Similar to the previous wetland example, co-benefits of urban food systems are habitat for beneficial insects, reduction of transportation and CO_2 emissions, healthy air, potential for soil stabilization, etc.

C) Humans evolved in natural settings and human health and enjoyment is greatly increased by the presence of nature.

Ecosystems provide services to humans that go far beyond the provision of basic needs and touch upon more intangible qualities of beauty and spiritual health. The Living Building concept integrates quality of life, including beauty, deeply into its standard for building design. The Bullitt Center embodies this holistic focus on human health and well-being in four important ways: non-toxic materials; natural ventilation; design for mental, physical, and spiritual health; and aesthetic beauty.

There are numerous ways in which human health is tied to the presence of nature. Some of these connections are direct and obvious—for instance, the presence of urban trees has been shown to improve air quality, which can greatly reduce the incidence of respiratory disease.[18] Some of the connections are less obvious, but no less real. For instance, studies suggest that the presence of

[18] Planting street trees has been shown to provide up to a 60 percent decrease in street level particulates—see Coder, Dr. Kim D., 1996. “Identified Benefits of Community Trees and Forests.” University of Georgia.

urban vegetation can provide considerable mental health benefits and improve social behavior.[19]

The benefits of natural conditions extend well beyond the basics of ensuring access to vegetation. For instance, most people have experienced the debilitating effects of sitting for long periods in a room with florescent lighting—only to feel revitalized when they go outside and experience natural light. This effect is very real and the benefits of natural light have been shown to have considerable implications in health care treatments.[20] Although natural light is not usually included in most lists of ecosystem services, it is one of nature's benefits and one that we often replace through technology in the urban context.

The list can continue with a variety of mechanisms through which integrating nature into urban design can improve human health. Just a few of the additional examples include: the use of natural materials in the building process; improving building health by avoiding red list materials; the reduced exposure to pathogens and improved productivity associated with providing natural ventilation; the emotional benefits provided by a feeling of spaciousness; and the potential health benefits of radiant heat. In their own way, all of these mechanisms involve choices around the integration of nature or natural processes into urban design—and are therefore very relevant to a consideration of urban ecosystem services.[21]

D) As we move along the spectrum from purely natural areas toward completely non-natural, technology-dependent areas, there is a transition to supporting increasingly higher levels of density.

Over the centuries humans have increasingly mechanized the provisioning functions we rely on for survival to allow ourselves to live at higher densities. Early advances in cultivated crops allowed the rise of fixed communities that were larger than a hunting and gathering lifestyle could accommodate. The aqueducts of Rome allowed the Imperial City to encompass all seven hills and and for people to live at much greater densities than their forebears had ever even considered. Our modern industrialized agriculture and water quality treatment and conveyance systems enable mega cities such as New York, Los Angeles, Miami, and Boston just to name a few. Without modern technology, the high densities of these cities would not be possible.

It is important to understand the full import of the population density issue as it pertains to urban design. First, high population density is an existing reality for many of our urban areas. Accordingly, it is an existing constraint that we must address as we seek to integrate natural solutions into our urban areas. Second, we need our urban areas to support high population densities. Our current world population is over 7 billion and is projected to reach 8 billion by 2025.[22] These people need to live somewhere, and if they are not congregated into urban areas, then they will be sprawled across the landscape with dangerous consequences.

[19] Kuo, F.E. 2001. "Environment and Crime in the Inner City: Does Vegetation Reduce Crime?" *Environment and Behavior*, Volume 33. pp 343-367.

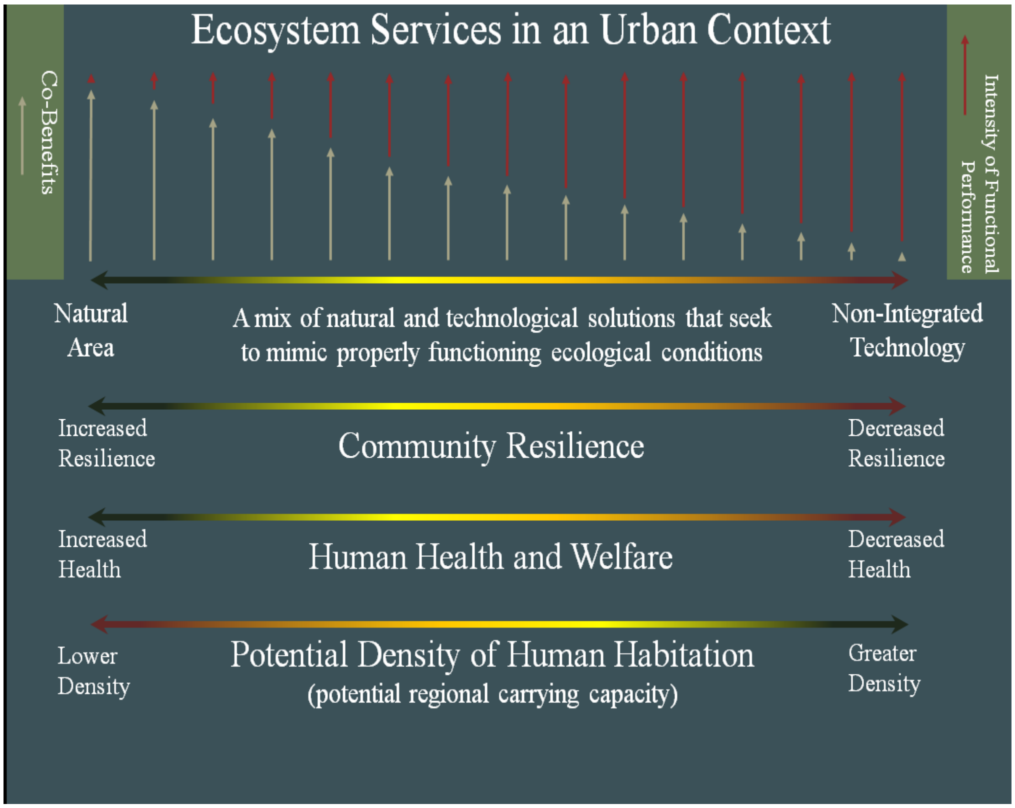
[20] Anjali Joseph, PhD. 2006. "The Impact of Light on Outcomes in Healthcare Settings". The Center for Health Design, Issue Paper #2.

[21] See generally Kellert, S., J. Heerwagen, and M. Mador. 2008. *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*. Wiley: New Jersey; Ulrich, R. S. 1991. "Effects of health facility interior design on wellness: theory and recent scientific research." *Journal of Health Care Design,* 3: 97-109. [Reprinted in Ulrich. 1995. *Innovations in Healthcare Design,* edited by S. O. Marberry, 88-104. New York: Van Nostrand Reinhold.]; and Ulrich, R. S. 1992. "How design impacts wellness." *Healthcare Forum Journal*, 20: 20-25.

[22] World Population Clock based on United Nations birth and death rate projections from the 2010 Revision of the World Population Prospects. The United States Census Bureau calculates a slightly smaller number of just of over 7.05 billion (see http://www.census.gov/main/www/popclock.html for current world population estimate).

FIGURE 12

Resilience, Human Health, and Population Density Along the Natural to Technological Spectrum



E) As density increases the potential for externalities to affect the landscape beyond the urban area increases, as density increases beyond the carrying capacity of the region, those externalities can become unsustainable.

Negative externalities occur when we make decisions about resources without addressing potential impacts to third parties. As population density grows beyond the ability of the urban landscape to sustain, it becomes necessary for resources to be acquired from outside the urban area. Large cities are generally maintained over time by the acquisition of these resources from surrounding areas. Food, water, energy, building materials, and other necessities are produced in surrounding areas and transported to urban centers. Human waste and garbage produced within the urban area are transported back out in exchange.

3.2 Biophilic Urbanism

Biophilic urbanism, or urban design which reflects humans' innate need for nature in and around and on top of our buildings, stands to make significant contributions to a range of national, state, and local government policies related to climate change mitigation and adaptation. Potential benefits include reducing the heat island effect, reducing energy consumption for thermal control, enhancing urban biodiversity, improving well being and productivity, improving water cycle management, and assisting in the response to growing needs for densification and revitalization of cities... [Recent research suggests a] 'daily minimum dose' of nature can be received through biophilic elements, and [that] planning and policy can underpin effective biophilic urbanism.[23]

TABLE 13

Possible applications of Biophilic Urbanism [24]

+ Green (vegetated) roofs	+ Parks (connected by wildlife corridors)
+ Green (vegetated) walls (incorporating vines and trellises)	+ Urban constructed wetlands (incorporating stormwater and wastewater capture and treatment)
+ Daylighting streams (refers to uncovering waterways contained in pipes, under roads, or under urban landscapes)	+ Shopping center greening (as communal public spaces, and taking advantage of increased sales in greened commercial districts)
+ Creating wildlife corridors along infrastructure corridors (such as roadways) based on tracked migration patterns	+ Running water (incorporating water capture and storage, and evaporative cooling)
+ Community information centers providing knowledge on local species and environment	+ Shade plantings (strategic planting to reduce internal building temperatures in summer)
+ Creating storm/sea buffer zones with vegetation	+ Swales (rather than traditional stormwater conduits)
+ Vegetable gardens and community gardens	+ The use of natural light and ventilation in buildings
+ Greening verging strips, including with food production	+ Green sidewalks (rather than pavement)
+ Street trees and canopies over streets, including for food production	+ Connectivity within green spaces and greenways
+ Internal plants and vegetation for buildings (incorporating aquaponics)	

[23] *Considering the Application of Biophilic Urbanism,* A Sustainable Built Environment National Research Center Briefing Report. Perth, Australia. 2011. p. 2.

[24] *Considering the Application of Biophilic Urbanism,* A Sustainable Built Environment National Research Center Briefing Report. Perth, Australia. 2011. p. 6.

3.3 Biomimicry

Biomimicry is a design approach that looks to nature for strategies, models, and measures of success. Biomimicry Puget Sound has developed the Urban Greenprint project to apply these ideas to the Seattle region:[25]

> Through the lens of biomimicry and with Nature as mentor, the Urban Greenprint identifies ways to strengthen ecological systems in urban centers. By understanding how Nature functioned in a location before urban development changed the balance, the Greenprint provides design guidelines and targets pilot projects that improve a city's ecological health and the well-being of its population.
>
> The goal of the Greenprint is not to recreate the predevelopment ecosystem but instead to understand how urban buildings and spaces can restore the functions those earlier ecosystems provided. Through place-based research and a biomimetic process to understand Nature's strategies, the Urban Greenprint identifies approaches cities can implement to operate more sustainably and improve quality of life.

+ How can a city function like a forest?
+ What can we learn from Nature to improve the health, resilience, and livability of our cities?
+ How can our buildings and roads sequester carbon, treat polluted runoff, and support biodiversity?

3.4 Regenerative Design

Regenerative Design has emerged from the work of John Tillman Lyle,[26] Bill Reed, and others since the early 1990s. It is a profoundly optimistic design framework that suggests that humans can help regenerate ecosystems using appropriate technologies and design strategies. In this section we draw from one of the few available studies linking ecosystem services and the built environment:[27]

> Regenerative design implies that ecosystems should return to or evolve to a state where they are thriving. . . . In discussing ecosystem health in the context of regenerative development, the question remains: what exactly are designers aiming to regenerate? And, how can moving toward this goal be evaluated? It is suggested here that mimicking or integrating with ecosystem services provides measurable and achievable goals for development that are based upon the physical reality of a specific place using the reference point of an ecosystem rather than other human activities or political trends.
>
> [. . .] The list of ecosystem services suggests that in a similar way to the functioning of an ecosystem, a building or development could be deliberately designed to be part of a system that:
>
> + deliberately provides habitat for species other than humans
> + contributes to soil formation and fertility through careful cycling of biodegradable wastes and recycling of non-biodegradable wastes
> + purifies air, water, and soil
> + regulates the climate through mitigating greenhouse gas emissions or possibly sequestering carbon
> + produces renewable energy
> + collects water
>
> [. .] The first step in applying ecosystem services analysis to regenerative design is to determine if there is an adequately healthy existing ecosystem in the locality that can be studied. If not, basing design targets on an ecosystem that existed prior to development on the site could be suitable as the focus of study. Measurable rates

[25] See www.urbangreenprint.org

[26] John Tillman Lyle. 1994. *Regenerative Design for Sustainable Development.* New York: John Wiley & Sons.

[27] Maibritt Pedersen Zari. 2012. "Ecosystem Services Analysis for the Design of Regenerative Built Environments." *Building Research & Information.* 40 (1): 54-64.

of ecosystem service provision that exist (or existed) on a site can then be determined. For example, specific figures such as annual rainfall and water retention in a particular place relate to the ecosystem service of provision of fresh water, and can be calculated with some accuracy. Although there are knowledge gaps in the field of ecology related to measuring ecosystem services, each ecosystem service has aspects that can be measured and are useful in setting initial design targets for regeneration. These targets can then be used to determine the optimal environmental performance of the built environment that is now (or will be) on the same site as the ecosystem studied. For instance, the level of habitat provision to be provided in a new (or retrofitted) development should ideally be equal to the level of habitat provision in the original ecosystem. In examining climate regulation, one aspect that could form a design goal would be to determine how much carbon was contained and/or sequestered by the original ecosystem. This then would suggest what an optimum level to aim for in a new development would be. Although it may be difficult in some cases to determine with accuracy certain rates or figures related to ecosystem services, an approximate figure is still useful in determining site-specific regeneration goals.

[. . .] The closest example of ecosystem services analysis being applied to design that the author is aware is the Lloyd Crossing Project proposed for Portland, Oregon. The design team investigated how the site's original ecosystem functioned before development in order to determine appropriate goals for the ecological performance of the project over a 50-year period. The stated goals of the project include: reducing environmental impact to predevelopment levels, achieving carbon balance, and living within the site's rainfall and solar budget. [28]

[28] Maibritt Pedersen Zari. 2012. "Ecosystem Services Analysis for the Design of Regenerative Built Environments." *Building Research & Information*. 40 (1): 54-64.

04 *Bullitt Center Case Study: Creating a Dialogue with Nature*

As the first multi-story, mixed-use building in a dense urban neighborhood to aspire to the Living Building Challenge, the Bullitt Center offers an unprecedented opportunity to communicate the value of ecosystem services in an urban context. From the stunning and innovative design, to the local and sustainable materials used throughout the building, to the building site in Seattle's Capitol Hill EcoDistrict, the Bullitt Center has the power to help us re-imagine our cities for the twenty-first century—no longer as places distinct from the natural world, but rather as adaptive, resilient, living urban ecosystems.

By applying the rigorous standards of the Living Building Challenge, the Bullitt Center will contribute in significant and measurable ways to the regeneration of its surrounding neighborhood and the broader Puget Sound landscape. While our primary research agenda has worked to create a rigorous definition and analysis of urban ecosystem values for the Bullitt Center, we also believe it is important to draw on that work to communicate those findings and values and engage both visitors to the building and others from around the world in a new understanding of urban landscapes.

The Bullitt Center has already generated a rich archive of compelling stories—even from the phase of the building's early construction, leading to its grand opening in the spring of 2013. The building has any number of stories to tell. Its posts and beams were sourced from the local forests. Supply chains created by the building transformed local economies: such as when Everett, Washington–based Goldfinch Brothers became North America's greenest window manufacturer for Germany's innovative Schüco company, or Oregon-based manufacturer Prosoco became red list compliant by replacing a phthalate (a known human endocrine disrupter) in their popular vapor barrier with nothing other than an edible material.

This archive of stories, which might be translated through interactive video or audio segments as visitors explore the building or the website, will only continue to grow as tenants and visitors begin to interact with the building as a center of commerce and education in the heart of Seattle.

In addition to these site-specific stories, the design of the Living Building Standard can be transformed into rich, dynamic, and aesthetically pleasing visualizations of the building's ecosystem services at any point in time. The seven "Petals" of the Living Building Standard provide a natural framework for storytelling and visual presentation that also easily translate to scientific and economic analyses of the direct and indirect benefits generated by the Bullitt Center's unique features. Each Petal maps to a series of clear "Imperatives," which, in the case of the Bullitt Center, have given rise to concrete ecosystem benefits at multiple spatial scales. A number of the Petals have also given rise to inspiring stories of innovations in technical production processes and supply chains, such as those identified in the previous paragraph. These visual stories, while specific to the Bullitt Center, could be derived from data visualization technologies that can be transferred to other contexts—other Living Buildings, for example, other green infrastructure endeavors, to tell other site-specific stories. This type of transferable value allows the Bullitt Foundation to offer enormous opportunities to its partners and other grantees—making the building, and this storytelling endeavor, truly a reflection of the foundation's overall goal of serving as a model for a new approach to human ecology.

4.1 Project Lifecycle Phases

Ecosystem services benefits in the Bullitt Center—and any building—may also be viewed through the phases of project design, construction, "induced innovation," operations, and deconstruction.

1. Adaptive Design

Is it possible that a new design process can have measurable positive effects on ecosystems? Is it likely that the collaborative design process of the client, architect, engineers, and the general contractor can generate efficiency and enhance ecosystem services in a dense urban neighborhood through an iterative and adaptive process? These questions reflect a powerful paradigm shift that allows for a change in the building design process, where ideas flow upstream and innovation is created downstream. This quality of collaboration in an adaptive iterative process allows for feedback, innovation, efficiency, and an elegance of design that is found in living systems. Emergent qualities in design at the urban scale may indeed be necessary for urban ecosystem services to be optimized.

Ecosystem services need to be introduced explicitly into the design process, allowing them to be optimized at all levels of scale. The Living Building Challenge implicitly does this, with its close correlation with most key ecosystem services, but it can be augmented with a variety of design tools, frameworks, and guidelines.

2. Construction Phase

Multiple ecosystem services can be impacted during the construction phase including stormwater, soil retention, biodiversity, and others. It would be worth assessing the construction process of the Bullitt Center to understand the ways that ecosystem services were preserved. It is worth noting that the Bullitt Center project encouraged construction workers to be attentive to every aspect of the Living Building Challenge, including the Red List of toxic substances to avoid. In more than one case, workers flagged materials with Red List substances on site and helped ensure that proper substitutes were found.

3. Induced Innovation Phase

This phase includes the ongoing effects of transforming the local economy through the introduction of new building products, systems, and processes inspired by meeting the imperatives of the Living Building Challenge. The cumulative ecosystem services benefits from these induced innovations can be very significant. In the case of the Bullitt Center, these innovations include:

A. High-performance windows previously only manufactured in Germany (by Schüco) are now being made under license by the manufacturer Goldfinch Brothers in Everett. This provides a massive reduction in transportation impacts.

B. During the project, it was determined that no exterior vapor barrier coating paint was available without Red List materials, typically highly toxic phthalates. When this was brought to the attention of a regional manufacturer (Prosoco), it was able to reformulate its product without phthalates, creating an important new product line.

C. The exterior of the building will be replaced every seventy years or so, and the intent is for each of these snakeskin shedding opportunities to allow even more restorative products to be installed.

4.Operations and Ongoing Adaptation Phase

During day-to-day operations, there will be many opportunities to provide ecosystem services benefits by engaging tenants and fine-tuning building systems. For instance, tenants will be able to closely monitor their energy usage and modify habits accordingly. Another key example is the transportation carbon emissions impact reduction the building will facilitate through its absence of parking and central city location well-served by walking, biking, bus, and (soon) streetcar. These behavioral adjustments and building adaptations may have a cumulative impact at least as significant as that of the building itself.

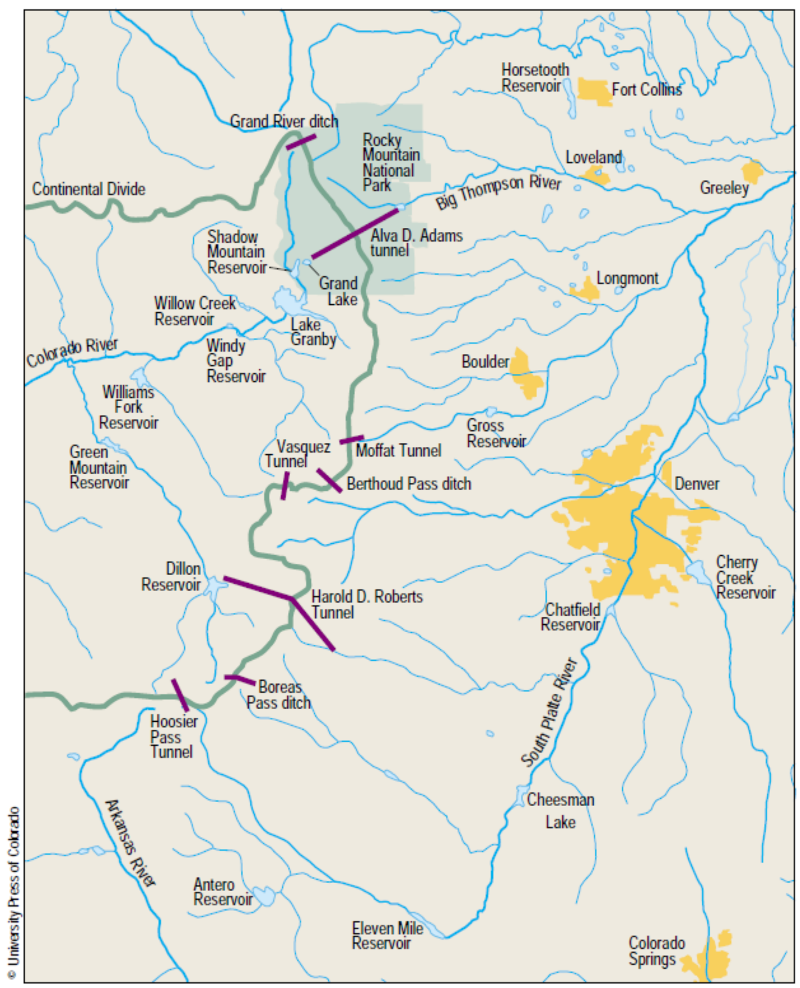
5. Deconstruction at End of Useful Life

At the end of its 250-plus year expected life, the Bullitt Center is designed to be deconstructed with maximum ability to reuse and recycle its component materials and systems. This will result in a significant amount of ecosystem services benefits and avoided costs by eliminating waste and reducing consumption of new building materials. Presumably, its site will either be restored to full functionality in the verdant Seattle of 2263 or become home to an even more restorative Bullitt Center that is currently beyond our imagination.

4.2 Spatial Scales

FIGURE 14

Water Diversions for the Colorado Front Range



SPATIAL SCALES

The issue of urban externalities brings a new variable into the analysis of urban ecosystem services—the variable of scale. Both temporal and spatial scales come into play as we consider the context in which our urban centers are embedded in the landscape. As an example of how an urban area can have a significant impact well beyond its immediate boundaries, consider the water supply situation on the Colorado Front Range. Figure 14 shows the various water diversion tunnels that are used to transfer water from the western side of the Continental Divide to the eastside, where it is collected in reservoirs and stored for use by the Front Range communities.[29] These diversions result in the annual transfer of over 802 million cubic meters of water from the western slope drainages to the rivers of the eastern slope, with resulting impacts to the ecological processes within the rivers on both sides of the divide.[30] Given the continuous water supply issues that affect the communities downstream from the western slope of the Rockies (e.g., Phoenix and its surrounding suburbs), this particular example illustrates how widespread the consequences of these externalities can be.

The same concern exists for all aspects of urban development and provisioning. Understanding the flow of materials and resources requires the ecosystem services analysis to expand to multiple spatial and temporal scales. Depending upon the system being considered, a scale may expand beyond a building unit to a regional system or watershed or to biogeochemical cycling. The sequence of time and measurement may be hourly, daily, seasonally, annually, or in the case of a building and usage patterns, may be tied to events that require engineered systems to fluctuate accordingly. The appropriate scale of analysis is determined by relevant ecological processes and the economic and social conditions being addressed.

The Bullitt Center provides some obvious examples of this aspect of the analysis—for instance, the FSC-certified wood products that comprise the primary structural component of the building. This material was an external flow of materials into the urban environment. The manner of wood production and harvest for the lumber that went into the building obviously has a considerable impact on the watershed from which the wood was sourced. Those watershed conditions translate into water quality, water quantity, biodiversity, and other benefits for that watershed, which in turn affects the ability of that watershed to sustainably support human populations.

The quest to reduce externalities from urban areas while maintaining high densities, community resilience, and quality of life requires a careful balancing of ecosystem services and technology within our urban planning and design. The ecosystem services spectrum allows us to find the optimum density for an urban area—allowing the urban planners to balance sprawl reduction with manageable supply chains that minimize externalities. To really understand ecosystem service benefits, it is necessary to understand how these benefits occur on the landscape at multiple scales. Ultimately, an understanding of what is happening at the site, neighborhood, watershed, regional, and larger scales will be critical to understanding the nature and value of the benefits being provided. This section provides an overview of the process for estimating and representing ecosystem service benefits at differing spatial scales. The results are summarized in Table 17 in the "Impact at Multiple Spatial Scales and Comments" column.

The scoping process identified strategies for understanding services at each of those scales along with mechanisms for using the multi-scale understanding to better inform the Bullitt Center's contribution to sustainability. The scoping process took an iterative approach to the three analysis aspects being scoped (i.e., type of benefit, spatial scale, and temporal scale). For instance, it is necessary to have some understanding of both site-level benefits and regional context before determining which ecosystem service benefits are most significant. Likewise, it is necessary to know which benefits are being given a greater level of scrutiny before it is possible to identify the proper approach to analysis across spatial scales.

[29] Graphic Copyrighted by University Press of Colorado, excerpted from U.S. Geological Survey Biological Resources Division; *Status and Trends of the Nation's Biological Resources Volumes 1 & 2;* U.S. Department of the Interior, U.S. Geological Survey, 1998.

[30] Id.

To address the need for iteration, the initial understanding of the relevant issues across the scales of analysis was provided through the understanding of local experts and practitioners as well as the results of existing studies. The first two pieces of this analysis are given below, along with a summary of the overall direction and process.

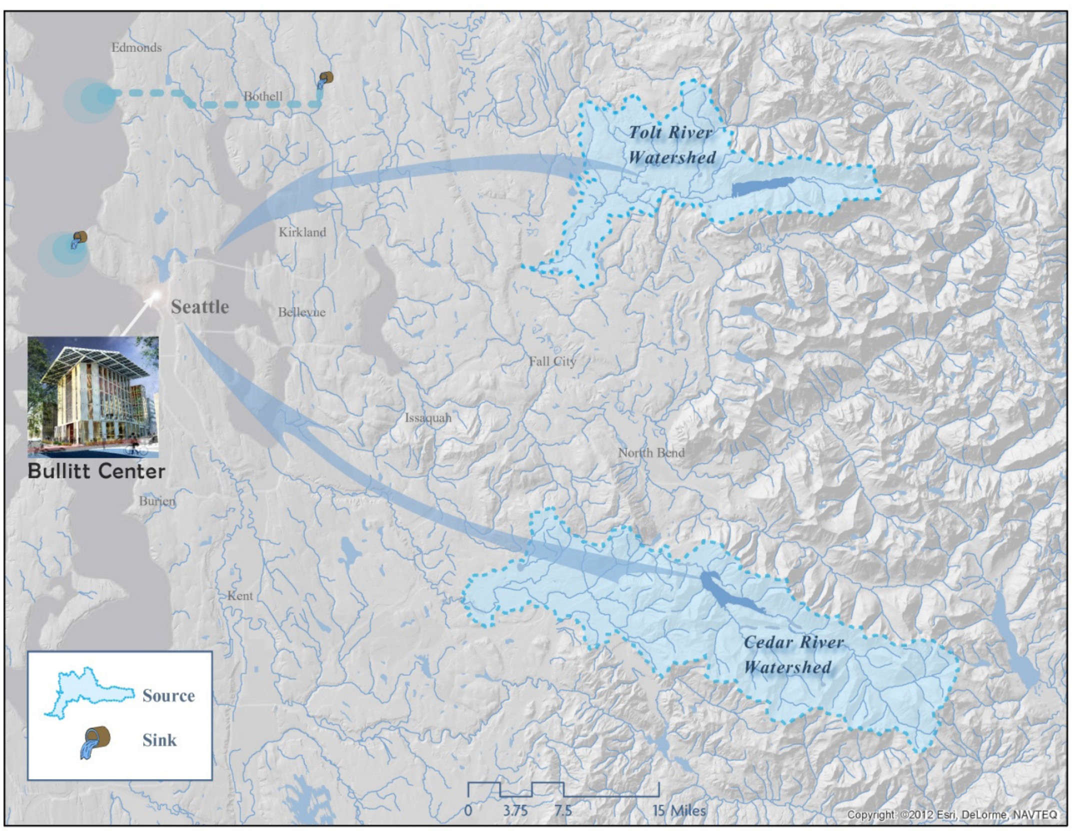
1. *Sources and Sinks: Nested Impacts at the Site and Watershed Level*

The Bullitt Center's water management systems provide examples of the watershed-level ecosystem service impacts of Living Building features. The stormwater management, greywater reuse, composting toilet, rainwater catchment, and on-site cistern systems not only provide direct, positive ecosystem service benefits at the scale of the building site, but also reduce ecosystem impacts at the watershed and regional level, increasing the net flow of ecosystem services available to other human and non-human communities.

