





The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

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# INTRODUCTION

The Living Building Financial Study documents the anticipated cost differential between a set of nine reference LEED Gold buildings and those same nine buildings conceptually designed to meet the Living Building Challenge in four separate climate cities. The study summarizes the cost premium range and expected payback for each building type in each climate city. It is comprised of four parts: the Cost Comparison Matrix, an Executive Summary, the Study Report and an Appendix. The report is organized to allow the reader to navigate through the study with links (indicated in colored text) to the various sections for easy review and comparison.

The information contained in the report is graphically summarized in the Living Building Financial Study: **Cost Comparison Matrix.** Similar to the Packard Study, the matrix format was selected to allow for easy comparison of the key variables studied. The matrix is organized with the climate cities on the X axis and building types on the Y axis. Each cell of the matrix represents the characteristics of the specific Living Building Modification. Each cell contains information about the building's layout, form, energy use, water use, photovoltaic array size, cost per square foot, percent increase over the base building (as modified for the climate city), and anticipated payback period. The reverse side of the matrix provides greater detail about each variable and summarizes the methodology of the study.

The Living Building Financial **Study Report** illustrates the assumptions and calculations made for each building type in each climate city and documents the process the study team undertook to arrive at the projected incremental cost. The Living Building Financial **Study Report** is divided into five sections:

#### **1. Study Methodology and Process:**

This section describes the process used by the study team to analyze the nine different building types in each of the four climate cities. Included in this section are subsections which describe the process of selecting each reference building and climate city and a detailed description of the methodology undertaken by each of the four study subgroups (design, energy, water, and cost estimating). This section also includes a Reference Building subsection, which consists of a one page comparison of the characteristics of the nine reference buildings used in the study.

#### 2. Key FIndings Description:

This section elaborates on the Key FIndings presented in the executive summary with concrete results and descriptions

# **3. Living Building Modifications:**

This section includes information about each of the 36 Living Buildings conceptually redesigned for the study. The Living Building Summary Descriptions are organized by climate city, with each description including a one page summary of the design modifications undertaken with selected illustrations, an energy worksheet which estimates the energy savings for each energy conservation strategy employed and calculates the amount of PV necessary for each building to achieve Net Zero Energy and a comparison cost model between the base building and the reference LEED building, as adjusted, for the climate study.

# 4. Living Building Strategy Descriptions:

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This section describes all of the strategies employed in each of the 36 Living Buildings. The strategies are numbered for easy reference to the Living Building modifications.

#### 5. Prerequiste Summary:

This section summaries the approach to each of the sixteen Living Building prerequisites.

# **Appendix:**

This section contains a glossary defining the terms used in the study and a set of Comparison Summaries that allows for detailed comparison of the variety of characteristics studied by the team. It also includes detailed information comparing the characteristics of the reference buildings, a water usage summary comparison, an energy summary comparison, and a comparison of the reference building's LEED point total. An outline of the Living Building Challenge Prerequisites is also included for reference. Detailed information about the Living Building Challenge is available at http://www.cascadiagbc.org/resources/ living-buildings.

The report is accompanied by an **Executive Summary** which provides an introduction to the rationale for the study and summarizes its key findings and a set of key finding diagrams which illustrate those concepts.

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# STUDY PROCESS AND METHODOLOGY

This section of the report outlines the process and methodology used for the study – discussing the work of each subgroup and how each subgroup built on each other's work to arrive at the cost conclusions presented in the cost summary matrix and the key findings. Although the information is presented in a linear fashion; the reader should note that the work was highly collaborative and iterative, utilizing an integrated design process for the entire study effort.

#### Selection of Building Types and Base Buildings

(click on each building type for more detailed information on the reference building)

Cascadia identified nine distinct building types (see below) to be investigated in four climate zones:, Cool, Temperate, Hot Humid and Hot Arid:

Single Family Residential Multi-Family Residential High Rise Mixed Use (including residential) Low Rise Office Building Mid Rise Office Builidng Mixed Use Renovation (including office) Elementary School University Classroom (non – lab) Hospital

One of the first tasks of the team was a brainstorming session where the building types and climate zones were reviewed and evaluated. The study deliberately selected different buildings types that are roughly the same scale – in the range of 140,000 to 160,000 sf to facilitate easy comparison of the effect of building type on similar sized projects. For residential and office projects – three different scales were selected to illustrate the effects of building size on cost premium.

Four cities, each of them known for demonstrating advanced green building practice, were selected to represent a range of climates. An additional criterion – the availability of good cost data – was also a factor in the choice of cities within each region.

The study required identification of actual reference projects for the group to use in evaluation of whole building systems. LEED Gold was chosen as a metric for the reference buildings in order to establish a reasonable base sustainability threshold for the projects before they were redesigned to meet the Living Building Challenge. LEED Gold was selected as the baseline reference for a typically green building, based on the Davis Langdon study "The Costs of Green Revisited" where they found there was no significant difference in the average cost of green buildings compared to non-green buildings. Three factors were of primary importance when selecting the reference buildings to be used in the study.

- **1**. **Availability of cost data:** The availability of cost information, in sufficient detail to be able to estimate the cost of all design modifications, including addition and subtraction of the various features of the Living Building Challenge, was critical to the outcome of the study.
- 2. Project's LEED status: To minimize the number of variables which affect the cost differential, the team endeavored to select buildings which started with similar green building goals, as represented by the buildings LEED status. LEED gold was selected as a baseline for the project as the highest level of green building performance commonly available without a significant cost increase. Two buildings studied in the project were targeted as LEED Platinum. For these projects, the most costly points were subtracted from the cost estimate to create a base building estimate that represents a LEED Gold building.
- **3. Project location:** To minimize the number of factors affecting the cost estimate baseline, all but one of the buildings selected were located in the Portland metro area, assisting in the process of normalizing the baseline cost models. The single exception to this was the OSU Kelly Engineering building, which is located 80 miles away in Corvallis, Oregon and thus would have very similar construction economics. All of the selected projects were assumed to be in compliance with the first two Living Building Challenge prerequisites prerequisite 1) Responsible Site Selection and prerequisite 2) Limits to Growth, since these pre-requisites in themselves do not carry cost implications.

# **Study Reference Buildings**

The following reference buildings were used for the study. Documentation, in the form of Construction Documents, was received from the respective design teams and was used to analyze the base building's characteristics. Site plans, floor plans, sections, and wall sections were the primary reference drawings culled for use in the study. In addition, the base building cost estimate for each building was also reviewed. See the Appendix for more detailed information on each building type.

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**SCHOOL K-8** 



LOW RISE OFFICE



#### **MID RISE OFFICE**



#### **MIXED USE RENOVATION**



Oregon State University Kelley Engineerin <b>Project Team:</b> Architect: Yost Grube Hall Architecture Contractor: Skanska USA Building, Inc. Developer: Oregon State University MEP Engineer: GLUMAC International	ng Center Location: Size: LEED Score: Date Completed:	Corvallis, OR 153,000 sf 41 (NC) 2005
Sherwood Elementary & Middle School <b>Project Team:</b> Architect: Dull Olson Weekes Architects, Inc. Contractor: Skanska USA Building, Inc. Developer: Sherwood School District MEP Engineer: MFIA Inc. Consulting Engineers	Location: Size: LEED Score: Date Completed:	Sherwood, OR 141,000 sf 47 (NC) 2009
Cascade Station Corporate Center II <b>Project Team</b> Architect: Fletcher Farr Ayotte, Inc. Contractor: Skanska USA Building, Inc. Developer: Trammell Crow Company MEP Engineer: PMC Mechanical; The Stoner Electric Group	Location: Size: LEED Score: Date Completed:	Portland, OR 35,000 sf 36 (CS) NA
Cascade Station Corporate Center I <b>Project Team</b> Architect: Fletcher Farr Ayotte, Inc. Contractor: Skanska USA Building, Inc. Developer: Trammell Crow Company MEP Engineer: Charter Mechanical, McCann Engineering; The Stoner Electric Group	Location: Size: LEED Score: Date Completed:	Portland, OR 99,000 sf 36 (CS) NA
NW 14th & Everett Mixed Use <b>Project Team</b> Architect/Designer: GBD Architects Contractor: Skanska USA Building, Inc. Developer: Gerding Edlen Development MEP Engineer: GLUMAC International	Location: Size: LEED Score: Date Completed:	Portland, OR 183,800 sf 60 (NC) 2009 (Est)

#### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

SINGLE FAMILY RESIDENCE	Bacon-Brenes Residence		
	<b>Project Team:</b> Designer: Debar Architecture Contractor: Coho Construction Developer: NA MEP Engineer: Christopher Diamond	Location: Size: LEED Score: Date Completed:	Portland, OR 1,800 sf N/A 2002
MULTI FAMILY RESIDENTIAL	Tupelo Alley Mizxed Use Development <b>Project Team:</b> Architect: SERA Architects, Inc. Contractor: TCR Pacific Northwest Construction Developer: Trammell Crow Residential MEP Engineer: MKE & Associates, Inc.	Location: Size: LEED Score: Date Completed:	Portland, OR 179,470 sf 41 (NC) 2009
HIGH RISE MIXED USE	12th & Washington <b>Project Team:</b> Architect: Zimmer Gunsul Frasca Architects Contractor: Hoffman Construction Company Developer: GerdingEdlen Development MEP Engineer: GLUMAC International	Location: Size: LEED Score: Date Completed:	Portland, OR 540,300 sf 56 (NC) 2009
HOSPITAL	Providence Newberg Health Center <b>Project Team:</b> Architect : Mahlum Architects Contractor: Skanska USA Building, Inc. Developer: Providence Health System MEP Engineer: GLUMAC International	Location Size: LEED Score: Date Completed:	Newberg, OR 180,000 sf 39 (CS) 2008

# **Selection of Climate Cities**

Victor Olgyay, in his book "Design with Climate," described four different climate zones for the North American continent. The climate zones he described are noted below:

**Temperate:** Describes a region across the middle of the United States extending into Canada and the Pacific NW on the west coast. Typically this climate is milder than the others, with less extremes both on the high and low side. Rainfall varies greatly across the region depending on location.

**Hot-Humid**: Describes a region from Louisiana to the east coast of the United States. The zone extends from the Gulf of Mexico north to Virginia. This climate zone is characterized by hot, humid days, especially in the summer season. Rainfall varies across the region, depending on location.

**Hot-Arid:** Describes a region from Southern California, east to Texas and across the Southwestern portion of the United States. This climate zone is characterized by hot, dry days and cooler nights, although cold days are possible in the winter months. The average rainfall in this climate is very low throughout the region.

**Cool:** Often designated as a "cold climate region", this climate area describes a region that extends across most of Canada, New England and the northern portion of the Mid Western portion of the United States. This climate typically has cold winter days, but can also have hot, humid summer evenings. Rainfall varies across the region depending on location, with snow fall adding to total precipitation.

It's important to note that the North American version of these climate zones do not represent the extremes of climate possible in the world. The intent of the Living Building Financial Study was to review the cost of Living Buildings in the North American marketplace. The intent of this study is to take a representative building and redesign it to address the climate characteristics of each region with the North American marketplace.



The strategies employed in each region were somewhat generic. It's important to note that climate is modified by specific site surroundings – a term called microclimate. The effects of microclimate were not addressed as a part of this study.

Climate characteristics reviewed for each climate city included:

**Temperature:** The study looked at both average daily high and low dry bulb temperatures and seasonal extremes. Seasonal temperatures were used to understand heating / cooling loads and develop appropriate strategies based on the expected energy use for the building. Daily variation provided an indication of the effectiveness of thermal mass and night ventilation strategies.

**Rainfall:** The study reviewed specific rainfall data for the cities selected for five average years. Daily data provided valuable information, enabling the team to adequately size water tanks for areas which have rainfall characteristics which vary by season.

**Sky Cover** (% Cloudy): Sky Cover (or the percent cloud cover expected seasonly) was used to determine whether a climate was predominately overcast or sunny, which influenced the daylight design techniques employed.

**Solar Radiation:** The availability of solar radiation was used to size photovoltaics.

Wind was not reviewed because it is so specific to the surrounding microclimate of a specific site.

# **Design Approach**

Members of the Design Subgroup included: Jason F. McLennan (Cascadia), Clark Brockman (SERA Architects), John Echlin (SERA Architects) and Lisa Petterson (SERA Architects).

The Design Subgroup was responsible for determining the design changes necessary for each reference building to achieve the sixteen prerequisites of the Living Building Challenge, and for documenting the changes in sufficient detail for the cost estimating group to price. The work of the design group included:

- Review of the nine reference buildings to determine which buildings did not meet specific criteria in the Living Building Challenge;
- Brainstorming about how to meet the net zero energy and net zero water prerequisites;
- Incorporation of the energy and water subgroups' strategies into the reference building; and
- Design of the how PV would be integrated into the buildings.

A more detailed description of the tasks of the Design Subgroup is noted below.

Construction document information (primarily site plans, floor plans, elevations, sections, and wall sections) was reviewed to determine which projects required design changes to meet the Living Building Challenge Prerequisites. Although achieving the goals of **prerequisite 4**) **Net Zero Energy** and **prerequisite 10**) **Net Zero Water** suggested some design modifications, the only prerequisite that mandated a design modification to meet the requirements of the Living Building Challenge vas **prerequisite 12**) **Civilized Environment**. The Living Building Challenge v1.2 has a footnote that clarifies the maximum distance an occupant may be located from a window. The footnote, which states "work spaces can be no more than 30 feet from a window" was used as a test of whether a project met this prerequisite or not. Several of the reference buildings had workspaces further than 30' from a window including:

Mid Rise Office Low Rise Office Hospital Mixed Use High Rise (housing / retail / office) Mixed Use Renovation

Modifications on the above building types to achieve **prerequisite 12**) Civilized **Environment** included:

- Creatation of a long thin building on sites with ample area;
- Addition of an atrium (or expanding an existing atrium) to create a donut shaped building with work areas no more than 30' from windows; and
- Insertion of light shafts to bring light and ventilation to areas that were functionally required to have light, but are necessary to keep at the interior of the building (like the nurse's station in the hospital).

The **Multi-Family Residential** building also had some units with habitable rooms without direct access to a window, requiring redesign of portions of the building to create units with less depth.

These changes generally resulted in a reconfiguration of the base building's floor plate and generally added skin area to the building. In some cases the reference building also was refined to achieve a more favorable building orientation to allow passive strategies to be more easily applied.

Strategies the Design Subgroup employed in order of priority were:

- Reduction of building loads: The design team first applied principles of good energy management, using Energy Conservation Measures (ECM's) to reduce demand. Strategies typically employed include: increasing building insulation, providing improved glazing, reducing plug loads and reducing lighting power density.
- 2. Application of passive design strategies: Each building design was analyzed to determine how the building could be reshaped to perform better in each climate zone employing simple techniques like elongating the building in the west /east direction. Next, the design team employed passive design strategies applicable for the region. Although many of the base buildings employed basic orientation related strategies, design strategies to maximize daylighting particular to each climate city were applied. Passive heating strategies were applied in skindominated buildings in temperate and cool climates. Natural ventilation and evaporative cooling strategies were applied in the hot-arid climate, where technically appropriate.
- **3. Application of active design strategies:** Mechanical systems were upgraded and optimized (and in some cases eliminated) for the building and climate.
- **4. Addition of Renewables:** The final step in the path to Net Zero Energy was the incorporation of photovoltaics in sufficient quantity to meet the remaining energy demand.

For Net Zero Water, a similar approach was used, with all buildings first upgraded to include the highest water conserving fixtures available in the market today. The remaining water usage was offset, first by rainwater collected from the building's roof, then through greywater and blackwater reclaimation systems. Different building types required different levels of waste water treatment, depending on if the water was proposed to be reused as potable or not.

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# Approach to Net Zero Energy

Members of the Energy Subgroup included: Jason F. McLennan (Cascadia), Mark Frankel (New Buildings Institute), Omid Nabipoor (Interface Engineering), Andy Frichtl (Interface Engineering), Clark Brockman (SERA Architects), Lisa Petterson (SERA Architects) and Kate Turpin (SERA Architects).

The Energy Subgroup was responsible for determining the strategies that would allow the buildings to achieve Net Zero energy performance, while working with the cost estimating group to determine the anticipated premium costs for the various energy strategies employed.

The work of the energy subgroup included three major categories of tasks:

- Determining a baseline energy use for each building type that could be used as a point of comparison for evaluating building efficiency performance;
- Analyzing the energy profiles of the Portland-based reference buildings and translating these to the other climate cities; and
- Converting each reference building (in each climate zone) to a Net Zero energy building through application of both Energy Conservation Measures (ECMs) and on-site renewable energy.

The approach to each of these tasks is described below in greater detail.

#### **Baseline Energy Use**

The baseline Energy Use Intensity (EUI) for each building type was determined using data from the 2003 Commercial Buildings Energy Consumption Survey (CBECS) and the 2005 Residential Energy Consumption Survey (RECS). The Energy subgroup set a target percentage improvement over CBECS for each building type of between 50-65%, based upon what was realistic given the substantial collective experience of the group. Energy Conservation Measures (ECMs) were conceptually applied to each building (by climate city) until the goal or target EUI was reached. On-site renewable energy systems were sized to meet remaining building annual energy needs.

Some of the building types in the study were either not represented by CBECS/ RECS data, or the particular circumstance of the reference building warranted a modification of the baseline EUI. For these buildings, the Energy Subgroup assigned a baseline EUI that was informed by available data and knowledge of the reference building.

#### **Energy Profiles of Reference Buildings**

Energy model results were obtained for each of the reference buildings where energy modeling was performed. These energy analysis reports (particularly LEED-NC Energy & Atmosphere Credit 1, EAc1, "Optimize Energy Performance" documentation) provided the Energy Subgroup with a basic knowledge of the energy performance for each reference building in Portland. The Energy Subgroup then developed a spreadsheet tool used for tracking the energy profiles of the reference buildings, modifying the energy performance to the other climate cities and converting the reference buildings to Net Zero Energy performance.

#### **Reference Design EUIs & Normalized EUI**

The Energy Subgroup chose to use a normalized building that reflected standard industry construction practices in Portland. The primary reason for creating the normalized EUI was that it greatly simplified the task of determining how much savings would be achieved by the ECM's that were applied. The procedure of using energy modeling to evaluate the cost-effectiveness of ECM's typically involves comparing each ECM to an alternate base system representing standard industry practice. The Energy Subgroup had greater expertise in predicting savings when applied to systems and buildings representing standard industry practice.

The normalized EUI was chosen by the Energy Subgroup for each reference building to reflect how that building would have performed if it had not pursued the energy efficiency measures associated with LEED Gold certification level. The normalized EUI assumes basic envelope, lighting and mechanical systems that are current standard industry practice in Portland. In addition, there were several other important reasons for using a normalized Design EUI rather than modeled results, including:

- The eight LEED projects had very different predicted performance in EAc1, each obtaining different quantities of points in this category, with some using LEED-NC v2.1 (comparing to the 1999 version of ASHRAE/ IESNA Standard 90.1 following the "Energy Cost Budget" modeling methodology), and some using LEED-NC v2.2 (comparing to the 2004 version of ASHRAE/IESNA Standard 90.1 and following the Appendix G "Performance Rating" modeling methodology);
- Only two reference buildings have been certified by the USGBC, and received the 3rd party review of EAc1 that accompanies certification; and
- NBI's study "Energy Performance of LEED for New Construction Buildings" indicated that there is fairly poor correspondence between individual LEED energy model results as compared to measured performance of the buildings.

The cost estimating group used the actual designed systems of each reference building for the purposes of cost estimating; the normalized EUI was a tool created solely for the use of the Energy Subgroup in evaluating ECM's impact on energy performance.

The normalized Design EUI for Portland was modified for each of the remaining climate cities using variations determined through use of the EPA's Target Finder tool. The reference building size and usage was entered into Target Finder for each climate city's representative zip code to determine relative EUIs for each city.

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#### **End Use Breakdowns**

Energy end use breakdown percentages (Lighting, Heating, Cooling, Domestic Hot Water, Fans & Pumps, and Misc Equip) were based on reference building model results; the results for some building types were modified by the energy Subgroup to reflect a more typical energy distribution for that building type in Portland. In translating these end-use breakdowns to the other climate cities required two basic assumptions: (1) Heating and Cooling end uses represent most of the difference in overall energy use for each city; (2) Energy use for Lighting, Misc Equipment and Domestic Hot Water is approximately the same in each climate city (i.e. the percentage of energy used in each of these categories changes from city to city in direct proportion to the change in overall energy use for that city). As a basic method, the relative proportion of heating degree days (HDD65) between Portland and the other climate cities was used to determine heating energy end use in each climate city, and cooling was adjusted as necessary to make up overall energy use.

#### **Conversion to Living Building**

The next task of the Energy Subgroup was to determine the energy conservation strategies to achieve the Net Zero Energy prerequisite.

#### **Energy Conservation Measures**

The first major task of the Energy Subgroup was to determine customized lists of ECMs that should theoretically be applied to each building type in each climate city, to allow the building to meet its target EUI before renewable energy systems were applied to cover the remaining energy use. These customized ECM lists were developed during a series of energy charrettes. Once the ECM lists were developed for each of the 36 buildings (nine types, four climate cities), the Energy subgroup was tasked with determining how much the suite of ECMs would reduce building energy consumption from that of the Normalized Design EUI.

As a first step in conversion to a Net Zero building, the changes to the building made by the Design Subgroup had to be reconciled with the Normalized Design EUI starting point. After both viewing sketches and reading a description of changes made by the Design subgroup, the Energy Subgroup determined a factor multiplier to modify the Normalized Design EUI. ECM reductions were then applied to the resulting Adjusted Design EUI.

ECM's were grouped into ten major impact categories, as follows: Glazing, Walls & Roof, Daylighting, Lighting, Plug Loads, Widen Setpoint Temperatures, Schedule Changes, Mechanical Distribution & Ventilation, Mechanical Plant Systems and Domestic Hot Water. Individual ECMs were then listed within their most relevant categories. Predicted energy savings were then applied as percent reductions to each energy end use category affected by that ECM.

A rolling baseline approach was taken in assigning ECM savings. The ECM's in the seven load reduction categories (Glazing, Walls & Roof, Daylighting, Lighting, Plug Loads, Widen Setpoint Temperatures, and Schedule Changes) were applied first. The new energy end use breakdown was then calculated before savings from Mechanical Distribution & Ventilation systems were applied. A subtotal of energy end use breakdown was calculated before the impact of Mechanical Plant Systems and Domestic Hot Water Systems were determined. A reduced EUI and end-use breakdown were tabulated after these ECM categories were applied. This reduced EUI was then modified by two multiplying factors: (1) a Building Operating Factor which reduced the EUI further to account for engaged occupants who are well trained in building functions and are actively participating in the Net Zero goal through individual efforts in conservation, as well as the ongoing building commissioning and maintenance of system performance required to meet a Net Zero goal, and (2) an Interactive ECM effects factor which increased the EUI (this factor accounts for the fact that all ECMs when applied together save less energy than the sum of savings of individual ECMs). After application of these factors, the final reduced EUI was used to determine the total annual amount of energy required by on-site renewable systems to meet Net Zero Energy.

#### Sizing of Renewable Energy systems

For most buildings, the primary source of on-site renewable energy was chosen to be solar photovoltaic (PV). RETScreen 4-1 was used to determine the annual electricity production for each applicable tilt and orientation for each climate city. Solar panels were added to building design with a preference for roof area first. Additional site area was used for PV production, as necessary, to achieve each building's net zero annual energy use prediction. For reference buildings that did not include additional site area (e.g. high-rise mixed use, and mixed use renovation), it was assumed that PV could be added to the rooftops of nearby parking garages, with the energy consumed by those parking garages also included in overall energy production of the PV array. In reality this may not be a realistic, so projects with tight urban sites and high density should carefully understand this assumption.

#### Advising Cost Estimating Group on Mechanical System Sizing

#### Mechanical System Sizing for cost analysis

A final task of the Energy Subgroup involved assisting the Cost Estimating group in understanding relevant ECMs, particularly related to mechanical systems. Appropriate sizing of mechanical systems was important to obtaining accurate cost estimates for the Living Buildings. Due to aggressive load reduction strategies, efficient mechanical distribution (e.g. radiant heating/cooling), and a substantial widening of acceptable inside temperature ranges, the mechanical plant system sizes would be substantially reduced. In addition, one of the most expensive ECM's was the ground source heat pump vertical well field used for a number of buildings. Where dominated by heating loads, the well fields were sized to meet the majority of the (already reduced) annualized heating load, with peak heating (design days) met by back-up electric boilers.

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# Water Subgroup Methodology

Members of the Water Subgroup included: Jon Gray (Interface Engineering), Dennis Kangas (Interface Engineering), Dennis Wilde (Gerding Edlen), Christina Skellenger (Gerding Edlen), Lisa Petterson (SERA Architects) and Matthew Schuler (SERA Architects).

The Water Subgroup assumed responsibility for determining the strategies necessary to achieve **prerequisite 10**) Net Zero Water and **prerequisite 11**) **Sustainable Water Discharge** and worked with the cost estimating group to arrive at the anticipated cost preminum for each water strategy employed.

The work of the Water Subgroup included:

- · Calculation of the base building's water use;
- Calculation of the reduction in water use from water conservation strategies;
- · Addition of water conserving fixtures were applied;
- 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 Sustainable Water Discharge strategy.

The study "Code and Regulatory Barriers to the Living Building Challenge for Sustainable, Affordable, Residential Development" prepared by Cascadia for the City of Vancouver, WA and Clark County, WA singles out **prerequisite 10**) **Net Zero Water** and **prerequisite 11**) **Sustainable Water Discharge** as one of the few prerequisites with absolute barriers to the Living Building Challenge. For the purposes of this study, it was assumed that all jurisdictional barriers to these prerequisites were eliminated. In reality, project teams need to carefully understand local and state jursidictional barriers to water use.

#### **Base Water Use**

Similar to for the Net Zero Energy prerequisite, water conservation was the first strategy employed to all buildings. Eight reference buildings anticipated achieving LEEDv2.2 credits WE 3-1 and 3-2, which means the reference projects already incorporated water saving devices that provided greater than 30% water savings when compared to a code 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 Livings Building Modifications, additional conservation measures were applied first in the form of optical sensors for the office and classroom buildings and composting toilets for the single family residence. 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 calculation procedure for figuring water usage it was used as a starting point for the Water Subgroup to calculate water usage for each building. In addition to the uses specifically identified by LEED

as part of the calculation procedure the Water Subgroup also brainstormed other uses which needed to be accounted for in a Net Zero water building. 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 (.8/ 1.1 gallon per flush), with office buildings and school projects using a flush valve dual flush mechanism (.8 / 1.6 gallons per flush). Because the primary system selected for heating and cooling was a closed loop ground source heat pump, no additional water was assumed for heating and cooling. Two of the nine reference buildings achieved the LEED threshold for exemplary performance - 40% less water usage than the water use baseline calculated for the building after meeting the Energy Policy Act of 1992 fixture performance requirements. These projects were normalized back to the LEED Gold standard - which the team established as 30% more efficent than existing code. The cost of the additional water saving measures to achieve the 40% reduction, was subtracted from the cost of the LEED Gold baseline cost model.

All of the reference projects achieved the first LEEDv2.2 Water Efficiency credit (WE 1.1) Water Efficient Landscaping, which requires a 50% reduction in water use for irrigation. To achieve the Living Building Challenge's Net Zero Water prerequisite the study 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.

#### Water Collection

After determining each building's water use, the amount of water available for collection from the building roof was calculated using daily precipitation data from the National Oceanagraphic and Atmospheric Association. The water subgroup created a water calculator based on the Rainwater Harvesting Model developed by the City of Portland Water Bureau. The purpose of the Portland Rainwater Harvesting Model is to estimate the effectiveness of rain water harvesting based on past weather conditions in the Portland area and estimated water consumption. The Portland Rainwater Harvesting Model uses daily precipitation data from 1963 to 2004 to calculate how much water could be harvested based on the size of the roof and the size of storage tank and calculates what percentage of the building's water use can be supplied from collected rainwater based on input provided by the user of the model.

For the Living Building Financial Study, the water calculator was reverse engineered to create a calculator that solves for tank size instead of number of gallons harvested. The calculator adds daily precipitation to the tank and subtracts out daily use. The calculator incorporates a 15% loss to account for the commonly applied first flush techniques, typically employed to eliminate containments. This factor also was intended to account for evaporation, processing and consumption losses. For the purposes of the Financial Study, the algorithm which selects "average" years was used. The calculator was adapted

with available rainfall data from the NOAA website for Atlanta, Phoenix and Boston.

The study group selected data from the folloiwing source as representative of rainfall.

#### National Climatic Data Center Monthly Average Rainfall

**PORTLAND** INTL ARPT, MULTNOMAH COUNTY data derived from NCDC TD 9641 Clim 81 1961-1990 Normals. 30 years between 1961 and 1990 http://www4.ncdc.noaa.gov/cgi-win/wwcgidll?wwDI~StnSrch~StnID~20016428 Elevation : 5.8m (19') above s/I Lat/Lon : 45°35'N / 122°36'W

ATLANTA HARTSFIELD INTL ARPT, FULTON COUNTY data derived from NCDC TD 9641 Clim 81 1961-1990 Normals. 30 years between 1961 and 1990 http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20004906 Elevation : 307.8m (1010') above s/I Lat/Lon : 33°38'N / 84°27'W

**BOSTON** LOGAN INTL AP, SUFFOLK COUNTY data derived from NCDC TD 9641 Clim 81 1961-1990 Normals. 30 years between 1961 and 1990

http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009288 Elevation : 6.1m (20') above s/I Lat/Lon : 42°22'N / 71°01'W

SOUTH **PHOENIX**, MARICOPA COUNTY data derived from NCDC TD 9641 Clim 81 1961-1990 Normals. 30 years between 1961 and 1990 http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20001013 Elevation : 352.0m (1155') above s/I Lat/Lon : 33°23'N / 112°04'W

#### Water Strategies

The way that each building could achieve Net Zero Water was calculated using a linear analysis model that checked strategies returning the result when the building's required water use was met.

**Scenario One: Rain Only** This scenario relied on rainwater only for both potable and non-potable uses

**Scenario Two: Rain + Grey** This scenario relied on rainwater for potable uses and added greywater collection and treatment to allow it to be reused for non-potable uses.

**Scenario Three: Black for Non-potabl**: This scenario relied on rainwater for as much potable use as possible, and provided additional treatment to the greywater to meet potable water standards. Blackwater was treated and reused for non-potable uses.

**Scenario Four: Black for Potable** For some buildings it was necessary to treat blackwater to potable standards creating a closed loop scenario. It is understood that in many jurisdictions this would not be allowed, but for the purposes of the study it was assumed black water reuse was able to be achieved.

## **Building Water Discharge**

If rainwater was sufficient to meet demand, the team investigated simple options for addressing the Sustainable Water Discharge prerequisite – such as composting toilets and septic fields for projects with sufficient site area to meet demand. If rainwater could not meet the entire building's water demand, it was checked 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 for a greywater-only system was provided in Scenario Two. Scenario Three typically used a membrane bioreactor to treat both grey and blackwater to class four levels. Scenario Four added an additional treatment module to bring the water to potable standards.

Water tanks smaller than 50,000 gallons were costed as a fiberglass tank; larger tanks were assumed to be built from poured in place concrete systems with treated walls. Typically tanks were located in the basement of projects – usually in place of mechanical rooms made smaller as a result of changes to the energy system. Costs for the tanks, UV treatment and water filtration were all added to the project above the line. Membrane bioreactors were added below the line as third party provided.

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# **Cost Estimating Approach**

Members of the Cost Estimating Subgroup included: Beth Heider, Steve Clem, Mark Jones, Bob McGinnis, and Dave Jackman, all of SKANSKA.

The cost estimating process was divided into three main tasks: collection of data and baseline establishment, pricing of modifications to achieve Living Building prerequisites and calculation of payback.

#### **Data Collection and Baseline Establishment**

The level of detail and format of the estimates varied substantially due to differences in industry practice, scope of work and confidentiality concerns. Therefore, the first effort was to reconfigure the data into the standard Uniformat estimate model which is most universally accepted. This systems-based approach was also chosen because the Living Building revisions could be added and subtracted with much more transparency than in a CSI based model. When the available data was not in Uniformat, the costs were redistributed by manually sorting the individual estimate line items or applying historical percentages for that building type. For core and shell reference projects such as the mid rise office building, cost for an open office model tenant improvement (TI) were added since the Living Building presupposes a complete build out.

At the highest level, the estimates were divided into two areas: Construction Costs and Development Costs. The estimates were intended to provide a turnkey project including development, design, construction and improvements; excluding only land purchase costs. This holistic approach was consistent with the intent of the Living Building Challenge and allowed for the developer's incentives to offset changes in the direct construction cost.

Once the data was collected and formatted, the costs were adjusted to current January 2009 values. If detailed unit prices were available, the adjustments were made at that base level. If not, a global escalation factor derived from RS Means and Skanska's own cost database was applied. It is worthwhile to note that the timeline of this study straddled one of the most volatile pricing periods in history and that typical projects are not likely to experience offset of the record pricing of commodities of July 2008 by the record drop in construction inputs into the PPI in the winter of 2008.

In addition to these macro adjustments, adjustments were also made for abnormal bidding conditions, campus efficiencies, and unusual contractual arrangements. The original building designs are location-sensitive and an attempt was made to account for these differences by adding and removing scope in the baseline estimates. These minor changes were vetted through local offices of Skanska in each climate city, who also made recommendation of the items required to make the project meet local quality, environmental, and marketability standards.

The final step in creating the direct cost baseline was to review the LEED scorecards for each project and determine the cost to add or remove credit points so that the project scored in the Gold range. Adjustments were made based on the most commonly achieved points, but particular focus was placed on the Energy and Atmosphere (EA) credits. Where an adjustment for LEED

considerations, it is shown as a discrete line item in the estimate summary.

Once the above revisions were made, a city cost index multiplier was applied to adjust the construction costs to each template city. The basis of this multiplier was the RS Means city cost index which was verified through review of actual project costs of one project type across the three non- base climate regions.

#### **Estimation of Living Building Costs**

Recognizing that the decision to build a Living Building is not an option exercised when design is nearing completion, the costs for Living Building premiums were priced as if they were part of the original design, not incremental changes. Similar to the Value Engineering process during design, changes were analyzed on a net-impact basis across disciplines. Although corollary price impacts were considered, detailed engineering was not completed and downstream impacts were often assumed to be cost-neutral. Most of the strategies from the Design Subgroup fit within one of the established Uniformat systems; a select few mechanical items had architectural components priced separately.

The strategies employed were state of the shelf technology, using products and techniques currently in use, simply on a much more comprehensive scale. The only notable exception to this rule was the vertical rainwater collection system on the High Rise which was an entirely conceptual construct.

The Estimating Subgroup provided initial cost feedback to the design team to facilitate best value solutions to the prerequisite challenges. While each option did not undergo a rigorous Value Management process, a test of reasonableness was applied to ensure that the strategy, although challenging, wasn't absurd. Each of the strategies is discussed in further detail in the Strategies Narrative.

Where a single multiplier or formula was used to calculate the premium for a specific Prerequisite, it was applied per the method further described in the Prerequisite Summary.

Once the 36 individual estimates were completed, the results were reviewed for accuracy and completeness. Any anomalies in pricing were identified and either corrected or explained. The findings are discussed in the Findings Section.

# Payback

In the US Federal Government's Whole Building Design Guide, Sieglinde Fuller of the National Institute of Standards and Technology (NIST) characterizes lowest life-cycle cost (LCC) as "the most straightforward and easy-to-interpret measure of economic evaluation. Some other commonly used measures are Net Savings (or Net Benefits), Savings-to-Investment Ratio (or Savings Benefit-to-Cost Ratio), Internal Rate of Return, and Payback Period. They are consistent with the Lowest LCC measure of evaluation if they use the same parameters and length of study period. Building economists, certified value specialists, cost engineers, architects, quantity surveyors, operations researchers, and others might use any or several of these techniques to evaluate a project."

"In order to be able to add and compare cash flows that are incurred at different times during the life cycle of a project, they have to be made time-equivalent. To make cash flows time-equivalent, the LCC method converts them to present values by discounting them to a common point in time."

The discount rate used for the LBC Financial Study was 4.5% in accordance with the Nominal Interest Rates on Treasury Notes and Bonds of Specified Maturities published in OMB Circular 94 for 2009.

"The interest rate used for discounting is a rate that reflects an investor's opportunity cost of money over time, meaning that an investor wants to achieve a return at least as high as that of her next best investment. Hence, the discount rate represents the investor's minimum acceptable rate of return."

The discount rate for federal energy and water conservation projects is determined annually by the Federal Energy Management Program (FEMP). The discount rate for energy is 3% in accordance with FEMP's rate for a 30 year time period.

"LCCA can be performed at various levels of complexity. Its scope might vary from a "back-of-the-envelope" study to a detailed analysis with thoroughly researched input data, supplementary measures of economic evaluation, complex uncertainty assessment, and extensive documentation. The extensiveness of the effort should be tailored to the needs of the project."

For the Living Building Financial study, we performed a simplified life cycle cost analysis. First the cost estimating team compared the LEED Gold building baseline costs to the costs projected for the Living Building Modification (adjusted to January 2009 dollars), to arrive at the present worth for each building. Energy and water for LEED Gold baseline building were calculated using a differential escalation rate of 3% for energy and water in accordance with FEMP. Current energy and water rates were multiplied by the present worth factor of 24.165. (This factor reflects a 30-year life-cycle, 4.5% discount rate and 3% differential escalation.) The total life cycle cost looks at both the annual cost and the present worth of the building to arrive at a Present worth for the LEED Gold building. The Living Building does not have costs added to it as it has Net-Zero Energy and Net-Zero Water usage.

We have used discount and differential escalation rates identified by the Federal Government as the basis of these analyses. In past and more conventional

economic times, Value Engineering/Value Analysis studies that incorporate Life Cycle Analysis might typically use a discount rate of 8%. The NIST tables indicate a discount rate lower than the 4.5% for the next several years. There is a possibility that if we end up with run-away inflation coming out of the depression (as was the case in the 80's early 90's) a discount rate of 12% would not be unreasonable. Consider the impact: The lower the future buying power of the dollar, the less it makes sense to invest in things that are more durable now, because, over the life of the investment, the value of the dollar is going down faster and it makes as much economic sense to replace something cheap today in cheap future dollars than to invest in something long-lived in current (high value) dollars.

By contrast – if energy costs skyrocket – it will have the opposite effect, because even if the building is properly maintained and in it's most efficient working order, the up front cost of high performance/low energy buildings will be offset over time more quickly through reduced energy costs. The higher and faster energy costs rise, the quicker the payback.

This analysis does not include the additional incentive value of carbon offsets or avoided future costs of low-performing buildings in a carbon-trade economy.

The big unknown and unknowable in these calculations is that no one knows what inflation will be, what energy prices will be or when/if carbon will be valued and at what price.

The calculations follow the Federal percentages which is a relatively conservative approach because, while runaway inflation is possible, it is even more likely that energy costs will rise and that carbon will play into the value equation soon.

For more on LCC see www.wbdg.org.

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# **KEY FINDINGS SUMMARY**

The study's primary finding that Living Buildings can be built cost effectively in today's market driven ecoonomy given the rising costs of energy and water is supported by the relatively short payback period reported by the study for many of the thirty six buildings. 24 of the 36 buildings had an average payback of less than twenty years. Across building types we saw the lowest payback for projects with the least first cost increase - the University Classroom Building and the Elementary School and for buildings with the largest energy and water usage - the hospital. Payback was also highly influenced by the cost of energy and water. Boston, which has roughly double the energy and water costs of Portland, saw a significantly shorter payback period, despite its much higher first cost increase. Incentives also played a significant role in the projects first cost premium which ultimately affected the payback interval. This study did not look at hard-to-quantify measures, such as productivity, focusing only on payback through tangible water and energy savings.

By isolating variables, we attempted to analyze which factors affect first cost increase the most and which affected it the least.

#### The role of the Client (Client Type Matters)

Who is developing the building and their goals and priorities affect the initial budget for the base building which in turn affects the first cost premium for creating a Living Building.

The market sector developing the building affects its funding parameters and how the initial budgets for the LEED Gold project were set. Perphaps one of the most important findings of this study is the how the significant investment we are seeing in our public buildings equates to lower first cost premiums for the University Cassroom and Elementary School, and the highest first cost premium for speculative office buildings, built without a client.

#### The role of Building Type (Building Type Matters)

The primary and secondary uses of a building greatly affect its energy and water usage, which in turn affects the cost premium to build a Living Building. Equally important is the longevity of the building type.

In comparing five of the nine buildings selected to be the same scale, and most importantly with the same relative floor to roof area ratio, we found that the cost premium for net zero energy and net zero water varied greatly. Some buildings, like the hospital inherently use more water and energy, which makes reducing their loads much more difficult and thus is more costly. The first cost premium for energy conservation measures for the hospital equated to over 40% for all four climate cities, and exceeded 50% in Boston. These buildings also saw a much greater benefit from the investment in Net Zero Energy and Net Zero Water technology, seeing a shorter return becuase of the huge energy and water savings a Living Building would have.

We also saw how buildings that are high water users, like the MultifFamily Residential building, had a considerably higher water premium than lower water using buildings.

#### The role of Climate (Climate Matters)

Climate exerts a significant influence on the cost premium to create a Living Building.

#### Net Zero Energy

Energy usage for each building was analyzed using CBECS data as a baseline to arrive at an initial energy usage EUI for each building type and climate city. Atlanta typically had the lowest EUI for its base buildings, followed closely by Phoenix and Portland. The base EUI of Boston, a mixed climate with both very cold and very warm days was always greatest –on average about 25% greater than the base EUI of the reference building. The EUI of Portland, Atlanta and Phoenix were consistently within 5% of each other – however the energy use for Portland is more evenly divided between heating and cooling – with heating typically dominating. The relatively mild climate in Portland allowed for consideration of elimination of air conditioning for several building types (the elementary school, multifamily and single family residence), thus reducing costs. Atlanta also has both a heating and cooling load – but the mix is weighted more heavily toward cooling. In Phoenix, cooling is by far the largest load.

Available solar radiation per given area is another factor affecting the cost of achieving net zero energy. Phoenix had the highest solar incidence rate producing more kWh per panel than any other climates. The next highest production rate was Atlanta, followed by Portland, followed by Boston.

If net zero energy was isolated from the other costs of achieving the LBC are removed as a parameter in the study, not surprisingly the cost premiums would be dramatically differet. Boston with its abundant and seasonly consistent rainfall become the city with the least cost premium.

#### **Net Zero Water**

Water availability also contributes to increased costs. As anticipated Phoenix required the most creative (and most costly) strategies to achieve net zero water. What surprised many of us was the difference in storage volume required for net zero water in Portland compared to other climates. Rainfall average in Portland and Boston are similar in terms of absolute quantity, but Boston's rainfall happens throughout the year while Portland's typically occurs in the months of November to May.

#### The Role of Building Size

The scale of the building, both in absolute size and in the ratio of floor area to roof area, affects the cost premium to achieve a Living Building.

For our study, we had three different scaled buildings that were primarily residential in makeup and three buildings that were primarily office. One of the more interesting findings of this study is the interrelationship of building's size to the net zero energy and net zero water prerequisites within a climate city. Not surprisingly, the smallest buildings in the study had the greatest percentage increase in first costs due to lack of economies of scale. The largest buildings were the most able to take advantage of the economy of scale offered when the additional measures required to achieve Net Zero Energy and Net Zero Water were added.

As an interesting correlation to the absolute building size, whihc also looked at the ratio of the floor area to roof area. For the larger buildings, which did not have enough rooftop to provide supply energy their rooftops, the energy premium was greater than it was for buildings which could meet the net zero standard using only building mounted PV The state of technology, both in the renewable energy field and in the water reclaimation systems are responsible for creating a tipping point beyond which the cost of adding additional technology increases dramatically. For example, the High-Rise Mixed Use Residential building and the Mixed Use Renovation, it was not possible to achieve Net-Zero Energy without adding photovoltacis on adjacent buildings – which also then needed to have their energy usage accounted for. As technology improves this tipping point will increase allowing larger and larger buildings to be built using only the building to support the photovoltaics.

#### The role of Incentives (Incentives Matter)

The availability of incentives for green building projects can dramatically decrease the first cost of a project.

To test this hypothesis, we looked at the difference incentives make in reducing the premium cost between LEED Gold buildings and Living Buildings. Portland, has two additional incentives that are not available in the other climate cities. Those additional incentives are:

- The Energy Trust of Oregon offers a .\$.10 kWh savings and has plans to increase the incentive greatly for buildings that achieve Net Zero Energy. For the purposes of the study, the assumption was this incentive would increase to \$.20 kWh.
- The Business Energy Tax provides an additional incentive for Platinum (For the purposes of the study we calculated that all Living Buildings would also achieve LEED platinum) that equates to an additional \$4.29 / sf for buildings less than \$10,000 sf, \$3.58 / sf for buildings between 10,000 and 40,000 sf and an additional \$2.85 /sf for areas beyond 50,000 sf

In addition, incentives for Photovoltaics are also greater in Oregon due to the added incentive from the Energy Trust of Oregon. The final incentive, a Systems Development credit was uniformly applied to all buildings.

The Clty of Portland is considering a High Performance Green Building Policy which will give additional incentives for buildings which exceed the goals set by the 2030 Challenge. The incentive proposed for Living Buildings varies between \$8.65 and \$17.30 sf. If this incentive passes as currently proposed, the incentives for Portland increase further, decreasing the cost premium even further. This incentive was not included in the cost premiums for the report as noted in the matrix. On the Portland cost estimates this premium was calculated as a separate line item using the average of \$12.97 / sf.

The anticipated construction cost for the translated LEED Gold base building, based on RS Means, is ranked as follows:

- Phoenix \$.85
- Atlanta \$.87
- Portland \$1.00

#### • Boston \$1.12

After incentives are applied, Portland was consistently the least expensive climate city, followed by Atlanta, Phoenix, and Boston. To address the question of whether it was incentives or climate that contributed the most to Portland's ranking, we looked at the cost premium before incentives were applied. This analysis showed that for all but, two of the Portland buildings, the cost before incentives ranked the same relative to the other climates as the LEED Gold Base. After incentives were applied the cost premium for the Portland building consistently dropped to making it the least expensive city.

#### The Cost of Energy and Water Matter

The cost of energy and water affect the payback.

Energy and water cost vary greatly among our four climate cities.

Average energy costs for each of the climate cities (not accounting for peak demand charges or time of use net metering) are:

٠	Portland	\$.08 kWI
٠	Portland	\$.08 kW

- Atlanta \$.10 kWh
- Phoenix \$.10 kWh
- Boston \$.17 kWh

Assuming an average energy escalation rate of 3% annually and a discount rate of 4.5%, we see the huge affect changing the cost of energy has on payback. Once the payback analysis was complete, Boston, the city with the highest cost premium, changed to be the city with the quickest payback. Water was similarly analyzed utilizing the following rates per one hundred cubic feet of water.

The combined water and sewer rates were:

- Phoenix \$6.63 CCF
- Portland \$8.32 CCF
- Boston \$10.27 CCF
- Atlanta \$10.99 CCF

Because the water cost premium was less than the energy cost premium, and the volumes of water were not as great, we did not see a dramatic improvement in the payback for Altanta as compared to Boston.



# UNIVERSITY CLASSROOM PORTLAND temperate



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =	153,531
Living Building Gross SF =	153,531
Site Gross Acreage =	2.75

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	2.6%	0.1%	\$2,123,369	\$13.83	\$2,179,470	\$14.20
Baseline Building W2 Rainwater Containment - 41,000 gal Rainwater Tank			\$2,123,369	\$13.83	\$2,123,369 \$56,101	\$13.83 \$0.37
B Shell	7.0%	0.8%	\$4,959,353	\$32.30	\$5,306,177	\$34.56
Baseline Building			\$4,959,353	\$32.30	\$4,959,353	\$32.30
E1A Improved Glazing (reduce solar heat gain)					\$35,324	\$0.23
D3B Change Roof at Atrium to Fritted PV Glass					\$443,500	( <del>\$0.86)</del> \$2.89
	2.00/	4 49/	¢16 405 034	\$107 AA	¢45 000 420	\$102.25
C Interiors	-3.0%	-1.4%	\$16,495,934	\$107.44	\$16,495,934	\$103.35
Map Carpet Reduction (remove carpet and retroplate concrete)			\$10,100,001	φ107.44	\$96.071	\$0.63
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$153,531	\$1.00
LIA Exposed Ceilings (white matte surfaces)					(\$160,397)	(\$1.04)
D3 Eliminate Raised Access Floor					(\$717,000)	(\$4.67)
D.1 Services - Conveying Systems	0.0%	0.0%	\$297,968	\$1.94	\$297,968	\$1.94
Baseline Building			\$297,968	\$1.94	\$297,968	\$1.94
D.2 Services - Plumbing Systems	5.3%	0.4%	\$2,968,571	\$19.34	\$3,124,871	\$20.35
Baseline Building			\$2,968,571	\$19.34	\$2,968,571	\$19.34
W6 Low-Flow Fixtures / Optical Sensors					\$6,300	\$0.04
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.98
D.3 Services - HVAC Systems	-1.1%	-0.1%	\$5,646,851	\$36.78	\$5,586,171	\$36.38
Baseline Building			\$5,646,851	\$36.78	\$5,646,851	\$36.78
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,941,435)	(\$19.16)
M2A In-Slab Radiant Heating and Cooling					\$1 940 600	\$5.00 \$12.64
M3A Glound Source Heat Fullip M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$172.500	\$1.04 \$1.12
M2C Carbon Dioxide Sensors (in base building)					\$0	<b>\$2</b>
D.4. Services - Fire Protection Systems	0.0%	0.0%	\$425 840	\$2 77	\$425 840	\$2 77
Baseline Building	- 0.070	-0.070	\$425,840	\$2.77	\$425,840	\$2.77
D.5. Services - Electrical Systems	2.0%	0.4%	\$6,000,950	\$20.00	\$6 174 252	\$40.22
Resoling Ruilding	2.378	0.4 /	\$6,000,852	\$39.09	\$6,000,852	\$39.00
PA Occupancy Sensor to Outlets			ψ0,000,00Z	ψ <b>39.0</b> 9	\$14,100	\$0.09
PE High Efficiency Transformers					\$67,000	\$0.44
L2E Occupancy Sensor for Transient and Egress Lighting					\$37,500	\$0.24

# BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =	153,531
Living Building Gross SF =	153,531
Site Gross Acreage =	2.75

		Division Premium (%)	Building Premium (%)	LEED™ Gold Baseline		Living Building	
				Total	Cost/SF	Total	Cost/SF
L2F Dimmable Direct/Indirect Fixtures						\$54,800	\$0.36
E Equipment and Furnishings		0.0%	0.0%	\$257,958	\$1.68	\$257,958	\$1.68
Baseline Building				\$257,958	\$1.68	\$257,958	\$1.68
F Special Construction		0.0%	0.0%	\$79,247	\$0.52	\$79,247	\$0.52
Baseline Building				\$79,247	\$0.52	\$79,247	\$0.52
G Sitework		2.0%	0.1%	\$2,460,261	\$16.02	\$2,510,261	\$16.35
Baseline Building				\$2,460,261	\$16.02	\$2,460,261	\$16.02
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.33
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$2,108,417	\$13.73	\$2,108,417	\$13.73
Baseline Building				\$2,108,417	\$13.73	\$2,108,417	\$13.73
Living Building Prerequisites				\$0	\$0.00	\$856,439	\$5.58
PR5 - Materials Red List		100.0%	0.8%			\$350,657	\$2.28
PR7 - Responsible Industry		100.0%	0.2%			\$101,591	\$0.66
PR8 - Appropriate Materials / Services Radius		100.0%	0.9%			\$404,191 ¢0	\$2.63
PR9 - Leadership in Construction Waste		0.078	0.0 %			φυ	
Subtotal Direct Costs			2.2%	\$43,824,622	\$285.44	\$44,775,212	\$291.64
General Conditions	8.0%	2.2%	0.2%	\$3,512,022	\$22.88	\$3,588,200	\$23.37
Fee, Construction Contingency, Insurance	7.0%	2.2%	0.2%	\$3,328,586 ¢0	\$21.68	\$3,400,786 ¢0	\$22.15
Location woollier for POR I LAND, OK	1.00	0.0 %	0.0 %	<b>Ф</b> О		<b>Ф</b> О	
TOTAL MODIFIED CONSTRUCTION COST			2.2%	\$50,665,230	\$330.00	\$51,764,198	\$337.16

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =153,531Living Building Gross SF =153,531Site Gross Acreage =2.75

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	0.1%			\$50,000	\$0.33
PV1 Photovoltaic Panels and Infrastructure	649,000 Watts		100.0%	11.1%			\$4,867,500	\$31.70
LB Prerequisite Items								
PR3 - Habitat Exchange	2.75482 acres		100.0%	0.0%			\$13,774	\$0.09
PR6 - Construction Carbon Footprint	6,800 tons		100.0%	0.2%			\$74,800	\$0.49
PR15 - Beauty and Spirit (included in A/E fe	es below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.2%			\$73,750	\$0.48
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	13.1%	4.2%	\$14,186,264	\$92.40	\$16,046,901	\$104.52
Architecture & Engineering	7.00%	9.00%	31.4%	2.5%	\$3,546,566	\$23.10	\$4,658,778	\$30.34
Credits / Rebates / Incentives								
BETC	35%		66.0%	-0.3%	(\$173,152)	(\$1.13)	(\$287,365)	(\$1.87)
ETO - Energy Trust of Oregon			559.3%	-0.8%	(\$59,000)	(\$0.38)	(\$389,000)	(\$2.53)
PV Credits-(state, city, utility)	80%		-100.0%	-8.9%	\$0		(\$3,894,000)	(\$25.36)
SDC Credits	50%		-100.0%	-0.8%	\$0		(\$349,890)	(\$2.28)
TOTAL OWNER & DESIGN-BUILD COSTS				19.2%	\$17,500,679	\$113.99	\$20,865,249	\$135.90

TOTAL CONCEPTUAL COST: \$68,165,909 \$443.99 \$72,629,447 \$473.06

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: UNIVERSITY CLASSROOM IN PORTLAND, OR	4%	то	9%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	2%	то	7%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### University Classroom

#### Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 85.0

#### Normalized Baseline Energy Use (kWh) 3,612,251

 Impact of Design Changes (see sketches)
 0.97

 Adjusted Baseline EUI (kBtu/SF)
 82.5

					DOM HOT			ΤΟΤΑΙ
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	20%	20%	18%	2%	10%	30%	100%
	calc'd EUI	16.5	16.5	14.8	1.6	8.2	24.7	82.5
Energy Conservation Measures:								
Glazing	E1		3.0%	7.5%		2.9%		2.2%
Improve Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		6.0%	3.0%		2.1%		2.0%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		10.2%
Daylight controls (continuous dimming)	L1c							
Orient windows to allow for illumination of teaching wall	L1f							
Top daylighting from Atrium	L1g							
Lighting	L2	20.0%	-1.5%	2.0%		0.3%		4.1%
Individual occupancy sensors & dimming controls: closed offices/low occucpan	c L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dimmable direct / indirect fixtures	L2f							
Occupancy sensor / time clock for corridor lighting	L2j							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	7.6%
Occupancy sensor controlled plug logds	Pa							
EneravStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.2%
Widen Set Point Temperatures (expand ASHRAE 55)	M15		5.070	5.070		2.370		2.2/0
Subtotal from above Load Reduction strategies (nercentage)	IVIId	70.0%	6.9%	32.0%	0.0%	8.9%	25.0%	29.5%
Subtotal Reduced FUI (kBTU/SE)		49	15 4	10 1	1.6	7.5	18.6	58 1
Mechanical - Distribution & Ventilation	M2		20.0%	100.0%	210	60.0%	2010	21 /1%
Regignst heating w/ dedicated outside air system (DOAS)	M2n		20.078	100.078		00.076		21.4/0
Formu recovery ventilation	Mab							
Energy recovery ventilation	Mac							
Minimize carpet (inculates against radiant system)	Mad							
Natural ventiletion, energeble windowe	M2o							
Fan accisted natural ventilation	Made							
Night fluch	M2g							
Night jush	Mab							
Eliminate cooling	M2i							
Cascadina make-un air	M2x							
Subtotal from Mechanical Distribution strategies (nercentage)	IVIZA	0.0%	20.0%	100.0%	0.0%	60.0%	0.0%	21 4%
Subtotal Reduced FIII (kBTII/SE)		4.9	12 3	0.0	1.6	3.0	18.6	40 4
Mechanical - Plant Systems	M3	4.5	20.0%	0.0	1.0	13.4%	10.0	3 5%
Ground course heat nume systems	M25		20.078			13.470		5.570
Bomostia Llat Mater	IVIDd				50.00/			1.00/
Domestic Hot water	vv				50.0%			1.0%
Low flow fixtures (snowers, lavs, sinks)	Wb							
Subtatel from Machanical Plant and DUM sustains (norsentate)	Wd	0.0%	20.0%	0.0%	50.0%	12 40/	0.0%	1 50/
Bodusod Elli from Energy Concernation Measures (kPTLI/SE)		0.0%	20.0%	0.0%	50.0%	13.4%	19.6	4.5%
Final Energy Lise Breakdown as Dercentage of Baseline Lise		4.5	5.0 17%	0.0	1%	2.0	22%	55%
That Energy ose breakdown as referringe of baseline ose		0/0	12/0	0/0	170	3/0	23/0	3370
Building Operating Facto	r 0.90			100.0	CBECS Baselin	ne EUI (kBTU/sf)		
Impact of Interactive ECM effects	s 1.06			60%	target reduct	ion from CBECS		
· · · · · · · · · · · · · · · · · · ·				Achievement:	0			
Total Poducad FUL/kPTU/cf	) 25.4			Achievement.	porcont rodu	ction from CRECO	-	
	) 55.4			03%	percent reduc	tion from Norm	olized Deceline	Dida
	(1.1.4.)	4 500 000		56%	percent reduc		alizeu baseline	ыця
Total reduced energy u	se (kwn)	1,502,333		Incentives:				
				\$ 400,884	ETO incentive	for reduced EUI		
Number of crystaline panels	s needed	3,164		\$ 59,043	Estimated ET	O incentive for o	riginal design b	ldg
Total kW of	PV array	649		\$ 114,213	BETC for Plati	num (minus Golo	d), pass-thru	
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanvo-		kW/h nor	Total name -	Input Are-				
205 panel, facing South (azimuth 0°)	angle	Kvvn per	rotal panels	Input Area	# of Panels			
		panel	needed at °	(SF)				
	0°	227.042	6617	35,840	2874	Panels at Parking lo	ot + sunshade + co	vered walkw
	15°	244.678	6141		0			
optimal angle	: 32.5°	281.857	5331	2,400	192	Panels at sloping ro	oof less atrium	
	45°	247.953	6059		0			
	90°	175.198	8576	1,230	98			
		-		Total kWh =	723,805			
Cover Adjacent parking lot with PV			Additional area	50.040	4012	panels at park	ing lot	
			Additional	kWh Produced	910,893	1,634,697	-	
					-			






# ENERGY USE INDEX

COST PREMIUM PAYBACK COST PER SF PHOTOVOLTAIC CAPACITY WATER USE

150,000 galRAIN WATER TANK SIZE148,981 sfBUILDING SIZE2 floorsBUILDING HEIGHT39.03 acresSITE AREA61,628 sfPHOTOVOLTAIC AREA97,650 sfROOF AREA (FLAT)

# **MAJOR DESIGN STRATEGIES:**

- ✓ Reorganize plan to eliminate N/S portions of classroom wings.
- Relocate mass to inside of building wall.
- Eliminate ceilings in classrooms.
- ✓ Lower roof in media centers.
- Revise windows to illuminate teaching wall.
- ✓ Remove windows below 2'-6" in classrooms, 2'-0" in corridors.
- Add skylights in Gym; eliminate south side clerestory.
- ✓ Eliminate windows on west and east facades at classrooms.



the Case



SWALE TO TREAT STORMWATER

WATER TREATMENT

SWALE AT PARKING LOT

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PORTLAND, OR

# **SKANSKA**

Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

CONSTRUCTION COST						
	18.6%	0.9%	\$1 466 210	\$0.84	¢1 738 337	\$11.67
Resoline Ruilding	10.076	0.376	\$1,466,210	\$0.94	\$1,466,210	10.07
Baseline Duliulity Mo. Painwater Containment 150,000 gal Painwater Tank			φ1, <del>4</del> 00,210	φ9.04	\$272 127	<b>ወ</b> 9.04 ¢1.92
					ΨΖΙΖ, ΙΖΙ	φ1.05
B Shell	7.2%	2.3%	\$9,540,845	\$64.04	\$10,225,720	\$68.64
Baseline Building			\$9,540,845	\$64.04	\$9,540,845	\$64.04
L1B Replace Roofing with Glazed Skylight					\$412,800	\$2.77
L1B Credit for Removing Clerestory Windows					(\$103,500)	(\$0.69)
D3 Lower Roof at Media Center (at both links)					(\$248,400)	(\$1.67)
D3 Reallocate South Wing (move SF to east-west wings)					(\$69,000)	(\$0.46)
E1A Improved Glazing (reduce solar heat gain at vision only)					\$22,000	\$0.15
E1B Exterior Shading Devices (credit reflecting PV as shading ele	ment)				(\$30,000)	(\$0.20)
M2H "High Mass" Concrete Inside Insulation (CMU to replace meta	al stud plus added reflective skin)				\$467,700	\$3.14
D2B Modifications to Roof Structure (sloped roof)					\$233,275	\$1.57
C Interiors	3.1%	0.5%	\$4,624,290	\$31.04	\$4,765,608	\$31.99
Baseline Building			\$4,624,290	\$31.04	\$4,624,290	\$31.04
M2D Carpet Reduction (replace with RetroPlate)					\$108,466	\$0.73
M2A Topping Slab / Stair Premium for Underfloor Radiant System	(3" concrete)				\$148,981	\$1.00
L1A Exposed Ceilings (white matte surfaces)					(\$116,128)	(\$0.78)
	0.00/	0.00/	<b>*</b> /00.000	<b>*</b> 0.07	<b>*</b> 400.000	<b>*</b> 0.07
D.1 Services - Conveying Systems	0.0%	0.0%	\$100,000	\$0.67	\$100,000	\$0.67
Baseline Building			\$100,000	\$0.67	\$100,000	\$0.67
D.2 Services - Plumbing Systems	10.4%	0.5%	\$1,438,830	\$9.66	\$1,588,830	\$10.66
Baseline Building			\$1,438,830	\$9.66	\$1,438,830	\$9.66
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$1.01
D.3 Services - HVAC Systems	5.8%	0.7%	\$3,684,937	\$24.73	\$3,900,270	\$26.18
Baseline Building			\$3,684,937	\$24.73	\$3,684,937	\$24.73
Baseline HVAC System Reduction (2/3 reduction in Air Hand	er and Ducting)				(\$2,652,772)	(\$17.81)
M2A In-Slab Radiant Heating and Cooling					\$744,905	\$5.00
M2L Solar Wall Mechanical Screen					\$145,000	\$0.97
M3A Ground Source Heat Pump					\$1,882,200	\$12.63
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside /	Air System(DOAS)				\$80,000	\$0.54
M2C Carbon Dioxide Sensors					\$16,000	\$0.11
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$345.589	\$2.32	\$345.589	\$2.32
Baseline Building			\$345.589	\$2.32	\$345.589	\$2.32
			• ,	¢2.02		\$2.0 <u>2</u>
D.5 Services - Electrical Systems	6.6%	0.7%	\$3,044,694	\$20.44	\$3,246,194	\$21.79
Baseline Building			\$3,044,694	\$20.44	\$3,044,694	\$20.44
PA Occupancy Sensor to Outlets					\$5,000	\$0.03
PE High Efficiency Transformers					\$97,500	\$0.65
L1C Daylight Controls (continuous dimming 15' from perimeter)					\$23,800	\$0.16
L2F Dimmable Direct/Indirect fixtures					\$47,500	\$0.32
L2B Occupancy Sensor for Lighting (closed office / conference sp	2000)				<u>0</u> 2	
· · · · · · · · · · · · · · · · · · ·	aces)				ψυ	
L2C Individual Light Level Control (open spaces, classrooms)	aces)				\$5,200	\$0.03

