NET ZERO AND LIVING BUILDING CHALLENGE FINANCIAL STUDY:

A COST COMPARISON REPORT FOR BUILDINGS IN THE DISTRICT OF COLUMBIA

PREPARED FOR:

DISTRICT DEPARTMENT OF THE ENVIRONMENT
green forward

SUSTAINABILITY DC

PREPARED BY:

INTERNATIONAL LIVING FUTURE INSTITUTE℠

nbi new buildings institute

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EXECUTIVE SUMMARY

The District of Columbia (the District) is a leader in green building implementation. According to the 2012 Green Building Report, the District has more green buildings than other large U.S. cities on a per capita basis.[1] While District policies have been a driver of high performance building development in the private sector, ambitious new goals will require the District to make another leap forward. To advance the industry into the next era of green design, the District of Columbia's Department of the Environment sought to understand the costs and benefits associated with net zero energy, net zero water, and Living Buildings.

The purpose of the *Net Zero and Living Building Challenge Financial Study: A Cost Comparison Report for Buildings in the District of Columbia* was twofold. First, to investigate costs, benefits and approaches necessary to improve building performance in the District of Columbia from LEED Platinum to zero energy, zero water and Living Building status. Second, to advise District government on policy drivers related to deep green buildings and to analyze the opportunities for the District to offer incentives to advance most rapidly toward zero energy, zero water and Living Buildings.

For the study, New Buildings Institute (NBI) teamed up with the International Living Future Institute (ILFI) and Skanska to conceptually transform three LEED v3 Platinum designed buildings in the District of Columbia to net zero energy, net zero water and Living Buildings. The LEED Platinum reference buildings represent three commonly developed types in the District: office new construction, multifamily new construction, and office renovation. All were either in design or recently completed, and the team benefited from recent cost estimates and detailed information about building characteristics and systems. A set of energy conservation strategies and rainwater harvesting techniques were applied to each building to arrive at reduced energy and water usage before photovoltaics ("PVs") and water reuse strategies were applied. However, incentivizing the creation of ultra-water and energy efficient buildings that provide some of their own resources puts the District of Columbia in a strong position to be a net zero water and energy city in the future, as technology advances and as solutions the neighborhood scale are developed.

Costs for getting to zero are difficult to distinguish from overall project costs. The team conducted an analysis to identify incremental cost premiums for deep energy and water conservation as well as for photovoltaic and water reuse systems that would bring a project to net zero. The cost premium for energy efficiency was approximately 1-12% depending on building type. This rose to 5-19% for net zero energy. The analysis made clear that if the owner has sufficient tax appetite, tax credits and renewable energy credits make the return on investment approximately 30%, whereas the return on investment for energy efficiency alone was in the range of 5-12%.

Achieving net zero is not only a matter of design; it requires careful attention to operations and maintenance (O&M), as well as to occupancy patterns and loads. While net zero buildings are possible with today's technologies, this research uncovered the challenge associated with achieving net zero in the large building types commonly found in the District's city center. When considered in isolation, even ultra-efficient 300,000 SF buildings may not be able to generate as much energy or collect as

1 Available at http://green.dc.gov/publication/green-building-reports

much water as they consume over the course of a year, given common rainfall patterns and today's onsite renewable energy technology.

A new policy framework is required if the building industry is to embrace net zero and Living Buildings at scale. To accelerate adoption, this research suggests the District develop a comprehensive roadmap that addresses all of the following issues over time and illustrates a clear pathway to the District's aggressive 2032 goals. The roadmap should consider these key recommendations from the study:

- **Define net zero.** Develop a clear and achievable definition of net zero in the District. In any net zero energy definition, policy makers should focus on energy efficiency and include a healthy balance of renewable energy production. Energy use and production should be verified with measured performance results.
- **Consider community-level approaches.** Boundaries that move beyond the building to multiple buildings or communities should be considered. Community approaches to energy and water (sometimes referred to as "district systems") are an effective way to address the challenges uncovered in this research. Individual buildings can benefit from economies of scale associated with community-based solutions. By connecting buildings, waste energy and water in one building can be utilized by another.
- **Encourage transition to outcome-based energy codes.** Use benchmarking and disclosure data to set outcome-based energy targets set within a scaled framework to encourage and focus designers, owners, operators and occupants toward an end result of ultra-low energy use. Future green building policies and incentives can be aligned and directly tied to this outcome-based energy target.
- **Establish new and modify existing financial incentives to encourage deep savings.** The next evolution of incentive programs should pay based on measured performance rather than predicted results. Piloting programs that utilize outcome-based targets and encourage net zero will require programs that are able to span multiple years and allow for more cost-effective measures to pay for others that may be less cost-effective. Financial incentives should focus on efficiency, since renewables already have significant incentives to benefit owners.
- **Address limitations of the grid and acknowledge the changing role of utilities.** The District should investigate technical issues associated with the capacity of the utility grid and net metering and work with local utilities to transition to a revenue model that will help to successfully integrate net zero buildings into the evolving utility system.

INTRODUCTION

The District of Columbia is a leader in green building implementation. District green building policies, specifically the Green Building Act of 2006, and a future-thinking private sector have driven increased rates of participation in the LEED building rating system. Significantly, 61% of certified projects are now either LEED gold or platinum, twice the national average. The Sustainable DC Plan has an ambitious goal to cut citywide energy use by 50% from the 2010 baseline by 2032 and increase use of renewable energy to make up 50% of the District's energy supply. Because buildings are so prominent in the District's energy use profile, steep reductions in energy use of new and existing buildings will be necessary to meet this goal.

Understanding the benefits of energy and water reduction strategies is helpful to a community and its leaders in establishing policy and incentives to support goals. Advancing net zero and Living Building policy means advancing economic development, energy leadership, ingenuity and resilience. Planning for a net zero future creates practical and achievable energy solutions for residents and economic and environmental benefits for a city itself. These benefits include: green jobs, a workforce trained in technical skills that cannot be outsourced, local economic development, energy independence, resiliency during extreme weather events, and the health and productivity of building occupants.

Understanding the costs provides the community and policy makers with insight as to what targets and incentive levels are necessary to achieve these benefits. This study investigates the anticipated cost differential between a set of three reference buildings designed to the LEED Platinum standard and those same three buildings conceptually designed for deep energy efficiency, net zero energy, net zero water and adherence to the Living Building Challenge™. The study summarizes the cost premium range for each building type, uncovers challenges associated with the large size of commercial buildings in the District of Columbia and provides policy recommendations for addressing them.

The Report is divided into three sections:

STUDY METHODOLOGY AND PROCESS

This section describes the process used by the study team to analyze the three reference building types in the District of Columbia—new construction office, new construction multifamily apartment and office renovation. Included in this section are subsections that describe the process of selecting each reference building and a description of the methodology undertaken by the International Living Future Institute, Skanska and New Buildings Institute to ascertain the building characteristics, costs and energy and water use.

BUILDING MODIFICATIONS – NET ZERO ENERGY, NET ZERO WATER AND LIVING BUILDINGS

This section includes information about each of the buildings conceptually redesigned for the study, the strategies employed and the associated costs. Summary descriptions are organized by building type, each including a one-page summary of the modifications undertaken. The analysis is separated into Energy, Water and Living Buildings. Illustrations include energy savings estimates for conservation strategies employed, calculations for the amount of PV necessary for each building to achieve net zero energy, the size of rainwater cisterns needed to achieve net zero water, and a comparison cost analysis between the reference LEED buildings and the conceptually redesigned buildings.

POLICY RECOMMENDATIONS

This section summarizes key approaches and recommendations for the District of Columbia to encourage and incentivize net zero energy, net zero water and Living Buildings.

STUDY METHODOLOGY AND PROCESS

This section describes the process used by the study team to analyze and transform the three reference buildings in the District of Columbia into net zero energy, net zero water and Living Buildings.

APPROACH TO ENERGY PERFORMANCE IMPROVEMENTS

NBI and ILFI determined the most appropriate energy efficiency and renewable energy strategies for for the buildings, while Skanska determined the anticipated premium costs for the various energy strategies employed. The work included four categories of tasks:

- Determining a starting Energy Use Intensity (EUI) in kBtu/SF/year for each building to be used as a point of comparison for evaluating building efficiency performance;
- Analyzing the building characteristics and estimating the energy profiles of the reference buildings;
- Establishing a net zero energy budget by calculating available solar energy production on site; and
- Applying Energy Conservation Measures (ECMs) and onsite renewable energy strategies to the reference buildings.

Using the best available information, the team estimated a starting energy use level and the impact of various ECMs for this order-of-magnitude analysis. The team chose not to make any significant alterations to orientation and massing on the three reference projects. Instead, ECMs focused on improving the performance of the existing design and systems to the maximum extent practicable.

While large design decisions were purposefully not altered for this analysis, one ECM did significantly alter the building aesthetic. This particular measure investigated energy and first-cost implications associated with changing from a curtain wall envelope system to one with punched openings. The performance of the envelope construction is a significant decision that impacts ongoing energy

EUI

EUI is a common measure used to normalize a building's annual energy performance as a function of its size. The EUI is expressed as units of energy, per square foot, per year (kBtu/SF/year). Generally, a low EUI signifies good energy performance. However, it is important to note that some building types are more energy intensive than others and will consistently have higher EUIs.

This analysis refers to *site* EUI as opposed to *source* EUI. Site EUI uses the energy (electric and gas) consumption as measured at the building site. Source EUI also considers the raw fuel mix and transmission losses associated with energy production and distribution.

performance for decades. Current trends of glass curtain wall buildings may have an inherent energy penalty at a significant first-cost increment. This research is an opportunity to dispel the myth that energy efficiency has to cost more. What matters is that, in any construction type, a strategy to significantly improve thermal performance is pursued. Teams may choose to spend more or less on aesthetic considerations within this context.

The predicted EUIs in this study are aggressive, but comparable results have been demonstrated in other high performance buildings and were considered appropriate for this analysis. Approaching EUI targets below 20 kBtu/SF/year is not simply a design or technical solution; achieving these EUIs requires careful attention to O&M as well as occupant use patterns and plug loads. However, in this order-of-magnitude analysis, the team assumes these factors are sufficiently addressed.

1. ESTABLISH AN EUI

The approach to the establishment of the LEED Platinum building characteristics, solar budget and EUI was different for the renovation and new construction projects. For the *office renovation project,* NBI took the starting EUI directly from the project's energy model. The new construction projects were in early design and did not have energy models. Therefore, NBI used two approaches to determine a range of code-required energy performance levels for the new construction office and apartment building. The first was to review the ASHRAE/IESNA Standard 90.1-2007 Preliminary Quantitative Determination[2] (May 2011) to determine relevant building type EUIs under the ASHRAE 90.1-2007 standard. Using the large office and multifamily building prototypes in Table 11.2, NBI identified the following EUI baselines:

- Large Office—40 kBtu/SF/year
- Apartment—41 kBtu/SF/year

The second approach investigated climate-specific EUIs. For this, NBI referred to an analysis by the Pacific Northwest National Laboratory that compares the cost-effectiveness of ASHRAE 90.1-2010 to ASHRAE 90.1-2007.[3] In this analysis, the District of Columbia was not modeled; instead, the reference is for the climate-specific EUIs in Baltimore, Maryland. The specific EUIs in the large office and apartment building types are as follows:

- Large Office—44 kBtu/SF/year
- Apartment—49 kBtu/SF/year

Therefore, for purpose of this analysis the starting EUI performance range of the reference buildings was between 40 and 44 kBtu/SF/year for office buildings and between 41 and 49 kBtu/SF/year for apartment buildings.

2 Available at: http://www.energycodes.gov/sites/default/files/documents/BECP_FinalQuantitativeAnalysisReport901-2007Determination_May2011_v00.pdf

3 http://www.energycodes.gov/sites/default/files/documents/Cost-effectiveness_of_ASHRAE_Standard_90-1-2010-Cost_Estimate.zip

The NBI Sensitivity Analysis[4] provides an estimated end use consumption split for the building before any energy conservation measures were applied, as shown in Figure 1.

2. CHARACTERISTICS AND ENERGY PROFILES OF REFERENCE BUILDINGS

Energy model results on the office renovation provided an understanding of the various energy conservation measures and predicted energy consumption of this reference building. Predicting the energy profiles of the new construction reference buildings was more difficult since energy models were not available. The team used all available information to learn more about the buildings. Drawings, early LEED scorecards and narratives provided details on base building characteristics such as building size and geometry, roof area, amount of roof area available for photovoltaic panels, and window-to-wall ratio. Cost estimates uncovered important details such as wall and roof insulation levels, glazing characteristics, and lighting and mechanical system selections.

The LEED scorecards also provided an estimate of 'percent better than' code thresholds. NBI assumed that the information garnered from cost estimates on building envelope material selections as well as mechanical and electrical systems would achieve the estimated 'percent better than' targets on the early LEED scorecards. For example, the new construction office building was

4 http://newbuildings.org/sensitivity-analysis-comparing-impact-design-operation-and-tenant-behavior-building-energy-performan

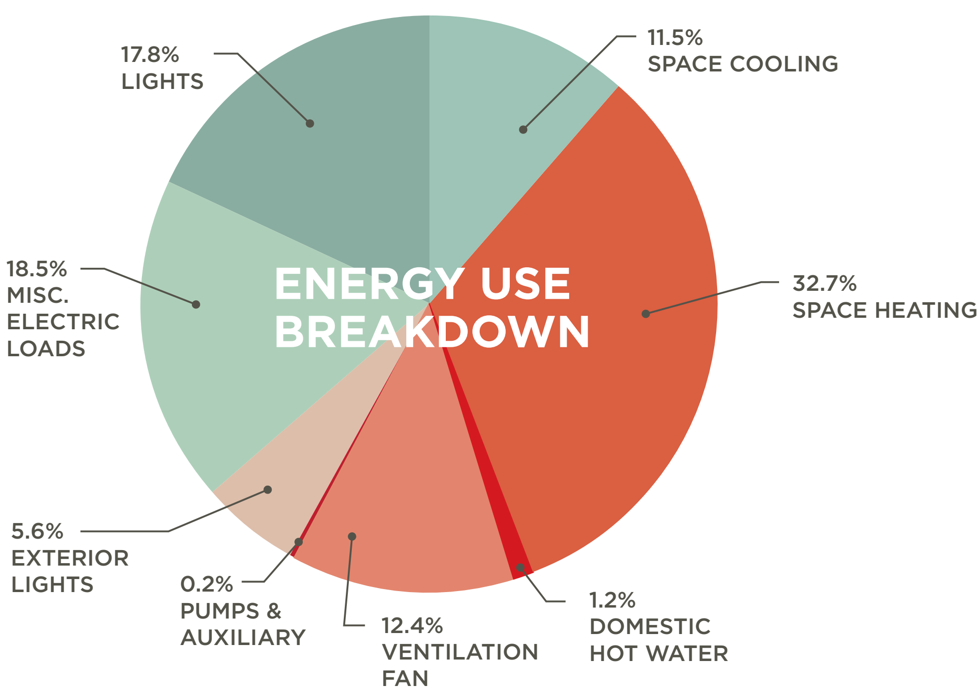


Figure 1: Estimated Energy End Use Consumption in Baltimore Code Office Building

Source: NBI Sensitivity Analysis

pursuing 14 LEED EAc1 points, which corresponds to 34% better than ASHRAE 90.1. In other words, the reference building's EUI was estimated to be 34% better than 44 kBtu/SF/year or 29 kBtu/SF/year.