Figure 15 provides a visual aid to understanding these impacts. The rainwater catchment and on-site cistern system reduce pressure on the Cedar River and Tolt watersheds, which provide the lion's share of Seattle metropolitan area potable water; these watersheds are labeled as "Sources" on the map. Meanwhile, the stormwater management, greywater reuse, and composting toilet systems reduce pressure on the wastewater treatment facilities at Brightwater and West Point. The water outflow from these facilities drains into Puget Sound. Reducing pressure on these facilities brings about a reduction in the total economic and environmental cost of treating wastewater, and additionally reduces the risk of pollution of the Sound. The treatment facilities and their corresponding drainages are labeled as "Sinks" on the map.

FIGURE 15

Areas of Positive Watershed Impact from the Bullitt Center



SPATIAL SCALES

Ecosystem service benefits from the Bullitt Center also occur through the lifecycle impacts of materials used in construction. The timber certified by the Forest Stewardship Council (FSC) used in constructing the framing, doors, and roofs of the building provides a good example. FSC-certified forests support a wider diversity of native species, sequester more carbon, produce cleaner water, and protect soil, water, native fish, and other aquatic species better than the dominant industrially managed forests in the region. In accordance with the Living Building Standard, the forests from which the lumber for the Bullitt Center was sourced are all located within one thousand kilometers of the building site.

4.3 Temporal Scales

Just as with spatial scales, the benefits provided by the Bullitt Center need to be understood in a temporal context. The scoping process determined that there are two primary types of analysis for temporal scales.

1. *Ecosystem Services Benefits Viewed at Different Timescales*

Ecosystem services flow from living systems in a constant dance of activity across timescales ranging from a fraction of a second to billions of years. Ecosystem services benefits in the built environment each have a variety of natural rhythms on timescales typically ranging from hourly (e.g., changing patterns of natural light or ventilation) to daily (solar panels are diurnal) to annual (heating and cooling loads) to decades and centuries (growth of street trees). Ecosystem services may also encounter threshold conditions resulting in qualitatively different behavior, which can also impact temporal modeling. These timescales have design implications and may create opportunities for associated economic value (e.g., building–smart grid interactions or cisterns forming part of a “distributed” water utility).

2. *Potential Shifts in Values of Ecosystem Services Over Long Time Periods Due to Climate Change and Other Large-Scale Shifts*

Ecosystem services are also likely to shift significantly in economic value, quality, resilience, and other characteristics as they are influenced by global, continental, and regional drivers including climate change, biodiversity loss, changes in the built environment, and economic activities. This can have a significant impact on modeling long-term streams of ecosystem services benefits and their economic benefits.

4.4 Bullitt Center Ecosystem Services Typology

Evaluating every ecosystem services benefit provided by the Bullitt Center would require significant resources to perform at anything beyond a very superficial level. Accordingly, the scoping process was used to prioritize the benefits explored in more detail in Section 4.6. The scoping process focused on a variety of criteria for prioritizing future study opportunities, including:

+ Issues with greatest regional importance
+ Benefits that are most illustrative of how the building contributes to sustainability
+ Issues that are most likely to fill existing knowledge gaps
+ Benefits that are most likely to lead to important follow-up opportunities

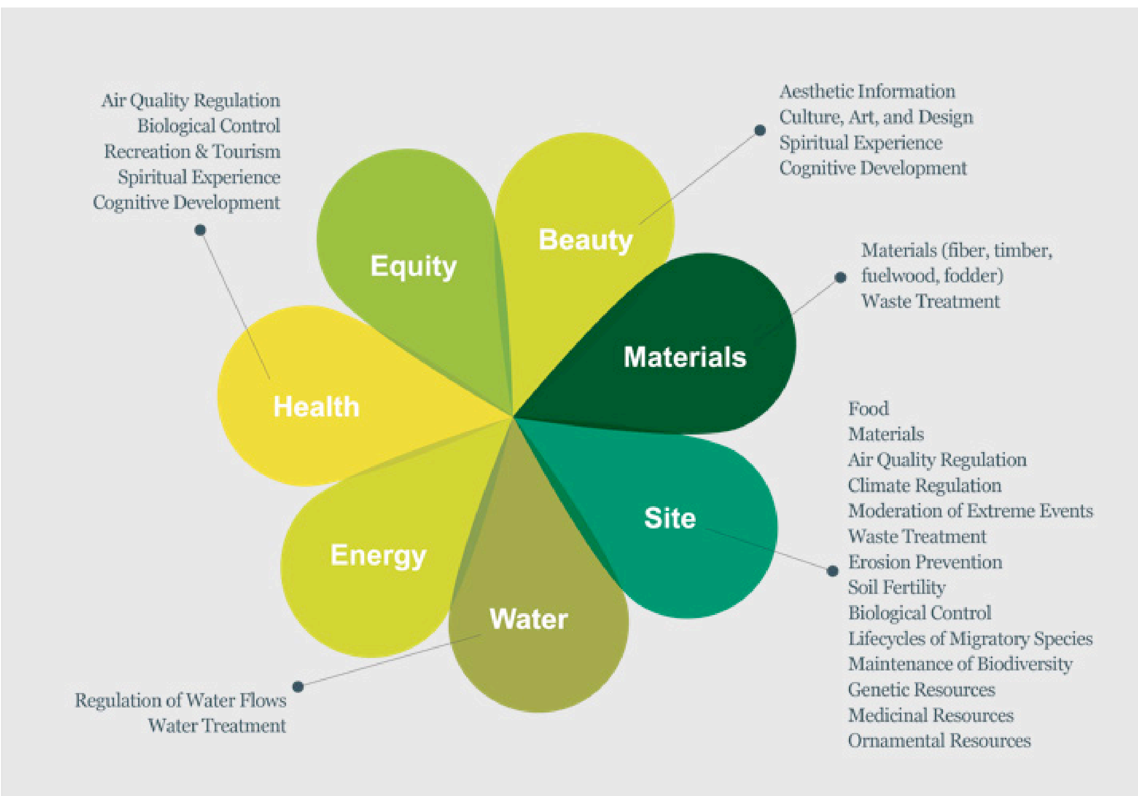
+ Benefits that are the most dramatically improved over current standard approaches
+ Benefits with the greatest potential financial impact on future Living Buildings
+ Benefits that can be effectively used to drive policy interventions

Of course, to prioritize the benefits, it is necessary to at least have a basic understanding of the range of benefits that are being provided. It is also necessary to at least have a preliminary understanding of the regional context in which the benefits are being provided. The scoping process relied on available information (existing planning documents, studies, etc.), surveys of relevant stakeholders, and existing knowledge of participants to assess the anticipated benefits provided by the Bullitt Center. A matrix that qualifies the extent to which the respective benefits meet the identified prioritization criteria was developed to help guide the prioritization process. This matrix was adapted from the Integrated Real Estate Investment Modeling Tool developed by the Economics of Change project to reflect the ecosystem services benefits provided Bullitt Center.[31] The matrix also follows the standard classification provided by the UN The Economics of Ecosystems and Biodiversity project except where noted.[32]

Ecosystem services of particular interest or importance for future research are highlighted in green, while those benefits that are significant but have been widely studied in other buildings are highlighted in blue.

FIGURE 16

Ecosystem Services and Living Building Challenge Petals



[31] Cowan, Stuart, David Batker, Theddi Wright Chappell, and Jason Twill. 2011. *Integrated Real Estate Investment Modeling Tool*. Tacoma, WA: Earth Economics.

[32] Pushpam Kumar. 2012. *The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations*. New York: Routlege. See page 26.

TABLE 17

Typology of Ecosystem Services in the Bullitt Center

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
PROVISIONING ECOSYSTEM SERVICES		
Energy	Solar energy; energy efficiency strategies; occupant energy efficiency [Avoids impacts from use of off-site, largely non-renewable energy sources.]	Site level: increases energy supply through direct provision, reduces energy demand through efficiency strategies. Municipal level: supports distributed energy generation. Magnitude of Benefit: High Regional Importance: High
	Transportation—Access to walking, biking, bus, streetcar [Decreases fuel consumption per capita for tenants and visitors.]	Neighborhood, district and municipal level: decreases traffic congestion, reduces emissions of CO_2. Neighborhood level: improves quality of life through increased pedestrian activity. Magnitude of Benefit: High Regional Importance: High
1. Food (e.g., fish, game, fruit)	Not provided.	This is also a Living Building Challenge imperative, but not required for this density transect (L6, with FAR ≥ 3.0).
2. Water (e.g., for drinking irrigation, cooling)	Water catchment (rooftop with cistern storage) that contributes to water supply. Reuse of greywater. Efficiency measures that reduce water consumption. [Avoids impacts from using regional potable water source.] [See Section 4.6 Water Petal: Rainwater Capture]	Site level: cistern increases site water supply, reduces site water demand. Municipal level: reuse of grey water reduces demand on stormwater treatment system. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
3. Raw materials (e.g., fiber, timber, fuel wood, fodder, fertilizer)	Building materials (wood, concrete, steel, glass); locally sourced; recycled content; non-toxic (avoid Red List); FSC wood [Decreases toxicity associated with use of these materials.] [See Section 4.6 Materials Petal: Whole Building Lifecycle Analysis]	Site level: reduces energy demand through good insulation, passive heating/cooling. Municipal level: reduces energy demand. Regional level: avoids cost of unsustainable raw material extraction and sourcing. In FSC case, improves forest ecosystem accordingly. Benefits ecosystems by avoiding toxic Red List. Magnitude of Benefit: High Regional Importance: High
4. Genetic resources (e.g., for crop-improvement and medicinal services)	Not provided.	These types of benefits are more likely to be provided in a low-density transect (L1. Natural Habitat Preserve or L2. Rural Agriculture Zone) or a specially cultivated open space area in a medium-to-high-density zone. However, it is possible some of these services could also be provided in special growing structures (e.g., greenhouses).
5. Medicinal resources (e.g., biochemical products, models, and test-organisms)	Not provided.	
6. Ornamental resources (e.g., artisan work, decorative plants, pet animals, fashion)	Not provided.	
REGULATING ECOSYSTEM SERVICES		
7. Air quality regulation (e.g., capturing dust, chemicals, etc.)	Non-toxic materials; natural ventilation; operable windows	Site level: improves human health. Neighborhood level: reduces uses of toxic materials in neighborhood. Regional level: reduces demand for polluting industries and increases demand for clean products. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
8. Climate regulation (carbon sequestration, influence of vegetation on rainfall, local climate influence, etc.)	Carbon sequestration within adjacent park and through habitat offsets achieved by Bullitt Foundation and allocated to building through Living Building Challenge.	Site Level: Avoids possible cost of carbon offsets. Global level: Reduces carbon emissions. Magnitude of Benefit: High Regional Importance: High
	Carbon sequestration in building materials: FSC wood stores many tons of carbon that would otherwise be emitted. [See Section 4.6 Materials Petal: FSC Wood]	Regional and Global levels: Reduces carbon emissions. Magnitude of Benefit: High Regional Importance: High
	Avoided carbon emissions from operations.	All levels: reduces emissions, forestalling climate change incrementally. Magnitude of Benefit: High Regional Importance: High
	Reduction in heat-island effect due to street trees and possibly solar PV roof system.	Site level: increases human health by reducing temperatures, cleaning air; avoids cost of air conditioning. Neighborhood level: improves quality of life for residents through reduced temperatures, clean air, stormwater interception. Municipal level: reduces local pollutant emissions by reducing demand for energy for air conditioning. Magnitude of Benefit: Medium Regional Importance: Medium

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
9. Moderation of extreme events (e.g., storm protection and flood prevention)	Seismic strategies; out of five hundred–year flood plain; possibly wind resistance	Site level: reduces risk of injury or property damage through natural disaster, thereby reducing insurance rates; possible additional source of economic value as FEMA center. Neighborhood, municipal, regional level: increases community resilience by providing secure and stable structure that can withstand natural disasters. Magnitude of Benefit: Medium to High Regional Importance: High
10. Regulation of water flows (e.g., natural drainage, irrigation, and drought prevention)	Rooftop rainwater catchment; cistern storage	Site level: improves human health through increased water quality (including filtration and temperature regulation); avoids cost of municipal water filtration. Directly increases water supply on site. Recharges groundwater and aquifer. Municipal level: reduces demand for water filtration, avoiding cost of depreciated equipment and improving budget. Magnitude of Benefit: Medium Regional Importance: High
	Most stormwater avoided through on-site water catchment. Ecological stormwater and infiltration for remaining stormwater.	Municipal level: reduces sewer overflow, demand for grey infrastructure for stormwater management. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
11. Waste treatment	Air quality: contribution to indoor and outdoor air quality—street trees, landscaping, nearby park.	Site level: vegetation reduces particulates, purifying air. Neighborhood, municipal level: enhances urban air quality. Magnitude of Benefit: Low to Medium Regional Importance: High
	Filtration of greywater through landscaping.	Site level: improves human health through increased water quality; avoids cost of municipal water filtration. Municipal level: reduces demand for water filtration, avoiding cost of depreciated equipment and improving budget. Magnitude of Benefit: Medium Regional Importance: High
	Composting toilets allow close to 100% nutrient recovery [See Section 4.6 Water Petal: Composting Toilet]	Site level: reduces demand for municipal water filtration and waste disposal, reducing costs; increases supply of compost and clean water. Neighborhood, municipal level: reduces demand for water filtration, sewage treatment, reducing total budget outlays. Magnitude of Benefit: High Regional Importance: High
	Recycling and reduce/reuse strategies for wide range of materials.	Site level: reduces demand for landfill, increases reuse of materials. (Avoided cost; partially offset by increased demand for recycling services.) Neighborhood, municipal level: reduces demand for landfill. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
12. Erosion prevention	Construction techniques to avoid erosion.	Site level: enhanced construction practices avoid soil loss and contaminated runoff. Regional level: use of FSC wood helps minimize erosion on well-managed FSC forests. Magnitude of Benefit: Medium Regional Importance: Medium
13. Maintenance of soil fertility (incl. soil formation) and nutrient cycling	Landscaping/Park/Habitat Offset	Site, neighborhood level: improves soil health that enhances the health of ecosystems; increases local supply of healthy soil, which enhances the health of ecosystems and possibly benefits community gardens. Magnitude of Benefit: Low Regional Importance: Medium
14. Pollination	Landscaping/Park/Habitat Offset	Municipal, regional level: increases supply of local cultivated and wild foods. Magnitude of Benefit: Low Regional Importance: Medium
15. Biological control (e.g., see dispersal, pest, and disease control)	Landscaping/Park	Neighborhood, municipal level: reduces risk of pest outbreak, preserving neighborhood and municipal biodiversity. Magnitude of Benefit: Low Regional Importance: Medium
	Non-toxic materials; natural ventilation; operable windows; restored ecosystem functioning of neighboring park and of habitat offsets	Site, neighborhood levels: improves human health. Magnitude of Benefit: Low to Medium Regional Importance: High
HABITAT SERVICES		
16. Maintenance of lifecycles of migratory species (including nursery service)	Composting toilets; rainwater catchment; ecological stormwater treatment; etc.	Regional level: contribution to salmon restoration and other biodiversity benefits by mimicking hydrological cycle. Magnitude of Benefit: Medium Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
17. Maintenance of genetic diversity	Biodiversity support in area around building and rural habitat offset land acquisitions related to building.	Site, neighborhood, municipal level: increases urban biodiversity. Regional level: if rural land acquisition, increases amount of preserved wildlands. Magnitude of Benefit: Medium Regional Importance: High
	Nutrient regulation and cycling in Landscaping/Park/Habitat Offset	All levels: improves nutrient cycling, increasing ecosystem health. Magnitude of Benefit: Low Regional Importance: Medium
	Habitat contribution, on and off-site.	Regional level: improves regional biodiversity and ecosystem health. Magnitude of Benefit: Low to Medium Regional Importance: High
CULTURAL AND AMENITY SERVICES		
18. Aesthetic information [Beauty]	Net aesthetic improvement to community (removed eyesore, Bullitt Center created with beauty as a goal).	Site, neighborhood level: increased well-being from aesthetic experiences of working in and living near the building. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
19. Opportunities for recreation and tourism	Recreational and health benefits	Site level: increases tenants' awareness of and experience of biodiversity through roof garden, pocket park, and other naturally embedded features. Neighborhood level: increases residents' experience of biodiversity. Magnitude of Benefit: High Regional Importance: High
	Creation of building that is an ecotourism destination—world's first urban Living Building, etc.	Neighborhood level: improves prestige of neighborhood and increases local economic activity through tourism. Municipal level: increases eco-tourism to the city. Magnitude of Benefit: High Regional Importance: High
20. Inspiration for culture, art, and design	Building contribution to scientific understanding of the connection between ecosystem services and the built environment; research program emerging from this scoping study contributes to this; building communication and publicity efforts.	Site level: Scientific and educational benefits directly add value to the building; intellectual property generated by the building's features increases tenants' economic well-being. Neighborhood, municipal and regional level: awareness of the building's features directly adds to the community's stock of scientific knowledge; intellectual property generated by the building increases economic activity. Magnitude of Benefit: High Regional Importance: High
21. Spiritual Experience	Building contribution to spiritual values.	Site level: improves sense of well-being through building's congruence with spiritual traditions' visions of wise stewardship of nature. Neighborhood, municipal, regional level: increases belief that "another world is possible" where people act in harmony with nature. Magnitude of Benefit: High Regional Importance: High

Ecosystem Service	Pathway to Generating Benefits or Avoiding Impacts from Bullitt Center Project	Impact at Multiple Spatial Scales and Comments
22. Information for cognitive development [Learning and Pedagogy]	Building contribution to opportunities for cognitive development, learning, and sustainability education.	Site level: improves opportunities for learning and sustainability education. Neighborhood, municipal, regional level: provides model of how to meet the Living Building Challenge (including zero energy and water) in a dense urban infill setting. Magnitude of Benefit: High Regional Importance: High

For comparison, the study cited above on ecosystem services and regenerative design assessed relevant ecosystem services using three ranking criteria:[33]

+ Services that are physically able to be mimicked by or integrated with the built environment
+ Services that have had the greatest impact on the maintenance of ecosystem health
+ The relative negative impact that the urban environment has on the service in question and the scale this relates to in terms of a local, regional, or global context

[33] Maibritt Pedersen Zari. 2012. "Ecosystem Services Analysis for the Design of Regenerative Built Environments." *Building Research & Information*. 40(1): 54-64.

TABLE 18

Table 18: Most Relevant Ecosystem Services in the Built Environment [Adapted from Zari study[34]]

Ecosystem Services	Ranking Criteria			Examples of Existing Design Methods That Could Potentially Be Used
	Applicability to the built environment	Ecological significance	Negative environmental impact caused by the built environment	
Supporting Services				
1. Habitat provision (including provision of genetic information; biological; fixation of solar energy; and species maintenance)	Medium	High	High at a local scale	Revegetation; preservation of existing flora and fauna; urban wildlife sanctuaries; living walls; urban forests; green roofs and facades; wildlife corridors; greenbelts
2. Nutrient cycling (including decomposition; soil building; and the provision of new materials)	Medium	High	High at a regional/global scale	Recycling and reuse techniques; cradle-to-cradle design; composting techniques; design for deconstruction; landfill mining; industrial ecology
Regulation Services				
3. Purification	High	High	High at a local/regional scale	Living machines; phyto-remediation and bio-remediation; filtration techniques; green roofs and facades; urban forests; constructed wetlands; composting techniques
4. Climate Regulation	High	High	High at a global scale	Storage of carbon in building structure; revegetation; design to enable behavior change in energy use; renewable energy generation; passive solar design; non-high thermal mass infrastructure and landscaping; design to reduce reliance on fossil fuels
Provisioning Services				
5. Provision of fuel/energy for human consumption	High	Medium	High at a global scale	Design for renewable energy generation; cogeneration methods; design to enable behavior change to reduce energy use; industrial/construction ecology
6. Provision of fresh water	High	High	High at a regional scale	Rainwater harvesting and storage; grey/black water recycling; design incorporating water saving equipment; porous paving surfaces; water efficient landscaping

[34] Maibritt Pedersen Zari. 2012. "Ecosystem Services Analysis for the Design of Regenerative Built Environments." *Building Research & Information*. 40(1): 54-64.

4.5 Integrating the Living Building Challenge and Ecosystem Services in the Bullitt Center

TABLE 18

Table 18: Map of Ecosystem Services and Living Building Challenge Imperatives

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
SITE		Petal intended to induce appropriate site selection, accommodate agriculture development, and ensure habitat protection.					
	01 LIMITS TO GROWTH						
		Only construct on previously developed sites, i.e., greyfields and brownfields that are not classified as sensitive ecological habitats, prime farmland, or within the one hundred–year flood plain.	Site Selection	Site redevelopment "greyfield"; increased density, reducing urban sprawl	Climate Regulation, Natural Hazard Regulation, Placemaking	Regulating, Cultural	Avoided Cost, Hedonic Pricing

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		On-site landscape may only include native and/ or naturalized species planted to emulate density and biodiversity of indigenous ecosystems and supports succession.	Landscaping /Park	Redevelopment of parkland outside building	Biodiversity, Soil formation and retention, Nutrient cycling, Pollination, Stormwater management, Water regulation, Shade and shelter, Aesthetic, Recreational, Placemaking	Regulating, Supporting, Cultural	Avoided Cost, Production Function, Hedonic Pricing, Travel Cost
		On-site landscape may only include native and/ or naturalized species planted to emulate density and biodiversity of indigenous ecosystems and support succession.	Green Roof	Native plants used on roof, stormwater management, reduced urban heat island effect, carbon capture and storage, removal of particulate matter from the air.	Biodiversity, Soil formation and retention, Nutrient cycling, Pollination, Stormwater management, Water regulation, Shade and shelter, Aesthetic, Recreational	Regulating, Supporting	Avoided Cost, Hedonic Pricing
			Bioswales	Native plants used to filter stormwater.	Biodiversity, Soil formation and retention, Nutrient cycling, Pollination, Stormwater management, Water regulation	Regulating, Supporting	Avoided Cost, Hedonic Pricing, Production Function

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	02 URBAN AGRICULTURE						
		Integrate agricultural opportunities appropriate to scale and density using FAR ratio.	FAR › 3.0, hence there is no requirement to undertake urban agriculture.	FAR › 3.0, hence none	N/A	N/A	-
	03 HABITAT EXCHANGE						
		For each hectare of development, an equal amount of land away from the project must be set aside in perpetuity.	Under discussion; Bullitt Foundation's extensive protection of wildlands may count as the exchange.	Wildlands protection	Various	All	-
	04 CAR-FREE LIVING						

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		Contribute to the creation of walkable, pedestrian-oriented communities (based on transect criteria discussed in the Standard, p.18).	Bicycle parking only	Creation of on-site bicycle parking spaces only, without car parking.	Air Purification, Climate Regulation, Placemaking	Provisioning, Regulating, Cultural	Avoided Cost (Emissions), Hedonic Pricing, Production Function (Health)
			Site Selection	Location in a walkable neighborhood with good transit access.	Air Purification, Climate Regulation, Placemaking	Provisioning, Regulating, Cultural	Avoided Cost (Emissions), Hedonic Pricing, Production Function (Health)
WATER		Account for water scarcity, incorporate water conservation into building design (p. 19).					

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	05 NET ZERO WATER	One hundred percent of project water needs must be supplied by captured precipitation or other natural closed loop water systems that account for downstream ecosystem impacts or by recycling used project water. Water must be appropriately purified without the use of chemicals (20).					
		Captured precipitation	Cistern for water catchment	Capture and storage of precipitation	Water Provision, Water Regulation	Provisioning, Regulating	Avoided Cost, Production Function
		Water purification without use of chemicals	Greywater reuse system	Accounts for downstream ecosystem impacts through recycling.	Water Provision, Water Regulation	Provisioning, Regulating	Avoided Cost, Production Function
		Closed loop water system that accounts for downstream ecosystem impacts.	Greywater reuse system	Recycles used project water: purifies used water, makes accessible for reuse.	Water Provision, Water Regulation	Provisioning, Regulating	Avoided Cost, Production Function

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	06 ECOLOGICAL WATER FLOW	One hundred percent of stormwater and used water discharge must be managed onsite to feed project's internal water demands or released onto adjacent sites for management through acceptable natural time-scale surface flow, groundwater recharge, agricultural use, or adjacent property needs.					
		Management of used water discharge	Greywater reuse system	Onsite management of used water discharge to feed project's internal water demands.	Water Provision, Water Regulation	Provisioning, Regulating	Avoided Cost, Production Function

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		Management of stormwater	Cistern for water catchment	Onsite management of stormwater through catchment and storage, to feed project's internal water demands.	Water Provision, Water Regulation, Stormwater Management	Provisioning, Regulating	Avoided Cost, Production Function
ENERGY		One hundred percent of project's energy needs must be supplied by on-site renewable energy on a net annual basis.					
	07 NET ZERO ENERGY						
		One hundred percent of project's energy needs must be supplied by on-site renewable energy on a net annual basis. Net Zero Energy Net Zero Energy	Solar array	On-site renewable energy supply source	Energy Provision (*), Climate Regulation	Provisioning, Regulating	Avoided Cost, Market Price
			Geothermal heat exchanger	On-site renewable energy supply source	Energy Provision (*), Climate Regulation	Provisioning, Regulating	Avoided Cost, Market Price
			Energy efficiency strategies	Various, including louvered windows that reduce heating/ cooling needs	Energy Provision (*), Climate Regulation	Provisioning, Regulating	Avoided Cost, Market Price

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
HEALTH		Focus on the major conditions that must be present to create robust, healthy spaces . . . . The LBC envisions a nourishing, highly productive and healthful indoor environment.					
	08 CIVILIZED ENVIRONMENT						
		Every occupiable, interior space must have operable windows that provide access to fresh air and daylight.	Louvered windows	Automatic window control mechanism in sync with local weather station.	Air Quality, Climate Regulation, Shade and Shelter, Aesthetic, Human Health, Worker Productivity, Comfort, Well-Being	Regulating, Cultural	Avoided Cost, Hedonic Pricing, Production Function
	09 HEALTHY AIR						
		Entryways must have external and internal dirt track-in systems.			Disease Control, Aesthetic, Human Health	Regulating, Cultural	

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		All kitchens, bathrooms, copy rooms, janitorial closets, and chemical storage spaces must be separately ventilated and exhaust directly to outside air.			Disease Control, Air Quality, Human Health	Regulating, Cultural	
		Ventilation rates must be ASHRAE 62–compliant and equipment must be installed to monitor CO_2, temperature and humidity.			Disease Control, Air Quality, Climate Regulation	Regulating, Cultural	
		No smoking			Disease Control, Air Quality, Aesthetic, Human Health	Regulating, Cultural	
	10 BIOPHILIA	Include elements that nurture innate human attraction to natural systems and processes. Six established Biophilic Design Elements must be represented, as listed below.					