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981 Site Gross Acreage = 39.03

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
						1		
_		-				<b>•</b> • • • • •		A
Е	Equipment and Furnishings		0.0%	0.0%	\$1,555,517	\$10.44	\$1,555,517	\$10.44
	Baseline Building				\$1,555,517	\$10.44	\$1,555,517	\$10.44
F	Special Construction		0.0%	0.0%	\$58,000	\$0.39	\$58,000	\$0.39
	Baseline Building	_			\$58,000	\$0.39	\$58,000	\$0.39
G	Sitework		1.6%	0.2%	\$3,701,152	\$24.84	\$3,761,152	\$25.25
-	Baseline Building				\$3,701,152	\$24.84	\$3.701.152	\$24.84
W4	Stormwater Retention / Building Water Discharge				<i>••</i> ,• <i>•</i> ,• <i>•</i> ,• <i>•</i> =	φ2 1.0 1	\$50.000	\$0.34
E1B	Trees for shading						\$10,000	\$0.07
W1	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
н	Logistics		0.0%	0.0%	\$524,694	\$3.52	\$524,694	\$3.52
	Baseline Building				\$524,694	\$3.52	\$524,694	\$3.52
Liv	ng Building Prereguisites				\$0	\$0.00	\$581,109	\$3.90
	PR5 - Materials Red List		100.0%	0.8%			\$248,507	\$1.67
	PR7 - Responsible Industry		100.0%	0.1%			\$41,508	\$0.28
	PR8 - Appropriate Materials / Services Radius		100.0%	1.0%			\$291,094	\$1.95
	PR9 - Leadership in Construction Waste		0.0%	0.0%				
Sub	total Direct Costs			7.7%	\$30,084,758	\$201.94	\$32,391,020	\$217.42
	General Conditions 3	3.7%	7.7%	0.3%	\$1,098,511	\$7.37	\$1,182,722	\$7 94
	Fee. Contingency. Insurance. Bonding	9.6%	7.7%	0.8%	\$3,008,433	\$20.19	\$3,239,056	\$21.74
	Location Modifier for PORTLAND, OR	1.00	0.0%	0.0%	\$0	<i><b>‡</b>_0110</i>	\$0	+=···· ·
	·							
TO	TAL MODIFIED CONSTRUCTION COST			7.7%	\$34,191,702	\$229.50	\$36,812,798	\$247.10

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

Di Pre	ivision emium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.7%			\$200,000	\$1.34
PV1 Photovoltaic Panels and Infrastructure	1,013,00	0 Watts		100.0%	25.3%			\$7,597,500	\$51.00
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.6%			\$195,150	\$1.31
PR6 - Construction Carbon Footprint	4,400	tons		100.0%	0.2%			\$48,400	\$0.32
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,000	\$0.42
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	19.2%	6.1%	\$9,573,677	\$64.26	\$11,411,967	\$76.60
Architecture & Engineering		7.00%	9.00%	38.4%	3.1%	\$2,393,419	\$16.07	\$3,313,152	\$22.24
Credits / Rebates / Incentives									
BETC	35%			66.4%	-0.4%	(\$167,753)	(\$1.13)	(\$279,116)	(\$1.87)
ETO - Energy Trust of Oregon				426.1%	-0.7%	(\$49,944)	(\$0.34)	(\$262,764)	(\$1.76)
PV Credits-(state, city, utility)	80%			-100.0%	-20.2%	\$0		(\$6,078,000)	(\$40.80)
SDC Credits	50%			-100.0%	-2.8%	\$0		(\$848,565)	(\$5.70)
TOTAL OWNER & DESIGN-BUILD COSTS					30.7%	\$11,749,399	\$78.87	\$15,360,725	\$103.11

TOTAL CONCEPTUAL COST: \$45,941,101 \$308.37 \$52,173,523 \$350.20

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: ELEMENTARY SCHOOL IN PORTLAND, OR	11%	то	16%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	9%	то	14%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## **Elementary School**

# Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 62.3

# Normalized Baseline Energy Use (kWh) 2,575,564

Impact of Design Changes (see sketches) 0.96

Adjusted Baseline EUI (kBtu/SF) 59.6

	90°	175.198	6651		0	]		
optimal angli	45°	281.857	4135		0	Paneis at sloping ro	ioi less atrium	
	15°	244.678	4763	50,700	4065	Dapole at electer	of loss at-i	
	0°	227.042	5133	10,928	876	Panels at parking lo	t, sunshade, cove	red walkway
		panel	needed at °	(SF)		4		
From KE i Screen 4-1: method 2, 2% misc iosses, 90% inverter efficiency, assumes Sanyo- 205 panel, facing South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
PV Panel Analysis:				1	1	1		
Total kW o	f PV array	1013		\$ 111,363	BETC for Plati	num (minus Gold	l), pass-thru	
Number of crystaline pane	ls needed	4,941		\$ 49,944	Estimated ETC	O incentive for or	iginal design b	oldg
				\$ 267,964	ETO incentive	for reduced EUI		
Total reduced energy	use (kWh)	1,165,228		Incentives:				
				55%	percent reduc	ction from Norma	alized Baseline	Bldg
Total Reduced EUI (kBTU/s	f) 28.2			66%	percent reduc	tion from CBECS		
				Achievement:				
Impact of Interactive ECM effect	ts 1.07			60%	target reducti	ion from CBECS		
Building Operating Factor	or 0.90			83.1	CBECS Baselin	ne EUI (kBTU/sf)		
			,.	570	270	270		- 1/0
Final Energy Use Breakdown as Percentage of Baseline Use		3%	24%	0.0	1%	2.9	16%	29.4 51%
Subiolar from Mechanical Plant and DHW systems (percentage) Reduced FUI from Energy Conservation Measures (VBTU/SE)		1.9	20.0%	0.0%	50.0%	-13.4%	9.6	0.8%
Water heating from water to water heat pump (gshp)	Wc	0.0%	20.0%	0.00/	E0 00/	13 40/	0.0%	6 00/
Low flow fixtures (showers, lavs, sinks)	Wb							
Domestic Hot Water	w				50.0%			1.4%
Ground source heat pump system	M3a							
Mechanical - Plant Systems	M3		20.0%			-13.4%		5.4%
Subtotal Reduced EUI (kBTU/SF)		1.8	17.9	0.0	1.7	2.6	9.6	33.5
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	100.0%	0.0%	60.0%	0.0%	14.7%
SolarWall mechanical screen or SolarDuct (pre-heat air)	M2I							
Displacement ventilation delivery for DOAS	M2k							
Eliminate coolina	M2i							
Nyn Jush High mass - concrete block on inside of insulation	M2b							
Fan assisted natural ventilation	M2f							
Natural ventilation: operable windows	M2e							
Minimize carpet (insulates against radiant system)	M2d							
Demand-based ventilation	M2c							
Energy recovery ventilation	M2b							
Radiant heating w/ dedicated outside air system (DOAS)	M2p		10.070	200.070		50.070		/0
Mechanical - Distribution & Ventilation	M2	1.0	15.0%	100.0%	1./	60.0%	5.0	14.7%
Subiolai jiom above Loaa keauction strategies (percentage) Subtotal Reduced FIII (kBTII/SF)		84.8%	9.8%	36.0%	0.0%	10.6%	25.0%	29.1% 42.2
Widen Set Point Temperatures (expand ASHRAE 55)	M1a	01 00/	0.00/	26.00/	0.0%	10 6%	25 0%	20 10/
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.5%
Shift uses for time of day in summer (east vs west)	M4b		E 00/	F 00/		2.5%		2.5%
Change of work hours (summer hours)	M4a							
Mechanical - Schedule	M4			7.0%				
Centralized power management	Pg							
Occupant buy-in / personal energy budget	Pf							
Energy efficient main transformer	Pe							
Remove phantom load / transformers	Pd							
EnergyStar appliances	Pb							
Occupancy sensor controlled plug loads	Pa		_10/0	2,0,0		2.175		
Plug Loads	P		-1 9%	2.5%		0.4%	25.0%	4.8%
Diminuum airect / inairect jixtures Occupancy sensor / time clock for corridor lighting	L2T							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Light colors on walls, ceiling surfaces	L2d							
Lighting	L2	9.8%	-0.7%	1.0%		0.1%		1.7%
Orient windows to allow for illumination of teaching wall	L1f							
Daylight controls (continuous dimming)	L1C							
Ton daylighting with skylights	L1b	/5.0%	-5.0%	1.3/0		1.1/0		13.3/0
Davlighting (incorporates tuned glazing/shading)	L1	75.0%	-5.6%	7 5%		1 1%		13 3%
Snaaea roof from solar panels Optimize insulation to core performance quide	E2a E2b							
Walls & Roof	E2		9.0%	4.0%		3.0%		4.1%
Add effective shading devices	E1b							
Improve Glazing	E1a							
Glazing	E1		4.0%	9.0%		3.5%		2.4%
Energy Conservation Measures	caic d EUI	11.9	23.3	2.7	1./	/.1	12.0	23.0
perc	ent of load	20%	39%	5%	3%	12%	21%	100%
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
					DOM. HOT			TOTAL



30.3

# LOW RISE OFFICE PORTLAND temperate



# LIVING BUILDIN DESIGN MODIFICATIO

STORMWATER

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 35,776 Living Building Gross SF = 35,776 Site Gross Acreage = 3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

со	NSTRUCTION COST						
Δ	Substructure	7 5%	0.6%	\$625 892	\$17 49	\$672 576	\$18.80
	Baseline Building	110 / 0	01070	\$625.892	\$17.49	\$625.892	\$17.49
W2	Rainwater Containment - 20.000 gal Rainwater Tank			+,	φ11.10	\$46,684	\$1.30
в	Shell	23.6%	10.1%	\$3,237,848	\$90.50	\$4,001,612	\$111.85
	Baseline Building			\$3,237,848	\$90.50	\$3,237,848	\$90.50
M2E	Operable Windows (manual)					\$31,680	\$0.89
D3C	Reallocate Glazing from East and West Façade to South (less spandrel panel, n	nore skin)				(\$17,472)	(\$0.49)
L1B	Replace Roofing with Glazed Skylight					\$141,600	\$3.96
E1A	Improved Glazing (reduce solar heat gain)					\$16,104	\$0.45
E1B	Exterior Shading Devices (windows and louvers at entry)					\$70,460	\$1.97
D2A	Added Wall / Skin for Modified Design (not in base building design)					\$274,560	\$7.67
M2H	"High Mass" Concrete Inside Insulation (added reflective skin)					\$49,500 \$169,522	\$1.38
D2B	Interior Light Shelves (remains from N/E/M/ keep south only)					\$100,002	\$4.71 ¢0.94
LID	Interior Light Shelves (remove from N/E/W, keep south only)					φ20,000	<b>Ф</b> 0.01
с	Interiors	17.2%	2.4%	\$1,076,571	\$30.09	\$1,261,402	\$35.26
	Baseline Building			\$1,076,571	\$30.09	\$1,076,571	\$30.09
M2D	Carpet Reduction (replace with RetroPlate)					\$25,500	\$0.71
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$48,264	\$1.35
L1A	Exposed Ceilings (white matte surfaces)					(\$68,213)	(\$1.91)
D3	Glass partitions in lieu of gypsum wallboard					\$179,280	\$5.01
D.1	Services - Conveying Systems	0.0%	0.0%	\$55.000	\$1.54	\$55.000	\$1.54
	Baseline Building			\$55,000	\$1.54	\$55,000	\$1.54
					• -		· -
D.2	Services - Plumbing Systems	73.8%	2.0%	\$208,354	\$5.82	\$362,154	\$10.12
	Baseline Building			\$208,354	\$5.82	\$208,354	\$5.82
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.11
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$4.19
D.3	Services - HVAC Systems	69.3%	5.4%	\$591,095	\$16.52	\$1,000,475	\$27.96
	Baseline Building			\$575,095	\$16.07	\$575,095	\$16.07
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$300,000)	(\$8.39)
M2A	In-Slab Radiant Heating and Cooling					\$178,880	\$5.00
МЗА	Ground Source Heat Pump					\$450,500	\$12.59
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$2.24
M2C	Carbon Dioxide Sensors			\$16,000	\$0.45	\$16,000	\$0.45
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$75,177	\$2.10	\$75,177	\$2.10
	Baseline Building			\$75,177	\$2.10	\$75,177	\$2.10
D.5	Services - Electrical Systems	6.5%	0.6%	\$723,416	\$20.22	\$770,116	\$21.53
<b>D</b> 1	Baseline Building			\$0U3,U16	\$16.86	\$10,500¢	\$16.86
PA	Uccupancy Sensor to Outlets					910,200 \$36 500	\$0.29
PE	Fight Enricency Italisionners			\$27 000	¢0.75	\$27 000	\$1.02 \$0.75
LIC	Edgingin Controls (continuous annining 15 11011 perifficient)			\$67 600	φU./Ο \$1.80	\$67 600	ອບ./ວ \$1 ຊດ
LZA	Contenency Sensor for Lighting (closed office / conference spaces)			\$12,000	φ1.09 \$0.34	\$12 000	\$0.34
L2E	Occupancy Sensor for Transient and Egress Lighting			\$13,800	\$0.39	\$13,800	\$0.34 \$0.39

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings		0.0%	0.0%	\$149,348	\$4.17	\$149,348	\$4.17
	Baseline Building				\$149,348	\$4.17	\$149,348	\$4.17
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building				\$0		\$0	
G	Sitework		7.6%	0.8%	\$791,671	\$22.13	\$851,671	\$23.81
	Baseline Building				\$791,671	\$22.13	\$791,671	\$22.13
W4	Stormwater Retention / Building Water Discharge						\$50,000	\$1.40
E1B	Trees for shading						\$10,000	\$0.28
W1	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
н	Logistics		0.0%	0.0%	\$40,261	\$1.13	\$40,261	\$1.13
	Baseline Building				\$40,261	\$1.13	\$40,261	\$1.13
Liv	ing Building Prerequisites				\$0	\$0.00	\$188,025	\$5.26
	PR5 - Materials Red List		100.0%	0.9%			\$68,202	\$1.91
	PR7 - Responsible Industry		100.0%	0.1%			\$6,707	\$0.19
	PR8 - Appropriate Materials / Services Radius		100.0%	1.5%			\$113,116	\$3.16
	PR9 - Leadership in Construction Waste		0.0%	0.0%				
Sul	ototal Direct Costs			24.5%	\$7,574,634	\$211.72	\$9,427,818	\$263.52
	General Conditions	4.0%	24.5%	1.0%	\$302,985	\$8.47	\$377,113	\$10.54
	Fee, Construction Contingency, Insurance	3.0%	24.5%	0.8%	\$238,965	\$6.68	\$297,429	\$8.31
	Location Modifier for PORTLAND, OR	1.00	0.0%	0.0%	\$0		\$0	
то	TAL MODIFIED CONSTRUCTION COST			24.5%	\$8,116,584	\$226.87	\$10,102,360	\$282.38

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS						-		_	
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.5%			\$40,000	\$1.12
PV1 Photovoltaic Panels and Infrastructure	273,000	) Watts		100.0%	30.6%			\$2,320,500	\$64.86
LB Prerequisite Items									
PR3 - Habitat Exchange	3.24	acres		100.0%	0.2%			\$16,200	\$0.45
PR6 - Construction Carbon Footprint	2,700	tons		100.0%	0.4%			\$29,700	\$0.83
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.3%			\$23,500	\$0.66
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	37.8%	11.3%	\$2,272,644	\$63.52	\$3,131,731	\$87.54
Architecture & Engineering		9.38%	11.38%	51.0%	5.1%	\$760,930	\$21.27	\$1,149,143	\$32.12
Credits / Rebates / Incentives									
BETC	35%			82.1%	-0.4%	(\$39,000)	(\$1.09)	(\$71,000)	(\$1.98)
ETO - Energy Trust of Oregon				939.5%	-0.9%	(\$7,600)	(\$0.21)	(\$79,000)	(\$2.21)
PV Credits-(state, city, utility)	80%			-100.0%	-24.5%	\$0		(\$1,856,400)	(\$51.89)
SDC Credits	50%			-100.0%	-3.1%	\$0		(\$231,353)	(\$6.47)
TOTAL OWNER & DESIGN-BUILD COSTS					49.8%	\$2,986,973	\$83.49	\$4,473,022	\$125.03

TOTAL CONCEPTUAL COST: \$11,103,558 \$310.36 \$14,575,382 \$407.41

	269/	то	249/
LIVING BUILDING CONCEPTUAL PREMIUM RANGE: LOWRISE OFFICE / CLASSROOMS IN PORTLAND, OR	29%	то	34%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### LowRiseOffice Portland

### Fortiallu

Normalized Baseline Energy Use Intensity (kBtu/SF) 74.3

Normalized Baseline Energy Use (kWh) 740,586

Impact of Design Changes (see sketches) 1.03

Adjusted Baseline EUI (kBtu/SF) 76.2

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	21%	26%	17%	4%	9%	23%	100%
	calc'd EUI	16.1	19.9	12.6	3.1	6.8	17.7	76.2
Energy Conservation Measures:			42.00/	7.50/				4.00/
Glazing	E1		12.0%	7.5%		4.7%		4.8%
Improve Glazing	E1a							
Add effective shading devices	E1b							
Walls & Root	E2		8.0%	3.5%		2.7%		2.9%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		10.5%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting with skylights	L1b							
Daylight controls (continuous dimming)	L1c							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		5.2%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimmina controls: closed offices/low occupan	c L2b							
Individual light level control (dimming) at open office areas	120							
Light colors on walls ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/hathrms)	12e							
Plug Loads	D		1.0%	2 59/		0.4%	25.0%	E 00/
Pildg Loads	r		-1.970	2.370		0.4%	23.0%	3.6%
Occupancy sensor controlled plug loads	Ра							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75.0%	17.5%	26.0%	0.0%	11.3%	25.0%	31.5%
Subtotal Reduced EUI (kBTU/SF)		4.0	16.4	9.3	3.1	6.0	13.3	52.2
Mechanical - Distribution & Ventilation	M2		25.0%	100.0%		60.0%		22.4%
Radiant heating w/ dedicated outside air system (DOAS)	M2p							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (inculates aggingt radiant system)	M2d							
Natural ventilation: operable windows	M20							
Fan assisted natural ventilation	M2E							
Fun ussistea natural ventilation Night flugh	10121							
Night Jush	IVI2g							
High mass - concrete block on inside of insulation	IVI2N	0.00/	25.00/	100.00/	0.00/	CO 00/	0.0%	22 40/
Subiolal from Wechanical Distribution strategies (percentage)		0.0%	25.0%	100.0%	0.0%	00.0%	0.0%	22.4%
Subtotal Reduced EUI (KBTU/SF)		4.0	12.3	0.0	3.1	2.4	13.3	35.1
Mechanical - Plant Systems	M3		20.0%			-15.0%		2.8%
Ground source heat pump system	M3a							
Domestic Hot Water	w				50.0%			2.1%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	0.0%	50.0%	-15.0%	0.0%	4.8%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	9.8	0.0	1.6	2.8	13.3	31.5
Final Energy Use Breakdown as Percentage of Baseline Use		5%	13%	0%	2%	4%	17%	59%
Building Operating Facto	r 0.90			92.9	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effects	s 1.07			60%	target reducti	on from CBECS		
				Achievement:				
Total Reduced EUI (kBTU/sf	) 30.3			67%	percent reduc	tion from CBECS		
				59%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced energy u	se (kWh)	301 985		Incontivos:	•			
iotal reduced energy a	50 (10011)	501,505		c e2.224	FTO in continue	for roduced FUI		
		4 004		\$ 65,554	ETO Incentive	Tor reduced EOI		
Number of crystaline panel	s needed	1,331		\$ 7,623	Estimated ETC	) incentive for oi	riginal design b	oldg
Total kW of	PV array	273		\$ 32,205	BETC for Plati	num (minus Golo	i), pass-thru	
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWb per	Total papels	Input Area				
205 panel, facing South (azimuth 0°)	angle	kwii per	notal parters	Input Area	# of Panels			
		panei	needed at °	(5F)		]		
	0°	227.042	1331		0	Panels at parking lo	ot, sunshade, cove	red walkway
	15°	244.678	1235	16,600	1331	]		
optimal angle	· 32.5°	281 857	1072		0	Panels at sloping ro	of less atrium	
	. 52.5	201.057						
	45°	247.953	1218		0			
	45° 90°	247.953 175.198	1218 1724		0	-		



# MID RISE OFFICE PORTLAND temperate



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

Division Building

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: PORTLAND, OR

# **SKANSKA**

Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

	Premium (%)	Premium (%)	LEED™ Gold Baseline		Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	9.6%	0.7%	\$1.420.795	\$14.30	\$1.557.795	\$15.67
Baseline Building			\$1,420,795	\$14.30	\$1,420,795	\$14.30
W2 Rainwater Containment - 78,800 gal Rainwater Tank			.,,,	••••••	\$137,000	\$1.38
B Shell	6.7%	2.4%	\$7,159,737	\$72.04	\$7,636,669	\$76.84
Baseline Building			\$7,159,737	\$72.04	\$7,159,737	\$72.04
M2E Operable Windows (manual)					\$61,920	\$0.62
D3C Reallocate Glazing from East and West Façade to South (less spandrel panel	, more skin)				(\$48,115)	(\$0.48
L1B Replace Roofing with Glazed Skylight					\$168,750	\$1.70
E1A Improved Glazing (reduce solar heat gain)					\$42,098	\$0.42
E1B Exterior Shading Devices					(\$207,300)	(\$2.09)
D2A Added Wall / Skin for Modified Design (not in base building design)					\$315,040	\$3.17
D2B Modifications to Roof Structure					\$52,539	\$0.53
L1D Interior Light Shelves					\$92,000	\$0.93
C Interiors	10.4%	2.0%	\$3,724,311	\$37.47	\$4,113,078	\$41.39
Baseline Building			\$3,724,311	\$37.47	\$3,724,311	\$37.47
M2D Carpet Reduction (Replaced with Retroplate)					\$99,385	\$1.00
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$149,078	\$1.50
L1A Exposed Ceilings (white matte surfaces)					(\$210,696)	(\$2.12)
D3 Atrium Space (smoke curtain, glazing, guardrails)					\$351,000	\$3.53
D.1 Services - Conveying Systems	24.1%	0.3%	\$207,466	\$2.09	\$257,466	\$2.59
Baseline Building			\$207,466	\$2.09	\$207,466	\$2.09
D3 Added Stop for 5th Floor					\$50,000	\$0.50
D.2 Services - Plumbing Systems	15.5%	0.7%	\$838,297	\$8.43	\$968,097	\$9.74
Baseline Building			\$838,297	\$8.43	\$838,297	\$8.43
W6 Low-Flow Fixtures / Optical Sensors					\$4,800	\$0.05
W2 Rain Harvesting (piping & pumps and filtration)					\$125,000	\$1.26
D.3 Services - HVAC Systems	57.2%	5.0%	\$1,725,708	\$17.36	\$2,713,598	\$27.30
Baseline Building			\$1,689,708	\$17.00	\$1,689,708	\$17.00
Baseline HVAC System					(\$938,935)	(\$9.45)
M2A In-Slab Radiant Heating and Cooling					\$496,925	\$5.00
M3A Ground Source Heat Pump					\$1,311,400	\$13.20
M2B Energy Recovery Wheel / Plate & Frame					\$118,500	\$1.19
M2C Carbon Dioxide Sensors			\$36,000	\$0.36	\$36,000	\$0.36
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$272,482	\$2.74	\$272,482	\$2.74
Baseline Building			\$272,482	\$2.74	\$272,482	\$2.74
D.5 Services - Electrical Systems	12.9%	1.5%	\$2,307,176	\$23.21	\$2,604,176	\$26.20
Baseline Building			\$2,024,176	\$20.37	\$2,024,176	\$20.37
PA Occupancy Sensor to Outlets					\$42,000	\$0.42
PE High Efficiency Main Transformer					\$43,000	\$0.43
L1C Daylight Controls (continuous dimming 15' from perimeter)			\$37,000	\$0.37	\$37,000	\$0.37
L2A Efficient Light Fixture Optics Premium			\$190,000	\$1.91	\$190,000	\$1.91
L2B Occupancy Sensor for Lighting (closed office / conference spaces)			\$22,000	\$0.22	\$22,000	\$0.22
L2C Individual Light Level Control (open spaces)					\$212,000	\$2.13
L2E Occupancy Sensor for Transient and Egress Lighting			\$34,000	\$0.34	\$34,000	\$0.34
E Equipment and Furnishings	0.0%	0.0%	\$472,675	\$4.76	\$472,675	\$4.76
Baseline Building			\$472,675	\$4.76	\$472,675	\$4.76

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

	Division Premium (%)	Building Premium (%)	LEED™ Gold Baseline		Living Building	
			Total	Cost/SF	Total	Cost/SF
						I
F Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
G Sitework	39.6%	2.9%	\$1,465,612	\$14.75	\$2,046,362	\$20.59
Baseline Building			\$1,465,612	\$14.75	\$1,465,612	\$14.75
W4 Stormwater Retention					\$50,000	\$0.50
D3 Parking revisions (pervious, deletion of piping, deletion of AC, lighting)					\$91,750	\$0.92
D3 Parking shading/PV structure					\$439,000	\$4.42
H Logistics	0.0%	0.0%	\$218,298	\$2.20	\$218,298	\$2.20
Baseline Building			\$218,298	\$2.20	\$218,298	\$2.20
Living Building Prerequisites			\$0	\$0.00	\$478,863	\$4.82
PR5 - Materials Red List	100.0%	0.9%			\$178,000	\$1.79
PR7 - Responsible Industry	100.0%	0.1%			\$18,863	\$0.19
PR8 - Appropriate Materials / Services Radius	100.0%	1.4%			\$282,000	\$2.84
PR9 - Leadership in Construction Waste	0.0%	0.0%			\$0	
Subtotal Direct Costs		17.8%	\$19,812,558	\$199.35	\$23,339,559	\$234.84
General Conditions 4	0% 17.8%	0.7%	\$792 502	\$7 07	\$933 582	\$9.30
Fee Construction Contingency Insurance	0% 17.8%	1.5%	\$1.648.405	\$16.59	\$1,941,851	\$19.53
Location Modifier for PORTLAND_OR	00 0.0%	0.0%	\$0	ψ10.00	\$0	ψ10.04
			<b>\$</b>		<i>Q</i>	
TOTAL MODIFIED CONSTRUCTION COST		17.8%	\$22,253,465	\$223.91	\$26,214,993	\$263.77

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 99,385 Living Building Gross SF = 99,385

Site Gross Acreage = 5.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.3%			\$60,000	\$0.60
PV1 Photovoltaic Panels and Infrastructure	876,000	Watts		100.0%	33.2%			\$6,570,000	\$66.11
LB Prerequisite Items									
PR3 - Habitat Exchange	5.24	acres		100.0%	0.1%			\$26,200	\$0.26
PR6 - Construction Carbon Footprint	2,700	tons		100.0%	0.1%			\$29,700	\$0.30
PR15 - Beauty and Spirit (included in A/E	fees above)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$43,500	\$0.44
Development Costs		LEED	LBC						
Develoment Costs		13.06%	16.06%	44.9%	6.6%	\$2,906,502	\$29.24	\$4,210,363	\$42.36
Architecture & Engineering		6.09%	8.09%	56.5%	3.9%	\$1,355,179	\$13.64	\$2,120,726	\$21.34
Credits / Rebates / Incentives									
BETC	35%			68.8%	-0.4%	(\$125,000)	(\$1.26)	(\$211,000)	(\$2.12)
ETO - Energy Trust of Oregon				831.8%	-0.9%	(\$22,000)	(\$0.22)	(\$205,000)	(\$2.06)
PV Credits-(state, city, utility)	80%			-100.0%	-26.5%			(\$5,256,000)	(\$52.89)
SDC Credits	50%		0.00%	-100.0%	-1.5%	\$0		(\$289,395)	(\$2.91)
TOTAL OWNER & DESIGN-BUILD COSTS					72.5%	\$4,114,681	\$41.40	\$7,099,094	\$71.43

TOTAL CONCEPTUAL COST: \$26,368,147 \$265.31 \$33,314,086 \$335.20

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: MIDRISE OFFICE IN PORTLAND, OR	24%	то	29%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	21%	то	26%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# MidRiseOffice

# Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 74.3

Normalized Baseline Energy Use (kWh) 2,156,413

Impact of Design Changes (see sketches/narrative) 1.03
Adjusted Baseline EUI (kBtu/SF) 76.2

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
per	cent of total use	21%	26%	17%	4%	9%	23%	100%
Energy Conservation Measures:	calc d EUI	10.1	19.9	12.0	5.1	0.8	17.7	70.2
Glazing	E1		12.0%	7 50/		1 70/		1 00/
Improved Glazina	E1 F1a		12.0%	1.576		4.776		4.0 /0
Add effective shading devices	F1b							
Walls & Roof	E2		8.0%	3.0%		2.5%		2.8%
Shaded roof from solar panels	E2a		0.070	5.070		2.570		2.070
Optimize insulation to core performance quide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		10.5%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		5.2%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed office	ces/low L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Decupancy sensors: transient lighting (corridors/stairs/butin	ns) Lze		1.0%	2.5%		0.49/	25.0%	F 00/
Plug Loads	P		-1.9%	2.5%		0.4%	25.0%	5.8%
EnergyStar appliances	Pa							
Ontimize printer layout/use	PC							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75%	18%	26%	0%	11%	25%	31%
Subtotal Reduced EUI (kBTU/SF)		4.0	16.4	9.4	3.1	6.0	13.3	52.3
Nechanical - Distribution & Ventilation	M2		25.0%	22.0%		60.0%		12.9%
Radiant heating w/ dealcated outside dir system (DOAS)	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Subtotal from Mechanical Distribution strategies (percentage	·)	0%	25%	22%	0%	60%	0%	13%
Subtotal Reduced EUI (KBTU/SF)		4.0	12.3	7.3	3.1	2.4	13.3	42.5
Ground source boot number sustem	IVI3		20.0%	20.0%		-15.0%		4.7%
Ground source near pump system	IVI3a				FO 0%			2 10/
Low flow fixtures (showers love sinks)	VV				50.0%			2.1%
Water heating from water to water heat nump (ashn)	WD M/c							
Subtotal from Mechanical Plant and DHW systems (percentag	ie)	0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	6.7%
Reduced EUI from All Energy Conservation Measures (kBTU/S	iF)	4.0	9.8	5.9	1.6	2.8	13.3	37.3
Final Energy Use Breakdown as Percentage of Baseline Use		5%	13%	8%	2%	4%	17%	51%
		0.00		00.0	00500.0	5111 (I D T 1 / C)		
Building Op	erating Factor	0.90		92.9	CBECS Baselin	e EUI (KBIU/ST)		
Impact of Interaction	le ECIVI effects	1.07		00%	target reducti	OII ITOIII CBECS		
				Achievement:				
Total Reduced	EUI (KBTU/ST)	36.0		52%	percent reduc	tion from CBECS	) alizad Bacalina	Blda
Total reduced on	ray uso (k)(h)	1 042 224		32/0	percent reduc		alizeu baselille	Diug
	ergy use (kwii)	1,045,554		Incentives:	FTO inconting	for reduced FU		
Number of crustaline	nanols noodod	4 152		\$ 211,465 \$ 22,105	Ertimated ETC	Tor reduced EOI	riginal docign h	Ida
Total	W of PV array	4,133		\$ 22,193	BETC for Plati	num (minus Gold	d) nass-thru	lug
DV Danel Analysia	www.urvdiidy	1001		.,430 ↓	DETCIULFIGUI	inani (ininus doli	.,, pass=unu	
PV Panel Analysis:				1	1			
assumes Sanvo-205 panel, facina South (azimuth 0°)	y, angle	kWh per	Total panels	Input Area	# of Panels			
		panel	needed at °	(SF)				
	0°	227.042	4596	27,922	2239	Panels at parking lo	ot, sunshade, cove	red walkway
	15°	244.678	4265	0	0	4		
optimal	angle: 32.5°	281.857	3702	23,871	1914	Panels at sloping ro	oof less atrium	
	45° 00°	247.953	4208		0	-		
	50	1/3.170	5550	Total kWh -	1 0/7 031	1		
					1,047,821			



# MIXED USE RENOVATION PORTLAND temperate



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

55,000 gal RAIN WATER TANK SIZE 185,043 sf BUILDING SIZE 6 floors BUILDING HEIGHT 1.0 acres SITE AREA 87,170 sf PHOTOVOLTAIC AREA 40,000 sf ROOF AREA (FLAT)

# **MAJOR DESIGN STRATEGIES:**

- ✓ Extend atrium down one level to allow access to operable windows for all workstations.
- ✓ Provide additional 1/2 level to make up for floor area lost with insertion of atrium.
- ✓ Change curved roof form to maximize PV production.
- ✓ Add PV sun shades on South.
- ✓ Add PV to adjacent parking garage to offset both the parking garage loads and the building's loads.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

со	NSTRUCTION COST						
Δ	Substructure	0.0%	0.0%	\$579,458	\$3.13	\$579,458	\$3,13
^	Baseline Building	0.070	0.070	\$579.458	\$3.13	\$579.458	\$3.13
W2	Rainwater Containment - 55,000 gal Rainwater Tank (in base building)			••••		\$0	
в	Shell	17.5%	4.8%	\$8,421,922	\$45.51	\$9,899,367	\$53.50
	Baseline Building			\$8,421,922	\$45.51	\$8,421,922	\$45.51
M2E	Operable Windows (manual, additional units beyond existing)					\$32,000	\$0.17
L1B	Replace Rooting with Glazed PV Frit Skylight					\$172,125	\$0.93
E1A	Improved Glazing (reduce solar heat gain)					\$25,000 \$100,275	\$0.14 ¢0.50
E1B	Exterior Shading Devices (PV as shading on South)					\$109,375	\$0.59
MOL	"High Mass" Concrete Inside Insulation (not included because this is a renovation)					\$0 \$0	
D2B	Modifications to Roof Structure and Roofing					\$99.000	\$0.54
E2C	Structure to Mount PV on Adjacent Parking Structure					\$349,945	\$1.89
D3	Renovation Work at Atrium (demo floor, railings, interior walls, structure for balcony)					\$150,000	\$0.81
D3	Added SF for Additional Floor (at penthouse)					\$240,000	\$1.30
D2A	Added Wall / Skin for Modified Design (not in base building design)					\$300,000	\$1.62
L1D	Interior Light Shelves (not included)					\$0	
с	Interiors	2.1%	0.5%	\$7,723,877	\$41.74	\$7,883,877	\$42.61
	Baseline Building			\$7,723,877	\$41.74	\$7,723,877	\$41.74
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$270,000	\$1.46
M2D	Retroplate Topping Slab (at TI locations)					\$690,000	\$3.73
L1A	Exposed Ceilings (existing white matte surfaces)					∪¢ (000 008 <b>⊉</b> )	(\$4.00)
D3	Remove Raised Access Flooring					(\$800,000)	(\$4.32)
D.1	Services - Conveying Systems	0.0%	0.0%	\$385,400	\$2.08	\$385,400	\$2.08
	Baseline Building			\$385,400	\$2.08	\$385,400	\$2.08
D.2	Services - Plumbing Systems	19.4%	0.5%	\$791,454	\$4.28	\$945,254	\$5.11
	Baseline Building			\$791,454	\$4.28	\$791,454	\$4.28
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
VV2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.81
D.3	Services - HVAC Systems	-2.4%	-0.2%	\$2,767,999	\$14.96	\$2,701,518	\$14.60
	Baseline Building			\$2,767,999	\$14.96	\$2,767,999	\$14.96
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,470,281)	(\$13.35)
M2A	In-Slab Radiant Heating and Cooling					\$600,000	\$3.24
МЗА	Ground Source Heat Pump					\$1,652,800	\$8.93
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$135,000	\$0.73
M2C	Carbon Dioxide Sensors					\$10,000	20.09
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$343,553	\$1.86	\$343,553	\$1.86
	Baseline Building			\$343,553	\$1.86	\$343,553	\$1.86
D.5	Services - Electrical Systems	24.1%	3.6%	\$4,539,215	\$24.53	\$5,631,885	\$30.44
	Baseline Building			\$4,571,685	\$24.71	\$4,571,685	\$24.71
PA	Uccupancy Sensor to Outlets						\$0.26
PE	Fight Enciency Transformers					φ100,000 ¢0	<b>Φ</b> 0.85
1.24	Edgingin Controls (Continuous unning 15 11011 perificient)					\$270 000	¢1 /6
LZA	Occupancy Sensor for Lighting (closed office / conference spaces)					\$0,000	φ1.40
L2C	Individual Light Level Control (open spaces, classrooms)					\$585,000	\$3.16
L2E	Occupancy Sensor for Transient and Egress Lighting			(\$32,470)	(\$0.18)	\$0	20.10

# BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

		Division Premium (%)	Building Premium (%)	LEED™ Gold Baseline		Living Building	
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$2.061.480	\$11.14	\$2.061.480	\$11.14
Baseline Building				\$2,061,480	\$11.14	\$2,061,480	\$11.14
F Special Construction		0.0%	0.0%	\$1,407,188	\$7.60	\$1,407,188	\$7.60
Baseline Building				\$1,407,188	\$7.60	\$1,407,188	\$7.60
G Sitework		4.4%	0.2%	\$1,131,528	\$6.11	\$1,181,528	\$6.39
Baseline Building				\$1,131,528	\$6.11	\$1,131,528	\$6.11
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.27
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$600,000	\$3.24	\$600,000	\$3.24
Baseline Building				\$600,000	\$3.24	\$600,000	\$3.24
Living Building Prerequisites				\$0	\$0.00	\$621,055	\$3.36
PR5 - Materials Red List		100.0%	0.8%			\$242,636	\$1.31
PR7 - Responsible Industry		100.0%	0.1%			\$34,692	\$0.19
PR8 - Appropriate Materials / Services Radius		100.0%	1.0%			\$309,388	\$1.67
PR9 - Leadership in Construction Waste		100.0%	0.1%			\$34,339	\$0.19
Subtotal Direct Costs			11.3%	\$30,753,074	\$166.19	\$34,241,563	\$185.05
General Conditions	4.0%	11.3%	0.5%	\$1,230,123	\$6.65	\$1,369,663	\$7.40
Fee, Construction Contingency, Insurance	0.7%	11.3%	0.1%	\$238,965	\$1.29	\$266,072	\$1.44
Location Modifier for PORTLAND, OR	1.00	0.0%	0.0%	\$0		\$0	
TOTAL MODIFIED CONSTRUCTION COST			11.3%	\$32,222,162	\$174.13	\$35,877,298	\$193.89

CASCADIA REGION GREEN BUILDING COUNCIL/SERA ARCHITECTS/SKANSKA USA BUILDING/GERDING EDLEN /INTERFACE ENGINEERING/NEW BUILDINGS INSTITUTE 3.PDX.27

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.2%			\$60,000	\$0.32
PV1 Photovoltaic Panels and Infrastructure	1,433,000	Watts		100.0%	34.9%			\$10,747,500	\$58.08
LB Prerequisite Items									
PR3 - Habitat Exchange	1	acres		100.0%	0.0%			\$5,000	\$0.03
PR6 - Construction Carbon Footprint	1,250	tons @ 50%		100.0%	0.0%			\$13,750	\$0.07
PR15 - Beauty and Spirit (included in A/E fee	∋s below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,500	\$0.34
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	23.3%	6.8%	\$9,022,205	\$48.76	\$11,121,962	\$60.10
Architecture & Engineering		7.00%	9.00%	43.2%	3.2%	\$2,255,551	\$12.19	\$3,228,957	\$17.45
Credits / Rebates / Incentives									
BETC	35%			66.0%	-0.4%	(\$173,152)	(\$0.94)	(\$287,365)	(\$1.55)
ETO - Energy Trust of Oregon				193.0%	-0.8%	(\$132,211)	(\$0.71)	(\$387,340)	(\$2.09)
PV Credits-(state, city, utility)	80%			-100.0%	-28.0%	\$0		(\$8,598,000)	(\$46.46)
SDC Credits	50%			-100.0%	-1.1%	\$0		(\$349,890)	(\$1.89)
TOTAL OWNER & DESIGN-BUILD COSTS					42.3%	\$10,972,394	\$59.30	\$15,618,074	\$84.40

TOTAL CONCEPTUAL COST: \$43,194,556 \$233.43 \$51,495,372 \$278.29

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: MIXED-USE RENOVATION IN PORTLAND, OR	17%	то	22%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	13%	то	18%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# **Complex Mixed Use Renovation**

# Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 83.6

Normalized Baseline Energy Use (kWh) 3,553,180

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 81.4

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	19%	30%	18%	4%	9%	21%	100%
Ensure Concernation Management	calc'd EUI	15.3	24.4	14.7	3.0	7.3	16.8	81.4
Energy Conservation Measures:			10.0%	10.0%		F 00/		F 20/
Giazing	E1		10.0%	10.0%		5.0%		5.2%
Add effective shading devices	F1b							
Walls & Roof	F2		15.0%	6.0%		4.8%		6.0%
Shaded roof from solar panels	E2a		13.070	0.070		4.070		0.070
Optimize insulation to core performance guide	E2b							
Davlighting (incorporates tuned glazing/shading)	L1	38.0%	-2.9%	3.8%		0.6%		7.0%
Remove ceiling, raise window head, add lightshelf	L1a							
Daylight controls (continuous dimming)	L1c							
Floorplan renovation for daylighting	L1e							
Lighting	L2	38.5%	-2.9%	3.9%		0.6%		7.1%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucpan	c L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
High color rendering metal balide retail lighting	LZe L2b							
Plug Loads	D		_1.0%	2 5%		0.4%	25.0%	5 1%
Occupancy sensor controlled plug loads	Pa		1.570	2.570		0.470	23.070	5.170
EnergyStar appliances	Ph							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybria)	Pk		F 00/	F 00/		2 50/		2.6%
Widen Set Point Temperatures			5.0%	5.0%		2.5%		2.6%
Subtotal from above Load Reduction strategies (nercentage	IVIT9	76 5%	22 4%	31.2%	0.0%	13.8%	25.0%	33 1%
Subtotal Reduced EUI (kBTU/SF)		3.6	19.0	10.1	3.0	6.3	12.6	54.5
Mechanical - Distribution & Ventilation	M2		15.0%	22.0%		60.0%		10.9%
Radiant heatina/coolina w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2o							
Subtotal from Mechanical Distribution strategies (nercentage)	11/20	0.0%	15.0%	22.0%	0.0%	60.0%	0.0%	10.9%
Subtotal Reduced EUI (kBTU/SF)		3.6	16.1	7.9	3.0	2.5	12.6	45.7
Mechanical - Plant Systems	M3		20.0%	20.0%		15.0%		6.4%
Ground source heat pump system	M3a							
Domestic Hot Water	w				50.0%			1.8%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	15.0%	0.0%	8.2%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.6	12.9	6.3	1.5	2.1	12.6	39.0
Final Energy Use Breakdown as Percentage of Baseline Use		4%	16%	8%	2%	3%	15%	52%
Building Operating Facto	r 0.90			92.9	CBECS Baselin	e FLII (kBTLI/sf)		
Impact of Interactive ECM effect	s 1.05			60%	target reducti	on from CBECS		
				Achievement:	TARGET REDI		т	
Total Reduced FUI (kBTU/sf	37.2			60%	nercent reduc	tion from CBECS		
	, 37.2			56%	percent reduc	tion from Norm	alized Baseline	Bldg
Total reduced energy u	se (kWh)	1.579.557		Incentives:	•			
	,			\$ 374.988	FTO incentive	for reduced FUI		
Number of crystaline panel	s needed	6,989		\$ 132.211	Estimated ETC	) incentive for o	riginal design b	ldg
Total kW of	PV array	1433		\$ 114,213	BETC for Plati	num (minus Golo	d), pass-thru	.0
PV Panel Analysis:							//	
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanvo-	1 1							
205 panel, facing South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
		panel	needed at °	(SF)				
	0°	227.042	6958	46,000	3688	_		
	15°	244.678	6456		0	4		
optimal angle	: 32.5°	281.857	5605		0	-		
Assume an equal area parking garage with an EUI of 1.7	45°	247.953	63/1		0	-		
	90.	1/2.198	9010	Total Little	0			
Entire parking garage reaf last -tourter			A al al i + i '		85/,331	Adle		
Entire parking galage root less elevator			6916 IGNUUUM A lenoitibbA	41,170	33U1 7/0 /66	1 586 707	ing garage	
					/ 4/,400	1,000,101		



# SINGLE FAMILY RESIDENTIAL PORTLAND temperate



# THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 1,840 Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
СС	INSTRUCTION COST						
						A	
А	Substructure	0.0%	0.0%	\$63,527	\$34.53	\$63,527	\$34.53
W2	Baseline Building Rainwater Containment - 10.000 gal Rainwater Tank (included in base building)			\$03,52 <i>1</i>	\$34.53	\$03,527 \$0	\$34.53
в	Shell	8.3%	3.8%	\$131,226	\$71.32	\$142,129	\$77.24
	Baseline Building			\$131,226	\$71.32	\$131,226	\$71.32
E1A	Improved Glazing (reduce solar heat gain)					\$4,303	\$2.34
E1B	Exterior Shading Devices					\$6,600	\$3.59
M2H	"High Mass" Concrete (existing exterior walls are ICF)					\$0	
с	Interiors	11.6%	1.5%	\$37,430	\$20.34	\$41,780	\$22.71
	Baseline Building			\$37,430	\$20.34	\$37,430	\$20.34
M2A	Thicken Lower Level Slab (2") and Gypcrete on Upper Level					\$4,350	\$2.36
L1A	Exposed Ceilings (white matte surfaces)					\$0	
D.*	Services - Conveying Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
<u>م</u>	Convisos - Diumbing Systems	57 2%	2 10/	\$10.654	¢5 70	¢16 754	¢0.11
D.4	Papeline Puilding	57.5%	2.170	\$10,654	\$5.79 \$5.70	\$10,734	\$9.11 ¢5.70
We	Low-Flow Fixtures / Ontical Sensors			ψ10,00 <del>4</del>	<i>ф</i> 0.79	\$0	<b>4</b> 0.79
W2	Rain Harvesting (piping & pumps and filtration)					\$0 \$0	
W7	Composting Toilets					\$6,100	\$3.32
D.:	Services - HVAC Systems	98.4%	4.1%	\$12,008	\$6.53	\$23,827	\$12.95
	Baseline Building			\$12,008	\$6.53	\$12,008	\$6.53
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$7,301) \$0,200	(\$4.01)
M2A	III-Slab Radiani, Healing and Cooling					\$9,200 \$0	\$5.00
M3C	Solar Thermal System					\$10.000	\$5 43
						. ,	
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
D.(	Services - Electrical Systems	<u>68.1%</u>	2.4%	\$10,136	\$5.51	\$17,036	\$9.26
	Baseline Building			\$10,136	\$5.51	\$10,136	\$5.51
L2K	Provide hardwired compact fluorescent fixtures in all spaces					\$2,200	\$1.20
L2L	Motion sensors for exterior lighting					\$300	\$0.16
M2Z	Ceiling Fans and window box fans ( five of each)					\$4,400	\$2.39

CASCADIA REGION GREEN BUILDING COUNCIL/SERA ARCHITECTS/SKANSKA USA BUILDING/GERDING EDLEN /INTERFACE ENGINEERING/NEW BUILDINGS INSTITUTE 3.PDX.32

# BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF =1,840Living Building Gross SF =1,840Site Gross Acreage =0.11

			Division Premium (%)	Building Premium (%)	um LEED™ Gold Baselin		Living Bu	iilding
					Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings		0.0%	0.0%	\$1,011	\$0.55	\$1,011	\$0.55
	Baseline Building				\$1,011	\$0.55	\$1,011	\$0.55
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building				\$0		\$0	
_								
G	Sitework		60.9%	4.2%	\$20,208	\$10.98	\$32,508	\$17.67
	Baseline Building				\$20,208	\$10.98	\$20,208	\$10.98
W4	Stormwater Retention / Building Water Discharge						\$12,300	\$6.68
н	Logistics		0.0%	0.0%	\$3,280	\$1.78	\$3,280	\$1.78
	Baseline Building				\$3,280	\$1.78	\$3,280	\$1.78
Liv	ing Building Prerequisites				\$0	\$0.00	\$13,603	\$7.39
	PR5 - Materials Red List		100.0%	1.0%			\$2,907	\$1.58
	PR7 - Responsible Industry		100.0%	2.6%			\$7,488	\$4.07
	PR8 - Appropriate Materials / Services Radius		100.0%	1.1%			\$3,208	\$1.74
	PR9 - Leadership in Construction Waste		0.0%	0.0%			\$0	
Su	ototal Direct Costs			22.8%	\$289,480	\$157.33	\$355,456	\$193.18
		0.50/	22.9%	2 20/	¢07 202	¢44.00	\$33 634	¢40.07
	General Conditions	9.5%	22.0%	2.2%	φ∠1,303 \$22,200	\$14.88	φοο,024 \$41.014	\$18.27 ¢00.00
	ree, construction contingency, insurance	10.5%	0.0%	0.0%	დი დი	\$18.15	⊅41,011 ¢∩	\$ZZ.29
		1.00	0.0%	0.0 //	<b>Ф</b> О		<b>Ф</b> О	
то	TAL MODIFIED CONSTRUCTION COST			22.8%	\$350,263	\$190.36	\$430,091	\$233.75

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 1,840

Living Building Gross SF = 1,840 Site Gross Acreage = 0.11

Sile	01055	Acreage	= 0.11	

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				0.0%	0.0%			\$0	
PV1 Photovoltaic Panels and Infrastructure	5,900	Watts		100.0%	18.3%			\$53,100	\$28.86
LB Prerequisite Items									
PR3 - Habitat Exchange	0.114784	acres		100.0%	0.2%			\$574	\$0.31
PR6 - Construction Carbon Footprint	50	tons		100.0%	0.2%			\$550	\$0.30
PR15 - Beauty and Spirit (included in A/	E fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.5%			\$1,500	\$0.82
Development Costs		LEED	LBC						
Develoment Costs		3.43%	2.79%	0.0%	0.0%	\$12,000	\$6.52	\$12,000	\$6.52
Architecture & Engineering		12.00%	15.00%	53.5%	7.8%	\$42,032	\$22.84	\$64,514	\$35.06
Credits / Rebates / Incentives									
RETC	35%			-100.0%	-4.0%	\$0		(\$11,590)	(\$6.30)
ETO - Energy Trust of Oregon				-100.0%	-3.9%	\$0		(\$11,400)	(\$6.20)
HPGBP - High Performing Green Buildir	igs of Portland	(\$5.19)	(\$12.87)	0.0%	0.0%	\$0		\$0	
PV Credits-(state, city, utility)	80%			-100.0%	-14.7%	\$0		(\$42,480)	(\$23.09)
SDC Credits	50%			-100.0%	-1.0%	\$0		(\$2,966)	(\$1.61)
TOTAL OWNER & DESIGN-BUILD COSTS					18.1%	\$54,032	\$29.36	\$63,802	\$34.68

TOTAL CONCEPTUAL COST:

\$404,294 \$219.73

\$493,893 \$268.42

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: SINGLE FAMILY RESIDENTIAL IN PORTLAND, OR	20%	то	25%

INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP): 16% TO 21%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# Single Family Residential

Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 39.4

### Normalized Baseline Energy Use (kWh) 21,027

Impact of Design Changes (see sketches) 0.95

Adjusted Baseline EUI (kBtu/SF) 37.3

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perc	ent of load	14%	38%	6%	10%	9%	23%	100%
	calc'd EUI	5.2	14.2	2.2	3.7	3.4	8.6	37.3
Energy Conservation Measures:								
Glazing	E1		10.0%	8.0%		4.4%		4.7%
High performance residential glazing	E1f							
Add effective shading devices	E1b							
Insulated panels for glazing (thermal window shades)	E1g							
Walls & Roof	EZ		7.0%	3.0%		2.3%		3.0%
Shaded roof from solar panels	E2a							
Optimize insulation - single family residential	E2I							
Lighting	LZ	53.8%	-4.0%	5.4%		0.8%		6.4%
Provide nardwired compact fluorescent fixtures in all spaces.	LZK							
Notion sensors for exterior lighting	L2I		2.201	2.02(		0.50/	20.00/	6.00/
Plug Loads	P		-2.3%	3.0%		0.5%	30.0%	6.3%
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Occupant buy-in / personal energy budget	PT							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a	53.00/	45 70/	24 40/	0.0%	40 50/	20.0%	22.00/
Subtotal from above Load Reduction strategies (percentage)		53.8%	15.7%	24.4%	0.0%	10.5%	30.0%	22.8%
Machanical Distribution & Vantilation		2.4	11.9	1.7	3.7	5.0	0.0	20.0
Redient floor besting	IVI2		15.0%	100.0%		60.0%		14.2%
Radiant floor neating	IVI2Y							
Energy recovery ventilation	IVI20							
Flimingto cooling	N/2e							
Calling fans and window box fans	NA27							
Subtotal from Mechanical Distribution strategies (nercentage)	10122	0.0%	15.0%	100.0%	0.0%	60.0%	0.0%	11 2%
Subtotal Reduced FUI (kBTU/SE)		2.4	10.1	0.0	3.7	1.2	6.0	23.5
Mechanical - Plant Systems	M3		40.0%	010	017		010	10.9%
Solar thermal (evacuated tubes) Heating System	M3c		40.070					10.570
Domestic Hot Water	w				75.0%			7 5%
Solar-thermal domestic water	VV				75.078			7.570
Low flow fixtures (chowers low sinks)	Wb							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	40.0%	0.0%	75.0%	0.0%	0.0%	18.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		2.4	6.1	0.0	0.9	1.2	6.0	16.6
Final Energy Use Breakdown as Percentage of Baseline Use		6%	16%	0%	3%	3%	16%	55%
Building Operating East	0.00			12.0	CRECS Racolin			
Impact of Interactive ECM offee	1 0.50			45.8	target reducti	on from CRECS		
Impact of Interactive ECW effec	.5 1.05			00%	target reducti	OIT ITOITI CBECS		
				Achievement				
Total Reduced EUI (kBTU/s	f) 15.5			65%	percent reduc	tion from CBECS		
				61%	percent reduc	tion from Norm	alized Baseline	BIDE
Total reduced energy	use (kWh)	8,294		Incentives:				
				\$ 2,419	ETO incentive	for reduced EUI		
Number of crystaline pane	ls needed	31		\$ -	Estimated ETC	D incentive for o	riginal design b	oldg
Total kW o	f PV array	6		\$ 1,952	BETC for Plati	num (minus Golo	d), pass-thru	
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh ner	Total nanels	Input Area				
205 panel, facing South (azimuth 0°)	angle	nanel	needed at °	(SE)	# of Panels			
		paner	neeueu al	(31)		_		
	0°	227.042	37		0	4		
	15°	244.678	34	202	0	-		
optimal angl	32.5	281.857	30	398	31	-		
	45	247.953	34		0	-		
	90-	1/5.198	48		U			

# Total kWh = 8,738



# MULTIFAMILY RESIDENTIAL PORTLAND temperate



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PORTLAND, OR**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	10.3%	0.3%	\$622 710	\$2 97	\$686 735	\$3.28
Baseline Building	101070	01070	\$622,710	\$2.97	\$622,710	\$2.97
W2 Rainwater Containment - 30,000 gal Rainwater Tank			<b>~~</b> , <b>~</b>	φ2.07	\$64,025	\$0.31
B Shell	5.0%	1.6%	\$7,656,970	\$36.52	\$8,040,942	\$38.35
Baseline Building			\$7,656,970	\$36.52	\$7,656,970	\$36.52
E1D Reduce Glazing (30% of original window glazing)					\$165,200	\$0.79
E1A Improved Glazing (reduce solar heat gain)					\$12,972	\$0.06
E1B Exterior Shading Devices					\$468,000	\$2.23
D2A Reduce Wall / Skin for Modified Design (not in base building design)					(\$405,600)	(\$1.93)
D3 Relocate Elevator					\$45,000	\$0.21
D3 Covered Walkway					\$98,400	\$0.47
C Interiors	5.3%	1.3%	\$5,891,333	\$28.10	\$6,205,850	\$29.60
Baseline Building			\$5,891,333	\$28.10	\$5,891,333	\$28.10
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$314,517	\$1.50
D.1 Services - Conveying Systems	0.0%	0.0%	\$244,158	\$1.16	\$244,158	\$1.16
Baseline Building			\$244,158	\$1.16	\$244,158	\$1.16
D.2 Services - Plumbing Systems	8.0%	0.6%	\$1,900,476	\$9.06	\$2,052,276	\$9.79
Baseline Building			\$1,900,476	\$9.06	\$1,900,476	\$9.06
W6 Low-Flow Fixtures / Optical Sensors					\$1,800	\$0.01
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.72
D.3 Services - HVAC Systems	387.3%	11.5%	\$717,870	\$3.42	\$3,498,260	\$16.68
Baseline Building			\$717,870	\$3.42	\$717,870	\$3.42
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$535,000)	(\$2.55)
M2A In-Slab Radiant Heating and Cooling					\$1,048,390	\$5.00
M3A Ground Source Heat Pump					\$1,959,000	\$9.34
M2B Energy Recovery wheel / Plate & Frame/Dedicated Outside Air System(DOAs	>)				\$308,000 Ω\$	φ1.4 <i>1</i>
M2C Carbon Dioxide Sensors					ΨΟ	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$462,507	\$2.21	\$462,507	\$2.21
Baseline Building			\$462,507	\$2.21	\$462,507	\$2.21
D.5 Services - Electrical Systems	0.6%	0.1%	\$3,452,618	\$16.47	\$3,471,778	\$16.56
Baseline Building			\$3,416,018	\$16.29	\$3,416,018	\$16.29
L2E Occupancy Sensor for Transient Lighting (corridors/stairs)			\$28,000	\$0.13		
L2I Dual day/night light levels in corridors; occupancy sensors			\$8,600	\$0.04		
L2K Provide hardwired compact fluorescent fixtures in all spaces					\$55,760	\$0.27

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PORTLAND, OR**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings		0.0%	0.0%	\$948,170	\$4.52	\$948,170	\$4.52
	Baseline Building				\$948,170	\$4.52	\$948,170	\$4.52
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
-	Baseline Building				\$0		\$0	
	Olderman h		C 29/	0.0%	¢0.004.400	¢40.50	¢0.050.000	¢44.05
G	Sitework Pesseline Building		0.2%	0.0%	\$2,221,402	\$10.59	\$2,330,902	\$11.23 \$10.50
14/2	Stormwater Potention / Ruilding Water Discharge				ψ2,221,402	\$10.59	\$50,000	\$10.59
D3	Added Courtyard						\$87,500	\$0.24 \$0.42
00							<i><b>Q</b></i> (1,000	ψ0.+2
н	Logistics		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building				\$0		\$0	
Liv	ing Building Proroquisitos				\$0	\$0.00	\$657.243	\$2.12
	PR5 - Materials Red List		100.0%	0.8%	Ψ	ψ0.00	\$194 424	\$0.03
	PR7 - Responsible Industry		100.0%	0.8%			\$202 298	\$0.95 \$0.96
	PR8 - Appropriate Materials / Services Radius		100.0%	1.1%			\$260.521	\$1.24
	PR9 - Leadership in Construction Waste		0.0%	0.0%			. ,	<b>*-</b> .
Su	btotal Direct Costs			18.7%	\$24,118,274	\$115.03	\$28,626,881	\$136.53
	General Conditions	4.0%	18.7%	0.7%	\$964,731	\$4.60	\$1,145,075	\$5.46
	Fee, Construction Contingency, Insurance	4.0%	18.7%	0.8%	\$1,003,320	\$4.79	\$1,190,878	\$5.68
	Location Modifier for PORTLAND, OR	1.00	0.0%	0.0%	\$0		\$0	
то	TAL MODIFIED CONSTRUCTION COST			18.7%	\$26,086,325	\$124.41	\$30,962,834	\$147.67

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PORTLAND, OR**



\$213.83

Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	4.1%			\$1,000,000	\$4.77
PV1 Photovoltaic Panels and Infrastructure	825,000 Watts		100.0%	25.7%			\$6,187,500	\$29.51
LB Prerequisite Items								
PR3 - Habitat Exchange	2.86961 acres		100.0%	0.1%			\$14,348	\$0.07
PR6 - Construction Carbon Footprint	PR6 - Construction Carbon Footprint 6,400 tons			0.3%			\$70,400	\$0.34
PR15 - Beauty and Spirit (included in A/E fees below)				0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.2%			\$43,500	\$0.21
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	31.4%	9.5%	\$7,304,171	\$34.84	\$9,598,479	\$45.78
Architecture & Engineering	7.00%	9.00%	52.6%	4.0%	\$1,826,043	\$8.71	\$2,786,655	\$13.29
Credits / Rebates / Incentives								
BETC	35%		43.4%	-0.4%	(\$244,440)	(\$1.17)	(\$350,601)	(\$1.67)
ETO - Energy Trust of Oregon			627.0%	-0.7%	(\$25,321)	(\$0.12)	(\$184,081)	(\$0.88)
PV Credits-(state, city, utility)	80%		-100.0%	-20.5%	\$0		(\$4,950,000)	(\$23.61)
SDC Credits	50%		-100.0%	-1.4%	\$0		(\$343,583)	(\$1.64)
TOTAL OWNER & DESIGN-BUILD COSTS				56.6%	\$8,860,453	\$42.26	\$13,872,617	\$66.16

TOTAL CONCEPTUAL COST: \$34,946,778 \$166.67 \$44,835,452

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: MULTI-FAMILY HOUSING IN PORTLAND, OR	26%	то	31%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	21%	то	26%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## **Multi- Family Residential**

Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 48.0

Normalized Baseline Energy Use (kWh) 1,880,891

TOTAL

Impact of Design Changes (see sketches) 0.98

Adjusted Baseline EUI (kBtu/SF) 47.0

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	15%	30%	7%	13%	10%	25%	100%
Ensure Concernation Measures	calc'd EUI	7.1	14.1	3.3	6.1	4.7	11.8	47.0
Charles			40.00/	40.00/		5.00/		
Glazing	E1		10.0%	10.0%		5.0%		4.2%
Improve Glazing	E1a							
Add effective shading devices	E1b							
Reduce glazing to 30%	E1d							
Walls & Roof	E2		6.0%	1.5%		1.7%		2.1%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Lighting	L2	56.6%	-4.2%	5.7%		0.8%		7.7%
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dual day/night light levels in corridors; occupancy sensors	L2i							
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	7.1%
EnerayStar appliances	Pb							
Remove phantom load / transformers	Pd							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pø							
Parking: variable flow ventilation based on CO monitor	Di							
Widen Set Boint Temporatures	F 1		E 0%	E 0%		2 E9/		2 10/
Widen Set Point Temperatures (ownered ASUBAE EE)			5.0%	3.0%		2.370		2.1/0
Widen Set Point Temperatures (expand ASHRAE 55)	IVIT9	FC C0/	11 50/	25 20/	0.0%	10 49/	20.0%	22 10/
Subtotal Reduced FIII (kBTII/SE)		30.0%	14.5%	25.2%	6.1	10.4% A 2	8.2	23.1%
Mechanical - Distribution & Ventilation	M2	3.1	15.0%	20.0%	0.1	60.0%	0.2	10.3%
Water to water heat numps, radiant slah heating/cooling	M2a							
Energy recovery ventilation	M2h							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (nercentage)	10121	0.0%	15.0%	20.0%	0.0%	60.0%	0.0%	10.3%
Subtotal Peduced FIII (kBTII/SE)		2 1	10.2	20.070	6.1	1 7	8.2	21.2
Machanical Blant Systems	142	3.1	20.0%	2.0	0.1	15.0%	0.2	4 70/
Ground course heat nume sustem	1413		20.0%	20.0%		-13.0%		4.770
Ground source near pump system	IVI3a				75.00/			0.00/
Domestic Hot water	w				/5.0%			9.8%
Solar-thermal domestic water	Wa							
Low flow fixtures (showers, lavs, sinks)	Wb							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	14.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.1	8.2	1.6	1.5	1.9	8.2	24.5
Final Energy Use Breakdown as Percentage of Baseline Use		7%	17%	3%	3%	4%	18%	48%
	0.00			60.0		5		
Building Operating Facto	or 0.90			60.0	CBECS Baselin	e EUI (KBIU/ST)		
Impact of Interactive ECM effect	s 1.05			60%	target reduction from CBECS			
				Achievement:				
Total Reduced EUI (kBTU/si	f) 23.2			61%	percent reduc	tion from CBECS		
				52%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced energy use (kWh)				Incentives:				
Number of crystaline panels needed				\$ 184,697	FTO incentive	for reduced FUI		
		4.025		\$ 25.321	Estimated ETC	incentive for or	iginal design h	Ida
		4,025		\$ 106.161	DETC for Distin	um (minus Cold		lug
	PV dridy	825		\$ 100,101	BETCTOF Platin	ium (minus Goid	i), pass-triru	
PV Panel Analysis:	1 1		1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
	C <sup>0</sup>	227.012	4000	50.000	4025	Denels on		
	0-	227.042	4003	50,200	4025	Pariels on root + su	i snades+ canopy	
	15"	244.678	3/15		U	-		
optimal angle		281.857	3225		0	+		
	45°	247.953	3666		0	-		
	90°	175.198	5188		0	J		
				Total kWh =	913,844			