3. SOLAR ENERGY BUDGET

The solar energy budget is the amount of energy available on that site through the production of renewable solar energy. A number of factors are used to estimate the budget. First is the amount of roof and other area on the building that is available to install photovoltaics (PVs). Due to the placement of mechanical systems on the roof, this is often less than the actual roof area. One way to increase the area available for PVs is to install PVs on elements of the building façade, such as sunshades. However, these may not receive the same amount of solar radiation depending on orientation or shading from neighboring buildings.

Besides the amount of space available for PVs, other important factors include the amount of energy production available from the solar panels themselves. This depends on the efficiency of the panels and the amount of solar radiation that falls on them. For this exercise, NBI based the solar production on using the Panasonic HIT 240S[5] solar panels (240 W per panel or 18 W/SF) and a solar power generation at the horizontal factor of 1220 kWh/kW.[6]

4. ENERGY CONSERVATION MEASURES (ECMS)

Energy savings assumptions were based on best practice, analysis and experience with other high performance building projects, and energy simulation results from NBI research. This information allowed the team to estimate the impact of a series of sequential improvements to building performance, leading to an assumed EUI (in kBtu/SF/year). Actual energy modeling of the buildings evaluated was not in the scope of the study.

NBI developed a spreadsheet tool used for tracking the energy profiles of the three building types. The tool outlined specific Energy Conservation Measure (ECM) scenarios that modified the energy performance of the three reference buildings. The analysis began with the starting EUI and a list of reference building characteristics—either installed or in consideration—for building envelope, lighting and mechanical systems.

NBI then customized ECM scenarios that were theoretically applied to each building to improve the EUI. As previously mentioned, NBI did not significantly alter the building form or geometry, with the exception of the curtain wall system replacement with punched openings. NBI took a rolling baseline approach that impacted envelope, lighting, mechanical systems and domestic hot water. The ECM impact categories were strategically ordered to (1) reduce energy loads in the building, (2) serve the loads with the most efficient system available, (3) manage plug loads and (4) serve remaining loads with renewable sources.

5 Product data sheet available at http://www.panasonic.com/business/pesna/includes/pdf/Panasonic%20HIT%20240S%20Data%20Sheet-1.pdf
6 Source PV Watts available at http://www.nrel.gov/rredc/pvwatts/

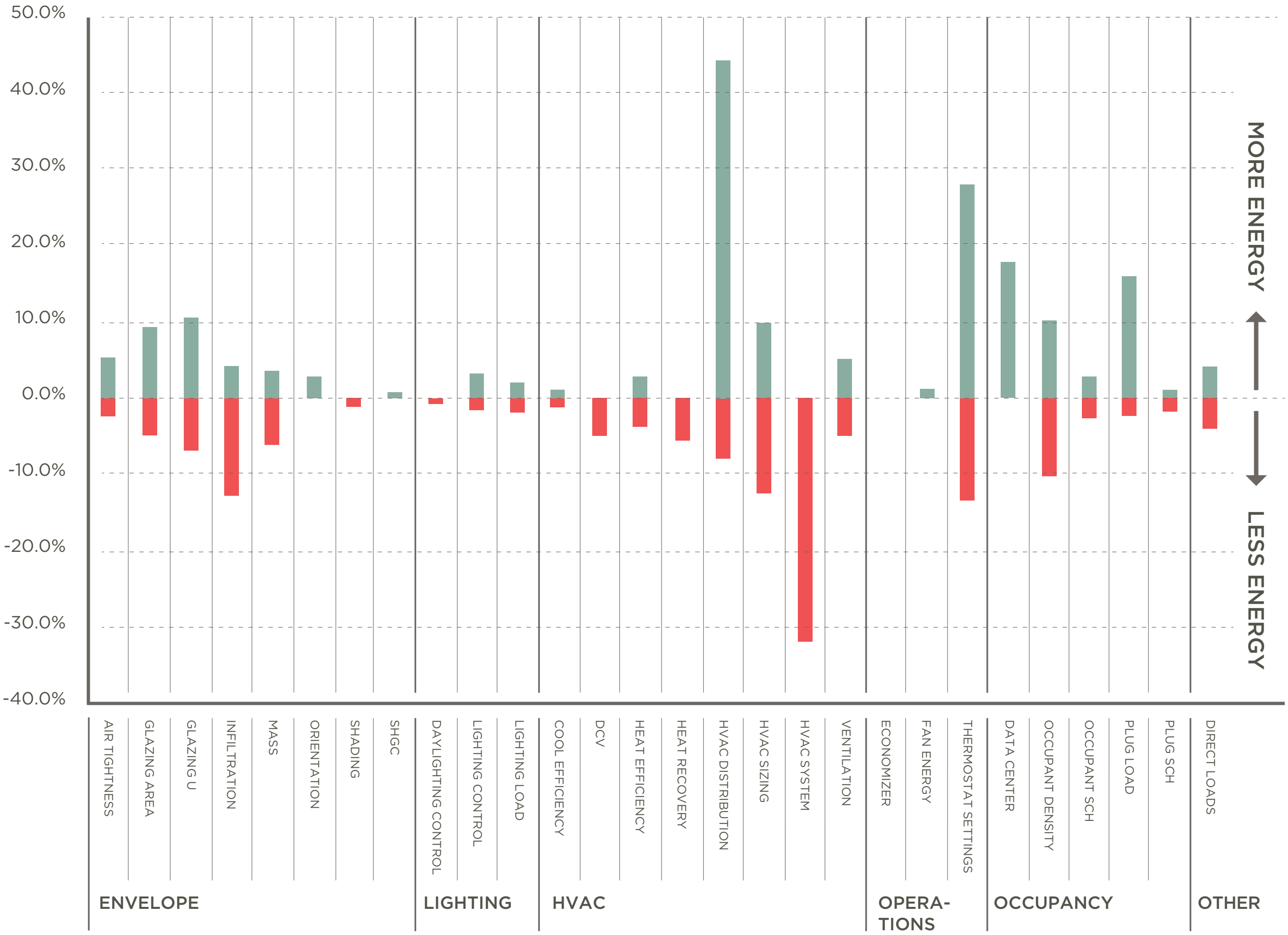


Figure 2: NBI Sensitivity Analysis Results for Baltimore, Maryland

Source: NBI Sensitivity Analysis

Each ECM scenario resulted in a reduced EUI estimate based on best practices, modeling analyses of the impact of various ECMs on recently completed high performance building projects, and the Sensitivity Analysis completed by NBI in July 2011. The Sensitivity Analysis[7] compared the magnitude of energy impact that various design characteristics, operations practices and tenant behaviors have on total building energy use. Again, NBI used the analysis from Baltimore for this particular study, as shown in Figure 2.

Green bars above the zero line indicate adverse impacts on building energy performance, while the red bars below the zero line represent the potential energy impact of improvements in each category. It is clear from the Sensitivity Analysis results in Figure 2 that occupancy, operations and maintenance are critical to meeting EUI targets and ensuring ongoing energy performance.

7 Available at http://newbuildings.org/sites/default/files/SensitivityAnalysisReport.pdf

Once all ECMs were applied, NBI estimated total amount of solar panel area that would theoretically be needed to meet the building's energy load.

APPROACH TO WATER PERFORMANCE IMPROVEMENTS

ILFI determined the strategies necessary to achieve the net zero water imperative of the Living Building Challenge and worked with Skanska to arrive at the anticipated cost premium for each water strategy employed.

The process included:

- Calculation of the base building's water use;
- Calculation of the reduction in water use from water conservation strategies including the addition of water conserving fixtures;
- Calculation of the rainwater available for collection;
- Calculation of potable and non-potable water uses;
- Calculation of greywater and blackwater produced;
- Determination of the net zero water strategy; and
- Determination of the Ecological Water Flow strategy.

Base Water Use: Similar to the net zero energy process, water conservation was the first strategy employed on all buildings. The reference buildings anticipated achieving all of the LEED v3 Water Efficiency (WE) Credits, except for WE Credit 2, which means the reference projects already incorporated water saving devices that provided greater than 30% water savings when compared to a code compliant building. Strategies most projects employ to achieve water use reduction, such as low flow fixtures for lavatories and showers, reduced flush or dual flush toilets, and waterless or reduced flush urinals, typically have little added cost. In determining the strategy for the Living Building modifications, research was done to determine the most efficient dishwasher and clothes washer for the residential buildings, with the cost premium for these appliances included in the cost estimate.

Because LEED has a well-established procedure for calculating water usage, it was only used as a starting point. In addition to the uses specifically identified by LEED as part of the calculation procedure, the residential buildings' water use was adjusted to account for dishwashing and clothes washing. Residential buildings were assumed to be equipped with the most efficient tank type dual flush toilets (0.8/1.1 gallon per flush), with office buildings using a flush valve dual flush mechanism (0.8/1.6 gallons per flush).

To achieve the Living Building Challenge's Net Zero Water Imperative, the team assumed that the existing landscaping for the reference building would be replaced by regionally appropriate native/adaptive landscaping. No irrigation was provided in any of the Living Building modifications.

1. WATER COLLECTION

After determining each building's water use, the amount of water available for rainwater collection from the building roof was calculated using daily precipitation data from the National Oceanographic and Atmospheric Association (NOAA). The team created a water calculator based on past weather conditions in the Washington, DC, area and estimated water consumption. The model used daily precipitation data to calculate how much water could be harvested based on the size of the roof and the size of storage tanks and what percentage of the building's water use could be supplied from collected rainwater based on provided inputs.

2. WATER STRATEGIES

The way that each building could achieve net zero water was calculated using an analysis model that checked strategies against the water use required and rainwater available.

A series of strategies were employed:

1. Rainwater was used for potable uses.

2. Greywater collection and treatment allowed it to be reused for non-potable uses.

3. Treatment of greywater to potable standards was considered.

4. Treatment of blackwater to greywater standards was considered.

It is understood that in many jurisdictions this would be prohibited, but for the purposes of the study it was assumed that blackwater reuse would be allowed.

3. BUILDING WATER DISCHARGE

In all cases, rainwater could not meet the entire building's water demand. It was measured against potable usage, which for the purposes of the study was defined as all water used at the kitchen sink, dishwasher, shower, and lavatories. Treatment using a greywater-only system was provided. The design typically used a membrane bioreactor to treat both grey and blackwater to class four levels; however, this is a very energy intensive strategy and should be avoided if scale jumping treatment alternatives, such as constructed wetlands and/or eco-machines, are possible.

Water tanks smaller than 50,000 gallons were assumed to be fiberglass tanks; larger tanks were assumed to be poured-in-place concrete with treated walls. Typically tanks were hypothetically located in the basement of each building—usually in place of mechanical rooms made smaller as a result of changes to the energy systems. Costs for the tanks, UV treatment and water filtration were all added to the project. Membrane bioreactors were added as an optional cost.

BUILDING MODIFICATIONS AND COSTS

The reference building cost for each project includes the direct construction costs for the core and shell and site development. In the case of the 'new construction office,' an allowance for an open office plan tenant improvement was also included in the baseline costs so that comparisons were made to a building with interior fit out included in the costs. The team estimated the cost and associated energy performance improvements resulting from the following measures:

ENERGY USE REDUCTION STRATEGIES

Energy Conservation Measure (ECM) scenarios described in this section were used to modify the energy performance of the three reference buildings. These are described in detail below.

IMPROVED ENVELOPE PERFORMANCE

Reduced Window-to-Wall Ratio. The team reduced the glazing by replacing the curtain wall assembly with a precast opaque skin, including framing and insulation. This is the only measure that made a significant impact to the overall appearance of the building. The amount of curtain wall that was reduced was rounded up to account for the 10% of the curtain wall assembly that was already opaque spandrel. In the new construction projects, window-to-wall ratios were reduced from approximately 48% to 35%, which will require attention to the placement of the glazing to maximize daylighting opportunities but will result in a cost savings. The renovation project did not experience a change in window-to-wall ratio.

Improved Insulation. The second major component of the improved building envelope was to add rigid insulation at the spandrel panels and the roof. The goal was to increase wall insulation to R-21 and roof insulation to R-40, assuming that the

New glazing technologies include triple glazed windows or dynamic glass. Dynamic glass uses electrochromic coating to change solar transmission properties in response to a small, applied voltage. This enables control of the amount of light and radiative heat passing through a window. The performance of electrochromic glass can form a solar heat gain coefficient of 0.46 to 0.09 and a visible transmission of 0.58 down to 0.04. For most installations, the dynamic glass facade is controlled by an algorithm that knows the position of the sun across the horizon and can predict the resulting heat and glare. While these technologies are increasingly available on the market, they were not included in this study.

R-value of the insulation was R5.5/inch and that the wall and roof geometries were unchanged by this addition.

Improved Glazing. No change was needed in the new construction buildings because the baseline glazing condition included high performance window assemblies with a whole frame U-value of 0.22. In the office renovation project, the glazing U-value was improved from 0.40 to 0.22 for the overall window assembly. While there are more efficient windows on the market, the selection was optimized to all other systems holistically.

IMPROVED LIGHTING PERFORMANCE

Improved Lighting Design, Controls and Operations. In the office projects, the team reduced Lighting Power Density (LPD) by hypothetically upgrading the fixture types and implementing an IP-addressable ballast control system similar to enLighted luminaire-level lighting control systems. The assumed fixtures in the redesigned building were Peerless/Acuity Brand STAPLE Baffle Indirect/Direct linear pendants, 3100 T8 lamps, with a dimming ballast and advanced controls.

The multifamily building lighting system was converted to dedicated compact fluorescent with a master occupancy sensor, or hospitality-type control system.

In all buildings, the team assumed all lighting was operated efficiently, turning off when occupants were not present or when sufficient daylight was available.

IMPROVED MECHANICAL SYSTEM PERFORMANCE

Ground Source Heat Pump. The team considered two improved HVAC systems, ground-source heat pumps and variable refrigerant flow units. In all three building types, a ground-source system with heat recovery is included in the modified net zero building. The baseline HVAC system components that are redundant between the options were removed, and the ground-source system was added. It was assumed to be a closed-loop vertical well system and that the spacing and number of wells achieves the necessary tonnage loads within the building footprint. The team assumed that the system operates efficiently with careful attention to temperature set points and scheduling.

LEDs have made great strides in recent years, and integral LED luminaires are available in the market today. LED luminaires can be highly efficient, provide good color, and be made to dim well. However, not all LEDs or LED luminaire systems are created equal. Unlike fluorescent lamp types, few standard LED array configurations exist. This means that standard lamp/ballast combinations that have evolved for fluorescent technologies have not yet been developed for LED array/driver combinations to any large extent. The additional concerns of compatibility and flicker with LED dimming drivers led the team to stick with linear fluorescent for this cost analysis. Fluorescent is still a strong technology, inexpensive, with good performance, easy dimming, and new long-life lamps that directly compete with or exceed LEDs with rated hours between 60,000-80,000 hours.

Solar Domestic Hot Water. Due to the large demand for hot water in multifamily buildings, the team added a 5,000 SF solar domestic hot water system in the new construction multifamily apartment building only.

PLUG LOAD MANAGEMENT

Plug load management was added at the circuit breaker level on approximately half of the circuits in the branch panels. The monitoring would be wireless/cloud-based and require an ongoing maintenance agreement, the costs of which were not incorporated into the analysis. The strategy is to monitor the troublesome circuits in an efficient manner in lieu of monitoring every one.

Multifamily new construction included hospitality style controls that turn appropriate equipment down or off when no occupants are present.

Successful operation of low-energy buildings requires that good information about ongoing building performance be available to building operators and tenants. Although the design team cannot guarantee the building will be operated well, a series of features can be specified and incorporated by the design team to make sure that good, actionable building performance feedback is available to operators and tenants. For operators, these features include load segregation, for example, separating plug, light and HVAC loads in the electrical panel so that energy use of these components can be evaluated independently. Also important is the incorporation of metering hardware and diagnostic tools capable of tracking building performance over time. For tenants, a building dashboard that displays day-to-day energy use can help empower tenants to participate in building efficiency strategies.