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		1. Environmental Features	Solar array	These features of the building all fall under the general category of "environmental features."	Energy Provision	Provisioning	See above
			Geothermal heat exchanger		Energy Provision	Provisioning	See above
			Composting toilets		Waste Absorption/ Break-down	Regulating	See above
			Cistern for water catchment		Water Provision, Water Regulation	Regulating	See above
			Greywater reuse system		Water Provision, Water Regulation, Waste Absorption/ Break-down	Regulating	See above
			Irresistible staircase		Energy Provision (Avoided Cost), Human Health	Provisioning, Cultural	Avoided Cost, Hedonic Pricing
			Green Roof	Native plants used on roof.	Biodiversity, Soil Formation and Retention, Nutrient Cycling, Pollination, Stormwater Management, Water Regulation	Regulating, Supporting	Avoided Cost, Hedonic Pricing, Production Function

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
			Green space/park and plaza		Climate Regulation, Air Quality, Disease Control, Water Regulation, Stormwater Management, Natural Hazard Regulation, Flood Protection, Shade and Shelter, Soil Formation/ Retention, Soil Health, Nutrient Cycling, Pollination, Biodiversity, Habitat; Well-Being, Placemaking, Biophilia	Regulating, Supporting, Cultural	See above
			Louvered windows		Energy Provision (Avoided Cost), Indoor Air Quality, Disease Control, Human Health, Comfort, Well-Being	Provisioning, Regulating, Cultural	See above
		2. Natural shapes and forms	Wooden beams	Natural material in construction	Materials Provisioning, Climate Stability, Aesthetic; Well-Being	Provisioning, Regulating, Cultural	Hedonic Pricing
			Windows	Allowing for natural light	Aesthetic; Human Health, Comfort, Satisfaction, Well-Being	Cultural, Social	Hedonic Pricing

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		3. Natural patterns and processes	Green space/park and plaza	The green space in and around the building allows the user to interact with natural forms and processes.	Climate Regulation, Air Quality, Disease Control, Water Regulation, Stormwater Management, Natural Hazard Regulation, Flood Protection, Shade and Shelter, Soil Formation/ Retention, Soil Health, Nutrient Cycling, Pollination, Biodiversity, Habitat; Well-Being, Placemaking, Biophilia	Regulating, Supporting, Cultural	See above
			Green Roof	Native plants used on roof.	Biodiversity, Soil Formation/ Retention, Nutrient Cycling, Pollination, Stormwater Management, Water Regulation	Regulating, Supporting	See above
		4. Light and space	Windows	Natural light	Air Quality, Aesthetic, Comfort, Satisfaction, Well-Being	Regulating, Cultural	See above
			High ceilings	Sense of spaciousness	Aesthetic, Comfort, Satisfaction, Well-Being	Cultural	Hedonic Pricing
			Southern exposure	Natural light	Aesthetic, Comfort, Satisfaction, Well-Being	Cultural	Hedonic Pricing

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		5. Place-based relationships	Green space/park and plaza	The public space in front of the building allows relationships to form that are place-based and integrated into the life of the neighborhood.	Well-Being, Placemaking	Cultural	See above
		6. Evolved human-nature relationships	Green space/park and plaza	The green space surrounding the building allows the users to interact directly with nature, increasing the quantity of urban ecosystem services provided, as well as human ecological consciousness.	Climate Regulation, Air Quality, Disease Control, Water Regulation, Stormwater Management, Natural Hazard Regulation, Flood Protection, Shade and Shelter, Soil Formation/ Retention, Soil Health, Nutrient Cycling, Pollination, Biodiversity, Habitat, Scientific/ Educational; Well-Being, Biophilia	Regulating, Supporting, Cultural	See above

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
MATERIALS		Induce a successful materials economy that is non-toxic, transparent, and socially equitable . . . . The LBC envisions a future where all materials in the built environment are replenishable and have no negative impact on human and ecosystem health. The precautionary principle guides all materials decisions.					
	11 RED LIST						
		Project cannot contain any of the fourteen Red List materials/ chemicals	ENTIRE BUILDING	Use of non-red list materials exclusively	Disease Control, Human Health	Regulating, Social	Avoided Cost
			Phthalate-free insulation	Induced Innovation by Prosocco, company in Clackamas	Disease Control, Scientific/ Educational	Regulating, Cultural	Production Function

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	12 EMBODIED CARBON FOOTPRINT						
		Project must account for total footprint of embodied carbon from construction through one-time carbon offset.	Dashboard system	Metering of energy through the RFID chip; monitoring of energy use on each floor	Climate Regulation, Air Quality, Natural Hazard Regulation, Scientific/ Educational, Well-Being	Regulating, Cultural, Social	Avoided Cost
	13 RESPONSIBLE INDUSTRY	Advocate for the creation and adoption of third-party certified standards for sustainable resource extraction and fair labor practices, including for stone and rock, metal, minerals, and timber (mandatory FSC certified timber).					

Petal	Imperative	Key Features of Petal/Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		FSC Certification	Wooden beams, desks, chairs	FSC-certified timber sourcing	Materials Provisioning, Climate Regulation, Air Quality, Water Regulation, Shade and Shelter, Soil Formation/Retention, Soil Health, Nutrient Cycling, Biodiversity, Habitat, Aesthetic, Spiritual, Recreation, Scientific/Educational	Provisioning, Regulating, Supporting, Cultural	Hedonic Pricing
	14 APPROPRIATE SOURCING						
		Incorporate place-based solutions and contribute to expansion of regional economy rooted in sustainable practices, products, and services.	Windows	Induced supply chain innovation from Germany (Schüco) to Washington State (Goldfinch Bros).	Climate Regulation (avoided transport cost), Scientific/Educational	Regulating, Cultural	Avoided Cost
	15 CONSERVATION AND REUSE						

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
		Strive to reduce or eliminate the production of waste during design, construction, operation, and end of life in order to conserve natural resources. Project team must create Material Conservation Management Plan that explains how the project optimizes materials in each of the following phases: Design, Construction, Operation, End of Life.	Composting toilets	Reduces amount of treated sewage.	Waste Absorption/ Breakdown, Disease Control, Human Health	Provisioning, Regulating	See above
			Geothermal heat exchanger	Reduces energy consumed in heating and cooling building.	Energy Provision	Provisioning	See above
			Louvered windows	Reduces energy consumed in heating and cooling building.	Energy Provision (Avoided Cost)	Provisioning	See above
			Cistern for water catchment	Reduces water pollution, cost of water treatment.	Water Provision, Water Regulation, Stormwater Management	Provisioning, Regulating	See above
			Greywater reuse system	Reduces water pollution, cost of water treatment; diverts waste material.	Waste Absorption/ Breakdown, Water Provision, Water Regulation	Regulating	See above
			Solar array	Reduces energy consumption from the grid.	Energy Provision, Climate Regulation	Provisioning, Regulating	See above
			Specific building materials choices	NOTE: We may want to talk to Joe David again to get some stories about optimizing materials use	TBA		Hedonic Pricing, Avoided Cost

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
EQUITY		Correlate the impacts of design and development to its ability to foster a true sense of community. Allow the dignity of equal access. Prioritize the concept of citizen over that of consumer.					
	16 HUMAN SCALE AND HUMANE PLACES						
		Human-scaled places	Site selection	Walkability, bikability, transit proximity	Well-Being, Transportation, Placemaking, Human Health	Cultural, Social	See above
			Bike parking	Bikability (alternative transport availability)	Transportation, Well-Being, Human Health	Cultural, Social	Hedonic Pricing, Avoided Cost
			Plaza and park	Green space, public space	Well-Being, Satisfaction, Human Health, Placemaking, Biophilia	Cultural, Social	See above
	17 DEMOCRACY AND SOCIAL JUSTICE						
		Equal accessibility to the public, including street furniture; ADA compliant	Entryway	Public space	Scientific/ Educational, Well-Being, Placemaking	Cultural, Social	Hedonic Pricing

Petal	Imperative	Key Features of Petal/Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	18 RIGHTS TO NATURE						
		Must not block access to nature for any member of society, including fresh air, sunlight, natural waterways.	Windows	Provide natural light and fresh air to all building occupants.	Air Quality, Disease Control, Aesthetic, Human Health, Comfort, Satisfaction, Well-Being	Regulating, Cultural, Social	See above
		Must not block access to nature for any member of society, including fresh air, sunlight, natural waterways.	Irresistible staircase	Enhances human health through encouraging stair walking with inspiring views.	Disease Control, Aesthetic, Human Health, Well-Being, Placemaking	Regulating, Cultural, Social	See above
			Plaza and park	Enhance access to nature for public.	Well-Being, Placemaking, Biophilia	Cultural, Social	See above
BEAUTY		Beauty inspires an ethic of care, preservation, and serving the greater good.					
	19 BEAUTY AND SPIRIT						
		Design features intended solely for human delight and celebration of culture, spirit, and place.	Irresistible staircase	Enlivening experiences while climbing/descending the stairs.	Well-Being, Placemaking, Biophilia	Cultural, Social	See above
			Plaza and park	Celebration of place through spending time in park, building relationships, and cultivating sense of place.	Well-Being, Placemaking, Biophilia	Cultural, Social	See above

Petal	Imperative	Key Features of Petal/ Imperative	Building Feature	Pathway	Ecosystem Services Provided	Ecosystem Services Type/s	Valuation Methods
	20 INSPIRATION AND EDUCATION	Educational materials about the building must be made public to motivate others; areas must be made open at least one day/year to the public.					
		Educational materials	Interactive design display/ exhibit in the entryway	Information provision	Scientific/ Educational, Well-Being	Cultural, Social	Hedonic Pricing
		Public access	Public events in ground floor entryway/ hall	Public access to the building, inspiration from its features	Scientific/ Educational, Well-Being	Cultural, Social	Hedonic Pricing

TABLE 20

Living Building Challenge Distance Zones and Supported Ecosystem Services

Zone	Max Distance	Materials or Services	Master Format 2012 Classification	Sample Contributions to Ecosystem Services
7	20,004 km	Ideas	N/A	Multiple Services
6	15,000 km	Renewable Technologies	Div. 42: Process Heating, Cooling, and Drying Equipment; Div. 48: Electrical Power Generation	Energy Provisioning
5	5,000 km	Assemblies that actively contribute to project performance and adaptable reuse once installed	Div. 08: Openings (all exterior products; Div. 14*: Conveying Equipment; Div. 22: Plumbing Equipment; Div. 23*: Heating Ventilating & Air Conditioning HVAC; Div. 26*: Electrical; Div. 33*: Utilities; Div. 44* Pollution Control Equipment; Div. 46* Water and Wastewater Equipment. Sections 073300 Natural Roof Coverings; 075000* Membrane Roof; 102200* Partitions; 107000* Exterior Specialties; 444000* Water Treatment Equipment (*Zone designation refers to the location of the manufacturing facility only; raw material sourcing is not tracked)	Energy Provisioning Water Provisioning Water Flow Regulation Wastewater Purification Air Quality Regulation
4	2,500 km	Consultant Travel		Multiple Services
3	2,000 km	Light or low-density materials	Sections: 073100 Singles & Shakes; 074000 Roofing & Siding Panels; 095000 Ceilings; 096000 Flooring	Energy Provisioning
2	1,000 km	Medium weight and density materials	Div. 06: Wood Plastics & Composites; Div. 08: Openings (all interior products). Sections 073200 Roof Tiles; 092000 Plaster & Gypsum Board; 093000 Tiling; 123000 Casework	Energy Provisioning Materials Provisioning Air Quality Regulation Climate Regulation
1	500 km	Heavv or high-density materials (Manufacturing facility only; raw materials not tracked)	Div. 03: Concrete; Div. 04: Masonry; Div. 05: Metals; Div. 31: Earthwork; Div. 32: Exterior Improvements	Energy Provisioning

FIGURE 21

Ecosystem Services and Living Building Challenge Petals

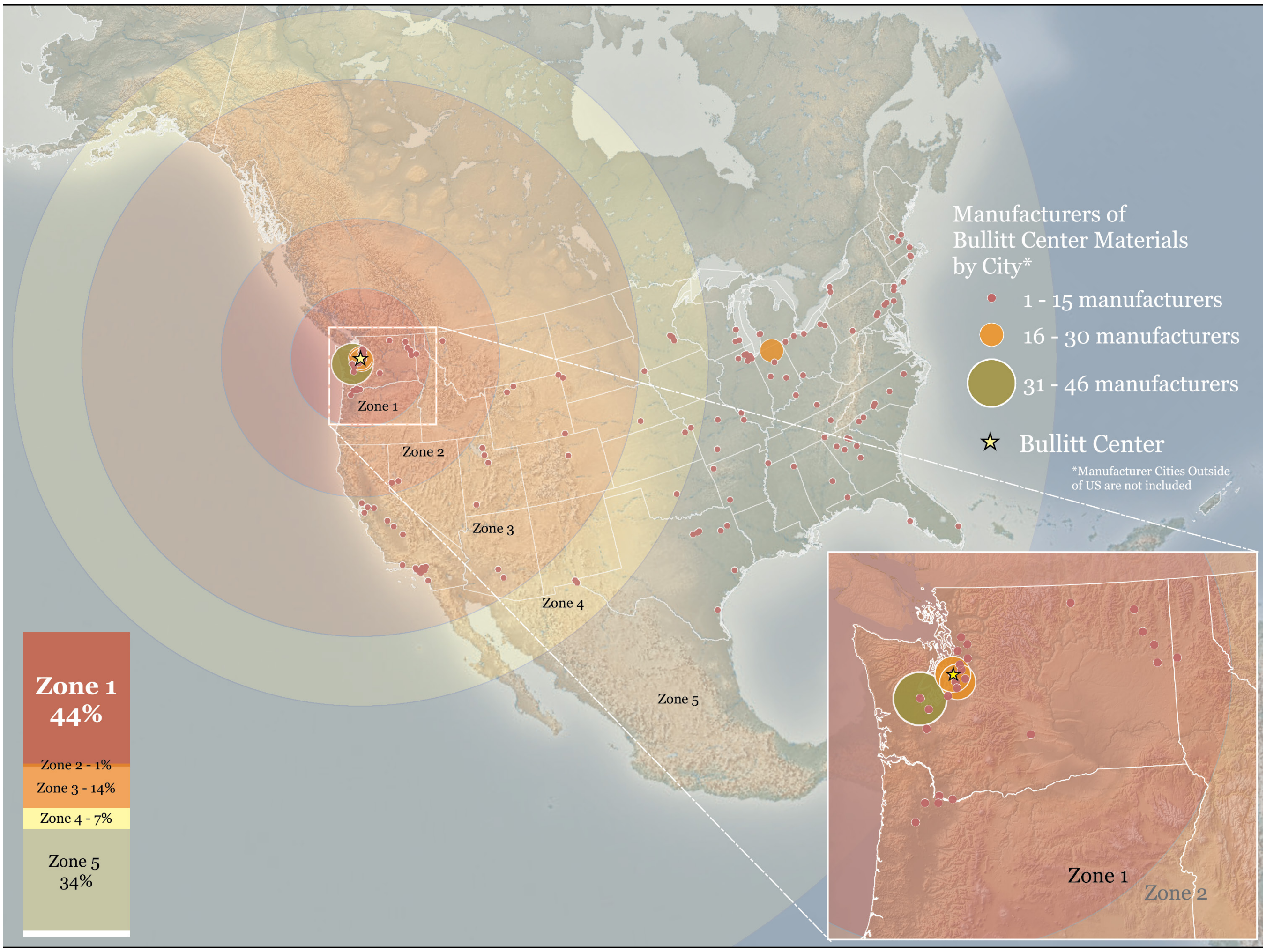


Figure 21 shows the location of products used in the Bullitt Center, and is based on the meticulous records kept during the project in order to demonstrate compliance with the Living Building Challenge zone requirements shown above.

4.6 Bullitt Center Ecosystem Services Valuations

As part of a broader qualitative and quantitative assessment of Bullitt Center green building features, functions, and ecosystem services provided, we have conducted a preliminary financial valuation of six important building strategies. A summary table is provided below along with a few key assumptions. Detailed calculations for each feature follow. As in all ecosystem service valuations, there are many different potential methodologies, and many detailed assumptions must be made to arrive at specific dollar figures. These assumptions should be made part of any communications strategy around these valuations, and should be carefully reviewed before releasing any specific figures.

It is important to emphasize that:

+ The additional "green" value created by the building occurs in many different layers, from many different features;
+ Even the value documented below from just a few layers indicates an additional value comparable to, and likely much larger than, any initial construction cost premium;
+ The valuations are highly sensitive to the discount rate. A strong case can be made for using a much lower discount rate than usual for public benefits including carbon emissions reduction or ecological stormwater treatment;
+ This study assumes a 3% annual increase in carbon, electricity, water, wastewater treatment and stormwater prices.

TABLE 22

Benefits by Feature, Assuming $200/Ton Carbon Price

PETAL	Feature	Annual Benefit	Initial One-Time Benefit	Present Value Over Lifetime of Project Based on Different Discount Rates		
				8%	6%	4%
Site	01 Site Transportation Benefits	$32,005	$0	$640,000	$1,070,000	$2,930,000
Water	02 Rainwater Capture and Reuse	$9,665	$20,650	$210,000	$340,000	$910,000
Water	03 Composting Toilet	$7,450	$0	$150,000	$250,000	$680,000
Energy	04 Energy Efficiency	$112,027	$0	$2,240,000	$3,730,000	$10,270,000
Energy	05 Solar Array	$35,776	$0	$720,000	$1,190,000	$3,280,000
Materials	06 FSC Wood	$0	$368,824	$370,000	$370,000	$370,000
	TOTAL	$196,922	$389,474	$4,330,000	$6,950,000	$18,450,000

TABLE 23

Total Measured Benefits by Carbon Price and Discount Rate

		PRICE OF CARBON ($ PER METRIC TON CO_2 EQUIVALENT)		
		30	75	200
DISCOUNT RATE	10%	$1,470,000	$1,930,000	$3,200,000
	8%	$2,030,000	$2,630,000	$4,330,000
	6%	$3,320,000	$4,280,000	$6,950,000
	4%	$9,010,000	$11,510,000	$18,450,000

Key Assumptions (see specific valuation calculations below for more detail)

+ Calculations for site transportation, energy efficiency, solar array, and FSC wood in Table 22 employ a widely used value of the full "social cost" of carbon (Ackerman and Stanton median of $200/metric ton). Table 23 provides a range of carbon prices as shown.

+ Calculations for site transportation benefits use Seattle average mode shares as baseline, and imputed Bullitt Center mode shares from a University of Washington transportation survey of Bullitt Center tenants.

+ Calculations for water and wastewater use market municipal rates. These values could be significantly higher if the actual marginal cost of municipal water supply and wastewater treatment was taken into account.

+ Calculation for solar array uses natural gas baseline to calculate avoided carbon emissions. While this is higher than Seattle's grid, it is representative of the US grid average.

+ Calculations for energy efficiency use a Seattle energy code compliant building for the baseline for comparison.

+ FSC Wood values are calculated in a lump sum payment, thus are identical across discount rates. A portion of this value is related to increased carbon storage in FSC managed forests that is "induced" by the Bullitt Center's choice of FSC wood rather than conventionally procured wood.

+ Additional Potential Valuation Studies.

+ Ecosystem services value related to adjacent pocket park (McGilvra Place).

+ Ecosystem services value related to site selection itself (underdeveloped greyfield) vs. building on equivalent area of functional land.

+ Ecosystem services value related to reduced toxicity, decreased materials transportation distances, etc. (will require detailed Lifecycle Analysis that may be beyond current capabilities of LCA software; we have coordinated with Kate Simonen on her approach to this).

+ Social benefits created from the building (e.g., comfort, health, worker productivity, reduced absenteeism, biophilia, pedagogical value, etc.) were largely beyond the scope of this study, but are being analyzed by other research teams. These benefits may also require a few years of operational experience subsequent to full occupancy to effectively quantify.

Site Petal: Site Transportation Benefits

This valuation study examines the decrease in carbon dioxide emissions (and associated climate impact) from the Bullitt Center's site selection strategy and decision to not provide on-site parking.

FIGURE 24

Total Measured Benefits by Carbon Price and Discount Rate

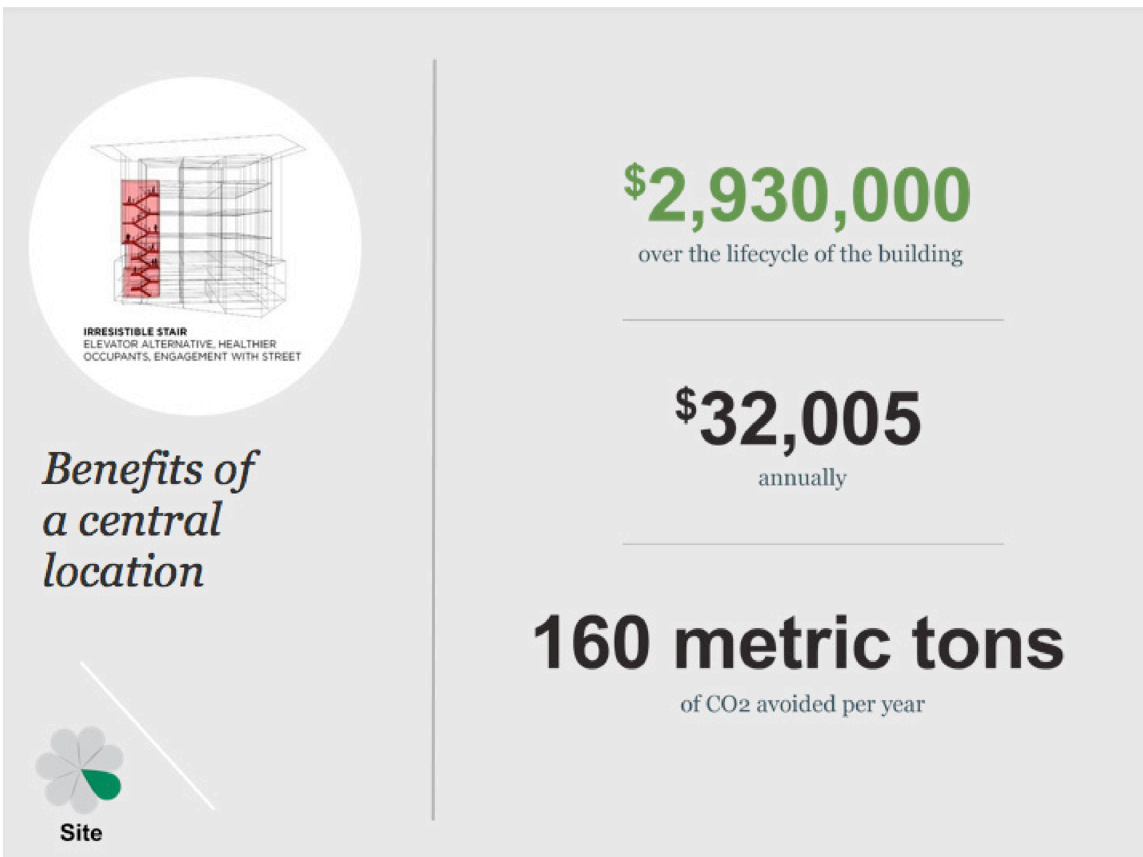


TABLE 25

Site Transportation Benefits Valuation

	Comments	
Building Feature		Walkability, Bikeability, and Transit Access
Ecosystem Service or Avoided Ecosystem Service Impact	The ecosystem service, or avoided ecosystem impact, produced by the feature.	Climate Regulation
Benefit	The benefit from the service that directly accrues to humans.	Avoided Climate Change
Baseline Impact	Impact for a building that has Seattle's average transportation mode share	5.431 kg CO_2 per person per day
Feature Impact	Impact for Bullitt Center based on International Physical Activity Questionnaire administered by University of Washington Research Assistant Professor Heather Burpee.[6]	3.655 kg CO_2 per person per day
Avoided Impact/Unit	The net impact of that feature, relative to the baseline. Measured in material units.	1.777 kg CO_2 per person per day
Workdays: Total Person-Days/Year	Assumes 240 workdays in a year, and 136 full-time building occupants[7]	32,640
Weekend: Total Person-Days/Year		5,355
Events: Total Person-Days/Year		25,680
Visitor's Center and Lab: Total Person-Days/Year		26,400
Total Person-Days/Year		90,075
Avoided Impact/Year		160 metric tons of CO_2
Dollar Value/Year	Uses median estimate of Ackerman and Stanton (2010) of $200/metric ton of carbon.	$32,005
Present Value with 8% Discount Rate, 250-Year Time Horizon		$640,000
Present Value with 4% Discount Rate, 250-Year Time Horizon		$2,930,000

TABLE 26

Modal Split for Bullitt Center vs. Seattle[35]

	Bullitt Center Mode Share	Average Seattle Mode Share	CO_2: g/ Passenger Mile	Round-Trip Commute Distance	Total CO_2: g/ Daily Commute
Bus	26.0%	35.7%	56	25.6	1,434
Solo Driver	30.2%	32.7%	371	25.8	9,572
Carpooled	7.8%	8.4%	185	27	4,995
Walked	22.0%	6.3%	0	3.8	0
Commuter Rail	0.0%	5.2%	177	44.4	7,859
Bike	14.0%	3.3%	0	11.8	0
Telecommute	0.0%	3.0%	0	32.6	0
Ferry	0.0%	2.2%	818	39.8	32,556
Motorcycle/ Scooter	0.0%	0.9%	132	24.4	3,221
Vanpool	0.0%	0.7%	101	45.8	4,626
Ferry with Vehicle	0.0%	0.6%	595	38.6	22,948
Compressed Workweek/Day Off	0.0%	0.1%	0	30	0
Other	0.0%	0.9%	190	26.6	5,093
Total	100.0%	100%	191.2	26.6	5,431
Bullitt Center			141.1	19.0	3,655

[35] Baseline modal split numbers for Seattle from 2012 Center City Commuter Mode Split Survey Results. See URL: http://commuteseattle.com/wp-content/uploads/2013/02/2012-Modesplit-Final-Report.pdf. Comparison of CO_2 use per mile by transportation mode from http://www.buses.org/files/ComparativeEnergy.pdf.

Site Petal: Landscaping/Park

Petal	Site
Imperative	**Limits to Growth**
Key Features of Imperative	On-site landscape may only include native and/or naturalized species planted to emulate density and biodiversity of indigenous ecosystems and supports succession.
Building Feature	Landscaping/Park
Pathway	Redevelopment of parkland outside building
Ecosystem Services Provided	Biodiversity, soil formation and retention, nutrient cycling, pollination, stormwater management, water regulating, shade and shelter, aesthetic, recreational
Service Types	Regulating, Supporting, Cultural
Valuation Method/s	Avoided Cost, Production Function, Hedonic Pricing, Travel Cost
Valuation Narrative	Parkland produces a suite of ecosystem services. It is appropriate to divide them into intermediate and final services. Intermediate (supporting) services include soil formation/retention, nutrient cycling, and pollination. Final (provisioning, regulating, and cultural) services include native biodiversity, stormwater management, water regulation, shade and shelter, aesthetics and recreation. Valuation can take a variety of different forms. If the budget for valuation is tight, benefit transfer from a sample site within the bioregion: select an analogous site for which a valuation study using original data was performed, and scale the value estimates of the chosen site to estimate the ecosystem services associated with the parkland you are studying. If budget permits, it is preferable to develop a stand-alone ecosystem services study using the production function method. Begin by modeling the contribution of the intermediate (supporting) ecosystem services to the final services that benefit humans. Identify the impacts of soil formation and retention, nutrient cycling, evapotranspiration, and pollination on the "final" services of stormwater management/water regulation, native biodiversity, shade and shelter, aesthetics and recreation. From here there are several possible methods. First, divide the final ecosystem services into two parts: the final services that contribute directly to experienced well-being/utility, and the services that contribute indirectly to well-being through their impact on public goods such as clean water and clean air. The directly experienced services are native biodiversity, shade and shelter, aesthetics and recreation. The indirectly experienced services are stormwater management/water regulation and biodiversity. (Note: biodiversity is indirectly experienced by humans through its existence, heritage, and option values. These are inherently difficult to measure.) For the directly experienced final services, there are two possibilities: 1. Develop a choice experiment to gauge the willingness to pay of building employees and the public for each of the final services that contribute directly to experienced utility, e.g., shade and shelter, aesthetics and recreation. 2. Develop or cite models of the monetized benefits of shade and shelter, aesthetic beauty, and recreation to human well-being including physical and mental health and work productivity. Scale the estimates to the magnitude of the services provided by the parkland and report the results. For the indirectly experienced services, there are two possibilities. 1. Avoided cost method: Identify and quantify the costs of water regulation/stormwater management that would be incurred by reliance on grey infrastructure if the parkland had not been developed. 2. "Production function" method: In the case of stormwater management/water regulation, this service is both a final service in itself, and an input to another final service enjoyed by humans: provision of clean water in sufficient and appropriate quantities. Identify (through models) the marginal contribution of stormwater management/water regulation to the provision of clean water, the unit value of clean water to humans, and the scale at which stormwater is provided. Report the resulting estimates.