## HIGH RISE MIXED USE PORTLAND temperate



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: PORTLAND, OR

## **SKANSKA**

## Base Building Gross SF = 547,624 Living Building Gross SF = 547,624 Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

cc	INSTRUCTION COST						
А	Substructure	0.5%	0.0%	\$8,695,116	\$15.88	\$8,738,640	\$15.96
	Baseline Building			\$8,695,116	\$15.88	\$8,695,116	\$15.88
	Rainwater Containment - 200,000 gal Rainwater Tank (walls added to existing b	asement)				\$43,524	\$0.08
в	Shell	6.0%	2.3%	\$35,629,047	\$65.06	\$37,779,069	\$68.99
	Baseline Building			\$35,629,047	\$65.06	\$35,629,047	\$65.06
L1B	Replace Roofing with Glazed Skylight					\$225,900	\$0.41
D3A	Raise Floor to Floor Height					\$918,000	\$1.68
E1B	Exterior Shading Devices					\$1,905,120	\$3.48
W5	vvater Collection on Vertical Surfaces / Top of Roof					\$210,000	\$0.38
D3	Relocate SF to additional 1/2 floor at top					(\$30,000)	φ0.07 (\$0.05)
D3	Medifications to Lehby Space (structural and finishes)					\$590,000	(\$0.05) ¢1.09
115	Tracking Mirror above Atrium					\$154,000	\$1.00 \$0.28
	Added Elevator Stop for Additional Eleor					\$105.000	\$0.20
F1D	Reduce Glazing to 30%					(\$2.315.798)	(\$4.23)
D3	Remove raised access flooring					(\$801,000)	(\$1.46)
PV3	Structure for PV on Adjacent Parking Structures					\$986,000	\$1.80
L1D	Interior Light Shelves (at office floors)					\$162,000	\$0.30
С	Interiors	6.7%	1.6%	\$22,739,127	\$41.52	\$24,272,474	\$44.32
	Baseline Building			φ22,739,127	\$41.52	\$22,739,127	\$41.52
M2D	Carpet Reduction (replace with RetroPlate)					\$900,720 \$547,624	\$1.80
M2C	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					φ <b>347,02</b> 4	\$1.00
<b>D.</b> 1	Services - Conveying Systems	0.0%	0.0%	\$2,636,557	\$4.81	\$2,636,557	\$4.81
	Baseline Building			\$2,636,557	\$4.81	\$2,636,557	\$4.81
D.2	Services - Plumbing Systems	0.0%	0.0%	\$3,874,587	\$7.08	\$3,874,587	\$7.08
	Baseline Building			\$3,874,587	\$7.08	\$3,874,587	\$7.08
W6	Low-Flow Fixtures / Optical Sensors					\$0	
W2	Rain Harvesting (piping & pumps and filtration)					\$0	
D.3	Services - HVAC Systems	44.0%	3.6%	\$7,599,577	\$13.88	\$10,945,160	\$19.99
	Baseline Building			\$7,599,577	\$13.88	\$8,449,577	\$15.43
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$6,085,700)	(\$11.11)
M2A	In-Slab Radiant Heating and Cooling					\$2,738,120	\$5.00
МЗА	Ground Source Heat Pump					\$5,557,000	\$10.15
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$286,163	\$0.52
M2C	Carbon Dioxide Sensors					\$0	
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$1,132,828	\$2.07	\$1,132,828	\$2.07
	Baseline Building			\$1,132,828	\$2.07	\$1,132,828	\$2.07
D.5	Services - Electrical Systems	12.4%	0.8%	\$6,138,326	\$11.21	\$6,901,276	\$12.60
	Baseline Building			\$6,209,026	\$11.34	\$6,209,026	\$11.34
PA	Occupancy Sensor to Outlets					\$35,100	\$0.06
PE	High Efficiency Transformers					\$165,000	\$0.30
L2A	Efficient light fixture optics					\$160,200	\$0.29
L2B	Occupancy Sensor for Lighting (closed office / conference spaces)					\$18,850	\$0.03
L2C	Individual Light Level Control (open spaces)					\$179,000	\$0.33
L2I	Dual day/night light levels in corridors; occupancy sensors					\$134,100	\$0.24
L2J	Occupancy sensor/time clock for corridor lighting					\$0	
1.014	Provide hardwired compact fluorescent fixtures in all spaces			(\$70,700)	(\$0.13)	\$0	

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
			-				
		0.00/	0.00/	AA AAA ATA	40.00		40.00
E Equipment and Furnishings		0.0%	0.0%	\$3,326,853	\$6.08	\$3,326,853	\$6.08
Baseline Building				\$3,326,853	\$6.08	\$3,326,853	\$6.08
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		9.3%	0.1%	\$537,417	\$0.98	\$587,417	\$1.07
Baseline Building				\$537,417	\$0.98	\$537,417	\$0.98
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.09
W1 Remove Storm Drainage Connection to Public/Add sewer	meter					\$0	
H Logistics		0.0%	0.0%	\$1.764.940	\$3.22	\$1.764.940	\$3.22
Baseline Building				\$1,764,940	\$3.22	\$1,764,940	\$3.22
				• , - ,	<b>\$0.22</b>	• , - ,	\$0. <u>2</u>
Living Building Prerequisites				\$0	\$0.00	\$2,107,638	\$3.85
PR5 - Materials Red List		100.0%	0.8%			\$746,050	\$1.36
PR7 - Responsible Industry		100.0%	0.2%			\$205,338	\$0.37
PR8 - Appropriate Materials / Services Radius		100.0%	1.2%			\$1,156,250	\$2.11
PR9 - Leadership in Construction Waste		0.0%	0.0%			\$0	
Subtotal Direct Costs			10.6%	\$94,074,376	\$171.79	\$104,067,440	\$190.03
General Conditions	3 2%	10.6%	0.3%	\$3.005.271	\$5 40	\$3.324.506	\$6.07
Fee Contingency Insurance Bonding	9.8%	10.6%	1.1%	\$9.471.412	\$17.30	\$10.477.514	\$19.07
Location Modifier for PORTLAND OR	1 00	0.0%	0.0%	\$0	ψ17.50	\$0	ψ15.10
						+-	
TOTAL MODIFIED CONSTRUCTION COST			10.6%	\$106,551,058	\$194.57	\$117,869,460	\$215.24

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

<b>OWNER &amp; DESIGN-BUILD COSTS</b>									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	1.1%			\$1,000,000	\$1.83
01 Wind Turbines (net cost including credits)	14,800 Watt	ts		-100.0%	0.1%	(\$82,000)		\$0	
PV1 Photovoltaic Panels and Infrastructure	3,128,200 Wat	ts		100.0%	24.9%			\$23,461,500	\$42.84
LB Prerequisite Items									
PR3 - Habitat Exchange	0.918274 acre	es		100.0%	0.0%			\$4,591	\$0.01
PR6 - Construction Carbon Footprint	24,100 tons	5		100.0%	0.3%			\$265,100	\$0.48
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.12
Development Costs	LE	EED	LBC						
Develoment Costs	28	8.00%	31.00%	22.5%	7.1%	\$29,834,296	\$54.48	\$36,539,533	\$66.72
Architecture & Engineering	7.	.00%	9.00%	42.2%	3.3%	\$7,458,574	\$13.62	\$10,608,251	\$19.37
Credits / Rebates / Incentives									
BETC	35%			49.7%	-0.3%	(\$566,795)	(\$1.04)	(\$848,446)	(\$1.55)
ETO - Energy Trust of Oregon				347.2%	-0.7%	(\$198,103)	(\$0.36)	(\$885,976)	(\$1.62)
PV Credits-(state, city, utility)	80%			-100.0%	-20.0%	\$0		(\$18,769,200)	(\$34.27)
SDC Credits (including stormwater)	50%			-100.0%	-0.5%	\$0		(\$509,464)	(\$0.93)
TOTAL OWNER & DESIGN-BUILD COSTS					39.7%	\$36,445,973	\$66.70	\$50,928,890	\$93.00

TOTAL CONCEPTUAL COST: \$142,997,031 \$261.12 \$168,798,350 \$308.24

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: HIGH RISE IN PORTLAND, OR	16%	то	21%
INCI UDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP)	13%	то	18%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### High Rise Mixed use

#### Portland

#### Normalized Baseline Energy Use Intensity (kBtu/SF) 73.2

#### Normalized Baseline Energy Use (kWh) 8,157,730

Impact of Design Changes (see sketches) 0.98

- · · ·	-							
		UCUTING	UFATING	COOLING	DOM. HOT			TOTAL
perc	ent of load	13%	33%	10%	11%	FANS & PUMPS	23%	100%
pere	calc'd EUI	9.3	23.7	7.2	7.9	7.2	16.5	71.7
Energy Conservation Measures:								
Glazing	E1		15.0%	15.0%		7.5%		7.2%
Improve Glazing	E1a							
Add effective shading devices	E1b							
Reduce glazing to 30%	E1d		6.0%	1 50/		4 70/		2.20/
Walls & Root	EZ		6.0%	1.5%		1.7%		2.3%
Ontimize insulation to core performance quide	EZa F2b							
Davlighting (incorporates tuned glazing/shading)	L1	15.0%	-1.1%	1.5%		0.2%		1.8%
Remove ceiling, raise window head, add lightshelf	L1a							
Daylight controls (continuous dimming)	L1c							
lighting	L2	69.7%	-5.2%	7.0%		1.0%		8.1%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucpan	1C L2b							
liabt colors on walls, ceiling surfaces	L2C							
Occupancy sensors: transient liahtina (corridors/stairs/bathrms)	L2u L2e							
Dual day/night light levels in corridors; occupancy sensors	L2i							
Occupancy sensor / time clock for corridor lighting	L2j							
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	6.5%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances Remove phantom load / transformers	PD							
Eneray efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk		5.00/	5.00/		2 50/		
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Subtotal from above Load Reduction strategies (percentage	IVIId	84.7%	17.4%	33.0%	0.0%	13.4%	30.0%	28.3%
Subtotal Reduced EUI (kBTU/SF)		1.4	19.5	4.8	7.9	6.2	11.5	51.4
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		60.0%		10.6%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system) Natural ventilation: operable windows	M2o							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Displacement ventilation delivery for DOAS	M2k							
Water to water heat pumps, radiant slab heating/cooling	M2q	0.0%	15 0%	20.0%	0.0%	60.0%	0.0%	10.0%
Subtotal from Mechanical Distribution strategies (percentage) Subtotal Reduced ELII (kBTLL/SE)		1.0%	15.0%	20.0%	0.0%	2 5	0.0%	10.6%
Mechanical - Plant Systems	M3	1.4	20.0%	20.0%	1.5	-15.0%	11.5	5.2%
Ground source heat pump system	M3a		20.070	20.070		15.070		5.270
Domestic Hot Water	w				75.0%			8.3%
Solar-thermal domestic water	Wa							
Low flow fixtures (showers, lavs, sinks)	Wb							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	13.4%
Final Energy Use Breakdown as Percentage of Baseline Use		2%	19%	5.1 4%	2.0	2.9	11.5	52%
		2/0	2070	.,,,	0,0	.,,,	20/0	02/0
Building Operating Factor	or 0.90			86.2	CBECS Baselin	ne EUI (kBTU/sf)		
Impact of Interactive ECM effect	ts 1.05			60%	target reduct	ion from CBECS		
				Achievement:				
Total Reduced EUI (kBTU/s	f) 32.0			63%	percent redu	ction from CBECS	5	
	(1.1.1.)	2 550 200		56%	percent redu	ction from Norm	alized Baseline	Bidg
lotal reduced energy	use (kwn)	3,559,206	_	Incentives:		6 1 150		
Number of excitation page	اممممطمط	6 020		\$ 8/3,/20	ETO incentive	e for reduced EUI	riginal dasign b	المام
Number of crystaline pane	f DV array	5,029		\$ 198,103	Estimated EI	D Incentive for o	riginal design d	lag
Total KW 0	I PV dridy	5145		\$ 281,050	BETCTOF PIAL	num (minus Goi	i), pass-triru	
2V Panel Analysis: From RETScreen 1-1: method 2-2% miss losses 90% inverter efficiency, assumes Sanvo-	1 1		1	1	1	1		
205 panel. facina South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
· · · · · · · · · · · · · · · · · · ·		panel	needed at °	(SF)		_		
	0°	227.042	15677	18,000	1443	4		
	15°	244.678	14547	57,200	4586	-		
Optimal angle Assume an equal area parking garage with an EUL of 1.7	2. 32.5°	281.857	14255		0	-		
issume an equal area parking garage with all EOLOL 1.7	90°	175.198	20316		0	1		
				Total kWh =	1,449,715			
Parking garage required for net zero energy = 3 (40,000 sf garages)			Additional area	116,000	9302			
			Additional k	Wh Produced	2,111,945	3,561,660		



# HOSPITAL PORTLAND temperate



## **COST PREMIUM** PAYBACK **COST PER SF**

120,000 gal RAIN WATER TANK SIZE 180,231 sf BUILDING SIZE 4 floors BUILDING HEIGHT 39.03 acres SITE AREA 301,700 sf PHOTOVOLTAIC AREA 84,900 sf ROOF AREA (FLAT)

### **MAJOR DESIGN STRATEGIES:**

- ✓ Add new light courts at Nurse's station.
- ✓ Add skylights at corridors for increased daylighting.
- ✓ Minimize screen at mechanical area, due to fact that mechancial is reduced
- ✓ Add fins to provide shading on west side of classrooms.
- ✓ Add shading devices on South side of hospital. office. etc.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: PORTLAND, OR

## **SKANSKA**

Base Building Gross SF = 180,231 Living Building Gross SF = 180,231 Site Gross Acreage = 39.03

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	7.6%	0.4%	\$2,895,319	\$16.06	\$3,115,421	\$17.29
Baseline Building			\$2,895,319	\$16.06	\$2,895,319	\$16.06
W2 Rainwater Containment - 120,000 gal Rainwater Tank					\$220,101	\$1.22
B Shell	2.1%	0.5%	\$14,789,139	\$82.06	\$15,102,359	\$83.79
Baseline Building			\$14,789,139	\$82.06	\$14,789,139	\$82.06
L1B Replace Roofing with Glazed Skylight					\$15,000	\$0.08
E1A Improved Glazing (reduce solar heat gain at vision only)					\$16,000	\$0.09
E1B Exterior Horizontal Shading Devices					\$87,600	\$0.49
L1D Interior Light Shelf					\$58,400	\$0.32
E1B Vertical Shading Fins (west end)					\$26,900	\$0.15
L1B New Light Shafts to Nurse Stations					\$387,000	\$2.15
E2B Infill Spandrel Panel with Framing and Insulation (replace g	glazed area)				\$22,320	\$0.12
D3 Reduce Mechanical Rooftop Screen					(\$300,000)	(\$1.66)
C Interiors	0.4%	0.1%	\$9,710,678	\$53.88	\$9,746,724	\$54.08
Baseline Building			\$9,710,678	\$53.88	\$9,710,678	\$53.88
M2A Topping Slab / Stair Premium for Underfloor Radiant Syste	em (3" concrete)				\$36,046	\$0.20
L1A Raise Ceilings (no cost impact)					\$0	
D.1 Services - Conveying Systems	0.0%	0.0%	\$826,462	\$4.59	\$826,462	\$4.59
Baseline Building			\$826,462	\$4.59	\$826,462	\$4.59
D.2 Services - Plumbing Systems	7.5%	0.4%	\$3,347,613	\$18.57	\$3,597,613	\$19.96
Baseline Building			\$3,347,613	\$18.57	\$3,347,613	\$18.57
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$250,000	\$1.39
D.3 Services - HVAC Systems	43.9%	7.2%	\$9,992,801	\$55.44	\$14,376,260	\$79.77
Baseline Building	·		\$9,992,801	\$55.44	\$9,992,801	\$55.44
Baseline HVAC System Reduction (2/3 reduction in Air Ha	ndler and Ducting)				(\$2,652,772)	(\$14.72)
$\ensuremath{^{\rm M2A}}$ In-Slab Radiant Heating and Cooling Common areas only					\$180,231	\$1.00
M3A Open Well Ground Source Heat Pump					\$6,276,000	\$34.82
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outsic	le Air System(DOAS), Chilled Bear	ns			\$360,000	\$2.00
M3C Solar Thermal					\$220,000	\$1.22
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$444,259	\$2.46	\$444,259	\$2.46
Baseline Building			\$444,259	\$2.46	\$444,259	\$2.46
D.5 Services - Electrical Systems	6.2%	0.8%	\$8,085,831	\$44.86	\$8,589,931	\$47.66
Baseline Building			\$8,085,831	\$44.86	\$8,085,831	\$44.86
PA Occupancy Sensor to Outlets					\$21,500	\$0.12
PE High Efficiency Transformers					\$217,000	\$1.20
LIC Daylight Controls (continuous dimming 15' from perimeter)	1				\$160,800	\$0.89
L2E Occupancy Sensor for Transient and Egress Lighting					\$44,500	\$0.25
L2G Patient Bed light with separate switching for ambient / task	ζ.				\$18,800	\$0.10
L2M Dual level light at egress stairs - off when not occupied					\$19,000	\$0.11
L2N Stairwell lighting on daylighting					\$22,500	\$0.12

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: PORTLAND, OR

**SKANSKA** 

Base Building Gross SF = 180,231 Living Building Gross SF = 180,231 Site Gross Acreage = 39.03

		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings	0.0%	0.0%	\$2,050,942	\$11.38	\$2,050,942	\$11.38
	Baseline Building			\$2,050,942	\$11.38	\$2,050,942	\$11.38
F	Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
G	Sitework	0.6%	0.1%	\$7,730,038	\$42.89	\$7,780,038	\$43.17
	Baseline Building			\$7,730,038	\$42.89	\$7,730,038	\$42.89
W4	Stormwater Retention / Building Water Discharge					\$50,000	\$0.28
W1	Remove Storm Drainage Connection to Public/Add sewer meter					\$0	
н	Logistics	0.0%	0.0%	\$920,558	\$5.11	\$920,558	\$5.11
	Baseline Building			\$920,558	\$5.11	\$920,558	\$5.11
	-						
Liv	ving Building Prerequisites			\$0	\$0.00	\$1,163,734	\$6.46
	PR5 - Materials Red List	100.0%	0.8%			\$501,624	\$2.78
	PR7 - Responsible Industry	100.0%	0.1%			\$67,580	\$0.37
	PR8 - Appropriate Materials / Services Radius	100.0%	1.0%			\$594,530	\$3.30
	PR9 - Leadership in Construction Waste	0.0%	0.0%			\$0	
Su	btotal Direct Costs		11.4%	\$60,793,639	\$337.31	\$67,714,299	\$375.71
	General Conditions 5.0%	11.4%	0.7%	\$3,599,939	\$19.07	\$4,009,750	\$22.25
	Fee Contingency Insurance 67%	11.4%	0.8%	\$4,309,196	\$23.91	\$4,799,749	\$26.63
	Location Modifier for PORTLAND, OR 1.00	0.0%	0.0%	\$0	φ <b>2</b> 0.01	\$0	Ψ <b>2</b> 0.00
	·						
тс	TAL MODIFIED CONSTRUCTION COST		11.4%	\$68,702,774	\$381.19	\$76,523,799	\$424.59

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: PORTLAND, OR



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231 Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	ilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	2.5%			\$1,500,000	\$8.32
PV1 Photovoltaic Panels and Infrastructure	4,959,000	0 Watts		100.0%	61.2%			\$37,192,500	\$206.36
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.3%			\$195,150	\$1.08
PR6 - Construction Carbon Footprint	5,400	tons		100.0%	0.1%			\$59,400	\$0.33
PR15 - Beauty and Spirit (included in A/E	E fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.35
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	23.3%	7.4%	\$19,236,777	\$106.73	\$23,722,378	\$131.62
Architecture & Engineering		7.00%	9.00%	43.2%	3.4%	\$4,809,194	\$26.68	\$6,887,142	\$38.21
Credits / Rebates / Incentives									
BETC	35%			69.9%	-0.2%	(\$199,034)	(\$1.10)	(\$338,185)	(\$1.88)
ETO - Energy Trust of Oregon				88.9%	-0.6%	(\$392,193)	(\$2.18)	(\$740,976)	(\$4.11)
PV Credits-(state, city, utility)	80%			-100.0%	-48.9%	\$0		(\$29,754,000)	(\$165.09)
SDC Credits	50%			-100.0%	-2.3%	\$0		(\$1,372,092)	(\$7.61)
TOTAL OWNER & DESIGN-BUILD COSTS					59.5%	\$23,454,744	\$130.14	\$37,414,317	\$207.59

TOTAL CONCEPTUAL COST: \$92,157,517 \$511.33 \$113,938,115 \$632.18

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: HOSPITAL IN PORTLAND, OR	21%	то	26%
INCLUDING HIGH PERFORMING GREEN BUILDINGS OF PORTLAND (HPGBP):	20%	то	25%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### Hospital Portland

Normalized Baseline Energy Use Intensity (kBtu/SF) 199.4

Normalized Baseline Energy Use (kWh) 10,517,233

 Impact of Design Changes (see sketches)
 1.02

 Adjusted Baseline EUI (kBtu/SF)
 203.3

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
r	percent of load	15%	20%	10%	15%	15%	25%	100%
	calc'd FUI	30.5	40.7	20.3	30.5	30.5	50.8	203 3
Energy Concervation Measures:		50.5	1017	20.5	5015	50.5	50.0	20010
Clasica			12.00/	1.00/		2 70/		2.00/
Glazing	El		12.0%	1.0%		2.7%		2.9%
Improve Glazing	Ela							
Add effective shading devices	Elb							
Walls & Roof	E2		6.0%	1.0%		1.5%		1.5%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	13.3%	-1.0%	1.3%		0.2%		2.0%
Top daylighting with skylights	L1b							
Davlight controls (continuous dimming)	L1c							
Add new courtvards at Nurses's station								
lighting	L2	31.1%	-2.3%	3.1%		0.5%		4.6%
Occupancy sensors: transient lighting (corridors (stairs (hathrms)	120	51.170	2.370	51270		0.070		11070
Detiant hadlight with congrate switching for ambient / task	120							
Putlent bedright with separate switching for unbient / tusk	L2g							
Stainual lighting on daylighting ( accurately concers	1.2.							
Stairweil lighting on adviighting / occupancy sensors	L2n							
Plug Loads	Р						10.0%	2.5%
EnergyStar appliances	Pb							
Energy efficient main transformer	Pe							
Super-efficient elevators (hybrid)	Pk							
Aggressive heat recapture - all equipment water cooled	PI							
Widen Set Point Temperatures	M1		2.0%	2.0%		1.0%		0.8%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage		44.4%	16.7%	8.4%	0.0%	5.9%	10.0%	14.2%
Subtotal Reduced FUI (kBTU/SE)		17.0	33.9	18.6	30.5	28.7	45.8	174.4
Mochanical Distribution & Vontilation	M2	2710	20.0%	11.0%	0010	20.0%	1010	7 29/
Redirectal - Distribution & Ventilation	11/2		20.076	11.0%		20.076		1.2/0
Radiant slab heating/cooling in lobby/atrium spaces	IVIZE							
Chilled beams	M2s							
Displacement ventilation in exam rooms	M2t							
Natural ventilation in stairwells	M2u							
Low pressure drop air filters	M2v							
OSA/Exhaust runaround heat recovery	M2w							
Cascading make-up air	M2x							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	20.0%	11.0%	0.0%	20.0%	0.0%	7.2%
Subtotal Reduced EUI (kBTU/SF)		17.0	27.1	16.6	30.5	23.0	45.8	159.9
Mechanical - Plant Systems	M3		20.0%	30.0%		13.4%		6.6%
Ground source heat pump with central heat pump chiller	M3e							
Chiller heat recovery	M3f							
Domestic Hot Water	w				50.0%			7 5%
Low flow fixtures (showers laws sinks)	14/6				50.070			7.570
Water begting from water to water best nump (achn)	VVD							
Water neuting from water to water neut pump (gsnp)	VVC							
Cubetel from Machinical Direct and Direct successful and the	we	0.00/	20.00/	20.0%	50.00/	4.2 40/	0.0%	A A A O/
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	30.0%	50.0%	13.4%	0.0%	14.1%
Reduced EUI from Energy Conservation Measures (KBTU/SF)		17.0	21.7	11.6	15.3	19.9	45.8	131.1
Final Energy Use Breakdown as Percentage of Baseline Use		8%	11%	6%	8%	10%	23%	30%
Duilding Opporting 5	t			240.2	CDECC Develo			
Building Operating F	actor 0.90			249.2	CBECS Baselin	ne EUI (KBIU/st)		
Impact of Interactive ECM ef	fects 1.05			60%	target reduct	ion from CBECS		
				Achievement:	TARGET RED	UCTION NOT ME	т	
Total Reduced EUI (kBT	U/sf) 123.9			50%	percent redu	ction from CBECS	5	
				38%	percent redu	ction from Norma	alized Baseline	Bldg
Total reduced ener	gy use (kWh)	6,538.000		Incentives				
	B) use (km/)	0,000,000		¢ 756.054	ETO incontiv	for reduced FUI		
Number of an abelian a		24 402		\$ 730,034	ETO incentive		statural destaur la	
Number of crystaline p	anels needed	24,192		\$ 392,193	Estimated ET	o incentive for oi	nginai design b	nag
Total k	W of PV array	4959		\$ 139,150	BETC for Plat	inum (minus Golo	d), pass-thru	
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sar	пуо-	kW/b por	Total papels	Input Area				
205 panel, facing South (azimuth 0°)	angle	kwn per	rotal pariels	input Area	# of Panels			
	_	panel	needed at °	(SF)				
	0°	227.042	28797	44,700	3584			
	15°	244.678	26721		0			
optimal a	ingle: 32.5°	281.857	23197	257,000	20608	1		
Assume an equal area problem areas with an EUL of 4.7						-		
Assume an equal area parking garage with an EUI of 1.7	45°	247.953	26368		0			



# UNIVERSITY CLASSROOM ATLANTA hot humid



180 degrees.

at Atrium.

window.

south wall

shade façade.

✓ Add sunshades out

of PV to each south

skylight at Atrium.

shading devices for

 $\checkmark$ 

 $\checkmark$ 

#### PV/ **ENERGY USE INDEX** SOLID WALL **STORMWATER COST PREMIUM** FEATURE PAYBACK **COST PER SF** HORIZ SUNSHADES PHOTOVOLTAIC **ENTIRE HEIGHT** CAPACITY WATER USE **10,000** gal TANK SIZE **PV SUNSHADES** 153,531 sf **BUILDING SIZE** SITE PLAN NTS 4 floors **BUILDING HEIGHT** 2.75 acres SITE AREA 78,830 sf GLAZED PHOTOVOLTAIC AREA PV 38,755 sf **ROOF AREA** 6' OVER-LOUVERS PV HANG 4' WIDE SUNSHADE **MAJOR DESIGN STRATEGIES: ENTIRE FACADE** FINS ATRIUM ✓ Reorient the building LIGHT SHELF **BLOCK** WEST SUN Add PV to entire roof. LAB ZONE Add fritted PV to glass **SECTION** PV SUNSHADE. CONTINUOUS HORIZ. LOUOVERS @ PV WALL ✓ North facing sawtooth Horizontal louvers as ✓ 6' overhang at roof to

-PV WALL

# LIVING BUILDI DESIGN MODIFICAT

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =	153,531
Living Building Gross SF =	153,531
Site Gross Acreage =	2.75

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
CONSTRUCTION C	720						
A Substructure		-0.5%	0.0%	\$2,123,369	\$13.83	\$2,113,711	\$13.77
Baseline Buildin	g			\$2,123,369	\$13.83	\$2,123,369	\$13.83
W2 Rainwater Conta	ainment - 10,000 gal Rainwater Tank					(\$9,658)	(\$0.06)
B Shell		3.6%	0.4%	\$4,959,353	\$32.30	\$5,137,677	\$33.46
Baseline Buildin	g			\$4,959,353	\$32.30	\$4,959,353	\$32.30
E1A Improved Glazir	ng (reduce solar heat gain)					\$35,324	\$0.23
E1B Exterior Shading	g Devices (outriggers for PV panels on south only)					(\$116,000)	(\$0.76)
E1B Exterior Shading	g Devices (vertical sun shades at north windows)					\$54,000	\$0.35
E1B Exterior Shading	g Devices (solid horizontal sun shades)					\$35,000	\$0.23
D2B Revised Atrium	Roof Structure (sawtooth)					\$170,000	\$1.11
C Interiors		-3.8%	-1.4%	\$16,495,934	\$107.44	\$15,868,139	\$103.35
Baseline Buildin	q	•	•	\$16,495,934	\$107.44	\$16,495,934	\$107.44
M2D Carpet Reduction	on (remove carpet and retroplate concrete)					\$96,071	\$0.63
M2A Topping Slab / S	Stair Premium for Underfloor Radiant System (3" concrete)					\$153,531	\$1.00
LIA Exposed Ceiling	gs (white matte surfaces)					(\$160,397)	(\$1.04)
D3 Eliminate Raise	d Access Floor					(\$717,000)	(\$4.67)
D.1 Services - Con	veying Systems	0.0%	0.0%	\$297,968	\$1.94	\$297,968	\$1.94
Baseline Buildin	g			\$297,968	\$1.94	\$297,968	\$1.94
D 2 Services - Plur	nhing Systems	5.2%	0.4%	\$2 968 571	\$19.34	\$3 122 371	\$20.34
Baseline Buildin		5.270	0.470	\$2,968,571	\$19.34	\$2,968,571	\$19.34
W6 Low-Flow Fixtur	es / Optical Sensors				φ10.01	\$3.800	\$0.02
W2 Rain Harvesting	(piping & pumps and filtration)					\$150,000	\$0.98
D. O. Million III/A	0.0	00.00/	4.40/	<b>*</b> 5 040 054	<b>*</b> *** <b>7</b> *	AT 404 700	<b>*</b> 40.00
D.3 Services - HVA		32.2%	4.1%	\$5,646,851	\$36.78 \$36.79	\$5 646 851	\$48.62
	9 System Reduction (2/3 reduction in Air Handler and Ducting)			\$0,010,001	φ30.70	(\$1,000,000)	(\$6.51)
M2A In-Slab Radiant	Heating and Cooling					\$767,655	\$5.00
M3A Ground Source	Heat Pump					\$1,970,200	\$12.83
M2B Energy Recover	y Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$0.52
M2C Carbon Dioxide	Sensors (in base building)					\$0	
D.4 Services - Fire	Protection Systems	0.0%	0.0%	\$425,840	\$2.77	\$425.840	\$2.77
Baseline Buildin	a			\$425,840	\$2.77	\$425,840	\$2.77
Dates into Dunan	3				<i>\</i>	,	<i>\</i>
D.5 Services - Elec	trical Systems	2.9%	0.4%	\$6,000,852	\$39.09	\$6,174,252	\$40.22
Baseline Buildin	g			\$6,000,852	\$39.09	\$6,000,852	\$39.09
PA Occupancy Sen	sor to Outlets					\$14,100	\$0.09
PE High Efficiency	I ransformers					\$67,000	\$0.44
L2E Occupancy Sen	sor for Transient and Egress Lighting				I	φ37,500	\$0.24

#### BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 153,531 Living Building Gross SF = 153,531 Site Gross Acreage = 2.75

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
L2F Dimmable Direct/Indirect Fixtures						\$54,800	\$0.36
E Equipment and Furnishings		0.0%	0.0%	\$257,958	\$1.68	\$257,958	\$1.68
Baseline Building				\$257,958	\$1.68	\$257,958	\$1.68
F Special Construction		0.0%	0.0%	\$79,247	\$0.52	\$79,247	\$0.52
Baseline Building				\$79,247	\$0.52	\$79,247	\$0.52
G Sitework		2.0%	0.1%	\$2,460,261	\$16.02	\$2,510,261	\$16.35
Baseline Building				\$2,460,261	\$16.02	\$2,460,261	\$16.02
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.33
w1 Remove Storm Drainage Connection to Public/Add sewer meter						\$U	
H Logistics		0.0%	0.0%	\$2,108,417	\$13.73	\$2,108,417	\$13.73
Baseline Building				\$2,108,417	\$13.73	\$2,108,417	\$13.73
				<b>A</b> = A==	40.05		<b>AT 44</b>
Living Building Prerequisites		100.0%	0.79/	\$7,677	\$0.05	\$905,401	\$5.90
PR7 - Responsible Industry		100.0%	0.7%			\$315,005 \$162 546	\$2.06
PR8 - Appropriate Materials / Services Radius		100.0%	1.0%			\$419.374	\$1.00
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$7,677	\$0.05	\$7,677	\$0.05
Subtotal Direct Costs			6.0%	\$43,832,298	\$285.49	\$46,465,950	\$302.65
General Conditions	8.0%	6.0%	0.5%	\$3,512,022	\$22.88	\$3,723,041	\$24.25
Fee, Construction Contingency, Insurance	7.0%	6.0%	0.5%	\$3,328,586	\$21.68	\$3,528,583	\$22.98
Location Modifier for ATLANTA, GA	0.87	6.0%	-0.9%	(\$6,587,478)	(\$42.91)	(\$6,983,285)	(\$45.48)
TOTAL MODIFIED CONSTRUCTION COST			6.0%	\$44,085,429	\$287.14	\$46,734,289	\$304.40

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =153,531Living Building Gross SF =153,531Site Gross Acreage =2.75

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	0.1%			\$50,000	\$0.33
PV1 Photovoltaic Panels and Infrastructure	743,000 Watts		100.0%	12.7%			\$5,572,500	\$36.30
LB Prerequisite Items								
PR3 - Habitat Exchange	2.75482 acres		100.0%	0.0%			\$13,774	\$0.09
PR6 - Construction Carbon Footprint	6,800 tons		100.0%	0.2%			\$74,800	\$0.49
PR15 - Beauty and Spirit (included in A/E fe	es below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.2%			\$73,750	\$0.48
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	17.4%	4.9%	\$12,343,920	\$80.40	\$14,487,630	\$94.36
Architecture & Engineering	7.00%	9.00%	36.3%	2.6%	\$3,085,980	\$20.10	\$4,206,086	\$27.40
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-6.4%	\$0		(\$2,786,250)	(\$18.15)
SDC Credits	50%		-100.0%	-0.8%	\$0		(\$349,890)	(\$2.28)
TOTAL OWNER & DESIGN-BUILD COSTS				38.3%	\$15,429,900	\$100.50	\$21,342,400	\$139.01

TOTAL CONCEPTUAL COST: \$59,515,329 \$3

\$387.64 \$68,076,689

\$443.41

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 12% TO 17% UNIVERSITY CLASSROOM IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### University Classroom

#### Atlanta

#### Normalized Baseline Energy Use Intensity (kBtu/SF) 82.1

#### Normalized Baseline Energy Use (kWh) 3,487,559

## Impact of Design Changes (see sketches) 0.98 Adjusted Baseline EUI (kBtu/SF) 80.8

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	21%	13%	23%	2%	10%	31%	100%
	calc'd EUI	16.7	10.6	18.6	1.7	8.1	25.1	80.8
Energy Conservation Measures:								
Glazing	E1		2.0%	10.0%		3.4%		2.9%
Improved Glazing	E1a							
Add effective snading devices	E10		F 00/	2.00/		4.00/		4.50/
Walls & Root	EZ		5.0%	3.0%		1.9%		1.5%
Snaded roof from solar panels	EZa							
Optimize insulation to core performance guide	E20							
Highly reflective exterior siding	EZU							
Move vanor barrier to outside of huilding	EZU EZo							
Davlighting (incorporates tuned glazing/shading)	11	50.0%	-3.8%	5.0%		0.8%		11 1%
Daylight controls (continuous dimming)	110	30.0%	-3.070	3.0%		0.8%		11.1/0
Duyingni controls (continuous ulmining) Orient windows to allow for illumination of teaching wall	LIC							
Ton daylighting from Atrium	110							
Lighting	12	20.0%	_1 5%	2.0%		0.3%		1 1%
Lighting	LZ L2h	20.0%	-1.570	2.0%		0.5%		4.470
Individual light level control (dimming) at open office greas	120							
Light colors on walls ceiling surfaces	12d							
Occupancy sensors: transient lighting (corridors/stairs/hathrms)	12e							
Dimmable direct / indirect fixtures	L2f							
Occupancy sensor / time clock for corridor liahtina	L2i							
Plug Loads	P		-1.9%	2.5%		0.4%	25.0%	8.1%
Occupancy sensor controlled plug loads	Ра							
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				0.3%
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.1%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage		70.0%	4.9%	34.5%	0.0%	9.2%	25.0%	31.8%
Subtotal Reduced EUI (kBTU/SF)		5.0	10.1	12.2	1.7	7.3	18.8	55.1
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		11.2%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2h							
Demand-hased ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Cascading make-up air	M2x							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	11.2%
Subtotal Reduced EUI (kBTU/SF)		5.0	8.6	9.7	1.7	2.2	18.8	46.0
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		4.1%
Ground source heat nump system	M3a							
Cascadina chilled water system	M3b							
Domestic Hot Water	W				50.0%			1.0%
Low flow fixtures (showers lavs sinks)	W/b				50.070			1.070
Water heating from tankless electric water heater	Wd							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	5.2%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		5.0	6.9	7.8	0.8	2.5	18.8	41.9
Final Energy Use Breakdown as Percentage of Baseline Use		6%	9%	10%	1%	3%	23%	48%
Building Operating Factor	r 0.90			100.0	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.06			60%	target reducti	on from CBECS		
				Achievement:	TARGET REDU	JCTION NOT ME	т	
Total Reduced EUI (kBTU/si	) 40.3			60%	percent reduc	tion from CBECS	5	
				50%	percent reduc	tion from Norm	alized Baseline	Bldg
Total reduced energy u	ise (kWh)	1,710,846						
Number of crystaline panel	s needed	3,624						
Total kW of	PV array	743						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kW/b per	Total papels	Input Area		1		
205 panel, facing South (azimuth 0°)	angle	nanol	needed at °	(CE)	# of Panels			
		parier	neeueu at	(3F)		_		
	0°	269.31	6353	38,800	3111	Panels on roof, wa	lkway, plaza	
	15°	284.95	6005		0	4		
optimal angle	25.7°	288.74	5926	6,400	513	4		
	45°	278.92	6134		0	4		
	90°	183.21	9339		0			
				Total kWh =	985,947			
Additional Parking Garage Offset Needed			Additional area	33,630	2696			
			Additional k	Wh Produced	726.060	1 712 007		







#### ENERGY USE INDEX

COST PREMIUM PAYBACK COST PER SF PHOTOVOLTAIC CAPACITY WATER USE

10,000 galTANK SIZE148,981 sfBUILDING SIZE2 floorsBUILDING HEIGHT39.03 acresSITE AREA47,180 sfPHOTOVOLTAIC AREA97,650 sfROOF AREA

### **MAJOR DESIGN STRATEGIES:**

- Reorganize plan to eliminate N/S portions of classrooms wings.
- Remove windows below 2'-6" in classrooms.
- Remove windows below 2'-0" in corridors.
- Tune glazing to have high performance glass at vision glass only.
- ✓ Reconfigure roof at clerestory.
- Add metal roofing for clipping of PV at Classroom and gym.
- ✓ Eliminate windows on west and east facades at classrooms.



- PV - EXTENDED OVERHANG - GLASS TO 'BORROW' LIGHT TO CLASSROOM —LOUVERED SUNSHADE





The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =148,981Living Building Gross SF =148,981Site Gross Acreage =39.03

	Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living B	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	2.0%	0.1%	\$1,466,210	\$9.84	\$1,495,552	\$10.04
Baseline Building			\$1,466,210	\$9.84	\$1,466,210	\$9.84
Rainwater Containment - 10,000 gal Rainwater Tank					\$29,342	\$0.20
B Shell	-1.7%	-0.5%	\$9,540,845	\$64.04	\$9,379,920	\$62.96
Baseline Building		•	\$9,540,845	\$64.04	\$9,540,845	\$64.04
D3 Lower Roof at Media Center (at both links)					(\$248,400)	(\$1.67)
D3 Reallocate South Wing (move SF to east-west wings)					(\$69,000)	(\$0.46)
E1A Improved Glazing (reduce solar heat gain at vision only)					\$22,000	\$0.15
E1B Additional Exterior Shading Devices					\$37,500	\$0.25
D2B Modify Roof Structure at Clerestory (butterfly roof)					\$99,975	\$0.67
D3C Relocate Clerestory (2 sides of 1 gym > 1 side of 2 gyms)					(\$3,000)	(\$0.02)
C Interiors	3.1%	0.5%	\$4,624,290	\$31.04	\$4,765,608	\$31.99
Baseline Building			\$4,624,290	\$31.04	\$4,624,290	\$31.04
M2D Carpet Reduction (replace with RetroPlate)					\$108,466	\$0.73
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$148,981	\$1.00
L1A Exposed Ceilings (white matte surfaces)					(\$116,128)	(\$0.78)
D.1 Services - Conveying Systems	0.0%	0.0%	\$100,000	\$0.67	\$100,000	\$0.67
Baseline Building			\$100,000	\$0.67	\$100,000	\$0.67
D.2 Services - Plumbing Systems	10.4%	0.5%	\$1,438,830	\$9.66	\$1,588,830	\$10.66
Baseline Building			\$1,438,830	\$9.66	\$1,438,830	\$9.66
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$1.01
D.3 Services - HVAC Systems	6.6%	0.8%	\$3,684,937	\$24.73	\$3,929,870	\$26.38
Baseline Building			\$3,684,937	\$24.73	\$3,684,937	\$24.73
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting	)				(\$2,652,772)	(\$17.81)
M2A In-Slab Radiant Heating and Cooling					\$744,905	\$5.00
M2L Solar Wall Mechanical Screen					\$145,000	\$0.97
M3A Ground Source Heat Pump					\$1,911,800	\$12.83
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DO	AS)				\$80,000	\$0.54
M2C Carbon Dioxide Sensors					\$16,000	\$0.11
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$345,589	\$2.32	\$345,589	\$2.32
Baseline Building			\$345,589	\$2.32	\$345,589	\$2.32
D.5 Services - Electrical Systems	6.6%	0.7%	\$3,044,694	\$20.44	\$3,246,194	\$21.79
Baseline Building			\$3,044,694	\$20.44	\$3,044,694	\$20.44
PA Occupancy Sensor to Outlets					\$5,000	\$0.03
PE High Efficiency Transformers					\$97,500	\$0.65
LIC Daylight Controls (continuous dimming 15' from perimeter)					\$23,800	\$0.16
L2F Dimmable Direct/Indirect fixtures					\$47,500	\$0.32
L2B Occupancy Sensor for Lighting (closed office / conference spaces)					\$0	
L2C Individual Light Level Control (open spaces, classrooms)					\$5,200	\$0.03
L2E Occupancy Sensor for Transient and Egress Lighting					\$22,500	\$0.15

#### BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings	0.0%	0.0%	\$1,555,517	\$10.44	\$1,555,517	\$10.44
Baseline Building			\$1,555,517	\$10.44	\$1,555,517	\$10.44
F Special Construction	0.0%	0.0%	\$58,000	\$0.39	\$58,000	\$0.39
Baseline Building			\$58,000	\$0.39	\$58,000	\$0.39
G Sitework	1.4%	0.2%	\$3,701,152	\$24.84	\$3,751,152	\$25.18
Baseline Building			\$3,701,152	\$24.84	\$3,701,152	\$24.84
W4 Stormwater Retention / Building Water Discharge					\$50,000	\$0.34
W1 Remove Storm Drainage Connection to Public/Add sewer meter					\$0	
H Logistics	0.0%	0.0%	\$524.694	\$3.52	\$524.694	\$3.52
Baseline Building			\$524,694	\$3.52	\$524,694	\$3.52
Dation to Danang			<b>**</b> = 1,*** 1	\$0.0 <u>2</u>	<b>4</b> ,	\$0.0 <u>2</u>
Living Building Prerequisites			\$7,449	\$0.05	\$563,860	\$3.78
PR5 - Materials Red List	100.0%	0.7%			\$208,779	\$1.40
PR7 - Responsible Industry	100.0%	0.2%			\$66,413	\$0.45
PR8 - Appropriate Materials / Services Radius	100.0%	0.9%			\$281,219	\$1.89
PR9 - Leadership in Construction Waste	0.0%	0.0%	\$7,449	\$0.05	\$7,449	\$0.05
Subtotal Direct Costs		4.0%	\$30,092,207	\$201.99	\$31,304,787	\$210.13
General Conditions 3.7%	4.0%	0.1%	\$1,098,511	\$7.37	\$1,142,776	\$7.67
Fee, Contingency, Insurance, Bonding 9.6%	4.0%	0.4%	\$3,009,175	\$20.20	\$3,130,431	\$21.01
Location Modifier for ATLANTA, GA 0.87	4.0%	-0.6%	(\$4,445,986)	(\$29.84)	(\$4,625,139)	(\$31.05)
TOTAL MODIFIED CONSTRUCTION COST		4.0%	\$29,753,907	\$199.72	\$30,952,854	\$207.76

#### BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Building				
		Total	Cost/SF	Total	Cost/SF			

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.7%			\$200,000	\$1.34
PV1 Photovoltaic Panels and Infrastructure	776,000	Watts		100.0%	19.3%			\$5,820,000	\$39.07
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.6%			\$195,150	\$1.31
PR6 - Construction Carbon Footprint	4,400	tons		100.0%	0.2%			\$48,400	\$0.32
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,000	\$0.42
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	15.2%	4.2%	\$8,331,094	\$55.92	\$9,595,385	\$64.41
Architecture & Engineering		7.00%	9.00%	33.8%	2.3%	\$2,082,773	\$13.98	\$2,785,757	\$18.70
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-9.7%	\$0		(\$2,910,000)	(\$19.53)
SDC Credits	50%			-100.0%	-2.8%	\$0		(\$848,565)	(\$5.70)
TOTAL OWNER & DESIGN-BUILD COSTS					43.6%	\$10,413,867	\$69.90	\$14,949,127	\$100.34

TOTAL CONCEPTUAL COST: \$40,167,774 \$269.62 \$45,901,981 \$308.11

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 12% TO 17% ELEMENTARY SCHOOL IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### ElementarySchool

#### Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 60.2

#### Normalized Baseline Energy Use (kWh) 2,486,658

Impact of Design Changes (see sketches) 0.96

Adjusted Baseline EUI (kBtu/SF) 57.5

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
p	ercent of load	21%	22%	20%	3%	12%	22%	100%
Energy Concernation Measures	calc d EUI	11.9	12.8	11.5	1.7	0.9	12.8	57.5
Closing	54		2.0%	45.00/		4.00/		4.00/
Giazing	EI E1-		2.0%	15.0%		4.9%		4.0%
Improved Glazing	E1a E1b							
Add ejjective shouling devices	E10		F 00/	7.00/		2 10/		2.09/
Chadad roof from color nanols	E2		5.0%	7.0%		5.1%		2.9%
Shuueu 100j jiom solut punels	E2d							
PV mounted 30" up to allow for shading	E2D							
Highly reflective exterior siding	E2d							
Move vapor barrier to outside of building	E20							
Davlighting (incorporates tuned glazing/shading)	11	75.0%	-5.6%	7 5%		1 1%		15.0%
Top daylighting with chulights		73.0%	-3.0%	1.370		1.1/0		13.9%
Davlight controls (continuous dimming)								
Orient windows to allow for illumination of teaching wall	116							
Lighting	12	9.8%	-0.7%	1.0%		0.1%		2.1%
Light colors on walls, cailing surfaces	12d	5.870	-0.778	1.076		0.170		2.1/0
Occupancy sensors: transient lighting (corridors (stairs /bathrms)	120							
Dimmable direct / indirect fixtures	1.2f							
Occupancy sensor / time clock for corridor lighting	121							
Plug Loads	P		-1.9%	2.5%		0.4%	25.0%	5.7%
Occupancy sensor controlled plug loads	Pa			2.570				
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				0.1%
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		84.8%	3.8%	45.0%	0.0%	12.1%	25.0%	34.4%
Subtotal Reduced EUI (kBTU/SF)		1.8	12.3	6.3	1.7	6.1	9.6	37.7
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		12.8%
Radiant heatina/coolina w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Eliminate cooling	M2j							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	12.8%
Subtotal Reduced EUI (kBTU/SF)		1.8	10.4	5.1	1.7	1.8	9.6	30.3
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		4.9%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	W				60.0%			1 7%
Low flow fixtures (showers, lavs, sinks)	W/b				00.070			1.770
Water heating from water to water heat pump (ashp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	60.0%	-15.0%	0.0%	6.6%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		1.8	8.3	4.0	0.7	2.1	9.6	26.5
Final Energy Use Breakdown as Percentage of Baseline Use		3%	15%	7%	1%	4%	17%	54%
Building Operating Fa	actor 0.90			83.1	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM ef	fects 1.05			60%	target reduction	on from CBECS		
				Achievement:				
Total Reduced EUI (kBTU	J/sf) 24.8			70%	percent reduc	tion from CBECS		
•				57%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced energy	gy use (kWh)	1.025.335			•			
	8,,	_,,-						
Number of crystaline na	nels needed	3 783						
Number of crystalline pa	A of DV orrow	3,765						
TOLdi KV	V OI PV dridy	//0						
PV Panel Analysis:			1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes San	yo-	kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
	0°	260.21	3000	10 590	3254	Panels on roof	kway plaza	
	10	209.31	3008	40,580	5254	raneis on root, wal	way, µidza	
ontimal a	15 ngle: 25.7°	204.90	3223	6 600	520	4		
optimara	лыс. 23.7 ЛС°	200.74	3677	0,000	0	1		
	45 90°	183 21	5597		0	1		
	50	103.21	5551	Total Little	1 030 070	1		
				rotar KWN =	1,029,078			



## LOW RISE OFFICE ATLANTA hot humid



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 35,776 Living Building Gross SF = 35,776 Site Gross Acreage = 3.24

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
со	NSTRUCTION COST						
А	Substructure	4.7%	0.4%	\$625,892	\$17.49	\$655,234	\$18.31
	Baseline Building			\$625,892	\$17.49	\$625,892	\$17.49
W2	Rainwater Containment - 10,000 gal Rainwater Tank					\$29,342	\$0.82
в	Shell	16.1%	6.9%	\$3,237,848	\$90.50	\$3,758,980	\$105.07
	Baseline Building			\$3,237,848	\$90.50	\$3,237,848	\$90.50
M2E	Operable Windows (manual)					\$31,680	\$0.89
D3C	Reallocate Glazing from East and West Façade to South (less spandrel panel, m	nore skin)				(\$17,472)	(\$0.49)
E1A	Improved Glazing (reduce solar heat gain)					\$16,104 \$70,460	\$0.45
E1B	Exterior Shading Devices (windows and louvers at entry)					\$70,400	\$1.97 ¢5.00
M2H	"High Mass" Concrete Inside Insulation (added reflective skin)					\$49.500	φυ.20 \$1.38
D2B	Modifications to Roof Structure					\$154.860	\$4.33
L1D	Interior Light Shelves (remove from N/E/W, keep south only)					\$28,800	\$0.81
с	Interiors	17.2%	2.4%	\$1,076,571	\$30.09	\$1,261,402	\$35.26
	Baseline Building			\$1,076,571	\$30.09	\$1,076,571	\$30.09
M2D	Carpet Reduction (replace with RetroPlate)					\$25,500	\$0.71
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$48,264	\$1.35
L1A	Exposed Ceilings (white matte surfaces)					(\$68,213)	(\$1.91)
D3	Glass partitions in lieu of gypsum wallboard					\$179,280	\$5.01
D.1	Services - Conveying Systems	0.0%	0.0%	\$55,000	\$1.54	\$55,000	\$1.54
	Baseline Building			\$55,000	\$1.54	\$55,000	\$1.54
D.2	Services - Plumbing Systems	73.8%	2.0%	\$208,354	\$5.82	\$362,154	\$10.12
	Baseline Building			\$208,354	\$5.82	\$208,354	\$5.82
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.11
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$4.19
D.3	Services - HVAC Systems	74.9%	5.8%	\$591,095	\$16.52	\$1,033,875	\$28.90
	Baseline Building			\$575,095	\$16.07	\$575,095	\$16.07
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$300,000)	(\$8.39)
M2A	In-Slab Radiant Heating and Cooling					\$170,000 \$457,000	\$5.00 \$12.90
M2R	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System/DOAS)					\$106,000	φ12.00 \$2.96
M2C	Carbon Dioxide Sensors			\$16,000	\$0.45	\$16,000	\$0.45
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$75,177	\$2.10	\$75,177	\$2.10
	Baseline Building			\$75,177	\$2.10	\$75,177	\$2.10
D.5	Services - Electrical Systems	6.5%	0.6%	\$723,416	\$20.22	\$770,116	\$21.53
	Baseline Building			\$603,016	\$16.86	\$603,016	\$16.86
PA	Occupancy Sensor to Outlets					\$10,200	\$0.29
PE	High Efficiency Transformers					\$36,500	\$1.02
L1C	Daylight Controls (continuous dimming 15' from perimeter)			\$27,000	\$0.75	\$27,000	\$0.75
L2A	Efficient Light Fixture Optics Premium			\$67,600	\$1.89	\$67,600	\$1.89
L2B	Occupancy Sensor for Lighting (closed office / conference spaces)			\$12,000 \$13,800	\$0.34	\$12,000 \$12,000	\$0.34
LZE	Occupancy Sensor for Transient and Egress Lighting			ψ15,000	фU.39	φ13,000	фU.39

#### BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

		Division Premium (%)	Building Premium (%)	g m LEED™ Gold Baseline		Living Building	
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$149,348	\$4.17	\$149,348	\$4.17
Baseline Building				\$149,348	\$4.17	\$149,348	\$4.17
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		7.6%	0.8%	\$791,671	\$22.13	\$851,671	\$23.81
Baseline Building				\$791,671	\$22.13	\$791,671	\$22.13
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$1.40
E1B Trees for shading						\$10,000	\$0.28
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$40,261	\$1.13	\$40,261	\$1.13
Baseline Building				\$40,261	\$1.13	\$40,261	\$1.13
				42.444			
Living Building Prerequisites		400.00/	0.00/	\$5,366	\$0.15	\$190,144	\$5.31
PR5 - Maleriais Red List		100.0%	0.0%			\$09,877 \$10,722	\$1.67
PR7 - Responsible Industry		100.0%	0.1%			\$10,732 \$114,160	\$0.30
PR0 - Loadership in Construction Wasto		0.0%	0.0%	\$5.366	¢0.45	\$114,109 \$5.366	\$3.19 © 15
PRS - Leadership in Construction Waste		0.078	0.078	<i>\$</i> 3,300	<b>Ф</b> 0.15	\$3,300	<b>Φ</b> υ.15
Subtotal Direct Costs			21.4%	\$7,580,000	\$211.87	\$9,203,363	\$257.25
General Conditions	4.0%	21.4%	0.9%	\$303,200	\$8 47	\$368,135	\$10.29
Fee. Construction Contingency. Insurance	3.0%	21.4%	0.7%	\$238,965	\$6.68	\$290,143	\$8.11
Location Modifier for ATLANTA, GA	0.87	21.4%	-3.0%	(\$1,055,882)	(\$29.51)	(\$1,282,013)	(\$35.83)
TOTAL MODIFIED CONSTRUCTION COST			21.4%	\$7,066,284	\$197.51	\$8,579,627	\$239.82

#### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: ATLANTA, GA



\$367.73

Base Building Gross SF = 35,776 Living Building Gross SF = 35,776

Site Gross Acreage = 3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total Cost/SF		Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.5%			\$40,000	\$1.12
PV1 Photovoltaic Panels and Infrastructure	250,000	Watts		100.0%	28.0%			\$2,125,000	\$59.40
LB Prerequisite Items									
PR3 - Habitat Exchange	3.24	acres		100.0%	0.2%			\$16,200	\$0.45
PR6 - Construction Carbon Footprint	2,700	tons		100.0%	0.4%			\$29,700	\$0.83
PR15 - Beauty and Spirit (included in A/E		0.0%	0.0%			\$0			
PR16 - Inspiration and Education				100.0%	0.3%			\$23,500	\$0.66
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	34.4%	9.0%	\$1,978,560	\$55.30	\$2,659,684	\$74.34
Architecture & Engineering		9.38%	11.38%	47.3%	4.1%	\$662,464	\$18.52	\$975,933	\$27.28
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-14.0%	\$0		(\$1,062,500)	(\$29.70)
SDC Credits	50%			-100.0%	-3.1%	\$0		(\$231,353)	(\$6.47)
TOTAL OWNER & DESIGN-BUILD COSTS					73.3%	\$2,641,024	\$73.82	\$4,576,164	\$127.91

TOTAL CONCEPTUAL COST: \$9,707,308 \$271.34 \$13,155,791

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 33% TO 38% LOWRISE OFFICE / CLASSROOMS IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### MidRiseOffice

#### Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 72.1

Normalized Baseline Energy Use (kWh) 718,454

Impact of Design Changes (see sketches) 1.03

Adjusted Baseline EUI (kBtu/SF) 73.9

					DOM. HOT	54446 A 8444 486		TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
percer	nt of load	22%	17%	24%	4%	9%	24%	100%
Energy Concernation Measures	Calc d EUI	10.1	12.0	17.7	5.1	0.9	17.7	74.2
Energy Conservation Measures:	-		2.00/	40.00/		2.64		0.00/
Giazing	E1		3.0%	10.0%		3.6%		3.3%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Root	E2		6.0%	3.0%		2.1%		1.9%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
PV mounted 30 <sup>m</sup> up to allow for shading	E2c							
Highly reflective exterior staing	E2d							
Move vapor barrier to outside of building	E2e							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		11.5%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Add light shelf	L1d							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		5.7%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucpanc	L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	6.3%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.3%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75.0%	6.5%	28.0%	0.0%	9.7%	25.0%	31.0%
Subtotal Reduced EUI (kBTU/SF)		4.0	11.8	12.8	3.1	6.3	13.3	51.3
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		11.8%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	11.8%
Subtotal Reduced EUI (kBTU/SF)		4.0	10.0	10.2	3.1	1.9	13.3	42.5
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		5.1%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				60.0%			2.5%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (ashp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	60.0%	-15.0%	0.0%	7.6%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	8.0	8.2	1.3	2.2	13.3	36.9
Final Energy Use Breakdown as Percentage of Baseline Use		5%	11%	11%	2%	3%	18%	50%
Building Operating Factor	0.90			92.9	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effects	1.07			60%	target reduction	on from CBECS		
				Achievement				
Total Reduced EUI (kBTU/sf)	35.5			62%	percent reduc	tion from CBFCS		
				52%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced energy us	se (kWh)	354.077						
Total reduced energy as		55 1,677						
Number of erictaling panels	noodod	1 2 2 1						
Number of crystaline panels	DV arrest	1,521						
Total kW of	rv array	2/1						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	nanel	needed at °	(SF)	# of Panels			
		punci	ACC-	(31)	4000			
	0°	269.31	1315	16,480	1321	Panels on roof, wal	kway, plaza	
	15°	284.95	1243		0	-		
optimal angle:	25.7°	288.74	1227		0	4		
	45°	278.92	1270		0	4		
	90°	183.21	1933		0	]		



# MID RISE OFFICE ATLANTA hot humid

34.9 kbtu/st/year	
	26-31 % 15-20 years \$222/sf
*	773 kw
	357k

**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY

10,000 gal TANK SIZE 99,385 sf BUILDING SIZE 4 floors BUILDING HEIGHT 5.24 acres SITE AREA 47,025 sf PHOTOVOLTAIC AREA 23,941 sf ROOF AREA

## **MAJOR DESIGN STRATEGIES:**

- ✓ Reorient building to be on axis with sun.
- ✓ Create long thin building for operable windows and daylight.
- ✓ Add shading devices to South side of building.
- ✓ Add PV cover at plaza.
- Reduce windows on  $\checkmark$ East and West: add fins.
- ✓ Create stormwater management area for excess rainfall.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: ATLANTA, GA

## SKANSKA

Base Building Gross SF = 99,385

Living Building Gross SF = 99,385 Site Gross Acreage = 5.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	I Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

CONSTRUCTION COST				
A Substructure 2.5% 0.2%	\$1,420,795	\$14.30	\$1,456,136	\$14.65
Baseline Building	\$1,420,795	\$14.30	\$1,420,795	\$14.30
W2 Rainwater Containment - 10,000 gal Rainwater Tank			\$35,342	\$0.36
B Shell 5.4% 2.0%	\$7,159,737	\$72.04	\$7,548,232	\$75.95
Baseline Building	\$7,159,737	\$72.04	\$7,159,737	\$72.04
M2E Operable Windows (manual)			\$79,877	\$0.80
D3C Reallocate Glazing from East and West Façade to South (less spandrel panel, more skin)			(\$62,069)	(\$0.62)
E1A Improved Glazing (reduce solar heat gain)			\$54,306	\$0.55
E1B Exterior Shading Devices			(\$207,300)	(\$2.09)
PV2 Added Structure for Roof Mounted PV Panels			\$405,000	\$4.08
L1D Interior Light Shelves			\$118,680	\$1.19
C Interiors 1.0% 0.2%	\$3,724,311	\$37.47	\$3,762,078	\$37.85
Baseline Building	\$3,724,311	\$37.47	\$3,724,311	\$37.47
M2D Carpet Reduction (Replaced with Retroplate)			\$99,385	\$1.00
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)			\$149,078	\$1.50
L1A Exposed Ceilings (white matte surfaces)			(\$210,696)	(\$2.12)
D.1 Services - Conveying Systems 0.0% 0.0%	\$207,466	\$2.09	\$207,466	\$2.09
Baseline Building	\$207,466	\$2.09	\$207,466	\$2.09
D.2 Services - Plumbing Systems 18.5% 0.8%	\$838,297	\$8.43	\$993,097	\$9.99
Baseline Building	\$838,297	\$8.43	\$838,297	\$8.43
W6 Low-Flow Fixtures / Optical Sensors			\$4,800	\$0.05
W2 Rain Harvesting (piping & pumps and filtration)			\$150,000	\$1.51
D.3 Services - HVAC Systems 63.9% 5.6%	\$1,725,708	\$17.36	\$2,829,298	\$28.47
Baseline Building	\$1,689,708	\$17.00	\$1,689,708	\$17.00
Baseline HVAC System			(\$938,935)	(\$9.45)
M2A In-Slab Radiant Heating and Cooling			\$496,925	\$5.00
M3A Ground Source Heat Pump			\$1,347,600	\$13.56
M2B Energy Recovery Wheel / Plate & Frame			\$198,000	\$1.99
M2C Carbon Dioxide Sensors	\$36,000	\$0.36	\$36,000	\$0.36
D.4 Services - Fire Protection Systems 0.0% 0.0%	\$272,482	\$2.74	\$272,482	\$2.74
Baseline Building	\$272,482	\$2.74	\$272,482	\$2.74
D.5 Services - Electrical Systems 16.8% 2.0%	\$2,339,676	\$23.54	\$2,733,076	\$27.50
Baseline Building	\$2,024,176	\$20.37	\$2,024,176	\$20.37
PA Occupancy Sensor to Outlets			\$59,200	\$0.60
PE High Efficiency Main Transformer			\$53,700	\$0.54
L1C Daylight Controls (continuous dimming 15' from perimeter)	\$44,500	\$0.45	\$44,500	\$0.45
L2A Efficient Light Fixture Optics Premium	\$210,000	\$2.11	\$210,000	\$2.11
L2B Occupancy Sensor for Lighting (closed office / conference spaces)	\$22,000	\$0.22	\$22,000	\$0.22
L2C Individual Light Level Control (open spaces)	¢20.000	<b>A</b> 0.65	\$280,500	\$2.82
L2E Occupancy Sensor for Transient and Egress Lighting	\$39,000	\$0.39	\$39,000	\$0.39
E Equipment and Furnishings 0.0% 0.0%	\$472,675	\$4.76	\$472,675	\$4.76
Baseline Building	\$472,675	\$4.76	\$472,675	\$4.76
F Special Construction 0.0% 0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building	\$0		\$0	
1				

#### BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

			Division Premium (%)	Building Premium (%)	ing um LEED™ Gold Base		Baseline Living Building	
					Total	Cost/SF	Total	Cost/SF
C	Sitowark		17 69/	1 20/	¢1 465 610	¢1475	¢1 700 060	¢17.24
0	Papalina Building		17.070	1.3 /0	\$1,465,612	¢14.75	\$1,722,002	¢14.75
10/4	Baseline Building				ψ1, <del>4</del> 03,012	φ14.75	\$50,000	\$14.75 \$0.50
VV4	Parking revisions (nervious deletion of nining deletion of AC lighting)						(\$30,750)	\$0.30 (\$0.31)
D3	Plaza PV/ Structure						\$238,000	( <del>0.31)</del> \$2.39
1 72							\$200,000	φ2.00
н	Logistics		0.0%	0.0%	\$218,298	\$2.20	\$218,298	\$2.20
	Baseline Building				\$218,298	\$2.20	\$218,298	\$2.20
Liv	ing Building Prerequisites				\$4,969	\$0.05	\$456,505	\$4.59
	PR5 - Materials Red List		100.0%	0.8%			\$149,453	\$1.50
	PR7 - Responsible Industry		100.0%	0.2%			\$30,181	\$0.30
	PR8 - Appropriate Materials / Services Radius		100.0%	1.4%			\$271,902	\$2.74
	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$4,969	\$0.05	\$4,969	\$0.05
Sul	ototal Direct Costs			14.2%	\$19,850,027	\$199.73	\$22,672,206	\$228.13
					<b>A-0</b> ( <b>0</b> -1)		<b>*</b> ***	
	General Conditions 4	.0%	14.2%	0.6%	\$794,001	\$7.99	\$906,888	\$9.13
	Fee, Construction Contingency, Insurance     8	3.0%	14.2%	1.2%	\$1,651,522	\$16.62	\$1,886,328	\$18.98
	Location Modifier for ATLANTA, GA	).87	14.2%	-2.1%	(\$2,898,422)	(\$29.16)	(\$3,310,505)	(\$33.31)
то	TAL MODIFIED CONSTRUCTION COST			14.2%	\$19,397,129	\$195.17	\$22,154,917	\$222.92

#### BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 99,385 Living Building Gross SF = 99,385

Site Gross Acreage = 5.24

Div Prei (	vision mium %)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.3%			\$60,000	\$0.60
PV1 Photovoltaic Panels and Infrastructure	724,000	Watts		100.0%	27.4%			\$5,430,000	\$54.64
LB Prerequisite Items									
PR3 - Habitat Exchange	5.24	acres		100.0%	0.1%			\$26,200	\$0.26
PR6 - Construction Carbon Footprint	2,500	tons		100.0%	0.1%			\$27,500	\$0.28
PR15 - Beauty and Spirit (included in A/E		0.0%	0.0%			\$0			
PR16 - Inspiration and Education				100.0%	0.2%			\$43,500	\$0.44
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	26.5%	7.2%	\$5,431,196	\$54.65	\$6,868,024	\$69.11
Architecture & Engineering		6.09%	8.09%	51.7%	3.1%	\$1,181,235	\$11.89	\$1,792,276	\$18.03
Credits / Rebates / Incentives									
Photovoltaic Credits-(state, city, utility)	50%			-100.0%	-13.7%			(\$2,715,000)	(\$27.32)
SDC Credits	50%		0.00%	-100.0%	-1.5%	\$0		(\$289,395)	(\$2.91)
TOTAL OWNER & DESIGN-BUILD COSTS					70.0%	\$6,612,432	\$66.53	\$11,243,105	\$113.13

TOTAL CONCEPTUAL COST: \$26,009,561 \$261.71 \$33,398,022 \$336.05

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	<b>26%</b>	то	31%	
MIDRISE OFFICE IN ATLANTA, GA				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### MidRiseOffice Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 71.9

Normalized Baseline Energy Use (kWh) 2,086,285

Impact of Design Changes (see sketches) 1.02

Adjusted Baseline EUI (kBtu/SF) 73.3

					DOM. HOT			TOTAL
	porcont of load	LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
	calc'd FUI	16.0	12.6	17.6	3.1	5.6	17.6	73.5
Energy Conservation Measures:		1010	12.0	2710	511	0.0	1/10	/ 5.5
Glazing	E1		3.0%	10.0%		3.6%		3.2%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		6.0%	3.0%		2.1%		1.9%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
PV mounted 30"' up to allow for shading	E2c							
Highly reflective exterior siding	E2d							
Move vapor barrier to outside of building	E2e							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		11.5%
Remove ceiling, raise window head, add lightshelf	L1a							
Top adylighting from Atrium Daylight controls (continuous dimming)	Lig							
Add light shelf	L1C							
Lighting	12	25.0%	1.0%	2 59/		0.4%		E 00/
Efficient fixture entice	1.20	23.0%	-1.970	2.370		0.470		5.670
Individual occupancy sensors & dimming controls: closed offic	es/low12h							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrn	ns) L2e							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	6.3%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.3%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a	== 00/	6 =0/	22.22/	0.00/	0 70/	25.00/	04.404
Subtotal from above Load Reduction strategies (percentage)		75.0%	6.5%	28.0%	0.0%	9.7%	25.0%	31.1%
Sublotal Reduced EDI (KB10/SF)	542	4.0	11.7	20.0%	3.1	70.0%	13.2	11 50/
Rediget begins (seeing weddigsted outside singusters (DOA			15.0%	20.0%		70.0%		11.5%
Radiant neating/cooling w dedicated outside air system (DOA	S) M2a							
Energy recovery ventilation	M2c							
Minimize carnet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (percentage		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	11.5%
Subtotal Reduced EUI (kBTU/SF)		4.0	10.0	10.1	3.1	1.8	13.2	42.2
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		5.1%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				60.0%			2.5%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentag	e)	0.0%	20.0%	20.0%	60.0%	-15.0%	0.0%	7.7%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	8.0	8.1	1.2	2.1	13.2	36.6
Final Energy Use Breakdown as Percentage of Baseline Use		5%	11%	11%	2%	3%	18%	50%
Puilding On	orating Eactor	0.00		02.0	CRECS Pacolin			
Total reduced energy use (kWh)		1.07		52.5	target reduction	on from CBECS		
		1.07						
		24.0	Achievement:					
		34.9		62% E 29/	percent reduc	tion from Norm	lized Paceline	Plda
		1 012 102		52/6	percent reduc		alizeu basellite	Diug
		1,012,192						
Number of emistaline way		2 770						
Number of crystaline p	banels needed	3,770						
Total k	w of PV array	//3						
PV Panel Analysis:				1		1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency	6	kWh per	Total panels	Input Area	# of Devel			
assumes Sanyo-205 panel, facing South (azimuth 0°) 0° 15° 0ptimal angle: 25.7° 45°		panel	needed at °	(SF)	# of Panels			
		269.31	3759	47,025	3770	Panels on roof roof + walkway + plaza		
		284.95	3553	,020	0			
		288.74	3506		0			
		278.92	3629		0	]		
	90°	183.21	5525		0	]		
				Total kWh =	1,015,299			


## **MIXED USE RENOVATION** ATLANTA hot humid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC

10,000 gal TANK SIZE 185,043 sf BUILDING SIZE 5 floors BUILDING HEIGHT 1.0 acres SITE AREA 69,570 sf PHOTOVOLTAIC AREA 40,000 sf ROOF AREA

## **MAJOR DESIGN STRATEGIES:**

- Extend open-air atrium  $\checkmark$ down one level to allow access to operable windows.
- ✓ Add extra 10,000sf of additional floor area.
- ✓ Add PV sun shades on South.
- ✓ Add PV to adjacent parking garage to offset both the parking garage loads and the building's loads.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 185,043 Living Building Gross SF = 185,043 Site Gross Acreage = 1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

со	INSTRUCTION COST						
Δ	Substructura	5 1%	0.1%	\$579.458	\$3.13	\$608 800	\$3.29
	Baseline Building	0.170	0.170	\$579,458	\$3.13	\$579 458	\$3.13
W2	Rainwater Containment - 10 000 gal Rainwater Tank			<i>QOTO<i>TOTOTOTOTO<i>TOTOTOTOTOTOTO<i>TOTOTOTO<i>TOTOTO<i>TOTOTO<i>TOTO<i>TOTOTO<i>TOTOTO<i>TOTOTO<i>TOTOTO<i>TOTO<i>TOTOTO<i>TOTOTO<i>TOTO<i>TOTOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TOTO<i>TO<i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i></i>	φ0.10	\$29.342	\$0.16
						• • • • •	<i><b>Q</b></i> <b>00</b>
в	Shell	13.8%	3.8%	\$8,421,922	\$45.51	\$9,586,517	\$51.81
	Baseline Building			\$8,421,922	\$45.51	\$8,421,922	\$45.51
M2E	Operable Windows (manual, additional units beyond existing)					\$32,000	\$0.17
L1B	Add Glazed Clerestory at Atrium (and remove skylight)					\$108,375	\$0.59
E1A	Improved Glazing (reduce solar heat gain)					\$25,000	\$0.14
E1B	Exterior Shading Devices (PV as shading on South)					\$126,875	\$0.69
L1D	Raise Window Head / Add Light Shelf (RAF removed)					\$U \$0	
M2H	"High Mass" Concrete Inside Insulation (not included because this is a renovation)					\$U \$E6.000	<b>*</b> 0.00
D2B	Modifications to Roof Structure and Roofing					\$200.345	\$0.30
E2C	Siluciule to Moulii PV on Adjacent Parking Siluciule					\$130.000	\$1.00 \$0.70
D3	Added SE for Additional Floor (at penthouse)					\$246,000	\$0.70 \$1.33
D24	Added Wall / Skin for Modified Design (not in base building design)					\$240.000	\$1.30
	Interior Light Shelves (not included)					\$0	φ1.00
LID							
С	nteriors	2.1%	0.5%	\$7,723,877	\$41.74	\$7,883,877	\$42.61
	Baseline Building			\$7,723,877	\$41.74	\$7,723,877	\$41.74
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$270,000	\$1.46
M2D	Retroplate Topping Slab (at TI locations)					\$690,000	\$3.73
L1A	Exposed Ceilings (existing white matte surfaces)					\$0	
D3	Remove Raised Access Flooring					(\$800,000)	(\$4.32)
_							
D.1	Services - Conveying Systems	0.0%	0.0%	\$385,400	\$2.08	\$385,400	\$2.08
	Baseline Building			\$385,400	\$2.08	\$385,400	\$2.08
D.2	Services - Plumbing Systems	19.4%	0.5%	\$791,454	\$4.28	\$945,254	\$5.11
	Baseline Building			\$791,454	\$4.28	\$791,454	\$4.28
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.81
D.3	Services - HVAC Systems	-1.6%	-0.1%	\$2,767,999	\$14.96	\$2,723,718	\$14.72
	Baseline Building			\$2,767,999	\$14.96	\$2,767,999	\$14.96
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,470,281)	(\$13.35)
M2A	In-Slab Radiant Heating and Cooling					\$600,000	\$3.24
МЗА	Ground Source Heat Pump					\$1,675,000	\$9.05
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$135,000	\$0.73
M2C	Carbon Dioxide Sensors					\$16,000	\$0.09
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$343,553	\$1.86	\$343,553	\$1.86
	Baseline Building			\$343,553	\$1.86	\$343,553	\$1.86
D.5	Services - Electrical Systems	24.1%	3.6%	\$4,539,215	\$24.53	\$5,631,885	\$30.44
	Baseline Building			\$4,571,685	\$24.71	\$4,571,685	\$24.71
PA	Uccupancy Sensor to Outlets					\$47,200	\$0.26
PE	High Efficiency Transformers					φ108,000 ¢0	\$0.85
LIC	Edglight Controls (continuous alimming 15 from perimeter)					₩ \$270.000	¢4.40
LZA	Endend Light Fixture Optics Flemium					φ270,000 ¢∩	φ1.40
1.20	Individual Light Level Control (open spaces, classrooms)					φ0 \$585.000	\$3.16
L2E	Occupancy Sensor for Transient and Egress Lighting			(\$32,470)	(\$0.18)	\$0	ψ0.10
				A 1 7 / T/	(200)		

#### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$2,061,480	\$11.14	\$2,061,480	\$11.14
Baseline Building				\$2,061,480	\$11.14	\$2,061,480	\$11.14
F Special Construction		0.0%	0.0%	\$1,407,188	\$7.60	\$1,407,188	\$7.60
Baseline Building				\$1,407,188	\$7.60	\$1,407,188	\$7.60
G Sitework		4.4%	0.2%	\$1,131,528	\$6.11	\$1,181,528	\$6.39
Baseline Building				\$1,131,528	\$6.11	\$1,131,528	\$6.11
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.27
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$600,000	\$3.24	\$600,000	\$3.24
Baseline Building				\$600,000	\$3.24	\$600,000	\$3.24
				<b>A</b> ( <b>A A</b>	<b>Aa aa</b>		<b>** * *</b>
Living Building Prerequisites		100.0%	0 79/	\$4,626	\$0.03	\$657,517	\$3.55
PR3 - Materials Red List		100.0%	0.7%			\$209,552 \$55,507	\$1.13
PR/ - Appropriate Materials / Services Radius		100.0%	1.0%			\$307 354	\$0.30 ©1.66
PR9 - Leadership in Construction Waste		1739.6%	0.3%	\$4.626	\$0.03	\$85,103	\$0.46
				• ,,	φ0.00	,	φ0.10
Subtotal Direct Costs			10.6%	\$30,757,700	\$166.22	\$34,016,716	\$183.83
Constal Conditions	4.00%	10.6%	0.4%	\$1 230 309	<b>\$6.65</b>	\$1.360.660	¢7.05
	4.0%	10.6%	0.4%	\$238,965	0.05 ¢1.20	\$264 285	\$7.35 ¢1.42
Location Modifier for ATLANTA, GA	0.7%	10.6%	-1.4%	(\$4,189,507)	91.29 (\$22.64)	(\$4,633,417)	په ۱.43 (\$25.04)
TOTAL MODIFIED CONSTRUCTION COST			10.6%	\$28,037,467	\$151.52	\$31,008,253	\$167.57

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: ATLANTA, GA



\$256.64

Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.2%			\$60,000	\$0.32
PV1 Photovoltaic Panels and Infrastructure	1,143,000	Watts		100.0%	27.9%			\$8,572,500	\$46.33
LB Prerequisite Items									
PR3 - Habitat Exchange	1	acres		100.0%	0.0%			\$5,000	\$0.03
PR6 - Construction Carbon Footprint	1,250	tons @ 50%		100.0%	0.0%			\$13,750	\$0.07
PR15 - Beauty and Spirit (included in A/E fe	es below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,500	\$0.34
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	22.4%	5.7%	\$7,850,491	\$42.43	\$9,612,558	\$51.95
Architecture & Engineering		7.00%	9.00%	42.2%	2.7%	\$1,962,623	\$10.61	\$2,790,743	\$15.08
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-13.9%	\$0		(\$4,286,250)	(\$23.16)
SDC Credits	50%			-100.0%	-1.1%	\$0		(\$349,890)	(\$1.89)
TOTAL OWNER & DESIGN-BUILD COSTS					68.0%	\$9,813,113	\$53.03	\$16,481,911	\$89.07

TOTAL CONCEPTUAL COST: \$37,850,580 \$204.55 \$47,490,164

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 23% TO 28% MIXED-USE RENOVATION IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### **Complex Mixed Use Renovation**

#### Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 81.0

Normalized Baseline Energy Use (kWh) 3,442,311

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 78.6

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	19%	20%	27%	4%	9%	21%	100%
	calc'd EUI	15.2	15.4	21.2	3.0	7.0	16.7	78.6
Energy Conservation Measures:								
Glazing	E1		10.0%	15.0%		6.5%		6.6%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		10.0%	6.0%		3.8%		3.9%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	38.0%	-2.9%	3.8%		0.6%		7.9%
Remove ceiling, raise window head, add lightshelf	L1a							
Daylight controls (continuous dimming)	L1c							
Add light shelf	L1d							
Floorplan renovation for daylighting	L1e							
Lighting	L2	38.5%	-2.9%	3.9%		0.6%		8.0%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucpan	ic L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
High color rendering metal halide retail lighting	L2h							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	5.7%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.6%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		76.5%	17.4%	36.2%	0.0%	14.3%	25.0%	34.6%
Subtotal Reduced EUI (kBTU/SF)		3.6	12.8	13.5	3.0	6.0	12.6	51.4
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		60.0%		10.5%
Radiant heatina/coolina w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Programmable thermostats	M2o							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	60.0%	0.0%	10.5%
Subtotal Reduced EUI (kBTU/SF)		3.6	10.8	10.8	3.0	2.4	12.6	43.2
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		5.1%
Ground source heat nump system	M3a		20.070	2010/0		10.070		5.1/0
Cascading chilled water system	M3b							
Demostis Hot Water	1415.5				F0.0%			1.09/
Low flow fixtures (chowers laws sinks)					50.0%			1.5/0
Low Jow Jixtures (Showers, 10vs, Shiks)	VVD							
Subtotal from Machanical Plant and DHM suctans (norcontage)	vva	0.0%	20.0%	20.0%	E0.0%	15.0%	0.0%	6.0%
Paduced EIII from Energy Concernation Measures (kPTI/CE)		3.6	20.0%	20.0%	1 5	-15.0%	17.6	27 7
Final Energy Lice Breakdown as Percentage of Baseline Lise		5%	0.7	0.7	2%	2.0	12.0	57.7
That Lifergy use breakdown as reicentage of baseline use		378	11/6	11/6	270	470	10/6	J2/0
Building Operating Facto	or 0.90			92.9	CRECS Baselin	e FLII (kBTLI/sf)		
Impact of Interactive FCM effect	s 1.05			60%	target reduction	on from CBECS		
					target reduction			
				Achievement				
I otal Reduced EUI (KBTU/st	1) 35.3			62%	percent reduc	tion from CBECS	) - l'a - d D l'a -	DI.I.
				55%	percent reduc	tion from Norm	alized Baseline	BIDE
Total reduced energy u	ise (kWh)	1,498,995						
Number of crystaline panel	ls needed	5,578						
Total kW of	FPV array	1143						
PV Panel Analysis:								
From RETScreen 4-1: method 2. 2% misc losses. 90% inverter efficiency. assumes Sanvo-		1			1	1		
205 panel, facing South (azimuth 0°)	angle	kwn per	I otal panels	Input Area	# of Panels			
		panel	needed at °	(SF)				
	0°	269.31	5567	46,000	3688	Roof + Sunshades		
	15°	284.95	5261		0			
optimal angle	e: 25.7°	288.74	5192		0	]		
	45°	278.92	5375		0	]		
	90°	183.21	8182		0	]		
		-		Total kWh =	993,215			
Additional Parking Garage Offset Needed			Additional area	23,570	1890	Adiacent p	artial parking	garage
			Additional k	Wh Produced	508.996	1,502,211		
					,	–		



# SINGLE FAMILY RESIDENTIAL ATLANTA hot humid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE



SITE PLAN NTS

SKYLIGHT WITH DEEP WELL AND

1.840 sf BUILDING SIZE 1 floors BUILDING HEIGHT 0.11 acres SITE AREA 400 sf PHOTOVOLTAIC AREA 2,000 ROOF AREA

10,000 gal TANK SIZE

## **MAJOR DESIGN STRATEGIES:**

- ✓ Add deep veranda to shade windows.
- ✓ Add PV on South side of building.
- Add cistern.  $\checkmark$
- $\checkmark$ Ground source heat pump.



**PV CLIPPED TO STANDING SEAM DEEP VERANDA TO SHADE WINDOWS CONCRETE SLAB** 





PLAN NTS

## LIVING BUILD DESIGN MODIFICA

#### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 1,840

Living Building Gross SF = 1,840 Site Gross Acreage = 0.11

		Premium (%)	Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
со	NSTRUCTION COST						
Α	Substructure	0.0%	0.0%	\$63,527	\$34.53	\$63,527	\$34.53
W2	Baseline Building Rainwater Containment - 10,000 gal Rainwater Tank (included in base building)			\$63,527	\$34.53	\$63,527 \$0	\$34.53
в	Shell	3.3%	1.5%	\$131,226	\$71.32	\$135,558	\$73.67
E1A D3 D3	Baseline Building Improved Glazing (reduce solar heat gain) Added Porch and Roofing (including credit for front porch removed) Modify Building to Single Story			\$131,226	\$71.32	\$131,226 \$4,303 \$16,060 ( <mark>\$16,031)</mark>	\$71.32 \$2.34 \$8.73 (\$8.71)
С	Interiors	11.6%	1.5%	\$37,430	\$20.34	\$41,780	\$22.71
M2A L1A	Baseline Building Thicken Lower Level Slab (2") and Gypcrete on Upper Level Exposed Ceilings (white matte surfaces)			\$37,430	\$20.34	\$37,430 \$4,350 \$0	\$20.34 \$2.36
D.1	Services - Conveying Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
D.2	Services - Plumbing Systems	57.3%	2.1%	\$10,654	\$5.79	\$16,754	\$9.11
	Baseline Building			\$10,654	\$5.79	\$10,654	\$5.79
W6	Low-Flow Fixtures / Optical Sensors					\$0 \$0	
W7	Composting Toilets					\$6,100	\$3.32
D.3	Services - HVAC Systems	190.0%	7.9%	\$12,008	\$6.53	\$34,827	\$18.93
	Baseline Building			\$12,008	\$6.53	\$12,008	\$6.53
MOA	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$7,381) \$9,200	(\$4.01) \$5.00
M3A	Ground Source Heat Pump					\$21,000	ຈວ.00 \$11.41
		0.0%	0.0%	<b>*</b> -	<b>\$</b> 0.00		¢0.00
D.4	Services - Fire Protection Systems Baseline Building	0.0%	0.0%	\$0 \$0	\$0.00	\$0 \$0	\$0.00
	Dasenie Duiding			ψυ		ΨΟ	
D.5	Services - Electrical Systems	68.1%	2.4%	\$10,136	\$5.51	\$17,036	\$9.26
	Baseline Building			\$10,136	\$5.51	\$10,136	\$5.51
L2K	Provide nardwired compact fluorescent fixtures in all spaces					\$2,200 \$300	\$1.20
L2L M2Z	Ceiling Fans and window box fans ( five of each)					\$4,400	φυ. το \$2,39
	5 · · · · · · · · · · · · · · · · · · ·			I I	. 1		

## BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 1,840

Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings	0.0%	0.0%	\$1,011	\$0.55	\$1,011	\$0.55
Baseline Building			\$1,011	\$0.55	\$1,011	\$0.55
F Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
G Sitework	69.8%	4.9%	\$20,208	\$10.98	\$34,308	\$18.65
Baseline Building			\$20,208	\$10.98	\$20,208	\$10.98
W4 Stormwater Retention / Building Water Discharge					\$14,100	\$7.66
H Logistics	0.0%	0.0%	\$3,280	\$1.78	\$3,280	\$1.78
Baseline Building			\$3,280	\$1.78	\$3,280	\$1.78
Living Building Prerequisites			\$1,150	\$0.63	\$19,338	\$10.51
PR5 - Materials Red List	100.0%	0.9%			\$2,737	\$1.49
PR7 - Responsible Industry	100.0%	4.1%			\$11,981	\$6.51
PR8 - Appropriate Materials / Services Radius	100.0%	1.2%	¢1 150 00	<b>\$0.00</b>	\$3,470	\$1.89
	0.078	0.078	\$1,150.00	\$0.63	φ1,130	\$0.63
Subtotal Direct Costs		26.4%	\$290,630	\$157.95	\$367,420	\$199.68
Constal Conditions (10	<u>26 4%</u>	2.6%	\$20.062	¢45.00	\$36 742	¢10.07
General Conditions 10.	0% <b>26.4%</b>	2.9%	\$31 969	\$15.80 \$17.27	\$40 416	\$19.97 \$21.07
Location Modifier for ATLANTA, GA 0.	87 <b>26.4%</b>	-4.2%	(\$45,716)	(\$24.85)	(\$57,795)	(\$31.41)
TOTAL MODIFIED CONSTRUCTION COST		26.4%	\$305,947	\$166.28	\$386,783	\$210.21

#### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: ATLANTA, GA



\$486,399 \$264.35

Base Building Gross SF = 1,840 Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS						T			
Design/Build Owner Items									
W3 Biological Bio-Reactor				0.0%	0.0%			\$0	
PV1 Photovoltaic Panels and Infrastructure	7,000	Watts		100.0%	21.7%			\$63,000	\$34.24
LB Prerequisite Items									
PR3 - Habitat Exchange	0.114784	acres		100.0%	0.2%			\$574	\$0.31
PR6 - Construction Carbon Footprint	50	tons		100.0%	0.2%			\$550	\$0.30
PR15 - Beauty and Spirit (included in A/	E fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.5%			\$1,500	\$0.82
Development Costs		LEED	LBC						
Develoment Costs		3.41%	2.70%	0.0%	0.0%	\$10,440	\$5.67	\$10,440	\$5.67
Architecture & Engineering		12.00%	15.00%	58.0%	7.3%	\$36,714	\$19.95	\$58,017	\$31.53
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-10.8%	\$0		(\$31,500)	(\$17.12)
SDC Credits	50%			-100.0%	-1.0%	\$0		(\$2,966)	(\$1.61)
TOTAL OWNER & DESIGN-BUILD COSTS					111.3%	\$47,154	\$25.63	\$99,616	\$54.14

TOTAL CONCEPTUAL COST: \$353,100 \$191.90

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 35% то 40% SINGLE FAMILY RESIDENTIAL IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### Single Family Residential

Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 36.5

Normalized Baseline Energy Use (kWh) 19,470

 Impact of Design Changes (see sketches)
 0.95

 Adjusted Baseline EUI (kBtu/SF)
 34.8

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	15%	26%	14%	11%	9%	25%	100%
	calc'd EUI	5.3	9.1	4.9	3.8	3.1	8.6	34.8
Energy Conservation Measures:								
Glazing	E1		10.0%	15.0%		6.5%		5.3%
High performance residential glazing	E1f							
Add effective shading devices	E1b							
Insulated panels for glazing (thermal window shades)	E1g							
Walls & Roof	E2		7.0%	6.0%		3.2%		3.0%
Shaded roof from solar panels	E2a							
Optimize insulation - single family residential	E2i							
Highly reflective exterior siding	E2d							
Lighting	L2	53.8%	-4.0%	5.4%		0.8%		7.9%
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Motion sensors for exterior lighting	L2I							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	7.3%
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Occupant buy-in / personal energy budget	Pf							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.2%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		53.8%	15.7%	34.4%	0.0%	13.5%	30.0%	25.8%
Subtotal Reduced EUI (kBTU/SF)		2.4	7.6	3.2	3.8	2.7	6.1	25.8
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		60.0%		9.8%
Water to water heat pumps, radiant slab heating/cooling	M2q							
Energy recovery ventilation	M2b							
Natural ventilation: operable windows	M2e							
Ceiling fans and window box fans	M2z							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	60.0%	0.0%	9.8%
Subtotal Reduced EUI (kBTU/SF)		2.4	6.5	2.6	3.8	1.1	6.1	22.4
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		4.8%
Ground source heat nump system	M3a							
Domestic Hot Water	w				75.0%			8 1%
Solar-thermal domestic water					/5.070			0.170
Low flow fixtures (showers lavs sinks)	Wd Wb							
Wastewater heat recovery	W/o							
Subtotal from Mechanical Plant and DHW systems (nercentage)	we	0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	12.9%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		2.4	5.2	2.1	0.9	1.2	6.1	17.9
Final Energy Use Breakdown as Percentage of Baseline Use		7%	15%	6%	3%	4%	17%	48%
Building Operating Facto	r 0.91			43.8	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.05			60%	target reduction	on from CBECS		
				Achievement				
Total Reduced FUI (kBTU/sf	) 17.1			61%	nercent reduc	tion from CBECS		
	, 1,.1			51%	percent reduc	tion from Norm	alized Baseline	Blde
Total reduced energy	co (k)(h)	0 122		5170	percentreduc		Jilzeu Busenne	Didg
Total reduced energy d	36 (KWII)	5,155						
Number of crystaline panel	s needed	32						
Total kW of	PV array	7						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	nanel	needed at °	(SE)	# of Panels			
		puller	necucu at	(31)		4		
	0°	269.31	34		0	Panels on roof root	+ walkway + plaza	3
	15°	284.95	33		0	4		
optimal angle	: 25.7°	288.74	32	400	32	4		
	45°	278.92	33		0	4		
	90°	183.21	50		0	1		

Total kWh = 9,240



# MULTIFAMILY RESIDENTIAL ATLANTA hot humid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

10,000 gal TANK SIZE 240,187 sf BUILDING SIZE 5 floors BUILDING HEIGHT 2.87 acres SITE AREA 39,800 sf PHOTOVOLTAIC AREA 42,393 sf ROOF AREA

## **MAJOR DESIGN STRATEGIES:**

- ✓ Increase floor to floor height to allow better daylight penetration.
- ✓ Reconfigure housing units to be oriented in N/S direction for better access to daylight.
- ✓ Reconfigure floor plans to allow units to have all habitable rooms within 30' of an operable window.



NTS

## LIVING DESIGNM **BUI** ODIF

#### BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **ATLANTA, GA**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

CONSTRUCTION COST					
A Substructure	4.7% 0.1%	\$622.710	\$2.97	\$652.052	\$3.11
Baseline Building		\$622,710	\$2.97	\$622,710	\$2.97
W2 Rainwater Containment - 10,000 gal Rainwater Tank				\$29,342	\$0.14
P. Shall	5.0% 1.6%	¢7 656 070	¢26 52	¢9 040 042	¢20.25
D Sileii Deceline Duilding	3.0% 1.07	\$7,656,970 \$7,656,970	\$30.52 \$26.50	\$7,656,970	\$30.30 \$26.50
Easeine Bulluling		ψ1,000,910	\$30.5Z	\$165,200	\$30.52 \$0.70
ETD Reduce Glazing (30% of original window glazing)				\$12 972	\$0.06
ETA Improved Glazing (reduce solar near gain)				\$468,000	\$0.00 \$2.23
D2A Reduce Wall / Skin for Modified Design (not in base building design)				(\$405,600)	ψ2.20 (\$1.03)
D3 Relocate Elevator				\$45,000	\$0.21
D3 Covered Walkway				\$98,400	\$0.21 \$0.47
				<i>\$66,100</i>	ψ0.47
C Interiors	5.3% 1.3%	\$5,891,333	\$28.10	\$6,205,850	\$29.60
Baseline Building		\$5,891,333	\$28.10	\$5,891,333	\$28.10
M20 Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)				\$314,517	\$1.50
D.1 Services - Conveying Systems	0.0% 0.0%	<b>6</b> \$244,158	\$1.16	\$244,158	\$1.16
Baseline Building	I	\$244,158	\$1.16	\$244,158	\$1.16
D.2 Services - Plumbing Systems	8.0% 0.6%	<b>\$1,900,476</b>	\$9.06	\$2,052,276	\$9.79
Baseline Building		\$1,900,476	\$9.06	\$1,900,476	\$9.06
W6 Low-Flow Fixtures / Optical Sensors				\$1,800	\$0.01
W2 Rain Harvesting (piping & pumps and filtration)				\$150,000	\$0.72
D.3 Services - HVAC Systems	387.3% 11.5	<b>%</b> \$717,870	\$3.42	\$3,498,260	\$16.68
Baseline Building		\$717,870	\$3.42	\$717,870	\$3.42
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)				(\$535,000)	(\$2.55)
M2A In-Slab Radiant Heating and Cooling				\$1,048,390	\$5.00
M3A Ground Source Heat Pump				\$1,959,000	\$9.34
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)				\$308,000	\$1.47
M2C Carbon Dioxide Sensors				\$0	
D.4 Services - Fire Protection Systems	0.0% _0.0%	\$462.507	\$2,21	\$462,507	\$2,21
Baseline Building		\$462,507	\$2.21	\$462,507	\$2.21
		¢ ···=,c o	<i>\\\</i>	,	ψε.ε Ι
D.5 Services - Electrical Systems	-1.6% -0.2%	\$3,530,018	\$16.84	\$3,471,778	\$16.56
Baseline Building		\$3,416,018	\$16.29	\$3,416,018	\$16.29
L2E Occupancy Sensor for Transient Lighting (corridors/stairs)		\$28,000	\$0.13		
L21 Dual day/night light levels in corridors; occupancy sensors		\$86,000	\$0.41		
L2K Provide hardwired compact fluorescent fixtures in all spaces				\$55,760	\$0.27

#### BUILDING TYPE: MULTI-FAMILY HOUSING BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

		Division Premium (%)	Building Premium (%)	g m LEED™ Gold Baseline		Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings	0.0%	0.0%	\$948,170	\$4.52	\$948,170	\$4.52
	Baseline Building			\$948,170	\$4.52	\$948,170	\$4.52
F	Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
-	Baseline Building			\$0		\$0	
G	Sitework	6.2%	0.6%	\$2.221.462	\$10.59	\$2.358.962	\$11.25
	Baseline Building			\$2,221,462	\$10.59	\$2,221,462	\$10.59
W2	Stormwater Retention / Building Water Discharge				·	\$50,000	\$0.24
D3	Added Courtyard					\$87,500	\$0.42
н	Logistics	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
Liv	ing Building Prerequisites			\$10,484	\$0.05	\$762,110	\$3.63
	PR5 - Materials Red List	100.0%	0.7%			\$177,292	\$0.85
	PR7 - Responsible Industry	100.0%	1.3%			\$323,676	\$1.54
	PR8 - Appropriate Materials / Services Radius	100.0%	1.1%	• · · · · · ·		\$261,142	\$1.25
	PR9 - Leadership in Construction Waste	-100.0%	0.0%	\$10,484	\$0.05		
Su	antal Direct Costs		18.6%	\$24 206 158	\$115.44	\$28 697 065	\$136.86
Ou			10.070	φ24,200,100	ψ110.++	φ20,007,000	φ100.00
	General Conditions 4.0%	18.6%	0.7%	\$968,246	\$4.62	\$1,147,883	\$5.47
	Fee, Construction Contingency, Insurance 4.0%	18.6%	0.8%	\$1,006,976	\$4.80	\$1,193,798	\$5.69
	Location Modifier for ATLANTA, GA 0.87	18.6%	-2.6%	(\$3,403,579)	(\$16.23)	(\$4,035,037)	(\$19.24)
то	TAL MODIFIED CONSTRUCTION COST		18.6%	\$22,777,801	\$108.63	\$27,003,708	\$128.79

#### BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **ATLANTA, GA**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	4.1%			\$1,000,000	\$4.77
PV1 Photovoltaic Panels and Infrastructure	654,000 Watts		100.0%	20.3%			\$4,905,000	\$23.39
LB Prerequisite Items								
PR3 - Habitat Exchange	2.86961 acres		100.0%	0.1%			\$14,348	\$0.07
PR6 - Construction Carbon Footprint	6,400 tons		100.0%	0.3%			\$70,400	\$0.34
PR15 - Beauty and Spirit (included in A/E	fees below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.1%			\$23,500	\$0.11
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	31.3%	8.2%	\$6,377,784	\$30.42	\$8,371,150	\$39.92
Architecture & Engineering	7.00%	9.00%	52.4%	3.5%	\$1,594,446	\$7.60	\$2,430,334	\$11.59
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-10.1%	\$0		(\$2,452,500)	(\$11.70)
SDC Credits	50%		-100.0%	-1.4%	\$0		(\$343,583)	(\$1.64)
TOTAL OWNER & DESIGN-BUILD COSTS				75.8%	\$7,972,230	\$38.02	\$14,018,649	\$66.86

TOTAL CONCEPTUAL COST: \$30,750,031 \$146.65 \$41,022,357 \$195.64

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 31% TO 36% MULTI-FAMILY HOUSING IN ATLANTA, GA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### Multi- Family Residential

Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 46.1

Normalized Baseline Energy Use (kWh) 1,807,944

Impact of Design Changes (see sketches) 0.99

Adjusted Baseline EUI (kBtu/SF) 45.7

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	16%	20%	15%	14%	10%	26%	100%
Frank Canadian Manager	calc'd EUI	7.1	9.0	6.9	6.2	4.6	11.9	45.7
Charles			5.00/	45.00/		5 50/		2.00/
Giazing	EL		5.0%	15.0%		5.5%		3.8%
Improved Glazing	E1a E1b							
Walls & Roof	E10 F2		5.0%	3.0%		1 0%		1.6%
Shaded roof from solar nanels	E20		5.078	3.078		1.570		1.070
Ontimize insulation to core performance quide	E2a E2h							
Highly reflective exterior siding	F2d							
Move vapor barrier to outside of building	E2e							
Lighting	L2	56.6%	-4.2%	5.7%		0.8%		8.9%
Occupancy sensors: transient liahtina (corridors/stairs/bathrms)	L2e							
Dual day/night light levels in corridors; occupancy sensors	L2i							
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	7.9%
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Occupant buy-in / personal energy budget	Pf							
Parking: variable flow ventilation based on CO monitor	Pi							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.0%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a	FC C0/	0 50/	21 70/	0.0%	11 30/	20.0%	24 20/
Subtotal from above Load Reduction strategies (percentage)		50.0%	8.5%	31.7%	0.0%	11.2%	30.0%	24.2%
Mechanical - Distribution & Ventilation	M2	3.1	20.0%	20.0%	0.2	70.0%	0.5	11.0%
Water to water heat number radiant slab heating/cooling	M2a		20.078	20.076		70.078		11.570
Energy recovery ventilation	M2b							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	20.0%	20.0%	0.0%	70.0%	0.0%	11.9%
Subtotal Reduced EUI (kBTU/SF)		3.1	6.6	3.8	6.2	1.2	8.3	29.2
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		4.1%
Ground source heat pump system	M3a							
Domestic Hot Water	w				75.0%			10.1%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Wastewater heat recovery	We	0.00/	20.0%	20.0%	75.0%	45.00/	0.0%	4 4 20/
Subtotal from Mechanical Plant and DHW systems (percentage) Reduced FLII from Energy Conservation Measures (kBTI1/SE)		3.1	20.0%	20.0%	1 5	-15.0%	83	22 7
Final Energy Use Breakdown as Percentage of Baseline Use		7%	12%	7%	3%	3%	18%	50%
Building Operating Facto	r 0.90			60.0	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effects	5 1.07			60%	target reducti	on from CBECS		
				Achievement	:			
Total Reduced EUI (kBTU/sf	21.8			64%	percent reduc	tion from CBECS	5	
				52%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced energy u	se (kWh)	855,050						
Number of crystaline panel	s needed	3,191						
Total kW of	PV array	654						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-	1	kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
	<u> </u>	200.01	2675	20,000	2101	-		
	U"	269.31	3175	39,800	3191	Panels on root only	1	
ontimal angle	25.7%	284.95	3001		0	-		
optinal angle	45°	278 92	3066		0	1		
	90°	183.21	4668		0	1		
			1					

0 Total kWh = 859,368



# HIGH RISE MIXED USE ATLANTA hot humid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC

10,000 gal TANK SIZE 547.624 sf BUILDING SIZE 22 floors BUILDING HEIGHT 0.92 acres SITE AREA 155,500 sf PHOTOVOLTAIC AREA 20,000 sf ROOF AREA

## MAJOR DESIGN STRATEGIES:

- ✓ Increase floor to floor height to allow better daylight penetration.
- ✓ Add atrium at edge of the office portion of the building to increase daylight.
- ✓ Add an office floor to tower portion of building to ensure all workers are within 30' of operable window.
- ✓ PV integrated with the building skin on South and East facades.
- ✓ PV screen at building West facade.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

Division Building

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: ATLANTA, GA

## SKANSKA

#### Base Building Gross SF = 547,624

Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

	Premium (%)	Premium (%)	LEED™ Gold Baseline		Living Building	
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	0.1%	0.0%	\$8,695,116	\$15.88	\$8,707,505	\$15.90
Baseline Building			\$8,695,116	\$15.88	\$8,695,116	\$15.88
W2 Rainwater Containment - 10,000 gal Rainwater Tank				• • • • •	\$12,389	\$0.02
B Shell	4.6%	1.7%	\$35,629,047	\$65.06	\$37,267,319	\$68.05
Baseline Building			\$35,629,047	\$65.06	\$35,629,047	\$65.06
L1B Replace Roofing with Glazed Skylight					\$225,900	\$0.41
D3A Raise Floor to Floor Height					\$918,000	\$1.68
E1B Exterior Shading Devices					\$1,905,120	\$3.48
W5 Water Collection on Vertical Surfaces / Top of Roof					\$0	
D3 Relocate SF to additional 1/2 floor at top					\$40,800	\$0.07
D3 Remove Existing Green Roof					(\$30,000)	(\$0.05)
D3 Modifications to Lobby Space (structural and finishes)					\$590,000	\$1.08
LIE Tracking Mirror above Atrium					\$154,000	\$0.28
D3 Added Elevator Stop for Additional Floor					\$105,000	\$0.19
E1D Reduce Glazing to 30%					(\$2,315,798)	(\$4.23)
D3 Remove raised access flooring					(\$801,000)	(\$1.46)
PV3 Structure for PV on Adjacent Parking Structures					\$684,250	\$1.25
L1D Interior Light Shelves (at office floors)					\$162,000	\$0.30
C Interiors	6.7%	1.6%	\$22,739,127	\$41.52	\$24,272,474	\$44.32
Baseline Building			\$22,739,127	\$41.52	\$22,739,127	\$41.52
M2D Carpet Reduction (replace with RetroPlate)					\$985,723	\$1.80
M2O Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$547,624	\$1.00
D.1 Services - Conveying Systems	0.0%	0.0%	\$2,636,557	\$4.81	\$2,636,557	\$4.81
Baseline Building			\$2,636,557	\$4.81	\$2,636,557	\$4.81
D.2 Services - Plumbing Systems	0.0%	0.0%	\$3,874,587	\$7.08	\$3,874,587	\$7.08
Baseline Building			\$3,874,587	\$7.08	\$3,874,587	\$7.08
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$0	
D.3 Services - HVAC Systems	45.0%	3.6%	\$7,599,577	\$13.88	\$11,022,160	\$20.13
Baseline Building			\$7,599,577	\$13.88	\$8,449,577	\$15.43
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$6,085,700)	(\$11.11)
M2A In-Slab Radiant Heating and Cooling					\$2,738,120	\$5.00
M3A Ground Source Heat Pump					\$5,634,000	\$10.29
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$286,163	\$0.52
M2C Carbon Dioxide Sensors					\$0	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$1,132,828	\$2.07	\$1,132,828	\$2.07
Baseline Building			\$1,132,828	\$2.07	\$1,132,828	\$2.07
D.5 Services - Electrical Systems	12.4%	0.8%	\$6,138,326	\$11.21	\$6,901,276	\$12.60
Baseline Building			\$6,209,026	\$11.34	\$6,209,026	\$11.34
PA Occupancy Sensor to Outlets					\$35,100	\$0.06
PE High Efficiency Transformers					\$165,000	\$0.30
L2A Efficient light fixture optics					\$160,200	\$0.29
L2B Occupancy Sensor for Lighting (closed office / conference spaces)					\$18,850	\$0.03
L2C Individual Light Level Control (open spaces)					\$179,000	\$0.33
L21 Dual day/night light levels in corridors; occupancy sensors					\$134,100	\$0.24
L2J Uccupancy sensor/time clock for corridor lighting			(\$70,700)	(00.10)	\$U	
L2K Provide hardwired compact fluorescent fixtures in all spaces			(\$70,700)	(\$0.13)	\$0	

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

		-					
		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$3,326,853	\$6.08	\$3,326,853	\$6.08
Baseline Building				\$3,326,853	\$6.08	\$3,326,853	\$6.08
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		9.3%	0.1%	\$537,417	\$0.98	\$587,417	\$1.07
Baseline Building				\$537,417	\$0.98	\$537,417	\$0.98
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.09
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$1,764,940	\$3.22	\$1,764,940	\$3.22
Baseline Building				\$1,764,940	\$3.22	\$1,764,940	\$3.22
Living Building Prerequisites				\$27,381	\$0.05	\$2,211,880	\$4.04
PR5 - Materials Red List		100.0%	0.7%			\$667,660	\$1.22
PR7 - Responsible Industry		100.0%	0.3%			\$328,542	\$0.60
PR8 - Appropriate Materials / Services Radius		100.0%	1.3%			\$1,188,297	\$2.17
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$27,381	\$0.05	\$27,381	\$0.05
Subtotal Direct Costs			10.2%	\$94,101,757	\$171.84	\$103,705,797	\$189.37
General Conditions	3.2%	10.2%	0.3%	\$3,005,271	\$5.49	\$3,311,989	\$6.05
Fee, Contingency, Insurance, Bonding	9.8%	10.2%	1.0%	\$9,471,412	\$17.30	\$10,438,065	\$19.06
Location Modifier for ATLANTA, GA	0.87	10.2%	-1.5%	(\$13,855,197)	(\$25.30)	(\$15,269,261)	(\$27.88)
TOTAL MODIFIED CONSTRUCTION COST			10.2%	\$92,723,242	\$169.32	\$102,186,590	\$186.60

#### BUILDING TYPE: HIGH RISE BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624 Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	1.1%			\$1,000,000	\$1.83
O1 Wind Turbines (net cost including credits)	14,800	Watts		0.0%	0.0%	(\$82,000)		(\$82,000)	(\$0.15)
PV1 Photovoltaic Panels and Infrastructure	2,556,000 \	Watts		100.0%	20.4%			\$19,170,000	\$35.01
LB Prerequisite Items									
PR3 - Habitat Exchange	0.918274 a	acres		100.0%	0.0%			\$4,591	\$0.01
PR6 - Construction Carbon Footprint	24,100 t	tons		100.0%	0.3%			\$265,100	\$0.48
PR15 - Beauty and Spirit (included in A/E fe	ees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.12
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	22.0%	6.1%	\$25,962,508	\$47.41	\$31,677,843	\$57.85
Architecture & Engineering		7.00%	9.00%	41.7%	2.9%	\$6,490,627	\$11.85	\$9,196,793	\$16.79
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-10.2%	\$0		(\$9,585,000)	(\$17.50)
SDC Credits	50%			-100.0%	-0.5%	\$0		(\$509,464)	(\$0.93)
TOTAL OWNER & DESIGN-BUILD COSTS					58.2%	\$32,371,135	\$59.26	\$51,200,864	\$93.50

TOTAL CONCEPTUAL COST: \$125,094,377 \$228.43 \$153,387,455 \$280.10

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 20% TO 25% High Rise in Atlanta, ga

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### High Rise Mixed use

Additional Parking Garage Offset Needed

#### Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 70.4

#### Normalized Baseline Energy Use (kWh) 7,841,346

## Impact of Design Changes (see sketches) 0.99 Adjusted Baseline EUI (kBtu/SF) 69.4

DOM. HOT TOTAL LIGHTING HEATING COOLING WATER FANS & PUMPS MISC, EQUIP BLDG percent of load 11% 100% 14% 20% 21% 10% 24% 9.4 13.7 16.6 calc'd EUI 14.8 7.9 6.9 69.4 **Energy Conservation Measures:** 5.0% 15.0% Glazing E1 5 5% 4 7% Improved Glazina E1a Add effective shading devices E1b Walls & Roof 5.0% 3.0% 1.9% 1.8% E2 Shaded roof from solar panels E2a Optimize insulation to core performance guide E2b Highly reflective exterior siding E2d Daylighting (incorporates tuned glazing/shading) L1 15.0% -1.1% 1.5% 0.2% 2.1% Remove ceiling, raise window head, add lightshelf L1a Daylight controls (continuous dimming) L1c Lighting 12 69.7% -5.2% 7.0% 1.0% 10.0% Efficient fixture optics L2a Individual occupancy sensors & dimmina controls: closed offices/low occupanc 12b Individual light level control (dimming) at open office areas L2c Light colors on walls, ceiling surfaces L2d Occupancy sensors: transient lighting (corridors/stairs/bathrms) L2e Dual day/night light levels in corridors; occupancy sensors Occupancy sensor / time clock for corridor lighting L2i L2j Provide hardwired compact fluorescent fixtures in all spaces. L2k Plug Loads -2.3% 3.0% 0.5% 30.0% 7.4% Occupancy sensor controlled plug loads Ра EnergyStar appliances Pb Remove phantom load / transformers Pd Energy efficient main transformer Pe Occupant buy-in / personal energy budget Pf Centralized power management Pg Parking: variable flow ventilation based on CO monitor Pi Super-efficient elevators (hybrid) Pk Widen Set Point Temperatures М1 2.5% 5.0% 5.0% 2.3% Widen Set Point Temperatures (expand ASHRAE 55) M1a 84.7% 30.0% Subtotal from above Load Reduction strategies (percentage) 6.4% 34.5% 0.0% 11.6% 28 4% Subtotal Reduced EUI (kBTU/SF) 1.4 12.8 9.7 7.9 6.1 11.6 49.7 Mechanical - Distribution & Ventilation M2 15.0% 20.0% 70.0% 11.8% Radiant heating/cooling w dedicated outside air system (DOAS) M2a Energy recovery ventilation M2b Demand-based ventilation M2c Minimize carpet (insulates against radiant system) M2d Natural ventilation: operable windows M2e Fan assisted natural ventilation M2f Night flush M2g High mass - concrete block on inside of insulation M2h Displacement ventilation delivery for DOAS M2k Water to water heat pumps, radiant slab heating/cooling M2a Subtotal from Mechanical Distribution strategies (percentage) 0.0% 15.0% 20.0% 0.0% 0.0% 11.8% 70.0% Subtotal Reduced EUI (kBTU/SF) 1.4 10.9 7.7 1.8 7.9 11.6 41.5 Mechanical - Plant Systems MЗ 20.0% -15.0% 20.0% 5.0% Ground source heat pump system M3a Cascading chilled water system M3b Domestic Hot Water 75.0% w 8.6% Low flow fixtures (showers, lavs, sinks) Wb Water heating from tankless electric water heater Wd Subtotal from Mechanical Plant and DHW systems (percentage) 0.0% 20.0% 20.0% 75.0% -15.0% 0.0% 13.6% Reduced EUI from Energy Conservation Measures (kBTU/SF) 1.4 8.7 6.2 2.0 2.1 11.6 32.1 Final Energy Use Breakdown as Percentage of Baseline Use 2% 13% 9% 3% 3% 17% 54% Building Operating Factor CBECS Baseline FUI (kBTU/sf) 0.90 86.2 Impact of Interactive ECM effects target reduction from CBECS 1.05 60% Achievement Total Reduced EUI (kBTU/sf) 30.6 65% percent reduction from CBECS percent reduction from Normalized Baseline Bldg 56% Total reduced energy use (kWh) 3,404,765 Number of crystaline panels needed 12,468 Total kW of PV array 2556 PV Panel Analysis: From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes SanyokWh per Total panels Input Area 205 panel, facing South (azimuth 0°) angle # of Panels panel needed at ° (SF) 0 18,000 1443 269.31 12643 anels on roof roof + walkway + plaza 15 284.95 11949 57,000 4570 25.7 optimal angle: 288.74 11792 0 45° 278.92 12207 0

18584

Additional area

0

1,690,836

6455

1,738,396

3.429.232

Total kWh =

80.500

Additional kWh Produced

90°

183.21







**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

10,000 gal 180,231 sf **3** floors 39.03 acres 271,600 sf 84,900 sf

### **MAJOR DESIGN STRATEGIES:**

- ✓ Add new light courts at Nurse's station.
- ✓ Add skylights at corridors for increased daylighting.
- ✓ Minimize screen at mechanical area, due to fact that mechancial is reduced
- ✓ Add fins to provide shading on west side of classrooms.
- ✓ Add shading devices on South side of hospital, office, etc.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: ATLANTA, GA

## **SKANSKA**

Base Building Gross SF = 180,231 Living Building Gross SF = 180,231 Site Gross Acreage = 39.03

••	 	

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

СС	NSTRUCTION COST						
Δ	Substructure	1.0%	0.0%	\$2,895,319	\$16.06	\$2,924,661	\$16.23
	Baseline Building			\$2,895,319	\$16.06	\$2,895,319	\$16.06
W2	Rainwater Containment - 10,000 gal Rainwater Tank			• ,,	¢10100	\$29,342	\$0.16
в	Shell	2.1%	0.5%	\$14,789,139	\$82.06	\$15,102,359	\$83.79
	Baseline Building			\$14,789,139	\$82.06	\$14,789,139	\$82.06
L1B	Replace Roofing with Glazed Skylight					\$15,000	\$0.08
E1A	Improved Glazing (reduce solar heat gain at vision only)					\$16,000	\$0.09
E1B	Exterior Horizontal Shading Devices					\$87,600	\$0.49
L1D	Interior Light Shelf					\$58,400	\$0.32
E1B	Vertical Shading Fins (west end)					\$26,900	\$0.15
L1B	New Light Shafts to Nurse Stations					\$387,000	\$2.15
E2B	Infill Spandrel Panel with Framing and Insulation (replace glazed area)					\$22,320	\$0.12
D3	Reduce Mechanical Rooftop Screen					(\$300,000)	(\$1.66)
с	Interiors	0.4%	0.1%	\$9,710,678	\$53.88	\$9,746,724	\$54.08
	Baseline Building			\$9,710,678	\$53.88	\$9,710,678	\$53.88
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$36,046	\$0.20
L1A	Raise Ceilings (no cost impact)					\$0	
D.1	Services - Conveying Systems	0.0%	0.0%	\$826,462	\$4.59	\$826,462	\$4.59
	Baseline Building			\$826,462	\$4.59	\$826,462	\$4.59
D.2	Services - Plumbing Systems	7.5%	0.4%	\$3,347,613	\$18.57	\$3,597,613	\$19.96
	Baseline Building			\$3,347,613	\$18.57	\$3,347,613	\$18.57
W6	Low-Flow Fixtures / Optical Sensors					\$0	
W2	Rain Harvesting (piping & pumps and filtration)					\$250,000	\$1.39
		04.5%	F 70/	<b>**</b> *** ***	AFF 44	<b>*</b> 10,100,001	A74 50
D.3	Services - HVAC Systems	34.5%	5.7%	\$9,992,801	\$55.44	\$13,438,384	\$74.56
	Baseline Building			\$9,992,801	\$55.44	\$9,992,801	\$55.44
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,652,772)	(\$14.72)
M2A	In-Slab Radiant Heating and Cooling					\$901,155	\$5.00
МЗА	Ground Source Heat Pump					\$5,101,200	\$28.30
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$0.44
M2C	Carbon Dioxide Sensors					\$16,000	\$0.09
D 4	Services - Fire Protection Systems	0.0%	0.0%	\$444 259	\$2.46	\$444 259	\$2.46
	Baseline Building	01070	01070	\$444 259	\$2.46	\$444 259	\$2.46
	Bascine Building			¢,200	ψ2.40	¢,200	ψ2.40
D.5	Services - Electrical Systems	6.2%	0.8%	\$8,085,831	\$44.86	\$8,589,931	\$47.66
	Baseline Building			\$8,085,831	\$44.86	\$8,085,831	\$44.86
PA	Occupancy Sensor to Outlets					\$21,500	\$0.12
PE	High Efficiency Transformers					\$217,000	\$1.20
LIC	Daylight Controls (continuous dimming 15' from perimeter)					\$160,800	\$0.89
L2E	Occupancy Sensor for Transient and Egress Lighting					\$44,500	\$0.25
L2G	Patient Bed light with separate switching for ambient / task					\$18,800	\$0.10
L2M	Dual level light at egress stairs - off when not occupied					\$19,000	\$0.11
L2N	Stairwell lighting on daylighting					\$22,500	\$0.12

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$2,050,942	\$11.38	\$2,050,942	\$11.38
Baseline Building				\$2,050,942	\$11.38	\$2,050,942	\$11.38
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		0.6%	0.1%	\$7,730,038	\$42.89	\$7,780,038	\$43.17
Baseline Building				\$7,730,038	\$42.89	\$7,730,038	\$42.89
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.28
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$920,558	\$5.11	\$920,558	\$5.11
Baseline Building				\$920,558	\$5.11	\$920,558	\$5.11
Living Building Prerequisites				\$9,012	\$0.05	\$1,160,573	\$6.44
PR5 - Materials Red List		100.0%	0.7%			\$443,365	\$2.46
PR7 - Responsible Industry		100.0%	0.2%			\$108,128	\$0.60
PR8 - Appropriate Materials / Services Radius		100.0%	1.0%			\$600,069	\$3.33
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$9,012	\$0.05	\$9,012	\$0.05
Subtotal Direct Costs			9.5%	\$60,802,650	\$337.36	\$66,582,503	\$369.43
General Conditions	5.9%	9.5%	0.6%	\$3,599,939	\$19.97	\$3,942,146	\$21.87
Fee, Contingency, Insurance	6.7%	9.5%	0.7%	\$4,309,196	\$23.91	\$4,718,825	\$26.18
Location Modifier for ATLANTA, GA	0.87	9.5%	-1.4%	(\$8,932,532)	(\$49.56)	(\$9,781,652)	(\$54.27)
TOTAL MODIFIED CONSTRUCTION COST			9.5%	\$59,779,253	\$331.68	\$65,461,823	\$363.21

#### BUILDING TYPE: HOSPITAL BUILDING LOCATION: ATLANTA, GA



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	2.5%			\$1,500,000	\$8.32
PV1 Photovoltaic Panels and Infrastructure	4,465,000	Watts		100.0%	55.1%			\$33,487,500	\$185.80
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.3%			\$195,150	\$1.08
PR6 - Construction Carbon Footprint	5,400	tons		100.0%	0.1%			\$59,400	\$0.33
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.35
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	21.2%	5.8%	\$16,738,191	\$92.87	\$20,293,165	\$112.60
Architecture & Engineering		7.00%	9.00%	40.8%	2.8%	\$4,184,548	\$23.22	\$5,891,564	\$32.69
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-27.5%	\$0		(\$16,743,750)	(\$92.90)
SDC Credits	50%			-100.0%	-2.3%	\$0		(\$1,372,092)	(\$7.61)
TOTAL OWNER & DESIGN-BUILD COSTS					107.3%	\$20,922,739	\$116.09	\$43,373,937	\$240.66

TOTAL CONCEPTUAL COST: \$80,701,992 \$447.77 \$108,835,760 \$603.87

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	32%	то	37%	
HOSPITAL IN ATLANTA, GA				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### Hospital Atlanta

Normalized Baseline Energy Use Intensity (kBtu/SF) 191.2

Normalized Baseline Energy Use (kWh) 10,084,425

Impact of Design Changes (see sketches) 1.00

Adjusted Baseline EUI (kBtu/SF) 191.2

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
per	cent of load	16%	13%	14%	16%	15%	26%	100%
	calc'd EUI	29.9	25.3	27.5	29.9	28.7	49.8	191.2
Energy Conservation Measures:								
Glazing	E1		5.0%	10.0%		4.0%		2.7%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		4.0%	3.0%		1.7%		1.2%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Highly reflective exterior siding	E2d							
Davlighting (incorporates tuned glazing/shading)	L1	13 3%	-1.0%	1 3%		0.2%		2.2%
Ton daylighting with skylights	11b	10.070	2.070	1.570		0.270		2.270
Davlight controls (continuous dimming)	110							
Lighting	12	21 10/	2.20/	2 10/		0.5%		E 10/
Company conserve transient lighting (corridors (stairs (bathrms)	120	51.1/0	=2.370	5.1/0		0.376		3.1/0
Decupulity sensors: transient lighting (cornuors/stairs/bathins)	LZe							
Putient bedight with separate switching for ambient / task	LZg						10.00/	2.50/
Plug Loads	P						10.0%	2.5%
EnergyStar appliances	Pb							
Energy efficient main transformer	Pe							
Super-efficient elevators (hybrid)	Pk							
Aggressive heat recapture - all equipment water cooled	PI							
Widen Set Point Temperatures	M1		2.0%	2.0%		1.0%		0.7%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		44.4%	7.7%	19.4%	0.0%	7.4%	10.0%	14.5%
Subtotal Reduced EUI (kBTU/SF)		16.6	23.4	22.2	29.9	26.6	44.9	163.5
Mechanical - Distribution & Ventilation	M2		15.0%	13.0%		19.0%		6.4%
Radiant slab heating/cooling in lobby/atrium spaces	M2r							
Chilled beams	M2s							
Displacement ventilation in exam rooms	M2t							
Natural ventilation in stairwells	M2u							
Low pressure drop air filters	M2v							
OSA/Exhaust runaround heat recovery	M2w							
Cascading make-up air	M2x							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	13.0%	0.0%	19.0%	0.0%	6.0%
Subtotal Reduced EUI (kBTU/SF)		16.6	19.9	19.3	29.9	21.5	44.9	152.1
Mechanical - Plant Systems	M3		25.0%	30.0%		-7.5%		4.8%
Ground source heat pump with central heat pump chiller	M3e							
Chiller heat recovery	M3f							
Domestic Hot Water	w				60.0%			9.4%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	25.0%	30.0%	60.0%	-7.5%	0.0%	14.2%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		16.6	14.9	13.5	12.0	23.1	44.9	125.0
Final Energy Use Breakdown as Percentage of Baseline Use		9%	8%	7%	6%	12%	23%	35%
Building Operating Fact	or 0.90			249.2	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effe	ts 1.05			60%	target reducti	on from CBECS		
				Achievement:	TARGET REDI	ICTION NOT ME	т	
Total Reduced FUI (kBTU/	cf) 117 4			53%	nercent reduc	tion from CBECS		
	51/ 11/.4			39%	percent reduc	tion from Norm	alized Baseline	Blde
Total reduced aparms	uco (k)M/b)	6 10E 772		3370	percentreduc		Jilzed Buseline	Didg
Total reduced energy	use (kvvn)	0,195,772						
Number of crystaline pan	els needed	21,779						
Total kW	of PV array	4465						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo	-	kW/h por	Total panala	Input Area	1	1		
205 panel, facing South (azimuth 0°)	angle	kwn per	notal pariels	input Area	# of Panels			
		panei	needed at °	(SF)				
	0°	269.31	23007	44,700	3584	Panels on roof root	i + walkway + plaz	а
	15°	284.95	21744		0			
optimal ang	le: 25.7°	288.74	21458	226,900	18195			
	45°	278.92	22214		0			
	90°	183.21	33818		0			

6,218,831

Total kWh =



## UNIVERSITY CLASSROOM PHOENIX hot arid



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

-

## BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =	153,531
Living Building Gross SF =	153,531
Site Gross Acreage =	2.75