ENERGY USE INDEX IMPROVEMENTS FROM ENERGY CONSERVATION MEASURES

The resulting EUIs in kBtu/sf/year from each ECM described above are outlined in Table A.

	Starting EUI kBtu/sf/year	Improved Envelope Performance kBtu/sf/year	Improved Lighting Performance kBtu/sf/year	Improved Mechanical / Domestic Hot Water Perfor-mance kBtu/sf/year	Plug Load Management kBtu/sf/year	Resulting EUI kBtu/sf/year
Office New Construction	29	27	25	22	20	20
Multifamily New Construction	37	34	33	26	23	23
Office Renovation	67	51	49	34	31	31

Table A: EUI of Reference Building and from of Energy Conservation Measures

RENEWABLE ENERGY

The PV panels priced were high-efficiency panels similar to the Panasonic HIT 240. In addition, PV sunshades were added to maximize the amount of solar energy available on the project site. Where sunshades were already included in the project, the fixed aluminum louvers were modified to accept PV cells. In the energy calculations, the team assumed this additional square footage of PVs would all produce at the same efficiency and that it would be located on the appropriate elevations of the building with solar access. The multifamily building included a solar thermal array for domestic hot water.

Despite the fact that deep efficiency measures have been added to the buildings, the size of the solar array needed to serve 100% of the energy needs was larger than the available roof area in all three building types. Therefore, the balance of the renewable power needed to achieve net zero energy on an annual basis was priced as a conceptual array that would involve multiple buildings. This is the most conceptual cost in the study and excludes property purchase or rooftop leasing costs and costs to wire the array to the building if not immediately adjacent to the site.

The cost estimate reflects taking advantage of two significant incentives for solar energy production. The first is the federal solar Investment Tax Credit (ITC), which is calculated at 30% of the installed construction cost. This analysis assumes the project owner has a large enough tax liability to capitalize on the full credit amount, or that the credit is accounted for on day one and taken over successive tax years.

The second incentive is the Solar Renewable Energy Credit (SREC) program in the District. This program allows solar generators to monetize their production and generate annual income. Although this is primarily a credit to ongoing operational costs, the first year's credit can be taken upon system commissioning. As a result, that credit has been figured into the construction costs. SREC values are based on current pricing as outlined in Table B below.

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Value of REC per wMWh	$475.00	$475.00	$475.00	$332.50	$285.00	$190.00	$190.00	$142.50	$142.50	$47.50

Table B: Solar Renewable Energy Credit Values Over Time

The ITC and first-year SREC credits have been taken with the cost of the renewable system 'above the line.' This eliminates contractor markups on these sizable numbers. It should be noted, however, that some developers may view the credit as a source of funds and keep it on the other side of the ledger. As a result, the premium for renewables will rise slightly as the markup on the credit goes away.

FINANCIAL ANALYSIS FOR ENERGY CONSERVATION MEASURES AND NET ZERO ENERGY

Costs for getting to zero are difficult to distinguish from overall project costs. While energy efficiency and renewable technologies do have specific costs that are analyzed in this section of the report, the design and technology tradeoffs due to the advanced systems can blur the line of incremental costs. Experienced design firms and early energy targets reduce cost premiums by establishing an explicit goal of ZNE throughout the process in order to manage costs and achieve net zero energy results.

For this analysis, costs are separated into two general categories: (1) incremental costs for ECMs, and (2) costs for purchase and installation of renewable energy systems. Increasing investment in and attention to energy efficiency reduces the quantity—and therefore the cost—of renewable energy systems that are required.

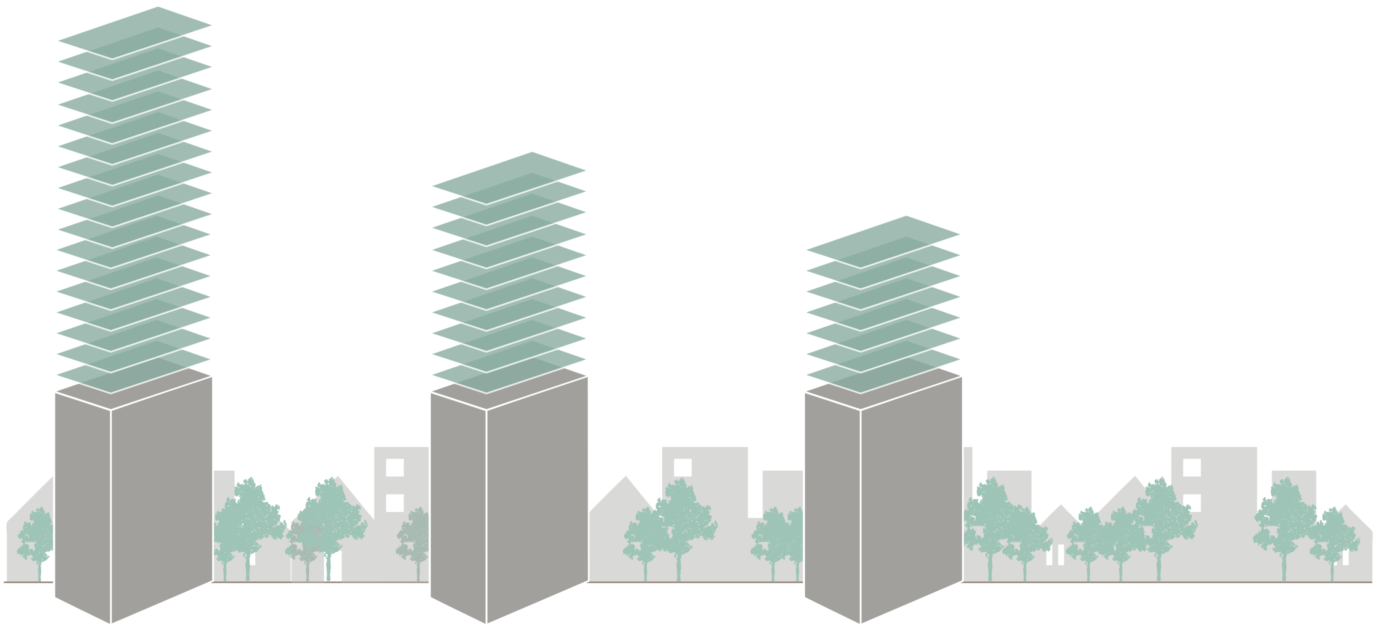


Figure 3: Photovoltaic Area to Offset Energy Use

Another reason reducing the size of renewable energy systems is especially important in communities with dense urban centers is the limited roof area available to install solar energy systems. In these 300,000 SF buildings, five to eight (depending on the building use) roof surfaces would be required to attain net zero energy status. Reliance on other buildings, whether next door or across town, in effect takes away the opportunity for owners of those host buildings to ever achieve net zero goals themselves. Therefore, focusing on efficiency first is an important strategy to pursue in the District.

First-cost premiums for energy efficiency only ranged from 1-12% depending on the building type. The new office premium was from 1-6%, while the new multifamily building was from 2-7%. The office renovation first cost increment range was higher, between 7-12%. Net zero energy cost ranges added the cost of renewable systems but took advantage of substantial tax credits and first year SREC reimbursements that were used to offset first costs associated with renewable systems. These incremental cost ranges are outlined in Table C.

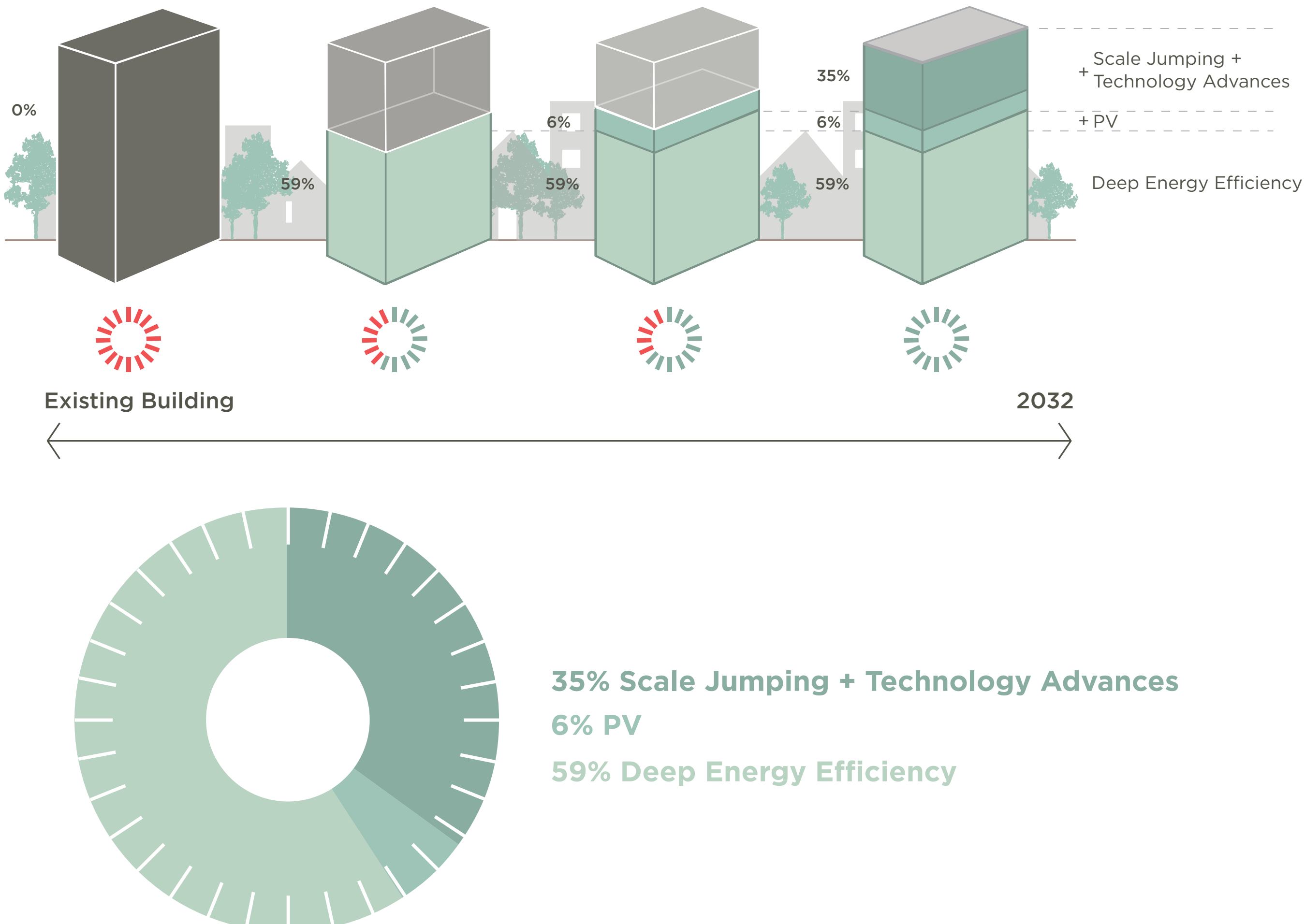


Figure 4: Getting to Net Zero

How do we power an existing DC building with all renewable energy? 59% comes from energy efficiency, 6% or more from p/v on the roof, and 35% will need to come from technology advancement in solar panels and from jumping to the district scale for energy solutions.

	Energy Conservation Measures	Net Zero Energy (Renewables with ECMs)
Office New Construction	1-6%	5-10%
Multifamily New Construction	2-7%	7-12%
Office Renovation	7-12%	14-19%

Table C: Cost Premium Range

When looking beyond first costs, the analysis considered a net present value (NPV), simple pay back (SPB), and return on investment (ROI). The analysis hinged on a number of assumptions, specifically:

- 10-year time horizon with a discount rate of 5.5%.
- Blended energy costs were $0.13/kWh and rose at 2.5% over the 10 years.
- During the 10 years, the solar carve-out for the Renewable Portfolio Standard (RPS) did not increase and no possible future carbon taxes were considered.
- Maintenance cost or savings over time were not included.
- Financial incentives from the District were not included.
- Importantly, the analysis assumes that the owner does have sufficient tax burden to take advantage of all tax credits.

The results of this analysis are outlined in Table D.

	Assumed Incremental Cost	ECM only			Net Zero with ECM			Net Zero without ECM		
		NPV	SPB	ROI	NPV	SPB	ROI	NPV	SPB	ROI
Office New Construction	$3,790,218	-$396,476	11 yrs	9.1%	$2,672,413	3.0 yrs	33.8%	$2,508,026	3.3 yrs	30.3%
Multifamily New Construction	$4,608,518	-$1,772,741	17.7 yrs	5.7%	$3,192,398	3.0 yrs	33.1%	$2,943,543	3.4 yrs	29.3%
Office Renovation	$3,464,015	-$137,039	8.1 yrs	12.3%	$1,260,704	2.7 yrs	36.8%	$3,008,046	3.4 yrs	29.2%

Table D: Net Present Value, Simple Pay Back and Return on Investment

This analysis demonstrates the significant financial impact associated with renewable energy incentives such as the federal tax credit and the ongoing SREC payments. ROIs in the range of 29-37% are available largely based on the generous incentives associated with renewable energy. Of course the assumption that sufficient tax appetite exists is fundamental to the analysis. However, it does show that sufficient incentives are already in place for renewables and suggests that any new incentives in the District be focused on reducing the cost of energy efficiency improvements.
The energy policy section provides additional recommendations on how this might be structured.

NET ZERO WATER AND ECOLOGICAL WATER FLOW STRATEGIES

For each building, a storm and rainwater retention system was added via a tank in the basement. The walls and floor of this tank were waterproofed and structurally upgraded to meet the load of the water. Related pipes, pumps and greywater distribution (purple pipe) systems were also added.

	Assumed Incremental Cost	Cost Premium per SF	Cost Premium %	NPV	SPB	ROI
Office New Construction	$1,190,133	$3.80	1.3%	($116,953)	10.18	9.8%
Multi-Family New Construction	$1,540,145	$4.65	1.7%	($72,580)	21.22	4.7%
Office Renovation	$1,846,100	$7.85	3.1%	($94,808)	19.47	5.1%

Table E: Cost and Payback of NetZero Water Strategies

Note: $2.00 per SRC was assumed for stormwater incentives.