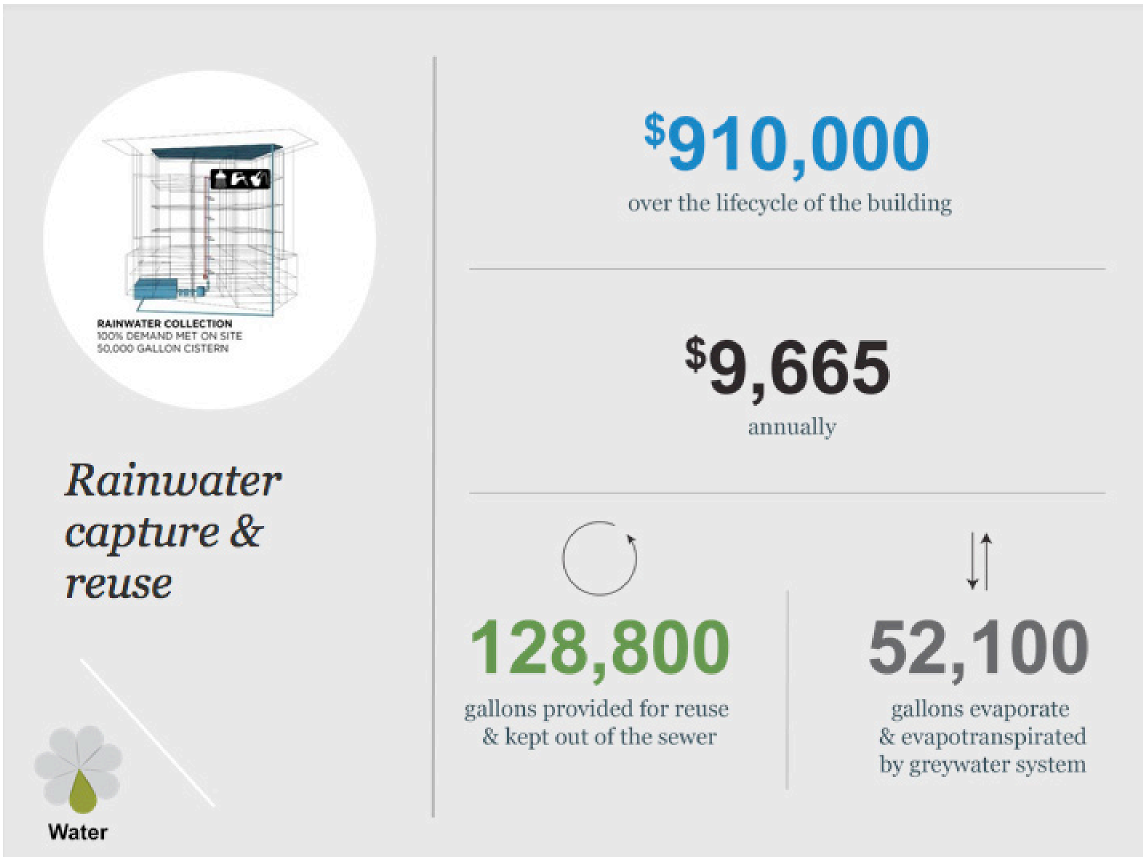
Site Petal: Site Selection

Petal	Site
Imperative	**Limits to Growth**
Key Features of Petal/Imperative	Only build on previously developed sites, i.e., greyfields and brownfields that are not classified as sensitive ecological habitats, prime farmland, or within the one hundred–year flood plain
Building Feature	Site Selection
Pathway	Site Redevelopment “greyfield”; Increased Density, reducing urban sprawl
Ecosystem Services Provided	Energy Provision (Avoided Cost), Climate Regulation, Natural Hazard Regulation, Transportation, Placemaking
ES Type/s	Provisioning, Regulating; Social
Valuation Methods	Avoided Cost, Hedonic Pricing
Valuation Methods Narrative	The site selection itself provides a source of ecosystem services. The value of these services can be modeled through two main methods, avoided cost and hedonic pricing. First, the avoided cost method allows one to estimate the ecosystem costs not incurred by choosing to build on a greyfield/brownfield that is not ecologically sensitive. The primary task is to choose an appropriate baseline site, and identify the loss of ecosystem services and human well-being associated with building on that site. The baseline site is the counterfactual scenario: what site would have been chosen for construction, had the building in question not been a Living Building candidate? This task can be split into three subtasks: 1. Identify the loss of ecosystem services, including resource consumption, associated with building on this baseline "greenfield" site, holding location amenities constant. 2. Identify the loss of ecosystem services associated with the lack of location amenities (e.g., proximity to services and transit) at the baseline site, including impacts of increased driving on carbon emissions and resource throughput. 3. Identify the positive impact on human well-being (physical and mental health, work productivity) associated with the Living Building location in comparison to the baseline location. Second, the hedonic pricing method allows one, given the right data, to estimate the subjective (hedonic) value of the ecological attributes of the site, such as its location in a dense urban area, its proximity to services and public transit, its street tree canopy, proximity to open space and parks, and amenability to walking and biking. The primary task in hedonic pricing is to collect data on a large number of transactions over properties with the attributes we are interested in valuing: for example, the density of the block or neighborhood, the proximity to the nearest transit stop, and the presence or absence of bike lanes. The task then remains to estimate statistically the impact of these attributes on property prices generally, and then scale the estimates to the levels of the attributes associated with this case.

Water Petal: Rainwater Capture and Reuse

FIGURE 27

Rainwater Capture and Reuse and Greywater System



The clean rainwater falling on the roof's surface through the gaps between the PV array will be collected, filtered, stored, and treated before being pumped to water fixtures to meet the building's overall water demands. The rainwater is stored in a 56,000-gallon cistern located in the basement of the building. The system supplies all non-potable water for fixtures in the building including toilets, hose spigots, and irrigation systems. In addition, the system has been designed and constructed to meet all potable water needs for the building when it is permitted in the future. By operating a few valves, and moving a short piece of pipe, the building can begin using rainwater to supply one hundred percent of the building's water needs. The treatment system was designed and constructed to allow for several different water treatment sequences to be tested and evaluated. By operating a few valves, water can be filtered through a series of cartridge filters, an ultrafilter, and an ultraviolet disinfection system to evaluate the performance of the different water treatment methods.

Greywater collected from sinks and showers is screened, and stored in a four hundred–gallon tank in the building's basement. The greywater is pumped to a recirculating vertical flow constructed wetland located on the building's third level green roof for treatment. Screened greywater is evenly distributed over the 479-square-foot constructed wetland, and is recirculated three times within the wetland for additional treatment. The recirculating design also helps keep the size of the wetland to a minimum. Some of the greywater is consumed through evapotranspiration by the plants and air in the wetland. The highly treated greywater flows by gravity down to a modified irrigation/infiltration drainfield located within the sidewalk planting strip along Fifteenth Street. As the greywater is evenly distributed through drip irrigation piping over the drainfield area it provides irrigation for the plantings, and the greywater is treated even further as it trickles through a sandy, compost amended soil layer, and infiltrates into the native soils below through a series of drywells. The 375-square-foot irrigation/infiltration drainfield area has been designed and constructed to infiltrate the average daily flow of approximately 345 gallons.

The human "waste," or resource as it is more fondly called, from toilets and urinals within the building will be conveyed to ten large composting units in the building's basement. Foam flush toilets use a very small volume of water (< 1 cup) and natural soap to convey the solids down through the piping to the basement. Wood chips or other bulking agents are added to the composting units as an additional carbon source, and to help manage moisture levels. The compost is rotated about once a week by turning a handle on the front of each composter incorporating air into the compost, which helps to accelerate the composting process. Temperatures maintained in the range of 135°F to 165°F ensure all pathogens and contaminants are sterilized or killed. Each of the composters produces approximately ninety gallons (twelve cubic feet) of compost each year. This valuable resource is taken to a nearby composting facility to be incorporated with other composted material, and used as a soil amendment.

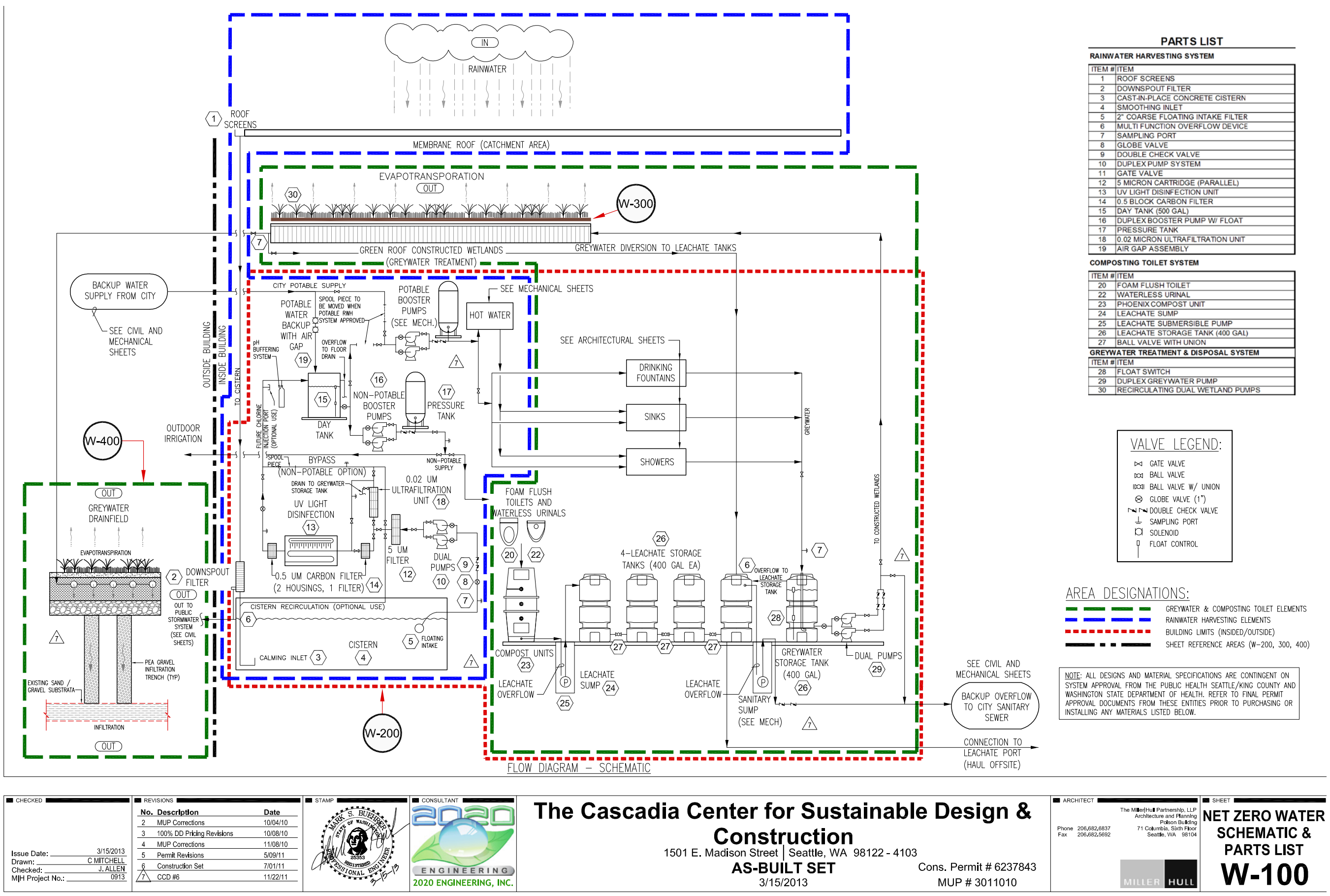
The ten thousand–square-foot Bullitt Center property is almost entirely occupied by the building footprint. When all of the building's water demands (both potable and non-potable) are served by harvested rainwater, approximately 69 percent (128,800 gallons) of the annual rainwater runoff is collected, stored, treated, and used for potable and non-potable uses; the remaining 31 percent will be discharged as stormwater, ensuring the integrity of downstream hydrology (Lake Union). Historically, in an old-growth forested condition, approximately 39 percent of the rainfall ran off the site, while the remaining balance, 61 percent, would have evapotranspired, or infiltrated into the native soils. On average, 237,400 gallons of rain fall on the ten thousand–square-foot site each year (based on fifty years of historic rainfall data). This results in approximately 185,300 gallons of runoff. The runoff volume is less than the rainfall volume due to evaporation on the membrane roofing and evapotranspiration on the green roofs. Indoor non-potable water fixtures consume an estimated 11,400 gallons per year. Approximately 100,600 gallons of greywater will be treated and evaporated/infiltrated onsite. Through a combination of infiltration, evapotranspiration, and piped discharge, the building is closely mimicking the historic old-growth hydrology of the site.[36]

Figure 28 on the following page shows a schematic drawing of the Bullitt Center's water, stormwater, greywater, and composting toilets prepared by 2020 Engineering.

[36] This section reproduces *Bullitt Center Water Narrative*, an unpublished note by 2020 Engineering.

FIGURE 28

Schematic Image of Bullitt Center Water System



Petal	Water
Imperative	**Net Zero Water**
Key Features of Imperative	One hundred percent of project water needs must be supplied by captured precipitation or other natural, closed-loop water systems that account for downstream ecosystem impacts or by recycling used project water. Water must be appropriately purified without the use of chemicals.
Building Feature 1	Rainwater Capture System, Including Cistern for Water Storage
Pathway	Capture and storage of precipitation
Ecosystem Services Provided	Water Provision, Water Regulation, Stormwater Management
Service Types	Provisioning, Regulating
Valuation Method/s	Avoided Cost
Valuation Narrative	Rainwater capture reduces the amount of stormwater runoff and absorbs pollutants otherwise bound for the Puget Sound. Therefore, the avoided cost method is the best way to capture the net ecosystem impact of the rainwater capture system. Capturing and storing rainwater also increases the total municipal water supply and makes the building self-sufficient in water, reducing its total utility costs. The value of rainwater capture can be estimated in terms of the avoided impacts on the municipal water supply system, the stormwater management system, and the Puget Sound ecosystem itself. Begin the valuation by asking how much water would run off the building and into the Sound in the absence of the rainwater capture system, and what quantity of pollutants it would carry. Identify the unit ecosystem impact per unit (gallon) of water at the estimated level of pollution, and multiply by the number of units. Then ask what the unit infrastructure costs (per gallon or square foot) of the baseline municipal stormwater management system would be, and multiply by the number of units. Finally, ask what it would cost to supply the building with the quantity of water captured by the on-site system. Add these three costs together to arrive at the total ecosystem service value of the rainwater capture system.
Building Feature 2	Greywater Recycling System
Pathway	Accounts for downstream ecosystem impacts through recycling. Recycles used project water: purifies used water, makes accessible for reuse.
Ecosystem Services Provided	Water Provision, Water Regulation, Stormwater Management
Service Types	Provisioning, Regulating
Valuation Method/s	Avoided Cost
Valuation Narrative	The screening/storage/pumping system and constructed wetland comprise the greywater recycling system. Greywater recycling ensures that the water used by the building will be returned to the Puget Sound ecosystem free of toxins. The avoided cost method is thus the best way of estimating the ecosystem service value of the greywater recycling system. The value of greywater recycling can be estimated in terms of the avoided impacts on the wastewater treatment and the Puget Sound ecosystem. The Bullitt Center water case study (2020 Engineering) estimates that 100,600 gallons of greywater will be treated and evaporated onsite per year.

TABLE 29

Rainwater Capture and Reuse Valuation

	Comments				TOTAL BENEFITS
Building Feature		Rainwater Harvesting System		Greywater Recycling System	
Ecosystem Service or Avoided Ecosystem Service Impact		Water Regulation	Water Provision	Water Filtration	
Benefit	The benefit from the service that directly accrues to humans.	Avoided Stormwater Pollution	Increased Potable and Non-Potable Water Supply	Avoided Wastewater Treatment	
Avoided Impact or Benefit/Year	The net avoided impact or benefit relative to the baseline.	128,800 gallons used in building plus 52,100 gallons evaporated and evapo-transpirated does not become untreated stormwater.	128,800 gallons provided by system.	100,600 gallons of greywater generated by building and infiltrated by greywater system.	
Fixed Cost of Avoided Impact	The avoided fixed cost (if any) associated with the net impact.[37]	$20,650			$20,650
Dollar Value/ Year	Based on Seattle Public Utilities rates.[38]	$7,239	$859	$1,567	$9,665
Present Value with 8% Discount Rate, 250-Year Time Horizon		$165,000	$17,000	$31,000	$210,000
Present Value with 4% Discount Rate, 250-Year Time Horizon		$684,000	$79,000	$144,000	$910,000

[37] This is the fixed infrastructure cost of managing stormwater as reported by City of Portland BES (2008). We do not have an estimate for Seattle. The one-time infrastructure cost is $2.71/s.f., multiplied by the number of square feet of the building's footprint (10,000 s.f.), multiplied by the building's retention/capture rate (76.2%). This number measures the avoided cost of grey infrastructure; it is not an ecosystem impact measurement."

[38] Except for avoided stormwater pollution, which uses the same Portland BES study cited in the previous footnote. This study quotes a value of $0.95/SF annually multiplied by the number of square feet of the building's footprint, multiplied by the building's capture/retention rate.

Water Petal: Composting Toilet

FIGURE 30

Composting Toilets

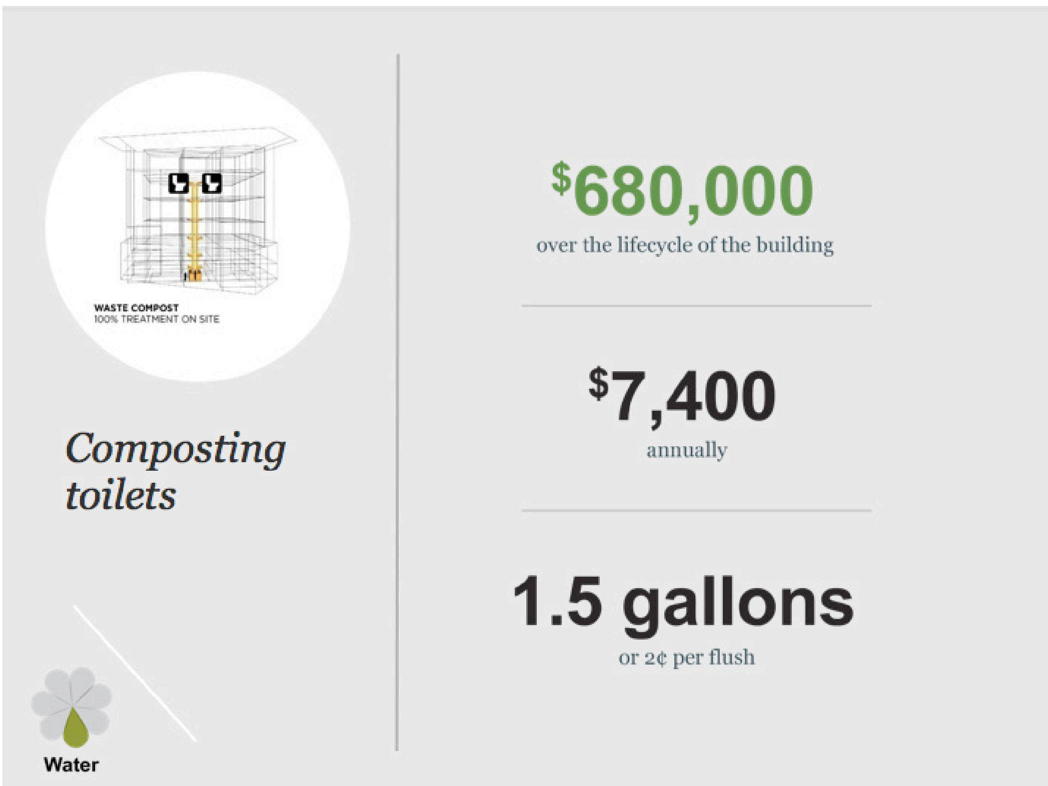


TABLE 31

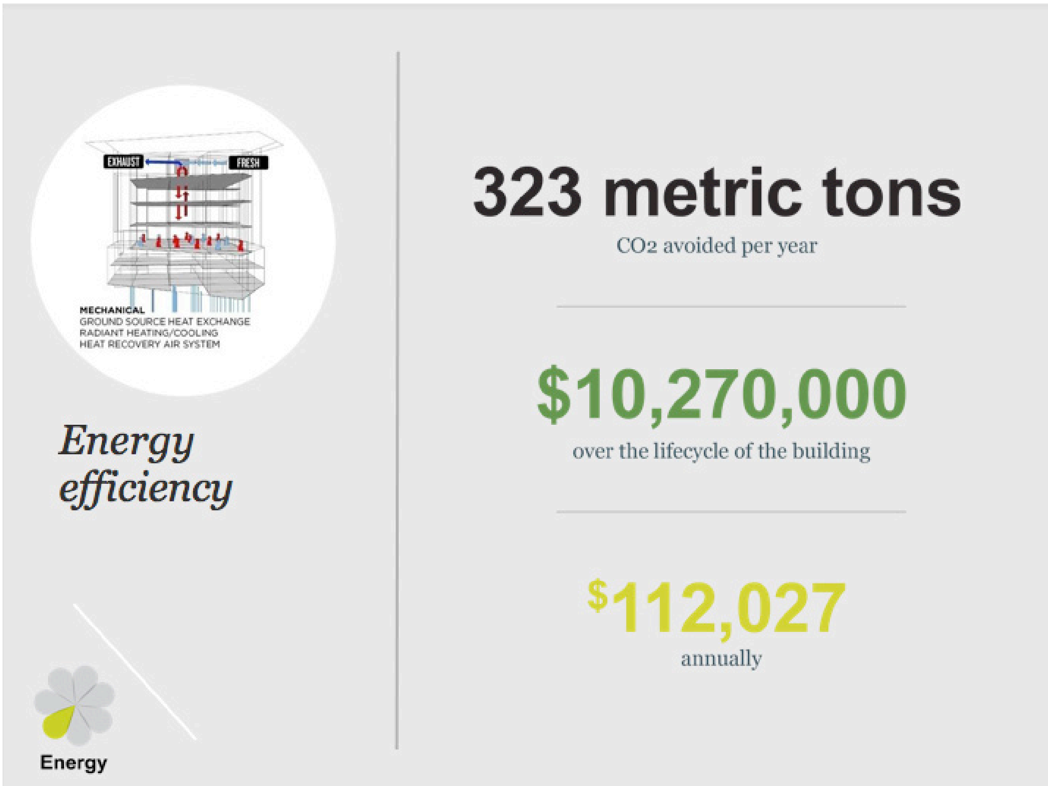
Composting Toilet Valuation

	Comments				**Total Benefits**
Building Feature		Composting Toilet			
Ecosystem Service or Avoided Ecosystem Service Impact		Avoided Wastewater Discharge	Compost Provision	Avoided Water Consumption	
Benefit	The benefit from the service that directly accrues to humans.	Avoided Wastewater Treatment	Increase Compost Supply	Avoided Water Consumption	
Additional Quantity Provided	The quantity of the service directly provided by the feature.	N/A	5,792 pounds/year	N/A	
Avoided Impact/Unit	The relevant unit of measurement of impact or benefit.	1.5375 gallons	N/A	1.5375 gallons	
Avoided Impact/Year	Based on usage assumptions above	313,742 gallons	N/A	313,742 gallons	
Dollar Value of Benefit/Impact	Seattle Public Utility wastewater treatment rate; Compost market rate	$4,890	$470	$2,040	$7,400
Present Value with 8% Discount Rate, 250-Year Time Horizon		$98,000	$9,000	$41,000	$150,000
Present Value with 4% Discount Rate, 250-Year Time Horizon		$448,000	$43,000	$187,000	$680,000

Energy Petal: Energy Efficiency

FIGURE 32

Energy Efficiency



In order to achieve Net Zero Energy, the Bullitt Center was designed with an extremely ambitious operational energy use index target of sixteen kBTU/s.f./year, based on available heat or electrical energy from a six-story building on the chosen site. This target will be met with a wide range of integrated energy efficiency strategies including:[39]

Energy Conservation

+ triple-glazed, high-performance windows
+ air-tight walls and roof
+ tall windows and narrow floor plans for daylighting
+ operable exterior blinds to control heat gains

Fresh Air Delivery

+ operable windows for ventilation and cooling
+ demand-controlled heat recovery ventilation

Plug Loads

+ daylight-integrated electric lighting using high-efficiency light fixtures
+ super-efficient workstations and cloud-based servers
+ digital dashboard with floor-by-floor energy monitoring
+ smart plug strip energy metering and displays

[39] This section excerpted from presentation board language about Energy originally written by Rob Peña.

Geothermal Heating and Cooling

- 26, 400-foot-deep closed loop wells provide a heat source/sink to heat or cool the building
- water-to-water heat pumps to convert this energy to warm or cool water
- warm or cool water is circulated through floor slabs for radiant space heating or cooling

TABLE 31

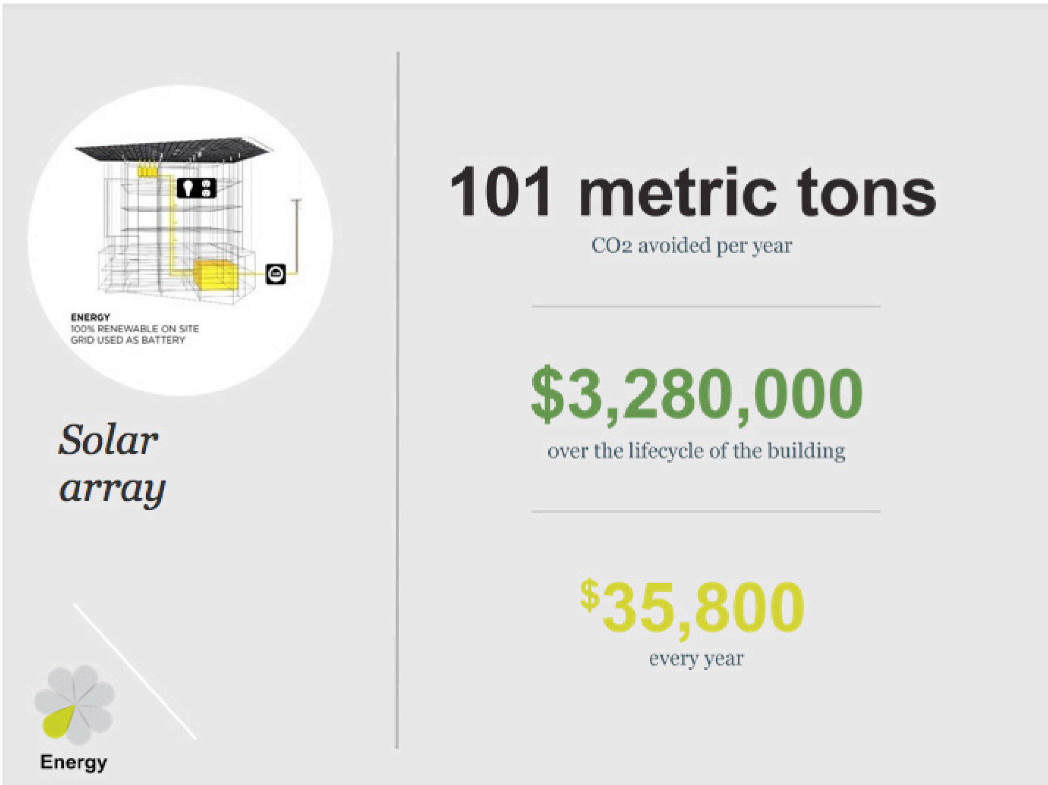
Energy Efficieny Valuation

	Comments			TOTAL BENEFITS
Building Feature		Combined Energy Efficiency Features		
Ecosystem Service or Avoided Impact	The ecosystem service, or avoided ecosystem impact, produced by the feature.	Avoided Carbon Emissions	Energy Provision	
Benefit	The benefit from the service that directly accrues to humans.	Avoided Climate Change	Avoided Energy Consumption	
Baseline Impact	Impact generated by a Seattle code building (64kBTU/s.f./yr) of same size powered by natural gas.	0.00880 metric tons CO_2/s.f./yr	18.76 kWh/s.f./yr	
Feature Impact	Impact generated by Bullitt Center (16kBTU/s.f./yr performance target).	0.00234 metric tons CO_2/s.f./yr	4.69 kWh/s.f./yr	
Avoided Impact/Unit	The net impact of energy efficiency, relative to the baseline.	0.00646 metric tons CO_2/s.f./yr	14.07 kWh/s.f./yr	
Total Units/Year	Size of building	50,071 s.f.	50,071 s.f.	
Avoided Impact/Year		323.47 metric tons CO_2	704,367 kWh	
Dollar Value/Year	Assume Ackerman and Stanton price of $200/metric ton for carbon and utility power rates respectively.	$64,693	$47,333	$112,027
Present Value with 8% Discount Rate, 250-Year Time Horizon		$1,295,000	$945,000	$2,240,000
Present Value with 4% Discount Rate, 250-Year Time Horizon		$5,930,000	$4,340,000	$10,270,000

Energy Petal: Rooftop Solar Array

FIGURE 34

Solar Array



The Bullitt Center's iconic photovoltaic (PV) array is a fitting way for a building with high aspirations to meet the sky. Like the ancient Douglas fir trees that thrived here for thousands of years, it converts sunlight into the energy needed to feed its metabolism, power its systems, and serve the needs of its occupants. This array:

+ contains 575 SunPower 425 PV panels
+ has a power rating of 242 kW
+ has an area of 14,303 square feet
+ generates approximately 230,000 kW hours of energy in a year

A PV array the size of about one-and-a-half typical floors provides enough energy to heat, cool, and power all the activities on six floors. This illustration of the roof array paints a picture of the number of PVs needed for each purpose in the building.

An Urban Power Plant

The Bullitt Center is like a small urban power plant that generates as much energy for all purposes as it uses each year. The sunlight landing on the 14,303-square-foot PV array generates a flow of electrons, DC power, which is converted through twenty inverters into usable AC electricity. All of this electricity is fed into the Seattle City

Light grid to power buildings around Seattle. An energy-production meter measures how much energy is being sold to the grid.

Just like its neighbors, this building **purchases** the electricity it uses from Seattle City Light, and an ***energy-use meter*** measures how much energy is consumed. Over the course of the year, the aim is to generate as much or more energy than the building uses.

From about the spring to autumn equinoxes, the PV array will generate more energy every day than the building uses. When Seattle's utility grid is peaking each summer afternoon, this building will be contributing a surplus of electricity. During the winter half of the year the building will still be producing electricity, but it will purchase more than it sells.

A PV panel tilted to the south captures more energy than one lying flat facing the sky. However, to build an *array* of tilted panels, they have to be spaced apart to avoid shading each other. To generate the most energy per square foot of roof area, these panels are arranged side-by-side in a single plane that slopes with the site to the west-southwest. Because Seattle's summers are so much sunnier than its winters, and because the sun travels a much higher arc through the sky in the summer, the penalty is only about 10 percent from an optimally south-tilted panel.[40]

[40] This section excerpted from presentation board language about PV Panels originally written by Rob Peña.