Т

	Premium (%)	Premium (%)	LEED™ Gold	LEED™ Gold Baseline Living Buildin		uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	1.7%	0.1%	\$2,123,369	\$13.83	\$2,160,394	\$14.07
Baseline Building			\$2,123,369	\$13.83	\$2,123,369	\$13.83
W2 Rainwater Containment - 30,000 gal Rainwater Tank					\$37,025	\$0.24
B Shell	5.9%	0.7%	\$4,959,353	\$32.30	\$5,252,677	\$34.21
Baseline Building			\$4,959,353	\$32.30	\$4,959,353	\$32.30
E1A Improved Glazing (reduce solar heat gain)					\$35,324	\$0.23
E1B Exterior PV Vertical Screen Wall Supports					\$72,000	\$0.47
E1B Exterior PV Sloping Wall Structure					\$133,000	\$0.87
E1B Exterior Shading Devices (vertical sun shades at north windows)					\$54,000	\$0.35
E1B Exterior Shading Devices (solid horizontal sun shades)					\$21,000	\$0.14
D2B Revised Atrium Roof Structure (with transluscent roofing)					(\$22,000)	(\$0.14)
C Interiors	-3.8%	-1.4%	\$16,495,934	\$107.44	\$15,868,139	\$103.35
Baseline Building			\$16,495,934	\$107.44	\$16,495,934	\$107.44
M2D Carpet Reduction (remove carpet and retroplate concrete)					\$96,071	\$0.63
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$153,531	\$1.00
L1A Exposed Ceilings (white matte surfaces)					(\$160,397)	(\$1.04)
D3 Eliminate Raised Access Floor					(\$717,000)	(\$4.67)
D.1 Services - Conveying Systems	0.0%	0.0%	\$297,968	\$1.94	\$297,968	\$1.94
Baseline Building			\$297,968	\$1.94	\$297,968	\$1.94
D.2 Services - Plumbing Systems	5.2%	0.4%	\$2,968,571	\$19.34	\$3,122,371	\$20.34
Baseline Building			\$2,968,571	\$19.34	\$2,968,571	\$19.34
W6 Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.98
D.3 Services - HVAC Systems	45.3%	5.8%	\$5,646,851	\$36.78	\$8,204,706	\$53.44
Baseline Building			\$5,646,851	\$36.78	\$5,646,851	\$36.78
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$1,000,000)	(\$6.51)
M2A In-Slab Radiant Heating and Cooling					\$767,655	\$5.00
M3A Ground Source Heat Pump					\$2,710,200	\$17.65
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$0.52
M2C Carbon Dioxide Sensors (in base building)					\$0	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$425,840	\$2.77	\$425,840	\$2.77
Baseline Building			\$425,840	\$2.77	\$425,840	\$2.77
D.5 Services - Electrical Systems	2.9%	0.4%	\$6,000,852	\$39.09	\$6,174,252	\$40.22
Baseline Building			\$6,000,852	\$39.09	\$6,000,852	\$39.09
PA Occupancy Sensor to Outlets					\$14,100	\$0.09
PE High Efficiency Transformers					\$67,000	\$0.44
L2E Occupancy Sensor for Transient and Egress Lighting					\$37,500	\$0.24

## BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 153,531 Living Building Gross SF = 153,531 Site Gross Acreage = 2.75

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
L2F Dimmable Direct/Indirect Fixtures						\$54,800	\$0.36
E Equipment and Furnishings		0.0%	0.0%	\$257,958	\$1.68	\$257,958	\$1.68
Baseline Building				\$257,958	\$1.68	\$257,958	\$1.68
F Special Construction		0.0%	0.0%	\$79,247	\$0.52	\$79,247	\$0.52
Baseline Building				\$79,247	\$0.52	\$79,247	\$0.52
G Sitework		1.0%	0.1%	\$2,460,261	\$16.02	\$2,485,261	\$16.19
Baseline Building				\$2,460,261	\$16.02	\$2,460,261	\$16.02
W4 Stormwater Retention / Building Water Discharge						\$25,000	\$0.16
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$U	
H Logistics		0.0%	0.0%	\$2,108,417	\$13.73	\$2,108,417	\$13.73
Baseline Building				\$2,108,417	\$13.73	\$2,108,417	\$13.73
Links Ball the Descent free				AT 077	<b>*</b> 0.05	\$4.400.0 <del>7</del> 0	AT 00
Living Building Prerequisites		100.0%	0.7%	\$7,677	\$0.05	\$1,123,676	\$7.32
PR7 - Responsible Industry		100.0%	0.4%			\$162 546	\$2.05 \$1.06
PR8 - Appropriate Materials / Services Radius		100.0%	1.5%			\$639,109	\$1.00 \$4.16
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$7,677	\$0.05	\$7,677	\$0.05
Subtotal Direct Costs			8.5%	\$43,832,298	\$285.49	\$47,560,908	\$309.78
General Conditions	8.0%	8.5%	0.7%	\$3,512,022	\$22.88	\$3,810,773	\$24.82
Fee, Construction Contingency, Insurance	7.0%	8.5%	0.6%	\$3,328,586	\$21.68	\$3,611,733	\$23.52
Location Modifier for PHOENIX, AZ	0.85	8.5%	-1.5%	(\$7,600,936)	(\$49.51)	(\$8,247,512)	(\$53.72)
TOTAL MODIFIED CONSTRUCTION COST			8.5%	\$43,071,971	\$280.54	\$46,735,903	\$304.41

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =153,531Living Building Gross SF =153,531Site Gross Acreage =2.75

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	0.1%			\$50,000	\$0.33
PV1 Photovoltaic Panels and Infrastructure	932,000 Watts		100.0%	15.9%			\$6,990,000	\$45.53
LB Prerequisite Items								
PR3 - Habitat Exchange	2.75482 acres		100.0%	0.0%			\$13,774	\$0.09
PR6 - Construction Carbon Footprint	6,800 tons		100.0%	0.2%			\$74,800	\$0.49
PR15 - Beauty and Spirit (included in A/E fe	es below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.2%			\$73,750	\$0.48
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	20.1%	5.5%	\$12,060,152	\$78.55	\$14,488,130	\$94.37
Architecture & Engineering	7.00%	9.00%	39.5%	2.7%	\$3,015,038	\$19.64	\$4,206,231	\$27.40
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-8.0%	\$0		(\$3,495,000)	(\$22.76)
SDC Credits	50%		-100.0%	-0.8%	\$0		(\$349,890)	(\$2.28)
TOTAL OWNER & DESIGN-BUILD COSTS				46.3%	\$15,075,190	\$98.19	\$22,051,795	\$143.63

TOTAL CONCEPTUAL COST: \$58,147,160 \$3

\$378.73 \$68,787,698

\$448.04

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 16% TO 21% UNIVERSITY CLASSROOM IN PHOENIX, AZ

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### University Classroom

#### Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 87.0

Normalized Baseline Energy Use (kWh) 3,699,271

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 84.0

		LIGHTING	HEATING	COOLING	DOM. HOT WATER	FANS & PUMPS	MISC. EQUIP	TOTAL BLDG
per	rcent of load	20%	5%	34%	2%	10%	29%	100%
Energy Concernation Measures	calc'd EUI	16.4	4.1	28.8	1.6	8.4	24.6	84.0
Glazing	F1		2.0%	10.0%		3.4%		3.9%
Improved Glazing	E1a		2.070	10.070		5.470		5.570
Add effective shading devices	E1b							
Walls & Roof	E2		5.0%	8.0%		3.4%		3.3%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
PV mounted 30 <sup>m</sup> up to allow for snading Highly reflective exterior siding	E2C E2d							
Davlighting (incorporates tuned glazing/shading)	11	50.0%	-3.8%	5.0%		0.8%		11.4%
Top daylighting with skylights	11b	50.070	5.676	5.070		0.070		11.470
Daylight controls (continuous dimming)	L1C							
Orient windows to allow for illumination of teaching wall	L1f							
Lighting	L2	20.0%	-1.5%	2.0%		0.3%		4.5%
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dimmable direct / indirect fixtures	L2f							
Occupancy sensor / time clock for corridor lighting	L2j		1.0%	2.5%		0.49/	25.0%	0.10/
Plug Loads	P		-1.9%	2.5%		0.4%	25.0%	8.1%
EnergyStar appliances	Pa							
Optimize printer lavout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				0.3%
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	IV14D		F 09/	F 0%		2 59/		2 20/
Widen Set Point Temperatures (expand ASHRAE 55)	N12		5.0%	5.0%		2.3%		2.270
Subtotal from above Load Reduction strategies (percentage)	IVIII	70.0%	4.9%	39.5%	0.0%	10.7%	25.0%	35.9%
Subtotal Reduced EUI (kBTU/SF)		4.9	3.9	17.4	1.6	7.5	18.5	53.9
Mechanical - Distribution & Ventilation	M2		15.0%	25.0%		60.0%		11.2%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Cascading make-up air	M2x							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	25.0%	0.0%	60.0%	0.0%	11.2%
Subtotal Reduced EUI (kBTU/SF)		4.9	3.3	13.1	1.6	3.0	18.5	44.4
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		3.4%
Ground source heat pump system	M3a							
Domestic Hot Water	w				50.0%			1.0%
Low flow fixtures (showers, lavs, sinks)	Wb							
Subtotal from Mechanical Plant and DHW systems (percentage)	Wd	0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	A A%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.9	2.7	10.5	0.8	3.4	18.5	40.8
Final Energy Use Breakdown as Percentage of Baseline Use		6%	3%	12%	1%	4%	22%	51%
Building Operating Fac	tor 0.90			100.0	CBECS Baselin	ne EUI (kBTU/sf)		
Impact of Interactive ECM effe	cts 1.05			60%	target reduct	ion from CBECS		
				Achievement:				
Total Reduced EUI (kBTU/	/sf) 38.4			62%	percent redu	ction from CBECS		
Total and so and an area		1 620 260		54%	percent redu	ction from Norm	alized Baseline	BIOS
Total reduced energy	/ use (kwn)	1,630,260						
Number of crystaline par	alc poodod	A 70E						
Number of crystaine part	of PV array	4,765						
DV Danal Analysia	orrvanay	561						
PV Patiel Attalysis. From RETScreen 4-1: method 2-2% misc losses 90% inverter efficiency, assumes Sanvi	n-		I	1	1	1		
205 panel, facing South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
· · · · · · · · · · · · · · · · · · ·		panel	needed at °	(SF)				
	0°	345.73	4716	44,470	3566	Panels at umbrella	roof and as shadir	ng devices in
	15°	372.11	4382	40	0	glazing		
optimal ang	gie: 29.7°	381.27	4276	10,100	809	-		
	45 90°	244 19	4300	5,120	410	-		
				Total kWh =	1,641.439	_		


# SCHOOL K-8 PHOENIX hot arid



# ENERGY USE INDEX

COST PREMIUM PAYBACK COST PER SF PHOTOVOLTAIC CAPACITY WATER USE

300,000 galRAINWATER TANK SIZE148,981 sfBUILDING SIZE2 floorsBUILDING HEIGHT39.03 acresSITE AREA74,470 sfPHOTOVOLTAIC AREA97,650 sfROOF AREA

# **MAJOR DESIGN STRATEGIES:**

- Reorganize plan to eliminate N/S portions of classrooms wings.
- Remove windows below 2'-6" in classrooms.
- Remove windows below 2'-0" in corridors.
- Tune glazing to have high performance glass at vision glass only.
- Add overhang at clerestory windows.
- ✓ Add skids for support of PV.
- Eliminate windows on West and East facades at classrooms.



SITE PLAN NTS





The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =148,981Living Building Gross SF =148,981Site Gross Acreage =39.03

		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living B	uilding
				Total	Cost/SF	Total	Cost/SF
CONSTRUCTION C	COST						
A Substructure		36.3%	1.8%	\$1,466,210	\$9.84	\$1,998,463	\$13.41
Baseline Buildir	ng			\$1,466,210	\$9.84	\$1,466,210	\$9.84
Rainwater Cont	ainment - 300,000 gal Rainwater Tank					\$532,253	\$3.57
B Shell		-1.9%	-0.6%	\$9,540,845	\$64.04	\$9,363,445	\$62.85
Baseline Buildir	ng			\$9,540,845	\$64.04	\$9,540,845	\$64.04
D3 Lower Roof at N	Aedia Center (at both links)					(\$248,400)	(\$1.67)
D3 Reallocate Sout	th Wing (move SF to east-west wings)					(\$69,000)	(\$0.46)
E1A Improved Glazin	ng (reduce solar heat gain at vision only)					\$22,000	\$0.15
E1B Additional Exter	rior Shading Devices					\$37,500	\$0.25
D2B Extend Roof Str	ructure at Clerestory (to the south)					\$80,500	\$0.54
C Interiors		3.1%	0.5%	\$4,624,290	\$31.04	\$4,765,608	\$31.99
Baseline Buildir	ng			\$4,624,290	\$31.04	\$4,624,290	\$31.04
M2D Carpet Reduction	on (replace with RetroPlate)					\$108,466	\$0.73
M2A Topping Slab / S	Stair Premium for Underfloor Radiant System (3" concrete)					\$148,981	\$1.00
L1A Exposed Ceiling	gs (white matte surfaces)					(\$116,128)	(\$0.78)
D.1 Services - Cor	nveying Systems	0.0%	0.0%	\$100,000	\$0.67	\$100,000	\$0.67
Baseline Buildir	ng			\$100,000	\$0.67	\$100,000	\$0.67
D.2 Services - Plu	mbing Systems	10.4%	0.5%	\$1,438,830	\$9.66	\$1,588,830	\$10.66
Baseline Buildir	ng			\$1,438,830	\$9.66	\$1,438,830	\$9.66
W6 Low-Flow Fixtur	res / Optical Sensors					\$0	
W2 Rain Harvesting	g (piping & pumps and filtration)					\$150,000	\$1.01
D.3 Services - HV	AC Systems	26.1%	3.2%	\$3,684,937	\$24.73	\$4,647,670	\$31.20
Baseline Buildir	ng			\$3,684,937	\$24.73	\$3,684,937	\$24.73
Baseline HVAC	System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,652,772)	(\$17.81)
M2A In-Slab Radiant	Heating and Cooling					\$744,905	\$5.00
M2L Solar Wall Mech	hanical Screen					\$145,000	\$0.97
M3A Ground Source	Heat Pump					\$2,629,600	\$17.65
M2B Energy Recover	ry Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$0.54
M2C Carbon Dioxide	Sensors					\$16,000	\$0.11
D.4 Services - Fire	Protection Systems	0.0%	0.0%	\$345,589	\$2.32	\$345,589	\$2.32
Baseline Buildin	ng			\$345,589	\$2.32	\$345,589	\$2.32
D.5 Services - Elec	ctrical Systems	6.6%	0.7%	\$3,044,694	\$20.44	\$3,246,194	\$21.79
Baseline Buildin	ng			\$3,044,694	\$20.44	\$3,044,694	\$20.44
PA Occupancy Sen	nsor to Outlets					\$5,000	\$0.03
PE High Efficiency	Transformers					\$97,500	\$0.65
LIC Daylight Contro	ls (continuous dimming 15' from perimeter)					\$23,800	\$0.16
L2F Dimmable Direc	ct/Indirect fixtures					\$47,500	\$0.32
L2B Occupancy Sen	nsor for Lighting (closed office / conference spaces)					\$0	
L2C Individual Light	Level Control (open spaces, classrooms)					\$5,200	\$0.03
L2E Occupancy Sen	nsor for Transient and Egress Lighting				l	\$22,500	\$0.15

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
ΕE	quipment and Furnishings		0.0%	0.0%	\$1,555,517	\$10.44	\$1,555,517	\$10.44
E	Baseline Building				\$1,555,517	\$10.44	\$1,555,517	\$10.44
FS	pecial Construction		0.0%	0.0%	\$58,000	\$0.39	\$58,000	\$0.39
E	Baseline Building				\$58,000	\$0.39	\$58,000	\$0.39
GS	itework		41.9%	5.2%	\$3,701,152	\$24.84	\$5,251,152	\$35.25
E	Baseline Building				\$3,701,152	\$24.84	\$3,701,152	\$24.84
W4 S	Stormwater Retention / Building Water Discharge						\$50,000	\$0.34
W1 F	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
W2 A	Additional Onsite Water Collection (in addition to roof)						\$1,500,000	\$10.07
ыт	oristics		0.0%	0.0%	¢504 604	¢2.50	\$524 604	¢2.50
			0.0%	0.0%	\$524,094	\$3.5Z	\$524,094	\$3.5Z
E	Baseline Building				\$524,694	\$3.52	<b>⊅</b> 5∠4,694	\$3.52
_								
Livin	a Buildina Prereauisites				\$7,449	\$0.05	\$722.737	\$4.85
F	PR5 - Materials Red List		100.0%	0.7%	• , -	•	\$211,872	\$1.42
F	PR7 - Responsible Industry		100.0%	0.2%			\$66,413	\$0.45
F	PR8 - Appropriate Materials / Services Radius		100.0%	1.5%			\$437,003	\$2.93
F	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$7,449	\$0.05	\$7,449	\$0.05
Subto	otal Direct Costs			13.5%	\$30,092,207	\$201.99	\$34,167,900	\$229.34
G	General Conditions	3.7%	13.5%	0.5%	\$1,098,511	\$7.37	\$1,247,293	\$8.37
F	Fee, Contingency, Insurance, Bonding	9.6%	13.5%	1.4%	\$3,009,175	\$20.20	\$3,416,738	\$22.93
L	ocation Modifier for PHOENIX, AZ	0.85	13.5%	-2.3%	(\$5,129,984)	(\$34.43)	(\$5,824,790)	(\$39.10)
тоти	AL MODIFIED CONSTRUCTION COST			13.5%	\$29,069,909	\$195.12	\$33,007,141	\$221.55

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

Di Pre	vision emium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.7%			\$200,000	\$1.34
PV1 Photovoltaic Panels and Infrastructure	499,000	Watts		100.0%	12.4%			\$3,742,500	\$25.12
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.6%			\$195,150	\$1.31
PR6 - Construction Carbon Footprint	4,400	tons		100.0%	0.2%			\$48,400	\$0.32
PR15 - Beauty and Spirit (included in A/E f	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,000	\$0.42
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	25.7%	7.0%	\$8,139,574	\$54.63	\$10,232,214	\$68.68
Architecture & Engineering		7.00%	9.00%	46.0%	3.1%	\$2,034,894	\$13.66	\$2,970,643	\$19.94
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-6.2%	\$0		(\$1,871,250)	(\$12.56)
SDC Credits	50%			-100.0%	-2.8%	\$0		(\$848,565)	(\$5.70)
TOTAL OWNER & DESIGN-BUILD COSTS					44.8%	\$10,174,468	\$68.29	\$14,732,092	\$98.89

TOTAL CONCEPTUAL COST: \$39,244,377 \$263.42 \$47,739,233 \$320.44

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 19% TO 24% ELEMENTARY SCHOOL IN PHOENIX, AZ

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# ElementarySchool

# Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 63.8

Normalized Baseline Energy Use (kWh) 2,637,610

Impact of Design Changes (see sketches) 0.96

Adjusted Baseline EUI (kBtu/SF) 61.0

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	20%	5%	40%	3%	12%	21%	100%
	calc'd EUI	11.9	2.9	24.4	1.7	7.3	12.8	61.0
Energy Conservation Measures:								
Glazing	E1		2.0%	15.0%		4.9%		6.7%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		7.0%	8.0%		3.8%		4.0%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
PV mounted 30"' up to allow for shading	E2c							
Highly reflective exterior siding	E2d							
Daylighting (incorporates tuned glazing/shading)	L1	75.0%	-5.6%	7.5%		1.1%		17.5%
Top daylighting with skylights	11b							
Davlight controls (continuous dimming)	110							
Orient windows to allow for illumination of teaching wall	L1C							
Lighting	12	0.8%	-0.7%	1.0%		0.1%		2 3%
	124	3.070	-0.776	1.076		0.170		2.370
Light colors on wans, centry surjuces	12-							
Diccupancy sensors: transient lighting (corritors/stairs/butinns)	LZe							
Dimmable direct / indirect fixtures	L2T							
Occupancy sensor / time clock for corridor lighting	L2j							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	6.2%
Occupancy sensor controlled plug loads	Ра							
EnergyStar appliances	Pb							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				0.1%
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.5%
Widen Set Point Temperatures (expand ASHPAE 55)	M15		5.070	5.070		2.570		2.570
Subtotal from above Load Reduction strategies (nercentage)	IVIId	84.8%	5.8%	46.0%	0.0%	12.8%	25.0%	42.0%
Subtotal Peduced FIII (kBTII/SE)		1.8	2.8	12.7	1 7	6.4	9.6	25 2
Machanical Distribution & Vantilation	142	1.0	15.0%	25.0%	1.7	60.0%	5.0	12.49/
Rechanical - Distribution & Ventilation	IVIZ		15.0%	25.0%		60.0%		12.4%
Radiant heating/cooling w dedicated outside air system (DOAS)	IVI2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	25.0%	0.0%	60.0%	0.0%	12.4%
Subtotal Reduced EUI (kBTU/SF)		1.8	2.4	9.9	1.7	2.5	9.6	27.8
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		3.4%
Ground source heat pump system	M3a							
Domestic Hot Water	w				70.0%			1.9%
Low flow fixtures (showers lays sinks)	Wb							
Water heating from water to water heat nump (asha)	W/c							
Subtotal from Mechanical Plant and DHW systems (nercentage)	VVC	0.0%	20.0%	20.0%	70.0%	-15.0%	0.0%	5 2%
Reduced FILI from Energy Conservation Measures (LPTLL/SE)		1.0	1.0	7.0	0.5	2.0	0.0%	2/ 6
Final Energy Lise Breakdown as Percentage of Baseline Lise		3%	3%	13%	1%	2.9	5.0 16%	60%
יוומי בוופיסן של של של של איז		3/0	3/0	13/0	2/0	570	10/0	00/0
Building Operating Facto	r 0.90			83.1	CBECS Baselin	e FUI (kBTU/sf)		
Impact of Interactive FCM effect	\$ 1.05			60%	target reducti	on from CRECS		
impact of interactive bein cried	5 1.05			0070	target reducti	on nom ebees		
				Achievement				
Total Reduced EUI (kBTU/si	) 23.0			72%	percent reduc	tion from CBECS		
				62%	percent reduc	tion from Norm	alized Baseline	Bldg
Total reduced energy u	ise (kWh)	950,643						
Number of crystaline pane	s needed	2,774						
Total kW of	PV arrav	569						
DV Banal Analysis:								
r v raher Andrysis.	1 1		1	1	1			
FIGHT RETSCIEVEN 4-1: MELTION 2, 2% MISC IOSSES, 90% INVERTER EFFICIENCY, ASSUMES SANYO-	anglo	kWh per	Total panels	Input Area	# of Papala			
205 punci, jucing south (uzimuth 0-)	angle	panel	needed at °	(SF)	# OF FallelS			
	0°	345 72	2750	34 600	2774	Panels at mm roof	only	
	150	272 11	2/30	34,000	2//4	. ancia ac gymroor	Silly	
	10 70	201 27	2000		0	-		
optimal angle	. 29.7 AF®	271.61	2494		0	-		
	45	3/1.01	2559		0	-		
	90-	244.19	3894		0	1		
				Total kWh =	959,055			



# LOW RISE OFFICE PHOENIX hot arid



COST PREMIUM PAYBACK COST PER SF PHOTOVOLTAIC CAPACITY WATER USE

ENERGY USE INDEX

15,000 galRAINWATER TANK SIZE35,776 sfBUILDING SIZE2 floorsBUILDING HEIGHT3.24 acresSITE AREA12,450 sfPHOTOVOLTAIC AREA17,888 sfROOF AREA

# **MAJOR DESIGN STRATEGIES:**

- Add an atrium to provide daylighting deep into the building
- Add a 6' overhang to provide additional water catchment area.
- Add 6' wide shading devices.
- Relocate windows on East and West sides of the building to North and South; glass area to remain the same.
- Add fins at center bay
   East where windows not eliminated.
- Provide evergreen trees on West side.



STORMWATER TREATMENT

**W**INTEGRAL

ITH ROOF

NTS

# LIVING BUILDING DESIGN MODIFICATION

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

со	NSTRUCTION COST						
Δ	Substructure	13.3%	1.1%	\$625,892	\$17.49	\$708,993	\$19.82
	Baseline Building			\$625,892	\$17.49	\$625,892	\$17.49
W2	Rainwater Containment - 41,000 gal Rainwater Tank				• -	\$83,101	\$2.32
в	Shell	18.1%	7.7%	\$3,237,848	\$90.50	\$3,824,935	\$106.91
	Baseline Building			\$3,237,848	\$90.50	\$3,237,848	\$90.50
M2E	Operable Windows (manual)					\$31,680	\$0.89
D3C	Reallocate Glazing from East and West Façade to South (less spandrel panel, n	nore skin)				(\$17,472)	(\$0.49)
L1B	Replace Rooting with Glazed Skylight					\$94,200 \$16,104	\$2.63
E1A	Improved Glazing (reduce solar heat gain)					\$10,104 \$70,460	\$0.45 ¢1.07
E1B	Added Wall / Skin for Modified Design (not in base building design)					\$274 560	\$1.97 \$7.67
M2H	"High Mass" Concrete Inside Insulation (added reflective skin)					\$49,500	\$1.38
D2B	Modifications to Roof Structure					\$39.255	\$1.00
L1D	Interior Light Shelves (remove from N/E/W, keep south only)					\$28,800	\$0.81
С	Interiors	17.2%	2.4%	\$1,076,571	\$30.09	\$1,261,402	\$35.26
	Baseline Building			\$1,076,571	\$30.09	\$1,076,571	\$30.09
M2D	Carpet Reduction (replace with RetroPlate)					\$25,500	\$0.71
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$48,264	\$1.35
L1A	Exposed Ceilings (white matte surfaces)					(\$68,213)	(\$1.91)
D3	Glass partitions in lieu of gypsum wallboard					\$179,280	\$5.01
D.1	Services - Conveying Systems	0.0%	0.0%	\$55,000	\$1.54	\$55,000	\$1.54
	Baseline Building			\$55,000	\$1.54	\$55,000	\$1.54
<b>D</b> 2	Sorvicos - Diumbing Systems	00.6%	2 5%	\$208.354	\$5.92	\$207 154	\$11.10
U.2	Services - Flumbing Systems	90.6%	2.3%	\$208,354	\$0.02	\$208 354	\$11.1U
We	Low-Flow Fixtures / Ontical Sensors			φ200,004	φ3.02	\$3 800	\$0.02 \$0.11
W2	Rain Harvesting (nining & numps and filtration)					\$185,000	\$0.11 \$5.17
v v Z						¢100,000	ψ0.17
D.3	Services - HVAC Systems	100.6%	7.8%	\$591,095	\$16.52	\$1,185,475	\$33.14
	Baseline Building			\$575,095	\$16.07	\$575,095	\$16.07
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$300,000)	(\$8.39)
M2A	In-Slab Radiant Heating and Cooling					\$178,880	\$5.00
МЗА	Ground Source Heat Pump					\$635,500	\$17.76
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)			<b>*</b> 4 <b>*</b> * * * *		\$80,000	\$2.24
M2C	Carbon Dioxide Sensors			\$16,000	\$0.45	\$16,000	\$0.45
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$75,177	\$2.10	\$75,177	\$2.10
	Baseline Building			\$75,177	\$2.10	\$75,177	\$2.10
_				<b>A-</b>			
D.5	Services - Electrical Systems	6.5%	0.6%	\$723,416	\$20.22	\$770,116	\$21.53
	Baseline Building			\$603,016	\$16.86	\$603,016	\$16.86
PA	Uccupancy Sensor to Outlets					910,200 \$36 500	\$0.29
PE	Tight Enricency Hanstofffers  Devilopt Controls (continuous dimming 15' from parimeter)			\$27,000	¢0.75	\$30,500 \$27,000	\$1.02 ¢0.75
LIC	Eaving Controls (continuous anning 15 11011 perimeter)			\$67.600	JU./5 \$1 80	\$67 600	ອບ./ວ \$1 ຊດ
LZA	Occupancy Sensor for Lighting (closed office / conference spaces)			\$12,000	\$0 34	\$12,000	\$0 3/
L2E	Occupancy Sensor for Transient and Egress Lighting			\$13,800	\$0.39	\$13,800	\$0.39
	Coopering Consol for Transient and Egross Eighting			<i>\</i> ,	ψ0.00	<i>\</i> ,	ψ0.00

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$149,348	\$4.17	\$149,348	\$4.17
Baseline Building				\$149,348	\$4.17	\$149,348	\$4.17
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		7.6%	0.8%	\$791,671	\$22.13	\$851,671	\$23.81
Baseline Building				\$791,671	\$22.13	\$791,671	\$22.13
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$1.40
E1B Cacti for shading						\$10,000	\$0.28
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$40,261	\$1.13	\$40,261	\$1.13
Baseline Building				\$40,261	\$1.13	\$40,261	\$1.13
Living Building Prerequisites		400.00/	0.00/	\$5,366	\$0.15	\$246,767	\$6.90
PR5 - Materials Red List		100.0%	0.8%			\$58,739	\$1.64
PR7 - Responsible Industry		100.0%	0.1%			\$10,732 \$171,030	\$0.30
PRO - Appropriate Materials / Services Radius		0.0%	2.3%	¢5 266	<b>*</b> 0.45	\$171,930 \$5.266	\$4.81
PR9 - Leadership III Construction Waste		0.0%	0.0%	\$5,500	\$0.15	\$3,300	\$0.15
Subtotal Direct Costs			26.2%	\$7,580,000	\$211.87	\$9,566,301	\$267.39
	4.00/	00.00/	4.00/	¢000.000	<b>*</b> • (=	\$200 CTC	<b>0</b> 40 ==
General Conditions	4.0%	26.2%	1.0%	\$303,200	\$8.47	\$382,652	\$10.70
Fee, Construction Contingency, Insurance	3.0%	26.2%	0.8%	\$238,965	\$6.68	\$301,585	\$8.43
Location Modifier for PHOENIX, AZ	0.85	26.2%	-4.2%	(\$1,218,325)	(\$34.05)	(\$1,537,581)	(\$42.98)
TOTAL MODIFIED CONSTRUCTION COST			26.2%	\$6,903,841	\$192.97	\$8,712,957	\$243.54

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# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS						I		ſ	
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.5%			\$40,000	\$1.12
PV1 Photovoltaic Panels and Infrastructure	175,000	Watts		100.0%	19.6%			\$1,487,500	\$41.58
LB Prerequisite Items									
PR3 - Habitat Exchange	3.24	acres		100.0%	0.2%			\$16,200	\$0.45
PR6 - Construction Carbon Footprint	2,700	tons		100.0%	0.4%			\$29,700	\$0.83
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.3%			\$23,500	\$0.66
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	39.7%	10.1%	\$1,933,075	\$54.03	\$2,701,017	\$75.50
Architecture & Engineering		9.38%	11.38%	53.1%	4.5%	\$647,235	\$18.09	\$991,099	\$27.70
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-9.8%	\$0		(\$743,750)	(\$20.79)
SDC Credits	50%			-100.0%	-3.1%	\$0		(\$231,353)	(\$6.47)
TOTAL OWNER & DESIGN-BUILD COSTS					67.2%	\$2,580,310	\$72.12	\$4,313,913	\$120.58

TOTAL CONCEPTUAL COST: \$9,484,151

\$265.10 \$13,026,869

\$364.12

40%

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 35% то LOWRISE OFFICE / CLASSROOMS IN PHOENIX, AZ

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The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### LowRiseOffice

Phoenix

# Normalized Baseline Energy Use Intensity (kBtu/SF) 76.0

Normalized Baseline Energy Use (kWh) 757,611

 Impact of Design Changes (see sketches)
 1.03

 Adjusted Baseline EUI (kBtu/SF)
 77.9

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
per	cent of load	21%	6%	36%	4%	9%	23%	100%
	calc'd EUI	16.1	5.0	28.4	3.1	7.3	17.7	77.6
Energy Conservation Measures:								
Glazing	F1		3.0%	15.0%		5.1%		6.1%
Improved Glazing	E10		3.070	15.070		5.170		0.170
Add effective shading devices	E1b							
Mulle 8 Deef	50		C 00/	F 00/		2 70/		2.50/
waiis & Roof	EZ		6.0%	5.0%		2.1%		2.5%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
PV mounted 30"' up to allow for shading	E2c							
Highly reflective exterior siding	E2d							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		12.0%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Add light shelf	L1d							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		6.0%
Efficient fixture ontics	122							
Individual accurancy concore & dimming controls: closed offices /low accurate	ncl2h							
Individual light loval control (dimming) at open office groas	120							
Light colors on walls, coiling surfaces	LZC							
Light colors off Walls, centing surjuces	120							
Divertionale	LZe			a		0		c/
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	6.5%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (evenend ASHBAE EE)	M15		5.070	5.070		2.570		2.470
Subtetal from above Load Deduction strategies (persentance)	IVIId	75.0%	6 59/	25.0%	0.0%	11 00/	25.0%	25 40/
Subtotal from above Load Reduction strategies (percentage)		75.0%	0.5%	35.0%	0.0%	11.8%	25.0%	55.4%
Subtotal Reduced EUI (KBTU/SF)		4.0	4.7	18.4	3.1	6.5	13.3	50.0
Mechanical - Distribution & Ventilation	M2		15.0%	25.0%		60.0%		11.8%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	25.0%	0.0%	60.0%	0.0%	11.8%
Subtotal Reduced FIII (kRTII/SE)		4.0	4.0	13.8	3.1	2.6	13.3	40.8
Machanical Blant Sustance	142	4.0	15.0%	20.0%	3.1	15.0%	10.0	2.00/
IVIECIIaliical - Plaint Systems	IVIS		15.0%	20.0%		-15.0%		3.8%
Ground source neat pump system	IVI3a							
Domestic Hot Water	w				70.0%			2.8%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	15.0%	20.0%	70.0%	-15.0%	0.0%	6.6%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	3.4	11.1	0.9	3.0	13.3	35.6
Final Energy Use Breakdown as Percentage of Baseline Use		5%	4%	14%	1%	4%	17%	54%
Building Operating Fac	tor 0.90			92.9	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive FCM effe	cts 1.07			60%	target reducti	on from CBECS		
				Achieven	0			
	0 000			Achievement:				
I otal Reduced EUI (KBTU/	ST) 34.3			63%	percent reduc	tion from CBECS	i - lilinlin	DI-I-
				56%	percent reduc	tion from Norm	alized Baseline	BIQ8
Total reduced energy	use (kWh)	342,057						
Number of crystaline pan	els needed	998						
Total kW	of PV array	205						
Total KW	5. i v airay	200						
PV Panel Analysis:	- I		1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo	⊢ <u> </u>	kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
				(3.7	-	4.		
	0°	345.73	990	12,450	998	Panels at umbrella	roof and as shadir	ng devices in
	15°	372.11	920		0	giazing		
optimal ang	le: 29.7°	381.27	898		0	1		
	45°	371.61	921		0	1		
	90°	244.19	1401		0			
				Total kWh -	3/15 030			



# MID RISE OFFICE PHOENIX hot arid



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow



Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

A         Substructure Baseline Building Rainwater/Containment - 41.000 gal Split Tank         64/s         0.5%         \$14.20,785         \$14.30         \$1.43,00         \$1.22,00         \$1.43,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.22,00         \$1.43,00         \$1.22,00         \$1.43,00         \$1.43,00         \$1.43,00         \$1.43,00	CONSTRUCTION COST						
Baseline Building         \$1,420,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,786         \$1,430,787         \$72,04         \$3,326,645         \$3,326,645         \$3,020,797,777         \$72,04         \$3,128,737,777,777,77,77,77,77,77,77,77,77,77,	A Substructure	6.4%	0.5%	\$1,420,795	\$14.30	\$1,511,895	\$15.21
No.         Rainwater Graywater Containment - 41,000 gal Split Tank:         Sol. 32         Shell         Sol. 32         Sol.	Baseline Building			\$1,420,795	\$14.30	\$1,420,795	\$14.30
B         Shell         16.5%         5.3%         57,159,737         572,04         53,28,645         583,78           Baseline Building         57,159,737         572,04         57,159,737         572,04         57,159,737         572,04         57,159,737         572,04         57,159,737         572,04         55,11200         51,11200         55,1120         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200         55,11200	W2 Rainwater/Graywater Containment - 41,000 gal Split Tank					\$91,100	\$0.92
B shell         16.3%         5.3%         7.159.737         72.04         88.28.66         98.37.86         97.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         72.04         87.159.737         87.203         87.159.737         87.203	, , , , , , , , , , , , , , , , , , ,						
Baselne Building         \$7,169,737         \$72,04         \$7,169,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$72,04         \$5,199,737         \$5,00 <t< td=""><td>B Shell</td><td>16.3%</td><td>5.9%</td><td>\$7,159,737</td><td>\$72.04</td><td>\$8,326,645</td><td>\$83.78</td></t<>	B Shell	16.3%	5.9%	\$7,159,737	\$72.04	\$8,326,645	\$83.78
Mate         Operation         Solution         Solution <t< td=""><td>Baseline Building</td><td></td><td></td><td>\$7,159,737</td><td>\$72.04</td><td>\$7,159,737</td><td>\$72.04</td></t<>	Baseline Building			\$7,159,737	\$72.04	\$7,159,737	\$72.04
100 Realizate Glazing forduc solar heat gain)               (64.115)             (54.115)	M2E Operable Windows (manual)					\$61,920	\$0.62
EIA Improved Glazing (reduce solar heat gain)       \$42.098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$34.2098       \$314.845       \$14.845       \$14.845       \$14.845       \$14.845       \$14.845       \$14.845       \$14.845       \$14.8400       \$14.8400       \$18.85         Courty and Space at Atrium       Courty and Space at Atrium       \$37.45       \$37.411       \$37.47       \$37.474	D3C Reallocate Glazing from East and West Façade to South (less spandrel panel	l, more skin)				(\$48,115)	(\$0.48)
020.4 Addia (Mail / Skin for Modified Design (mot in base building design)         \$194,700         \$194,700         \$19,86           02.4 Addiade Skin at Atrium         \$100,500         \$10,12         \$10,05,300         \$10,12           03. Reduced Roofing Area at Atrium         \$100,000         \$11,000         \$11,000	E1A Improved Glazing (reduce solar heat gain)					\$42,098	\$0.42
MS         Addies Sin at Artum         \$154,845         \$1,56           MS         Addies Sin at Artum         \$20,000	D2A Added Wall / Skin for Modified Design (not in base building design)					\$194,700	\$1.96
D2A Added Skin at Atrium         \$1,005,360         \$10,105,360         \$10,05,360         \$10,105,360         \$10,105,360         \$10,105,360         \$10,105,360         \$10,105,360         \$10,105,360         \$10,105,379,200         \$10,805,379,200         \$11,805,379,200         \$10,805,379,200         \$10,805,379,395,379,356,370,399,385,370,399,385,370,399,385,370,399,385,370,399,385,370,399,395,370,370,370,399,393,370,370,370,370,370,370,370,370,370,37	W5 Additional 6' Roof Overhang and Structure for Water Collection					\$154,845	\$1.56
Image         Call Reduced Rooling Area at Attium         (20,20,400)         (50,27,000)         (50,20,000)         (50,20,000)         (50,20,000)         (50,20,000)         (50,20,000)         (50,20,000)         (51,20,000)         (52,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,10,000)         (53,	D2A Added Skin at Atrium					\$1,005,360	\$10.12
Dis         Contry and Space at Artium         \$79,200         \$50,800         \$50,800         \$51,850           ED         Change Stution Highly Reflective Siding (White Stucco)         \$1,0%         0.2%         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,724,311         \$37,47         \$3,520,786         \$1,00         \$1,40,000	D3 Reduced Roofing Area at Atrium					(\$26,400)	(\$0.27)
Less Change Skin to Highly Reflective Siding (White Slucco)         (8480,700)         (84.	D3 Courtyard Space at Atrium					\$79,200	\$0.80
L1D Interior Double Light Shelves       3184,000       \$184,000       \$185         C Interiors       337.47       \$37.24,311       \$37.47       \$37.47       \$37.24,311       \$37.47       \$37.47       \$37.431       \$37.47       \$37.47       \$37.431       \$37.47       \$37.431       \$37.47       \$37.47       \$37.431       \$37.47       \$37.47       \$37.431       \$37.47       \$37.47       \$37.47       \$37.47       \$37.431       \$37.47	E2D Change Skin to Highly Reflective Siding (White Stucco)					(\$480,700)	(\$4.84)
C         Interiors         Size         <	L1D Interior Double Light Shelves					\$184,000	\$1.85
Baseline Building         S37.4311         S37.44311         S37.44311         S37.4311         S37.43111         S37.43111         S37.4311	C Interiors	1.0%	0.2%	\$3,724.311	\$37.47	\$3,762.078	\$37.85
M2D         Carpet Reduction (replace with Retroplate)         Sinth	Baseline Building			\$3,724,311	\$37.47	\$3,724,311	\$37.47
M2A         Topping Slab / Stair Premium for Underfloor Radiant System (3' concrete)         S149,078         \$1.50           L1A         Exposed Ceilings (white matte surfaces)         0.0%         0.0%         \$207,466         \$2.09         \$207,466         \$2.09           D.1         Services - Conveying Systems Baseline Building         \$207,466         \$2.09         \$207,466         \$2.09         \$207,466         \$2.09           D.2         Services - Plumbing Systems Baseline Building         \$838,297         \$8.43         \$1193,097         \$112.00           D.2         Services - Plumbing Systems Baseline Building         \$838,297         \$8.43         \$838,297         \$8.43         \$838,007         \$81,600         \$0.00         \$350,000         \$352           D.3         Services - HVAC Systems Baseline Building         \$1,720,00         \$17.36         \$3,332,498         \$33.53         \$349,025         \$5,000         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,809,708         \$17.00         \$1,850,800         \$18.60         \$18.60         \$18.60         \$18.60         \$18.60         \$18.60         \$18.60         \$18.60         \$18.60 <td>M2D Carpet Reduction (replace with Retroplate)</td> <td></td> <td></td> <td>• • • • • •</td> <td><i><b>Q</b></i><b>0111</b></td> <td>\$99,385</td> <td>\$1.00</td>	M2D Carpet Reduction (replace with Retroplate)			• • • • • •	<i><b>Q</b></i> <b>0111</b>	\$99,385	\$1.00
L1A         Exposed Ceilings (white matte surfaces)         (\$210,686)         (\$210,686)         (\$212)           D.1         Services - Conveying Systems Baseline Building         0.0%         0.0%         9207,466         \$2.09         \$207,466         \$2.09           D.2         Services - Plumbing Systems Baseline Building         1.8%         \$838,297         \$8.43         \$1,193,097         \$12.00           D.2         Services - Plumbing Systems Baseline Building         \$838,297         \$8.43         \$538,297         \$8.43         \$538,297         \$8.43         \$500,007         \$352           D.3         Services - HVAC Systems Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building         \$11,700         \$11,736         \$33,32,498         \$33,53           D.3         Services - Hire Protection Systems Baseline Building         \$11,689,708         \$11,700         \$1,689,708         \$17,00         \$1,689,708         \$17,00         \$1,850,800         \$18,62           D.4         Services - Fire Protection Systems Baseline Building         \$36,000         \$20,74         \$27,7482         \$2,74         \$27,7482         \$2,74         \$27,7482         \$2,74         \$27,7482         \$2,74         \$2,72,482         \$2,74         \$27,7482         \$2,74	M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$149,078	\$1.50
D.1 Services - Conveying Systems         0.0%         0.0%         0.0%         \$207,466         \$2.09         \$207,466         \$2.09           D.2 Services - Plumbing Systems         ssaline Building         \$207,466         \$2.09         \$207,466         \$2.09           D.2 Services - Plumbing Systems         ssaline Building         \$207,466         \$2.09         \$207,466         \$2.09           D.2 Services - Plumbing Systems         ssaline Building         \$8.43         \$1,193,097         \$12.00           Baseline Building         \$8.43         \$1,93,097         \$8.43         \$533,000         \$335,000         \$335,000         \$335,000         \$355,000         \$335,000         \$355,000         \$355,000         \$358,000         \$36,000         \$36,000         \$36,000         \$1,689,708         \$17,06         \$1,89,708         \$17,00         \$1,689,708         \$17,00         \$1,689,708         \$17,00         \$1,689,708         \$17,00         \$1,689,708         \$17,00         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,000         \$1,850,00	L1A Exposed Ceilings (white matte surfaces)					(\$210,696)	(\$2.12)
D.1 Services - Conveying Systems Baseline Building         0.0%         0.0%         5207,466         52.09         5207,466         52.09           D.2 Services - Plumbing Systems Baseline Building         \$207,466         \$2.09         \$207,466         \$2.09           D.2 Services - Plumbing Systems Baseline Building         42.3%         1.8%         \$838,297         \$8.43         \$1133,097         \$12.00           Wa Cow-Flow Fixtures / Optical Sensors         \$803,297         \$8.43         \$535,207         \$353.000         \$335.33           Wa Cow-Flow Fixtures / Optical Sensors         \$93.1%         8.1%         \$1,725,708         \$17.30         \$31,800         \$35.53           Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building Baseline Building         \$1,689,708         \$17.00         \$1,689,708         \$17.00         \$1,689,708         \$17.00         \$1,850,800         \$18.62           M2A In-Slab Radiant Heating and Cooling MaG Carobon Dioxide Sensors         \$36,000         \$0.36         \$336,000         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         \$1.850,800         <							
Baseline Building         \$207,466         \$2.09         \$207,466         \$2.09         \$207,466         \$2.09           D.2 Services - Plumbing Systems Baseline Building         42.3%         1.8%         \$838,297         \$8.43         \$1193,097         \$12.00           Baseline Building         \$833,297         \$8.43         \$433,297         \$8.43         \$430,00         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$335,000         \$336,000         \$11,689,708         \$11,700         \$11,680,708         \$11,90,907         \$11,00         \$14,80,80,00         \$18,80,80,00         \$18,80,80,00         \$11,80,80,708         \$11,90,80,00         \$19,90,800         \$19,9	D.1 Services - Conveying Systems	0.0%	0.0%	\$207,466	\$2.09	\$207,466	\$2.09
D.2 Services - Plumbing Systems         42.3%         1.8%         \$838,297         \$8.43         \$1,193,097         \$12.00           Baseline Building         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$838,297         \$8.43         \$81,690         \$83,332,498         \$83,353         \$835,000         \$335,000         \$335,000         \$335,000         \$335,000         \$31,689,708         \$17.00         \$1,899,708         \$17.00         \$1,899,708         \$17.00         \$1,899,708         \$17.00         \$1,899,708         \$17.00         \$1,899,708         \$10,900         \$1,890,000         \$1,949,000         \$1,890,000         \$1,890,000         \$1,890,000         \$1,890,000         \$1,890,000         \$1,890,000         \$1,890,000         \$1,91,000         \$1,91,000         \$1,91,000         \$1,91,000         \$1,91,000         \$1,91,000         \$1,91,000         \$1,91,000 <td< td=""><td>Baseline Building</td><td></td><td></td><td>\$207,466</td><td>\$2.09</td><td>\$207,466</td><td>\$2.09</td></td<>	Baseline Building			\$207,466	\$2.09	\$207,466	\$2.09
D.2 Services - Plumbing Systems       42.3%       1.8%       \$838,297       \$8.43       \$1,193,097       \$12.00         Baseline Building       \$8038,297       \$8.43       \$1,93,097       \$8.43       \$838,297       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.43       \$8.4							
Baseline Building       \$838.297       \$8.43       \$838.297       \$8.43       \$838.297       \$8.43       \$838.297       \$8.40       \$0.05         Vie       Low-Flow Fixtures / Optical Sensors       \$1.697.08       \$1.7.36       \$3.332.498       \$3.353         D.3 Services - HVAC Systems       \$1.689.708       \$11.7.36       \$3.332.498       \$33.53         Baseline Building       \$1.689.708       \$17.00       \$1.689.708       \$17.00         Baseline HVAC System       \$1.689.708       \$17.00       \$1.689.708       \$17.00         Baseline HVAC System       \$1.689.708       \$17.00       \$1.89.000       \$1.80         M2A In-Slab Radiant Heating and Cooling       \$1.800.00       \$1.800       \$1.80       \$1.800       \$1.900       \$1.900 <td>D.2 Services - Plumbing Systems</td> <td>42.3%</td> <td>1.8%</td> <td>\$838,297</td> <td>\$8.43</td> <td>\$1,193,097</td> <td>\$12.00</td>	D.2 Services - Plumbing Systems	42.3%	1.8%	\$838,297	\$8.43	\$1,193,097	\$12.00
W6       Low-Flow Fixtures / Optical Sensors       \$4,800       \$0.05         W2       Rain Harvesting (piping & pumps and filtration) plus gray plus black       \$1,725,708       \$17.36       \$33.32,498       \$33.53         D.3       Baseline Building       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$17.00       \$1,89,708       \$18,000       \$18,62         M2A       In-Slab Radiant Heating and Cooling       \$34,800       \$0.05       \$36,000       \$0.36       \$36,000       \$18,62         M2E       Energy Recovery Wheel / Plate & Frame       \$36,000       \$0.36       \$36,000       \$0.36       \$36,000       \$0.36         D.4       Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$22.04       \$2.04       \$1.69         D.5       Services - Electrical Systems       Baseline Building       \$2.024,176       \$20.37	Baseline Building			\$838,297	\$8.43	\$838,297	\$8.43
W2 Ran Harvesting (piping & pumps and hitration) plus gray plus black       93.1%       8.1%       \$1,725,708       \$17.36       \$33,322,498       \$33.53         D.3 Services - HVAC Systems       93.1%       8.1%       \$1,725,708       \$17.36       \$3,332,498       \$33.53         Baseline Building       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,850,800       \$18.62         M20 Carbon Dioxide Sensors       \$36,000       \$0.36       \$36,000       \$0.36       \$36,000       \$0.36       \$36,000       \$0.36         D.4 Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74         D.5 Services - Electrical Systems       12.9%       1.5%       \$2,308,176       \$23.22       \$2,605,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$2,024,176       \$20.3	W6 Low-Flow Fixtures / Optical Sensors					\$4,800	\$0.05
D.3 Services - HVAC Systems       93.1%       8.1%       \$1,725,708       \$17.36       \$3,332,498       \$33.53         Baseline Building       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$18.62       \$249,6925       \$5.00       \$1,850,800       \$1,850,800       \$1,850,800       \$1,850,800       \$1,862       \$1,860       \$1,890,000       \$1,890,000       \$1,890,000       \$1,890,000       \$1,990,000       \$1,990,000       \$1,990,000       \$1,990,000       \$0,36       \$272,482       \$2,74       \$272,482       \$2,74       \$272,482       \$2,74       \$272,482       \$2,74       \$20,27,76       \$20,37       \$2,024,176       \$20,37       \$42,000       \$0,42       \$43,000       \$0,43       \$43,000       \$0,43       \$43,000       \$0,43       \$43,000	W2 Rain Harvesting (piping & pumps and filtration) plus gray plus black					\$350,000	\$3.52
Baseline Building Baseline HVAC System       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,708       \$17.00       \$1,689,925       \$5.00         M2A Ground Source Heat Pump       Scource Heat Pump       \$36,000       \$0.36       \$198,000       \$1.99       \$36,000       \$1.99       \$0.36       \$198,000       \$1.99       \$36,000       \$0.36       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74       \$20.27,76       \$2.02,77       \$2.024,176       \$20.37       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$42,000       \$0.42       \$43,000       \$0.43       \$43,000       \$0.43       \$43,000       \$0.43       \$44,000       \$0.42       \$43,000       \$0.42       \$44,000       \$0.42       \$44,000       \$0.43	D.3 Services - HVAC Systems	93.1%	8.1%	\$1,725,708	\$17.36	\$3,332,498	\$33.53
Baseline HVAC System       (\$938,935)       (\$9,45)         M2A       In-Slab Radiant Heating and Cooling       \$496,925       \$5.00         M3A       Ground Source Heat Pump       \$18,600       \$18,600       \$18,600       \$198,000       \$1.99         M2E       Energy Recovery Wheel / Plate & Frame       \$36,000       \$0.36       \$36,000       \$0.36       \$36,000       \$0.36         D.4       Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         Baseline Building       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74         D.5       Services - Electrical Systems       12.9%       1.5%       \$2,024,176       \$22.027       \$2,024,176       \$22.037         PA       Occupancy Sensor to Outlets       \$38,000       \$0.38       \$338,000       \$0.43         PE       High Efficiency Main Transformer       \$38,000       \$0.38       \$338,000       \$0.38         12.9       Fiftient Light Fixture Optics Premium       \$38,000       \$0.38       \$38,000       \$0.38         12.2       Cocupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$221,200       \$0.22         12.2	Baseline Building			\$1,689,708	\$17.00	\$1,689,708	\$17.00
M2A       In-Slab Radiant Heating and Cooling       \$496,925       \$5.00         M3A       Ground Source Heat Pump       \$18,50,800       \$18,62         M2B       Energy Recovery Wheel / Plate & Frame       \$36,000       \$0.36       \$18,600       \$10         M2C       Carbon Dioxide Sensors       \$0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.4       Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.5       Services - Electrical Systems       12.9%       1.5%       \$2,008,176       \$23.22       \$2,005,676       \$26.22         Baseline Building       \$2,024,176       \$2.037       \$2,024,176       \$2.037       \$42,000       \$0.42         PA       Occupancy Sensor to Outlets       \$38,000       \$0.38       \$38,000       \$0.38       \$38,000       \$0.43         PE       High Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91       \$190,000       \$1.91         L2       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2       Individual Light Level Control (open spaces)       \$34,000	Baseline HVAC System					(\$938,935)	(\$9.45)
M3A Ground Source Heat Pump       \$1,850,800       \$18.62         M2B Energy Recovery Wheel / Plate & Frame       \$36,000       \$0.36       \$199,000       \$1.99         M2C Carbon Dioxide Sensors       \$0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.4 Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.5 Services - Electrical Systems       12.9%       1.5%       \$2,008,176       \$22.22       \$2,005,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$42,000       \$0.42         PA Occupancy Sensor to Outlets       \$38,000       \$0.38       \$38,000       \$0.38       \$38,000       \$0.43         L1C Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38       \$38,000       \$0.38         L2A Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91       \$190,000       \$1.91         L2O Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2 Individual Light Level Control (open spaces)       \$24,000       \$0.34       \$34,000	M2A In-Slab Radiant Heating and Cooling					\$496,925	\$5.00
M2B Energy Recovery Wheel / Plate & Frame       \$36,000       \$199,000       \$1.99         M2C Carbon Dioxide Sensors       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.4 Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         D.5 Services - Electrical Systems       12.9%       1.5%       \$2,308,176       \$23.22       \$2,605,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$42,000       \$0.42         PA Occupancy Sensor to Outlets       \$2,024,176       \$20.37       \$42,000       \$0.42         PE High Efficiency Main Transformer       \$38,000       \$0.38       \$38,000       \$0.38         L1C Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2 Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E Occupancy Sensor for Transient and Egress Lighti	M3A Ground Source Heat Pump					\$1,850,800	\$18.62
M2C Carbon Dioxide Sensors       \$36,000       \$0.36       \$36,000       \$0.36         D.4 Services - Fire Protection Systems       0.0%       0.0%       \$272,482       \$2.74       \$272,482       \$2.74         Baseline Building       \$272,482       \$2.74       \$272,482       \$2.74       \$272,482       \$2.74         D.5 Services - Electrical Systems       12.9%       1.5%       \$2,308,176       \$23.22       \$2,605,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$4,000       \$0.42         PA Occupancy Sensor to Outlets       \$38,000       \$38,000       \$0.42       \$43,000       \$0.42         PE High Efficiency Main Transformer       \$38,000       \$0.38       \$38,000       \$0.38       \$38,000       \$0.38         L2A Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2C Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34	M2B Energy Recovery Wheel / Plate & Frame					\$198,000	\$1.99
D.4 Services - Fire Protection Systems Baseline Building         0.0%         0.0%         \$272,482         \$2.74         \$272,482         \$2.74           D.5 Services - Electrical Systems Baseline Building         \$272,482         \$2.74         \$272,482         \$2.74         \$272,482         \$2.74           D.5 Services - Electrical Systems Baseline Building         12.9%         1.5%         \$2,08,176         \$23.22         \$2,605,676         \$20.27           PA         Occupancy Sensor to Outlets         \$2,024,176         \$20.37         \$42,000         \$0.42           PE         High Efficiency Main Transformer         \$38,000         \$0.38         \$38,000         \$0.38           L2A Efficient Light Fixture Optics Premium         \$38,000         \$1.91         \$190,000         \$1.91           L2B Occupancy Sensor for Lighting (closed office / conference spaces)         \$22,000         \$0.22         \$22,000         \$0.22           L2A Efficient Light Level Control (open spaces)         \$22,000         \$0.22         \$22,000         \$0.22           L2D Occupancy Sensor for Transient and Egress Lighting         \$34,000         \$0.34         \$34,000         \$0.34           L2E Occupancy Sensor for Transient and Egress Lighting         0.0%         0.0%         \$472,675         \$4.76         \$472,675         \$4.76	M2C Carbon Dioxide Sensors			\$36,000	\$0.36	\$36,000	\$0.36
D.F. Gervices - Hier Friction Gystems       0.0%       0.	D.4. Services - Fire Protection Systems	0.0%	0.0%	\$272 482	\$2.74	\$272 482	\$2 74
Descrives - Electrical Systems       12.9%       1.5%       \$2,308,176       \$23.22       \$2,605,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$42,000       \$0.42         PA       Occupancy Sensor to Outlets       \$38,000       \$0.38       \$38,000       \$0.38       \$38,000       \$0.38         L1C       Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A       Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,200       \$0.22         L2C       Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         E       Equipment and Furnishings       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76	Baseline Building	0.070	0.070	\$272,482	\$2.74	\$272,482	\$2.74
D.5 Services - Electrical Systems       12.9%       1.5%       \$2,308,176       \$23.22       \$2,605,676       \$26.22         Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37       \$42,000       \$0.42         PA       Occupancy Sensor to Outlets       \$38,000       \$0.38       \$38,000       \$0.43         L1C       Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A       Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,200       \$0.22         L2C       Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76	Bacomio Ballang			<b>*</b> , * <b>*</b> _	Ψ2.7 1	<b>.</b> ,	φ2.7 1
Baseline Building       \$2,024,176       \$20.37       \$2,024,176       \$20.37         PA       Occupancy Sensor to Outlets       \$42,000       \$0.42         PE       High Efficiency Main Transformer       \$38,000       \$0.38       \$43,000       \$0.43         L1C       Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A       Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,200       \$0.22         L2C       Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675         L2E       Decupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675         L2E       Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	D.5 Services - Electrical Systems	12.9%	1.5%	\$2,308,176	\$23.22	\$2,605,676	\$26.22
PA       Occupancy Sensor to Outlets       \$42,000       \$0.42         PE       High Efficiency Main Transformer       \$38,000       \$0.38         L1C       Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A       Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,200       \$0.22         L2C       Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34         E       Equipment and Furnishings       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	Baseline Building			\$2,024,176	\$20.37	\$2,024,176	\$20.37
PE       High Efficiency Main Transformer       \$43,000       \$0.43         L1C       Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A       Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B       Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,200       \$0.22         L2C       Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E       Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34         E       Equipment and Furnishings       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	PA Occupancy Sensor to Outlets					\$42,000	\$0.42
L1C Daylight Controls (continuous dimming 15' from perimeter)       \$38,000       \$0.38       \$38,000       \$0.38         L2A Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2C Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E Occupancy Sensor for Transient and Egress Lighting       \$0.0% <b>0.0% \$472,675 \$4.76 \$472,675 \$4.76</b> Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	PE High Efficiency Main Transformer					\$43,000	\$0.43
L2A Efficient Light Fixture Optics Premium       \$190,000       \$1.91       \$190,000       \$1.91         L2B Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2C Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34       \$34,000       \$0.34         L2E Occupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	L1C Daylight Controls (continuous dimming 15' from perimeter)			\$38,000	\$0.38	\$38,000	\$0.38
L2B Occupancy Sensor for Lighting (closed office / conference spaces)       \$22,000       \$0.22       \$22,000       \$0.22         L2C Individual Light Level Control (open spaces)       \$34,000       \$0.34       \$34,000       \$0.34         L2E Occupancy Sensor for Transient and Egress Lighting       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	L2A Efficient Light Fixture Optics Premium			\$190,000	\$1.91	\$190,000	\$1.91
L2C Individual Light Level Control (open spaces)       \$34,000       \$212,500       \$2.14         L2E Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34         E Equipment and Furnishings       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	L2B Occupancy Sensor for Lighting (closed office / conference spaces)			\$22,000	\$0.22	\$22,000	\$0.22
L2E Occupancy Sensor for Transient and Egress Lighting       \$34,000       \$0.34       \$34,000       \$0.34         E Equipment and Furnishings       0.0%       0.0%       \$472,675       \$4.76       \$472,675       \$4.76         Baseline Building       \$472,675       \$4.76       \$472,675       \$4.76       \$472,675       \$4.76	L2C Individual Light Level Control (open spaces)					\$212,500	\$2.14
E Equipment and Furnishings 0.0% 0.0% \$472,675 \$4.76 \$472,675 \$4.76 \$472,675 \$4.76 \$472,675 \$4.76	L2E Occupancy Sensor for Transient and Egress Lighting			\$34,000	\$0.34	\$34,000	\$0.34
Baseline Building \$472,675 \$475 \$472,675 \$472,675 \$472,675 \$472,675 \$472,67	E Equipment and Eurnishings	0.0%	0.0%	\$472 675	\$4.76	\$472 675	\$4.76
	Baseline Building	010 /0	0.070	\$472,675	\$4.76	\$472 675	\$4.76

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
•	Baseline Building		01070	01070	\$0	<i><b>Q</b>0.00</i>	\$0	<i><b>Q</b>0.00</i>
G	Sitework		8.9%	0.7%	\$1,465,612	\$14.75	\$1,595,612	\$16.05
	Baseline Building				\$1,465,612	\$14.75	\$1,465,612	\$14.75
W6	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
W2	Rain Collection and Treatment						\$130,000	\$1.31
н	Logistics		0.0%	0.0%	\$218,298	\$2.20	\$218,298	\$2.20
	Baseline Building				\$218,298	\$2.20	\$218,298	\$2.20
15	ving Building Proroquisitos				\$4.969	¢0.05	\$620.004	\$6.22
	PR5 - Materials Red List		100.0%	0.8%	\$4,909	φ <b>0.0</b> 5	\$156.477	\$0.33 \$1.57
	PR7 - Responsible Industry		100.0%	0.0%			\$30,181	\$1.37
	PR8 - Appropriate Materials / Services Radius		100.0%	2.2%			\$437.467	\$0.30 \$4.40
	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$4,969	\$0.05	\$4.969	\$0.05
	·				. ,		. ,	
Su	btotal Direct Costs			21.7%	\$19,818,527	\$199.41	\$24,127,516	\$242.77
	Caparal Conditiona	4.09/	21 7%	0.9%	\$702 7/1	¢7.00	\$965 101	¢0.74
		4.0% 8.0%	21.7%	1.8%	\$1 648 901	\$7.98 \$16.50	\$2 007 409	\$9.71 \$20.20
	Location Modifier for PHOENIX AZ	0.0%	21.7%	-3.7%	(\$3 330 026)	(\$22 EO)	(\$4 065 004)	φ20.20 (\$40.00)
		0.00	21.170	0.170	(\$0,000,020)	(#33.00)	(\$4,000,004)	(φ <del>4</del> 0.90)
то	TAL MODIFIED CONSTRUCTION COST			21.7%	\$18,921,145	\$190.38	\$23,035,023	\$231.78

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 99,385 Living Building Gross SF = 99,385

Site Gross Acreage = 5.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Building				
		Total	Cost/SF	Total	Cost/SF			

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.3%			\$60,000	\$0.60
PV1 Photovoltaic Panels and Infrastructure	453,000	Watts		100.0%	19.4%			\$3,850,500	\$38.74
LB Prerequisite Items									
PR3 - Habitat Exchange	5.24	acres		100.0%	0.1%			\$26,200	\$0.26
PR6 - Construction Carbon Footprint	2,500	tons		100.0%	0.1%			\$27,500	\$0.28
PR15 - Beauty and Spirit (included in A/E fe	es above)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$43,500	\$0.44
Development Costs		LEED	LBC						
Develoment Costs		13.06%	16.06%	49.7%	6.2%	\$2,471,271	\$24.87	\$3,699,631	\$37.23
Architecture & Engineering		6.09%	8.09%	61.7%	3.6%	\$1,152,249	\$11.59	\$1,863,474	\$18.75
Credits / Rebates / Incentives									
Photovoltaic Credits-(state, city, utility)	50%			-100.0%	-9.7%			(\$1,925,250)	(\$19.37)
SDC Credits	50%		0.00%	-100.0%	-1.5%	\$0		(\$289,395)	(\$2.91)
TOTAL OWNER & DESIGN-BUILD COSTS					103.0%	\$3,623,520	\$36.46	\$7,356,161	\$74.02

TOTAL CONCEPTUAL COST: \$22,544,665 \$226.84 \$30,391,183 \$305.79

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	32%	то	37%	
MIDRISE OFFICE IN PHOENIX, AZ				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# LowRiseOffice

# Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 76.0

Normalized Baseline Energy Use (kWh) 757,611

Impact of Design Changes (see sketches) 1.03

Adjusted Baseline EUI (kBtu/SF) 77.9

		LIGHTING	HFATING	COOLING	DOM. HOT WATER	FANS & PUMPS	MISC. FOUIP	TOTAL BLDG
perce	ent of load	21%	6%	36%	4%	9%	23%	100%
	calc'd EUI	16.1	5.0	28.4	3.1	7.3	17.7	77.6
Energy Conservation Measures:								
Glazing	E1		3.0%	15.0%		5.1%		6.1%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Root	EZ		6.0%	5.0%		2.7%		2.5%
Shaded roof from solar panels	E2a							
PV mounted 30" up to allow for shading	E2D E2c							
Highly reflective exterior siding	F2d							
Davlighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		12.0%
Remove ceilina, raise window head, add liahtshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Add light shelf	L1d							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		6.0%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucpan	c L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e		4.00/	2 50/		0.49/	25.00/	6 50(
Plug Loads	P		-1.9%	2.5%		0.4%	25.0%	6.5%
Occupancy sensor controlled plug loads	Pa							
Ontimize printer lavout /use	PD							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.4%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75.0%	6.5%	35.0%	0.0%	11.8%	25.0%	35.4%
Subtotal Reduced EUI (kBTU/SF)		4.0	4.7	18.4	3.1	6.5	13.3	50.0
Mechanical - Distribution & Ventilation	M2		15.0%	25.0%		60.0%		11.8%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Fan assisted natural vantilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2b							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	25.0%	0.0%	60.0%	0.0%	11.8%
Subtotal Reduced EUI (kBTU/SF)		4.0	4.0	13.8	3.1	2.6	13.3	40.8
Mechanical - Plant Systems	M3		15.0%	20.0%		-15.0%		3.8%
Ground source heat pump system	M3a							
Domestic Hot Water	w				70.0%			2.8%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	15.0%	20.0%	70.0%	-15.0%	0.0%	6.6%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	3.4	11.1	0.9	3.0	13.3	35.6
Final Energy Use Breakdown as Percentage of Baseline Use		5%	4%	14%	1%	4%	17%	54%
Building Operating Facto	or 0.90			92.9	CBECS Baseli	ne FUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.07			60%	target reduct	ion from CBECS		
				Achievement:				
Total Reduced FUI (kBTU/sf	34.3			63%	percent redu	ction from CBECS		
	,			56%	percent redu	ction from Norm	alized Baseline	Bldg
Total reduced energy u	ise (kWh)	342,057						
Number of crystaline panel	s needed	998						
Total kW of	PV array	205						
PV Panel Analysis:			1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-	angle	kWh per	Total panels	Input Area	# of Dangla			
205 panei, jacing South (azimuth 0°)	angle	panel	needed at °	(SF)	# OF Panels			
	٥°	345.73	990	12.450	998	Panels at umbrella	roof and as shadi	ng devices in
	15°	372.11	920	,	0	glazing		
optimal angle	e: 29.7°	381.27	898		0	]		
	45°	371.61	921		0			
	90°	244.19	1401		0			



# MIXED USE RENOVATION PHOENIX hot arid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

29,000 gal RAINWATER TANK SIZE 185,043 sf BUILDING SIZE 6 floors BUILDING HEIGHT 1.0 acres SITE AREA 45,110 sf PHOTOVOLTAIC AREA 40,000 sf ROOF AREA

# **MAJOR DESIGN STRATEGIES:**

- ✓ Extend atrium down one level allow access to operable windows for all workstations.
- ✓ Open air atrium.
- ✓ Add PV sun shades on South.
- ✓ Provide additional 1/2 level to make up for floor area lost with insertion of atrium.
- ✓ Add a roof cover and PV struts similar to the renovated building.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 185,043 Living Building Gross SF = 185,043 Site Gross Acreage = 1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total Cost/SF		Total	Cost/SF

со	ISTRUCTION COST						
Δ	Substructure	5 1%	0.1%	\$579 458	\$3.13	\$608 800	\$3.29
	Baseline Building	0.170	0.170	\$579,458	\$3.13	\$579.458	\$3.13
W2	Rainwater Containment - 10,000 gal Rainwater Tank			••••		\$29,342	\$0.16
в	Shell	11.4%	3.1%	\$8,421,922	\$45.51	\$9,386,172	\$50.72
	Baseline Building			\$8,421,922	\$45.51	\$8,421,922	\$45.51
M2E	Operable Windows (manual, additional units beyond existing)					\$32,000	\$0.17
L1B	Add Glazed Clerestory at Atrium (and remove skylight)					\$108,375	\$0.59
E1A	Improved Glazing (reduce solar heat gain)					\$25,000	\$0.14
E1B	Exterior Snading Devices (PV as snading on South)					\$120,075 \$0	\$0.69
MOL	"High Mass" Concrete Inside Insulation (not included because this is a reportation)					\$0 \$0	
	Modifications to Roof Structure and Roofing					\$56,000	\$0.30
D3	Renovation Work at Atrium (demo floor, railings, interior walls, structure for balcony)					\$130,000	\$0.70
D3	Added SF for Additional Floor (at penthouse)					\$246,000	\$1.33
D2A	Added Wall / Skin for Modified Design (not in base building design)					\$240,000	\$1.30
L1D	Interior Light Shelves (not included)					\$0	
<b>_</b>	nteriors	2 1%	0.5%	\$7 723 877	\$11 71	\$7 883 877	\$42.61
Ŭ		2.170	0.378	\$7,723,877	\$41.74 \$44.74	\$7,723,877	¢44.74
142.4	Dasellite Dullulity Topping Slob / Stair Bromium for Linderfloor Padiant System (2" concrete)			φ1,123,011	<b>Φ</b> 41.74	\$270,000	\$41.74 \$1.46
M2D	Retronlate Tonning Slab (at TL locations)					\$690,000	\$1.40 \$3.73
I 1A	Exposed Ceilings (existing white matte surfaces)					\$0	φ0.70
D3	Remove Raised Access Flooring					(\$800,000)	(\$4.32)
	, , , , , , , , , , , , , , , , , , ,						(* - <i>)</i>
D.1	Services - Conveying Systems	0.0%	0.0%	\$385,400	\$2.08	\$385,400	\$2.08
	Baseline Building			\$385,400	\$2.08	\$385,400	\$2.08
D.2	Services - Plumbing Systems	19.4%	0.5%	\$791,454	\$4.28	\$945,254	\$5.11
	Baseline Building			\$791,454	\$4.28	\$791,454	\$4.28
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.81
D.3	Services - HVAC Systems	20.6%	1.9%	\$2,767,999	\$14.96	\$3,337,918	\$18.04
	Baseline Building			\$2,767,999	\$14.96	\$2,767,999	\$14.96
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,470,281)	(\$13.35)
M2A	In-Slab Radiant Heating and Cooling					\$600,000	\$3.24
МЗА	Ground Source Heat Pump					\$2,289,200	\$12.37
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$135,000	\$0.73
M2C	Carbon Dioxide Sensors					\$16,000	\$0.09
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$343,553	\$1.86	\$343,553	\$1.86
	Baseline Building			\$343,553	\$1.86	\$343,553	\$1.86
D.5	Services - Electrical Systems	24.1%	3.6%	\$4,539,215	\$24.53	\$5,631,885	\$30.44
	Baseline Building			\$4,571,685	\$24.71	\$4,571,685	\$24.71
PA	Occupancy Sensor to Outlets					\$47,200	\$0.26
PE	High Efficiency Transformers					\$158,000	\$0.85
L1C	Daylight Controls (continuous dimming 15' from perimeter)					\$0	
L2A	Efficient Light Fixture Optics Premium					\$270,000	\$1.46
12B	Occurrency Sensor for Lighting (closed office / conference spaces)					0.2	
	Occupancy Sensor for Lighting (closed office / conference spaces)					φ0	
L2C	Individual Light Level Control (open spaces, classrooms)			(*****		\$585,000	\$3.16

### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
		-					
F. Equipment and Eurnishings		0.0%	0.0%	\$2 061 480	\$11 14	\$2 061 480	\$11 14
Baseline Building		0.070	0.070	\$2,061,480	\$11.14	\$2,061,480	\$11.14
Baconno Banang				•_,•••,•••	ψ11.14	<b>,</b> ,	ψ11.14
F Special Construction		0.0%	0.0%	\$1,407,188	\$7.60	\$1,407,188	\$7.60
Baseline Building				\$1,407,188	\$7.60	\$1,407,188	\$7.60
		4 40/	0.0%	\$1.101 F00	<b>*</b> 0.44	\$4 404 F00	<b>*</b> 0.00
G Sitework		4.4%	0.2%	\$1,131,528	\$0.11 ¢c.11	\$1,181,528	\$0.39 0c.11
Baseline Building				\$1,131,520	\$0.11	\$1,131,520	\$0.11 ¢0.07
W4 Stormwater Retention / Building Water Discharge						\$50,000 ¢0	\$0.27
wi Remove Storm Drainage Connection to Public/Add sewer meter						<b>4</b> 0	
H Logistics		0.0%	0.0%	\$600,000	\$3.24	\$600,000	\$3.24
Baseline Building				\$600,000	\$3.24	\$600,000	\$3.24
Livian Dvildina Decembrica				¢4.000	¢0.00	¢04.4.444	¢4.40
DP5 - Materials Red List		100.0%	0.7%	\$4,020	<b>\$0.03</b>	\$207 176	\$4.40 \$4.40
PR7 - Responsible Industry		100.0%	0.2%			\$55 507	φ1.12 ¢0.20
PR8 - Appropriate Materials / Services Radius		100.0%	1.5%			\$465,283	\$0.30 \$2.51
PR9 - Leadership in Construction Waste		1762.1%	0.3%	\$4 626	\$0.03	\$86 144	\$2.51 \$0.47
				\$ 1,020	ψ0.00	\$00,111	ψ0.+7
Subtotal Direct Costs			12.5%	\$30,757,700	\$166.22	\$34,587,165	\$186.91
General Conditions	4.0%	12.5%	0.5%	\$1 230 308	\$6.65	\$1 383 487	\$7.48
Fee Construction Contingency Insurance	4.0 % 0 <b>7</b> %	12.5%	0.1%	\$238,965	\$1.20	\$268 717	φ1.+0 \$1.45
Location Modifier for PHOENIX AZ	0.7 %	12.5%	-2.0%	(\$4 834 046)	φ1.29 (\$26.12)	(\$5 435 905)	(\$20 28)
	0.00			(\$ 1,00 1,010)	(ψ20.12)	(40, 100,000)	(ψ <b>2</b> 0.00)
TOTAL MODIFIED CONSTRUCTION COST			12.5%	\$27,392,927	\$148.04	\$30,803,464	\$166.47

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.2%			\$60,000	\$0.32
PV1 Photovoltaic Panels and Infrastructure	741,000	Watts		100.0%	18.1%			\$5,557,500	\$30.03
LB Prerequisite Items									
PR3 - Habitat Exchange	1	acres		100.0%	0.0%			\$5,000	\$0.03
PR6 - Construction Carbon Footprint	1,250	tons @ 50%		100.0%	0.0%			\$13,750	\$0.07
PR15 - Beauty and Spirit (included in A/E fee	es below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,500	\$0.34
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	24.5%	6.1%	\$7,670,020	\$41.45	\$9,549,074	\$51.60
Architecture & Engineering		7.00%	9.00%	44.6%	2.8%	\$1,917,505	\$10.36	\$2,772,312	\$14.98
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-9.0%	\$0		(\$2,778,750)	(\$15.02)
SDC Credits	50%			-100.0%	-1.1%	\$0		(\$349,890)	(\$1.89)
TOTAL OWNER & DESIGN-BUILD COSTS					55.3%	\$9,587,524	\$51.81	\$14,892,496	\$80.48

TOTAL CONCEPTUAL COST: \$36,980,452 \$199.85 \$45,695,959

••••••

\$246.95

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 21% TO 26% MIXED-USE RENOVATION IN PHOENIX, AZ

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### **Complex Mixed Use Renovation**

# Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 84.9

Normalized Baseline Energy Use (kWh) 3,608,465

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 81.9

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
	percent of load	18%	7%	41%	4%	9%	20%	100%
Energy Conservation Measures	calc d EUI	15.1	0.1	33.8	2.9	7.5	10.0	81.9
Glazing	F1		10.0%	15.0%		6.5%		7 5%
Improved Glazina	Ela		10.070	13.070		0.570		7.570
Add effective shading devices	E1b							
Walls & Roof	E2		10.0%	10.0%		5.0%		5.3%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	38.0%	-2.9%	3.8%		0.6%		8.4%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting with skylights	L1b							
Daylight controls (continuous dimming)	L1c							
Add light shelf	L1d							
Floorplan renovation for daylighting	L1e							
Lighting	L2	38.5%	-2.9%	3.9%		0.6%		8.5%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occu	cpanc L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Uccupancy sensors: transient lighting (corridors/stairs/bathrms)	LZe							
Righ color rendering metal hande retail lighting	LZn		1.00/	2.5%		0.49/	25.0%	C 00/
Occupancy concor controlled plug loads	P		-1.9%	2.5%		0.4%	25.0%	0.0%
EnergyStar appliances	Pa							
Ontimize printer lavout/use	PD							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.7%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		76.5%	17.4%	40.2%	0.0%	15.5%	25.0%	38.4%
Subtotal Reduced EUI (kBTU/SF)		3.6	5.0	20.2	2.9	6.2	12.5	50.4
Mechanical - Distribution & Ventilation	M2		15.0%	25.0%		60.0%		11.6%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	N/2n							
Subtotal from Mechanical Distribution strategies (nercentage)	IVIZO	0.0%	15.0%	25.0%	0.0%	60.0%	0.0%	11.6%
Subtotal Reduced FUI (kBTU/SE)		3.6	4.3	15.2	2.9	2.5	12.5	40.9
Mechanical - Plant Systems	M3	5.0	20.0%	20.0%	2.5	-15.0%	12.0	4 3%
Ground source heat nump system	M3a		20.070	20.070		15.070		4.570
Domestic Hot Water	W				E0.09/			1 00/
Low flow fixtures (chowers laws sinks)					50.0%			1.6%
Low Jow Jixlures (showers, luvs, shiks) Water heating from tankless electric water heater	Wd							
Subtotal from Mechanical Plant and DHW systems (nercentage)	vu	0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	6.1%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.6	3.4	12.1	1.5	2.9	12.5	35.9
Final Energy Use Breakdown as Percentage of Baseline Use		4%	4%	15%	2%	3%	15%	56%
Building Operating	Factor 0.90			92.9	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM e	effects 1.05			60%	target reducti	on from CBECS		
				Achievement:				
Total Reduced EUI (kB	TU/sf) 33.6			64%	percent reduc	tion from CBECS	i	
				59%	percent reduc	tion from Norma	alized Baseline	Bldg
Total reduced ene	rgy use (kWh)	1,427,923						
Number of crystaline	panels needed	4,169						
Total k	W of PV array	855						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sa	inyo-	kWh ner	Total nanels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
		245		(31)				
	0°	345.73	4131	52,000	4169	Additional overhan	g +sunshades	
antimal	15 <sup>-</sup>	3/2.11	3838		0	-		
optimal	ALS 1	371 61	3/40		0	-		
	90°	244 19	5848		0	1		
	50		1 3340	Total W/h -	1 441 249			
				rotar KVVII =	1,441,348			



# SINGLE FAMILY RESIDENTIAL PHOENIX hot arid



# THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF =1,840Living Building Gross SF =1,840Site Gross Acreage =0.11

0110 0	noss Acreage =	0.11
	-	

	Division Premium (%)	Premium (%)	LEED™ Gold	l Baseline	Living B	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	0.0%	0.0%	\$63,527	\$34.53	\$63,527	\$34.53
Baseline Building			\$63,527	\$34.53	\$63,527	\$34.53
W2 Rainwater Containment - 3,000 gal Rainwater Tank (included in base building	ng)				\$0	
B Shell	-2.6%	-1.2%	\$131,226	\$71.32	\$127,778	\$69.44
Baseline Building			\$131,226	\$71.32	\$131,226	\$71.32
L1B Replace Roofing with Glazed Skylight					\$3,000	\$1.63
E1A Improved Glazing (reduce solar heat gain)					\$4,303	\$2.34
E1B Exterior Shading Devices					\$7,200	\$3.91
D3 Delete Porch					(\$1,920)	(\$1.04)
D3 Modify Building to Single Story					(\$16,031)	(\$8.71)
C Interiors	11.6%	1.5%	\$37,430	\$20.34	\$41,780	\$22.71
Baseline Building			\$37,430	\$20.34	\$37,430	\$20.34
M2A Thicken Lower Level Slab (2") and Gypcrete on Upper Level					\$4,350	\$2.36
L1A Exposed Ceilings (white matte surfaces)					\$0	
D.1 Services - Conveying Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
D.2 Services - Plumbing Systems	57.3%	2.1%	\$10,654	\$5.79	\$16,754	\$9.11
Baseline Building			\$10,654	\$5.79	\$10,654	\$5.79
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$0	
W7 Composting Toilets					\$6,100	\$3.32
D.3 Services - HVAC Systems	98.4%	4.1%	\$12,008	\$6.53	\$23,827	\$12.95
Baseline Building			\$12,008	\$6.53	\$12,008	\$6.53
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting	1)				(\$7,381)	(\$4.01)
M2A In-Slab Radiant Heating and Cooling					\$9,200	\$5.00
M3C Solar Thermal System					\$10,000	\$5.43
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
D.5 Services - Electrical Systems	68.1%	2.4%	\$10,136	\$5.51	\$17,036	\$9.26
Baseline Building			\$10,136	\$5.51	\$10,136	\$5.51
L2K Provide hardwired compact fluorescent fixtures in all spaces					\$2,200	\$1.20
L2L Motion sensors for exterior lighting					\$300	\$0.16
M2Z Ceiling Fans and window box fans (five of each)					\$4,400	\$2.39

# BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 1,840

Т

Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
E Equipment an	d Furnishings		0.0%	0.0%	\$1,011	\$0.55	\$1,011	\$0.55
Baseline Build	ing				\$1,011	\$0.55	\$1,011	\$0.55
F Special Const	ruction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Build	ing				\$0		\$0	
G Sitework			277.6%	19.3%	\$20,208	\$10.98	\$76,308	\$41.47
Baseline Build	ing				\$20,208	\$10.98	\$20,208	\$10.98
W4 Stormwater Re	etention / Building Water Discharge						\$14,100	\$7.66
W2 Additional Rain	nwater Collection (in addition to roof)						\$42,000	\$22.83
H Logistics			0.0%	0.0%	\$3,280	\$1.78	\$3,280	\$1.78
Baseline Build	ing				\$3,280	\$1.78	\$3,280	\$1.78
Living Building P	rerequisites				\$920	\$0.50	\$20,316	\$11.04
PR5 - Material	s Red List		100.0%	0.9%			\$2,521	\$1.37
PR7 - Respons	sible Industry		100.0%	4.1%			\$11,981	\$6.51
PR8 - Appropr	hin in Construction Waste		100.0%	1.7%	\$920.00	¢0 50	\$4,894 \$920	\$2.66 \$0.50
T ING - Leaders			0.070	0.070	φ <u>32</u> 0.00	\$0.50	<b>\$</b> 320	\$0.50
Subtotal Direct Co	sts			34.9%	\$290,400	\$157.83	\$391,618	\$212.84
		40.00	24.0%	2 59/	¢20.040	<b>A</b> 45 - 50	¢20.400	<b>004 65</b>
General Condi	tions	10.0%	34.9%	3.3%	\$29,040 \$21,044	\$15.78	\$39,162 \$42,079	\$21.28
Fee, Construct		10.0%	34.9%	-6.3%	φ31,944 (\$52,709)	\$17.36 (\$29.65)	φ43,078 (\$71,070)	\$23.41
Location Modif		0.85	34.9%	-0.3%	(\$32,708)	(\$∠8.65)	(\$71,079)	(\$38.63)
TOTAL MODIFIED	CONSTRUCTION COST			34.9%	\$298,677	\$162.32	\$402,779	\$218.90

# THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 1,840 Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				0.0%	0.0%			\$0	
PV1 Photovoltaic Panels and Infrastructure	3,000	Watts		100.0%	9.3%			\$27,000	\$14.67
LB Prerequisite Items									
PR3 - Habitat Exchange	0.114784	acres		100.0%	0.2%			\$574	\$0.31
PR6 - Construction Carbon Footprint	50	tons		100.0%	0.2%			\$550	\$0.30
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.5%			\$1,500	\$0.82
Development Costs		LEED	LBC						
Develoment Costs		3.42%	2.53%	0.0%	0.0%	\$10,200	\$5.54	\$10,200	\$5.54
Architecture & Engineering		12.00%	15.00%	68.6%	8.5%	\$35,841	\$19.48	\$60,417	\$32.84
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-4.6%	\$0		(\$13,500)	(\$7.34)
SDC Credits	50%			-100.0%	-1.0%	\$0		(\$2,966)	(\$1.61)
TOTAL OWNER & DESIGN-BUILD COSTS					82.0%	\$46,041	\$25.02	\$83,775	\$45.53

TOTAL CONCEPTUAL COST: \$344,718 \$187.35

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:

SINGLE FAMILY RESIDENTIAL IN PHOENIX, AZ

**39%** то

\$486,554 \$264.43

44%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# Single Family Residential

Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 30.8

Normalized Baseline Energy Use (kWh) 16,426

 Impact of Design Changes (see sketches)
 0.95

 Adjusted Baseline EUI (kBtu/SF)
 29.1

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$						DOM. HOT			TOTAL
precent of load         12%         12%         13%         9%         20%         100%           Careary Conservation Measures:         I         5.05         20.05         7.05         5.05           Careary Conservation Measures:         I         5.05         20.05         7.05         5.05           Mail S Roof         I         I         7.05         10.076         4.445         5.05           Distain S Roof         I         I         5.05         5.05         5.05         0.076         4.445         3.15           Distain S Roof         I         I         5.05         5.05         0.076         0.076         3.05         0.025         0.055         0.025			LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
Interp         Construction Measures:         Construction Measures: <th< td=""><td>perco</td><td>ent of load</td><td>18%</td><td>12%</td><td>19%</td><td>13%</td><td>9%</td><td>29%</td><td>100%</td></th<>	perco	ent of load	18%	12%	19%	13%	9%	29%	100%
Cale of Cale o	Franks Concernation Management	calc'd EUI	5.2	3.6	5.4	3.7	2.6	8.6	29.1
Link mp         Link mp         SAM         AUXP         AUXP         Jord         Jord           Walk & Roof         10         7.0%         10.0%         4.4%         3.1%           Value & Roof         10         7.0%         10.0%         4.4%         3.1%           Optimizer substoor	Closing	F4		5.00/	20.0%		7.00/		F 00/
Implementation function of the solution space of the solution o	Glazing	E1		5.0%	20.0%		7.0%		5.0%
Walk per loss of parts         Lo         TO         No.0%         4.4%         3.1%           Optimize subtloarsingle family residential         Ea         7.0%         10.0%         4.4%         3.1%           Optimize subtloarsingle family residential         Ea         53.8%         -4.0%         5.4%         0.8%         0.8%         10.2%           Upting         Ea         53.8%         -4.0%         5.4%         0.8%         10.2%           Provide hordwind compact floaresent floating         Ea         -	Add effective shading devices	E1T E1b							
Name         Los         Los <thlos< th=""> <thlos< th=""></thlos<></thlos<>	Male & Roof	E10		7.0%	10.0%		1 10/		2 10/
approve insolution - single (ponily residential (pily) reflective servine staling         Data         53.8%         -4.0%         5.4%         0.8%         10.2%           Lighting         Data         53.8%         -4.0%         5.4%         0.8%         10.2%           Motion sensors for exterial inplating         Data         5.3%         -4.0%         5.4%         0.8%         30.0%         9.2%           Encryption appliances         Poil         -2.3%         3.0%         0.5%         30.0%         9.2%           Encryption appliances         Poil         -2.3%         3.0%         0.5%         30.0%         9.2%           Motion sensors for exterial inplating         Poil         -2.3%         3.0%         5.0%         2.5%         1.8%           Widen SE Point Temperatures (expand ASH4K 55)         Mat         -         -         1.5%         10.7%         43.4%         0.0%         15.2%         30.0%         2.9.2%         30.0%         2.9.2%         30.0%         30.7%         9.0%         16.7%           Babdial form back load features in attrabules forecratage         NA         1.5.0%         100.7%         43.4%         0.0%         6.0%         6.0%         6.0%         15.7%         Babdial features (expand ASH4K 55)	Shaded roof from solar nanels	F2a		7.078	10.0%		4.470		5.170
high reflective exterior siding         Iz         5.8%         -4.0%         5.4%         0.0%         10.2%           Provide handwired compart futures in all spaces.         IZ         3.0%         -0.5%         20.0%         2.2%           Plug Loads.         P         -2.3%         3.0%         0.5%         20.0%         2.2%           Plug Loads.         P         -2.3%         3.0%         0.5%         20.0%         2.2%           Compart Login for textrol lighting         P         -2.3%         3.0%         0.5%         20.0%         2.2%         1.8%           Widen Set Point Temperatures (expand ASHRA 55)         M1a	Optimize insulation - single family residential	E2i							
Lighting         IQ         S.3.8%         -4.0%         S.4.%         O.8.%         D.2.9.%           Motion sensors for exteriol highting         IQ1             0.2.9.%	Highly reflective exterior siding	E2d							
provide compart fluorescent fluctures in all spaces.         121           Plug Loads         P         2.3%         3.0%         0.5%         30.0%         2.2%           Plug Loads         P         2.3%         3.0%         0.5%         30.0%         2.2%           Derry Stor appliances         Pd	Lighting	L2	53.8%	-4.0%	5.4%		0.8%		10.2%
Motion sensors (or exterior lighting)         120           Plug Loads         P         2.3%         3.0%         0.5%         30.0%         9.2%           Energystor appliances         Pd          5.0%         0.5%         30.0%         9.2%           Energystor appliances         Pd          5.0%         5.0%         0.5%         30.0%         9.2%           Motion Set Point Temperatures (expand ASTMARE 55)         Mia          5.2%         3.0.0%         5.2%         30.0%         2.9.2%         3.0%         2.0%         2.0%         2.0%         2.0%         2.0.2%         3.0%         2.9.2%         5.0%         5.0%         5.0%         5.0%         6.0.0%         6.0         2.9.2%         5.0%         5.0%         5.0%         6.0.0%         6.0         2.9.2%         5.0%         5.0%         5.0%         6.0.0%         6.0         6.0         6.0         6.0         7.0.9         6.0         5.0% <td>Provide hardwired compact fluorescent fixtures in all spaces.</td> <td>L2k</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Ping Cooks         P         2.3%         3.0%         0.5%         30.0%         5.2%           Derary3for applances         PD	Motion sensors for exterior lighting	L2I							
Energy Stor appliances Bennove phonot load / transformers Occupant bay-in / personal energy budget         Pd Pd           Widen SEP Orint Temperatures (expand SFMAE SS)         M1a         5.0%         5.0%         2.5%         1.8%           Widen SEP Orint Temperatures (expand SFMAE SS)         M1a         3.7         2.2         6.0         20.6%           Subtotati fram obsor Load Reduced EUI (RETU/SF)         2.4         3.2         3.1         3.7         2.2         6.0         20.6%           Reducint floor hosting Percury records wentidiation         M2         15.0%         100.0%         60.0%         0.0%         15.7%           Reducint floor hosting Percury records wentidiation: operable windows Sibilated in Muchanical Distribution strategies (percentage)         M2e         100.0%         0.0%         0.0%         15.7%         100.0%         60.0%         0.0%         15.7%           Subtotal in Muchanical Distribution strategies (percentage)         M2e         2.4         2.7         0.0         3.7         0.9         6.0         15.7%           Subtotal in Muchanical Distribution strategies (percentage)         Wa         7.3%         0.0%         0.0%         15.7%           Subtotal inform (Decard USTUBE)         2.4         0.7         0.0         0.0%         0.0%         16.3% <t< td=""><td>Plug Loads</td><td>Р</td><td></td><td>-2.3%</td><td>3.0%</td><td></td><td>0.5%</td><td>30.0%</td><td>9.2%</td></t<>	Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	9.2%
lemone phontom load / transformers         Pd           Occupant bury-in personal energy budget         Pf           Widen Set Point Temperatures (expand ASHAR 55)         Mia           Subtotal Reducetion strategies (percentage)         5.3.8%         10.7%         43.4%         0.0%         15.2%         29.2%           Subtotal Reducetion strategies (percentage)         5.3.8%         10.7%         43.4%         0.0%         15.2%         30.0%         29.2%           Subtotal Reducet UL (BATU/ST)         2.4         3.2         3.1         3.7         2.2         6.0         0.60           Madian flow heating         M2         15.0%         100.0%         60.0%	EnergyStar appliances	Pb							
Occupant buy-in / personal energy budget         Pf           Widen Set Point Temperatures (expand ASHAE ES)         M1a           Widen Set Point Temperatures (expand ASHAE ES)         M1a           Kathal Reduced EUI (RETU/SF)         2.4         3.2         3.1         3.7         2.2         6.0         29.2%           Subtation from obve loand Reduced EUI (RETU/SF)         2.4         3.2         3.1         3.7         2.2         6.0         20.6%         29.2%           Subtation from obve loand Reduced EUI (RETU/SF)         2.4         3.2         3.1         3.7         2.2         6.0         20.6%         29.2%           Redunn floor heating Energy recovery ventilation         M2         100.0%         0.0%         60.0%         10.7%         3.7         0.9         6.0         15.7%           Redunal Infoar heating Bitting on and window box fons         M2         2.4         2.7         0.0         3.7         0.9         6.0         15.7%           Subtation from Mechanical Distribution strategies (percentage)         2.4         2.7         0.0         3.7         0.9         6.0         15.7%           Subtation from Mechanical Distribution strategies (percentage)         Widen Set Point Reduced EUI (RETU/SF)         2.4         0.7         0.0         0.9	Remove phantom load / transformers	Pd							
Wide Sci Point Temperatures       Mit       5,0%       2,5%       2,5%       1,3%         Subtotal Temperatures (expand ASIMAE 55)       Mit       5,3%       10,7%       43,4%       0,0%       15,2%       30,0%       2,3,2%         Subtotal Reduced EUI (BTU/S7)       2,4       3,2       3,1       3,7       2,2       6,0       2,6       3,2%       3,1       3,7       2,2       6,0       2,6       3,2%       3,2%       3,1       3,7       2,2       6,0       2,6       0,0%       16,7%       8,00%       6,0,0%       16,7%       8,00,0%       6,0,0%       16,7%       100,0%       6,0,0%       6,0,0%       16,7%       100,0%       0,0%       6,0,0%       16,7%       100,0%       0,0%       6,0,0%       16,7%       10,0,0%       0,0%       6,0,0%       16,7%       10,0,0%       0,0%       0,0%       16,7%       10,0,0%       0,0%       0,0%       16,7%       10,0,0%       0,0%       0,0%       16,7%       10,0,0%       0,0%       0,0%       16,5%       10,0       15,5%       10,0       15,5%       10,0       16,5%       10,0       16,5%       10,0       16,5%       10,0       15,5%       10,0       15,5%       10,0       15,5%       10,0 <td>Occupant buy-in / personal energy budget</td> <td>Pf</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	Occupant buy-in / personal energy budget	Pf							
Wiles 62 Point Temperatures (expand ASHAE 55)       Mia         Subtotal fram obvoc Load Reduction strutegies (percentage)       5.8 %       10.7%       43.4 %       0.0%       15.2%       30.0%       29.2%         Subtotal fram obvoc Load Reduction strutegies (percentage)       2.4       3.2       3.1       3.7       2.2       6.0       20.6         Radiant floor heating       M2       15.0%       100.0%       60.0%       16.7%         Radiant floor heating       M2       15.0%       100.0%       60.0%       0.0%       16.7%         Radiant floor heating       M2       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtotal fram who box (nns       M2       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtotal fram who box (nns       M2       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtotal fram who box (nns       M2       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Solar thermal (evocuated tubes) Heating System       M2       2.4       2.7       0.0       3.8       2.4       2.7       0.0       3.8       2.6%       3.6% <td>Widen Set Point Temperatures</td> <td>M1</td> <td></td> <td>5.0%</td> <td>5.0%</td> <td></td> <td>2.5%</td> <td></td> <td>1.8%</td>	Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		1.8%
Subtration and veloat keauction strategies (percentage)         5.3.8%         10.7%         43.4%         0.0%         15.2%         30.0%         20.2%           Mechanical – Distribution & Ventilation         M2         15.0%         100.0%         60.0%         15.7%           Mechanical – Distribution & Ventilation         M2         15.0%         100.0%         60.0%         15.7%           Madiant (low heating Enrorp vecovery ventilation         M2         15.0%         100.0%         60.0%         15.7%           Machant (low fams         M2         2.0         15.0%         100.0%         60.0%         16.7%           Natural ventilation: operable windows fams         M2         2.0         15.0%         100.0%         0.0%         60.0%         16.7%           Subtratil Reduced EUI (k8TU/Sf)         2.4         2.7         0.0         3.7         0.9         6.0         15.7           Mechanical - Plant System         M3         74.3%         0.0%         75.0%         0.0%         15.5%         50%         50%         100.0%         15.5%         6.0         5.0%         5.0%         50%         50%         50%         15.7%         6.0         5.0%         5.0%         50%         5.0%         5.0%         15.5% <td>Widen Set Point Temperatures (expand ASHRAE 55)</td> <td>M1a</td> <td>50.00/</td> <td>4.0 =0(</td> <td>10 10/</td> <td>0.00/</td> <td>45.00/</td> <td>22.00/</td> <td>00.001</td>	Widen Set Point Temperatures (expand ASHRAE 55)	M1a	50.00/	4.0 =0(	10 10/	0.00/	45.00/	22.00/	00.001
2.4       3.1       3.1       3.7       2.2       6.0       20.0         Mechanical Distribution & Vertilation       M2       15.0%       100.0%       60.0%       16.7%         Radiant floor heating       M2y       5.0%       100.0%       60.0%       16.7%         Radiant floor heating       M2y       5.0%       100.0%       60.0%       16.7%         Energy recovery ventilation       M2y       5.0%       100.0%       60.0%       16.7%         Energy recovery ventilation       M2y       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtatal from Mechanical Situation strategies (percentage)       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtatal from Mechanical Situation strategies (percentage)       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtatal from Mechanical Situation strategies (percentage)       2.4       2.7       0.0       3.7       0.9       6.0       15.7%         Subtatal from Mechanical Plant dystems       M3c       74.3%       0.0%       75.0%       0.0%       16.5%         Subtatal from Mechanical Plant and DHW systems (percentage)       0.0%       74.3%	Subtotal from above Load Reduction strategies (percentage)		53.8%	10.7%	43.4%	0.0%	15.2%	30.0%	29.2%
Metalant John Construction of Ventulation       Met       15.0%       100.0%       00.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       10.0%       0.	Subtotal Reduced EUI (KBTU/SF)	142	2.4	3.2	3.1	3.7	2.2	6.0	20.6
nature	Redirect floor besting	IVIZ		15.0%	100.0%		60.0%		16.7%
Ling yr Lcorely Yermation       M2         Motural ventilitan: operable windows       M2         Subtator Reventable windows of fans       M2         Subtator Reventable Windows       M3         Subtator Reventable Windows       M3         Subtator Reventable Windows       M3         Thermal levacuated tubes) Heating System       M3         Domestic Hot Water       W         Solar thermal domestic water       Wa         Solar thermal domestic water       Wa         Subtator Revenues (hows, lows, sinks)       Wb         We watewater heat recovery       Wa         Subtator Revenues (howers, lows, sinks)       Wb         Subtator Revenues (howers, lows, sinks)       We         Subtator Revenues (LBTORT Revenues (LBTORT)ST)       2.4       0.7       0.0       0.9       0.9       6.0       10.5         Generative Schowers, lows, sinks)       We       Schort Reference <td>Energy recovery ventilation</td> <td>M2b</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	Energy recovery ventilation	M2b							
Eliminate cooling Celling fans and window box fans       M21 M22         Subtotal for Mechanical Distribution strategies (percentage) Subtotal Reduced EUI (kBTU/SF)       0.0%       15.0%       100.0%       0.0%       60.0%       16.7%         Mechanical Plant Systems       M3       74.3%       0.0       3.7       0.9       6.0       15.7         Mechanical Plant Systems       M3       74.3%       0.0%       3.7       0.9       6.0       15.7         Mechanical Plant Systems       M3       74.3%       0.0%       75.0%       0.9%       6.0       15.7         Solar thermal domestic water       Wa       75.0%       0.0%       0.0%       16.5%       9.6%         Solar thermal domestic water       Wa       Wa       75.0%       0.0%       0.0%       16.5%         Subtotal from Mechanical Plant and DHW systems (percentage)       0.0%       74.3%       0.0%       75.0%       0.0%       16.5%         Subtotal from Mechanical Plant and DHW systems (percentage)       0.0%       74.3%       0.0%       75.0%       0.0%       16.5%         Subtotal from Mechanical Plant and DHW systems (percentage of Baseline Use       8%       24       0.7       0.0       0.9       6.0       10.9         Final Energy Use Breakdown as	Natural ventilation: operable windows	M2e							
Celling fans and window bax fans         M2z           Subtatal from Mechanical Distribution strategies (percentage)         0.0%         15.0%         00.0%         0.0%         60.0%         0.0%         15.7%           Subtatal Reduced EUI (kTU/SF)         2.4         2.7         0.0         3.7         0.9         6.0         15.7%           Mechanical - Plant Systems         M3         74.3%         -         6.9%         6.9%           Domestic Hot Water         W         75.0%         0.0%         16.7%         9.6%           Solar thermal domestic water         Wa         -         75.0%         0.0%         16.5%           Solar thermal domestic water         Wa         -         -         9.6%         16.5%           Solar thermal domestic water         Wa         -         -         16.5%         9.6%           Solar thermal domestic water         Wa         -         -         -         16.5%           Solar thermal domestic water         Wa         -         -         0.0%         0.0%         0.0%         10.9           Solar thermal domestic water         Building Operating Factor         0.0%         75.0%         0.0%         10.9           Final Energy Use Breakdown as Percentage of Base	Eliminate coolina	M2i							
Subtotal from Mechanical Distribution strategies (percentage)         0.0%         15.0%         100.0%         0.0%         60.0%         0.0%         15.7%           Subtotal Reduced EUI (kBTU/SF)         2.4         2.7         0.0         3.7         0.9         6.0         15.7%           Mechanical - Plant Systems         M3         74.3%         6.9%         6.9%           Solar thermal (evocuted tubes) Heating System         M3         74.3%         6.9%         6.0%         0.0%         6.0         15.7%           Solar thermal (evocuted tubes) Heating System         M3         74.3%         0.0%         0.0%         6.0         0.5%           Solar thermal domestic water         Wa         Values         5.0%         0.0%         0.0%         0.0%         0.0%         16.5%           Subtotal from Mechanical Plant and DHW systems (percentage)         0.0%         74.3%         0.0%         3.8%         0.0%         3.8%         0.0%         3.8%         0.0%         3.6%         6.0	Ceiling fans and window box fans	M2z							
Subtoal Reduced EUI (kBTU/SF)       2.4       2.7       0.0       3.7       0.9       6.0       15.7         Mechanical - Plant System       M3       74.3%       74.3%       6.9%       6.9%       6.9%         Domestic Hot Water       Wa       Wa       Wa       Solar-thermal domestic water       Wa       9.6%       9.6%         Solar-thermal domestic water       Wa       Wa       Wa       9.6%       0.0%       75.0%       0.0%       0.0%       16.5%         Solar-thermal domestic water       Wa       Wa       Wa       Wa       Wa       9.6%       16.5%         Solar-thermal domestic water       Wa       Wa       Wa       Wa       Wa       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%       9.6%       16.5%	Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	100.0%	0.0%	60.0%	0.0%	16.7%
Machanical - Plant Systems         M3         74.3%         6.9%           Solar thermal (vacuated tubes) Heating System         M3c	Subtotal Reduced EUI (kBTU/SF)		2.4	2.7	0.0	3.7	0.9	6.0	15.7
Solar thermal (evaluated tubes) Heating System         Mac         75.0%         9.6%           Domestic Hot Water         Wa         75.0%         9.6%           Solar-thermal domestic water         Wa         We         9.6%           Solar-thermal domestic water         Wa         We         9.6%           Subtated from Mechanical Plant and DHW systems (percentage)         0.0%         74.3%         0.0%         75.0%         0.0%         0.0%         16.5%           Reduced EUI from Energy Conservation Measures (kBTU/SF)         2.4         0.7         0.0         0.9         0.9         6.0         10.9           Final Energy Use Breakdown as Percentage of Baseline Use         0.9%         14.3.8         CBECS Baseline EUI (kBTU/Sf)         62%           Mapped         Total Reduced EUI (kBTU/Sf)         10.2         43.8         CBECS Baseline EUI (kBTU/Sf)         66%         target reduction from CBECS         Achievement:         77%         percent reduction from CBECS         5450           Number of crystaline panels needed         18         Total KW of PV array         4         18         10         14         9         14         14         14         14         14         14         14         14         14         14         14         14	Mechanical - Plant Systems	M3		74.3%					6.9%
Domestic Hot Water         w         75.0%         9.6%           Solar-thermal domestic water         Wa         Wa         Solar-thermal domestic water solar s	Solar thermal (evacuated tubes) Heating System	M3c							
Solar-thermal domestic water Low flow fixtures (showers, low, sinks) Wastewater heat recovery         Wa Wb           Subtotal from Mechanical Plant and DHW systems (percentage)         0.0%         74.3%         0.0%         75.0%         0.0%         16.3%           Reduced EUI from Mechanical Plant and DHW systems (percentage of Baseline Use         8%         2%         0%         3%         2.1%         62%           Final Energy Use Breakdown as Percentage of Baseline Use         8%         2%         0%         3%         2.1%         62%           Main Conservation Measures (kBTU/SF)         2.4         0.7         0.0         0.9         6.0         10.9%           Final Energy Use Breakdown as Percentage of Baseline Use         8%         2%         0%         3%         2.1%         62%           Mumper of Interactive ECM effects         1.05         43.8         CBECS Baseline EUI (kBTU/sf)         60%         10.9%         67%         percent reduction from CBECS         Achievement:         70%         65%         percent reduction from Normalized Baseline Bidg           PV Panel Analysis:         Total Reduced FUI (kBTU/sf)         10.2         65%         65%         percent reduction from Normalized Baseline Bidg           205 panel, facing South (azimuth 0°)         Mingle Area analysis:         10         10 <td< td=""><td>Domestic Hot Water</td><td>w</td><td></td><td></td><td></td><td>75.0%</td><td></td><td></td><td>9.6%</td></td<>	Domestic Hot Water	w				75.0%			9.6%
Low flow fixtures (showers, lows, sinks)       Wb         Wastewater heat recovery       0.0%       74.3%       0.0%       75.0%       0.0%       0.0%       16.5%         Reduced EUI from Energy Conservation Measures (kBTU/SF)       2.4       0.7       0.0       0.9       0.9       6.0       10.9         Final Energy Use Breakdown as Percentage of Baseline Use       8%       2%       0%       3%       3%       21%       62%         Building Operating Factor Impact of Interactive ECM effects       0.90       1.05       43.8       CBECS Baseline EUI (kBTU/sf)       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10.9       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       60%       10%       10%       10%       10%       10%       10%       10%	Solar-thermal domestic water	Wa							
Wasewater heat recovery         We           Subtatal from Mechanical Plant and DHW systems (percentage)         0.0%         74.3%         0.0%         75.0%         0.0%         0.0%         16.5%           Subtatal from Mechanical Plant and DHW systems (percentage)         2.4         0.7         0.0         0.9         0.9         6.0         10.9           Final Energy Use Breakdown as Percentage of Baseline Use         8%         2%         0%         3%         3%         21%         62%           Building Operating Factor         0.90         1.05         60%         target reduction from CBECS         Achievement:         77%         percent reduction from CBECS         65%         percent reduction from CBECS         65%         percent reduction from Normalized Baseline Bldg           Total Reduced EUI (kBTU/sf)         10.2         10.8         65%         percent reduction from CBECS         65%         percent reduction from CBECS         65%         percent reduction from Normalized Baseline Bldg           PV Panel Analysis:         Total Reduced EUI (kBTU / stray 4         18         16         225         18         15*         372.11         15         0         0         15*         15*         16         225         18         15*         0         15*         372.11         15	Low flow fixtures (showers, lavs, sinks)	Wb							
Subtotal from Mechanical Plant and DHW systems (percentage)       0.0%       74.3%       0.0%       75.0%       0.0%       0.0%       16.5%         Reduced EUI from Energy Conservation Measures (kBTU/SF)       2.4       0.7       0.0       0.9       0.9       6.0       10.9         Final Energy Use Breakdown as Percentage of Baseline Use       8%       2%       0%       3%       21%       62%         Building Operating Factor       0.90       10.9       6.0       10.9       3%       21%       62%         Impact of Interactive ECM effects       1.05       10.2       63%       careet reduction from CBECS       Achievement:       77%       percent reduction from Normalized Baseline Bldg         Total reduced energy use (kWh)       5,450       65%       percent reduction from Normalized Baseline Bldg         Number of crystaline panels needed       18       75.0%       0.0       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.9       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%       0.0%	Wastewater heat recovery	We							
Reduced EUI from Energy Conservation Measures (RB U/SF)       2.4       0.7       0.0       0.9       0.9       20.9       6.0       10.9         Final Energy Use Breakdown as Percentage of Baseline Use       8%       2%       0%       3%       3%       21%       62%         Building Operating Factor Impact of Interactive ECM effects       0.90       43.8       CBECS Baseline EUI (kBTU/sf)       60%       target reduction from CBECS         Achievement:       77%       percent reduction from Normalized Baseline Bldg       65%       percent reduction from Normalized Baseline Bldg         Number of crystaline panels needed Total kW of PV array       18       77%       percent reduction from Normalized Baseline Bldg         From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo       angle       KWh per panel       Total panels needed at *       Input Area (SF)       # of Panels         0*       345.73       16       225       18         15*       372.11       15       0       0         0*       345.73       16       225       18         15*       0       0       0       0       0         205 panel, facing South (azimuth 0*)       0       345.73       16       225       18         15*       <	Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	74.3%	0.0%	75.0%	0.0%	0.0%	16.5%
Initial Lifergy Ose Dreakdown as reflecting of Dasenite Ose       Ox       Dx	Reduced EUI from Energy Conservation Measures (KB10/SF)		2.4	0.7	0.0	0.9	0.9	6.0 21%	10.9 62%
Building Operating Factor Impact of Interactive ECM effects       0.90         Impact of Interactive ECM effects       1.05         Total Reduced EUI (kBTU/sf)       10.2         Total Reduced EUI (kBTU/sf)       10.2         Total reduced energy use (kWh)       5,450         Number of crystaline panels needed Total kW of PV array       18 Total kW of PV array         PV Panel Analysis:       From RETscreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo- 205 panel, facing South (azimuth 0*)         Q*       345.73       16       225       18 (SF)         15*       372.11       15       0         Q0*       345.73       16       225       18         15*       372.11       15       0       0         90*       244.19       23       0       0	That there y use breakdown as Percentage of baseline use		070	270	078	378	370	21/0	02/0
Impact of Interactive ECM effects       1.05         Impact of Interactive ECM effects       1.05         Total Reduced EUI (kBTU/sf)       10.2         Total reduced energy use (kWh)       5,450         Number of crystaline panels needed Total kW of PV array       18 Total kW of PV array         PV Panel Analysis:       angle       kWh per panel       Total panels needed at *       Input Area (SF)       # of Panels         0*       345.73       16       225       18         15*       372.11       15       0         0ptimal angle:       29.7*       381.27       15       0         90*       244.19       23       0       0	Building Operating Factor	or 0.90			43.8	CBECS Baseli	ne EUI (kBTU/sf)		
Achievement:         77%       percent reduction from CBECS         65%       percent reduction from Normalized Baseline Bldg         65%       percent reduction from Normalized Baseline Bldg         Number of crystaline panels needed Total kW of PV array       18         PV Panel Analysis:       Total panels         From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo- 205 panel, facing South (azimuth 0°)       angle       kWh per panel       Total panels needed at *       Input Area (SF)       # of Panels         0*       345-73       16       225       18         15*       372.11       15       0         optimal angle:       29.7*       381.27       15       0         90*       244.19       23       0       0          09*       244.19       26       0	Impact of Interactive ECM effect	s 1.05			60%	target reduct	tion from CBECS		
Total Reduced EUI (kBTU/sf)       10.2         Total reduced energy use (kWh)       5,450         Number of crystaline panels needed Total kW of PV array       18 Total kW of PV array         PV Panel Analysis:       angle       kWh per panel       Total panels needed at °       Input Area (SF)       # of Panels         205 panel, facing South (azimuth 0°)       optimal angle:       29.7°       381.27       15       0         15°       377.13       15       0       0       45°       371.61       15       0         90°       244.19       23       0       0       0       0       0       0					Achievement				
State       65%       percent reduction from Normalized Baseline Bldg         65%       percent reduction from Normalized Baseline Bldg         Number of crystaline panels needed Total kW of PV array       18         Total reduced energy use (kWh)       5,450         PV Panel Analysis:       rotal kW of PV array         From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo- 205 panel, facing South (azimuth 0°)       angle       kWh per panel       Total panels needed at °       from V array         0°       345.73       16       225       18         15°       372.11       15       0         0ptimal angle:       29.7°       381.27       15       0         0°       244.19       23       0       0         Total kWh =       6,223	Total Reduced EUI (kBTU/s	f) 10.2			77%	percent redu	ction from CBECS	S	
Total reduced energy use (kWh)       5,450         Number of crystaline panels needed Total kW of PV array       18 4         PV Panel Analysis:       angle       kWh per panel       Total panels needed at *       Input Area (SF)       # of Panels         205 panel, facing South (azimuth 0*)       angle       345.73       16       225       18         15*       372.11       15       0       0         205 panel, facing South (azimuth 0*)       potimal angle:       29.7*       381.27       15       0         0°       244.19       23       0       0					65%	percent redu	ction from Norm	alized Baseline	Bldg
Number of crystaline panels needed Total kW of PV array18PV Panel Analysis:anglekWh per panelTotal panels needed at °Input Area (SF)# of Panels205 panel, facing South (azimuth 0°)anglekWh per panelTotal panels needed at °Input Area (SF)# of Panels0°345.73162251815°372.1115045°371.6115090°244.19230Total kWh =6,223	Total reduced energy of	ise (kWh)	5,450						
Number of crystaline panels needed Total kW of PV array         18 4           PV Panel Analysis:									
Total kW of PV array       4         PV Panel Analysis:	Number of crystaline pane	ls needed	18						
PV Panel Analysis:         From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo- 205 panel, facing South (azimuth 0°)       angle       kWh per panel       Total panels needed at °       Input Area (SF)       # of Panels         0°       345.73       16       225       18         15°       372.11       15       0         20°       281.27       15       0         45°       371.61       15       0         90°       244.19       23       0	Total kW o	f PV array	4						
From RETScreen 4.1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo       angle       kWh per panel       Total panels       Input Area (SF)       # of Panels         205 panel, facing South (azimuth 0°)       0°       345.73       16       225       18         0°       345.73       16       225       18         15°       372.11       15       0         29.7°       381.27       15       0         90°       244.19       23       0	PV Panel Analysis:								
205 panel, facing South (azimuth 0*)     angle     with period     four panels     intiput Area     # of Panels       0°     345.73     16     225     18       15°     372.11     15     0       205 pointel, facing South (azimuth 0*)     0°     345.73     16     225       15°     372.11     15     0       205 pointel, facing South (azimuth 0*)     0°     244.19     23       0°     244.19     23     0	From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kW/h no-	Total panala	Input Area				
$\rho$ $\rho$ $\rho$ $\rho$ $\rho$ $\rho$ 0°345.73162251815°372.1115029.7°381.2715045°371.6115090°244.19230Total kWh =6,223	205 panel, facing South (azimuth 0°)	angle	nanel	needed at °	(SE)	# of Panels			
$0^{\circ}$ 345.73       16       225       18         15°       372.11       15       0         optimal angle:       29.7°       381.27       15       0         45°       371.61       15       0         90°       244.19       23       0			parier	neeueu al	(3F)		4		
$15^{\circ}$ $3/2.11$ $15$ $0$ optimal angle: $29.7^{\circ}$ $381.27$ $15$ $0$ $45^{\circ}$ $371.61$ $15$ $0$ $90^{\circ}$ $244.19$ $23$ $0$		0°	345.73	16	225	18			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	ontimal angle	15°	3/2.11	15		0			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	optinai angi	45°	371.61	15		0			
Total kWh = 6,223		90°	244.19	23		0	-		
		·1			Total kWh =	6,223	_		



# **MULTIFAMILY RESIDENTIAL** PHOENIX hot arid



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

ENERGY USE INDEX

ΡV

40,000 gal RAINWATER TANK SIZE 240.187 sf BUILDING SIZE 5 floors BUILDING HEIGHT 2.87 acres SITE AREA 30,500 sf PHOTOVOLTAIC AREA 42,393 sf ROOF AREA

# MAJOR DESIGN STRATEGIES:

- ✓ Increase floor to floor height to allow better daylight penetration.
- ✓ Reconfigure housing units to be oriented in N/S direction for better access to daylight.
- ✓ Reconfigure floor plans to allow units to have all habitable rooms within 30' of an operable window.
- Add retractable awning to provide additional water collection.



**RETRACTABLE AWNING TO** SPAN BETWEEN BUILDING FOR ADDI-TIONAL WATER COLLECTION AREA





The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PHOENIX, AZ**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

	Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living B	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	13.1%	0.3%	\$622,710	\$2.97	\$704,077	\$3.36
Baseline Building			\$622,710	\$2.97	\$622,710	\$2.97
W2 Rainwater Containment - 40,000 gal Rainwater Tank					\$81,367	\$0.39
B Shell	12.3%	3.9%	\$7,656,970	\$36.52	\$8,600,942	\$41.02
Baseline Building			\$7,656,970	\$36.52	\$7,656,970	\$36.52
E1D Reduce Glazing (30% of original window glazing)					\$165,200	\$0.79
E1A Improved Glazing (reduce solar heat gain)					\$12,972	\$0.06
E1B Exterior Shading Devices					\$468,000	\$2.23
D2A Reduce Wall / Skin for Modified Design (not in base building design)					(\$405,600)	(\$1.93)
D3 Relocate Elevator					\$45,000	\$0.21
D3 Covered Walkway					\$98,400	\$0.47
W5 Rain Harvesting Canopy					\$560,000	\$2.67
C Interiors	5.3%	1.3%	\$5,891,333	\$28.10	\$6,205,850	\$29.60
Baseline Building			\$5,891,333	\$28.10	\$5,891,333	\$28.10
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$314,517	\$1.50
D.1 Services - Conveying Systems	0.0%	0.0%	\$244,158	\$1.16	\$244,158	\$1.16
Baseline Building		-	\$244,158	\$1.16	\$244,158	\$1.16
D.2 Services - Plumbing Systems	8.0%	0.6%	\$1,900,476	\$9.06	\$2,052,276	\$9.79
Baseline Building			\$1,900,476	\$9.06	\$1,900,476	\$9.06
W6 Low-Flow Fixtures / Optical Sensors					\$1,800	\$0.01
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.72
D.3 Services - HVAC Systems	387.3%	11.5%	\$717,870	\$3.42	\$3,498,260	\$16.68
Baseline Building			\$717,870	\$3.42	\$717,870	\$3.42
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$535,000)	(\$2.55)
M2A In-Slab Radiant Heating and Cooling					\$1,048,390	\$5.00
M3A Ground Source Heat Pump					\$1,959,000	\$9.34
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS	)				\$308,000	\$1.47
M2C Carbon Dioxide Sensors					\$0	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$462,507	\$2.21	\$462,507	\$2.21
Baseline Building			\$462,507	\$2.21	\$462,507	\$2.21
D.5 Services - Electrical Systems	0.6%	0.1%	\$3,452,618	\$16.47	\$3,471,778	\$16.56
Baseline Building			\$3,416,018	\$16.29	\$3,416,018	\$16.29
L2E Occupancy Sensor for Transient Lighting (corridors/stairs)			\$28,000	\$0.13		Ţ
L2I Dual day/night light levels in corridors: occupancy sensors			\$8,600	\$0.04		
L2K Provide hardwired compact fluorescent fixtures in all spaces					\$55,760	\$0.27

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PHOENIX, AZ**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678

Site Gross Acreage = 2.87

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$948,170	\$4.52	\$948,170	\$4.52
Baseline Building				\$948,170	\$4.52	\$948,170	\$4.52
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		6.2%	0.6%	\$2,221,462	\$10.59	\$2,358,962	\$11.25
Baseline Building				\$2,221,462	\$10.59	\$2,221,462	\$10.59
W2 Stormwater Retention / Building Water Discharge						\$50,000	\$0.24
D3 Added Courtyard						\$87,500	\$0.42
H Logistics		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
Living Building Prerequisites				\$10,484	\$0.05	\$899,738	\$4.29
PR5 - Materials Red List		100.0%	0.7%			\$177,145	\$0.84
PR7 - Responsible Industry		100.0%	1.3%			\$323,676	\$1.54
PR8 - Appropriate Materials / Services Radius		100.0%	1.7%			\$398,917	\$1.90
PR9 - Leadership in Construction Waste		-100.0%	0.0%	\$10,484	\$0.05		
Subtotal Direct Costs			22.0%	\$24,128,758	\$115.08	\$29,446,718	\$140.44
General Conditions	4.0%	<b>22.0%</b>	0.9%	\$965,150	\$4.60	\$1,177,869	\$5.62
Fee, Construction Contingency, Insurance	4.0%	22.0%	0.9%	\$1,003,756	\$4.79	\$1,224,983	\$5.84
Location Modifier for PHOENIX, AZ	0.85	22.0%	-3.6%	(\$3,914,650)	(\$18.67)	(\$4,777,436)	(\$22.78)
TOTAL MODIFIED CONSTRUCTION COST			22.0%	\$22,183,015	\$105.80	\$27,072,135	\$129.11

# BUILDING TYPE: **MULTI-FAMILY HOUSING** BUILDING LOCATION: **PHOENIX, AZ**



Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	4.1%			\$1,000,000	\$4.77
PV1 Photovoltaic Panels and Infrastructure	501,000 Watts		100.0%	15.6%			\$3,757,500	\$17.92
LB Prerequisite Items								
PR3 - Habitat Exchange	2.86961 acres		100.0%	0.1%			\$14,348	\$0.07
PR6 - Construction Carbon Footprint	6,400 tons		100.0%	0.3%			\$70,400	\$0.34
PR15 - Beauty and Spirit (included in A/E	E fees below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.1%			\$23,500	\$0.11
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	35.1%	9.0%	\$6,211,244	\$29.62	\$8,392,362	\$40.02
Architecture & Engineering	7.00%	9.00%	56.9%	3.7%	\$1,552,811	\$7.41	\$2,436,492	\$11.62
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-7.8%	\$0		(\$1,878,750)	(\$8.96)
SDC Credits	50%		-100.0%	-1.4%	\$0		(\$343,583)	(\$1.64)
TOTAL OWNER & DESIGN-BUILD COSTS				73.5%	\$7,764,055	\$37.03	\$13,472,269	\$64.25

TOTAL CONCEPTUAL COST: \$29,947,070 \$142.82 \$40,544,404 \$193.37

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 33% TO 38% MULTI-FAMILY HOUSING IN PHOENIX, AZ

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# Multi- Family Residential

Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 49.7

Normalized Baseline Energy Use (kWh) 1,947,354

Impact of Design Changes (see sketches) 0.98 Adjusted Baseline EUI (kBtu/SF) 48.5

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	14%	7%	31%	13%	10%	24%	100%
	calc'd EUI	7.0	3.5	15.3	6.1	4.8	11.7	48.5
Energy Conservation Measures:								
Glazing	E1		5.0%	15.0%		5.5%		5.6%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		4.0%	4.0%		2.0%		1.8%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance auide	E2b							
Highly reflective exterior siding	F2d							
Lighting	12	56.6%	-4.2%	5.7%		0.8%		9.8%
Occupancy sensors: transient lighting (corridors (stairs (hathrms)	120	30.070	4.270	5.776		0.070		5.070
Dual day/night light levels in corridors: occupancy sensors	121							
Provide hardwired compact fluorescent fivtures in all spaces	1.24							
Plug Loads	D		2 20/	2 0%		0.5%	20.0%	0 10/
	P		=2.370	5.0%		0.3%	30.0%	0.1/0
EnergyStar appliances	PD							
Remove phantom load / transformers	Pa							
Occupant buy-in / personal energy budget	PT							
Parking: variable flow ventilation based on CO monitor	Ы							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.2%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		56.6%	7.5%	32.7%	0.0%	11.3%	30.0%	27.4%
Subtotal Reduced EUI (kBTU/SF)		3.0	3.3	10.3	6.1	4.3	8.2	35.2
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		60.0%		10.6%
Water to water heat pumps, radiant slab heating/cooling	M2q							
Energy recovery ventilation	M2b							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	60.0%	0.0%	10.6%
Subtotal Reduced EUI (kBTU/SF)		3.0	2.8	8.2	6.1	1.7	8.2	30.0
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		4.0%
Ground source heat pump system	M3a							
Domestic Hot Water	w				75.0%			9.4%
Solar-thermal domestic water	Wa							
Low flow fixtures (showers, lavs, sinks)	Wh							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	13.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.0	2.2	6.6	1.5	2.0	8.2	23.5
Final Energy Use Breakdown as Percentage of Baseline Use		6%	5%	14%	3%	4%	17%	51%
Building Operating Facto	r 0.90			60.0	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.05			60%	target reduction	on from CBECS		
				Achievement:				
Total Reduced FUII (kBTI1/d	) 22.0			63%	nercent reduc	tion from CBECS	:	
	) 22.0			55%	percent reduc	tion from Norm	, alized Baceline	Blda
Total reduced energy	co (1/14/h)	963 735		55%	percent reduc		alizeu baselille	Blug
i otal reduced energy t	se (kwn)	862,735						
Number of crystaline panel	s needed	2,501						
Total kW of	PV array	513						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kW/h por	Total papels	Input Area	1	1		
205 panel, facing South (azimuth 0°)	angle	kwn per	notal pariels	input Area	# of Panels			
		panei	needed at °	(5F)		]		
	0°	345.73	2496	31,200	2501	Panels on two build	dings only	
	15°	372.11	2319		0			

381.27 371.61

244.19

optimal angle: 29.7°

45°

90°

2263

2322

3534

Total kWh =

0

0

0

864,671


# HIGH RISE MIXED USE PHOENIX hot arid



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: HIGH RISE BUILDING LOCATION: PHOENIX, AZ