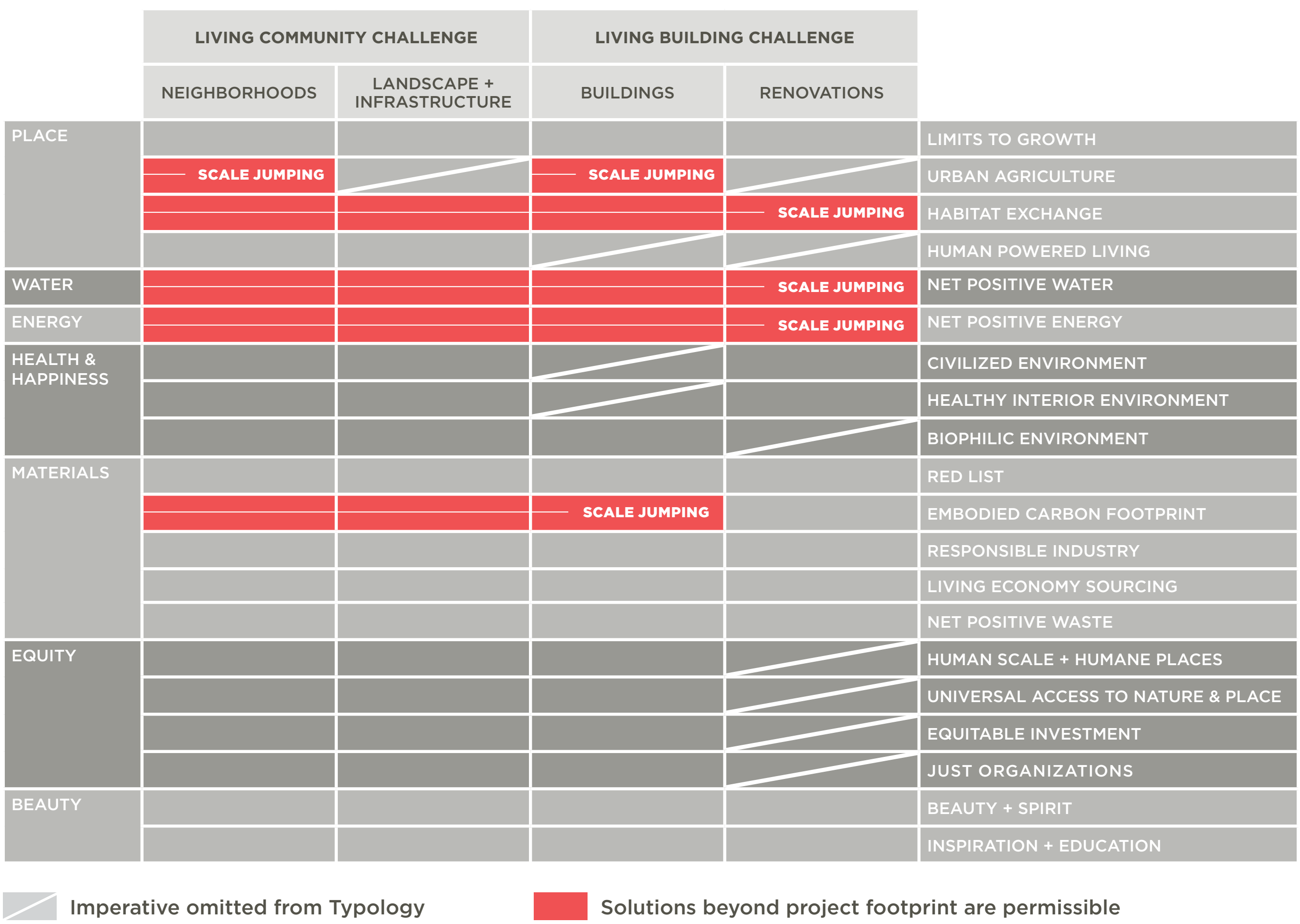
Due to the LEED Platinum baseline, low and ultra-low flow fixtures are already included in the baseline design and cost.

Greywater and blackwater are treated by a membrane bioreactor (MBR) that is sized for the building flows. The basis of design for this system is an Aquacell MBR.

The non-chemical filtration system for the process water is priced as a Dolphin brand pulse system.

COSTS AND STRATEGIES FOR ACHIEVING LIVING BUILDING CHALLENGE IMPERATIVES

Typically, the fee and general conditions percentage drops as the project value rises. Those costs are primarily based on project staffing and schedule. In this case, the percentages have been held the same to acknowledge the difficulty of managing a Living Building Challenge (LBC) project, and one full-time project engineer position has been added to the team for an 18-month duration. More specific costs relating to particular LBC Imperatives are outlined below based on the authors' combined experience on the projects.



01 – Limits to Growth

All sites selected met this imperative; therefore no additional costs were associated with it.

02 – Urban Agriculture

All sites selected met this imperative; therefore no additional costs were associated with it. Under LBC 2.1, there is no Urban Agriculture requirement for sites with an FAR greater than 3.0. Future versions of the LBC may have a small requirement for contributions to the food network by dense buildings, but even then the additional cost will be negligible and accomplished with balcony boxes, green roofs or bee keeping.

03 – Habitat Exchange

All projects accounted for this cost at the same rate of $1/square meter. This cost was set based on the average cost to protect an acre of land in perpetuity through an accredited land trust.

04 – Car Free Living

Requirements for this Imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level; therefore no additional costs were associated with it.

05 – Net-Zero Water

See specific scenarios described one page 26.

06 – Ecological Water Flow

See specific scenarios described on page 26.

07 – Net-Zero Energy

See specific scenario descriptions on page 18.

08 – Civilized Environment

It was assumed that a cost-neutral combination of space planning, operable windows and open office tenant improvements would be used to achieve this imperative at no cost above the LEED Platinum baseline.

Finding and confirming Red List free materials for LBC projects has been time consuming for the early projects. The report assumed a level of material research time equivalent to one FTE staff person through design and construction. However, the availability of both information and products that are Red List free is changing rapidly. More and more project teams are sharing their product research databases, products are listing their information with the Declare product label, and manufacturers are integrating the LBC into the upgrade of existing products and the development of new products. With more project teams and municipalities pushing for healthy, local and responsible products, the material requirements of the LBC will hopefully become business as usual.

09 – Healthy Air

Requirements for this imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level; therefore no additional costs were associated with it.

10 – Biophilia

No costs were added specifically for Biophilia. The costs to create a building and site that meet this imperative are assumed to be captured in the premiums applied to the architecture and engineering fees. Many prescriptive strategies are included in the LBC 2.1 Handbook.

11 – Red List

An added cost of 1.25% of direct construction cost was added to the base building to account for increased costs due to substitution of materials that did not meet the Red List or are not currently subject to an exception. Additional costs for Red List research are included in the architectural premium fee and additional direct costs as explained below.

12 – Embodied Carbon Footprint

The project's embodied carbon footprint was estimated using the Green Footstep carbon calculator for each building type. The offset cost of $20/ton was used based on the average pricing from several high-quality offset providers.

13 – Responsible Industry

At the time of this study, the costs to meet this imperative only include the provision of 100% FSC-certified wood on the project. Where the value of the wood products was known, a premium was applied to upgrade to certified wood. The additional costs for this imperative were discounted by slightly more than half for projects achieving LEED MRc7 in recognition of the costs already included in the baseline. A straight 50% factor was used in order to account for the premiums for the temporary wood (e.g. concrete formwork) that none of the LEED baseline projects included.

14 – Appropriate Sourcing

For the purposes of this cost study, it was assumed that all products needed for the building could be obtained within the materials/service radius but that reduced competition would result in increased costs. Specific materials that pose procurement issues are aluminum windows and glazing, elevators, mechanical equipment, electrical switchgear and light fixtures. The team assumed that an 8% premium would be incurred on one-third of the material purchases when selection is based on weight/distance in lieu of lowest cost. This resulted in an approximate 1.25% premium on the direct cost of work.

15 – Conservation and Reuse

Requirements for this imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level. A cost premium of 10% has been added to the demolition costs for the renovation project to account for the expense of deconstruction and salvage.

16 – Human Scale and Humane Places

Requirements for this imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level; therefore no additional costs were associated with it. In LBC 2.1, a set of design requirements are included for the articulation of buildings and the site. There are no cost implications when incorporated into the design from the beginning.

17 – Democracy and Social Justice

Requirements for this imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level; therefore no additional costs were associated with it. In the LBC 2.1, all that is required of projects of this type is ADA compliance and minimal public street furniture.

18 – Rights to Nature

Requirements for this imperative were assumed to have been met by all projects achieving the LEED Platinum baseline level; therefore no additional costs were associated with it.

19 – Beauty and Spirit

No costs were added specifically for Beauty and Spirit. The costs to create a building and site that meet this imperative are assumed to be captured in the premiums applied to the architecture and engineering fees.

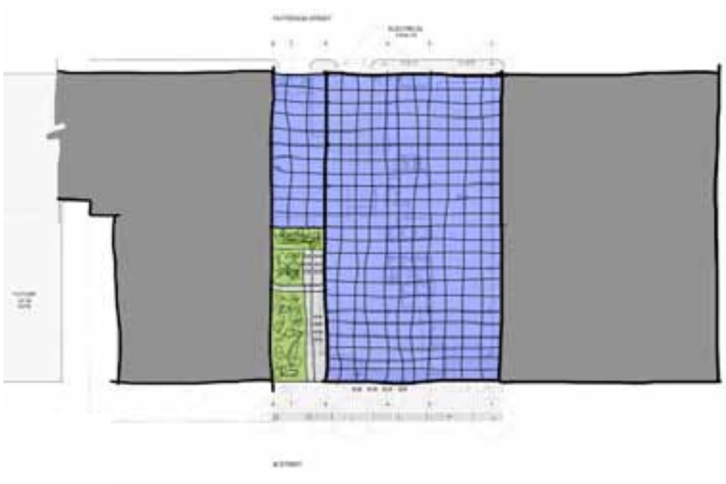
20 – Inspiration and Education

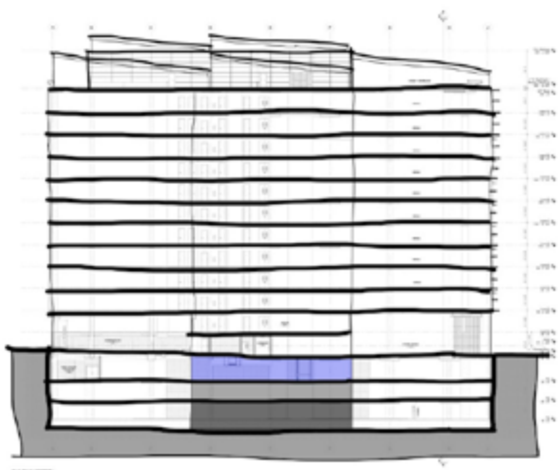
A lump sum cost based on Gross Square Footage (GSF) was added to each building type for an instructional signage program to convey the sustainability message of the project.

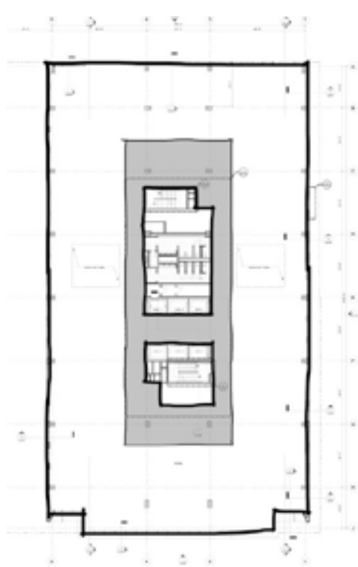
DEVELOPMENT COSTS

The costs for development were adjusted to meet the unique demands of a net zero water, net zero energy or full Living Building project. Direct costs include the addition of one full time equivalent employee on staff to address LBC requirements for 18 months during pre-construction and construction. The percentage-based development costs were allowed to rise with the cost of work at a rate 2% greater than the traditional development costs. The effect is masked, however, by keeping the purchase price of the property fixed. The architecture and engineering fee percentages were increased nominally due to the extra effort required for the deep green design, including the specific items listed in the imperative review above.

NEW CONSTRUCTION OFFICE







BUILDING DETAILS

436,015 Total SF

328,095 Size Excluding Parking SF

1.12 Site Gross Acreage

12 Story Building Above Grade

27,079 Roof Area SF

ENERGY AND WATER PERFORMANCE

20 kBtu/SF/year EUI

1570 kW photovoltaic array

1843 k Water Use

833 k Rainfall

VALUE

$283 / SF LEED Platinum

$305 / SF Net Zero Energy

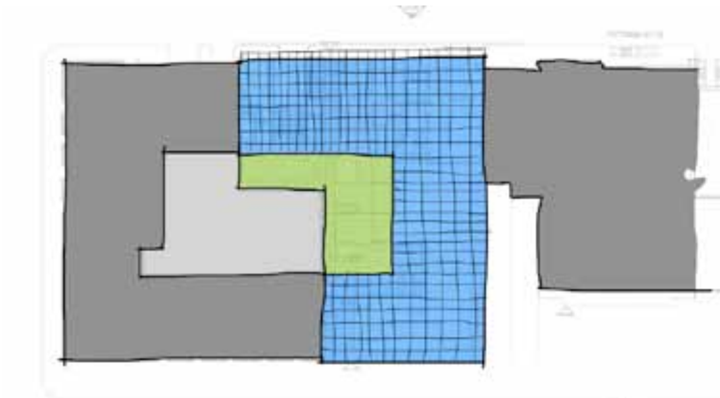
$288 / SF Net Zero Water

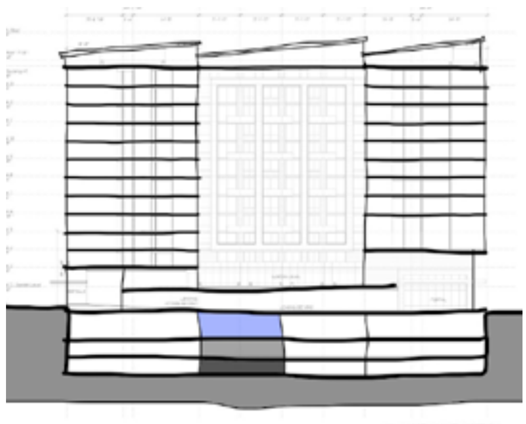
$321 / SF Living Building Challenge

MAJOR DESIGN STRATEGIES

- Reduce window-to-wall ratio from 47% to 35%
- Improve wall insulation from R-13 to R-21
- Improve roof insulation from R-20 to R-40
- Add workstation specific lighting controls
- Convert to variable refrigerant flow system with dedicated ventilation system with heat recovery
- Add aggressive plug load circuit separation and occupancy sensors
- Rainwater collection with subgrade cisterns
- Greywater and blackwater treatment
- Greywater piping and storage
- Non-chemical filtration system

NEW CONSTRUCTION APARTMENT





BUILDING DETAILS

426,511 Total SF

329,164 Size Excluding Parking SF

0.80 Site Gross Acreage

12 Story Building Above Grade

25,487 Roof Area SF

ENERGY AND WATER PERFORMANCE

23 kBtu/SF/year EUI

1820 kW photovoltaic array

2670 k Water Use

858 k Rainfall

VALUE

$277 / SF LEED Platinum

$304 / SF Net Zero Energy

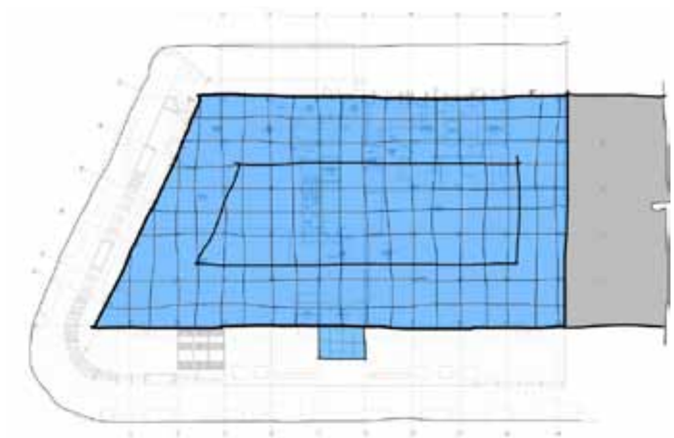
$285 / SF Net Zero Water

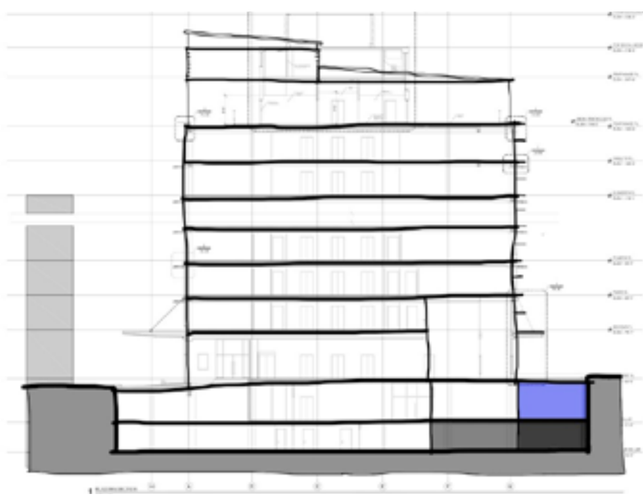
$320 / SF Living Building Challenge

MAJOR DESIGN STRATEGIES

- Reduce window-to-wall ratio from 48% to 35%
- Improve wall insulation from R-13 to R-21
- Improve roof insulation from R-20 to R-40
- Convert all light fixtures to dedicated CFL or LED. Add master occupancy sensor control to all units (hospitality type)
- Convert to ground source heat pump with heat recovery
- Add 5,000 SF of domestic solar hot water heating
- Add aggressive plug load circuit separation and occupancy sensors
- Rainwater collection with subgrade cisterns
- Greywater and blackwater treatment
- Greywater piping and storage
- Non-chemical filtration system