TABLE 35

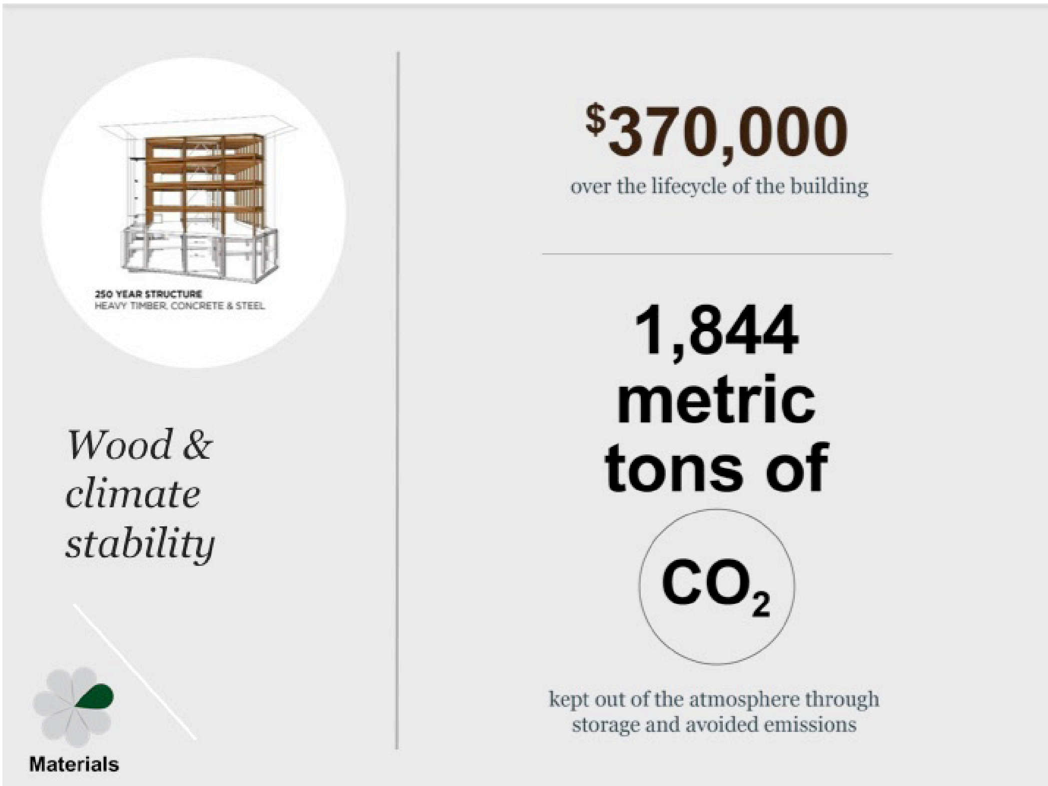
Rooftop Solar Array Valuation

	Comments			TOTAL BENEFITS
Building Feature		Solar Array		
Ecosystem Service or Avoided Ecosystem Service Impact	The ecosystem service, or avoided ecosystem impact, produced by the feature.	Avoided Carbon Emissions	Energy Provision	
Benefit	The benefit from the service that directly accrues to humans.	Avoided Climate Change	Increased Energy Supply	
Additional Quantity Provided	Electricity production from PV Panels.	N/A	230,000 kilowatt hours	
Annual Baseline Impact	Impact if energy provided by panels was provided by natural gas baseline (similar to US grid average).	107.87 metric tons CO_2	N/A	
Annual Feature Impact	Impact provided by feature based on LCA of solar panels.	6.27 metric tons CO_2	N/A	
Annual Avoided Impact/ Unit	The net impact of feature relative to baseline.	101.60 metric tons CO_2	N/A	
Annual Dollar Value of Avoided Impact/Unit	Based on Ackerman-Stanton carbon cost ($200/metric ton).	$20,320	N/A	
Dollar Value of Direct Benefit/Year	Comparable utility power rates.	N/A	$15,456	
Present Value with 8% Discount Rate, 250-Year Time Horizon		$406,000	$309,000	$720,000
Present Value with 4% discount rate, 250-year Time Horizon		$1,863,000	$1417,000	$3,280,000

Materials Petal: FSC Wood

FIGURE 36

FSC Wood



Benefits of FSC

Forests provide numerous invaluable ecosystem services. Among these services are the provision of water, food, medicines, biodiversity habitat, flood protection, recreational opportunities, and carbon sequestration and storage as described below. The forests that provided wood for the Bullitt Center were all certified by the Forest Stewardship Council (FSC). FSC's mission is to "promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests," and the organization holds the restoration and protection of ecosystem services as one of its top priorities. This is demonstrated in one of its ten Principles that make up their rules for certification. Principle 6 is "to maintain or restore the ecosystem, its biodiversity, resources and landscapes."

To describe the benefits associated with the FSC wood purchase in the Bullitt Center, it is important to note the considerable differences in forest management practices between FSC-certified forests and the industrial forests that dominate the Pacific Northwest and that produce the majority of wood purchased for building construction. Forest practice laws in both Oregon and Washington allow clear cut harvests up to 120 acres in size, while FSC certification allows a maximum average harvest size of 40 acres. FSC also requires 10-30% retention within 40-acre openings, which provides crucial habitat for birds, mammals, and amphibians that depend on large live trees, snags, and trees that have fallen to the ground. Retention outside of riparian buffers is rarely practiced on industrial lands. These laws also set the minimum standard for leaving light- and no-touch buffers around streams that are commonly followed by industrial managers. FSC buffer requirements can range up to five times larger than minimum state regulations, depending on stream type (e.g., stream size, fish-bearing, domestic water sources, etc.). Larger riparian buffers protect more habitat for a variety of species, reduce erosion by helping to prevent sediment from entering waterways, and provide shade that contributes to maintaining cool in-stream temperatures important to endangered salmon and other aquatic species. FSC forest managers must also go above and beyond the legal requirements to protect old growth forests; rare, threatened, or endangered ecosystems; and areas that provide critical ecosystem services, such as drinking water. FSC also restricts the use of chemicals and prohibits the use of certain highly hazardous pesticides and herbicides. Spraying chemicals from helicopters, including atrazine for example, is legal and a commonly used forest practice on private, industrial land in the Oregon and Washington. Atrazine is a known endocrine disruptor and is prohibited by FSC.

There is a paucity of research comparing the ecosystem service benefits of different forest practices, but a 2011 study compared various forest certification systems and found that "The Forest Stewardship Council was the best performer for ecological health and social sustainable forest management criteria."[41] While it is difficult to quantitatively describe the myriad environmental benefits that result from purchasing FSC-certified wood products instead of wood from industrially managed forests in the Pacific Northwest, this purchase can lead to cleaner air and water; more biodiversity habitat, including habitat for rare and endangered species such as the northern spotted owl and Pacific salmon; more and arguably better recreational opportunities; and enhanced scenic beauty. Quantifying some of these benefits remains an important research opportunity.

FIGURE 37

From WoodWorks Bullitt Center Case Study[42]

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

[41] Clark, M,R,. and J.S. Kozar. 2011. "Comparing sustainable forest management certification standards: a meta-analysis." Ecology and Society 16(1): 3. URL: http://www.ecologyandsociety.org/vol16/iss1/art3/

[42] From "WoodWorks Case Study WW-011: Bullitt Center." 2013. WoodWorks.

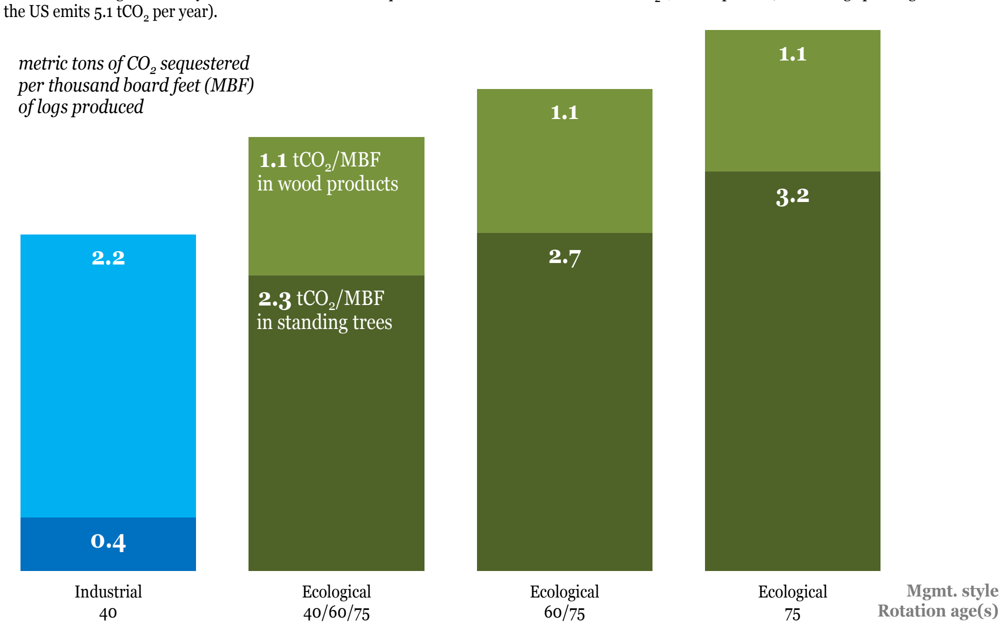
Wood products continue to store carbon absorbed by the trees while growing, keeping it out of the atmosphere indefinitely. Using wood in place of fossil fuel–intensive materials such as steel and concrete also “avoids” greenhouse gases that would have been emitted during manufacturing. Now, with the Carbon Calculator, it is possible to quantify these benefits for wood buildings.[43]

FIGURE 38

Ecological Forestry and Carbon Storage in Standing Trees vs. Timber Products

Ecological forestry not only increases carbon storage in our forests, it also shifts the balance of carbon storage from wood products to standing trees

Over the course of 100 years, a 2,700 acre working forest on the Olympic Peninsula managed with typical industrial practices would produce nearly 100 thousand board feet in logs (MBF) per acre and sequester an average of 263 metric tons of carbon dioxide (tCO_2) per acre in trees and wood products. This amounts to 2.6 tCO_2 sequestered for each MBF in logs produced. Under industrial management, most of this carbon storage is in the form of wood products. If the land is shifted instead to longer rotations and wider buffers around streams commonly used in ecological forestry, most of the carbon stored shifts to standing trees (live and dead). Every thousand board feet of logs you purchased from this property as it transitions to ecological forestry would contribute to the sequestration of an additional 0.8-1.6 tCO_2 (for comparison, the average passenger vehicle in the US emits 5.1 tCO_2 per year).



Source: David Diaz | Ecotrust

Context for Interpretation

To estimate the carbon benefit for the Bullitt Center’s sourcing of FSC wood, an FSC-certified property (Ecotrust Forests’ Sooes Forest) from the Olympic Peninsula was utilized as a case study. In general, the carbon (and other environmental benefits) associated with FSC-certified forest management are directly tied to place. That is, unique place-based aspects such as the location, forest types, and geography of the forest supplying FSC wood significantly affect the corresponding additional environmental benefit that FSC offers compared to traditional timber production following minimum regulatory requirements. For example, stream protections required within the FSC program make a major contribution to greater carbon storage on properties with

[43] From http://woodworks.org website.

lots of streams; these FSC stream requirements would have no meaningful additional carbon benefit if the property sourcing FSC-certified wood had no streams on the property. Depending on the source of the wood, it is possible that FSC certification alone would not necessarily correspond to significantly greater carbon storage; this would probably be limited to forest properties with low conservation value, no streams, small acreages that would not be affected by clearcut size limitations, etc.

Information About the Sooes Property

The Sooes Property is located on the northwestern tip of the Olympic Peninsula. This property was purchased from an industrial timber owner in 2005 and is now managed by Ecotrust Forest Management and certified under FSC. Although the property offers several unique conservation values and features, the forest composition clearly reflects a legacy of typical industrial forest management: less than 25 percent of the property has forest greater than forty years old, and only 1 percent of the property has forest greater than sixty years old. The property is dominated by western hemlock (65 percent), followed by Douglas fir (11 percent), Sitka spruce (7 percent), silver fir (7 percent), red alder (5 percent) and western red cedar (3 percent). A forest inventory conducted in 2009 covering 2,700 forested acres of the property was used as the basis for this analysis. A total of 120 acres were removed from pre-defined management units and treated as a riparian buffer zone (based on a fifty-foot buffer surrounding the no-harvest riparian "core" described further below).

Methods for Calculating the Carbon Benefit of Sourcing Wood from the Sooes Property

Similar to current approaches used for forest carbon credit accounting, carbon benefits were estimated by comparing a "business-as-usual" or baseline management scenario to an "improved forest management" scenario consistent with the property's current management plan and objectives. Both the baseline and "improved" scenarios were simulated using a forest growth-and-yield model, the Forest Vegetation Simulator (FVS). FVS was developed and is maintained by the US Forest Service. It is broadly used by the Forest Service as well as other public and private forest managers for forest management planning. FVS is also approved for use with several US standards for carbon credit certification.

Each management scenario shown in the figure above corresponds to a one hundred-year simulation applying a specific combination of management prescriptions across twenty-seven hundred acres of the Sooes property. FVS calculates a variety of metrics, including timber yields as well as carbon storage in several carbon "pools." For this analysis, the following carbon pools were considered: above-ground, live trees; below-ground, live trees; standing dead trees; and harvested wood products. Other relevant forest carbon pools that were not considered in this analysis include downed dead wood (also known as coarse woody debris), forest floor/litter, or soil carbon. FVS does not account for soil carbon. FVS can account for litter and downed wood but will not provide reliable predictions unless field-measurements for these pools are used as inputs to run the model.

In contrast to the current forest carbon protocols, this analysis includes all carbon stored in harvested wood products (most carbon protocols only consider the amount of carbon stored in 'long-lived' wood products that would be left after one hundred years following harvest, accounting for decay, disposal, etc.) The net effect of this accounting change is conservative. That is, it produces higher carbon storage estimates under the industrial style of management. The difference in carbon storage between "ecological" and "industrial" scenarios would be even larger if only "long-lived' wood products were considered.

Simulation of Forest Management Scenarios

Four different management scenarios are presented in the figure above. The "industrial" management scenario corresponds to forty-year rotations across the property, retaining four live trees per acre at final harvest and replanting with a fifty-fifty mixture of Douglas fir and western hemlock.

- The three "ecological" scenarios correspond to one or more longer rotations:
- 40/60/75—each stand in the property is randomly assigned to a 40-, 60-, or 75-year rotation
- 60/75—each forest stand on the property is randomly assigned to a 60- or 75-year rotation.
- 75—each forest stand on the property is assigned a 75-year rotation.

As the steepness of the slope for each forest stand increases, pre-commercial and commercial thinning entries are phased out, such that stands with slopes greater than 60 percent would only be subject to the final harvest at the rotation age without intermediate pre-commercial or commercial thinning entries. Under "ecological" scenarios, final harvest retains fourteen trees per acre, and re-plants with a mixture of Sitka spruce, western hemlock, Douglas fir, and western red cedar.

These management scenarios assume that all stands on the forest property are accessible and harvested within a forty to seventy-five year rotation cycle. In reality, many of these stands (especially on very steep slopes) would likely be left un-harvested if managed according to the current Sooes management plan and FSC principles. This simplification is likely to overestimate the timber yield, and underestimate the average carbon storage for the "ecological" scenarios. The net effect of excluding these non-harvested areas is conservative. That is, had more areas been left un-touched in the "ecological" scenarios, the difference in the carbon/yield metric between "industrial" and "ecological" scenarios would be even larger.

Under Washington Forest Practices regulations, harvesting within a "core" riparian zone around streams (typically fifty feet wide) is generally prohibited. All areas within this no-harvest zone for the property were assumed to be left unmanaged in all management scenarios, and excluded from further calculations. An additional fifty-foot buffer was added to this no-touch riparian "core" for application of distinct riparian harvest practices. Under the "industrial" scenario, this outer riparian buffer is harvested in a forty-year rotation, but at final harvest, a greater number of live trees are retained (twenty trees per acre). Under the "ecological" approach, this outer buffer is not harvested (i.e., it is treated as "grow only," just like the "core" riparian zone).

The Carbon/Yield Metric

The values shown in the figure above are calculated by combining two different forest metrics: cumulative timber yield and average carbon storage:

Carbon/Yield Metric = Average Carbon Storage/ Cumulative Timber Yield

The average amount of carbon stored in trees and wood products over the course of the one hundred-year modeling timeframe is divided by the total volume of timber harvested over the same period. This calculation is intended to reflect the long-term performance of each forest management style in terms of both timber yield and carbon storage.[44]

As discussed in the footnote below, this carbon per board foot yield metric is novel. It is important to consider that the value of this metric will increase if the numerator (i.e., carbon storage) increases, but also if the denominator (i.e., timber yield) decreases. The pattern observed in the figure above reflects both of these effects:

Mgmt Style Rotation Age(s)	Carbon/Yield Metric Tons CO_2/MBF logs	Average Carbon Storage (tCO_2/acre)	Change in Carbon Value	Cumulative Yield (log MBF/ acre)	Change in Yield Value
Industrial 40	2.7	263.4	--	98.9	--
Ecological 40-60-75	3.4	267.7	+1.6%	78.0	-21.2%
Ecological 60-75	3.8	277.4	+5.3%	72.7	-26.5%
Ecological 75	4.3	278.1	+5.6%	65.0	-34.3%

[44] To our knowledge, the direct combination of timber yields and carbon storage into a single metric is not common practice. In general, timber yields and carbon storage values are reported separately. However, it would not be possible to directly estimate the carbon benefits of procuring FSC wood without somehow being able to translate a specific volume of wood products purchased into a corresponding average amount of carbon stored for that forest.

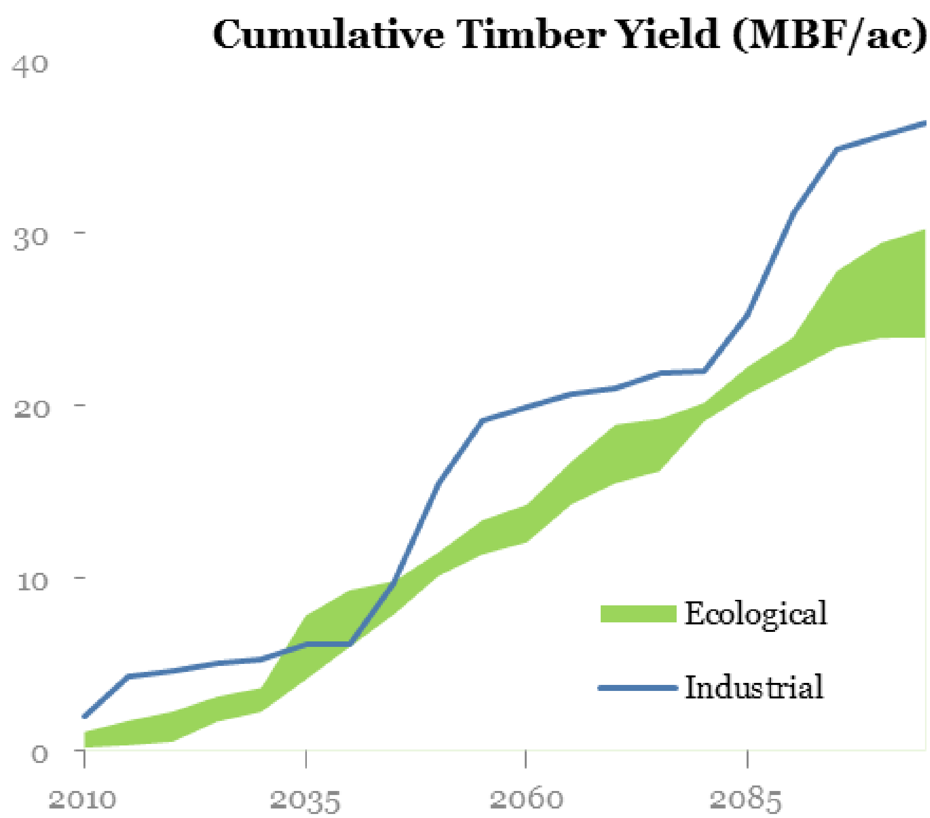
Interpreting the Changes Underlying the Carbon/Yield Metric

In general, the ecological forestry approach leaves more carbon standing in the form of trees. This is due both to longer rotations as well as greater retention of live trees at final harvest. For this property, these practices are also likely to reduce the yield of timber over one hundred years compared to the industrial management scenario.

Over the course of one hundred years, the "ecological" scenarios store more carbon per unit of wood production. This corresponds to 0.8 to 1.6 metric tons of CO_2 stored in trees and wood products for each thousand board feet in logs. The carbon benefit associated with purchasing FSC-certified wood from this property could be calculated by dividing the volume of lumber purchased (in thousands of board feet) by 2.5 to convert to the volume of MBF in logs, then multiply by 0.8 to get the low end of the carbon savings range, or by 1.6 to get the high end of the carbon savings range. Although both log numbers are measured in boardfeet, the measured amount of lumber produced can often be 2–3 times larger than the estimated log volume. This is commonly referred to as 'overrun' in the forest products industry, and is driven by the differences between how volumes are measured and estimated in logs compared to finished lumber. A middle-of-the-road estimate of 2.5 MBF lumber per 1.0 MBF logs is used in this report.

FIGURE 39

Cumulative Timber Yield



Additional Detail Behind One Hundred-Year Averages and Totals

Boiling down one hundred years of forest growth and management to single metrics can often obscure a lot of dynamic changes in the forest. The graphs below are intended to offer a glimpse behind these long-term totals and averages. To make these graphs easier to read, the "industrial" scenario is shown as one blue line, and a green cloud is used to show the maximum and minimum range observed in the "ecological" scenarios.

In the approach to carbon accounting used by all modern carbon standards, a one hundred-year or other long-term average is used to report the carbon stored by a particular forest management strategy. In reality, forest carbon storage fluctuates over time. Even-aged rotations, such as the forty-, sixty-, and seventy-five-year rotations used in this analysis, will often produce a "bumpy" carbon trajectory, as shown in the graphs below. The one hundred-year average is intended to approximate the long-term value of how much carbon is stored for that particular scenario, essentially smoothing out the bumpiness caused by rotations on properties where most of the forests are in similar age classes. The one hundred-year average for carbon storage in trees and wood products are reported in the table above. In addition to the "industrial" and "ecological" scenarios, a "grow only" scenario is also shown to indicate the maximum carbon storage potential for the forests on the property.

FIGURE 40

Carbon, Trees and Products

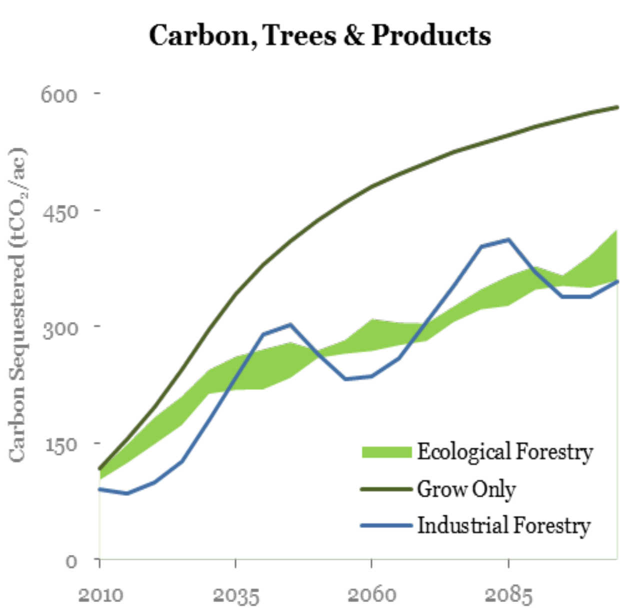
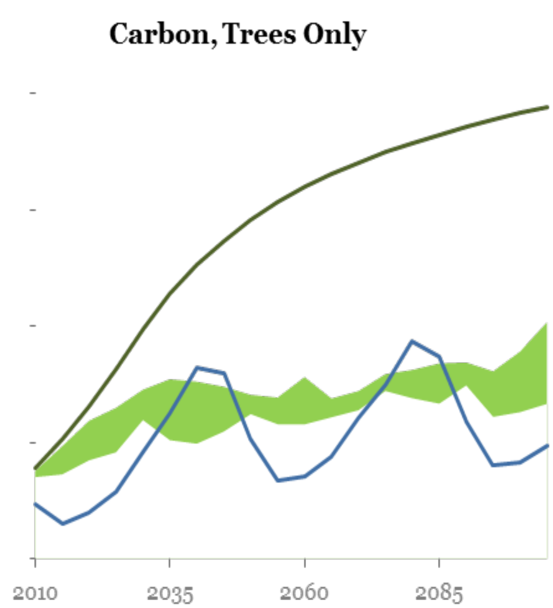


FIGURE 41

Carbon, Trees Only



FSC-Certified Wood Products Usage in the Bullitt Center

This section summarizes and describes the lessons learned in procuring FSC wood for the Bullitt Center and draws heavily from an interview with Matheus Lumber in Woodinville, Washington, a company that served as the wood broker for the Bullitt Center.

Allow for plenty of lead time.

Lee Zulch at Schuchart, the project's general contractor, created a quantity survey of the FSC material he would need and provided it to the FSC wood-broker six months in advance of when the job needed the product. This was very beneficial for the FSC wood-broker, who usually has six weeks or less lead-time. The typical lead-time would not have worked for such a large quantity of FSC material. The FSC wood-broker informed the FSC-certified mills, and they helped arrange their production schedule for processing this volume of material. The FSC wood-broker also informed the glulam manufacturers to give them the same lead-time to integrate this large FSC order into their production schedule. This careful planning with plenty of lead-time eliminates the "panic."

Be prepared to pay more for FSC wood than non-FSC wood.

The Bullitt Foundation spent a little more money per board foot to use FSC wood. Matheus Lumber was very forthcoming with the incremental cost of using FSC-certified wood products, and the company understood what the project team goals were for the Living Building Challenge and the need for a 250-year lifecycle design. Matheus Lumber created transparency in the FSC wood procurement process and was clear in communicating the higher price for FSC wood.

FSC wood is generally more expensive than non-FSC wood because of the inefficiencies in the distribution system. The extra expense does not go to FSC landowners for producing FSC logs, but is spent on additional handling costs, such as longer hauling costs. Trucks can drive by five lumber mills on their way to pick up FSC wood. Wood markets can fluctuate dramatically and local mills and builders were hit hard during the nation's recent economic recession. An FSC Chain of Custody (COC) certification can add time and money to projects. It can also help access new markets for COC certificate holders.

FSC lumber can be challenging to find, particularly for small projects.

In addition to the slightly higher cost for FSC lumber, it is not readily available at most lumberyards. The limited and uncoordinated supply of FSC logs increases the challenges for mills to consistently stock FSC products and reduces the mills' incentives to get and maintain certified.

Full units or trucks are cost effective for shipping. The quantities specified by architects are often very small, and the transportation costs are exorbitant to transport small truckloads. For example, an architect might specify sixteen pieces of fire-treated ACX FSC, but transporting one plywood unit by truck is prohibitively expensive for most projects. FSC lumber orders need a certain quantity to make them cost effective for mills to process FSC products.

FSC-Certified Wood Products Usage in the Bullitt Center

Key Features of Petal	Induce a successful materials economy that is non-toxic, transparent, and socially equitable. The LBC envisions a future where all materials in the built environment are replenishable and have no negative impact on human and ecosystem health. The precautionary principle guides all materials decisions.
Key Features of Imperative	Advocate for the creation and adoption of third-party-certified standards for sustainable resource extraction and fair labor practices, including for stone and rock, metal, minerals, and timber. Mandatory FSC-certified timber.
Building Feature	Wooden beams, desks, chairs
Pathway	FSC Certification
Ecosystem Services Provided	Materials Provisioning, Climate Regulation, Air Quality, Water Regulation, Shade and Shelter, Soil Formation/Retention, Soil Health, Nutrient Cycling, Biodiversity, Habitat, Aesthetic, Spiritual, Recreation, Scientific/Educational
ES Type/s	Provisioning, Regulating, Supporting, Cultural
Valuation Methods	Hedonic Pricing, Travel Cost, Production Function
Valuation Methods Narrative	FSC certification ensures sustainable, ecological forest management including selective cutting, protection of riparian buffers, and preservation of biodiversity. The ecosystem services generated by FSC-certified forests can be measured via the production function method. The production function method would model the impact of FSC-style forestry on the generation of key ecosystem services such as biodiversity, water provision, soil formation, nutrient cycling, and biomass production, in comparison to a baseline such as SFI or the timber industry standard. Dollar values for each of these forest ecosystem services would be estimated. The contribution of FSC management to the preservation of these ecosystem services would determine the dollar value of the ecosystem services attributable to FSC management. Essentially, by choosing a baseline, this method would be a hybrid between production function and avoided cost; it would be measuring the avoided ecosystem impact of FSC relative to the less-sustainable forest management alternative. Evaluating FSC relative to a “do-nothing” forest preservation alternative might not produce meaningful results. The impact of FSC wood on human well-being could be measured by hedonic pricing: How much more are building tenants willing to pay to rent an office in a building with FSC wood relative to a baseline?