# **SKANSKA**

Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

С	DNSTRUCTION COST						
Α	Substructure	0 79/	0.49/	\$0.005.440	<b>A</b> / <b>a</b> - a		
	Baseline Building	0.7%	0.1%	\$8,695,116	\$15.88	\$8,754,929	\$15.99
W2	Rainwater Containment - 350.000 gal Rainwater Tank			\$8,695,116	\$15.88	\$8,695,116	\$15.88
_						\$59,814	\$0.11
в	Shell	7.6%	2.9%	\$35,629,047	\$65.06	\$38,323,069	\$69.98
140	Baseline Building			\$35,629,047	\$65.06	\$35,629,047	\$65.06
LIB	Replace Rooling with Glazed Skylight					\$225,900	\$0.41
						\$918,000	\$1.68
	Water Collection on Vertical Surfaces / Tax of D					\$1,905,120	\$3.48
03	Relocate SE to additional 1/2 floor at tar					\$1,400,000	\$2.56
D3	Remove Existing Green Roof					\$40,800	\$0.07
D3	Modifications to Lobby Space (structural and finishes)					(\$30,000)	(\$0.05)
1 1 F	Tracking Mirror above Atrium					\$590,000	\$1.08
D3	Added Elevator Stop for Additional Elect					\$154,000	\$0.28
E1D	Reduce Glazing to 30% (need to define stratogy)					\$105,000	\$0.19
D3	Remove raised access flooring					(\$2,315,798)	(\$4.23)
PV3	Structure for PV on Adjacent Parking Structures					(\$801,000)	(\$1.46)
L1D	Interior Light Shelves (at office floors)					\$340,000	\$0.62
						\$162,000	\$0.30
С	Interiors	6.7%	1.6%	\$22,739,127	\$41.52	\$24,272,474	\$44.32
	Baseline Building			\$22,739,127	\$41.52	\$22,739,127	\$41.52
M2D	Carpet Reduction (replace with RetroPlate)				,=	\$985,723	\$1.80
/12A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$547,624	\$1.00
D.1	Services - Conveying Systems	0.0%	0.0%	\$2,626,557	¢4.94	\$0.000 FF7	<b>A</b> ( <b>A</b> (
	Baseline Building	0.078	0.0%	\$2,636,557	\$4.81	\$2,636,557 \$2,636,557	\$4.81 \$4.91
<b>م</b> م	Camilana Dhumht o d			. , .,	φ1.01	\$2,000,007	Ψ4.01
D.2	Services - Plumbing Systems	0.0%	0.0%	\$3,874,587	\$7.08	\$3,874,587	\$7.08
	Baseline Building			\$3,874,587	\$7.08	\$3,874,587	\$7.08
W6	Low-Flow Fixtures / Optical Sensors					\$0	
W2	Rain Harvesting (piping & pumps and filtration)					\$0	
D.3	Services - HVAC Systems	69.2%	5.6%	\$7,599,577	\$13.88	\$12,856,160	\$23.48
	Baseline Building			\$7,599,577	\$13.88	\$8,449,577	\$15.43
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$6.085.700)	(\$11.11)
12A	In-Slab Radiant Heating and Cooling					\$2,738,120	\$5.00
13A	Ground Source Heat Pump					\$7,468,000	\$13.64
12B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$286,163	\$0.52
12C	Carbon Dioxide Sensors					\$0	++··02
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$1,132,828	\$2.07	\$1 132 828	\$2.07
	Baseline Building			\$1,132,828	\$2.07	\$1,132,828	\$2.07
<b>)</b> .5	Services - Electrical Systems	10 49/	0.00/	<b>.</b>			<b>*</b> =
	Baseline Building	12.4%	0.8%	\$6,138,326	\$11.21	\$6,901,276	\$12.60
PA (	Occupancy Sensor to Outlets			\$0,209,026	\$11.34	\$6,209,026	\$11.34
ΡE	High Efficiency Transformers					\$35,100	\$0.06
2A	Efficient light fixture optics					\$165,000	\$0.30
2B (	Occupancy Sensor for Lighting (closed office / conference spaces)					\$160,200	\$0.29
2C	ndividual Light Level Control (open spaces)					\$18,850 \$170,000	\$0.03
21	Dual day/night light levels in corridors; occupancy sensors					\$179,000	\$0.33
2J (	Decupancy sensor/time clock for corridor lighting					φ134,100 ¢0	\$0.24
2K	Provide hardwired compact fluorescent fixtures in all spaces			(\$70,700)	(0.12)	\$U	
				(4,0,100)	(\$0.13)	<b>Ф</b> О	

# BUILDING TYPE: HIGH RISE BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
					Total	Cost/SF	Total	Cost/SF
F	Equipment and Eurnishings		0.0%	0.0%	\$3 326 853	\$6.08	\$3 326 853	\$6.08
-	Baseline Building		0.070	0.070	\$3.326.853	\$6.08	\$3.326.853	\$6.08
						<i><b>Q</b></i> 0.00		<i><b>Q</b></i> 0.00
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building				\$0		\$0	
G	Sitework		9.3%	0.1%	\$537,417	\$0.98	\$587,417	\$1.07
	Baseline Building				\$537,417	\$0.98	\$537,417	\$0.98
W4	Stormwater Retention / Building Water Discharge						\$50,000	\$0.09
W1	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
н	Logistics		0.0%	0.0%	\$1,764,940	\$3.22	\$1,764,940	\$3.22
	Baseline Building				\$1,764,940	\$3.22	\$1,764,940	\$3.22
	in a Duildin a Danas suisites				¢07.004	¢0.05	¢0.007.000	¢5.40
LIV	PR5 Matariala Pad List		100.0%	0.7%	\$27,381	\$0.05	\$2,967,929	\$ <b>5.42</b>
	PR7 - Responsible Industry		100.0%	0.7 %			\$328 542	\$1.20 \$0.60
	PR8 - Appropriate Materials / Services Radius		100.0%	2.0%			\$1 925 712	\$0.00 \$3.52
	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$27,381	\$0.05	\$27,381	\$0.02
					• ,	<i><b>Q</b></i> 0100	• ,	¢0100
Sul	ototal Direct Costs			14.1%	\$94,101,757	\$171.84	\$107,399,021	\$196.12
	Conoral Conditions	2.20/	14 1%	0.5%	\$3 005 271	¢5.40	\$3 429 937	¢6.26
	Fee Contingency Insurance Bonding	3.∠% 9.8%	14.1%	1.4%	\$9.471.412	ອບ.49 \$17 30	\$10,809,791	₽0.20 \$19.74
	Location Modifier for PHOENIX, AZ	0.85	14.1%	-2.4%	(\$15,986,766)	(\$29.19)	(\$18,245,812)	(\$33.32)
		0.00			(, , , , , , , , , , , , , , , , , , ,	(4=0.10)	(; -; -; -; -; -; -;	(\$00.02)
то	TAL MODIFIED CONSTRUCTION COST			14.1%	\$90,591,673	\$165.43	\$103,392,936	\$188.80

# BUILDING TYPE: HIGH RISE BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624 Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	1.1%			\$1,000,000	\$1.83
O1 Wind Turbines (net cost including credits)	14,800	Watts		0.0%	0.0%	(\$82,000)		(\$82,000)	(\$0.15)
PV1 Photovoltaic Panels and Infrastructure	1,236,000	Watts		100.0%	9.9%			\$9,270,000	\$16.93
LB Prerequisite Items									
PR3 - Habitat Exchange	0.9182736	acres		100.0%	0.0%			\$4,591	\$0.01
PR6 - Construction Carbon Footprint	24,100	tons		100.0%	0.3%			\$265,100	\$0.48
PR15 - Beauty and Spirit (included in A/E fe	es below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.12
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	26.4%	7.1%	\$25,365,669	\$46.32	\$32,051,810	\$58.53
Architecture & Engineering		7.00%	9.00%	46.7%	3.1%	\$6,341,417	\$11.58	\$9,305,364	\$16.99
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-4.9%	\$0		(\$4,635,000)	(\$8.46)
SDC Credits	50%			-100.0%	-0.5%	\$0		(\$509,464)	(\$0.93)
TOTAL OWNER & DESIGN-BUILD COSTS					47.8%	\$31,625,086	\$57.90	\$46,733,402	\$85.34

TOTAL CONCEPTUAL COST: \$122,216,759 \$223.18 \$150,126,339 \$274.14

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 20% TO 25% HIGH RISE IN PHOENIX, AZ

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# High Rise Mixed use

#### Phoenix

Normalized Baseline Energy Use Intensity (kBtu/SF) 75.8

### Normalized Baseline Energy Use (kWh) 8,445,989

# Impact of Design Changes (see sketches) 0.98 Adjusted Baseline EUI (kBtu/SF) 73.9

					DOM HOT			TOTAL
			HEATING	COOLING	MATER	EANIS & DUMDS		RIDG
ner	ent of load	13%	8%	37%	11%	10%	22%	100%
per	cole'd FUI	0.3	5.0	27.0	7.0	7.4	16.4	72.0
Energy Conservation Measures:		5.5	5.5	27.0	7.5	7.4	10.4	73.5
Charles Conservation Measures.			5.00/	45.00/		E 50/		6 494
Glazing	E1		5.0%	15.0%		5.5%		6.4%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		4.0%	4.0%		2.0%		2.0%
Shaded roof from solar panels	E2a							
Ontimize insulation to core performance quide	F2h							
Highly reflective exterior siding	E2d							
De l'abite (le company tester de la cia a (ab a l'acc)	LZU	45.00/		4 50/		0.00/		0.444
Daylighting (incorporates tuned glazing/shading)	11	15.0%	-1.1%	1.5%		0.2%		2.4%
Remove ceiling, raise window head, add lightshelf	L1a							
Daylight controls (continuous dimming)	L1c							
Lighting	L2	65.1%	-4.9%	6.5%		1.0%		10.3%
Efficient fixture ontics	L2a							
Individual occupancy sensors & dimming controls: closed offices /low occucan	inc L2b							
Individual light loval control (dimming) at open office grags	120							
individual light level control (alimning) at open office areas	LZC							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dual day/night light levels in corridors; occupancy sensors	L2i							
Occupancy sensor / time clock for corridor lighting	L2j							
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Plug Loads	D		2 20/	2 00/		0.5%	20.0%	7 6%
nug Lugus	r		-2.3%	5.0%		0.5%	50.0%	1.0%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occurrent huw in / norsonal onorgy hudget	P C							
Controlling buy-in / personal energy budget	PI							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.5%
Widen Set Point Temperatures (averand ASHBAE EE)	M110		5.670	5.676		2.570		21370
widen set Point Temperatures (expana ASHRAE 55)	IVITA							
Subtotal from above Load Reduction strategies (percentage)		80.1%	5.7%	35.0%	0.0%	11.7%	30.0%	31.1%
Subtotal Reduced EUI (kBTU/SF)		1.8	5.6	17.6	7.9	6.5	11.5	50.9
Mechanical - Distribution & Ventilation	M2		15.0%	22.0%		60.0%		11.7%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	Mab							
	IVIZD							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
Night jush	NADE							
High mass - concrete block on inside of insulation	IVIZN							
Displacement ventilation delivery for DOAS	M2k							
Water to water heat pumps, radiant slab heating/cooling	M2q							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	22.0%	0.0%	60.0%	0.0%	11.7%
Subtotal Reduced EUI (kBTU/SF)		1.8	4.8	13.7	7.9	2.6	11.5	42.3
Mechanical - Plant Systems	M2		20.0%	20.0%		-15.0%		1 50/
Niconanical - Flatt Systems	IVI3		20.0%	20.0%		-13.0%		4.3%
Ground source heat pump system	M3a							
Domestic Hot Water	w				75.0%			8.0%
Solar-thermal domestic water	14/2							2.070
Les fles fisteres (sherrer les sinh)	wa							
LOW JIOW JIXtures (snowers, lavs, sinks)	Wb							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	12.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		1.8	3.8	11.0	2.0	3.0	11.5	33.1
Final Energy Use Breakdown as Percentage of Baseline Use		2%	5%	15%	3%	4%	16%	55%
Building Operating Fact	or 0.90			86.2	CRECS Racelin	EIII (kBTII/cf)		
Building Operating Fact	01 0.90			60.2	CDECS Daselli			
Impact of Interactive ECM effect	ts 1.05			60%	target reducti	on from CBECS		
				Achievement:				
Total Reduced FUI (kBTU/	f) 30.9			64%	nercent reduc	tion from CBECS		
Total Acadeca Eor (KDTO).	50.5			E 90/	percent reduc	tion from Norm	alized Paceline	Dida
				3670	percent reduc		alizeu baselille	Diug
Total reduced energy	use (kWh)	3,446,711						
Number of existeling per-	als needed	0 627						
Number of crystallite part	els needed	9,037						
Total kW d	ot PV array	1976						
PV Panel Analysis:								
From DETErrand 1, mathed 2, 2% mice locate 0.0% investor officiary of the	1 1		1	1	1	1		
FIGHT RETSCIEVEN 4-1: METHOD 2, 2% MISC IOSSES, 90% INVERTER EFFICIENCY, ASSUMES SANYO	-	kWh per	Total panels	Input Area	# of Deser			
205 panei, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
		Parier	uu	(31)		4		
	0°	345.73	9970	18,000	1443			
	15°	372.11	9263	57,200	4586			
ontimal and	e: 29.7°	381 27	9041		0	1		
optinarang	AE0	271 61	0276		0	1		
	45	3/1.01	92/0	-	0	-		
	90°	244.19	14115		0			
				Total kWh =	2,205,385			
One Parking garage required for net zero energy				45,000	3608	Actual kWh Pr	oduced	
one i oning buldge required for her zelo chergy				43,000	1 247 200	2 452 220		
					1,247,394	3,452,779		



# HOSPITAL PHOENIX hot arid

118.7 kbtu/sf/yea	III		
		32-3 10-1 \$	<b>5</b> years 368/sf
*	Z	34	39 kw
	3903k	4288k	386k

# **ENERGY USE INDEX**

**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

130,000 gal 180,231 sf  $\mathbf{3}$  floors 39.03 acres 208,200 sf 84,900 sf

# MAJOR DESIGN STRATEGIES:

- ✓ Add new light shafts with louvered shades at Nurse's station.
- ✓ Add skylights at corridors for increased lighting.
- Minimize screen at  $\checkmark$ mechanical area - not needed.
- ✓ West shading at classrooms.
- ✓ Add shading devices on South side of hospital. office. etc.
- ✓ Add shading at patient courtyards.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## BUILDING TYPE: HOSPITAL BUILDING LOCATION: PHOENIX, AZ



\$36.046

\$826,462

\$826,462

\$3,597,613

\$3,347,613

\$14,230,184

\$9,992,801

(\$2,652,772

\$0 \$250,000

\$0

\$0.20

\$4.59

\$4.59

\$19.96

\$18.57

\$1.39

\$78.96

\$55.44

Base Building Gross SF = 180,231

		Living Building Gross SF = 180,231 Site Gross Acreage = 39.03									
		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	ilding				
				Total	Cost/SF	Total	Cost/SF				
со	INSTRUCTION COST										
Α	Substructure	8.2%	0.4%	\$2,895,319	\$16.06	\$3,132,762	\$17.38				
	Baseline Building			\$2,895,319	\$16.06	\$2,895,319	\$16.06				
W2	Rainwater Containment - 130,000 gal Rainwater Tank					\$237,443	\$1.32				
в	Shell	2.4%	0.6%	\$14,789,139	\$82.06	\$15,138,359	\$83.99				
	Baseline Building			\$14,789,139	\$82.06	\$14,789,139	\$82.06				
L1B	Replace Roofing with Glazed Skylight					\$15,000	\$0.08				
E1A	Improved Glazing (reduce solar heat gain at vision only)					\$16,000	\$0.09				
E1B	Exterior Horizontal Shading Devices					\$87,600	\$0.49				
E1B	Exterior Fins at West End of Curtainwall					\$36,000	\$0.20				
L1D	Interior Light Shelf					\$58,400	\$0.32				
E1B	Vertical Shading Fins (west end)					\$26,900	\$0.15				
L1B	New Light Shafts to Nurse Stations					\$387,000	\$2.15				
E2B	Infill Spandrel Panel with Framing and Insulation (replace glazed area)					\$22,320	\$0.12				
D3	Reduce Mechanical Rooftop Screen					(\$300,000)	(\$1.66)				
с	Interiors	0.4%	0.1%	\$9,710,678	\$53.88	\$9,746,724	\$54.08				
	Baseline Building			\$9,710,678	\$53.88	\$9,710,678	\$53.88				

0.0%

0.4%

7.0%

\$826,462

\$826,462

\$3,347,613

\$3,347,613

\$9,992,801

\$9,992,801

\$4.59

\$4.59

\$18.57

\$18.57

\$55.44

\$55.44

0.0%

7.5%

42.4%

M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete) L1A Raise Ceilings (no cost impact) **D.1 Services - Conveying Systems Baseline Building D.2 Services - Plumbing Systems Baseline Building** W6 Low-Flow Fixtures / Optical Sensors W2 Rain Harvesting (piping & pumps and filtration) **D.3 Services - HVAC Systems Baseline Building** Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting) M2A In-Slab Radiant Heating and Cooling M3A Ground Source Heat Pump M2C Carbon Dioxide Sensors

(\$14.72 \$901,155 \$5.00 \$5,893,000 \$32.70 M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS) \$80,000 \$0.44 \$16,000 \$0.09 \$2.46 \$2.46 0.0% \$444,259 \$444,259 **D.4 Services - Fire Protection Systems** 0.0% **Baseline Building** \$444,259 \$2.46 \$444,259 \$2.46 **D.5 Services - Electrical Systems** 0.8% \$8,085,831 \$44.86 \$8,597,131 \$47.70 6.3% \$8,085,831 \$44.86 \$8 085 831 \$44.86 **Baseline Building** \$21,500 PA Occupancy Sensor to Outlets \$0.12 \$217,000 PE High Efficiency Transformers \$1.20 \$168,000 LIC Daylight Controls (continuous dimming 15' from perimeter) \$0.93 L2E Occupancy Sensor for Transient and Egress Lighting \$44,500 \$0.25 \$18,800 L2G Patient Bed light with separate switching for ambient / task \$0.10 \$19,000 L2M Dual level light at egress stairs - off when not occupied \$0.11 \$22.500 L2N Stairwell lighting on daylighting \$0.12

# BUILDING TYPE: HOSPITAL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

	Divis Premi (%	ion ium )	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings	0.0	%	0.0%	\$2,050,942	\$11.38	\$2,050,942	\$11.38
Baseline Building				\$2,050,942	\$11.38	\$2,050,942	\$11.38
F Special Construction	0.09	%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework	16.2	%	2.1%	\$7,730,038	\$42.89	\$8,980,038	\$49.83
Baseline Building				\$7,730,038	\$42.89	\$7,730,038	\$42.89
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.28
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
W2 Rainwater Collection from Solar Panel Array						\$1,200,000	\$6.66
H Logistics	0.0	%	0.0%	\$920,558	\$5.11	\$920,558	\$5.11
Baseline Building				\$920,558	\$5.11	\$920,558	\$5.11
Living Building Prerequisites			0.70/	\$9,012	\$0.05	\$1,468,485	\$8.15
PR5 - Materials Red List	100.0	<b>)%</b>	0.7%			\$439,890	\$2.44
PR7 - Responsible industry	100.0	J%	0.2%			\$108,128	\$0.60
PRo - Appropriate Materials / Services Radius	100.0	J 70	0.0%	¢0.012	¢0.05	\$911,450 \$0,012	\$5.06
PR9 - Leadership in Construction Waste	0.0	/0	0.0%	\$9,012	\$0.05	\$9,012	\$0.05
Subtotal Direct Costs			13.7%	\$60,802,650	\$337.36	\$69,133,516	\$383.58
Concret Conditions	5.0% 13.7	%	0.8%	\$3 599 939	¢10.07	\$4 093 184	¢00.74
Fee Contingency Insurance	6.7% <b>13.7</b>	%	1.0%	\$4,309,196	\$23.97	\$4,899,620	φ22.71 \$27.19
Location Modifier for PHOENIX, AZ	0.85 13.7	%	-2.3%	(\$10,306,768)	(\$57.19)	(\$11,718,948)	(\$65.02)
TOTAL MODIFIED CONSTRUCTION COST			13.7%	\$58,405,018	\$324.06	\$66,407,372	\$368.46

# BUILDING TYPE: HOSPITAL BUILDING LOCATION: PHOENIX, AZ



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	2.5%			\$1,500,000	\$8.32
PV1 Photovoltaic Panels and Infrastructure	3,422,000 Wat	itts		100.0%	42.2%			\$25,665,000	\$142.40
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03 acre	es		100.0%	0.3%			\$195,150	\$1.08
PR6 - Construction Carbon Footprint	5,400 tons	s		100.0%	0.1%			\$59,400	\$0.33
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.35
Development Costs	L	EED	LBC						
Develoment Costs	28	8.00%	31.00%	25.9%	7.0%	\$16,353,405	\$90.74	\$20,586,285	\$114.22
Architecture & Engineering	7	7.00%	9.00%	46.2%	3.1%	\$4,088,351	\$22.68	\$5,976,664	\$33.16
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-21.1%	\$0		(\$12,832,500)	(\$71.20)
SDC Credits	50%			-100.0%	-2.3%	\$0		(\$1,372,092)	(\$7.61)
TOTAL OWNER & DESIGN-BUILD COSTS					94.9%	\$20,441,756	\$113.42	\$39,840,907	\$221.05

TOTAL CONCEPTUAL COST: \$78,846,774 \$437.48 \$106,248,279 \$589.51

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	32%	то	37%	
HOSPITAL IN PHOENIX, AZ				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

#### Hospital Phoenix

### Normalized Baseline Energy Use Intensity (kBtu/SF) 207.6

### Normalized Baseline Energy Use (kWh) 10,950,041

Impact of Design Changes (see sketches) 1.00 Adjusted Baseline EUI (kBtu/SF) 207.6

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
pe	rcent of load	14%	5%	27%	14%	15%	24%	100%
	calc'd EUI	29.9	10.1	56.7	29.9	31.1	49.8	207.6
Energy Conservation Measures:								
Glazing	E1		5.0%	10.0%		4.0%		3.6%
Improved Glazina	F1a							
Add effective shading devices	F1b							
Walls & Poof	E10		4.0%	4.0%		2.0%		1 60/
	EZ		4.0%	4.0%		2.0%		1.0%
Snaded roof from solar panels	EZa							
Optimize insulation to core performance guide	E2b							
Highly reflective exterior siding	E2d							
Daylighting (incorporates tuned glazing/shading)	L1	13.3%	-1.0%	1.3%		0.2%		2.0%
Top daylighting with skylights	L1b							
Daylight controls (continuous dimming)	L1c							
Add new courtyards at Nurses's station								
Lighting	L2	31.1%	-2.3%	3.1%		0.5%		4.6%
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Patient bedlight with separate switching for ambient / task	1.29							
Dual level light at earess stairs - off when not occupnied	8							
Stairwell lighting on daylighting / occupancy sensors	12n							
Plug Loods	D						10.0%	2 50/
	Dh.						10.076	2.370
Energystul uppliulites	PD							
Energy ejjicient main transformer	Pe							
Super-efficient elevators (nybrid)	Pk							
Aggressive neat recapture - all equipment water cooled	PI							
Widen Set Point Temperatures	M1		2.0%	2.0%		1.0%		0.8%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		44.4%	7.7%	20.4%	0.0%	7.7%	10.0%	15.9%
Subtotal Reduced EUI (kBTU/SF)		16.6	9.3	45.1	29.9	28.7	44.9	174.6
Mechanical - Distribution & Ventilation	M2		17.0%	14.0%		20.0%		6.9%
Radiant slab heatina/coolina in lobby/atrium spaces	M2r							
Chilled beams	M2s							
Displacement ventilation in exam rooms	M2t							
Natural ventilation in stairwells	M2u							
I ow pressure drop gir filters	M2v							
OSA/Exhaust runground heat recovery	M2w							
Cascadina make-un air	M2v							
Subtotal from Mechanical Distribution strategies (nercentage)	IVIZA	0.0%	17.0%	1/ 0%	0.0%	20.0%	0.0%	6.6%
Subtotal Poducod EIII /kPTII/SE		16.6	7.7	20.0	20.0	20.0%	11.0	160.0
Masherical Dient Custome		10.0	15.00/	25.00/	23.5	25.0	44.5	100.5
iviecnanical - Plant Systems	IVI3		15.0%	35.0%		-7.5%		4.0%
Ground source heat pump with central heat pump chiller	МЗе							
Chiller heat recovery	M3f							
Domestic Hot Water	w				70.0%			10.5%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	15.0%	35.0%	70.0%	-7.5%	0.0%	16.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		16.6	6.6	25.2	9.0	24.7	44.9	127.0
Final Energy Use Breakdown as Percentage of Baseline Use		8%	3%	12%	4%	12%	22%	39%
Building Operating Fac	tor 0.90			249.2	CBECS Baseli	ne EUI (kBTU/sf)		
Impact of Interactive ECM effe	ects 1.05			60%	target reduct	ion from CBECS		
				Achievement:	TARGET RED		т	
Total Poducod FUII /kPTU	(cf) 110 7			E 20/	norcont rodu	ction from CREC	-	
	(51) 110.7			13%	percent redu	ction from Norm	) alized Baseline	Blde
	(1.1.(1.)	6 96 4 4 96		4378	percentredu	ction non non	anzeu basenne	Diug
Total reduced energy	y use (kwn)	6,264,106						
Number of crystaline par	nels needed	16,775						
Total kW	of PV array	3439						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sany	0-			1		1		
205 panel, facina South (azimuth 0°)	angle	кWh per	I otal panels	Input Area	# of Panels			
		panel	needed at °	(SF)				
	0°	345.73	18119	44,700	3584	7		
	15°	372.11	16835		0	7		
optimal an	gle: 29.7°	381.27	16430	164,500	13191	7		
	45°	371.61	16857	,	0	7		
	90°	244.19	25653		0	1		
				Total kWh =	6.268.429			
					-,,			

CASCADIA REGION GREEN BUILDING COUNCIL/SERA ARCHITECTS/SKANSKA USA BUILDING/GERDING EDLEN /INTERFACE ENGINEERING/NEW BUILDINGS INSTITUTE 3.PHX.161



# UNIVERSITY CLASSROOM BOSTON mixed



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =	153,531
Living Building Gross SF =	153,531
Site Gross Acreage =	2.75

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	1.1%	0.1%	\$2,123,369	\$13.83	\$2,145,723	\$13.98
Baseline Building			\$2,123,369	\$13.83	\$2,123,369	\$13.83
W2 Rainwater Containment - 25,000 gai Rainwater Tank					<b>₽</b> ∠2,354	\$0.15
B Shell	2.5%	0.3%	\$4,959,353	\$32.30	\$5,083,677	\$33.11
Baseline Building			\$4,959,353	\$32.30	\$4,959,353	\$32.30
E1A Improved Glazing (reduce solar heat gain)					\$35,324 (\$116,000)	\$0.23
ETB Exterior Shading Devices (solid horizontal sun shades)					\$35,000	( <del>0</del> 0.70) \$0.23
D2B Revised Atrium Roof Structure (sawtooth)					\$170,000	\$1.11
C Interiors	-3.8%	-1.4%	\$16,495,934	\$107.44	\$15,868,139	\$103.35
Baseline Building			\$16,495,934	\$107.44	\$16,495,934	\$107.44
M2D Carpet Reduction (remove carpet and retroplate concrete)			. , ,	φ107.11	\$96,071	\$0.63
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$153,531	\$1.00
L1A Exposed Ceilings (white matte surfaces)					(\$160,397)	(\$1.04)
D3 Eliminate Raised Access Floor					(\$717,000)	(\$4.67)
D.1 Services - Conveying Systems	0.0%	0.0%	\$297,968	\$1.94	\$297,968	\$1.94
Baseline Building			\$297,968	\$1.94	\$297,968	\$1.94
D.2 Services - Plumbing Systems	5.2%	0.4%	\$2,968,571	\$19.34	\$3,122,371	\$20.34
Baseline Building			\$2,968,571	\$19.34	\$2,968,571	\$19.34
W6 Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.98
D.3 Services - HVAC Systems	39.3%	5.1%	\$5,646,851	\$36.78	\$7,864,306	\$51.22
Baseline Building			\$5,646,851	\$36.78	\$5,646,851	\$36.78
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$1,000,000)	(\$6.51)
M2A In-Slab Radiant Heating and Cooling					\$767,655	\$5.00
M3A Ground Source Heat Pump					\$2,369,600 \$80,000	\$15.44
M2B Energy Recovery wheel / Plate & Flame/Dedicated Outside All System(DOAS)					\$00,000	φ0.5Z
M20 Garbon Dioxide Sensors (in base building)					ΨŬ	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$425,840	\$2.77	\$425,840	\$2.77
Baseline Building			\$425,840	\$2.77	\$425,840	\$2.77
D.5 Services - Electrical Systems	2.9%	0.4%	\$6,000,852	\$39.09	\$6,174,252	\$40.22
Baseline Building			\$6,000,852	\$39.09	\$6,000,852	\$39.09
PA Occupancy Sensor to Outlets					\$14,100	\$0.09
PE High Efficiency Transformers					\$67,000	\$0.44
L2E Occupancy Sensor for Transient and Egress Lighting					\$37,500	\$0.24

#### BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =153,531Living Building Gross SF =153,531Site Gross Acreage =2.75

		Premium (%)	Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
				Total	Cost/SF	Total	Cost/SF
L2F Dimmable Direct/Indirect Fixtures						\$54,800	\$0.36
E Equipment and Furnishings		0.0%	0.0%	\$257,958	\$1.68	\$257,958	\$1.68
Baseline Building				\$257,958	\$1.68	\$257,958	\$1.68
F Special Construction		0.0%	0.0%	\$79,247	\$0.52	\$79,247	\$0.52
Baseline Building				\$79,247	\$0.52	\$79,247	\$0.52
G Sitework		2.0%	0.1%	\$2,460,261	\$16.02	\$2,510,261	\$16.35
Baseline Building				\$2,460,261	\$16.02	\$2,460,261	\$16.02
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.33
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$2,108,417	\$13.73	\$2,108,417	\$13.73
Baseline Building				\$2,108,417	\$13.73	\$2,108,417	\$13.73
				40.007	<b>Aa a i</b>	A	40.50
Living Building Prerequisites		400.0%	0.00/	\$6,397	\$0.04	\$1,003,256	\$6.53
PR5 - Materials Red List		100.0%	0.9%			\$410,636 \$162,546	\$2.67
PR8 - Appropriate Materials / Services Radius		100.0%	0.4 %			\$423 677	\$1.00 \$2.76
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$6,397	\$0.04	\$6,397	\$2.70 \$0.04
				\$0,001	φ0.04	\$0,001	ψ0.04
Subtotal Direct Costs			7.1%	\$43,831,019	\$285.49	\$46,941,417	\$305.75
General Conditions	8.0%	7.1%	0.6%	\$3,512,022	\$22.88	\$3,761,247	\$24,50
Fee, Construction Contingency, Insurance	7.0%	7.1%	0.5%	\$3,328,586	\$21.68	\$3,564,794	\$23,22
Location Modifier for BOSTON, MA	1.12	7.1%	1.0%	\$6,080,595	\$39.61	\$6,512,095	\$42.42
TOTAL MODIFIED CONSTRUCTION COST			7.1%	\$56,752,222	\$369.65	\$60,779,553	\$395.88

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The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: UNIVERSITY CLASSROOM BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =153,531Living Building Gross SF =153,531Site Gross Acreage =2.75

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	0.1%			\$50,000	\$0.33
PV1 Photovoltaic Panels and Infrastructure	1,617,000 Watts		100.0%	27.7%			\$12,127,500	\$78.99
LB Prerequisite Items								
PR3 - Habitat Exchange	2.7548209 acres		100.0%	0.0%			\$13,774	\$0.09
PR6 - Construction Carbon Footprint	6,800 tons		100.0%	0.2%			\$74,800	\$0.49
PR15 - Beauty and Spirit (included in A/E fe	0.0%	0.0%			\$0			
PR16 - Inspiration and Education			100.0%	0.2%			\$73,750	\$0.48
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	18.6%	6.7%	\$15,890,622	\$103.50	\$18,841,661	\$122.72
Architecture & Engineering	7.00%	9.00%	37.7%	3.4%	\$3,972,656	\$25.88	\$5,470,160	\$35.63
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-13.8%	\$0		(\$6,063,750)	(\$39.50)
SDC Credits	50%		-100.0%	-0.8%	\$0		(\$349,890)	(\$2.28)
TOTAL OWNER & DESIGN-BUILD COSTS				52.2%	\$19,863,278	\$129.38	\$30,238,005	\$196.95

TOTAL CONCEPTUAL COST: \$76,615,500 \$499.02 \$91,017,558

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: UNIVERSITY CLASSROOM IN BOSTON, MA 16% то 21%

\$592.83

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# University Classroom

Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 105.8

### Normalized Baseline Energy Use (kWh)

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 102.1

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	16%	28%	20%	2%	10%	24%	100%
	calc'd EUI	16.4	28.9	20.3	1.6	10.2	24.6	102.1
Energy Conservation Measures:								
Glazing	E1		15.0%	10.0%		6.0%		6.8%
Improved Glazina	E1a							
Add effective shading devices	F1b							
Reduce alazina to 30%	F1d							
Walls & Boof	E2		£ 0%	2.0%		2 10/		2 50/
	52		0.0%	5.0%		2.1%		2.5%
Snaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		8.0%
Daylight controls (continuous dimming)	L1c							
Orient windows to allow for illumination of teaching wall	L1f							
Top daylighting from Atrium	L1g							
Lighting	L2	20.0%	-1.5%	2.0%		0.3%		3.2%
Individual occupancy sensors & dimmina controls: closed offices/low occupar	c L2b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls ceiling surfaces	12d							
Occupancy sensors: transient lighting (corridors (stairs /bathrms)	120							
Dimmable direct / indirect fixtures	1.26							
Diminuble unett / munett jixtures	12:							
Dicupancy sensor / time clock for cornaor lighting	-		4.00/	0.50/		0.40/	25.00/	6.00/
	Ρ		-1.9%	2.5%		0.4%	25.0%	b.U%
Uccupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Mechanical - Schedule	M4			7.0%				
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2 7%
Widen Set Point Temperatures (ownand ASUDAE EE)	N41-		5.078	5.078		2.370		2.770
Widen Set Point Temperatures (expand ASHRAE 55)	IVITA	70.0%	10.00/	24 50/	0.0%	12.00/	25.0%	20 70/
Subtotal from above Load Reduction strategies (percentage)		10.0%	18.9%	34.5%	0.0%	12.0%	25.0%	30.7%
Subtotal Reduced EUI (KBTU/SF)		4.9	23.4	13.3	1.6	9.0	18.5	70.8
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		12.2%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Cascadina make-un air	M2x							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	12.2%
Subtotal Reduced FIII (kBTII/SF)		49	19.9	10.7	1.6	27	18 5	58.3
Mochanical Blant Systems	142	4.5	20.0%	20.0%	1.0	15.0%	10.0	E 60/
Ground annual - Flant Systems	1015		20.0%	20.0%		-13.0%		5.0%
Ground source neat pump system	IVI3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				50.0%			0.8%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	6.4%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.9	15.9	8.5	0.8	3.1	18.5	51.8
Final Energy Use Breakdown as Percentage of Baseline Use		5%	16%	8%	1%	3%	18%	49%
Building Operating Facto	r 0.90			100.0	CBECS Baselin	e EUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.05			60%	target reduction	on from CBECS		
· · · · ·				Achioucomontu	TARCET REDU		-	
Tatal Daduard FUL (DTU/	100			Achievement:	TARGET REDU			
	48.6			51%	percent reduc	tion from CBECS		
				54%	percent reduc	tion from Norma	alized Baseline	BIDE
Total reduced energy u	ise (kWh)	2,066,972						
Number of crystaline panel	s needed	7,889						
Total kW of	PV array	1617						
DV Danal Analysis	y							
PV Panel Analysis:			1	1	1	1		
From KEIScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area	4-65			
205 punei, jucing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
	09	252 770	0470	20.000	2114	4		
	0	252.778	81/8	38,800	3111	+		
	15"	272.61	/583		0	-		
optimal angle	: 35.0°	286.98	7203	22.555	0	4		
	45°	284.06	7277	33,590	2693	4		
	90°	205.17	10075		0	J		
				Total kWh =	1,551,366			
Additional Parking Garage Offset Needed			Additional area	26,010	2085	Parking lot		
			Additional k	Wh Produced	527,042	2,078,408		



# SCHOOL K-8 BOSTON mixed



# ENERGY USE INDEX

COST PREMIUM PAYBACK COST PER SF PHOTOVOLTAIC CAPACITY WATER USE

80,000 gal 148,981 sf 2 floors 39.03 acres 74,470 sf 97,650 sf

RAINWATER TANK SIZE BUILDING SIZE BUILDING HEIGHT SITE AREA PHOTOVOLTAIC AREA ROOF AREA





- ✓ Reorganize plan to eliminate N/S portions of classrooms wings.
- Remove windows below 2'-6" in classrooms.
- Remove windows below 2'-0" in corridors.
- Tune glazing to have high performance glass at vision glass only.
- Reconfigure roof at clerestory.
- Add metal roofing for clipping of PV at classroom and gym.
- ✓ Eliminate windows on West and East facades at classrooms.



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =148,981Living Building Gross SF =148,981Site Gross Acreage =39.03

		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living B	uilding
				Total	Cost/SF	Total	Cost/SF
СС	INSTRUCTION COST						
Δ	Substructure	10.3%	0.5%	\$1 466 210	\$9.84	\$1 616 944	\$10.85
~	Paseline Ruilding	10.376	0.376	\$1,466,210	\$0.94	\$1,466,210	¢0.03
	Bainwater Containment - 80 000 gal Bainwater Tank			ψ1, <del>4</del> 00,210	φ9.0 <del>4</del>	\$150,734	\$9.04 \$1.01
						<b>.</b> ,	ψ1.01
в	Shell	0.9%	0.3%	\$9,540,845	\$64.04	\$9,627,945	\$64.63
	Baseline Building			\$9,540,845	\$64.04	\$9,540,845	\$64.04
D3	Lower Roof at Media Center (at both links)					(\$248,400)	(\$1.67)
D3	Reallocate South Wing (move SF to east-west wings)					(\$69,000)	(\$0.46)
E1A	Improved Glazing (reduce solar heat gain at vision only)					\$22,000	\$0.15
E1B	Exterior Shading Devices (credit reflecting PV as shading element)					(\$30,000)	(\$0.20)
M2H	"High Mass" Concrete Inside Insulation (CMU to replace metal stud plus added r	reflective skir	ו)			\$467,700	\$3.14
D2B	Reduce Overhang above Clerestory Glazing					(\$55,200)	(\$0.37)
с	Interiors	3.1%	0.5%	\$4.624.290	\$31.04	\$4.765.608	\$31.99
	Baseline Building			\$4,624,290	\$31.04	\$4,624,290	\$31.04
M2D	Carpet Reduction (replace with RetroPlate)				<i>\\</i> 0.1101	\$108.466	\$0.73
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$148,981	\$1.00
L1A	Exposed Ceilings (white matte surfaces)					(\$116,128)	(\$0.78)
<b>D.</b> 1	Services - Conveying Systems	0.0%	0.0%	\$100,000	\$0.67	\$100,000	\$0.67
	Baseline Building			\$100,000	\$0.67	\$100,000	\$0.67
D.2	2 Services - Plumbing Systems	10.4%	0.5%	\$1,438,830	\$9.66	\$1,588,830	\$10.66
	Baseline Building			\$1,438,830	\$9.66	\$1,438,830	\$9.66
W6	Low-Flow Fixtures / Optical Sensors					\$0	
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$1.01
D.3	3 Services - HVAC Systems	17.3%	2.1%	\$3,684,937	\$24.73	\$4,322,070	\$29.01
	Baseline Building			\$3,684,937	\$24.73	\$3,684,937	\$24.73
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,652,772)	(\$17.81)
M2A	In-Slab Radiant Heating and Cooling					\$744,905	\$5.00
M2L	Solar Wall Mechanical Screen					\$145,000	\$0.97
МЗА	Ground Source Heat Pump					\$2,304,000	\$15.47
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$80,000	\$0.54
M2C	Carbon Dioxide Sensors					\$16,000	\$0.11
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$345,589	\$2.32	\$345,589	\$2.32
	Baseline Building			\$345,589	\$2.32	\$345,589	\$2.32
D.5	5 Services - Electrical Systems	6.6%	0.7%	\$3.044.694	\$20.44	\$3,246,194	\$21.79
2.0	Baseline Building			\$3,044,694	\$20.44	\$3,044,694	\$20.44
PA	Occupancy Sensor to Outlets					\$5,000	\$0.03
PE	High Efficiency Transformers					\$97,500	\$0.65
LIC	Daylight Controls (continuous dimming 15' from perimeter)					\$23,800	\$0.16
L2F	Dimmable Direct/Indirect fixtures					\$47,500	\$0.32
L2B	Occupancy Sensor for Lighting (closed office / conference spaces)					\$0	
L2C	Individual Light Level Control (open spaces, classrooms)					\$5,200	\$0.03
L2E	Occupancy Sensor for Transient and Egress Lighting					\$22,500	\$0.15

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

			Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
					Total	Cost/SF	Total	Cost/SF
Е	Equipment and Furnishings		0.0%	0.0%	\$1,555,517	\$10.44	\$1,555,517	\$10.44
	Baseline Building				\$1,555,517	\$10.44	\$1,555,517	\$10.44
F	Special Construction		0.0%	0.0%	\$58,000	\$0.39	\$58,000	\$0.39
	Baseline Building				\$58,000	\$0.39	\$58,000	\$0.39
G	Sitework		1.6%	0.2%	\$3,701,152	\$24.84	\$3,761,152	\$25.25
	Baseline Building				\$3,701,152	\$24.84	\$3,701,152	\$24.84
W4	Stormwater Retention / Building Water Discharge						\$50,000	\$0.34
E1B	Trees for shading						\$10,000	\$0.07
W1	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
н	Logistics		0.0%	0.0%	\$524,694	\$3.52	\$524,694	\$3.52
	Baseline Building				\$524,694	\$3.52	\$524,694	\$3.52
Liv	ing Building Prerequisites				\$6 208	\$0.04	\$637 472	\$4 28
	PR5 - Materials Red List		100.0%	0.9%	<i><b>40,200</b></i>		\$275,991	\$1.85
	PR7 - Responsible Industry		100.0%	0.2%			\$66,413	\$0.45
	PR8 - Appropriate Materials / Services Radius		100.0%	1.0%			\$288,860	\$1.94
	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$6,208	\$0.04	\$6,208	\$0.04
						•		•
Su	btotal Direct Costs			6.8%	\$30,090,966	\$201.98	\$32,150,016	\$215.80
	General Conditions 3.	7%	6.8%	0.2%	\$1,098,511	\$7.37	\$1,173,679	\$7.88
	Fee, Contingency, Insurance, Bonding 9.	6%	6.8%	0.7%	\$3,009,051	\$20.20	\$3,214,953	\$21.58
	Location Modifier for BOSTON, MA 1.	.12	6.8%	0.9%	\$4,103,823	\$27.55	\$4,384,638	\$29.43
то	TAL MODIFIED CONSTRUCTION COST			6.8%	\$38,302,351	\$257.10	\$40,923,286	\$274.69

# BUILDING TYPE: ELEMENTARY SCHOOL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 148,981 Living Building Gross SF = 148,981

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.7%			\$200,000	\$1.34
PV1 Photovoltaic Panels and Infrastructure	1,224,000	) Watts		100.0%	30.5%			\$9,180,000	\$61.62
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.6%			\$195,150	\$1.31
PR6 - Construction Carbon Footprint	4,400	tons		100.0%	0.2%			\$48,400	\$0.32
PR15 - Beauty and Spirit (included in A/	E fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,000	\$0.42
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	18.3%	6.5%	\$10,724,658	\$71.99	\$12,686,219	\$85.15
Architecture & Engineering		7.00%	9.00%	37.4%	3.3%	\$2,681,165	\$18.00	\$3,683,096	\$24.72
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-15.3%	\$0		(\$4,590,000)	(\$30.81)
SDC Credits	50%			-100.0%	-2.8%	\$0		(\$848,565)	(\$5.70)
TOTAL OWNER & DESIGN-BUILD COSTS					53.8%	\$13,405,823	\$89.98	\$20,617,299	\$138.39

TOTAL CONCEPTUAL COST: \$51,708,174 \$347.08 \$61,540,585 \$413.08

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 17% TO 22% ELEMENTARY SCHOOL IN BOSTON, MA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# ElementarySchool

# Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 77.6

### Normalized Baseline Energy Use (kWh) 3,205,369

Impact of Design Changes (see sketches) 0.96

Adjusted Baseline EUI (kBtu/SF) 74.5

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perc	ent of load	16%	44%	8%	2%	12%	17%	100%
	calc'd EUI	12.0	33.1	6.0	1.7	8.9	12.8	74.5
Energy Conservation Measures:								
Glazing	E1		4.0%	9.0%		3.5%		2.9%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		9.0%	4.0%		3.0%		4.7%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance auide	E2b							
Davlighting (incorporates tuned glazing/shading)	11	75.0%	-5.6%	7 5%		1 1%		10.3%
Ton doulighting with skulights	116	75.070	5.070	7.570		1.170		10.570
Devlight controls (continuous dimming)								
Duyingni controls (continuous uninining)	LIC							
Orient windows to allow for illumination of teaching wall	Lit							
Lighting	L2	9.8%	-0.7%	1.0%		0.1%		1.3%
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dimmable direct / indirect fixtures	L2f							
Occupancy sensor / time clock for corridor lighting	L2j							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	3.7%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Ph							
Remove nhantom load / transformers	Pd							
Energy efficient main transformer	Ro							
Occurrent huw in / nersonal anargy hydrot	Df.							
Controlized newer management	PI							
Centralized power management	rg			7.00/				0.40/
Niechanicai - Schedule	1/14			7.0%				0.1%
Change of work hours (summer hours)	M4a							
Shift uses for time of day in summer (east vs west)	M4b							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.9%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		84.8%	9.8%	36.0%	0.0%	10.6%	25.0%	26.4%
Subtotal Reduced EUI (kBTU/SF)		1.8	29.9	3.8	1.7	8.0	9.6	54.8
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		14.5%
Radiant heatina/coolina w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2h							
Demand-based ventilation	M2c							
Minimize carpet (inculates against radiant system)	Mad							
Network was tile tiese and a windows	IVIZU							
Natural ventilation: operable windows	IVIZe							
Fan assisted natural ventilation	M2f							
SolarWall mechanical screen or SolarDuct (pre-heat air)	M2I							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	14.5%
Subtotal Reduced EUI (kBTU/SF)		1.8	25.4	3.1	1.7	2.4	9.6	43.9
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		7.2%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				50.0%			1.1%
Low flow fixtures (showers, lavs, sinks)	Wh							
Water heating from water to water heat pump (ashp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	8.3%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		1.8	20.3	2.4	0.8	2.8	9.6	37.8
Final Energy Use Breakdown as Percentage of Baseline Use		2%	27%	3%	1%	4%	13%	49%
Building Operating Fact	or 0.90			83.1	CBECS Baselin	ie EUI (kBTU/sf)		
Impact of Interactive ECM effect	ts 1.05			60%	target reducti	on from CBECS		
				Achievement:	TARGET REDU	JCTION NOT ME	т	
Total Reduced EUI (kBTU/s	f) 35.7			57%	percent reduc	tion from CBECS	5	
	,			54%	percent reduc	tion from Norm	alized Baseline	Bldg
Total reduced energy	use (kWh)	1.475.601						
	use (ittrii)	1,175,001						
Number of existeline new	le noodod	F 071						
Number of crystaline pane	els needed	5,971						
Total kW c	or PV array	1224						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kW/b per	Total papels	Input Area				
205 panel, facing South (azimuth 0°)	angle	nanol	needed at °	(ce)	# of Panels			
		parier	neeueu at	(31)				
	0°	252.778	5838	74,470	5971			
	15°	272.61	5413		0			
optimal ang	e: 35.0°	286.98	5142		0			
	45°	284.06	5195		0			
	90°	205.17	7193		0			
				Total kWh =	1,509,337			





# LIVING BUILDING DESIGN MODIFICATION

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 35,776 Living Building Gross SF = 35,776

Site Gross Acreage = 3.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

со	NSTRUCTION COST						
^	Substructure	0 1%	0.8%	\$625,802	\$17.40	\$692.091	\$10.00
^		3.170	0.0 /6	\$625,892	\$17.49	\$625,892	\$17.09
W2	Rainwater Containment - 26.000 gal Rainwater Tank			+,	ψ17.45	\$57,089	\$1.60
в	Shell	21.6%	9.2%	\$3,237,848	\$90.50	\$3,937,735	\$110.07
	Baseline Building			\$3,237,848	\$90.50	\$3,237,848	\$90.50
M2E	Operable Windows (manual)					\$31,680	\$0.89
D3C	Reallocate Glazing from East and West Façade to South (less spandrel panel, n	nore skin)				(\$17,472)	(\$0.49)
L1B	Replace Roofing with Glazed Skylight					\$207,000	\$5.79
E1A	Exterior Shading Devices (windows and louvers at entry)					\$70,104 \$70,460	\$0.45 \$1.97
E1D	Added Wall / Skin for Modified Design (not in base building design)					\$274,560	\$7.67
M2H	"High Mass" Concrete Inside Insulation (added reflective skin)					\$49,500	\$1.38
D2B	Modifications to Roof Structure					\$39,255	\$1.10
L1D	Interior Light Shelves (remove from N/E/W, keep south only)					\$28,800	\$0.81
С	Interiors	17.2%	2.4%	\$1,076,571	\$30.09	\$1,261,402	\$35.26
	Baseline Building			\$1,076,571	\$30.09	\$1,076,571	\$30.09
M2D	Carpet Reduction (replace with RetroPlate)					\$25,500	\$0.71
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$48,264	\$1.35
L1A	Exposed Ceilings (white matte surfaces)					(\$68,213)	(\$1.91)
D3	Glass partitions in lieu of gypsum waliboard					φ179,200	\$5.01
D.1	Services - Conveying Systems	0.0%	0.0%	\$55,000	\$1.54	\$55,000	\$1.54
	Baseline Building			\$55,000	\$1.54	\$55,000	\$1.54
	Comisso Diverting Contemp	70.00/	0.0%	¢000.054	¢5 00	¢000.454	¢40.40
D.2	Services - Plumbing Systems	73.8%	2.0%	\$208,354	\$5.82	\$362,154	\$10.12
14/0	Baseline Building			\$206,354	\$5.82	\$206,354 \$3,800	\$5.82 ¢0.11
00V	Pain Harvesting (pining & pumps and filtration)					\$150,000	Φ0.11 \$4.10
VVZ	Kain Harvesting (piping & pumps and initiation)					φ100,000	<b>\$4.19</b>
D.3	Services - HVAC Systems	91.2%	7.1%	\$591,095	\$16.52	\$1,130,075	\$31.59
	Baseline Building			\$575,095	\$16.07	\$575,095	\$16.07
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$300,000)	(\$8.39)
M2A	In-Slab Radiant Heating and Cooling					\$178,880	\$5.00
МЗА	Ground Source Heat Pump					\$554,100	\$15.49
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$106,000	\$2.96
M2C	Carbon Dioxide Sensors			\$16,000	\$0.45	\$16,000	\$0.45
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$75.177	\$2.10	\$75.177	\$2.10
	Baseline Building			\$75,177	\$2.10	\$75,177	\$2.10
	-						
D.5	Services - Electrical Systems	6.5%	0.6%	\$723,416	\$20.22	\$770,116	\$21.53
	Baseline Building			\$603,016	\$16.86	\$603,016	\$16.86
PA	Occupancy Sensor to Outlets					\$10,200	\$0.29
PE	High Efficiency Transformers			¢27.000	<b>MA 75</b>	\$35,500 \$27,000	\$1.02
L1C	Daylight Controls (continuous dimming 15' from perimeter)			φ∠7,000 \$67,600	\$0.75 ¢1.00	- 927,000 \$67,600	\$0.75
L2A	Enrotent Light Fixture Optics Memium			\$12 000	\$0.34 \$1.89	\$12 000	\$0.34 \$1.89
12B	Occupancy Sensor for Transient and Earess Lighting			\$13.800	\$0.34 \$0.39	\$13,800	\$0.34 \$0.39
LZĽ	Company densition management and Lyress Lighting			ψ10,000	ψ0.59	ψ10,000	ψ0.59

3.BOS.176 CASCADIA REGION GREEN BUILDING COUNCIL/SERA ARCHITECTS/SKANSKA USA BUILDING/GERDING EDLEN /INTERFACE ENGINEERING/NEW BUILDINGS INSTITUTE

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =35,776Living Building Gross SF =35,776Site Gross Acreage =3.24

		Division Premium (%)	Building Premium (%)	ing ium LEED™ Gold Baseli		Living Building	
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$149,348	\$4.17	\$149,348	\$4.17
Baseline Building				\$149,348	\$4.17	\$149,348	\$4.17
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		7.6%	0.8%	\$791,671	\$22.13	\$851,671	\$23.81
Baseline Building				\$791,671	\$22.13	\$791,671	\$22.13
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$1.40
E1B Trees for shading						\$10,000	\$0.28
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$40,261	\$1.13	\$40,261	\$1.13
Baseline Building				\$40,261	\$1.13	\$40,261	\$1.13
Living Building Prerequisites				\$4,472	\$0.13	\$211,042	\$5.90
PR5 - Materials Red List		100.0%	1.0%			\$78,927	\$2.21
PR7 - Responsible Industry		100.0%	0.1%			\$10,732	\$0.30
PR8 - Appropriate Materials / Services Radius		100.0%	1.5%	<b>A</b> 4 4 <b>T</b> A	• • • • •	\$116,911	\$3.27
PR9 - Leadership in Construction Waste		0.0%	0.0%	\$4,472	\$0.13	\$4,472	\$0.13
Subtotal Direct Costs			25.7%	\$7,579,106	\$211.85	\$9,526,963	\$266.29
General Conditions	4.0%	25.7%	1.0%	\$303,164	\$8.47	\$381,079	\$10.65
Fee, Construction Contingency, Insurance	3.0%	25.7%	0.8%	\$238,965	\$6.68	\$300,380	\$8.40
Location Modifier for BOSTON, MA	1.12	25.7%	3.3%	\$974,548	\$27.24	\$1,225,011	\$34.24
TOTAL MODIFIED CONSTRUCTION COST			25.7%	\$9,095,784	\$254.24	\$11,433,431	\$319.58

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# BUILDING TYPE: LOWRISE OFFICE / CLASSROOMS BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 35,776 Living Building Gross SF = 35,776

Site Gross Acreage = 3.24

D P	Division remium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.5%			\$40,000	\$1.12
PV1 Photovoltaic Panels and Infrastructure	564,000	Watts		100.0%	55.8%			\$4,230,000	\$118.24
LB Prerequisite Items									
PR3 - Habitat Exchange	3.24	acres		100.0%	0.2%			\$16,200	\$0.45
PR6 - Construction Carbon Footprint	2,700	tons		100.0%	0.4%			\$29,700	\$0.83
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.3%			\$23,500	\$0.66
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	39.2%	13.2%	\$2,546,819	\$71.19	\$3,544,364	\$99.07
Architecture & Engineering		9.38%	11.38%	52.5%	5.9%	\$852,730	\$23.84	\$1,300,553	\$36.35
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-27.9%	\$0		(\$2,115,000)	(\$59.12)
SDC Credits	50%			-100.0%	-3.1%	\$0		(\$231,353)	(\$6.47)
TOTAL OWNER & DESIGN-BUILD COSTS					101.1%	\$3,399,549	\$95.02	\$6,837,964	\$191.13

TOTAL CONCEPTUAL COST: \$12,495,333 \$349.27 \$18,271,395 \$510.72

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: LOWRISE OFFICE / CLASSROOMS IN BOSTON, MA TO 49%

44%

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# MidRiseOffice

Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 93.3

Normalized Baseline Energy Use (kWh) 929,563

Impact of Design Changes (see sketches) 1.03

Adjusted Baseline EUI (kBtu/SF) 95.6

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
per	rcent of load	17%	32%	20%	3%	9%	18%	100%
	calc'd EUI	16.1	30.2	19.1	3.1	9.0	17.7	95.2
Energy Conservation Measures:								
Glazing	E1		12.0%	7.5%		4.7%		5.7%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		10.0%	3.0%		2.9%		4.0%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		8.3%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		4.1%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/low occucp	anc L2b							
Individual light level control (dimming) at open office areas	L2C							
Light colors on wans, centrig surjaces	L2d							
Dicupuncy sensors, transient lighting (corridors/stairs/butinns)	LZE		1.09/	2 50/		0.49/	25.0%	4 60/
Cosupancy consor controlled plug locate	P		-1.9%	2.3%		0.4%	25.0%	4.0%
EnergyStar appliances	Pa							
Chergystul uppliulites	PD							
Remove phantom load / transformers	PC							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pø							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.8%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75.0%	19.5%	25.5%	0.0%	11.6%	25.0%	29.6%
Subtotal Reduced EUI (kBTU/SF)		4.0	24.3	14.2	3.1	7.9	13.3	66.9
Mechanical - Distribution & Ventilation	M2		25.0%	20.0%		70.0%		15.2%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	25.0%	20.0%	0.0%	70.0%	0.0%	15.2%
Subtotal Reduced EUI (kBTU/SF)		4.0	18.2	11.4	3.1	2.4	13.3	52.4
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		5.8%
Ground source neat pump system	M3a							
Cascading chilled water system	IVI3D							
Domestic Hot water	W				50.0%			1.6%
Low flow fixtures (showers, lavs, sinks)	Wb							
Subtotal from Mechanical Plant and DHW systems (percentage)	VVC	0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	7 5%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	14.6	9.1	1.6	2.7	13.3	45.3
Final Energy Use Breakdown as Percentage of Baseline Use		4%	15%	10%	2%	3%	14%	52%
Building Operating Fac	tor 0.90			92.9	CBECS Baselin	ne EUI (kBTU/sf)		
Impact of Interactive ECM effe	cts 1.07			60%	target reduct	ION FROM CBECS		
				Achievement:	TARGET RED	JCTION NOT ME	Т	
Total Reduced EUI (kBTU/	/sf) 43.6			53%	percent redu	ction from CBECS	S alized Deceline	Dida
Total reduced energy	uco (kWh)	124 611		53%	percent redu	LUON ITOTTI NOTTI	alizeu baseline	ыағ
Total reduced energy	use (kwii)	454,011						
Number of crystaline par	els needed	1,608						
Total kW	of PV array	330						
PV Panel Analysis:	unay							
From RETScreen 4-1; method 2, 2% misc losses, 90% inverter efficiency, assumes Sanvi	o-	1.1.4				1		
205 panel, facing South (azimuth 0°)	1 1	кwn per	i otai panels	Input Area	# of Panels			
	angle	mar - I	nood ^ ^	1001				
	angle	panel	needed at °	(SF)		_		
	angle 0°	panel	needed at °	(SF) 720	57	-		
	angle 0° 15°	panel 252.778 272.61	needed at ° 1720 1595	(SF) 720 19,350	57 1551	-		
optimal ang	angle 0° 15° gle: 35.0°	panel 252.778 272.61 286.98 284.06	needed at ° 1720 1595 1515 1530	(SF) 720 19,350	57 1551 0	-		
optimal ang	angle 0° 15° gle: 35.0° 45°	panel 252.778 272.61 286.98 284.06 205.17	needed at ° 1720 1595 1515 1530 2119	(SF) 720 19,350	57 1551 0 0			

Total kWh = 437,226



# MID RISE OFFICE BOSTON mixed



- Reconfigure floor plan so all spaces are within 30' of an operable window.
- Add an atrium to for improved daylighting
- ✓ Slope the roof 20° for maximum PV production.
- Provide 5th level on north side to provide for additional area.
- ✓ Add PV sunshades
- Relocate windows on West and East to North and South - glass area to remain the same.
- ✓ Add fins at center bay windows.
- Additional parking lot cover for PV.