OFFICE RENOVATION





BUILDING DETAILS

235,172 Total SF
185,487 Parking SF
0.77 Site Gross Acreage
12 Story Building Above Grade
17,500 Roof Area SF

ENERGY AND WATER PERFORMANCE

31 kBtu/SF/year EUI
1364 kW photovoltaic array
2394 k Water Use
806 k Rainfall

VALUE

$250 / SF LEED Platinum
$291 / SF Net Zero Energy
$262 / SF Net Zero Water
$312 / SF Living Building Challenge

MAJOR DESIGN STRATEGIES

- Improve wall insulation from R-11 to R-21
- Improve roof insulation from R-20 to R-40
- Improve window assembly U-value from 0.42-0.22
- Add workstation specific lighting controls
- Convert to variable refrigerant flow loop with central chiller, dedicated outside air ventilation system with heat recovery
- Add aggressive plug load circuit separation and occupancy sensors
- Rainwater collection with subgrade cisterns
- Greywater and blackwater treatment
- Greywater piping and storage
- Non-chemical filtration system

NEW CONSTRUCTION OFFICE

Building Location: Washington, DC

Base Building Gross SF: 436,015

Building Area without Garage: 328,095

Site Gross Acreage: 1.12

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
COSTRUCTION COST											
Baseline Building (Direct Cost of Work)				$70,816,452	$162.42	$70,816,452	$162.42	$70,816,452	$162.42	$70,816,452	$162.42
Baseline Building				$70,816,452	$162.42	$70,816,452	$162.42	$70,816,452	$162.42	$70,816,452	$162.42
ENERGY REDUCTION STRATEGIES											
Reduce window to wall ratio	35%		Unit Cost	$0	$0.00	($570,000)	($1.31)			($570,000)	($1.31)
Increase Precast & Punched Window Assembly											
Replace curtain-wall with precast & furring	15,000	sf	$47.00			$705,000	$1.62			$705,000	$1.62
Decrease curtainwall assembly	(15,000)	sf	$85.00			($1,275,000)	($2.92)			($1,275,000)	($2.92)
Improved insulation			Unit Cost	$0	$0.00	$152,290	$0.00			$152,290	$0.00
R-13 to R-21 at span-drels, add 2" rigid	6,722	sf	$2.50			$16,805	$0.04			$16,805	
R-20-R-40 at roof, add 4" rigid	27,097	sf	$5.00			$135,485	$0.31			$135,485	
Lighting upgrade			Unit Cost	$0	$0.00	$820,238	$1.88			$820,238	$1.88
Reduce LPD from 0.7 to 0.3	328,095	gsf	$2.50			$820,238	$1.88			$820,238	$1.88
Ground Source Heat Pump			Unit Cost	$0	$0.00	$734,615	$1.68			$734,615	$1.68
Baseline HVAC system reduction											
Delete chillers, VAV boxes, cooling towers & associated pumps						($1,265,385)	($2.90)			($1,265,385)	($2.90)

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Ground source hHeat pump system, including:	800	tons	$2,500.00			$2,000,000	$4.59			$2,000,000	$4.59
Wells							$0.00			incl	$0.00
Well piping							$0.00			incl	$0.00
Heat Ex-changers & pumps							$0.00			incl	$0.00
Heat Pumps							$0.00			incl	$0.00
Controls							$0.00			incl	$0.00
Variable Refriger-ant Flow System (Option)			Unit Cost								
	$503,355		(Includes Indirects, Design & Owner Costs)								
Plug Load Manage-ment			Unit Cost	$0	$0.00	$147,643	$0.34			$147,643	$0.34
Plug load monitoring, cloud-based	328,095	gsf office	$0.45			$147,643	$0.34			$147,643	$0.34
WATER REDUCTION STRATEGIES											
Stormwater Retention and/or Infiltration System			Unit Cost	$0	$0.00					$1,658,372	$3.80
Remove green roof to allow for water capture	(12,421)	sf	$20.00					($248,420)	($0.57)	($248,420)	($0.57)
Rain Harvesting (piping & pumps & filtration)	436,015	gsf	$1.25					$545,019	$1.25	$545,019	$1.25

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
55,000 gallon rainwater cistern 30'x30'x10'								$78,600	$0.18	$78,600	$0.18
Concrete Tank Construction											
Walls and Footings	1,200	sf	$50.00								
SOG upgrade	900	sf	$2.00								
Water-proofing	2,100	sf	$8.00								
Low Flow Fixtures	Included in Baseline							$0		$0	
Membrane BioReactor								$890,760	$2.04	$890,760	$2.04
Graywater Reuse System (piping)	436,015	gsf	$0.60					$261,609	$0.60	$261,609	$0.60
Non chemical filtration	436,015	gsf	$0.30					$130,805	$0.30	$130,805	$0.30
RENEWABLE ENERGY STRATEGIES											
Increase PV area			Unit Cost	$0	$0.00	$1,318,040	$3.02			$1,318,040	$3.02
Add PV to existing available roof structure	12,421	sf	$80.00			$993,680	$2.28			$993,680	$2.28
Additional PV at available sunshades	4,050	sf	$50.00			$202,500	$0.46			$202,500	$0.46
Additional PV at additional sunshades	3,529	sf	$50.00			$176,450	$0.40			$176,450	$0.40
Additional sunshades for additional PV	1176	lf	$120.00			$141,160	$0.32			$141,160	$0.32

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Reduce existing sunshade cost by 55% to eliminate blades	1350	lf	-$145.00			($195,750)	($0.45)			($195,750)	($0.45)
Meet Total Load with PV			Unit Cost	$0	$0.00	$5,383,703	$12.35			$5,655,703	$12.97
Add PV to additional theoretical structure	67,296	sf	$80.00			$5,383,703	$12.35			$5,383,703	$12.35
Add PV to offset MBR demand	1,700	sf	$80.00							$272,000	$0.62
Credits / Rebates / Incentives	Federal	REC/ MWh		$0	$0.00	($2,911,525)	($6.68)			($3,010,328)	($6.90)
PV Credits-(federal, state, city, utility)	30%	$470.00				($2,911,525)	($6.68)			($3,010,327)	($6.90)
Living Building Challenge Imperatives				$0	$0.00	$0	$0.00	$0	$0.00	$1,616,013	$3.71
Red List										$536,625	$1.23
Responsible Industry										$483,689	$1.11
Appropriate Sourcing										$595,699	$1.37
Subtotal Direct Costs				$70,816,452	$162.42	$75,891,455	$173.88	$71,645,638.13	$164.32	$79,339,038	$181.61
General Conditions, Fee, Contingency, Insurance, Bonding				$7,447,298	$17.08	$7,954,798	$18.24	$7,530,217	$17.27	$8,982,057	$20.60
TOTAL MODIFIED CONSTRUCTION COST				$78,263,750	$179.50	$83,846,253	$192.13	$79,175,854.74	$181.59	$88,321,095	$202.22

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
OWNER & DEVELOPMENT COSTS											
Living Building Challenge Imperatives											
Habitat Exchange	1.12	acres								$4,522	$0.01
Embodied Carbon Footprint	15,000	tons								$300,000	$0.69
Inspira- tion and Education										$82,024	$0.19
Develop- ment Costs	LEED	LBC									
Develop- ment Costs	31.50%	29.33%		$38,823,750	$89.04	$40,046,176	$91.85	$39,018,688	$89.49	$41,030,641	$94.10
Archi- tecture & Engineering	5.00%	7.26%		$6,162,500	$14.13	$9,165,000	$21.02	$7,500,000	$17.20	$10,150,000	$23.28
Credits / Rebates / Incentives											
SDC Credits										$0	
TOTAL OWNER & DEVELOPMENT COSTS				$44,986,250	$103.18	$49,211,176	$112.87	$46,518,688.04	$106.69	$51,567,187	$118.27
TOTAL CONCEPTUAL FIRST COST:				$123,250,000	$282.67	$133,057,429	$305.17	$125,694,543	$288.28	$139,888,281	$320.83
New Office Building CONCEPTUAL PREMIUM RANGE:						5% TO	10%	0% TO	4%	11% TO	16%
Premium range without renewables:						1% TO	6%			6% TO	11%

NEW CONSTRUCTION APARTMENT

Building Location: Washington, DC
Base Building Gross SF: 426,511
Building Area without Garage: 329,164
Site Gross Acreage: 0.80

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
COSTRUCTION COST											
Baseline Building (Direct Cost of Work)				$73,591,978	$172.54	$73,591,978	$172.54	$73,591,978	$172.54	$73,591,978	$172.54
Baseline Building				$73,591,978	$172.54	$73,591,978	$172.54	$73,591,978	$172.54	$73,591,978	$172.54
ENERGY REDUCTION STRATEGIES											
Reduce window-to-wall ratio	35%		Unit Cost	$0	$0.00	($134,814)	($0.32)			($134,814)	($0.32)
At Precast & Punched Window Assembly											
Reduce window system 25%	(9,399)	sf	$65.00			($610,906)	($1.43)			($610,906)	($1.43)
Replace with precast & furring	9,399	sf	$47.00			$441,732	$1.04			$441,732	$1.04
At Curtainwall Assembly											
Add insu-lation and furring to 20% of vi-sion glass	3,436	sf	$10.00			$34,360	$0.08			$34,360	$0.08
Improved insulation			Unit Cost	$0	$0.00	$306,553	$0.72			$306,553	$0.72
R-13 to R-21 at spandrels, add 2" rigid	71,665	sf	$2.50			$179,163	$0.42			$179,163	$0.42
Rigid Wall Insulation - Roxul Cavity Rock at Precast	22,114	sf									

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Underslab Insulation at occupied spaces	28,506	sf									
Insulated Wall Panels	21,045	sf									
R-20-R-40 at roof, add 4" rigid	25,478	sf	$5.00			$127,390	$0.30			$127,390	$0.30
Lighting Upgrade			Unit Cost	$0	$0.00	$822,910	$1.93			$822,910	$1.93
Reduce LPD from 0.7 to 0.3	329,164	gsf	$2.50			$822,910	$1.93			$822,910	$1.93
Ground Source Heat Pump			Unit Cost	$0	$0.00	$1,354,230	$3.18			$1,354,230	$3.18
Baseline HVAC System Reduction											
Delete cooling towers & associated pumps	1	ls	($1,395,770)			($1,395,770)	($3.27)			($1,395,770)	($3.27)
Ground Source Heat Pump System, including:	1,100	tons	$2,500.00			$2,750,000	$6.45			$2,750,000	$6.45
Wells							$0.00			incl	$0.00
Well Piping							$0.00			incl	$0.00
Heat Exchangers & pumps							$0.00			incl	$0.00
Heat Pumps							$0.00			incl	$0.00
Controls							$0.00			incl	$0.00
Solar DHW			Unit Cost	$0	$0.00	$660,000	$1.55			$660,000	$1.55

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Provide 5,000 sf of Solar Hot Water Panels	329,164	sf	$2.01			$660,000	$1.55			$660,000	$1.55
(Panels only, utilize existing tanks and piping)											
Plug Load Manage-ment			Unit Cost	$0	$0.00	$108,624	$0.25			$108,624	$0.25
Plug load monitor-ing, cloud-based, 329 units	329,164	sf	$0.33			$108,624	$0.25			$108,624	$0.25
WATER REDUCTION STRATEGIES											
Storm-water Retention and/or In-filtration System			Unit Cost	$0	$0.00	$0	$0.00	$1,581,379	$3.71	$1,581,379	$3.71
Remove green roof to allow for water capture	(10,499)	sf	$20.00					($209,980)	($0.49)	($209,980)	($0.49)
Rain Har-vesting (piping & pumps & filtration)	426,511	gsf	$1.25					$533,139	$1.25	$533,139	$1.25
53,000 gallon rainwater cistern 30'x30'x10'								$78,600	$0.18	$78,600	$0.18
Concrete Tank Construction											
Walls and Footings	1,200	sf	$50.00								
SOG upgrade	900	sf	$2.00								

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Water-proofing	2,100	sf	$8.00								
Low Flow Fixtures	In-cluded in Baseline							$0		$0	
Mem-brane BioReac-tor								$795,760	$1.87	$795,760	$1.87
Graywater Reuse System (piping)	426,511	gsf	$0.60					$255,907	$0.60	$255,907	$0.60
Non chemical filtration	426,511	gsf	$0.30					$127,953	$0.30	$127,953	$0.30
RENEWABLE ENERGY STRATEGIES											
Increase PV area			Unit Cost	$0	$0.00	$1,745,870	$4.09			$1,745,870	$4.09
Add PV to existing avail-able roof structure	16,093	sf	$80.00			$1,287,440	$3.02			$1,287,440	$3.02
Additional PV at available sunshades	1,830	sf	$50.00			$91,500	$0.21			$91,500	$0.21
Additional PV at additional sunshades	4,077	sf	$50.00			$203,850	$0.48			$203,850	$0.48
Additional sunshades for addi-tional PV	1359	lf	$120.00			$163,080	$0.38			$163,080	$0.38
Meet To-tal Load with PV			Unit Cost	$0	$0.00	$6,328,475	$14.84			$6,576,475	$15.42
Add PV to additional theo-retical structure	79,106	sf	$80.00			$6,328,495	$14.84			$6,328,495	$14.84
Add PV to offset MBR demand	1,400	sf	$80.00							$248,000	$0.58

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Credits / Rebates / Incentives	Federal	REC/ MWh		$0	$0.00	($3,465,841)	($8.13)			($3,554,576)	($8.33)
PV Credits- (federal, state, city, utility)	30%	$470.00				($3,465,841)	($8.13)			($3,554,576)	($8.33)
Living Building Challenge Imperatives				$0	$0.00	$0	$0.00	$0	$0.00	$1,756,582	$4.12
Red List										$646,623	$1.52
Respon-sible Industry										$474,779	$1.11
Appro-priate Sourcing										$635,180	$1.49
Subtotal Direct Costs				$73,591,978	$172.54	$81,317,985	$190.66	$75,173,356.65	$176.25	$84,815,210	$198.86
General Conditions, Fee, Contingency, Insurance, Bonding				$9,008,022	$21.12	$9,780,623	$22.93	$9,166,160	$21.49	$11,077,946	$25.97
TOTAL MODIFIED CONSTRUCTION COST				$82,600,000	$193.66	$91,098,608	$213.59	$84,339,516.52	$197.74	$95,893,156	$224.83