TABLE 42

FSC Wood Valuation

	Description				TOTAL BENEFITS
Building Feature		Sustainably Sourced (FSC) Wood			
Ecosystem Service or Avoided Impact	The ecosystem service, or avoided ecosystem impact, produced by the feature.	Carbon Sequestration (Carbon stored in building's wood products)	Carbon Sequestration (Carbon standing in FSC forests induced by purchase of building's wood products)	Avoided Carbon Emissions (From avoiding use of more carbon intensive materials like steel and concrete through use of wood)	
Benefit	The benefit from the service that directly accrues to humans.	Avoided Climate Change	Avoided Climate Change	Avoided Climate Change	
Avoided Impact	Decrease in atmospheric CO_2 from carbon storage and avoided carbon emissions.	545 metric tons CO_2 sequestered (From WoodWorks study)	141 metric tons sequestered (from Ecotrust carbon study, 294 MBF lumber in Bullitt Center = 117 MBF logs x median 1.2 tCO_2 additional carbon stored for FSC vs. industrial)	1,158 metric tons CO_2 emission avoided (from WoodWorks study)	1,844 metric tons CO_2
Total Dollar Value	Based on Ackerman and Stanton carbon price of $200/metric ton	$109,000	$28,224	$231,600	$370,000
Present Value with 8% Discount Rate, 250-Year Time Horizon	The dollar value is a one-time event at completion of construction, not an ongoing annual stream.	$109,000	$28,224	$231,600	$370,000
Present Value with 4% Discount Rate, 250-Year Time Horizon		$109,000	$28,224	$231,600	$370,000

Materials Petal: Red List and Precautionary Principle

It is noteworthy that with the Living Building Challenge, green building in the United States has entered the realm of the Precautionary Principle. The Red List LBC imperative is intended to exclude the most harmful families of synthetic materials and heavy metals from buildings.

"The *precautionary principle* or precautionary approach states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking an action. The principle is used by policy makers to justify discretionary decisions in situations where there is the possibility of harm from taking a particular course or making a certain decision when extensive scientific knowledge on the matter is lacking. The principle implies that there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk."[45]

During the finish stage of construction, there are many subcontractors coming to a building site to paint, install carpet, hang mirrors, lay tile, varnish woodwork, and so on. It is common in this phase for many toxic products including phthalates, formaldehyde, halogenated flame retardants, and others to be utilized and for the building to have a harmful "toxic soup" indoor air quality while many of these products off gas. It is noteworthy that in the finish stage of construction of a Living Building, this does not occur due to the elimination of the Red List of toxic chemicals.

The Living Building Challenge Red List materials[46] and chemicals are shown below. This list is composed of materials that should be phased out of production due to health concerns and will be updated as new science becomes available. A building project may not contain any of the following Red List materials or chemicals. There is a small component exception for some complex products.

+ Asbestos
+ Cadmium
+ Chlorinated polyethylene and chlorosulfonated polyethlene (CSPE); HDPE and LDPE are excluded from the Red List.
+ Chlorofluorocarbons (CFCs)
+ Chloroprene (neoprene)
+ Formaldehyde (added)
+ Halogenated flame retardants
+ Hydrochlorofluorocarbons (HCFCs)
+ Lead (added)
+ Mercury
+ Petrochemical fertilizers and pesticides—for the duration of the certification period or needed for subsequent operations and maintenance
+ Phthalates
+ Polyvinyl Chloride (PVC)
+ Wood treatments containing creosote, arsenic, or pentachlorophenol

The elimination of these products is no small feat. In the case of the Bullitt Center, the developer and the general contractor vetted each material for the project and created a list of the materials by zone of the LBC (see map in Section 4.5.) They stayed three to six weeks ahead of the construction schedule and suggested in future projects to stay six months ahead of schedule. The developer believes that future LBC projects can specify between 80 to 90 percent of the architectural specifications based on the research of the Bullitt Center. Furthermore, subcontractors on the job site of the Bullitt Center noted the absence of the "toxic soup" smell during the finish stage of construction and would often comment about the different environment of a LBC project. The BCAT team did not calculate avoided costs in harmful exposure to chemicals to workers in our case study.

[45] http://en.wikipedia.org/wiki/Precautionary_principle

[46] See https://living-future.org/node/208/#red

The BCAT research team discovered that in FSC-managed forests, foresters prefer and enjoy working in these environments, and the absence of spraying of toxic herbicides and pesticides has an avoided cost for health impacts to humans and the more-than-human world. Additionally, the overall impact of the FSC-managed forest is more pleasant and creates a more positive work environment, just as a Living Building creates a positive impact on the building trades. Thus, there is an important parallel in positive impact between construction workers on Living Building projects and timber industry workers in FSC forests.

Joe David, one of the Bullitt Center project manager for Point32, describes the experience of working with the LBC like this[47]:

> **Iterative Selection and Vetting Process: The Developer's Method for obtaining the LBC Materials Petal**
>
> The learning curve was steeper than any project that I have previously worked on. The materials Red List research for the Bullitt Center was simultaneously exciting and incredibly tedious. Achieving compliance with the Red List, and all of the environmental goals inherent in the standard required a level of collaboration that I have never experienced before on a construction project. I was sitting down every day with installers and fabricators, combining knowledge of the Red List with their technical expertise to select products for use in the building. Larger coordination meetings were weekly, at a minimum. Walking through the project every other day it was important to ask, "Are there any remaining products you intend to use? We will try to vet them ASAP."

During the process, the architects began with their best LEED specification, which was distributed early on to key sub-contractors. The specification included additional language that prohibited the use of Red List materials, and defined which chemicals were prohibited from the project. There was a general understanding that the specs were to be used as a guideline. The project team recognized that there were many aspects of the material selection and compliance that would only be fully understood once the process began. We did not fully comprehend the scope of work at the beginning of the vetting process. All sub-contractors were asked to provide a product "pre-submittal" six months prior to construction, so that the products could be fully vetted.

The vetting process began with Morgan Hudson, of Schuchart Corporation, who would review product submittals, and evaluate them in terms of cost, constructability, and warranty. Once a product was deemed acceptable from a constructability perspective, it was entered into an Excel spreadsheet and sent to me each day for LBC Red List approval or disapproval. In most cases, I would review the MSDS (Material Safety Data Sheet) and cold call the manufacturer or chemist to determine what level of chemical information could be disclosed to the project team. For the LBC Materials Petal Red List certification we asked each manufacturer to confirm their product Red List compliant in writing. Some gave 100 percent disclosure. Sometimes manufacturers could not provide full disclosure, or were unwilling to share proprietary information. In these cases I would ask, "Can you meet us half way and tell us what is NOT in your product? Specifically, the Red List prohibited chemicals." Often times, we encountered products that would not meet the LBC Red List criteria, e.g., adhesive (glue substrate). In these cases, I would work with the contractor to quickly identify our next best option, and an iteration of the vetting process would begin, so that when construction came around we were ready.

Joe David also highlighted the benefits of working on a LBC project:

> The Bullitt Center provided a unique opportunity to conduct research on the toxicity of materials found in common building products. Point32 made the decision to invest the time to manage the LBC Materials Petal as part of our commitment to this project, so we budgeted the time required to meet this goal. The development

[47] Interview with Joe David of Point32.

> and construction process helped us to better understand how material selection can create a healthier built environment. Moving forward, we hope to share this knowledge with the building community at-large.
>
> The Bullitt Center website will offer a downloadable list of products used in the building, not to endorse particular products, but to share three years of research.

Materials Petal: Whole Building Lifecycle Analysis

In order to assess the overall impact of The Bullitt Center's materials use, we drew on University of Washington Assistant Professor Kate Simonen's initial work with the Athena Impact Estimator for Buildings, a Lifecycle Analysis (LCA)–based tool for assessing whole building impacts developed by the Athena Sustainable Materials Institute. According to the project site[48]:

> This whole-building tool is used by design teams to explore the environmental footprint of different material choices and core-and-shell system options. It was first released in 2002 and has undergone numerous updates since then. The Athena Impact Estimator is applicable for new construction, renovations and additions in all North American building types. It can model over 1,200 structural and envelope assembly combinations. It allows for quick and easy comparison of multiple design options.
>
> The Impact Estimator provides a cradle-to-grave lifecycle inventory profile for a whole building. The inventory results comprise the flows from and to nature: energy and raw material flows plus emissions to air, water and land.
>
> The software reports footprint data for the following environmental impact measures consistent with the US EPA TRACI methodology: global warming potential, acidification potential, human health respiratory effects potential, ozone depletion potential, smog potential, and eutrophication potential. The Impact Estimator additionally reports fossil fuel consumption.
>
> The Impact Estimator takes into account the environmental impacts of the following lifecycle stages: material manufacturing, including resource extraction and recycled content; related transportation; on-site construction; maintenance and replacement effects; and demolition and disposal. Decomposition of materials in landfill is not included.

LCA models are complex and rely on many layers of assumptions about materials extraction, manufacturing processes, transportation, building operations, and other factors. Results must be carefully calibrated and validated, and Professor Simonen's research will ultimately contrast multiple LCA models for the Bullitt Center in order to understand strengths and limitations of the LCA modeling processes.

In this section, we merely want to highlight LCA analysis as another way of understanding ecosystem services benefits of high performance green buildings. These benefits occur through the avoided impairment of a wide range of ecosystem services relative to a baseline building, as measured by a range of standard LCA outputs. These benefits would be very difficult to model across hundreds of different building materials and multiple project lifecycle stages without LCA techniques.

[48] See http://www.athenasmi.org/our-software-data/impact-estimator/

TABLE 43

Lifecycle Analysis Measures Correlated with Ecosystem Services

Lifecycle Analysis (LCA) Measure	Major Avoided Impairment to Ecosystem Services
Fossil Fuel Consumption (Millions of MJ)	Food, Water, Raw Materials, Genetic Resources, Medicinal Resources, Ornamental Resources, Climate Regulation, Moderation of Extreme Events, Regulation of Water Flows, Waste Treatment, Maintenance of Soil Fertility, Pollination, Biological Control, Maintenance of Lifecycles of Migratory Species, Maintenance of Genetic Diversity, Cultural and Amenity Services
Global Warming Potential (Metric Tons of CO_2 eq)	
Acidification Potential (Metric Tons of SO_2 eq)	Food, Water, Raw Materials, Genetic Resources, Waste Treatment, Maintenance of Soil Fertility, Maintenance of Genetic Diversity
Human Health Particulate (kg $PM_{2.5}$ eq)	Air Quality Regulation
Eutrophication Potential (kg N eq)	Food, Water, Waste Treatment, Maintenance of Soil Fertility, Maintenance of Genetic Diversity
Ozone Depletion Potential (kg CFC-11 eq)	Food, Climate Regulation, Maintenance of Genetic Diversity
Smog Potential (Metric Tons of O_3 eq)	Air Quality Regulation, Aesthetic Information

The following tables show a preliminary analysis of the Bullitt Center by Professor Simonen's research team. They were generated by applying the Athena Impact Estimator for Buildings to Bullitt Center building characteristics over a 250-year lifecycle horizon. These results are only estimates as they reflect many limits of specifying exact material properties, transportation distances, etc. To emphasize the preliminary nature of these estimates, impacts are reported as percentages only. More definitive results will be obtained by using multiple LCA programs and refining the analysis accordingly.

In Table 44 below, LCA measures are summarized by building assembly groups (foundations, walls, columns and beams, roofs, floors, and additional materials). In Table 45, LCA measures are summarized by lifecycle stages (products, construction process, use, end of life.) Each row shows the contribution of these building assembly groups or lifecycle stages to a particular LCA measure, with cells contributing 10 to 50 percent colored orange, and cells contributing over 50 percent in red. Combined with Table 43, this provides a qualitative picture of the degree to which different building assembly groups and different lifecycle stages affect a range of ecosystem services.

TABLE 44

Summary LCA Measure Table By Assembly Groups

Summary Measures	Foundations	Walls	Columns and Beams	Roofs	Floors	Extra Basic Materials	Total
Fossil Fuel Consumption (millions of MJ)	1%	64%	2%	6%	3%	24%	100%
Global Warming Potential (metric tons of CO_2 eq)	1%	61%	2%	3%	3%	30%	100%
Acidification Potential (metric tons SO_2 eq)	1%	63%	2%	2%	4%	29%	100%
HH Particulate (kg $PM_{2.5}$ eq)	1%	40%	3%	19%	5%	32%	100%
Eutrophication Potential (kg N eq)	‹1%	50%	‹1%	43%	1%	6%	100%
Ozone Depletion Potential (kg CFC-11 eq)	NEGLIGIBLE (TOTAL OF ‹‹ 1kg)						
Smog Potential (metric tons O_3 eq)	1%	49%	2%	2%	4%	41%	100%

TABLE 45

Summary LCA Measure Table By Lifecycle Stage

Summary Measures	PRODUCT	CONSTRUCTION PROCESS	USE	END OF LIFE	TOTAL EFFECTS
Fossil Fuel Consumption (millions of MJ)	35%	6%	53%	6%	100%
Global Warming Potential (metric tons CO_2 eq)	46%	6%	48%	<1%	100%
Acidification Potential (metric tons SO_2 eq)	35%	8%	50%	7%	100%
HH Particulate (kg $PM_{2.5}$ eq)	52%	3%	44%	1%	100%
Eutrophication Potential (kg N eq)	5%	2%	91%	2%	100%
Ozone Depletion Potential (kg CFC-11 eq)	NEGLIGIBLE (TOTAL OF << 1kg)				
Smog Potential (metric tons O_3 eq)	31%	17%	36%	16%	100%

Health, Equity, and Beauty Petals

These petals are most closely associated with the category of Cultural and Amenity ecosystem services. These services (Aesthetic Information, or Beauty; Opportunities for Recreation and Tourism; Inspiration for Culture, Art, and Design; Spiritual Experience; and Information for Cognitive Development) will take a few years to begin to evaluate fully, and will likely be assessed qualitatively rather than quantitatively, with economic valuations speculative at best. Ongoing post-occupancy assessment of the Bullitt Center should include a variety of research methods to characterize these cultural ecosystem services, including surveys, visitor activity analysis, interviews, and investigation of artistic, cultural, and "induced innovation" responses to the building.

Health

While social- and health-related benefits of the Bullitt Center were beyond the scope of this case study, they are significant and worthy of additional research. A good starting point is the large research literature on the subject of worker productivity gains, health benefits, comfort, satisfaction, well-being, and other social benefits associated with high performance green buildings and biophilic design.

Buildings have an enormous impact on the health and vitality of their occupants. For instance, a 1984 World Health Organization report suggested that up to 30 percent of buildings worldwide may be the subject of excessive complaints regarding Indoor Air Quality. The term "Sick Building Syndrome" has been coined to describe situations in which building occupants experience acute health and comfort impacts that appear to be linked to time spent in a building, but where no specific illness or cause can be identified.[49]

A comprehensive review of the literature cites studies with these findings[50]:

- Window views reduce Sick Building Syndrome by over 20 percent
- Natural ventilation reduces Sick Building Syndrome by 15 percent; doctor visits by 15 percent; and headaches and colds by 30 percent
- Indoor plants reduce Sick Building Syndrome by over 20 percent

Absenteeism due to allergies or asthma dropped by as much as 50 percent, while the amount of time participants felt the effects of allergies or asthma declined by up to 60 percent. Absenteeism due to depression and/or stress dropped by up to 30 percent.[51]

Worker Productivity Gains

Buildings also have a significant impact on worker productivity. Workers experiencing greater health, vitality, alertness, and connection to natural views are able to work more effectively than workers in conventional buildings. Studies have found the following productivity gains[52]:

- Daylighting, 0.5 percent to 40 percent
- Window views, 7 percent
- Natural ventilation, 0.4 percent to 3.2 percent
- Operable windows, 7.5 percent
- Mixed-mode conditioning, 10 percent to 18 percent
- Indoor plants, 0.6 percent

One way to think about the monetary value of the worker productivity benefit is to estimate the salaries of

[49] Adapted from URL: www.epa.gov/iaq/pubs/sbs.html.

[50] Loftness, Vivian and Megan Snyder. 2008. "Where Windows Become Doors." *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life.* editors Stephen R. Kellert, Judith H. Heerwagen, and Martin L. Mador. Hoboken, New Jersey: John Wiley & Sons.

[51] Amanjeet Singh et al. 2010. "Effects of Green Buildings on Employee Health and Productivity." American Journal of Public Health. 100(9): 1665-8.

[52] Loftness, Vivian and Megan Snyder. 2008. "Where Windows Become Doors." Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. editors Stephen R. Kellert, Judith H. Heerwagen, and Martin L. Mador, Hoboken. New Jersey: John Wiley & Sons. For additional worker productivity studies see http://blog.vista-films.com/2013/02/green-building-productivity/.

tenants in the Bullitt Center and multiply by the worker productivity increase relative to a conventional office building. This is one measure of the additional value created by these workers. Most of the value will accrue to the tenant community (tenants and their employers), while some of the value might be realized in the form of increased rents over time. However, this is tangible benefit (integrated value) created by the building. A similar calculation can be done for reductions in absenteeism.

Assume 130 tenants

Assume average salary of $75,000 (this is a rough estimate)

Annual payroll associated with building = 130 x $75,000 = $9,750,000

Value of 1 percent increase in worker productivity, per year = $97,500

Value of 5 percent increase in worker productivity, per year = $487,500

This 5 percent increase is quite conservative based on the research below

Value over 250 years at 5 percent discount rate = $9,750,000

This preliminary calculation shows that worker productivity benefits alone are of a similar order of magnitude as the environmental benefits from the Bullitt Center, consistent with recent research on other high performance green buildings.

Comfort, Satisfaction, and Well-Being

Many building factors contribute to occupant perceptions of comfort (e.g., thermal comfort, appropriate lighting); satisfaction; and overall well-being. A recent, large-scale study of sixteen buildings in England identified several features consistently associated with overall levels of satisfaction[53]:

+ Shallower plan forms and depths of space (buildings and rooms that are long and narrow)
+ Thermal mass
+ Stable and comfortable temperature conditions
+ Operable windows
+ Views out
+ Usable controls and interfaces
+ Places to go at break time
+ A well-informed and responsive building management.

[53] Adrian Leaman and Bill Bordass. March-April 2001. "Assessing Building Performance in Use 5", BR&I 29(2), 144-157.

05 *Synergies with Economics of Change Project*

Background[54]

The built environment accounts for roughly 50 percent of US carbon emissions and contributes to a web of significant, interconnected environmental and social problems. Over the past decade, the green building movement has incubated a critical mass of professionals capable of designing and delivering buildings that dramatically reduce or eliminate greenhouse gas emissions while also creating enduring ecological and social value. However, current lending approaches, appraisal protocols, and valuation models largely fail to account for ecological and social value creation, distorting the market and slowing innovation and green building market growth.

In order to transcend these barriers, the *Economics of Change* project was established in 2011 as an interdisciplinary market transformation project under the leadership of the International Living Future Institute. By integrating practical knowledge of the real estate market with expertise in sustainable design, complex systems analysis, and ecological economics, a diverse team of experts has been pooled together with the ability to support a catalytic shift in both theory and practice within the real estate investment sector. *Economics of Change* has defined a theory of change for the real estate industry that includes three closely linked initiatives:

+ Local, state, and national policy innovation to provide incentives for high-performance green buildings.
+ *Integrated Valuation Tool™* development to inform a new generation of appraisal and valuation models that account for ecological and social value creation.
+ Industry transformation through new standards, protocols, and processes around appraisals, valuation, lending, and investment.

Implications of Bullitt Center Case Study for Economics of Change

The *Economics of Change* continues to build out frameworks and protocols for measuring and valuing both environmental and social benefits of buildings and infrastructure. The difficult question of how best to include ecosystem services in this analysis remains a point of ongoing research and industry consultation. The Bullitt Center Case Study has been shared with all *Economics of Change* principal researchers and will inform the evolution of this project, providing an invaluable building level case study, a detailed classification of ecosystem services at the building scale, new approaches to ecosystem services measurement, and fresh perspectives on a range of methodological issues.

While ecosystem services valuation was only a secondary emphasis of this case study, the results in Section 4.6 appear to confirm one of the primary hypotheses of the *Economics of Change*: the total ecological and social value created by high performance building (including public and tenant value, not just that value accruing directly to the project owners) can often justify investment in Net Zero Energy and Living Building Challenge buildings.

[54] This section is adapted with permission from Wright Chappell, Theddi, Stuart Cowan, Richard Graves, and Jason Twill. 2013. The *Economics of Change: Integrated Valuation Tool™ Development. Seattle: International Living Future Institute.*

Approach

At the core of the *Economics of Change* is the development of the *Integrated Valuation Tool.*™ The key deliverable is an open-source, real estate investment, modeling software platform that is compatible with current industry standard platforms such as ARGUS® and Excel, yet will enable investors—for the first time—to tap into new value streams for the built environment beyond conventional methods. The tool will embed a wide range of identified avoided externality risks as well as make transparent new ecological and social value layers presently unrecognized using industry standard methods.

The core elements of this work will consider how the five forms of capital (human, social, built, natural, and financial)[55] may be directly woven into an investment model to both expand and challenge the current definition of value within the real estate industry.

Key Benefits

The Integrated Valuation Tool™ will help shift the market toward restorative new construction and deep green retrofits in three distinct ways:

+ In the hands of private investors, the tool will demonstrate potential added income (from positive externalities) or losses (from negative externalities) that may occur in the medium to long-term through changes in policy, tenant preferences, etc., allowing owners to systematically evaluate risks, liabilities, and upsides. This will influence and shift decision making toward outcomes that benefit both investors and the public.
+ In the hands of policy makers, the tool will serve as a catalyst to support *integrated policy measures* that will shepherd an era of full spectrum, true-cost, lifecycle accounting for buildings, communities, cities, and regions. This will give new opportunities for the world's cities and towns to evolve in more socially and ecologically beneficial ways.
+ In the hands of public and private project developers, the tool will provide a transparent and credible accounting of neighborhood, city, and regional-scale benefits that can be used as the basis for negotiating public-private partnerships (PPPs) and mission-related investments.

The Economics of Change project has developed a comprehensive framework for understanding the combined economic (market), social, human, and ecological value creation in buildings, districts, and infrastructure.[56] The project has introduced a critical new valuation concept:

Integrated Value = Market Value + Net Externalities

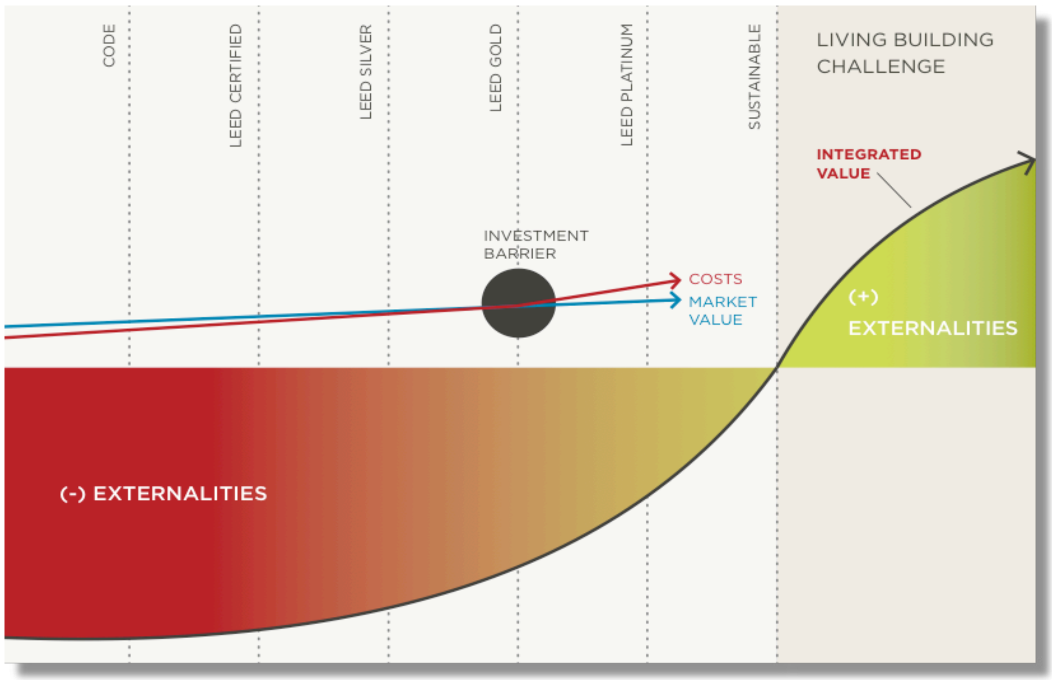
This concept serves as a bridge between existing valuation (and appraisal) models that by definition focus on current market value and more comprehensive, twenty-first century valuation models that explicitly account for the economic value of positive (and negative) ecological and social impacts resulting from buildings and infrastructure.

[55] See http://www.forumforthefuture.org/project/five-capitals/overview.

[56] See Twill, Jason, David Batker, Stuart Cowan, and Theddi Wright Chappel. 2011. The Economics of Change: Catalyzing the Investment Shift Toward a Restorative Built Environment. Tacoma, WA: Earth Economics.

FIGURE 46

Shifting Investment Toward Living Buildings Using Integrated Value



As our built environment moves along the sustainable design spectrum from code minimum standards toward "less bad" outcomes, more and more negative externalities are mitigated or avoided. By merging improved design processes with appropriate technologies we can even begin to transcend the "neutral impact" sustainable threshold, as demonstrated in the image above, to restorative standards by generating positive externalities. This is a point along the spectrum where the environmental and social impacts of our buildings and infrastructure shift from a *net negative burden* borne solely by the public to a *net positive benefit* that can be largely enjoyed by the public while also offering enhanced, multiple-bottom-line returns for owners and investors.

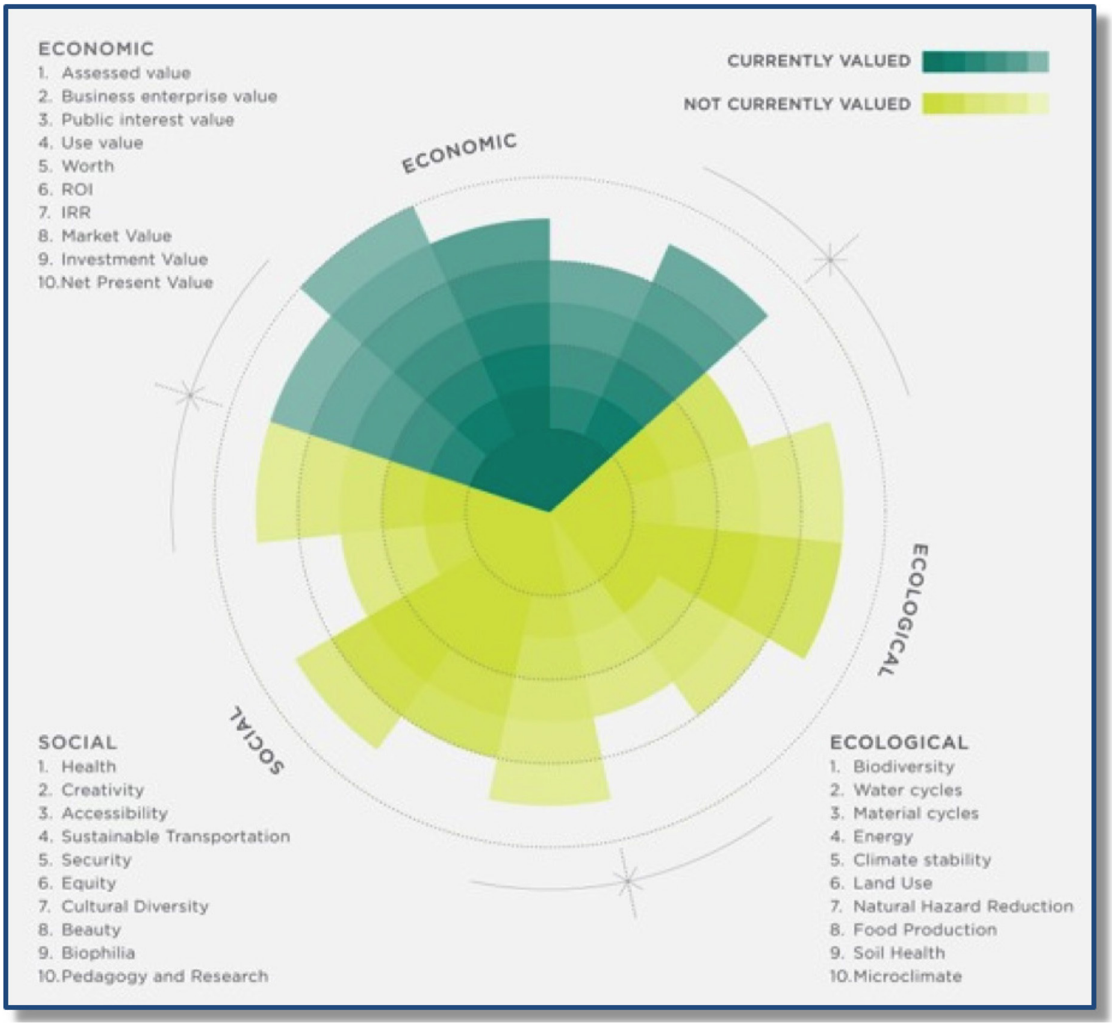
Currently, within the United States, our research suggests that an investment barrier exists around LEED™ Gold/ Platinum thresholds. We attribute this barrier to the "market value/cost horizon," the point at which costs incurred to achieve more sustainable outcomes are no longer justified through increased market value recognition.