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
OWNER & DEVELOPMENT COSTS											
Living Building Challenge Imperatives											
Habitat Exchange	0.80	acres								$3,227	$0.01
Embodied Carbon Footprint	15,000	tons								$300,000	$0.70
Inspira-tion and Education										$82,291	$0.19
Devel-opment Costs	LEED	LBC									
Develop-ment Costs	24.00%	22.83%		$28,320,000	$66.40	$30,453,805	$71.40	$29,507,532	$69.18	$31,125,042	$72.98
Archi-tecture & Engineer-ing	6.00%	6.57%		$7,080,000	$16.60	$8,027,500	$18.82	$7,800,000	$18.29	$8,960,000	$21.01
Credits / Reabates / Incentives											
SDC Credits										$0	
TOTAL OWNER & DEVELOPMENT COSTS				$35,400,000	$83.00	$38,481,305.07	$90.22	$37,307,532.31	$87.47	$40,470,560	$94.89
TOTAL CONCEPTUAL FIRST COST:				$118,000,000	$276.66	$129,579,913	$303.81	$121,647,049	$285.21	$136,363,716	$319.72
Multi-Family Residential Building CONCEPTUAL PREMIUM RANGE:						7% TO	12%	1% TO	6%	13% TO	18%
Premium range without renewables:						2% TO	7%			8% TO	13%

OFFICE RENOVATION

Building Location: Washington, DC

Base Building Gross SF: 235,172

Building Area without Garage: 185,487

Site Gross Acreage: 0.77

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
CONSTRUCTION COST											
Baseline Building (Direct Cost of Work)				$34,084,768	$144.94	$34,084,768	$144.94	$34,084,768	$144.94	$34,084,768	$144.94
Baseline Building				$34,084,768	$144.94	$34,084,768	$144.94	$34,084,768	$144.94	$34,084,768	$144.94
ENERGY REDUCTION STRATEGIES											
Improve window perfor-mance			Unit Cost	$0	$0.00	$821,540	$3.49			$821,540	$3.49
Decrease window U-value from 0.42 to 0.22											
Cur-tainwall - vision glazing	38,132	sf	$20.00			$762,640	$3.24			$762,640	$3.24
Punched Windows	2,945	sf	$20.00			$58,900	$0.25			$58,900	$0.25
Improved insulation			Unit Cost	$0	$0.00	$89,685	$0.38			$89,685	$0.38
R-11 to R-26 at span-drels, add 2” rigid	9,104	sf	$2.50			$22,760	$0.10			$22,760	$0.10
R-26-R-40 at roof, add 4” rigid	13,385	sf	$5.00			$66,925	$0.28			$66,925	$0.28
Lighting Upgrade			Unit Cost	$0	$0.00	$463,718	$1.97			$463,718	$1.97
Reduce LPD from 0.7 to 0.3	185,487	gsf	$2.50			$463,718	$1.97			$463,718	$1.97
Ground Source Heat Pump			Unit Cost	$0	$0.00	$680,644	$2.89			$680,644	$2.89

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	**Cost/ SF**	**Total**	**Cost/ SF**	**Total**	**Cost/ SF**	**Total**	**Cost/ SF**
Baseline HVAC System Reduction											
Delete chillers, VAV boxes, cooling towers & associ-ated pumps						($1,239,356)	($5.27)			($1,239,356)	($5.27)
Ground Source Heat Pump System, including:	640	tons	$3,000.00			$1,920,000	$8.16			$1,920,000	$8.16
Wells							$0.00			incl	$0.00
Well Piping							$0.00			incl	$0.00
Heat Ex-changers & Pumps							$0.00			incl	$0.00
Heat Pumps							$0.00			incl	$0.00
Controls							$0.00			incl	$0.00
			Unit Cost								
Variable Refriger-ant Flow System (Option)	$425,355	(Includes Indirects, Design & Owner Costs)									
Plug Load Manage-ment			Unit Cost	$0	$0.00	$83,469	$0.35			$83,469	$0.35
Plug load moni-toring, cloud-based	185,487	gsf office	$0.45			$83,469	$0.35			$83,469	$0.35
WATER REDUCTION STRATEGIES											
Storm-water Retention and/or Infiltra-tion System			Unit Cost	$0	$0.00			$1,474,980	$6.27	$1,474,980	$6.27

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
No green roof in baseline	0	sf	$0.00					$0		$0	
Rain Harvesting (piping & pumps & filtration)	235,172	gsf	$1.25					$293,965	$1.25	$293,965	$1.25
55,000 gallon rainwater cistern 30'x30'x10'								$78,600	$0.33	$78,600	$0.33
Concrete Tank Construction											
Walls and Footings	1,200	sf	$50.00								
SOG upgrade	900	sf	$2.00								
Waterproofing	2,100	sf	$8.00								
Low Flow Fixtures	Included in Baseline							$0		$0	
Membrane BioReactor								$890,760	$3.79	$890,760	$3.79
Graywater Reuse System (piping)	235,172	gsf	$0.60					$141,103	$0.60	$141,103	$0.60
Non chemical filtration	235,172	gsf	$0.30					$70,552	$0.30	$70,552	$0.30
RENEWABLE ENERGY STRATEGIES											
Increase PV area			Unit Cost	$0	$0.00	$1,761,920	$7.49			$1,761,920	$7.49
Add PV to existing available roof structure	8,040	sf	$80.00			$643,200	$2.74			$643,200	$2.74

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Additional PV at available sunshades (West side only)	3,442	sf	$50.00			$172,100	$0.73			$172,100	$0.73
Additional PV at additional sunshades	10,518	sf	$50.00			$525,900	$2.24			$525,900	$2.24
Additional sunshades for additional PV	3506	lf	$120.00			$420,720	$1.79			$420,720	$1.79
Meet Total Load with PV			Unit Cost	$0	$0.00	$4,304,382	$18.30			$4,528,382	$19.26
Add PV to additional theoretical structure	53,805	sf	$80.00			$4,304,382	$18.30			$4,304,382	$18.30
Add PV to offset MBR demand	1,100	sf	$80.00							$224,000	$0.95
Credits / Rebates / Incentives	**Federal**	**REC/ MWh**		$0	$0.00	($2,602,287)	($11.07)			($2,680,955)	($11.40)
PV Credits-(federal, state, city, utility)	30%	$470.00				($2,602,287)	($11.07)			($2,680,955)	($11.40)
Living Building Challenge Imperatives				$0	$0.00	$0	$0.00	$0	$0.00	$1,074,873	$4.96
Red List										$285,905	$1.22
Responsible Industry										$133,718	$0.57

	Quantities		Unit Cost	LEED™ Platinum Baseline		Net Zero Energy		Net Zero Water		Living Building	
				Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF	Total	Cost/ SF
Appro-priate Sourcing										$317,250	$1.35
Conser-vation and Reuse										$338,000	$1.82
Subtotal Direct Costs				$34,084,768	$144.94	$39,687,838	$168.76	$35,559,747.80	$151.21	$42,383,023	$180.61
General Conditions, Fee, Contingency, Insurance, Bonding				$4,444,559	$18.90	$5,004,866	$21.28	$4,592,057	$19.53	$5,449,385	$23.17
TOTAL MODIFIED CONSTRUCTION COST				$38,529,327	$163.83	$44,692,704	$190.04	$40,151,804.78	$170.73	$47,832,408	$203.78

OWNER & DEVELOPMENT COSTS											
Living Building Challenge Imperatives											
Habitat Exchange	0.77	acres								$3,104	$0.01
Embodied Carbon Footprint	10,000	tons								$200,000	$0.85
Inspira-tion and Education										$46,372	$0.20
Devel-opment Costs	LEED	LBC									
Develop-ment Costs	30.61%	29.90%		$18,000,000	$76.54	$20,880,000	$88.79	$18,900,000	$80.37	$21,960,000	$93.38
Archi-tecture & Engineer-ing	3.85%	4.63%		$2,266,388	$9.64	$2,832,985	$12.05	$2,493,027	$10.60	$3,399,582	$14.46
Credits / Rebates / Incentives											
SDC Credits										$0	
TOTAL OWNER & DEVELOPMENT COSTS				$20,266,388	$86.18	$23,712,985	$100.83	$21,393,027	$90.97	$25,609,058	$108.90
TOTAL CONCEPTUAL FIRST COST:				$58,795,715	$250.01	$68,405,689	$290.88	$61,544,832	$261.70	$73,441,466	$312.29
Office Building Renovation CONCEPTUAL PREMIUM RANGE:						14% TO	19%	2% TO	7%	22% TO	27%
Premium range without renewables:						7% TO	12%			16% TO	21%

ENERGY POLICY RECOMMENDATIONS

INTRODUCTION

Communities are facing the very real threat of climate change. Resiliency during severe weather events or power outages is becoming more of a concern for residents and policy makers alike. Since buildings consume approximately 40% of fossil fuels nationwide, and represent approximately 75% of the carbon emissions in the District, they are a critical component to curbing climate change. Energy efficiency, renewable energy systems and district energy approaches are proven ways to address these challenges while creating jobs and economic opportunities within communities.

The Sustainable DC Plan lays out a path to make the District the healthiest, greenest and most livable city in the nation. The plan sets goals for sustainable solutions in categories of built environment, energy, food, nature, transportation, waste and water. In order to achieve the aggressive goals in the Sustainable DC Plan, the District will need to revise its policy infrastructure to eliminate barriers, fill gaps and incentivize movement toward these ambitious goals.

While the Sustainable DC Plan lays a path, there is also a complex framework of codes, policies and regulations that impact the energy and water consumption of buildings in the District. This section briefly summarizes the regulatory framework most relevant to net zero energy, net zero water and Living Buildings. It also builds on the lessons learned in this research study to recommend a future course of action that stimulates sustainable economic development and contributes to the achievement of the District's goals.

EXISTING ENERGY POLICY FRAMEWORK

Key elements of some major energy policy drivers are outlined briefly below.

Sustainable DC Plan.[8] Initiated in 2011, the Sustainable DC Plan lays out an approach to make the District the healthiest, greenest and most livable city in the nation within the next 20 years. The Sustainable DC Plan has an ambitious goal to cut citywide energy use by 50% by 2032 from the 2010 baseline and increase the use of renewable energy to make up 50% of the District's energy supply. Because buildings are so prominent in the energy use profile of the District, steep reductions in the energy use of new and existing buildings will be necessary to meet this goal.

Green Building Act of 2006.[9] The Green Building Act requires a minimum of LEED Silver certification for all public new construction and substantial improvement commercial projects (LEED Gold for schools), and Enterprise Green Communities certification for similar publically supported multifamily residential projects 10,000 square feet and larger. For the private sector, the Act requires all new construction and substantial improvement commercial projects 50,000 square feet and larger to be a minimum of LEED Certified. Amendments to the Act in 2008 also require the public

8 http://sustainable.dc.gov/finalplan
9 http://green.dc.gov/publication/green-building-act-2006

disclosure of energy benchmarking data for public buildings 10,000 square feet and larger and for private buildings 50,000 square feet and larger.

Energy Codes.[10] In February 2008, the District overhauled its building codes to include greater energy efficiency by incorporating the 2006 International Energy Conservation Code (IECC) standard with stronger local amendments. ASHRAE 90.1-2007 is considered an alternative compliance method. More recently, the District is moving toward adoption of the 2012 IECC and an amended version of the new 2012 International Green Construction Code (IgCC).

Net Metering.[11] Net metering regulations in the District allow for reimbursement of onsite renewable energy production. The policy has a 100 kW threshold for retail rate payments for systems, above which reimbursement rates fall to lower generation rates. The net metering policy also has an absolute 5 MW limit on system size. Net metering opportunities have been expanded through the recently approved Community Renewables Energy Act of 2013 to allow for "virtual" net metering.

Building Height Restrictions. The Height of Buildings Act of 1899[12] sets maximum building heights, thereby increasing demand for maximizing Floor Area Ratio (FAR) in the District. This places a large quantity of building square footage under a limited amount of roof area that can host renewable energy production. This makes it challenging given today's technology to serve the remaining energy loads with onsite renewable production at the building level. A district energy approach may be needed to compliment single building energy efficiency and onsite renewable energy to achieve net zero energy across the District.

Historic Buildings. As the nation's capital, the District is home to numerous historic buildings covered under the Historic Landmark and Historic District Protection Act (1978)[13] and the National Historic Preservation Act.[14] The approximately 50 historic districts and more than 800 individually designated historic buildings present a challenge for both energy efficiency and renewable energy production.

Protecting the historic integrity and character-defining features of a building can limit the scope of retrofits that can be undertaken. While many pre-war historic buildings have passive design features that can foster energy efficiency, improving the energy efficiency of historic buildings can also be challenging because efficiency measures may not impact the visual appearance of the building in a way that is incompatible with its historic designation.

Historic district regulations also generally prohibit alterations that are visible from the public right of way, thereby limiting some opportunities for renewable energy installations. This issue will only be intensified as more and more buildings cross the 50-year age threshold after which buildings can be considered historic. This is especially a concern as the energy inefficient designs of the 1960s through the 1980s become subject to historic designation.

10 http://www.energycodes.gov/adoption/states/washington-dc
11 http://www.dcregs.dc.gov/Gateway/FinalAdoptionHome.aspx?RuleVersionID=3604731
12 http://dccode.org/simple/sections/6-601.05.html
13 http://www.dc.gov/OP/HP/DC%20Pres%20Law%20PDF/DC_Preservation_Law_%20UPDATED_%20August_%202010.pdf
14 http://www.cr.nps.gov/local-law/nhpa1966.htm

DC Sustainable Energy Utility (DC SEU).[15] The DC SEU helps DC residents and businesses use less energy and save money. It delivers financial incentives, technical assistance and information to commercial and residential buildings for equipment upgrades, major renovations and new construction projects.

DC PACE Commercial.[16] The DC PACE Commercial program provides attractive financial options to help commercial property owners implement energy efficiency and water conservation improvements. It provides long-term financing that is repaid through special tax assessments that are attached to the property.

POLICIES TO ENCOURAGE NET ZERO ENERGY

We have found the District has several progressive policies that will help support the advancement of the net zero energy goal, but additional policy approaches should be evaluated and integrated into existing and new policies to ensure a smoother and more rapid transition to net zero buildings.

OVERARCHING THEMES

Significant change in the building stock toward net zero energy is possible. Already, net zero energy has become a powerful tool to encourage highly efficient buildings served by renewable energy sources. Reaching energy and climate goals will require that the District create a framework around the following key themes:

- **Focus on energy efficiency -** Because the cost of most energy efficiency strategies is less than the cost of renewables, ensuring that maximum levels of energy efficiency are achieved is critical to cost-effective net zero energy performance.
- **Encourage Renewable Energy Systems -** While emphasizing the fundamental role of reducing energy consumption as the foundation of net zero buildings, the District also needs to continue encouraging the use of renewable energy systems such as photovoltaic solar panels, solar thermal systems, biogas, etc. Advancements and cost reductions in onsite technologies will help cover the gap between building energy consumption and net zero energy performance.
- **Consider District Approaches -** Given the size of buildings in the District, current renewable technologies will sometimes not generate enough energy to meet the demand of most medium and large buildings. Instead, the District should pursue policies that encourage 'scale jumping' beyond the building site, such as the recently enacted Community Renewables Energy Act of 2013.

Keeping these themes in mind, the following recommendations provide guidance to policy makers in the District to deploy net zero energy projects.

15 http://www.dcseu.com/
16 http://www.dcpace.com/

RECOMMENDATION 1 - DEFINE NET ZERO ENERGY

For policy goals to be successful, they must be clearly defined and achievable. Net zero energy is not a clearly defined term nationally or locally within the District. In fact, there are several net zero energy definitions used in the U.S. that define net zero energy achievement in unique ways and result in widely divergent performance outcomes for those buildings designated under the definitions. Policy makers are in a position to thoughtfully define net zero energy so that it is technically feasible, clear and achievable. Building owners need to know that the decisions they are making with their design teams and consultants will actually lead to meeting the net zero goals set by the District.

Several considerations become important for policy makers when defining net zero:

Focus on efficiency. Any net zero energy definition should emphasize the importance of energy efficiency and clarify expectations with regard to a healthy balance of renewable energy. One approach policy makers can use to encourage deep energy efficiency is to create outcome-based energy targets set within an EUI-based framework. These are explained further in Recommendation 2.

Predicted versus measured performance. Research shows that modeled energy results often do not predict actual measured energy performance in high performance buildings.[17] This might be because the building is used differently than expected or that systems are not working as efficiently as predicted during design. To ensure that the District achieves its aggressive energy goals, the definition of net zero should use measured performance data on both energy use and energy production.

The boundary included in the definition. The boundary condition defines specific pieces that are considered when evaluating net zero. For example, in the European Union 'nearly net-zero buildings' sometimes refers only to regulated loads (i.e. envelope, mechanical, lighting and domestic hot water) and excludes plug loads. However, it is clear that plug loads are becoming an increasingly large proportion of energy use[18] in high performance

The International Living Future Institute[19] is organizing Living Communities to not only meet the energy, water and vehicle emission targets of the Architecture 2030 program, but also to achieve the performance of the Living Building Challenge at the neighborhood and, ultimately, city scale. The added focus on human health, materials, habitat restoration, equity and beauty represents an opportunity for communities to go beyond simple building level sustainability, and provide community resilience and regenerate ecological and social systems.

17 http://newbuildings.org/index.php?q=energy-performance-leed-new-construction-buildings
18 http://newbuildings.org/sites/default/files/PlugLoadBestPracticesGuide.pdf
19 www.living-future.org

buildings and warrant attention in any definition. Definitions of net zero energy should include all energy used in the building.

As uncovered and explained in this research, the size and scale of buildings in the District create challenges for achieving net zero at the building level. Policy makers should carefully consider whether policy approaches should encourage Living Communities where energy (and water) resources are shared within a defined boundary. Therefore, instead of an individual building goal, the District might choose to recast alternative goals on levels such as adjacent building partners, neighborhoods, campuses or Ecodistricts.

District energy systems offer a creative solution that has been proven to work in the District and other urban areas. District energy systems can allow for buildings to be directly interconnected. For example, the waste energy from commercial cooling or process loads during the day can be utilized for space heating and/or domestic hot water in residential buildings in the evening. Individual buildings can benefit from the economies of scale of central utility plants. New district energy systems could be powered exclusively by renewable energy, which could help alleviate the pressure on building sites to accommodate sufficient onsite renewable energy systems. A district energy system could also be defined as a renewable energy system shared by multiple buildings through virtual net metering.

Time period for achieving net zero. Net zero energy doesn't necessarily mean 'off the grid.' Instead, some buildings will rely on grid-source energy during certain periods in the year when their renewable production does not meet their demand, then make up for that grid energy consumption when the renewable generation increases above the energy consumption levels. Since net zero may not be achievable each day, week or month, policy makers should consider making the time horizon one year for defining net zero.

Renewable Sources. Policy makers should clearly define what are considered renewable sources of energy and include a healthy balance between minimum energy efficiency requirements and renewable energy production. Renewable sources should include those defined in the International Energy Conservation Code (IECC)—photovoltaic solar panels, solar thermal, wind and biogas. As these sources become more efficient and cost-effective, they will bridge the gap between building energy use and energy production, moving the District toward its citywide net zero goals.

Natural Gas. The Living Building Challenge prohibits combustion on site, including the use of natural gas or biogas for energy generation. While there is great debate and complexity about climate change and natural gas consumption, there may be limited options in the short term for using natural gas efficiently, potentially as a bridge strategy for an interim period only.

RECOMMENDATION 2 - ENCOURAGE TRANSITION TO OUTCOME-BASED ENERGY TARGETS

Outcome-based energy targets set within an EUI-based energy scale framework can promote progress toward increasing energy efficiency and achieving net zero energy goals. Specific targets set a clear energy metric and create interim energy efficiency goals for building owners to achieve. The ZEPI (Zero Energy Performance Index) in the IgCC is one such scale that might be considered. Since different building types use different amounts of energy per square foot, any metric will need to accommodate various building use types. When high energy consumption is a consequence of the building's use and not attributable to inefficiencies, it should not be penalized. For example, building types such as research laboratories, commercial kitchens and hospitals use much more energy per square foot than others such as offices and schools; therefore, targets for labs, kitchens and hospitals would be set higher.

The District can use measured performance energy data from benchmarking and disclosure ordinances to establish District-specific baselines. It is anticipated that a predicted energy outcome scale will also be developed for LEED within the next few versions. Targets based on experience in actual buildings are useful for both policy makers and owners alike in evaluating progress toward a more efficient building stock and net zero energy.

Once outcome-based energy targets have been set within the scale framework, the District could implement some or all of the following policies, depending on political will and market acceptance:

Recognition program. The best performing buildings in the District could be publicly identified and celebrated. Building on the many examples throughout the United States, the District could adapt a model for net zero recognition in order to hail the efforts of progressive owners and developers. Conversely, the worst-performing buildings could also be identified to provide incentive to improve.

Minimum performance requirements for buildings. The District can mirror existing requirements for LEED or other green goals in buildings by requiring minimum ratings on the scale for new

While an Energy Star score uses building-specific monthly energy bills and information like building use and size, it relies on a national average source conversion factor rather than a District-specific conversion factor to develop a score. Additionally, an Energy Star score represents a statistical comparison of energy use to the median consumption of the 2003 Commercial Building Energy Consumption Survey (CBECS) dataset. These factors mean that incremental improvements in Energy Star scores do not necessarily correspond to consistent improvements in energy performance. This makes it problematic to rely on the Energy Star scale to track progress toward the ultimate goal of net zero energy or carbon neutrality. Instead, the recommendation is to focus on the site EUI as reported in the Energy Star Statement of Energy Performance, which is already a reporting requirement in the District.

construction, major renovations and even for existing buildings. Over time, requirements such as this can be adjusted to meet the District's goals, including net zero energy.

Property tax breaks. The District can institute a special property tax rate for buildings that achieve a certain EUI rating over a period of time.

Energy rate breaks. Working through the Public Service Commission, the District could institute a lower utility rate for buildings that achieve a certain rating on the energy scale.

"Fee-Bates." Buildings that achieve the best rating on the scale could have some or all of their fees returned. This would also create a direct connection between the green-related fees and their purpose, by returning them to deep green building owners.

Code citations. The District has adopted the International Property Maintenance Code (IPMC) that requires that buildings maintain a certain set of minimum standards. The code is enforced with citations. Extremely poor energy performance is likely to accompany other poor conditions, so the addition of an energy element to the IPMC could help more aggressively address those properties that waste the most energy in the District. A proposal for targeting high energy usage levels (e.g., the bottom quartile of energy performance within any building type class based on CBECS) was submitted by New Buildings Institute to the 2015 International Property Maintenance Code. The District can amend their adoption of the IPMC to include this provision.

Mandated outcome-based targets suffer the challenge of enforcement after issuance of the certificate of occupancy. This challenge may need to be addressed by existing or new District statutory authority, providing a temporary certificate of occupancy that expires after a period of one to three years, or it may be in accordance with the proposed Green Construction Code requirements for commissioning. Financial mechanisms such as requiring performance bonds could help ensure measured performance outcomes.

RECOMMENDATION 3 - PROMOTE THE EVOLUTION OF ENERGY CODES

Despite advancements in energy codes, without fundamental alterations, current codes may not facilitate net zero energy for a number of reasons. First, codes do not regulate all energy use in a building and the unregulated loads are becoming an increasingly large portion of total energy consumption. Additionally, as NBI's Sensitivity Analysis suggests[20], codes only regulate the design aspect of buildings, yet operations, maintenance and occupants have a significant impact on ongoing energy use. Also, code compliance can be established by prescriptive measures such as insulation levels, window performance and equipment efficiency. However these elements may omit many elements of building design that have a significant impact on energy use, such as orientation and massing. Finally, current codes allow the use of energy modeling to demonstrate compliance, however, varying assumptions lead to different results and may not accurately predict net zero outcomes.

20 http://newbuildings.org/sensitivity-analysis-comparing-impact-design-operation-and-tenant-behavior-building-energy-performan

While it may seem counterintuitive, codes do not always encourage the most efficient building possible. For example, buildings with an efficient air conditioning system may perform much "better than code" compared to a passive building designed to eliminate the need for air conditioning through the use of thermal mass, shading and natural ventilation. This is because in code modeling, a passive building is compared to a hypothetical building with no air conditioning, while a building with an efficient air conditioning system is compared to a building with the least efficient system that can legally be installed under the code. In other words, under current codes, the savings from passive systems may not be realized even though those systems use less energy than a building with efficient mechanical systems.

Transitioning to an outcome-based metric will help address this problem. The District is in a position to be a strong advocate for the evolution of energy codes. While it is unlikely that the District would ever create its own code, it can be quite influential in the process by continuing to participate in the development of national model codes. Specific topics to encourage include:

Encourage usage-based codes. With experience from the benchmarking and disclosure regulations, the District can help establish a usage-based energy code that would set actual energy consumption levels as the code compliance threshold. This could eventually be an alternative compliance path or replace the prescriptive approach now in effect. These alternative compliance paths are being piloted in Seattle, Washington and Vancouver, British Columbia, Canada.

Federal preemption. The federal law guiding minimum HVAC equipment efficiency requirements does not allow state and local jurisdictions to set higher standards in their energy codes. This situation significantly limits the ability of state and local jurisdictions to achieve their energy policy goals by depriving them of one of the more effective measures for improving efficiency in buildings. Federal minimums are important, but the District should support the ability to set local requirements that exceed the federal minimums if, and when, the decision comes before Congress. In the interim, if classified as a state for this purpose, the District should seek a waiver for setting requirements on "covered products" from the Secretary of Energy under 42 USC SEC 6297 (d).

RECOMMENDATION 4 – ADVANCE INCENTIVES FOR ENERGY EFFICIENCY

Incentive programs and technical assistance can reduce the risks inherent in piloting new approaches to design and construction. It is also important to realize that ultra-low energy and net zero energy buildings may rely on passive strategies that are difficult to incentivize since they can actually eliminate the need for systems. As noted earlier, plug loads controlled by occupants and quality operations after occupancy can also be an issue for programs.

These limitations on the current incentive structure challenge utilities and public purpose funds administrators to look beyond technology-based incentives and consider incentives that pay based on actual energy performance. Currently most energy efficiency incentive programs do not have a strong tie to actual performance. Since net zero energy is ultimately a goal grounded in actual performance, the disconnect between the incentive program and actual performance creates a corresponding disconnect between the incentive program and net zero energy.

The District or the DC SEU might consider a pilot program that incentivizes deep energy savings and advancement toward net zero energy. These pilot programs may present challenges for meeting current cost-effectiveness criteria for utility programs. However, policy makers might consider suspending these requirements and allowing packages of measures to meet both energy and cost-effectiveness goals, instead of the typical measure-by-measure approach.

In addition to multi-year incentive programs and integrated, whole-building measures, another specific way to promote deep retrofits could be to incentivize design team and utility technical staff participation in early design charrettes. In the evaluation of the Energy Trust of Oregon Net Zero pilot program,[21] this was cited as an effective strategy to promote an integrated design process that encourages appropriate building orientation, passive strategies for the reduction of internal energy loads, and the installation of smaller and more efficient HVAC equipment. Hosting these meetings very early in design is one proven way to influence the overall design of the building and impact its ongoing energy use for years to come. At this meeting, an energy budget can be established to help guide decisions throughout design, construction and value engineering. The outcome-based energy target is integral to guiding the design team toward aggressive energy efficiency. Incentives can dovetail with achievement of certain thresholds of performance via modeling and/or actual measured performance.

Finally, advanced incentive programs can mandate monitoring and reporting on the measured performance of the projects. Incentives might be structured to pay a portion of the incentive over time, as performance levels are achieved and verified. Clarifying these requirements and ensuring the systems are in place to collect and report the data is crucial to success. EPA and utilities (such as in New Jersey) are running pilots on these pay-for-performance programs.

RECOMMENDATION 5 - REVISE NET METERING POLICIES AND ACKNOWLEDGE THE CHANGING ROLE OF UTILITIES

A policy should be pursued that recognizes the benefits that all renewable energy generated on site contributes towards net zero energy goals. The District's net metering limit is a potential barrier to net zero energy. While the "net" part of the metering allows for reimbursement at the retail rate, above 100kW reimbursement rates fall to the much lower generation rates. Many buildings are going to require systems larger than 100kW in order for them to achieve net zero energy.

Long term, the District's regulated electricity utility, Potomac Electric Power Company (Pepco), will also need to address a reality of a customer base with a large population of net zero buildings and communities. A revenue model based on transmission charges tied to energy consumption will become increasingly unsustainable as net consumption drops. Pepco will likely need to move to

21 http://energytrust.org/library/reports/121204_PTNZ_Report.pdf

a different revenue model such as a flat connection rate based on service size. This is a medium-term challenge faced by energy utilities across the country.

RECOMMENDATION 6 - BALANCE COMPETING GOALS

Base energy codes, stretch energy codes and green building systems are in a state of periodic or continuous updating. At some point in the cycles, an "advanced" standard may have little or no energy savings over the most recent base codes. This situation could provide sub-optimal goals for the District's green goals.

Green building standards are not always strong on energy efficiency, yet even these compete with other green building considerations for attention and resources. The International Green Construction Code (IgCC) only requires performance 10% better than the 2012 IECC. ASHRAE Standard 189.1 only requires an improvement of about 10% over ASHRAE Standard 90.1. LEED prerequisites only require 10% efficiency improvement over ASHRAE Standard 90.1.

The District might specify that a minimum number of points (such as 10) come from the Energy and Atmosphere section or a minimum improvement over the baseline (such as 30%) in order to push LEED projects to prioritize energy as they select which points to pursue. Green building goals should also require verification of actual performance achieved.

SUMMARY OF ENERGY POLICY RECOMMENDATIONS

The District has the policy infrastructure and organizational motivation to develop and advance net zero energy goals and provide a roadmap for successful implementation over time. And by expanding and deepening the definition of net zero energy to include district energy systems, the District will provide pathways to assist owners and developers in successful implementation of net zero by investigating approaches that may be more optimal than those just relying on single buildings.

The District should create an overarching framework that emphasizes the fundamental role of reducing energy consumption and encourages a healthy balance of renewable energy. This new and ambitious program must be developed in a comprehensive and holistic manner in order to steer policies, codes and incentives toward the same desired outcomes.

WATER POLICY RECOMMENDATIONS

INTRODUCTION

The District of Columbia's water supply comes from the Potomac River near Great Falls, is treated at the Dalecarlia Reservoir by the Washington Aqueduct (a division of the U.S. Army Corps of Engineers) and is then sold to DC Water, the public water utility for the city. That water is then pumped to reservoirs all over the city. The reservoirs are located at different elevations and supply water to points below them. From those reservoirs, the water flows downhill to houses and businesses.

Increased water usage from the Potomac could lower levels below the depth that streamside or wetland vegetation needs to survive. The overall effect is a loss of riparian vegetation and wildlife habitat.