The framework developed by the *Economics of Change* project offers a pathway to transcend this investment barrier and *support a wholesale investment shift toward more restorative outcomes* in our built environments. However, the framework will only be effective when fully supported by rigorous underlying valuation algorithms and data sets.

Economics of Change has created a comprehensive taxonomy of ecological and social benefits (and costs) of the built environment. Some of these are shown schematically in Figure 47 below as a sample "dashboard" of key project indicators that could be displayed by the software tool.

FIGURE 47

Sample "Dashboard" of Integrated Value



Standard templates will be used to describe, qualitatively and quantitatively, the attributes of green building features such as vegetative roofs, natural ventilation, enhanced air quality, and human health through elimination of toxins, etc. in order to derive an assessment of ecological and social benefits (and costs) for a given building or infrastructure project in a specified location. Appropriate methods from the field of ecological economics will then be used to determine a range of equivalent economic values, taking into account demographic, climatic, and other site-specific factors as well as inherent uncertainties in the modeling process. These valuation algorithms will include:

+ *Hedonic pricing* (statistical modeling based on a sample set of existing buildings to determine the relative contribution to building market value of specific factors like proximity to open space or fresh food)
+ *Market price–based* approaches when there are existing markets for benefits
+ *Cost-based approaches* that estimate the cost to provide a benefit stream (e.g., occupant health and well-being) using other methods
+ *Production function-based approaches, contingent valuation, choice modeling, group valuation,* and other widely accepted methods
+ *Benefit transfer* techniques to extrapolate values from one geography to another

06 *Next Steps*

NEXT STEPS

This case study has demonstrated that it is possible to apply a rigorous and consistent ecosystem services lens to specific buildings, and to the built environment more broadly. It has also sought to delineate where the ecosystem services perspective can inspire architects, planners, and engineers with a vision of fusing buildings and nature; and where existing ecological design frameworks and approaches can supplement ecosystem services.

It is our hope that this work can be extended in a variety of research and policy directions over the next few years.

Some of our recommended next steps include:

1. Undertake a comprehensive valuation and assessment of social and environmental benefits and costs of the Bullitt Center with accounting of amounts accruing to the general public vs. tenants vs. developer.
2. Share this case study widely and encourage replication on other buildings and EcoDistricts.
3. Work on communication strategies with the architecture, engineering, planning, landscape architecture, and allied communities to create a dialogue between ecosystem services and other design terminologies and frameworks.
4. Use the Bullitt Center as a lens to support the development of more comprehensive ways of linking together ecology and economics (ecosystem services) and design (ecological design, regenerative design, biomimicry) into a larger, more comprehensive approach (e.g., "regenerative economics").
5. Develop extensions to ecosystem services modeling tools so they can operate effectively with natural, hybrid natural-technical (ecologically engineered), and technical (engineered) systems.
6. Develop policy and market transformation initiatives that can provide better visibility into the FSC supply chain (e.g., woodlot → mill → distributor → building); offer opportunities to link orders to reduce shipping costs; support regional level coordination between general contractors preparing to order wood and FSC suppliers on a seasonal cycle; and integrate more flexible wood product dimensions that can allow FSC wood to be used in highly durable applications.
7. Conduct more detailed carbon storage and related ecosystem services (water, biodiversity, etc.) calculations that are tied to the specific forests where FSC wood is procured.
8. Formally submit this case study to the International Living Future Institute to initiate dialogue on how best to incorporate ecosystem services in Version 3.0 of the Living Building Challenge.

Appendix 01

Workshop 1 Outcomes—Seattle, June 11, 2013

Design Tools for Optimizing Urban Ecosystem Services

June 11, 2013—Bullitt Foundation, Bullitt Center, Seattle, Washington

Bullitt Center—Internalize external costs that are not usually accounted for.

Kathryn Langstaff—Autopoiesis LLC, ecological designer, trying to understand ecosystem services within living systems framework.

Abby Hook—Tulalip Tribes, hydrologist, conservation planner, fighting development until recently, trying to connect these ideas to the watershed scale.

Kevin Halsey—Parametrix, how can ecosystem services be applied to decision making processes?

Deb Guenther—Partner at Mithun, architects, landscape architects, planners, Board of Landscape Architecture Foundation, series on landscape performance case studies—economics, ecosystem services; SITES rating tool—based on ecosystem services, modeled after LLED, US Green Building Council.

Tom Knittlel—HOK, twenty-five offices, Janine Benyus—Biomimicry 3.8 strategic partnership, early collaboration between biologist, ecologists, and architects, landscape is an extension of biome, building is extension of landscape, need ecological performance standards—genius of biome report—hok.com/biome.

Noah Enelow—Ecotrust, economist, studied development economics, also interested in ecological economics—ecosystem services as a way to guide decision making in the context of economic development.

Amanda Sturgeon—VP for Living Building Challenge for International Living Future Institute (ILFI), see how some of this work can play into the round of LBC standard development.

Jennifer Barnes—architect, sustainability consultant, Biomimicry Puget Sound, Urban Greenprint project—long-term goal is for Seattle to function like a very healthy ecosystem with an engaged citizenry—using biomimicry as a guide.

Alexandra Ramsden—Biomimicry Puget Sound, sustainability director at Rushing—MEP engineering and sustainability consulting, how can this translate into the developer world, e.g., multi-family housing.

Vivek Shandas—faculty member at Portland State University, thinking about ecosystem services, training the next generation leaders in this field, got National Science Foundation grant to train thirty PhD students in ecosystem services—spending 2013 on a book project.

Neelima Shah—program officer at Bullitt Foundation—looking around and seeing grantees and projects, manages Urban Ecology, reinventing cities so they function like nature—EcoDistricts—finding barriers to green development policy.

Clark Brockman—SERA Architects, architect working on Oregon Sustainability Center, steering committee for EcoDistricts, former board member of ILFI, working on scale bigger than building—different systems at different scales, opportunity to work with Google.

Rob Peña—faculty member in architecture at University of Washington (UW)—taught at UO, San Luis Obispo—have UW Integrated Design Lab, will provide unbiased research on building.

Stuart Cowan—Autopoiesis LLC, interested in modeling production of ecosystem services within a building.

KEVIN HALSEY PRESENTATION

What is the "envelope" of tradeoffs that you are optimizing?

What are the boundary conditions? You can easily get the edges of the watershed.

What does efficiency mean in this context? Allows greater intensity of use or population support.

There are economies of scale for different systems—efficiency can be used to enhance quality of life or ecosystem services at a given density.

ILFI—did study looking at optimal scale of infrastructure systems

Multiple meanings of efficiency

Tradeoff categories—who is the audience?, values of community, goals of community

Function at a building, EcoDistrict, city, or ecoregion scale

Biomimicry is one way to think about that intermediate scale.

Creating a parallel dashboard at a larger scale

Areas—connection to the landscape that provisioning services originally provided, sense of place, cultural component

What are the boundary conditions?

Most cities are post-industrial and in transition? Ecotones as boundaries, overlapping boundaries—degree of perforation or permeability

Industrial zones are a mix of new green technologies and ecosystem services.

Boundaries between levels of scale are human system.

Functional productivity

Threats to increased density—danger of disease

Removes pathogens, reduce eutrophication, recycling of nutrients on landscapes

Water availability—influences technology choices, loss of infiltration capacity

Resource generation and air quality

SITES—go online and look

ESRI—possible software partner

Sustainable sites.org

Danielle at the Wildflower center + ASLA + US Botanical Garden

ASLA—Deb was on committee

Landscape Architecture—research agenda for the field

Biomimicry Puget Sound—identify pilot projects

Carbon, water, biodiversity—map a variety of projects city wide

Biomimicry Conference next week

Bullitt Foundation—supporting EcoDistricts organization in Portland, three years ago

Seattle 2030 District

UBC—Living Neighborhood, Living Campus, what can they learn from their Living Building for a regenerative approach to the campus

Coordinate with Capitol Hill EcoDistrict

Apply living building model to affordable housing

JUST—new ILFI program to measure social equity

Yessler Terrace (Seattle Housing Authority)—affordable housing—could be an equity driven, living systems project

Coalition for a Livable Future—was considering Second Story for Equity Atlas

Go to Wieden & Kennedy

Wieden & Kennedy—worked on "We Build Green Cities"

BRENT DAVIES—WHAT DATA DO WE HAVE? WHAT IS MISSING?

There's probably not as much data as we would like, and it's probably not as widespread as we would like . . .

How do we deal with these limitations? Want it to be as useful as possible, as real as possible, high quality, transparent data, "righteous data"

Most valuable data you can zoom in and get more detail

Tool "Watershed Characterization" by WA Dept. of Ecology—move beyond developed areas as "sacrifice zones"—where you could you rebuild these processes with tools like Bullitt has used

A lot of existing data has little visibility into urbanized zone

Importance—roll in the bigger context of the context

Does data tend to silo itself? Back to fragmentation

Data we want is water and energy

Aquatic Priorities—can weight different data sets—a manager can weight them differently and come up with different scenarios and approaches

A rigorous weighting process, you don't have enough information to be rigorous, need to know where your range is

Can explore different options with different options and share it online and let others view it

Genius of biome, "the temperate forest biome"

Bullitt Center—energy budgets—VALUES

Greenfire Project-Wilburforce Foundation

Including threats in the discussion

New development is restorative compared to what?

Tradeoff between urban development vs. rural development

BASELINE or BUDGET for "Sense of Place"

Open standards process—adaptive management process

Culture and spirituality—PlaceSpeak—what is your connection to place?—is it quiet, access to

Two dimensions to tool—there is a community that may present a series of values in an integrated way

Another group connecting the values framework for different community DOWN to inform the optimization process.

Canopy cover standards

Vegetation is important to health, but other vegetation has negative impact.

Are we designing for an individual home, building, neighborhood—an ecosystem is a complex array of habitats, species, and structures.

An individual design

Ecodistricts—overlay zones—housing and office buildings have opposite heat needs by time of day—can work on this with zoning overlays that optimize multiple building systems.

Are we trying to work across urban AND rural? But there needs to be a careful phasing.

With SITES, how can work it with planning

Urban Greenprint—other cities are interested—predevelopment vs. current conditions around carbon, water, and biodiversity

Ecosystem Services—nature has patch dynamics—FRACTAL—why is it structured the way that it is—heterogenous landscape, redundancy, corridors, pathways

Novel ecosystems to solve problems

Boston outlawed Norway maple because it was salt tolerant

Climate change hydrology modeling at the watershed scale

WORKSHOP 1 OUTCOMES—SEATTLE, JUNE 11, 2013

Change the watershed to mimic future hydrological changes with climate change

Studio 360 advisory board—science & technology

Rockefeller Foundation—supporting urban ecosystem services

Pilot project + tool together—building practices and research agenda

Organized gathering at Packard Foundation in January—ecosystem services plus some emphasis on urban ecosystem services

Amy Solomon—on the board of the Funder's Network of Smart Growth and Livable Communities

Workshop Notes

What are the boundary conditions?

When designing new or existing you have to define . . . as applied to only one variable

Functional productivity = output per unit input

- nutrient cycling

- multiple benefits

- economy of scale

Ecotones as mix of old to new, very diverse, what are the synergies

Cultural anthropologists and communications specialists (storytelling)

Design imagination: shift to "we are living systems"

Have a storytelling charrette

For Bullitt Center, energy trumps everything else

4-6 Floor Area Ratio (FAR) worldwide as limit (i.e., Parisian model)

Spatial structures of cities

Optimization → translate into a user friendly interface in the realm of human values

Design tool with flexibility

Ecosystem services—range of values

Data—hard to translate to hybrid solutions

SITES TOOL TEMPLATE is coming online and landscape architects and planners are adopting it

ESRI—GIS—open source

Build so tool's only purpose is to get you to actual performance!

Dashboard + cost

Humans are part of ecosystem services.

Cultural benefits of ecosystem services

Who's the audience?

How will the tool optimize ecosystem services based on unique values?

Engaging people and process are needed to make the "tool" useful

ILFI—materials petal—altering to include economics and bioregions

Ecosystem services as heuristic tool vs. communicative platform to inform people

Systematically tries to understand connections

Is there a way to personalize the tool on the dashboard?

Different systems optimize at different scales

Identify systems you have agency over

Reverse engineering

WORKSHOP 1 OUTCOMES—SEATTLE, JUNE 11, 2013

Can you use ecosystem services to solve the gap?

Then create a visual map

Very place-based tool

High level pre-tool: water, energy, nutrients, materials, and threats to the system

Hard to assign economic value to place

PLACE SPEAK (tool)—developed in Vancouver, Canada, should research

Similar to "Story of Place"—Regenesis/Bill Reed

TOOL: values tied to budget

Wilburforce "Green Fire" project

Biomimicry Puget Sound

Delta—predevelopment & Today (novel ecosystems)

Carbon sequestration, water flows, biodiversity

GOAL: Identifying pilot projects

ECODISTRICT—Bullitt Center has three-year involvement

Portland—five pilots

Seattle 2030 District

UBC

Capitol Hill EcoDistrict—Affordable Housing, social equity

GAP: COST

Seattle Housing Authority project—Yesler Terrace

Want to make "tool" user friendly and useful in our media world

Possibly engage Second Story (based in Portland) in project storytelling

"We Build Green Cities" (Portland) is a relevant campaign created with significant pro bono assistance from Wieden + Kennedy (Portland)

2.5X or more carbon sequestration with FSC wood vs. conventional forestry

Thought experiment—OPTIMAL SCALES (Brock Dolman)

TOOL: Watershed Characterization

Currently urban areas are written off as degraded; shift to levels of "importance"

Where is the potential to rebuild existing tools

SILO: Is the nature of data collection silos or can it be interconnected? Such as water and energy

WEIGHTING PROCESS: RANGE; make it RIGOROUS; iterative + feedback; save scenarios and make it transparent

RE-USE: Embodied energy of existing buildings (see ILFI study)

Framing: What are the threats of densification?

Pathogen management, water collection, nitrate reduction, nutrient transfer/cycling

Biomimicry 3.8—provisioning, regulating, enriching ecosystem services

What do we need to measure?

Morphology

Carbon assessment tools—decades long to become useful

Difficult to quantify Lifecycle Analysis (LCA) because of supply chains

At least a two-part tool:

Link cultural values as identified

How to identify cultural values—create a framework

THEN design to production functions of ecosystem services

Maybe it is more of an INDEX

Gather values: stakeholder engagement

Can we create a TOOL that shares benefits across scales and entities?

(recharge: discharge in a shared way, NOT a single design)

College campus early adopters, i.e., zoning for relationships and shared functions

Look at a natural system and identify—why is it structured the way it is?

(i.e., fire grazing, wind throw—tree: nutrient cycles)

Redundancy, corridors, pathways

Workshop Notes

Blog Post Idea:

- What discount rate will be appropriate for a project that builds natural capital??

Premise: Projects assume a discount rate equal to the rate of return on investment in an alternative project. However, in the case of natural capital this doesn't make sense . . .

Purpose: To analyze the Bullitt Center in an intellectually rigorous way

Ecosystem Services in the Built Environment

* internalize external costs that most buildings impose on the world *

Katy Langstaff—working in finance for rural areas—how can we create sustainable jobs in rural areas

Brent—conservation and econ dev in PNW—there is unrealized potential in urban areas

Stuart—valuation; ES as a design tool

Steve—natural green infrastructure—extends from pocket parks to issues of regional planning/regional governance/open space networks/working lands

Abby Hook—self-employed consultant—hydrologist and conservation planning—spent many years fighting development—now thinking about finding common space between tribal, economic and conservation interests—interest in scaling up

Kevin—ES in urban context

Deb Guenther—Mithune—landscape architecture foundation board member—performance series on landscape performance in urban and rural environment—case studies to generate economic metrics/performance metrics. Partnerships, grants with universities to pair faculty and graduate students

Tom Knittel—HOK—twenty-five offices—based in Seattle, working in LA—joined in 2007 with strategic partnership with Janine Benyus et al—what happens when you collab ecologists with architects—biome --> landscape --> building. Buildings should perform at level of landscape. Report available on website.

hok.com/biome

Amanda Sturgeon—Living Future Institute. How can this work play into the current LBC work with Jason McLennan, etc.?

Jennifer Barnes—architect, sustainability consultant, cofounder of Biomim PS. Urban Greenprint. Seek Seattle functioning like a healthy ecosystem.

Alexandra Ramsden—Biomimicry Sustainability Director at Rushing (engineering firm) —how does this work translate into developer world, e.g., multifamily housing, high rise, etc.?

Vivek Shandas—PSU—thinking about ES as part of national project, training next gen of leaders thinking about this. NSF grant to train thirty PhD students in thinking about ES in urban regions—these folks will be interested in a platform where they can contribute. These projects are perfect. Also working on book project thinking about urban ES

Neelima—Program Officer at Bullitt—manages Urban Ecology program—reinventing cities so that they function like healthy ecosystem. Economics of Change (Stuart) e.g., appraisal, real estate practices; EcoDistricts; policy organizations, issues from a variety of angles

Clark Brockman—SERA—architect—was working on the Oregon Sustainability Center—steering committee for EcoDistricts work in PDX. Former board member for ILFI. Big idea—working on the scale bigger than a building. ”Recovering architect”—now thinking about watersheds.

”Uncertainty”/”Resilience”

Rob Pena—Dept of Architecture, UW—career divided between teaching and practicing architecture —Eco Design institute (Van der Rhyn)—Integrated Design Lab—Urban Ecology Partnership—Level 1 Education and Outreach—building platform to provide world with unbiased information about this bldg

Tom De Luca—soil microbiology, nutrient cycling; forest systems; U of Montana; Wilderness Society; now U of W; aiming to promote and catalyze sustainability in PNW and beyond

name

company

field—originally, development economics. However, become increasingly interested in ecological economics generally and in particular ecosystem services as a way to guide environmental decision making. Interest in the bound

2. Kevin

FRAMEWORK for URBAN ES:

Attributes --> Functions --> Services --> Values

Breaking down the natural/built dichotomy

Integration of natural and built environment to generate urban ecosystem services

E.g., bioswales, community gardens, rain gardens, ecoroofs, open space/parks, wetlands

Cobenefits ------ functional efficiency (productivity) spectrum

Community resilience associated with functional redundancy; vulnerability associated with “one pipe”

Human health associated with a well-ordered mix of natural and manufactured benefits

(forests; vaccines; sunlight; sanitation facilities; clean water; computers)

SW—There are tradeoffs among ecosystem services as well as between ES and built environment.

VS—seeking an “envelope” of potential tradeoffs. What metrics might be most meaningful?

KH—example: cultural aspects of ecosystem services

CB—What are the boundary conditions? What is maximum spatial scale? What do you mean by efficient?

AS—how efficient are centralized systems? Recent LCA shows that they are not more efficient?

TK—ecotones—overlapping boundaries—most vibrant places are ecotones

TD—identify the real concerns of densification (i.e., the objective function)

*****

BRAINSTORM

- Think about functional systems first.

Example: Estimate the volume of water captured by the building’s rainwater harvesting system; the volume that is filtered for drinking; the volume that is filtered through the ecoroof and ends up back in the soil

- Link attributes of the building to functions.

Example: Rainwater capture system; filtration system and cistern; ecoroof

- Identify services from the functions.

Example: drinking water; water filtration; water storage

TFP: output per factor input denominated in currency units

Does a wetland have higher TFP than a treatment plant?

It depends on what is counted as an "output." If water filtration is the only output, then the treatment plant probably has higher TFP. If nutrient management, cycling, species diversity, biomass production are the outputs, then the wetland probably has higher TFP.

Design Tool: MODULARITY

Example: Water Systems. Identify the pieces/subsystems of water systems that make differential use of natural vs. built. Ecoroofs; cisterns; filtration systems; composting toilets. Collect data on the inputs and outputs associated with each system/subsystem.

SCALE LINKAGES

Building Module

District Module

City Module

Region Module

Complication: the "adding-up" problem. A district is not just an additive collection of buildings; there are complementarities and substitutions. There are Pareto improvements and zero-sum effects. There are tradeoffs: open space vs. commercial space, for example. Et cetera.

Optimization: usually means maximization of an objective function subject to one or more constraints.

- What is the objective function? How are cobenefits included? Prioritization of objectives? Rank ordering? Weighting system?

- How to design the user interface so that people are doing this without having to do the heavy lifting?

- What are the constraints?

Unit: output per input; e.g., water filtered per unit of input

Scaling function: as the size of the system increases, how does the function increase?

Start with the number of people and the size of the area

Identify the objectives for the area: residence for x, x amount of office space, x amount of open space

Alternative: Define the area. Load up the data for the area: what exists, what is nearby, etc. Percent trees, percent open space.

1. Do you want to remove whatever currently exists?

2. Identify the parameters

- Desired density

- Human use function/s (office, industry, commercial, residential)

- Energy, water, food production, species diversity

- Social, cultural benefits/values

***

3. Stuart—Design Tools for Optimizing Urban Ecosystem Services

Ecological Performance Standard

Goal 2100—four stories—Paris!! Noted in Christopher Alexander—Pattern Language

NS—Optimizing based on what?

TK—Biomim 3.8 EPS—Provisioning, Regulating and Enriching. Enriching are all of the social benefits. Designing a living building in India. Regulating phase became very important. Example—water regulation, erosion prevention in an area with drought and monsoon. Morphological concerns—how do plants perform this function? Mostly we don't know how the ecological system works.

DG—Green Building calculators already exist and we can aggregate them together

TK—ESRI—GIS open source work. Everyone needs access to the data.

What are we measuring—what are the units? —Range of values

AS—Regional materials sourcing

VS—To what extent can this tool be good for communicating the concept of ES?

CB—Importance of narrative—enlist cultural anthropologists, communications experts

DG—Transect planning tool is about separating city and nature

***

4. Brent

Partners Projects

TK—EPS, Biomim 3.8

SC—Econ of Change

JB, AR —Urban Greenprint: CO_2, water flows, biodiversity. Research on pre-dev levels in Greater Seattle—identify pilot projects that will bring Seattle closer to pre-dev ES levels

NS—EcoDistricts in PDX, Seattle. Support (former) PoSI. Working with UBC to take the idea to a "Living Campus" idea. Capitol Hill EcoDistrict. EDs need an anchor institution and someone leading the work. Affordable housing org, Capitol Hill Housing, playing that role. How do we apply the ED concept to affordable housing/equity? "Just" program at ILFI. Trying to measure social equity.

Wieden and Kennedy "We Build Green Cities" (for PoSI) new branding mechanism for PDX to aggregate all of the sustainable urbanism projects/initiatives—the PDX brand has a lot of cachet, as does the PNW brand as well. People in Boston are watching this place. SERA is getting international contracts through the PDX brand.

Benefits of moving to FSC—2.5 times carbon benefit (Brent et al—ask for ref)

Aquatic Prioritization Tool

Conservation Priorities

THE DATA QUESTION: the output is as good as the data that goes in

What is the data for urban ES design projects?

Puget Sound data - protect/restore/preserve/develop: Watershed Characterization

Weighting system --> priorities

CB: Energy, water and waste optimize at a scale bigger than a building.

Trying to draw lines around a district. But then there was always one system whose boundaries did not reflect these lines. Next approach: identify the center of gravity for a given area and then figure out what the right scale is to plan the different systems. "Spaghetti diagram."

Potable water system optimizes at a totally different scale than a wastewater treatment system.

Bayesian belief networks

Abby—Coquitlam project—hard to assign a budget for "sense of place"—using an adaptive management framework—asking them to identify their goals—one goal is culture/spirituality—hard to come up with indicators—trying to identify connection to place—PlaceSpeak tool—(similar tool: Story of Place)—how do you put a budget on these intangibles?

Vivek—Two-way road

Community values, i.e., what's important --> Services to Humans <-- Ecosystem Functions

EUI—Energy Use Index

CB—Zoning overlays. Example: residential peak energy and water is evening/early morning. Office and classroom peak energy/water is midday. Residence and office can share resources through reuse/recycling systems.

Appendix 02

Workshop 2 Outcomes—Portland, Oregon, September 19, 2013

Meeting Notes: Design Tools for Optimizing Urban Ecosystem Services

Thursday, September 19, 2013—Billy Frank Conference Room, 2nd Floor
Jean Vollum Natural Capital Center, 721 NW Ninth Avenue, Portland, Oregon

12:00-1:00 pm Informal lunch

1:00-1:10 pm Welcome: Brent Davies, Ecotrust

1:10-1:30 pm Participant Introductions

1:30-3:10 pm Context Framing Presentations

1. Bullitt Center Ecosystem Services Overview (Stuart Cowan & Katy Langstaff, Autopoiesis LLC)
2. Ecosystem Services Software Tools (Kevin Halsey, EcoMetrix Solutions Group)
3. Ecosystem Services Valuation Techniques Supporting Design Tools (Noah Enelow, Ecotrust)
4. Decision Support Tools (Brent Davies & Mike Mertens, Ecotrust)
5. Bullitt Center Water Petal, Living Building Challenge Case Study (Mark Buehrer, 2020 Engineering)
6. Storytelling Strategies in Data-Rich Contexts (Andrew DeVigal and Daniel Meyers, Second Story)

3:10-3:20 pm Break

3:20-4:20 pm Topic-Based Working Groups using World Café Facilitation (Katy Langstaff, Autopoiesis LLC)

4:20-4:45 pm Plenary Discussion on Findings

4:45-5:00 pm Next Steps & Adjourn

Final Participant List

Jennifer	Allen	Portland State University
David	Barmon	Fiddlehead Landscapes
Katie	Bohren	Biohabitats
Mark	Buehrer	2020 Engineering
Bobby	Cochran	Willamette Partnership
Stuart	Cowan	Autopoiesis LLC
Caitlin Pope	Daum	Fiddlehead Landscapes
Brent	Davies	Ecotrust
Andrew	DeVigal	Second Story
Noah	Enelow	Ecotrust
Megan	Gibb	Metro
Erin	Goodling	Portland State University
Jamaal	Green	Portland State University
Deb	Guenther	Mithun
Kevin	Halsey	EcoMetrix Solutions Group
Nathan	Kadish	Ecotrust
Jason	King	Herrera
Jim	Labbe	Audubon
Katy	Langstaff	Autopoiesis LLC
Mike	Mertens	Ecotrust
Daniel	Meyers	Second Story
Pete	Muñoz	Biohabitats
Rob	Peña	UW Architecture Dept.
Tom	Puttman	Puttman Infrastructure
Nick	Schreiner	Biohabitats
Maggie	Skenderian	Bureau of Environmental Services
Tim	Smith	SERA Architects
Henry	Stevens	Bureau of Environmental Services
Larry	Wallack	OHSU Fellow
Steve	Whitney	Bullitt Foundation
Collen	Wolfe	PLACE

WORLD CAFÉ TABLE 1

How to not dumb it down!?

EcoDistrict + “Meyers Briggs” personality test—INTP becomes Energy/Water/Materials/Food

Each project has its own individuality -> collection of personalities complement each other

How do these fit together?

Wide perspective -> context -> visualize the whole city

Superhero -> inspire others

Emulate traits

Complexity

Multi-dimensional -> multiple personality? Tradeoffs determine personality

Tool or the building

Storytelling is about character -> building is a character? Personality place-based

Until one day . . . event/resilience

Multiple layers—limited amount of data for each project—open-source—allow for evolution

WORLD CAFÉ TABLE 2

Ecosystem services is a terrible name

Common sense explanation

Keep it simple

Importance of metaphor to understanding

Values vs. value important distinction

First establish community

The building as a symbol of a movement (motivating factor for large-scale change)

Equity: start where the people are

Shared core values

Co-creation is about forming the story (data is framed by story)

Cultural aspects

With some languages, one word means a lot

Fairness—how are benefits distributed?

What kind of contribution do you want to make with this project?

“A day in the life of . . .”

What is a metaphor that we can use to engage people into a discussion about shared values?

Sacred Economics—Charles Eisenstein—challenge status quo

Living Building will not pencil in current system, maybe it will pencil into a larger story about a different economics

The Righteous Mind—Jonathan Haidt— “elephant and rider” metaphor—we later justify where our instincts tell us we want to go anyway

Language of community vs. language of individual

WORLD CAFÉ TABLE 3

What is the payback time? Why?

What do you care about?

What do you value?

How do you express value? Money? Happiness? Health?

Who is our audience? Delivery vehicle: web, tours

What is the "perfect" outcome?

Audit the pitfalls of a utopian vision for the future

Competition—Mayors in Ten Cities! Bloomberg (NYC), Emmanuel (Chicago)

Is project going to measure connections to human well-being and health?

Audience:

- Users of building
- Community (out to scale of city)
- Global
- Phased 1st industry (encourages replication)
- 2nd wider audience (encourage policy change)

WORLD CAFÉ TABLE 4

The challenge is not design and construction, it is financing, policy, etc., need more than one example

Inputs—disconnected from the grid and watershed

The story + the data underneath = The Package delivered to audience

What is the "this" that is replicated?

"Target 100" project Integrated Design Lab

"Get on the phone with a story to tell"—analytical template . . . serve different users

Audience—how do different audiences view this?

Ten Key People—local governments, high profile mayors

Connect with Rockefeller on green infrastructure

Boundaries of measurement? . . . construction, operation

"What's the payback on this project?" To whom?

Desired end state? -> Replication? How will replicators emerge? Provoke questions? Set the bar higher? Further economic delta?

Measuring aesthetic/spiritual value? Should we try to do this?

Focus audience for analysis on ten "leader" cities (Rockefeller Cities Fund)

Narrative <-> Analysis

WORLD CAFÉ TABLE 5

Analyze things that support policy, regulatory, political change

Could this happen in Houston or LA?

Different audiences

Can you make a broader shift?

What is the context for the building?

How do you convince people they need it before they want it?

Building didn't excite me to "live differently"

What attributes do we build out in project? Full range of environmental/social benefits that meet communities' needs

How to engage the customer?

As a one-off building, means nothing

How is the building a catalyst for an EcoDistrict? For neighborhood?

In 250 years what is the value?

How do we change discussion around terms of investing?

Building started as illegal! Next time it won't be

Will people engage with building in a new way?

Does this pencil? Wrong metaphor?

What are political strategies to replicate?

Visitor Center engages people differently?

Energy story!

Closing Comments

Ten Mayors or Ten Public Works Directors

What level of rigor? 1 or 1.0 or 1.00 or 1.000?

Qualitative vs. Quantitative

Need cost figures on the order of $500,000 +/- $100,000 (+/- 20 percent)

Modeling layers add uncertainty

The story!

Who are the Ten Mayors? Or Public Works Directors?

Who is around the mayors and agency leads?

Stable city with visionary thinking

Create pull from market

Here's a way to meet policy goals

Accelerates sustainability

Venn diagram: Public + Private + Civic = Speak to all!

Aesthetic/spiritual values are potentially divisive

What are the values of the Bullitt Center?

Steve's day in the building is moving

How we use our resources defines our culture

Analysis should not be building-centric

Systems in green buildings do not optimize at building scale

Analysis and metrics should catalyze EcoDistricts not just buildings

Bullitt Center's "personality" how it fits in community

Often systems optimize at five thousand to fifteen thousand people

Data in context of shared, core values

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Even Google wants the story

Data is for "due diligence"

What kind of world do we want to live in? Connects to larger story

Core value of efficiency

One Living Buildings is just a start . . . on to whole district

Commitment to long-range transformation for Bullitt Foundation

Imagining an ideal end state

Need government to support permitting Living Buildings

End vision— Living Buildings should pencil out in a restorative economy

Policy/Values/Audience

People care about clean water and livability—see Ted Talk "The Why"

Connect with Urban Sustainability Directors Network

Policy agenda—Living Building Ordinance in other cities

Bullitt looking at a broader scale, e.g., Capital Hill EcoDistrict

Building as educational tool

Link to Interpretive Center displays—provoke discussion!

Building is part of movement

"Home Economics"—Wendell Berry

Local Change

We need to work together across sectors

NOTES—Brent Davies, Ecotrust

"There is no such thing as waste: everything is a resource. If it's a resource, we can use it." Mark Buehrer

"To engage audiences in complicated stories, remember to ask why before attempting to define how . . . How do we make people care? People will remember what they feel more often than what they know." Daniel Meyers

Listen/watch Simon Sinek's Ted Talk "The Why"

Create a metaphor. Children should understand it.

This should be a Tool of Engagement.

Inquiry around shared values.

The building itself is a tool. Which pieces of the tool lend themselves to changes in policies that need to happen to allow for many more Living Buildings?

Local government is the main lever of change in this context.

Limit the audience to ten mayors of ten cities.

What would it take to make the building an icon for a movement?

Huge importance on the rigor of the analysis, then the story.

The Righteous Mind, Jonathan Haidt. Read it.

Find the people who want to go where you want to go.

One core value that appeals to government (both Democrats and Republicans) is efficiency.

"Catalyst to change the economy, so that the building pencils out—it's not the lead in to engage new audiences. Efficiency is the lead in. This is guerilla work." Tim Smith

NOTES—Katy Langstaff, Autopoiesis LLC

INSIGHTS

Here are some observations and insights to ponder as we move forward:

1. The appropriate scale for urban ecosystem services is larger than one building.
2. Qualitative and Quantitative information are both beneficial.
3. A movement is afoot. With the Living Building Challenge Red List, the precautionary principle has now entered the building industry.
4. Many people participating in the workshop have made significant contributions to the green building movement and ecosystem services locally, regionally, and internationally.
5. There is a generational quality to "this movement or the work that we are all doing." A very moving example was Jennifer Allen, PSU Associate Professor and Director of the Institute for Sustainable Solutions, introduced herself, as funding the IGERT (Integrative Graduate Education and Research Traineeship) fellows in the room, working on sustainable forestry community in the Pacific Northwest, and signing the real estate agreement for the purchase of the Jean Vollum Natural Capital Center, the first LEED Gold Building in the United States and the first Historic LEED Gold building in 2001. Leadership in Energy and Environmental Design LEED began in 2000. Mark Buehrer, 2020 Engineering, who was the lead water systems engineer for the Bullitt Center said, "When I saw who was going to be in the room for this workshop, I decided to make the trip." Later he mentioned that his first grandchild was due any day.
6. Steve Whitney's personal account of a day in the life of an employee based in the Bullitt Center was a very compelling story.

KEY QUESTIONS

I was left wondering these things:

1. What decisions did the Bullitt Foundation make along their design journey to achieving the LBC? We learned of one significant decision: to create an ordinance for Living Buildings in King County, which could be used in other cities to further urban ecosystem services. Would it be beneficial to understand the decisions they were faced with as we consider the design of a broader decision support tool?
2. Are there some shared or core values that we can identify such as "do no harm" and "basic needs for all," or other qualitative measures of the LBC that when supported by modeling, research, and data that will support urban ecosystem services and humans?
3. Will a decision support tool be most beneficial to specific user group(s)? Within the varied range of scales available, can some scales be identified for application in specific cases to support urban ecosystem services?
4. Noah pointed out there isn't much literature on valuing ecosystem services in the built environment context. Are there new valuation approaches that could also give us some direction on ecosystem services in buildings and districts?

Future Possibilities to consider:

1. Is this the right time for a "movement"? "Do No Harm" campaign for the built environment based on the first LBC buildings coming online in the United States?
2. Is there a campaign that will garner wide support from leadership in many industries that can be applied through management of ecosystem services in urban areas? Is this the time for such a movement? Are there similar initiatives already underway that could benefit from the current research we are engaged in such as Healthcare Without Harm

http://www.noharm.org/all_regions/about/

The Children's Environmental Health Network http://www.cehn.org/about

The Science and Environmental Health Network http://www.sehn.org/precaution.html; others . . .

As an example of citywide legislation based on the precautionary principle, here is an excerpt from The Science and Environmental Health Network:

The precautionary principle, virtually unknown here six years ago, is now a U.S. phenomenon. In December 2001 the *New York Times Magazine* listed the principle as one of the most influential ideas of the year, describing the intellectual, ethical, and policy framework SEHN had developed around the principle.

In June 2003, the Board of Supervisors of the City and County of San Francisco became the first government body in the United States to make the precautionary principle the basis for all its environmental policy.

Chapter One of the Environment Code for the City and County of San Francisco states, "All officers, boards, commissions, and departments of the City shall implement the Precautionary Principle in conducting the City and County's affairs." This White Paper describes the history, intent, content, and implications of the Precautionary Principle. It explains how, by taking this step, San Francisco's leaders and citizens affirm that:

- People have a duty to take anticipatory action to prevent harm;
- Proponents of products and services bear responsibility for the safety of those products and services;
- Decision makers will examine a full range of alternatives and select alternatives with the least harmful impact on environmental health and human health;
- Decisions will be participatory, transparent, and informed by the best available science and complete product information;
- Decision makers will consider a full range of costs of products and services, including manufacturing, use, and disposal. Economic evaluations will broadly consider long-term costs and savings of environmental policies.

Appendix 03

Ongoing Related Research Initiatives

ONGOING RELATED RESEARCH INITIATIVES

The project team is grateful for conversations and research coordination with the following ongoing research initiatives also connected to the Bullitt Center:

1. Kate Simonen, University of Washington—Lifecycle Analysis of the Bullitt Center
2. Biomimicry Puget Sound—Seattle Greenprint project identifying regional-scale ecological performance metrics and biomimicry approaches
3. Rob Peña, University of Washington Integrated Design Lab—Detailed analysis of post-occupancy building performance and tenant behavior
4. Heather Burpee, University of Washington—transportation studies of the Bullitt Center
5. Mark Buehrer & Colleen Mitchell, 2020 Engineering—Bullitt Center water systems
6. Capitol Hill Ecodistrict—includes Bullitt Center as a catalytic component
7. Landscape Architecture Foundation—have developed case studies on ecosystem services benefits of landscapes
8. Economics of Change—developing new real estate investment models incorporating environment and social benefits; Bullitt Center analysis frameworks for ecosystem services will inform this project
9. Janine Benyus & Chris Allen—Biomimicry 3.8—national biomimicry organization developing a regional "Ecological Performance Standard" for urban ecosystems
10. International Living Future Institute—developed and administers Living Building Challenge; they are supportive of opportunities to better integrate LBC and ecosystem services

Appendix 04

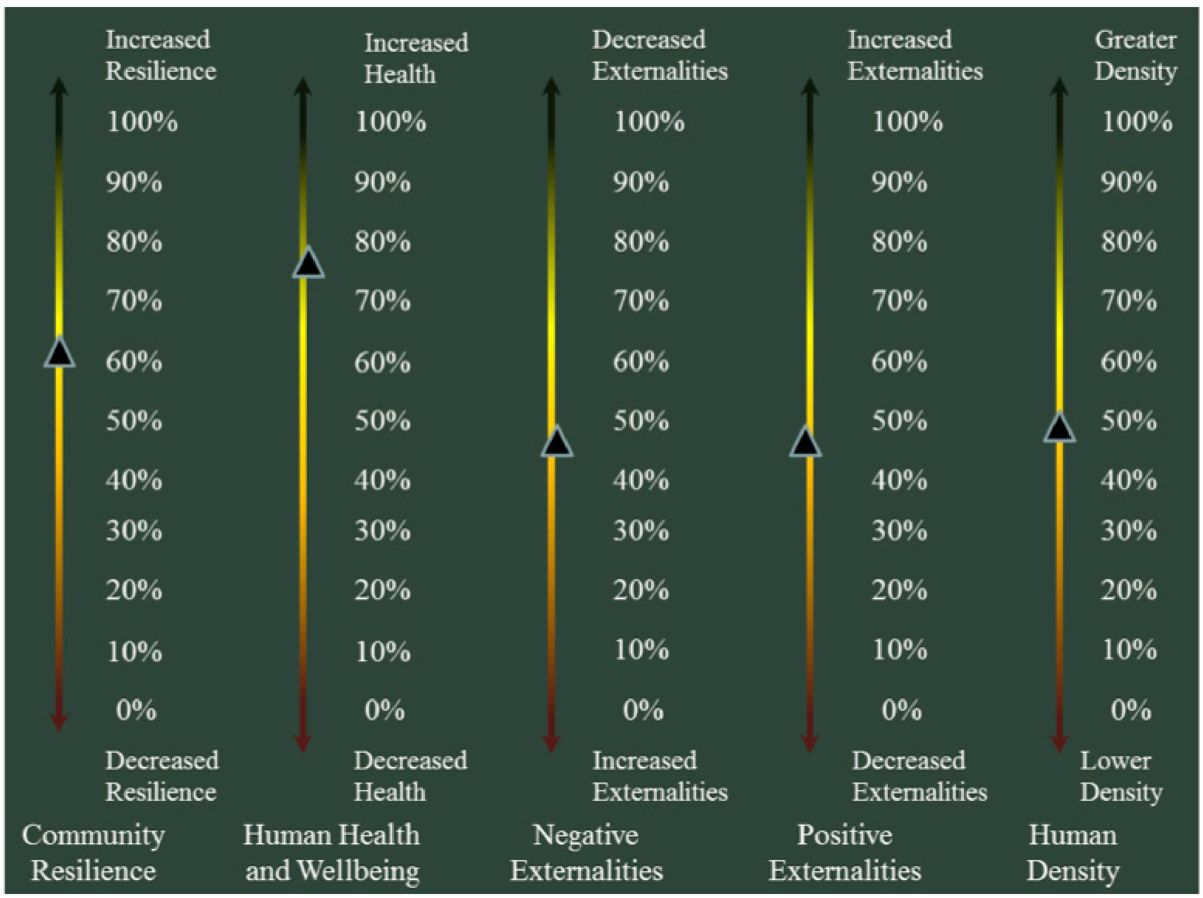
Initial Concepts for an Ecosystem Services Design and Planning Tool at the EcoDistrict Scale

As part of the Bullitt Center case study, the BCAT team developed initial concepts for an ecosystem services optimization tool that could be applied at the EcoDistrict scale. These concepts were tested during the two design charrettes, and user feedback indicated that the tool concept may be difficult to realize without a large scale, long-term software development and modeling effort. This Appendix includes an overview of these optimization tool concepts. Hopefully other initiatives will emerge to help move these concepts forward over time.

In an urban environment, we cannot eliminate hard infrastructure or the technology that allows us to live at density. However, we can and should be thinking about how we are integrating natural elements and processes with infrastructure and technology in urban areas. There are currently no standardized approaches for understanding the trade-offs associated with how ecosystem services are integrated into our built environment. Yet, to understand sustainability in the urban context these trade-offs must be clear and the consequences of the trade-offs must be part of the information upon which our planning and design decisions are made. Accordingly, we are proposing the creation of an analysis tool built around a framework with the principles expressed in Section 3 above.

FIGURE 48

Example Dashboard for Optimization Tool



The tool will be designed to help optimize across the various competing outcomes embedded within our current pursuit for sustainable development. The tool will be designed to provide a dashboard for designers and planners that will allow them to quickly and easily understand the consequences of design decisions. In particular, the tool will help designers understand when and under what circumstances, incorporation of natural attributes, or focus on ecological outcomes will improve building performance. The assumption inherent within the tool being that the closer the building is to optimal, the better it is performing. Figure 48 shows an example of the type of dashboard structure that the tool will have. At this time the specific categories that will comprise the dashboard have not been identified. The example uses the preliminary categories that emerged during the scoping research. The project team anticipates that these categories may grow or be refined through outreach and collaboration with others within the green building and ecosystem services industries.

Each of the categories provided within the dashboard will be based on a set of pre-identified indices that capture the relevant issues necessary for measuring that category. For resilience, human health, and externalities we presume there are a suite of ecosystem services that contribute to resilience, and human health, and that help inform our understanding of societal externalities. The performance scores for each of the relevant ecosystem services will provide the basis for the scoring of the main dashboard categories.

FIGURE 49

Scoring Underlying Dashboard Categories

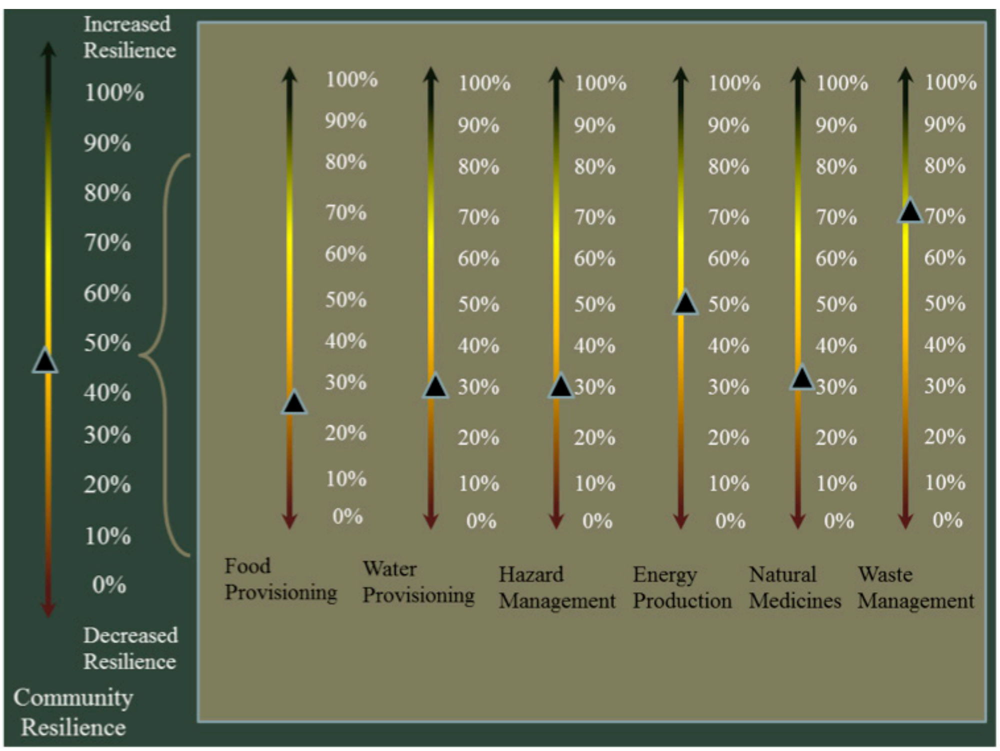
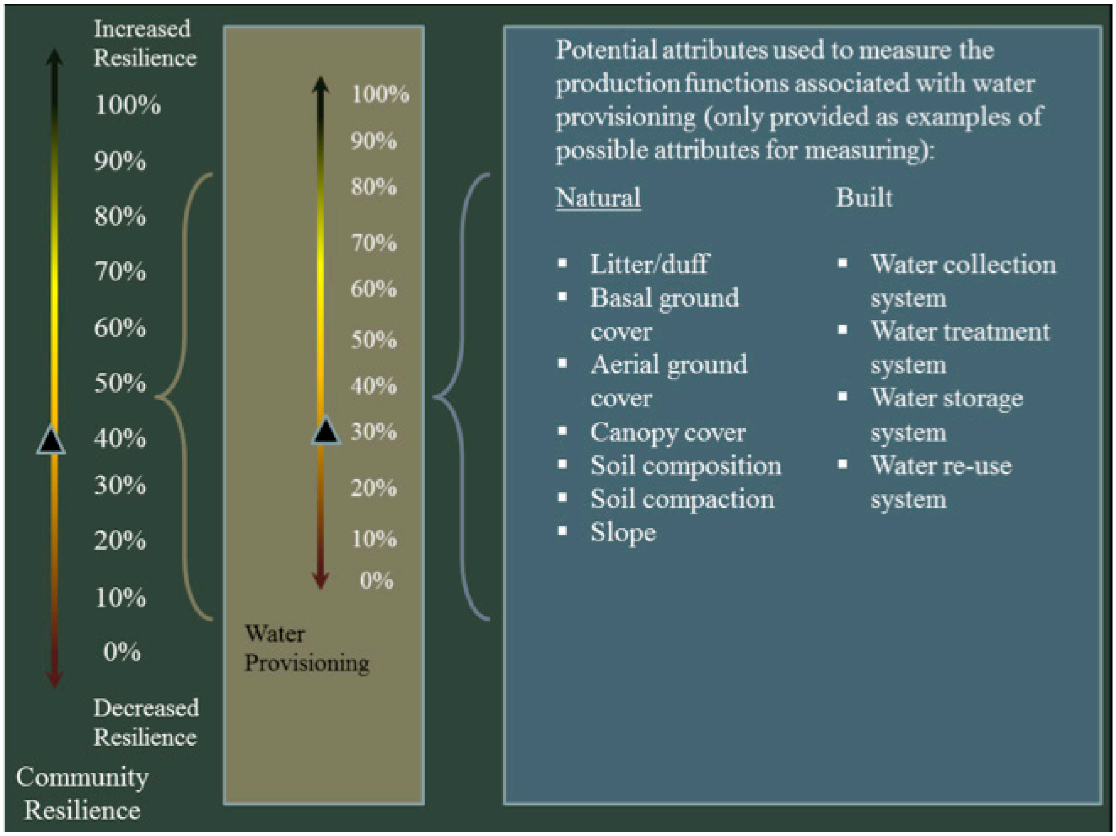


Figure 49 shows an example of the type of scoring underlying each of the main dashboard categories. This underlying analysis will itself provide a dashboard that planners and designers can use to understand the consequences of their proposals. The team's preliminary assumption is that density will be measured based on potential target ranges for particular building or land use types.

FIGURE 50

Substructure for Optimization Tool



The assumption within this stage of analysis is that as we evaluate the planning or design approach to determine where on the ecosystem services spectrum the solution lands, we will be able to identify the breadth and efficiency of functional performance. Our understanding of the levels of functional performance will come from an assessment of the actual natural or technological attributes incorporated into the plan or design. The expectation of the team is that as the scoring is developed for each of the production functions underlying these services, there will be different potentials for technological replacement of the function and service. For instance, some of the aspects of human well-being and sense of place are likely to be less replaceable. Other services, such as water provisioning may be more replaceable, but such replacement will have consequences for how well other functions are performed.

The approach of measuring services based on production functions and to measuring the production functions by assessing landscape or technology attributes shown in Figure 50 will rely on a modification of analysis approaches currently used by EcoMetrix Solutions Group (ESG) for measuring and valuing ecosystem services.[57] These analytical approaches have been tested in a variety of regions throughout the country as well as internationally.

[57] http://www.ecometrixsolutions.com/decision-support-tools.html

This approach will lead to a framework for urban ecosystem services analysis that focuses on the ecological outcomes sought, with the use of natural features to achieve these outcomes where possible. Where technology is used it should be assessed on its ability to increase density while furthering ecologically defined objectives. Within this framework urban ecosystem services would approach a building as a living organism—an aspect of the landscape that has a fully functional ecological presence. The extent to which we are able to integrate natural features will affect the extent to which the building can provide a properly functioning ecological condition. However, within this ecosystem services construct, many of the attributes of a building or project may be technological in nature, and the question is the extent to which they move the space toward greater ecological integrity throughout the relevant scales of project influence.

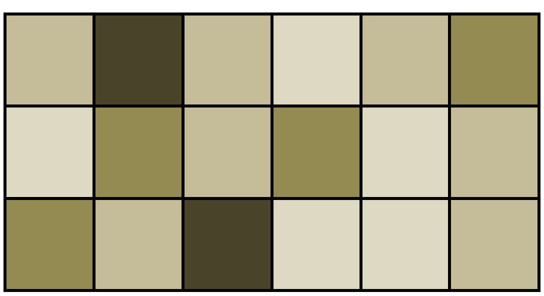
The urban ecosystem services concept would also approach the functional organism that is the living building as an integrated component of a larger organic system. Again in the urban context that larger organic system will of necessity blend natural features, hard infrastructure, and technology to achieve a properly functioning ecological condition. This integrated approach to urban ecosystem services analysis will provide important information to urban planners, architects, landscape architects, and civil engineers about how to optimize our urban areas.

The following is a spatial illustration of the premise upon which our approach is based:

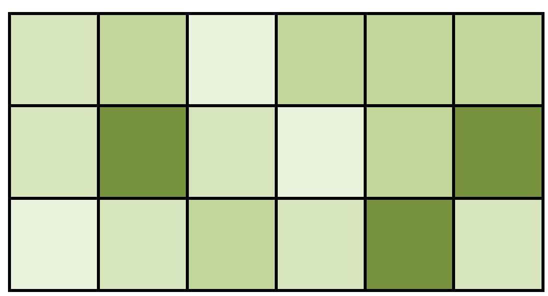
In a natural system all functions/services are spread across the landscape. The landscape's benefits range from providing clean air and clean water, to providing space for homes, stores, offices or manufacturing facilities. A landscape must provide an adequate level of service for all of these potential uses.

While a given service may be produced at a different intensity at various portions of the landscape, the conditions for production of benefits are generally spread throughout the landscape. The figure below illustrates how the landscape contributes to improving water quality, air quality, and food production and how those respective services may be spread across the landscape at varying intensities.

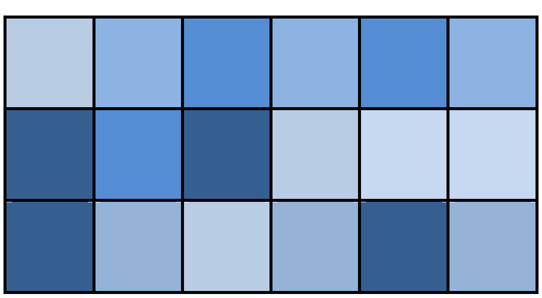
Food Production



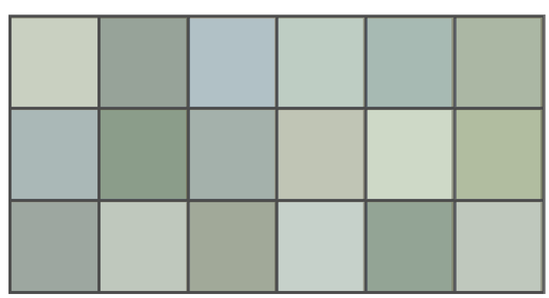
Air Quality



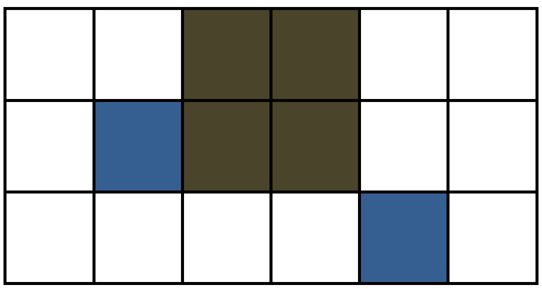
Water Quality



Synthesis of Food Production, Air Quality, and Water Quality



In contrast, an urbanized area is moving toward a landscape allocation where a given space is specifically dedicated to a particular purpose. In the example below, specific squares are dedicated as water quality treatment facilities and food production areas, while a specific air quality benefit is no longer provided by the landscape. At the extremes of this urbanization, the spaces represented by the squares will provide the benefit for which it is dedicated, but very few, if any additional benefits will be provided. In addition, the water quality and food production benefits will not be provided anywhere else on the landscape.



While the uses have been limited to specific locations on the landscape, the respective benefits are now provided at a greater level of intensity, such that all the needs of the population within the region are met. Urban landscapes vary in the extent to which uses have been segregated. While few landscapes are fully segregated for all uses, most urban landscapes include some level of segregation. In addition, in the process of replacing natural benefits like provisioning of water and air quality, many other services important to quality of life have been lost entirely from the landscape. What a tool is measuring is the extent to which integrating a more natural, or desegregated, landscape into the urban environment can improve overall performance of the landscape and return important missing ecosystem services.

In a decision support tool built to that purpose, we have identified the following necessary inputs into the analysis:

Population goal for the analysis area—We are currently planning to base this on Congress for New Urbanism standards for desired density for particular LU types. Ideally this becomes a pick list question for the user. The categories may be different, but essentially, all the user should see is a question something like the following:

- Commercial percentage
- Industrial percentage
- Residential percentage

Based on the user's selection, an appropriate population target will be selected.

Appropriate goal for job support—This will ideally capture the desired target for the number of jobs associated with the nature of the neighborhood (e.g., business/retail/manufacturing levels). Hopefully the CNU can also provide guidance for some standard numbers that can be used. Ideally the user's response to the previous question also provides the target goals for supporting a particular level of jobs an area would be expected to support.

Area—This should be a simple GIS exercise. The analysis area will need to support both the population and job level goals that are being plugged into the tool. This will set up a balancing between production of ecosystem services benefits and the job supporting benefits of business/retail/manufacturing.

Level of ecosystem service performance—The level of performance will need to be measured at the map unit (an area of relative homogeneity of characteristics and purpose), site, and neighborhood scales. The site score is derived from aggregating the total performance of all map units within the site. The neighborhood measure will likely be measured primarily using available existing GIS datasets. Ideally this measure will be set up to provide a result using only datasets that are commonly available, but the tool will have the ability to allow users to improve the quality of the analysis by adding higher quality local data-sets. The Bayes Nets that we are currently using to measure our ecosystem service measures will automatically give us the improvement in quality based on improved data.

- Food provisioning
- Waste Management
- Water Provisioning
- Clean Air
- Flood Hazard Regulation
- Energy Production
- Sense of Place (emotional/mental health; connection to nature)

ecotrust