In addition, saltwater intrusion also poses a threat to water quality in the District. All of the water in the ground is not fresh water; much of the very deep groundwater and water below oceans is saline. In fact, an estimated 3.1 million cubic miles (12.9 cubic kilometers) of saline groundwater exists on the globe compared to about 2.6 million cubic miles (10.5 million cubic kilometers) of fresh groundwater.[22] Under natural conditions, the boundary between the freshwater and saltwater tends to be relatively stable, but pumping can cause saltwater to migrate inland and upward, resulting in saltwater contamination of the water supply.

In parts of the Mid-Atlantic, pumping water for domestic supply has lowered the water table, reduced or eliminated the base flow of streams, and caused saline groundwater to move inland. The District is situated right on the edge of the "fall line" between the coastal and interior zones of groundwater[23] and is therefore vulnerable to changes in climate, sea level rise and regional water cycle changes.

More than 34 miles of rivers and streams in and around the District of Columbia do not support swimming and diverse aquatic life because of historical toxicity and stormwater pollution.

EXISTING WATER POLICY FRAMEWORK

To address the stormwater pollution problem, DDOE issued new regulations in the summer of 2013. Under the regulations, activities that disturb 5,000 square feet (SF) or greater of land area must retain the volume from the 1.2 inch storm. Major substantial improvement activities, where the combined footprint of improved buildings and land-disturbance is 5,000 SF or greater and the cost of the activity equals or exceeds 50% of the pre-project assessed value of the structure, must retain the volume from the 0.8 inch storm.

22 Gleick, P. H., 1996: "Water resources". In *Encyclopedia of Climate and Weather*, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp. 817-823

23 Watt, M.H., O'Connor, James V. O., Truong, Hung V., and Marks, Willie D. 1984. *Groundwater Problems in the Mid-Atlantic Fall Line Cities*. University of the District of Columbia.

To provide regulated sites with flexibility in meeting these requirements and other properties with incentives for voluntarily installing best management practices (BMPs), the District created an innovative trading program. Through the Stormwater Retention Credit (SRC) trading program, regulated sites may achieve 50% of their required stormwater retention volume offsite, using privately tradable SRCs generated by other properties that either exceed their regulatory requirements for retaining stormwater or achieve retention beyond the baseline for the property. Regulated sites may also achieve their retention volume through payments of an in-lieu fee. DDOE expects SRCs to be more cost-effective than in-lieu fee payments.

Approximately 43% of the District's land area is composed of rooftops, parking lots, and other impervious surfaces, and only 1% of the District's land area would trigger these regulations in a typical year. Therefore, property owners who do not trigger the regulations will have tremendous opportunity to voluntarily retrofit their properties in order to generate SRCs for sale.

By creating a market for stormwater retrofits on properties that otherwise would not be retrofitted in the near future, SRC trading offers a range of impressive sustainability benefits. In addition to having the potential to reduce compliance costs and maximize flexibility for regulated sites, SRC trading can result in a significant increase in total stormwater retention in the District and provide other benefits to District water bodies, when compared to strictly requiring regulated sites to achieve retention on site. By increasing the installation of green infrastructure, SRC trading can also provide other sustainability benefits, including new job opportunities, improved community health, and attractive new green spaces across the city.[24] It is a great example of "scale jumping," or finding a solution to a problem at the scale of the system. Community-wide stormwater system improvements require a community-wide solution.

POLICIES TO ENCOURAGE NET ZERO WATER

OVERARCHING THEMES

Now is the perfect moment to ask if there isn't a better way to manage water systems. The International Living Future Institute has performed extensive research in the area of net zero water, partnering with regional governments, health departments and other stakeholders to create a water infrastructure road map for the 21st century.

When planning for new or upgraded water infrastructure, local communities have the opportunity to choose systems at a variety of different scales that are adaptable and resilient.

Resilient Water Systems:

- enable conservation practices through education, water audits and full-cost pricing of water;
- do not require potable water for every use;

24 http://green.dc.gov/release/district-proposes-new-river-protecting-stormwater-management-standards

- take into consideration the life-cycle impacts of water collection, conveyance, treatment and discharge back into the environment;
- recover water and nutrients from the wastewater stream;
- manage risks in light of long-term ecosystem health and population growth.

The District should promote integrated water systems that recognize the interconnected nature of water, stormwater and "waste" water management, and evaluate solutions as well as costs and benefits of the entire system (rather than in isolation). Integrated approaches can be used to reduce the burden on existing systems and provide guidance for communities planning new infrastructure to serve their growing populations.

Integrated Water Systems:

- provide education to residents and businesses about how to use water wisely;
- manage demand via high efficiency fixtures and other conservation strategies;
- augment existing resources through rainwater harvesting and water reuse;
- treat water only as needed for its application;
- manage stormwater and wastewater discharge at a diversity of scales;
- recover resources from the waste stream.

SUMMARY OF WATER POLICY RECOMMENDATIONS

1. Establish a shared vision of how the District's water system will serve people and the planet: Local communities need safe drinking water, responsible wastewater treatment, and effective stormwater management over the long term. The public and regulatory agencies are demanding environmental protections at increasing levels of stringency. The government should raise awareness about the viability of the community's water systems in light of climate change, growing population and aging infrastructure.

- The District should identify and convene key stakeholders in local water systems and engage them in discussions around the risks and opportunities associated with possible water system alternatives at varying scales. Key stakeholders may include present and future system users, environmental and business interests, community groups, public health agencies, utilities, plumbers, builders, and system designers (engineers, architects, landscape architects, public artists).
- Rainwater harvesting, storage, and greywater reuse systems increase the costs of construction of 1% to 3% or between $3.80 and $7.85 per square foot and dramatically reduce the water needs and waste and water discharge of the buildings studied (reductions of 45-60%). This translates

into around 10 to 21 years simple payback period given the District's current price and incentive structure for water. The District should analyze the true cost of providing water to determine the actual return on investment of water efficiency.

2. Create incentives and remove barriers for relatively low-cost, but high-impact water efficiency and net zero water strategies:

- Promote the use of lower-technology and lower-cost but high-benefit strategies like greywater reuse, rainwater capture, constructed wetlands and water efficiency whenever possible.
- Rainwater harvesting, storage, and greywater reuse systems increased the costs of construction less than one percent, or around $2 per square foot, and dramatically reduced the water needs and waste and water discharge of the buildings studied (reductions of 45-60%). This translates into around 12 to 14 years simple payback period given the District's current price structure for water. The District should analyze the true cost of providing water to determine the actual return on investment of
water efficiency.
- Conduct a detailed comparison of the cost/benefits of building scale strategies combined with or in lieu of infrastructure scale upgrades.
- Consider incentives for mixed-use buildings and districts that can balance greywater creation and use.

3. Water and Energy Nexus. The District should consider the connection between water and energy when making policy decisions.

- Solve water quantity and quality issues at a system scale to avoid expensive and high-energy technologies for use in individual buildings.
- Relentlessly require gravity-only systems for moving water and waste around the city, and research opportunities for distributed treatment to reduce the amount of energy used for water and waste systems.

Additional water policy resources can be found at www.living-future.org

LIVING BUILDING CHALLENGE POLICY RECOMMENDATIONS

A paradigm shift is underway in how buildings and developments are designed and built. Long-held assumptions on which much current regulatory thinking is based are no longer valid. These assumptions are that we will continue to have adequate supplies of affordable energy, fresh water and other key resources, a stable and predictable climate, and that the natural systems on the planet are robust enough to withstand the growing level of human impact. Increasing evidence of the falseness of these assumptions obligates us to take action.[25]

The impacts of building and development contribute substantially to environmental crises, and arise throughout the life cycle of built projects. The impacts begin far from the building site and long before the building exists, and they extend far beyond the site and the life of the building. The impacts emerge during the acquisition of resources and their transportation and processing. They include impacts on the land and natural systems at the site, and related impacts that infrastructure projects typically create. Impacts occur during construction and throughout the life of a building to maintain, repair, heat, cool, ventilate, illuminate, remodel, and eventually recycle, dismantle and dispose of a building. Only a small fraction of those impacts are regulated.

LIVING BUILDING CHALLENGE RECOMMENDATIONS:

The following summary of the recommendations is broadly organized, beginning with those that can likely be implemented in the short term in order to support the goals of the Living Building Challenge, and extending to strategies for addressing systemic barriers that will require larger and longer-term processes.

1. Identify and address regulatory impediments to green building and development:

- Provide regulatory support for energy and water conservation and demand management.
- Analyze the true cost of providing a gallon of water and removing a gallon of stormwater from a property in the District. See the white paper *Valuing water to drive more effective decisions*.[26]
- Develop protocols and systems for third-party monitoring, operations, and maintenance service delivery for onsite water supply and treatment; regulatory provisions that restrict onsite rainwater harvesting should be updated to encourage this practice where appropriate.
- Eliminate zoning and utility regulatory barriers to viable site and district renewable energy and water system opportunities in relation to centralized alternatives.
- Update building and energy codes and valuation systems in relation to natural building materials. Provide regulatory guidance on natural building materials, low-energy, and passive systems. For example, update code restrictions for the use of heavy-timber construction and other types of natural materials when protected by fireproof assemblies.

25 Adapted from Eisenberg, David and Persham, Sonja: *Code, Regulatory and Systemic Barriers Affecting Living Building Projects*. Cascadia Green Building Council. 2009.
26 Van Ast, Liesel, Maclean, Rebecca, Sireyjol, Alice, *Valuing water to drive more effective decisions*. Trucost and Yarra Valley Water, April 2013.

- Develop closed-loop waste management systems to enable appropriate reuse of materials, local materials supply in a low-carbon environment, and local economic development. See the *Design for Disassembly Guide*.[27]
- Reassess the basis for the regulatory requirements in terms of what they protect and whether the public interest is served when viable opportunities to optimize crucial resources are constrained by regulations, independent of their safety or efficacy.

2. Create incentives matched with desired goals to facilitate the creation of comprehensive green development incentives in the building, planning and related sectors to encourage sustainability goals:

- Provide financial incentives to recognize and encourage inclusion of building and development measures with significant societal benefits, including improving public health, reduced consumption of natural resources, reduction of heat island effect, and avoidance of infrastructure supply, repair, and expansion costs.
- Decouple water utility revenues from sales so that revenues do not disproportionately increase with consumption. This will allow utilities to engage in conservation and demand management programs without an associated loss of income.

27 Guy, Brad and Ciarimboli, Nicholas, *Design for Disassembly in the Built Environment for City of Seattle*, King County and Resource Ventures.

CONCLUSION

The District of Columbia is a leader in green building implementation. District policies have been a driver of high performance building development in the private sector, and the District is now in a strong position to advance the industry toward net zero water, energy and Living Buildings. This *Net Zero and Living Building Challenge Financial Study: A Cost Comparison Report for Buildings in the District of Columbia* investigated the costs, benefits and approaches necessary to improve building performance in the District of Columbia and recommended a framework for policy to advance most rapidly toward those results.

The study conceptually transformed three LEED Platinum buildings (office new construction, multifamily new construction, and office renovation) in the District to net zero energy, net zero water and Living Buildings. Using recent data, the team considered the cost of enhanced energy conservation strategies, renewable energy, rainwater harvesting techniques and water reuse strategies, and those that would create Living Buildings.

Costs for getting to zero are difficult to distinguish from overall project costs. However, the team conducted an analysis to identify incremental cost premiums for energy and water conservation as well as for photovoltaic and water reuse systems that would bring the project to net zero. The cost premium for energy efficiency was approximately 1-12% depending on the building type. This rose to 5-19% for net zero energy. The analysis made clear that if the owner has sufficient tax appetite, tax credits and renewable energy credits make the return on investment approximately 30%, whereas the return on investment for energy efficiency alone was in the range of 5-12%.

Achieving net zero is not only a matter of design; it requires careful attention to operations and maintenance, as well as to occupancy patterns and loads. While net zero buildings are possible with today's technologies, this research uncovered the challenge associated with achieving net zero in large buildings, like those that are common in the District's city center. When considered in isolation, even ultra-efficient 300,000 SF buildings with today's onsite renewable energy technology may not be able to generate as much energy or collect as much water as they consume over the course of a year. However, the encouragement of net zero at the building scale sets the stage for future technology solutions and the removal of barriers to district energy and water systems to get the District of Columbia to energy and water independence.

Most of the barriers to achieving net zero for water are in the regulatory arena. Allowing district systems, rainwater capture and grey water reuse would open the door to significant water capacity building in the District. At the building scale, water-efficient strategies and water systems have a minimal impact on building costs compared to the value and resilience they create in the community.

Most of the cost and time implications for achieving the Living Building Challenge outside of the energy and water requirements involves the research for the Materials Petal. Most other requirements have small cost implications and have more to do with careful design. In fact, one the most important things to encourage in the District is the use of Integrative Design for projects to get the highest performance with the lowest cost implications. The Living Building Challenge should expand the cost conversation around building in the District of Columbia to include what the community values.

A new policy framework is required if the building industry is going to embrace net zero and Living Buildings at scale. In order to accelerate adoption, this research suggests the District should develop a comprehensive roadmap that addresses all of the following issues over time and illustrates a clear pathway to the District's aggressive 2032 goals. The roadmap should consider the following key recommendations from the study:

Recommendation	Approach
1. Define net zero energy	• Focus on energy efficiency first • Require disclosure of measured energy use and renewable energy production over an annual basis to verify net zero energy results • Consider community based approaches to achieving net zero energy results at a scale beyond a building • Clarify qualified sources of renewable energy
2. Encourage transition to outcome-based energy codes	• Set specific energy use targets to create metrics and interim goals for building owners and design teams to achieve on the path to net zero • Consider using the Zero Energy Performance Index (ZEPI) from the IgCC to establish these targets • Create voluntary, mandatory and compliance programs based on outcome-based energy codes (such as ZEPI) that could include: minimum performance requirements for buildings, tax incentives, energy rate breaks, 'fee-bates,' and/or code citations.
3. Promote the evolution of energy codes	• Continue to participate in national and international model code development process • Encourage usage or outcome-based energy code approaches in model energy codes • Encourage Congress to allow states and cities to set higher minimum HVAC equipment efficiency standards than currently allowed by federal law
4. Advance incentives for energy efficiency	• Consider a pilot incentive program for deep energy retrofits and net zero energy • Encourage multiyear framework for projects • Move toward pay for performance model that looks beyond individual widget-based measures to incentivize suites of measures or that eliminate systems through passive design
5. Revise net metering policies and acknowledge the changing role of utilities	• Change the net metering policy to allow for retail rates of all onsite-generated renewable energy • Address the reality of a changing role for utilities • Consider a new revenue model for utilities based on service size
6. Balance competing goals	• Consider requiring a minimum level of LEED points to encourage the prioritization of energy efficiency in green building programs.

Recommendation	Approach
7. Establish a shared water vision for the District.	• The District should convene key stakeholders in the local watershed and engage them in discussions about risk and opportunities.
8. Create incentives and remove barriers for net zero water strategies	• Greywater reuse, rainwater capture and other low cost and high reward strategies should be encouraged in the district.
9. Consider the connection between energy and water when developing new policies	• Require gravity only systems when upgrading water infrastructure. In addition, begin to research and analyze the potential of distributed ecological water infrastructure systems.
10. Identify and remove regulatory impediments to deep green and Living Buildings	• Remove barriers to district water and energy systems • Review and update building codes in regards to natural materials. • Identify and communicate the true cost of provided energy, water and removing waste and stormwater from buildings in the District.
11. Create incentives for sustainable building goals	• Provide financial incentives to recognize and encourage inclusion of building and development measures with significant societal benefits, including improving public health, reduced consumption of natural resources, reduction of heat island effect, and avoidance of infrastructure supply, repair, and expansion costs.

Front and back cover photo: Istock