# LIVING BUILDING DESIGN MODIFICATION

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

Division Building

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: BOSTON, MA

# SKANSKA

# Base Building Gross SF = 99,385

Living Building Gross SF = 99,385

Site Gross Acreage = 5.24

	Premium (%)	Premium (%)	LEED™ Gold	Baseline	Living Building	
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	4.2%	0.3%	\$1,420,795	\$14.30	\$1,480,883	\$14.90
Baseline Building			\$1,420,795	\$14.30	\$1,420,795	\$14.30
W2 Rainwater Containment - 26,000 gal Rainwater Tank					\$60,089	\$0.60
B Shell	7.4%	2.7%	\$7,159,737	\$72.04	\$7,686,669	\$77.34
Baseline Building			\$7,159,737	\$72.04	\$7,159,737	\$72.04
M2E Operable Windows (manual)					\$61,920	\$0.62
D3C Reallocate Glazing from East and West Façade to South (less spandrel panel	l, more skin)				(\$48,115)	(\$0.48)
L1B Replace Roofing with Glazed Skylight					\$168,750	\$1.70
E1A Improved Glazing (reduce solar heat gain)					\$42,098	\$0.42
E1B Exterior Shading Devices					(\$207,300)	(\$2.09)
D2A Added Wall / Skin for Modified Design (not in base building design)					\$365,040	\$3.67
D2B Modifications to Roof Structure					\$52,539	\$0.53
L1D Interior Light Shelves					\$92,000	\$0.93
C Interiors	10.4%	2.0%	\$3,724,311	\$37.47	\$4,113,078	\$41.39
Baseline Building			\$3,724,311	\$37.47	\$3,724,311	\$37.47
M2D Carpet Reduction (Corridors Carpeted Only)					\$99,385	\$1.00
M2A Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$149,078	\$1.50
L1A Exposed Ceilings (white matte surfaces)					(\$210,696)	(\$2.12)
L1B Atrium Space (smoke curtain, glazing, guardrails)					\$351,000	\$3.53
D.1 Services - Conveying Systems	24.1%	0.3%	\$207,466	\$2.09	\$257,466	\$2.59
Baseline Building			\$207,466	\$2.09	\$207,466	\$2.09
D3 Added Stop for 5th Floor					\$50,000	\$0.50
D.2 Services - Plumbing Systems	18.5%	0.8%	\$838,297	\$8.43	\$993,097	\$9.99
Baseline Building			\$838,297	\$8.43	\$838,297	\$8.43
W6 Low-Flow Fixtures / Optical Sensors					\$4,800	\$0.05
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$1.51
D.3 Services - HVAC Systems	77.7%	6.8%	\$1,725,708	\$17.36	\$3,067,098	\$30.86
Baseline Building			\$1,689,708	\$17.00	\$1,689,708	\$17.00
Baseline HVAC System					(\$938,935)	(\$9.45)
M2A In-Slab Radiant Heating and Cooling					\$496,925	\$5.00
M3A Ground Source Heat Pump					\$1,621,400	\$16.31
M2B Energy Recovery Wheel / Plate & Frame					\$198,000	\$1.99
M2C Carbon Dioxide Sensors			\$36,000	\$0.36		
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$272,482	\$2.74	\$272,482	\$2.74
Baseline Building			\$272,482	\$2.74	\$272,482	\$2.74
D.5 Services - Electrical Systems	12.9%	1.5%	\$2,307,176	\$23.21	\$2,604,676	\$26.21
Baseline Building			\$2,024,176	\$20.37	\$2,024,176	\$20.37
PA Occupancy Sensor to Outlets					\$42,000	\$0.42
PE High Efficiency Main Transformer					\$43,000	\$0.43
L1C Daylight Controls (continuous dimming 15' from perimeter)			\$37,000	\$0.37	\$37,000	\$0.37
L2A Efficient Light Fixture Optics Premium			\$190,000	\$1.91	\$190,000	\$1.91
L2B Occupancy Sensor for Lighting (closed office / conference spaces)			\$22,000	\$0.22	\$22,000	\$0.22
L2C Individual Light Level Control (open spaces)					\$212,500	\$2.14
L2E Occupancy Sensor for Transient and Egress Lighting			\$34,000	\$0.34	\$34,000	\$0.34

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =99,385Living Building Gross SF =99,385Site Gross Acreage =5.24

	Division Premium (%)	Building Premium (%)	ling ium LEED™ Gold Base )		Living Building	
			Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings	0.0%	0.0%	\$472.675	\$4.76	\$472.675	\$4.76
Baseline Building			\$472,675	\$4.76	\$472,675	\$4.76
F Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
G Sitework	68.0%	5.0%	\$1,465,612	\$14.75	\$2,462,362	\$24.78
Baseline Building			\$1,465,612	\$14.75	\$1,465,612	\$14.75
W4 Stormwater Retention					\$50,000	\$0.50
D3 Parking revisions (pervious, deletion of piping, deletion of AC, lighting)					\$91,750	\$0.92
D3 Shading Structure over Parking with Rain Collection Piping (45,000 sf)					\$855,000	\$8.60
H Logistics	0.0%	0.0%	\$219 209	¢2.20	\$219 209	¢2.20
	0.0%	0.0%	\$218,290	\$ <b>2.20</b>	\$218,290	\$2.20
baseline building			φ210,290	φ2.20	φ210,290	φ2.2U
Living Building Prerequisites			\$4,141	\$0.04	\$537,491	\$5.41
PR5 - Materials Red List	100.0%	1.1%			\$208,500	\$2.10
PR7 - Responsible Industry	100.0%	0.2%			\$30,181	\$0.30
PR8 - Appropriate Materials / Services Radius	100.0%	1.5%			\$294,669	\$2.96
PR9 - Leadership in Construction Waste	0.0%	0.0%	\$4,141	\$0.04	\$4,141	\$0.04
Subtotal Direct Costs		21.9%	\$19,816,699	\$199.39	\$24,166,275	\$243.16
General Conditions 4 0%	21.9%	0.9%	\$792 668	\$7 08	\$966 651	\$9.73
Fee Construction Contingency Insurance 8.0%	21.9%	1.8%	\$1.648.749	\$16.59	\$2.010.634	\$20.23
Location Modifier for BOSTON, MA 1.12	21.9%	3.0%	\$2,670,974	\$26.88	\$3,257,227	\$32.77
			<b>AA A AA A A A</b>	4050.65		
TOTAL MODIFIED CONSTRUCTION COST		21.9%	\$24,929,091	\$250.83	\$30,400,788	\$305.89

# BUILDING TYPE: MIDRISE OFFICE BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 99,385 Living Building Gross SF = 99,385

Site Gross Acreage = 5.24

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Membrane Bio-Reactor				100.0%	0.3%			\$60,000	\$0.60
PV1 Photovoltaic Panels and Infrastructure	944,000	Watts		100.0%	35.7%			\$7,080,000	\$71.24
LB Prerequisite Items									
PR3 - Habitat Exchange	5.24	acres		100.0%	0.1%			\$26,200	\$0.26
PR6 - Construction Carbon Footprint	2,600	tons		100.0%	0.1%			\$28,600	\$0.29
PR15 - Beauty and Spirit (included in A/E f	ees above)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$43,500	\$0.44
Development Costs		LEED	LBC						
Develoment Costs		13.06%	16.06%	50.0%	8.2%	\$3,255,963	\$32.76	\$4,882,639	\$49.13
Architecture & Engineering		6.09%	8.09%	62.0%	4.7%	\$1,518,118	\$15.28	\$2,459,346	\$24.75
Credits / Rebates / Incentives									
Photovoltaic Credits-(state, city, utility)	50%			-100.0%	-17.9%			(\$3,540,000)	(\$35.62)
SDC Credits	50%		0.00%	-100.0%	-1.5%	\$0		(\$289,395)	(\$2.91)
TOTAL OWNER & DESIGN-BUILD COSTS					125.2%	\$4,774,081	\$48.04	\$10,750,890	\$108.17

TOTAL CONCEPTUAL COST: \$29,703,171 \$298.87 \$41,151,678 \$414.06

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	36%	то	41%	
MIDRISE OFFICE IN BOSTON, MA				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

# MidRiseOffice

#### Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 92.7

Normalized Baseline Energy Use (kWh) 2,691,133

Impact of Design Changes (see sketches) 1.03

Adjusted Baseline EUI (kBtu/SF) 95.	1
-------------------------------------	---

		DOM. HOT						
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
per	ent of load	17%	32%	20%	3%	9%	19%	100%
	calc'd EUI	16.1	30.2	19.0	3.1	8.6	17.7	94.6
Energy Conservation Measures:								
Glazing	F1		12.0%	7 5%		4 7%		5.7%
Improved Glazina	F1a							
Add effective shading devices	F1b							
Walls & Poof	53		10.0%	2.0%		2.0%		4.0%
Charled as of from color and a	52		10.0%	5.0%		2.970		4.076
Snadea roof from solar panels	EZa							
Optimize insulation to core performance guide	E2D							
Daylighting (incorporates tuned glazing/shading)	L1	50.0%	-3.8%	5.0%		0.8%		8.3%
Remove ceiling, raise window head, add lightshelf	L1a							
Top daylighting from Atrium	L1g							
Daylight controls (continuous dimming)	L1c							
Lighting	L2	25.0%	-1.9%	2.5%		0.4%		4.2%
Efficient fixture optics	L2a							
Individual occupancy sensors & dimming controls: closed offices/lowL2b								
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	4.6%
Occupancy sensor controlled plug loads	Pa		2.570	2.370		0.470	20.070	
EnergyStar annliances	Ph							
Ontimize printer loyout/use	P.U De							
Remove phantom load / transformarc	PC							
Remove phantom load / transjormers	Ра							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	PT							
Centralized power management	Pg							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.8%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		75.0%	19.5%	25.5%	0.0%	11.6%	25.0%	29.7%
Subtotal Reduced EUI (kBTU/SF)		4.0	24.3	14.2	3.1	7.6	13.3	66.4
Mechanical - Distribution & Ventilation	M2		25.0%	20.0%		70.0%		14.9%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Ean assisted natural ventilation	M2f							
Subtotal from Machanical Distribution stratogics (percentage)		0.0%	25 0%	20.0%	0.0%	70.0%	0.0%	1/ 00/
Subtotal Poducod EIII /kPTII/CE)		1.0	10 2	11.2	2 1	2.2	12 2	E2 2
Subtotal Reduced Edi (KB10/SF)		4.0	10.2	11.5	5.1	2.5	15.5	52.2
iviecnanicai - Plant Systems	1113		20.0%	20.0%		-15.0%		5.9%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				50.0%			1.6%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from water to water heat pump (gshp)	Wc							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	7.5%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		4.0	14.6	9.1	1.6	2.6	13.3	45.1
Final Energy Use Breakdown as Percentage of Baseline Use		4%	15%	10%	2%	3%	14%	52%
Building Operating Factor Impact of Interactive ECM effects		0.90		92.9	CBECS Baselin	ne EUI (kBTU/sf)		
		1.07	60% target reduction from CBECS					
			Achievement: TARGET REDUCTION NOT MET					
Total Reduced EUI (kBTU/sf)				53%	percent reduc	tion from CBECS		
				53%	percent reduc	tion from Norm	alized Baseline	Bldg
Total reduced energy use (MMh)		1 260 045		5576	percentreduc		Lizea Baseine	5.05
Total reduced energy	use (kwiii)	1,200,045						
Number of crystaline panels needed								
Total kW of PV array		930						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency,		kW/b per	Total papels	Input Area				
assumes Sanyo-205 panel, facing South (azimuth 0°)	angle	kwii pel	nooded at 9	/cr/	# of Panels			
		panei	needed at *	(31)		_		
	0°	252.778	4985		0	_		
	15°	272.61	4623	32,723	2624			
optimal ang	e: 35.0°	286.98	4391	23,871	1914			
	45°	284.06	4436		0			

Total kWh = 1,264,608
- Extend atrium down level to allow access operable windows for workstations.
- Provide additional 1 level to make up for area lost with insert of atrium.
- Change curved roof to maximize PV prod tion.
- ✓ Add PV sun shades of South.
- Add PV to adjacent p ing garage to offset the parking garage l and the building's lo



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# **MIXED USE RENOVATION** BOSTON mixed



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Total Cost/SF		Cost/SF

CON	ISTRUCTION COST						
Δ 9	Substructure	0.0%	0.0%	\$579,458	\$3.13	\$579.458	\$3.13
	Baseline Building			\$579,458	\$3.13	\$579,458	\$3.13
W2	Rainwater Containment - 30,000 gal Rainwater Tank (included in base)			. ,	••••	\$0	••••
в	Shell	19.1%	5.2%	\$8,421,922	\$45.51	\$10,033,922	\$54.22
	Baseline Building			\$8,421,922	\$45.51	\$8,421,922	\$45.51
M2E	Operable Windows (manual, additional units beyond existing) Replace Reofing with Clazed RV Frit Skulight					\$32,000 \$172,125	\$0.17
	Improved Glazing (reduce solar beat gain)					\$25,000	\$0.93 \$0.14
E1A	Exterior Shading Devices (PV as shading on South)					\$109.375	\$0.14
L1D	Raise Window Head / Add Light Shelf (RAF removed)					\$0	<b>\$0.00</b>
M2H	"High Mass" Concrete Inside Insulation (not included because this is a renovation)					\$0	
D2B	Modifications to Roof Structure and Roofing					\$99,000	\$0.54
E2C	Structure to Mount PV on Adjacent Parking Structure					\$484,500	\$2.62
D3	Renovation Work at Atrium (demo floor, railings, interior walls, structure for balcony)					\$150,000	\$0.81
D3	Added SF for Additional Floor (at penthouse)					\$240,000	\$1.30
D2A	Added Wall / Skin for Modified Design (not in base building design)					\$300,000	\$1.62
L1D	Interior Light Shelves (not included)					\$0	
сı	nteriors	2.1%	0.5%	\$7,723,877	\$41.74	\$7,883,877	\$42.61
	Baseline Building			\$7,723,877	\$41.74	\$7,723,877	\$41.74
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$270,000	\$1.46
M2D	Retroplate Topping Slab (at TI locations)					\$690,000	\$3.73
L1A	Exposed Ceilings (existing white matte surfaces)					\$0	
D3	Remove Raised Access Flooring					(\$800,000)	(\$4.32)
D.1	Services - Conveying Systems	0.0%	0.0%	\$385,400	\$2.08	\$385,400	\$2.08
	Baseline Building			\$385,400	\$2.08	\$385,400	\$2.08
D.2	Services - Plumbing Systems	19.4%	0.5%	\$791,454	\$4.28	\$945,254	\$5.11
	Baseline Building			\$791,454	\$4.28	\$791,454	\$4.28
W6	Low-Flow Fixtures / Optical Sensors					\$3,800	\$0.02
W2	Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.81
D.3	Services - HVAC Systems	11.2%	1.0%	\$2,767,999	\$14.96	\$3,078,918	\$16.64
	Baseline Building			\$2,767,999	\$14.96	\$2,767,999	\$14.96
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,470,281)	(\$13.35)
M2A	In-Slab Radiant Heating and Cooling					\$600,000	\$3.24
МЗА	Ground Source Heat Pump					\$2,030,200	\$10.97
M2B	Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$135,000	\$0.73
M2C	Carbon Dioxide Sensors					\$10,000	\$0.09
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$343,553	\$1.86	\$343,553	\$1.86
	Baseline Building			\$343,553	\$1.86	\$343,553	\$1.86
D.5	Services - Electrical Systems	24.1%	3.6%	\$4,539,215	\$24.53	\$5,631,885	\$30.44
	Baseline Building			\$4,571,685	\$24.71	\$4,571,685	\$24.71
PA	Occupancy Sensor to Outlets					\$47,200	\$0.26
PE	High Efficiency Transformers					\$158,000	\$0.85
L1C	Daylight Controls (continuous dimming 15' from perimeter)					¢070.000	<b>*</b> • • •
L2A	Efficient Light Fixture Optics Premium					\$270,000	\$1.46
L2B	Occupancy Sensor for Lighting (closed office / conference spaces)					\$585,000	\$2.16
L2C	Occupancy Sensor for Transient and Egress Lighting			(\$32.470)	(\$0.18)	\$0 \$0	φ <b>3.</b> 10
L2E	Occupancy Sensor for Transient and Egress Lighting			(\$32,470)	(\$0.18)	\$0	

### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
Γ							
E Equipment and Furnishings		0.0%	0.0%	\$2,061,480	\$11.14	\$2,061,480	\$11.14
Baseline Building			-	\$2,061,480	\$11.14	\$2,061,480	\$11.14
F Special Construction		0.0%	0.0%	\$1,407,188	\$7.60	\$1,407,188	\$7.60
Baseline Building				\$1,407,188	\$7.60	\$1,407,188	\$7.60
G Sitework		4.4%	0.2%	\$1,131,528	\$6.11	\$1,181,528	\$6.39
Baseline Building				\$1,131,528	\$6.11	\$1,131,528	\$6.11
W4 Stormwater Retention / Building Water Discharge						\$50,000	\$0.27
W1 Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
H Logistics		0.0%	0.0%	\$600,000	\$3.24	\$600,000	\$3.24
Baseline Building				\$600,000	\$3.24	\$600,000	\$3.24
							••••=
Living Building Prerequisites		400.0%	0.00/	\$3,855	\$0.02	\$733,817	\$3.97
PR5 - Materials Red List		100.0%	0.9%			\$276,063	\$1.49
PR7 - Responsible industry		100.0%	1.0%			\$35,507 \$315,010	\$0.30
PR0 - Appropriate Materials / Services Radius		2162.7%	0.3%	\$3,855	\$0.02	\$87 227	\$1.70 \$0.47
		2102.17	0.070	ψ0,000	φ0.02	ψ01,221	φ0.4 <i>1</i>
Subtotal Direct Costs			13.4%	\$30,756,929	\$166.22	\$34,866,280	\$188.42
Canaral Conditiona	4.0%	13 /0/	0.5%	\$1 230 277	¢c ce	\$1 304 651	¢7.54
General Conditions	4.0%	13.4%	0.5%	\$238.965	00.00 \$1.20	\$270,892	⊅7.04 \$1./6
Location Modifier for BOSTON, MA	1.12	13.4%	1.7%	\$3,867,141	\$20.90	\$4,383,819	\$23.69
TOTAL MODIFIED CONSTRUCTION COST			13.4%	\$36,093,312	\$195.05	\$40,915,642	\$221.11

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: MIXED-USE RENOVATION BUILDING LOCATION: BOSTON, MA



\$337.48

Base Building Gross SF =185,043Living Building Gross SF =185,043Site Gross Acreage =1.00

Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	0.2%			\$60,000	\$0.32
PV1 Photovoltaic Panels and Infrastructure	1,433,000	Watts		100.0%	34.9%			\$10,747,500	\$58.08
LB Prerequisite Items									
PR3 - Habitat Exchange	1	acres		100.0%	0.0%			\$5,000	\$0.03
PR6 - Construction Carbon Footprint	1,250	tons @ 50%		100.0%	0.0%			\$13,750	\$0.07
PR15 - Beauty and Spirit (included in A/E fe	es below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.2%			\$63,500	\$0.34
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	25.5%	8.4%	\$10,106,127	\$54.62	\$12,683,849	\$68.55
Architecture & Engineering		7.00%	9.00%	45.7%	3.8%	\$2,526,532	\$13.65	\$3,682,408	\$19.90
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-17.5%	\$0		(\$5,373,750)	(\$29.04)
SDC Credits	50%			-100.0%	-1.1%	\$0		(\$349,890)	(\$1.89)
TOTAL OWNER & DESIGN-BUILD COSTS					70.4%	\$12,632,659	\$68.27	\$21,532,367	\$116.36

TOTAL CONCEPTUAL COST: \$48,725,971 \$263.32 \$62,448,009

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 26% TO 31% MIXED-USE RENOVATION IN BOSTON, MA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### **Complex Mixed Use Renovation**

Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 104.6

### Normalized Baseline Energy Use (kWh) 4,447,053

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 101.0

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	ent of load	15%	37%	20%	3%	9%	16%	100%
Energy Conservation Measures	calc d EUI	15.1	57.1	20.1	2.9	9.1	10.0	101.0
Clasing	F.4		10.0%	10.00/		F 00/		6.40/
Giazing	E1		10.0%	10.0%		5.0%		6.1%
Add affective chading devices	E1d							
Walls & Poof	E10		15.0%	E 0%		1 90/		7 10/
Charled reaf from color namels	E2		15.0%	0.0%		4.8%		7.1%
Shuueu 100j Jiom solar punels Optimize insulation to core performance quide	EZd							
Device the second	E20	29.0%	2.0%	2.00/		0.6%		F 40/
Remove seiling, reise window head, add lightshelf	110	58.0%	-2.970	5.670		0.0%		5.470
Davlight controls (continuous dimming)	LId							
Elooralan renovation for daylighting	110							
Lighting	12	38 5%	-2.0%	3.0%		0.6%		5 5%
Efficient fixture ontics	120	56.570	-2.970	3.5%		0.0%		5.5%
Individual occupancy sensors & dimming controls: closed offices/low occupan	12b							
Individual light level control (dimming) at open office areas	L2c							
Light colors on walls, ceiling surfaces	L2d							
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
High color rendering metal halide retail lighting	L2h							
Plug Loads	Р		-1.9%	2.5%		0.4%	25.0%	4.0%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Optimize printer layout/use	Pc							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		3.1%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		76.5%	22.4%	31.2%	0.0%	13.8%	25.0%	31.2%
Subtotal Reduced EUI (kBTU/SF)		3.6	28.8	13.8	2.9	7.8	12.5	69.4
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		70.0%		12.4%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	NIZE							
Night flush	M2a							
High mass - concrete block on inside of insulation	M2b							
Programmable thermostats	M20							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	70.0%	0.0%	12.4%
Subtotal Reduced EUI (kBTU/SF)		3.6	24.5	11.1	2.9	2.3	12.5	56.9
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		6.7%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				50.0%			1.5%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	50.0%	-15.0%	0.0%	8.2%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.6	19.6	8.8	1.5	2.7	12.5	48.6
Final Energy Use Breakdown as Percentage of Baseline Use		4%	19%	9%	1%	3%	12%	52%
Building Operating Facto	r 0.90			92.9	CBECS Baseline	e EUI (kBTU/sf)		
Impact of Interactive ECM effect	s 1.05			60%	target reduction	on from CBECS		
				Achievement:	TARGET REDU	CTION NOT ME	Г	
Total Reduced EUI (kBTU/si	) 45.5			51%	percent reduct	tion from CBECS		
				57%	percent reduct	tion from Norma	alized Baseline	Bldg
Total reduced energy u	ise (kWh)	1,933,654						
Number of crystaline panel	s needed	7,697						
Total kW of	PV array	1578						
PV Panel Analysis								
From RETScreen 4-1' method 2 2% misc losses 90% inverter efficiency assumes Sanvo-	1 1			1	1			
205 panel, facing South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
, .,	5.0	panel	needed at °	(SF)				
	0°	252.778	7650	40,000	3207	Roof only		
	15°	272.61	7094		0	]		
optimal angle	: 35.0°	286.98	6738		0			
	45°	284.06	6808		0			
	90°	205.17	9425		0	]		
				Total kWh =	810,659			
Additional Parking Garage Offset Needed, EUI of 1.7			Additional area	56,000	4490			
			Additional k	Wh Produced	1,134,973	1,945,632		



# SINGLE FAMILY RESIDENTIAL BOSTON mixed



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =1,840Living Building Gross SF =1,840Site Gross Acreage =0.11

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
			Total	Cost/SF	Total	Cost/SF
A Substructure	0.0%	0.0%	\$63,527	\$34.53	\$63,527	\$34.53
Baseline Building			\$63,527	\$34.53	\$63,527	\$34.53
$_{\rm W2}~$ Rainwater Containment - 8,000 gal Rainwater Tank (included in base building)					\$0	
B Shell	13.7%	6.2%	\$131,226	\$71.32	\$149,258	\$81.12
Baseline Building			\$131,226	\$71.32	\$131,226	\$71.32
L1B Replace Roofing with Glazed Skylight					\$960	\$0.52
E1A Improved Glazing (reduce solar heat gain)					\$4,303	\$2.34
E1B Exterior Shading Devices					\$10,800	\$5.87
D3 Retaining Wall / Footings (house into hill)					\$18,000	\$9.78
D3 Modify Building to Single Story					(\$16,031)	(\$8.71)
C Interiors	14.4%	1.9%	\$37,430	\$20.34	\$42,810	\$23.27
Baseline Building			\$37,430	\$20.34	\$37,430	\$20.34
M2A Thicken Lower Level Slab (2") and Gypcrete on Upper Level				•	\$4,350	\$2.36
L1A Exposed Ceilings (white matte surfaces)					\$0	
D3 Additional Railings and Beams (including credit for modified stair railing)					\$1,030	\$0.56
D.1 Services - Conveying Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0	•	\$0	
D.2 Services - Plumbing Systems	57 3%	2 1%	\$10.654	\$5 7 <b>0</b>	\$16 754	\$0.11
Baseline Building	01.070	2.170	\$10,654	\$5.70	\$10,654	\$5.70
W6 Low-Flow Fixtures / Ontical Sensors			\$10,001	ψ0.75	\$0	ψ0.19
W2 Rain Harvesting (nining & numps and filtration)					\$0 \$0	
W7 Composting Toilets					\$6,100	\$3.32
D.2. Services - HVAC Systems	08 /9/	1 19/	\$12.008	¢6 52	¢02 907	\$12.05
Dio Gennices - Trado Systems	90.470	4.1 /0	\$12,000	φ0.33 ¢0.50	\$12,027	\$12.90
Baseline Building			ψ12,000	\$0.03	(\$7,381)	\$0.53 (\$4.01)
Max In-Slab Radiant Heating and Cooling					\$9,200	(\$4.01) \$5.00
M2R Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)	)				\$0,200	ψ0.00
M3C Solar Thermal System	/				\$10,000	\$5.43
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
D.5 Services - Electrical Systems	68.1%	2.4%	\$10,136	\$5.51	\$17,036	\$9.26
Baseline Building			\$10,136	\$5.51	\$10,136	\$5.51
L2K Provide hardwired compact fluorescent fixtures in all spaces					\$2,200	\$1.20
L2L Motion sensors for exterior lighting					\$300	\$0.16
M2Z Ceiling Fans and window box fans ( five of each)					\$4,400	\$2.39

### BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF =1,840Living Building Gross SF =1,840Site Gross Acreage =0.11

	Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	iilding
			Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings	0.0%	0.0%	\$1,011	\$0.55	\$1,011	\$0.55
Baseline Building			\$1,011	\$0.55	\$1,011	\$0.55
F Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building			\$0		\$0	
G Sitework	92.9%	6.5%	\$20,208	\$10.98	\$38,988	\$21.19
Baseline Building			\$20,208	\$10.98	\$20,208	\$10.98
W4 Stormwater Retention / Building Water Discharge					\$14,100	\$7.66
D3 Trellis Parking Structure					\$4,680	\$2.54
H Logistics	0.0%	0.0%	\$3,280	\$1.78	\$3,280	\$1.78
Baseline Building			\$3,280	\$1.78	\$3,280	\$1.78
Living Building Prerequisites			\$920	\$0.50	\$20,064	\$10.90
PR5 - Materials Red List	100.0%	1.2%			\$3,608	\$1.96
PR7 - Responsible Industry	100.0%	4.1%			\$11,981	\$6.51
PR8 - Appropriate Materials / Services Radius	100.0%	1.2%			\$3,555	\$1.93
PR9 - Leadership in Construction Waste	0.0%	0.0%	\$920.00	\$0.50	\$920	\$0.50
Subtotal Direct Costs		29.7%	\$290,400	\$157.83	\$376,556	\$204.65
General Conditions 9.4%	29.7%	2.8%	\$27,383	\$14.88	\$35,507	\$19.30
Fee, Construction Contingency, Insurance 10.6%	29.7%	3.4%	\$33,591	\$18.26	\$43,557	\$23.67
Location Modifier for BOSTON, MA 1.12	29.7%	4.3%	\$42,165	\$22.92	\$54,674	\$29.71
TOTAL MODIFIED CONSTRUCTION COST		29.7%	\$393,540	\$213.88	\$510,295	\$277.33

### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

BUILDING TYPE: SINGLE FAMILY RESIDENTIAL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 1,840 Living Building Gross SF = 1,840

Site Gross Acreage = 0.11

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				0.0%	0.0%			\$0	
PV1 Photovoltaic Panels and Infrastructure	8,600	Watts		100.0%	26.7%			\$77,400	\$42.07
LB Prerequisite Items									
PR3 - Habitat Exchange	0.114784	acres		100.0%	0.2%			\$574	\$0.31
PR6 - Construction Carbon Footprint	50	tons		100.0%	0.2%			\$550	\$0.30
PR15 - Beauty and Spirit (included in A/E	E fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.5%			\$1,500	\$0.82
Development Costs		LEED	LBC						
Develoment Costs		3.42%	2.63%	0.0%	0.0%	\$13,440	\$7.30	\$13,440	\$7.30
Architecture & Engineering		12.00%	15.00%	<b>62.1%</b>	10.1%	\$47,225	\$25.67	\$76,544	\$41.60
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-13.3%	\$0		(\$38,700)	(\$21.03)
SDC Credits	50%			-100.0%	-1.0%	\$0		(\$2,966)	(\$1.61)
TOTAL OWNER & DESIGN-BUILD COSTS					111.6%	\$60,665	\$32.97	\$128,343	\$69.75

TOTAL CONCEPTUAL COST: \$454,205 \$246.85

38% то

\$638,637 \$347.09

43%

SINGLE FAMILY RESIDENTIAL IN BOSTON, MA

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### Single Family Residential

Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 41.5

Normalized Baseline Energy Use (kWh) 22,121

 Impact of Design Changes (see sketches)
 0.96

 Adjusted Baseline EUI (kBtu/SF)
 39.6

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
percer	nt of load	13%	42%	6%	10%	7%	22%	100%
	calc'd EUI	5.3	16.6	2.4	3.8	2.9	8.7	39.6
Energy Conservation Measures:								
Glazing	E1		10.0%	8.0%		4.4%		5.0%
High performance residential glazing	E1f							
Add effective shading devices	E1b							
Insulated panels for glazing (thermal window shades)	E1g							
Walls & Roof	E2		7.0%	3.0%		2.3%		3.3%
Shaded roof from solar panels	E2a							
Optimize insulation - single family residential	E2i							
Lighting	L2	53.8%	-4.0%	5.4%		0.8%		5.9%
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Motion sensors for exterior lighting	L2I							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	5.8%
Occupancy sensor controlled plug loads	Pa							
EnergyStar appliances	Pb							
Occupant buy-in / personal energy budget	Pf							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.6%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		53.8%	15.7%	24.4%	0.0%	10.5%	30.0%	22.5%
Subtotal Reduced EUI (kBTU/SF)		2.4	14.0	1.8	3.8	2.6	6.1	30.7
Mechanical - Distribution & Ventilation	M2		15.0%	100.0%		60.0%		13.8%
Radiant floor heating	M2y							
Energy recovery ventilation	M2b							
Natural ventilation: operable windows	M2e							
Eliminate cooling	M2j							
Ceiling fans and window box fans	M2z							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	100.0%	0.0%	60.0%	0.0%	13.8%
Subtotal Reduced EUI (kBTU/SF)		2.4	11.9	0.0	3.8	1.1	6.1	25.2
Mechanical - Plant Systems	M3		20.0%					6.0%
Solar thermal (evacuated tubes) Heating System	M3c							
Domestic Hot Water	w				75.0%			7.1%
Solar-thermal domestic water	Wa							
Low flow fixtures (showers, lavs, sinks)	Wb							
Wastewater heat recovery	We	0.00/	22.22	0.00/	75.00/	0.001	0.00/	40 40/
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	0.0%	75.0%	0.0%	0.0%	13.1%
Final Energy Lise Breakdown as Percentage of Baseline Lise		6%	24%	0%	2%	3%	15%	50%
That Energy use breakdown as referringe of baseline use		0/0	24/0	0/0	270	370	13/0	3070
Building Operating Factor	0.90			43.8	CBECS Baselir	ne EUI (kBTU/sf)		
Impact of Interactive ECM effects	1.05			60%	target reduct	ion from CBECS		
p				Achievement	TARGET REDI	ICTION NOT ME	т	
Total Reduced FUI (kBTU/sf)	19.1			56%	nercent redu	ction from CBECS		
	13.1			54%	percent redu	ction from Norm	, alized Baseline	Bldg
Total reduced energy us	se (kWh)	10 165		5170	percentredu		dilect baseline	Didg
Total reduced energy a		10,105	-					
Number of existeling panels	noodod	42						
Number of crystaline panels	D) ( arrow	45						
I Otal KW Of	PV array	9						
PV Panel Analysis:			1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angie	panel	needed at °	(SF)	# of Panels			
	0°	252 778	<u>/1</u>	540	13	-		
	15°	272.61	38	340	43	-		
alanc lemina	35.0°	286.98	36		0	1		
optima angle.	45°	284.06	36		0	-		
	90°	205.17	50		0	1		
				Total kWb =	10.869			



# MULTIFAMILY RESIDENTIAL BOSTON mixed



### THE LIVING BUILDING FINANCIAL STUDY The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

## **SKANSKA**

### BUILDING TYPE: MULTI-FAMILY HOUSING BUILDING LOCATION: BOSTON, MA

Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

	Division Premium (%)	Building Premium (%)	LEED™ Gold	d Baseline	Living B	uilding
			Total	Cost/SF	Total	Cost/SF
CONSTRUCTION COST						
A Substructure	7.5%	0.2%	\$622,710	\$2.97	\$669,394	\$3.19
Baseline Building			\$622,710	\$2.97	\$622,710	\$2.97
W2 Rainwater Containment - 20,000 gal Rainwater Tank					\$46,684	\$0.22
B Shell	5.0%	1.6%	\$7,656,970	\$36.52	\$8,040,942	\$38.35
Baseline Building			\$7,656,970	\$36.52	\$7,656,970	\$36.52
E1D Reduce Glazing (30% of original window glazing)					\$165,200	\$0.79
E1A Improved Glazing (reduce solar heat gain)					\$12,972	\$0.06
E1B Exterior Shading Devices					\$468,000	\$2.23
D2A Reduce Wall / Skin for Modified Design (not in base building design)					(\$405,600)	(\$1.93)
D3 Relocate Elevator					\$45,000	\$0.21
D3 Covered Walkway					\$98,400	\$0.47
C Interiors	5.3%	1.3%	\$5,891,333	\$28.10	\$6,205,850	\$29.60
Baseline Building			\$5,891,333	\$28.10	\$5,891,333	\$28.10
M2O Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$314,517	\$1.50
D.1 Services - Conveying Systems	0.0%	0.0%	\$244,158	\$1.16	\$244,158	\$1.16
Baseline Building			\$244,158	\$1.16	\$244,158	\$1.16
D.2 Services - Plumbing Systems	8.0%	0.6%	\$1,900,476	\$9.06	\$2,052,276	\$9.79
Baseline Building			\$1,900,476	\$9.06	\$1,900,476	\$9.06
W6 Low-Flow Fixtures / Optical Sensors					\$1,800	\$0.01
W2 Rain Harvesting (piping & pumps and filtration)					\$150,000	\$0.72
D.3 Services - HVAC Systems	387.3%	11.5%	\$717,870	\$3.42	\$3,498,260	\$16.68
Baseline Building			\$717,870	\$3.42	\$717,870	\$3.42
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$535,000)	(\$2.55)
M2A In-Slab Radiant Heating and Cooling					\$1,048,390	\$5.00
M3A Ground Source Heat Pump					\$1,959,000	\$9.34
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)	)				\$308,000	\$1.47
M2C Carbon Dioxide Sensors					\$U	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$462,507	\$2.21	\$462,507	\$2.21
Baseline Building			\$462,507	\$2.21	\$462,507	\$2.21
D.5 Services - Electrical Systems	0.6%	0.1%	\$3,452,618	\$16.47	\$3,471,778	\$16.56
Baseline Building			\$3,416,018	\$16.29	\$3,416,018	\$16.29
L2E Occupancy Sensor for Transient Lighting (corridors/stairs)			\$28,000	\$0.13		
L2I Dual day/night light levels in corridors; occupancy sensors			\$8,600	\$0.04		
L2K Provide hardwired compact fluorescent fixtures in all spaces					\$55,760	\$0.27

### BUILDING TYPE: MULTI-FAMILY HOUSING BUILDING LOCATION: BOSTON, MA



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Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

		Division Premium (%)	Building Premium (%)	LEED™ Gold	Baseline	Living Bu	uilding
				Total	Cost/SF	Total	Cost/SF
E Equipment and Furnishings		0.0%	0.0%	\$948,170	\$4.52	\$948,170	\$4.52
Baseline Building				\$948,170	\$4.52	\$948,170	\$4.52
F Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
G Sitework		6.2%	0.6%	\$2,221,462	\$10.59	\$2,358,962	\$11.25
Baseline Building				\$2,221,462	\$10.59	\$2,221,462	\$10.59
W2 Stormwater Retention / Building Water Discharge						\$50,000	\$0.24
D3 Added Courtyard						\$87,500	\$0.42
H Logistics		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
Baseline Building				\$0		\$0	
Living Building Prereguisites				\$8,737	\$0.04	\$814,089	\$3.88
PR5 - Materials Red List		100.0%	0.9%			\$228,644	\$1.09
PR7 - Responsible Industry		100.0%	1.3%			\$323,676	\$1.54
PR8 - Appropriate Materials / Services Radius		100.0%	1.1%			\$261,769	\$1.25
PR9 - Leadership in Construction Waste		-100.0%	0.0%	\$8,737	\$0.04		
Subtotal Direct Costs			19.2%	\$24,127,011	\$115.07	\$28,766,386	\$137.19
General Conditions	4 0%	19.2%	0.8%	\$965.080	\$4 60	\$1 150 655	\$5. <b>∕</b> 0
Fee Construction Contingency Insurance	4.0%	19.2%	0.8%	\$1.003.684	\$4 79	\$1,196,682	\$5.49 \$5.71
Location Modifier for BOSTON. MA	1.12	19.2%	2.5%	\$3,131,493	\$14.93	\$3,733,647	\$17.81
					, ,,		· ·
TOTAL MODIFIED CONSTRUCTION COST			19.2%	\$29,227,268	\$139.39	\$34,847,369	\$166.19

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: MULTI-FAMILY HOUSING BUILDING LOCATION: BOSTON, MA



\$252.63

Base Building Gross SF = 209,678 Living Building Gross SF = 209,678 Site Gross Acreage = 2.87

Division Premium (%)	Building Premium (%)	LEED™ Gold	d Baseline	Living Bu	uilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS								
Design/Build Owner Items								
W3 Biological Bio-Reactor			100.0%	4.1%			\$1,000,000	\$4.77
PV1 Photovoltaic Panels and Infrastructure	912,000 Watts		100.0%	28.3%			\$6,840,000	\$32.62
LB Prerequisite Items								
PR3 - Habitat Exchange	2.86961 acres		100.0%	0.1%			\$14,348	\$0.07
PR6 - Construction Carbon Footprint	6,400 tons		100.0%	0.3%			\$70,400	\$0.34
PR15 - Beauty and Spirit (included in A/E	fees below)		0.0%	0.0%			\$0	
PR16 - Inspiration and Education			100.0%	0.1%			\$23,500	\$0.11
Development Costs	LEED	LBC						
Develoment Costs	28.00%	31.00%	32.0%	10.9%	\$8,183,635	\$39.03	\$10,802,684	\$51.52
Architecture & Engineering	7.00%	9.00%	53.3%	4.5%	\$2,045,909	\$9.76	\$3,136,263	\$14.96
Credits / Rebates / Incentives								
PV Credits-(state, city, utility)	50%		-100.0%	-14.2%	\$0		(\$3,420,000)	(\$16.31)
SDC Credits	50%		-100.0%	-1.4%	\$0		(\$343,583)	(\$1.64)
TOTAL OWNER & DESIGN-BUILD COSTS				77.2%	\$10,229,544	\$48.79	\$18,123,613	\$86.44

TOTAL CONCEPTUAL COST: \$39,456,811 \$188.18 \$52,970,983

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 32% то 37% MULTI-FAMILY HOUSING IN BOSTON, MA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### Multi- Family Residential

### Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 59.3

### Normalized Baseline Energy Use (kWh) 2,323,374

Impact of Design Changes (see sketches) 0.97

Adjusted Baseline EUI (kBtu/SF) 57.2

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	12%	38%	9%	11%	10%	20%	100%
	calc'd EUI	6.9	21.9	5.1	6.0	5.7	11.6	57.2
Energy Conservation Measures:								
Glazing	E1		10.0%	10.0%		5.0%		5.2%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Reduce glazing to 30%	E1d							
Insulated panels for glazing (thermal window shades)	E1g							
Walls & Roof	F2		6.0%	1 5%		1 7%		2.6%
Chadad roof from colar nanolo	52-		0.070	1.570		1.770		2.070
Siluded TODJ JTOTT SoldT parters	EZa							
Optimize insulation to core performance guide	EZD							
Lighting	12	56.6%	-4.2%	5.7%		0.8%		5.8%
Occupancy sensors: transient lighting (corridors/stairs/bathrms)	L2e							
Dual day/night light levels in corridors; occupancy sensors	L2i							
Provide hardwired compact fluorescent fixtures in all spaces.	L2k							
Plug Loads	Р		-2.3%	3.0%		0.5%	30.0%	5.5%
Occupancy sensor controlled plug loads	Pa							
EnerayStar appliances	Pb							
#N/A								
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pu Do							
Occupant huw in / nersonal energy hudget	re Df							
Controlined newer management	P1							
Centruized power munugement	Pg							
Parking: Variable flow Ventilation based on CO monitor	PI							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.6%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		56.6%	14.5%	25.2%	0.0%	10.4%	30.0%	21.8%
Subtotal Reduced EUI (kBTU/SF)		3.0	18.7	3.8	6.0	5.1	8.1	44.8
Mechanical - Distribution & Ventilation	M2		15.0%	20.0%		60.0%		11.6%
Radiant heating (cooling w dedicated outside air system (DOAS)	M25		10.070	20.070		00.070		11.070
Energy recovery ventilation	M2b							
Energy recovery ventilation	NIZU NADa							
Minimine connect (insulates against radiant sustem)	IVIZC							
Winninize curpet (insulates against radiant system)	IVIZO							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Displacement ventilation delivery for DOAS	M2k							
Water to water heat pumps, radiant slab heating/cooling	M2q							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	20.0%	0.0%	60.0%	0.0%	11.6%
Subtotal Reduced EUI (kBTU/SF)		3.0	15.9	3.0	6.0	2.0	8.1	38.1
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		6.1%
Ground source heat nump system	M3a							
Cascading chilled water system	M2b							
Dementia Het Mater	10150				75.00/			7.00/
Domestic Hot water	w				75.0%			7.9%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)		0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	14.0%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		3.0	12.7	2.4	1.5	2.4	8.1	30.1
Final Energy Use Breakdown as Percentage of Baseline Use		5%	22%	4%	3%	4%	14%	47%
Building Operating Factor	r 0.90			60.0	CBECS Baseline	e EUI (kBTU/sf)		
Impact of Interactive ECM effects	1.05			60%	target reduction	on from CBECS		
				Achiovomont:	TARGET REDU		<b>T</b>	
Total Deduced FUL/I/PTU/of	10 F			Achievement:	TARGET REDU	tion from CDECC		
Total Reduced EUT (KBTU/st)	28.5			53%	percent reduc	tion from CBECS	,	
				52%	percent reduc	tion from Norma	alized Baseline	BIDE
Total reduced energy us	se (kWh)	1,115,634						
Number of crystaline panels	s needed	4,450						
Total kW of	PV arrav	912						
DV Danal Analysia								
PV Panel Analysis:	1 1		1	1	1	1		
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanyo-		kWh per	Total panels	Input Area				
205 panel, facing South (azimuth 0°)	angle	panel	needed at °	(SF)	# of Panels			
		paner		(31)		4 .		
	0°	252.778	4414	50,200	4025	Panels on roof + Su	inshade+ canopy	
	15°	272.61	4093		0	-		
optimal angle	: 35.0°	286.98	3888		0			
	45°	284.06	3928		0	]		
	90°	205.17	5438		0			
				Total kWh =	1.017.431	-		
			Additional area	5 300	425	nanels on adia	acent narking (	
			Additional	Wh Broduced	423	puncis on aujo	sector parking 5	
			Augultional K		107,431			



# HIGH RISE MIXED USE BOSTON mixed



The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: HIGH RISE BUILDING LOCATION: BOSTON, MA

### **SKANSKA**

Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92

Divisio Premiu (%)	on Building m Premium (%)	LEED™ Gold	I Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

CONSTRUCTION COST						
A Substructure	0.3%	0.0%	\$8,695,116	\$15.88	\$8,724,082	\$15.93
Baseline Building			\$8,695,116	\$15.88	\$8,695,116	\$15.88
Rainwater Containment - 92,000 gal Rainwater Tank					\$28,967	\$0.05
B Shell	6.1%	2.3%	\$35,629,047	\$65.06	\$37,794,319	\$69.02
Baseline Building			\$35,629,047	\$65.06	\$35,629,047	\$65.06
L1B Replace Roofing with Glazed Skylight					\$225,900	\$0.41
D3A Raise Floor to Floor Height					\$918,000	\$1.68
E1B Exterior Shading Devices					\$1,905,120	\$3.48
W5 Water Collection on Vertical Surfaces / Top of Roof					\$0	
D3 Relocate SF to additional 1/2 floor at top					\$40,800	\$0.07
D3 Remove Existing Green Roof					(\$30,000)	(\$0.05)
D3 Modifications to Lobby Space (structural and finishes)					\$590,000	\$1.08
LIE Tracking Mirror above Atrium					\$154,000	\$0.28
D3 Added Elevator Stop for Additional Floor					\$105,000	\$0.19
E1D Reduce Glazing to 30%					(\$2,315,798)	(\$4.23)
D3 Remove raised access flooring					(\$801,000)	(\$1.46)
PV3 Structure for PV on Adjacent Parking Structures					\$1,211,250	\$2.21
L1D Interior Light Shelves (at office floors)					\$162,000	\$0.30
C Interiors	6.7%	1.6%	\$22,739,127	\$41.52	\$24,272,474	\$44.32
Baseline Building			\$22,739,127	\$41.52	\$22,739,127	\$41.52
M2D Carpet Reduction (replace with RetroPlate)					\$985,723	\$1.80
M20 Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$547,624	\$1.00
D.1. Services - Conveying Sustame	0.0%	0.0%	\$2,626,557	¢1 01	¢2 626 557	¢1 01
D.1 Services - Conveying Systems	0.0 /8	0.0 /8	\$2,030,337	φ <b>4.01</b>	\$2,030,337	\$4.01
Baseline Building			\$2,030,557	\$4.81	\$2,030,557	\$4.81
D.2 Services - Plumbing Systems	0.0%	0.0%	\$3,874,587	\$7.08	\$3,874,587	\$7.08
Baseline Building			\$3,874,587	\$7.08	\$3,874,587	\$7.08
W6 Low-Flow Fixtures / Optical Sensors					\$0	
W2 Rain Harvesting (piping & pumps and filtration)					\$0	
D.3 Services - HVAC Systems	58.2%	4.7%	\$7,599,577	\$13.88	\$12,023,160	\$21.96
Baseline Building			\$7,599,577	\$13.88	\$8,449,577	\$15.43
Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$6,085,700)	(\$11.11)
M2A In-Slab Radiant Heating and Cooling					\$2,738,120	\$5.00
M3A Ground Source Heat Pump					\$6,635,000	\$12.12
M2B Energy Recovery Wheel / Plate & Frame/Dedicated Outside Air System(DOAS)					\$286,163	\$0.52
M2C Carbon Dioxide Sensors					\$0	
D.4 Services - Fire Protection Systems	0.0%	0.0%	\$1,132,828	\$2.07	\$1,132,828	\$2.07
Baseline Building			\$1,132,828	\$2.07	\$1,132,828	\$2.07
D.5 Services - Electrical Systems	12.4%	0.8%	\$6,138,326	\$11.21	\$6,901,276	\$12.60
Baseline Building			\$6,209,026	\$11.34	\$6,209,026	\$11.34
PA Occupancy Sensor to Outlets					\$35,100	\$0.06
PE High Efficiency Transformers					\$165,000	\$0.30
L2A Efficient light fixture optics					\$160,200	\$0.29
L2B Occupancy Sensor for Lighting (closed office / conference spaces)					\$18,850	\$0.03
L2C Individual Light Level Control (open spaces)					\$179,000	\$0.33
L2I Dual day/night light levels in corridors; occupancy sensors					\$134,100	\$0.24
L2J Occupancy sensor/time clock for corridor lighting					\$0	
L2K Provide hardwired compact fluorescent fixtures in all spaces			(\$70,700)	(\$0.13)	\$0	

### BUILDING TYPE: HIGH RISE BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624

Site Gross Acreage = 0.92 Т

			Premium (%)	Premium (%)	LEED™ Gold	Baseline	Living Bu	ilding
					Total	Cost/SF	Total	Cost/SF
-	Fault ment and Furnishings		0.0%	0.0%	¢2 220 052	¢c 00	¢2 220 052	¢c 00
-			0.0%	0.0%	\$3,320,033	\$0.00	\$3,320,033	\$0.06
	Baseline Building				<i>ф</i> 3,320,655	\$6.08	<i>ф</i> 3,320,033	\$6.08
F	Special Construction		0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building				\$0		\$0	
G	Sitework		9.3%	0.1%	\$537,417	\$0,98	\$587,417	\$1.07
-	Baseline Building				\$537.417	\$0.98	\$537.417	\$0.98
W4	Stormwater Retention / Building Water Discharge				. ,		\$50,000	\$0.09
W1	Remove Storm Drainage Connection to Public/Add sewer meter						\$0	
н	Logistics		0.0%	0.0%	\$1,764,940	\$3.22	\$1,764,940	\$3.22
	Baseline Building				\$1,764,940	\$3.22	\$1,764,940	\$3.22
Liv	ving Building Prerequisites				\$22,818	\$0.04	\$2,426,415	\$4.43
	PR5 - Materials Red List		100.0%	0.9%			\$869,927	\$1.59
	PR7 - Responsible Industry		100.0%	0.3%			\$328,542	\$0.60
	PR8 - Appropriate Materials / Services Radius		100.0%	1.3%			\$1,205,129	\$2.20
	PR9 - Leadership in Construction Waste		0.0%	0.0%	\$22,818	\$0.04	\$22,818	\$0.04
Su	btotal Direct Costs			12.1%	\$94,097,194	\$171.83	\$105,464,910	\$192.59
	General Conditions	3 2%	12.1%	0.4%	\$3.005.271	\$5 49	\$3.368.332	\$6 15
	Fee, Contingency, Insurance, Bonding	9.8%	12.1%	1.2%	\$9,471,412	\$17.30	\$10,615,636	\$19.38
	Location Modifier for BOSTON, MA	1.12	12.1%	1.6%	\$12,788,865	\$23.35	\$14,333,865	\$26.17
					• • • • • • • •			
тс	TAL MODIFIED CONSTRUCTION COST			12.1%	\$119,362,741	\$217.96	\$133,782,743	\$244.30

### BUILDING TYPE: HIGH RISE BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 547,624 Living Building Gross SF = 547,624 Site Gross Acreage = 0.92

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	iilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	1.1%			\$1,000,000	\$1.83
O1 Wind Turbines (net cost including credits)	14,800	Watts		-100.0%	0.1%	(\$82,000)		\$0	
PV1 Photovoltaic Panels and Infrastructure	3,567,200	Watts		100.0%	28.4%			\$26,754,000	\$48.85
LB Prerequisite Items									
PR3 - Habitat Exchange	0.918274 a	acres		100.0%	0.0%			\$4,591	\$0.01
PR6 - Construction Carbon Footprint	24,100 t	tons		100.0%	0.3%			\$265,100	\$0.48
PR15 - Beauty and Spirit (included in A/E fe	ees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.12
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	24.1%	8.6%	\$33,421,567	\$61.03	\$41,472,650	\$75.73
Architecture & Engineering		7.00%	9.00%	44.1%	3.9%	\$8,355,392	\$15.26	\$12,040,447	\$21.99
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-14.2%	\$0		(\$13,377,000)	(\$24.43)
SDC Credits	50%			-100.0%	-0.5%	\$0		(\$509,464)	(\$0.93)
TOTAL OWNER & DESIGN-BUILD COSTS					62.4%	\$41,694,959	\$76.29	\$67,713,325	\$123.65

TOTAL CONCEPTUAL COST: \$161,057,700 \$294.10 \$201,496,068 \$367.95

LIVING BUILDING CONCEPTUAL PREMIUM RANGE: 23% TO 28% HIGH RISE IN BOSTON, MA

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### High Rise Mixed use

### Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 90.5

### Normalized Baseline Energy Use (kWh) 10,076,852

 Impact of Design Changes (see sketches)
 0.98

 Adjusted Baseline EUI (kBtu/SF)
 88.7

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
perce	nt of load	11%	40%	12%	9%	10%	19%	100%
	calc'd EUI	9.3	35.8	10.2	7.9	8.9	16.5	88.7
Energy Conservation Measures:								
Glazing	E1		15.0%	15.0%		7.5%		8.5%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Root	E2		6.0%	1.5%		1.7%		2.8%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	11	15.0%	-1.1%	1.5%		0.2%		1.3%
Remove celling, raise window nead, add lightshelf	L1a							
Daylight controls (continuous alimming)	L1C	CO 70/	F 20/	7.0%		4.00/		6.40/
Lighting	L2	69.7%	-5.2%	7.0%		1.0%		6.1%
Efficient fixture optics	L2a							
Individual occupancy sensors & aimming controls: closed offices/low occucpan	C L2D							
Light colors on walls, coiling surfaces	L2C							
Occupancy sensors: transient lighting (corridors/stairs/hathrms)	120							
Dual day/night light levels in corridors: occupancy sensors	121							
Occupancy sensor / time clock for corridor lighting	121							
Provide hardwired compact fluorescent fixtures in all spaces	12k							
Plug Loads	P		-2.3%	3.0%		0.5%	30.0%	5 1%
Occupancy sensor controlled plug loads	Pa		2.370	5.070		0.370	50.070	3.1/0
EnerayStar appliances	Ph							
#N/A	r o							
Remove phantom load / transformers	Pd							
Energy efficient main transformer	Pe							
Occupant buy-in / personal energy budget	Pf							
Centralized power management	Pg							
Parking: variable flow ventilation based on CO monitor	Pi							
Super-efficient elevators (hybrid)	Pk							
Widen Set Point Temperatures	M1		5.0%	5.0%		2.5%		2.8%
Widen Set Point Temperatures (expand ASHRAE 55)	M1a							
Subtotal from above Load Reduction strategies (percentage)		84.7%	17.4%	33.0%	0.0%	13.4%	30.0%	26.7%
Subtotal Reduced EUI (kBTU/SF)		1.4	29.6	6.9	7.9	7.7	11.6	65.0
Mechanical - Distribution & Ventilation	M2		15.0%	18.0%		60.0%		11.6%
Radiant heating/cooling w dedicated outside air system (DOAS)	M2a							
Energy recovery ventilation	M2b							
Demand-based ventilation	M2c							
Minimize carpet (insulates against radiant system)	M2d							
Natural ventilation: operable windows	M2e							
Fan assisted natural ventilation	M2f							
Night flush	M2g							
High mass - concrete block on inside of insulation	M2h							
Displacement ventilation delivery for DOAS	M2k							
Water to water heat pumps, radiant slab heating/cooling	M2q							
Subtotal from Mechanical Distribution strategies (percentage)		0.0%	15.0%	18.0%	0.0%	60.0%	0.0%	11.6%
Subtotal Reduced EUI (kBTU/SF)		1.4	25.2	5.6	7.9	3.1	11.6	54.7
Mechanical - Plant Systems	M3		20.0%	20.0%		-15.0%		6.4%
Ground source heat pump system	M3a							
Cascading chilled water system	M3b							
Domestic Hot Water	w				75.0%			6.7%
Low flow fixtures (showers, lavs, sinks)	Wb							
Water heating from tankless electric water heater	Wd							
Wastewater heat recovery	We							
Subtotal from Mechanical Plant and DHW systems (percentage)	_	0.0%	20.0%	20.0%	75.0%	-15.0%	0.0%	13.1%
Reduced EUI from Energy Conservation Measures (kBTU/SF)		1.4	20.1	4.5	2.0	3.5	11.6	43.1
Final Energy Use Breakdown as Percentage of Baseline Use		2%	23%	5%	2%	4%	13%	51%
Building Operating Facto	r 0.90			86.2	CBECS Baselin	e FUI (kBTU/sf)		
Impact of Interactive FCM effects	s 1.05			60%	target reducti	on from CBECS		
	1.05			Achioucomontu			<b>-</b>	
Total Daduced FUL/I/DTU//6	) 40 F			Achievement:	TARGET REDU	JUIION NOT ME	1	
Total Reduced EUI (KBTU/ST	) 40.5			53%	percent reduc	ction from CBECS	lized Paceline	Plda
Total reduced energy u	co (k)//b)	1 506 189		3376	percent reduc		alizeu baselille	Blug
Total reduced chergy a	50 (10011)	4,500,405						
Number of crystaline panel	s needed	17,472						
Total kW of	PV arrav	3582						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes Sanvo-	1 1		I	1	1	1		
205 nanel, facina South (azimuth 0°)	angle	kWh per	Total panels	Input Area	# of Panels			
,	<b>U</b>	panel	needed at °	(SF)				
	0°	252.778	17828	18,000	1443			
	15°	272.61	16531	57,400	4602	_		
optimal angle	: 35.0°	286.98	15704		0	1		
	45°	284.06	15865		0	4		
	90°	205.17	21965		0			
				Total kWh =	1,619,310			
Additional Parking Garage Offset Needed, EUI of 1.7			Additional area	142,500	11427			
			Additional k	Wh Produced	2,888,494	4,507,804		



# HOSPITAL BOSTON mixed

ADDITIONAL GROUND-



**COST PREMIUM** PAYBACK **COST PER SF** PHOTOVOLTAIC CAPACITY WATER USE

**ENERGY USE INDEX** 

70,000 gal RAINWATER TANK SIZE 180,231 sf BUILDING SIZE 4 floors BUILDING HEIGHT 39.03 acres SITE AREA 339,400 sf PHOTOVOLTAIC AREA 84,900 sf ROOF AREA

- ✓ Add new light courts at Nurse's station.
- ✓ Add skylights at corridors for increased daylighting.
- ✓ Minimize screen at mechanical area, due to fact that mechancial is reduced
- ✓ Add fins to provide shading on west side of classrooms.
- ✓ Add shading devices on South side of hospital, office, etc.



SWALE

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### BUILDING TYPE: HOSPITAL BUILDING LOCATION: BOSTON, MA

### **SKANSKA**

Base Building Gross SF = 180,231

Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

		Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	iilding
				Total	Cost/SF	Total	Cost/SF
СС	INSTRUCTION COST						
Α	Substructure	4.6%	0.2%	\$2,895,319	\$16.06	\$3,028,712	\$16.80
	Baseline Building			\$2,895,319	\$16.06	\$2,895,319	\$16.06
W2	Rainwater Containment - 70,000 gal Rainwater Tank					\$133,392	\$0.74
в	Shell	2.1%	0.5%	\$14,789,139	\$82.06	\$15,102,359	\$83.79
	Baseline Building			\$14,789,139	\$82.06	\$14,789,139	\$82.06
L1B	Replace Roofing with Glazed Skylight					\$15,000	\$0.08
E1A	Improved Glazing (reduce solar heat gain at vision only)					\$16,000	\$0.09
E1B	Exterior Horizontal Shading Devices					\$87,600	\$0.49
L1D	Interior Light Shelf					\$58,400	\$0.32
E1B	Vertical Shading Fins (west end)					\$26,900	\$0.15
L1B	New Light Shafts to Nurse Stations					\$387,000	\$2.15
E2B	Infill Spandrel Panel with Framing and Insulation (replace glazed area)					\$22,320	\$0.12
D3	Reduce Mechanical Roottop Screen					(\$300,000)	(\$1.66)
С	Interiors	0.4%	0.1%	\$9,710,678	\$53.88	\$9,746,724	\$54.08
	Baseline Building			\$9,710,678	\$53.88	\$9,710,678	\$53.88
M2A	Topping Slab / Stair Premium for Underfloor Radiant System (3" concrete)					\$36,046	\$0.20
L1A	Raise Ceilings (no cost impact)					\$0	
D.′	Services - Conveying Systems	0.0%	0.0%	\$826,462	\$4.59	\$826,462	\$4.59
	Baseline Building			\$826,462	\$4.59	\$826,462	\$4.59
D.2	2 Services - Plumbing Systems	7.5%	0.4%	\$3,347,613	\$18.57	\$3,597,613	\$19.96
	Baseline Building			\$3,347,613	\$18.57	\$3,347,613	\$18.57
W6	Low-Flow Fixtures / Optical Sensors					\$0	
W2	Rain Harvesting (piping & pumps and filtration)					\$250,000	\$1.39
D.:	3 Services - HVAC Systems	34.5%	5.7%	\$9,992,801	\$55.44	\$13,438,384	\$74.56
	Baseline Building			\$9,992,801	\$55.44	\$9,992,801	\$55.44
	Baseline HVAC System Reduction (2/3 reduction in Air Handler and Ducting)					(\$2,652,772)	(\$14.72)
M2A	In-Slab Radiant Heating and Cooling					\$901,155 \$5 101 200	\$5.00
МЗА	Ground Source Heat Pump					\$5,101,200	\$28.30
M2E	Carbon Dioxide Songera					\$16,000	\$0.44 \$0.00
IVI2C						φ10,000	\$0.09
D.4	Services - Fire Protection Systems	0.0%	0.0%	\$444,259	\$2.46	\$444,259	\$2.46
	Baseline Building			\$444,259	\$2.46	\$444,259	\$2.46
D.!	5 Services - Electrical Systems	6.2%	0.8%	\$8,085,831	\$44.86	\$8,589,931	\$47.66
	Baseline Building			\$8,085,831	\$44.86	\$8,085,831	\$44.86
PA	Occupancy Sensor to Outlets					\$21,500	\$0.12
PE	High Efficiency Transformers					\$217,000	\$1.20
LIC	Daylight Controls (continuous dimming 15' from perimeter)					\$160,800	\$0.89
L2E	Occupancy Sensor for Transient and Egress Lighting					\$44,500	\$0.25
L2G	Patient Bed light with separate switching for ambient / task					\$18,800 \$10,000	\$0.10
L2M	Dual level light at egress stairs - off when not occupied				1	φ19,000	\$0.11

L2N Stairwell lighting on daylighting

\$22,500

\$0.12

### BUILDING TYPE: HOSPITAL BUILDING LOCATION: BOSTON, MA



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Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Т

Site Gross Acreage = 39.03

		Division Premium (%)	Premium (%)	LEED™ Gold	l Baseline	Living Bu	ilding
				Total	Cost/SF	Total	Cost/SF
<b></b>							
E	Equipment and Furnishings	0.0%	0.0%	\$2.050.942	\$11.38	\$2,050,942	\$11.38
_	Baseline Building			\$2,050,942	\$11.38	\$2,050,942	\$11.38
				• ,,-	¢11100	• ,,-	<b>\$</b> 1100
F	Special Construction	0.0%	0.0%	\$0	\$0.00	\$0	\$0.00
	Baseline Building			\$0		\$0	
G	Sitework	0.6%	0.1%	\$7,730,038	\$42.89	\$7,780,038	\$43.17
	Baseline Building			\$7,730,038	\$42.89	\$7,730,038	\$42.89
W4	Stormwater Retention / Building Water Discharge					\$50,000	\$0.28
W1	Remove Storm Drainage Connection to Public/Add sewer meter					\$0	
н	Logistics	0.0%	0.0%	\$920,558	\$5.11	\$920,558	\$5.11
	Baseline Building			\$920,558	\$5.11	\$920,558	\$5.11
						• • • • • • • • • •	
Li	ving Building Prerequisites	100.00/	0.00/	\$7,510	\$0.04	\$1,289,480	\$7.15
	PR5 - Materials Red List	100.0%	0.9%			\$571,658	\$3.17
	PR7 - Responsible Industry	100.0%	0.2%			\$108,128	\$0.60
	PR8 - Appropriate Materials / Services Radius	100.0%	1.0%	¢7 540	<b>\$0.04</b>	\$602,185	\$3.34
	PR9 - Leadership in Construction Waste	0.0%	0.0%	\$7,510	\$0.04	\$7,510	\$0.04
Su	btotal Direct Costs		9.9%	\$60,801,148	\$337.35	\$66,815,461	\$370.72
	General Conditions 5 0%	9.9%	0.6%	\$3 599 939	\$19.07	\$3 956 036	\$21.05
	Fee Contingency Insurance 67%	9.9%	0.7%	\$4,309,196	\$23.01	\$4,735,452	\$26.27
	Location Modifier for BOSTON, MA 1 12	9.9%	1.3%	\$8,245,234	\$45.75	\$9,060,834	\$50.27
				., ., -	ţ lon o	. , , .	÷30121
т	TAL MODIFIED CONSTRUCTION COST		9.9%	\$76,955,517	\$426.98	\$84,567,784	\$469.22

### BUILDING TYPE: HOSPITAL BUILDING LOCATION: BOSTON, MA



Base Building Gross SF = 180,231 Living Building Gross SF = 180,231

Site Gross Acreage = 39.03

Division Premium (%)	Building Premium (%)	LEED™ Gold	l Baseline	Living Bu	ilding
		Total	Cost/SF	Total	Cost/SF

OWNER & DESIGN-BUILD COSTS									
Design/Build Owner Items									
W3 Biological Bio-Reactor				100.0%	2.5%			\$1,500,000	\$8.32
PV1 Photovoltaic Panels and Infrastructure	V1 Photovoltaic Panels and Infrastructure 5,579,000 Watts			100.0%	68.8%			\$41,842,500	\$232.16
LB Prerequisite Items									
PR3 - Habitat Exchange	39.03	acres		100.0%	0.3%			\$195,150	\$1.08
PR6 - Construction Carbon Footprint	PR6 - Construction Carbon Footprint 5.400 tons				0.1%			\$59,400	\$0.33
PR15 - Beauty and Spirit (included in A/E	fees below)			0.0%	0.0%			\$0	
PR16 - Inspiration and Education				100.0%	0.1%			\$63,000	\$0.35
Development Costs		LEED	LBC						
Develoment Costs		28.00%	31.00%	21.7%	7.7%	\$21,547,545	\$119.56	\$26,216,013	\$145.46
Architecture & Engineering		7.00%	9.00%	41.3%	3.7%	\$5,386,886	\$29.89	\$7,611,101	\$42.23
Credits / Rebates / Incentives									
PV Credits-(state, city, utility)	50%			-100.0%	-34.4%	\$0		(\$20,921,250)	(\$116.08)
SDC Credits	50%			-100.0%	-2.3%	\$0		(\$1,372,092)	(\$7.61)
TOTAL OWNER & DESIGN-BUILD COSTS					104.9%	\$26,934,431	\$149.44	\$55,193,821	\$306.24

TOTAL CONCEPTUAL COST: \$103,889,948 \$576.43 \$139,761,605 \$775.46

LIVING BUILDING CONCEPTUAL PREMIUM RANGE:	32%	то	37%	
HOSPITAL IN BOSTON, MA				

The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow

### Hospital Boston

Normalized Baseline Energy Use Intensity (kBtu/SF) 245.3

Normalized Baseline Energy Use (kWh) 12,940,958

Impact of Design Changes (see sketches) 1.00

Adjusted Baseline EUI (kBtu/SF) 245.3

					DOM. HOT			TOTAL
		LIGHTING	HEATING	COOLING	WATER	FANS & PUMPS	MISC. EQUIP	BLDG
L L L L L L L L L L L L L L L L L L L	percent of load	12%	26%	15%	12%	15%	20%	100%
	calc'd EUI	29.9	62.7	36.2	29.9	36.8	49.8	245.3
Energy Conservation Measures:								
Glazing	E1		12.0%	1.0%		2.7%		3.6%
Improved Glazing	E1a							
Add effective shading devices	E1b							
Walls & Roof	E2		6.0%	1.0%		1.5%		1.9%
Shaded roof from solar panels	E2a							
Optimize insulation to core performance guide	E2b							
Daylighting (incorporates tuned glazing/shading)	L1	13.3%	-1.0%	1.3%		0.2%		1.6%
Top davlighting with skylights	L1b							
Davlight controls (continuous dimming)	L1c							
Lighting	12	31.1%	-2.3%	3.1%		0.5%		3.7%
Occupancy sensors: transient lighting (corridors/stairs/hathrms)	12e							
Patient hedlight with separate switching for amhient / task	1.20							
Plug Loads	P						10.0%	2.0%
EnergyStar appliances	Ph						10.070	2.070
Energy efficient main transformer	Po							
Super-efficient elevators (hybrid)	PL							
Agaressive heat recenture - all equipment water cooled	DI							
Widen Set Point Temperatures	M1		2.0%	2.0%		1.0%		1.0%
Widen Set Point Temperatures (overand ASHRAE EE)	N/1a		2.070	2.070		1.076		1.070
Subtotal from above Load Reduction strategies (nercentage	IVIII	11 1%	16 7%	8 1%	0.0%	5.0%	10.0%	12.8%
Subtotal Profil above Load Reduction Strategies (percentage)		44.4/0	52.2	0.4/0	20.0	3.370	10.0%	211 /
Machanical Distribution & Vontilation	M2	10.0	20.0%	11.0%	29.9	34.0	44.5	211.4
Rediant data besting (see ling in lether (station	1112		20.0%	11.0%		20.0%		8.0%
Chilled begins	IVI2r							
Crimed beams	IVI25							
Natural ventilation in stairwells	M2u							
Low process drop gir filters	Max							
OSA/Exhaust runground heat recovery	N/2w							
Cascadina make-un air	M2x							
Subtotal from Mechanical Distribution strategies (nercentage)	IVIZA	0.0%	20.0%	11.0%	0.0%	20.0%	0.0%	8.6%
Subtotal Reduced EUI (kBTU/SF)		16.6	41.8	29.5	29.9	27.7	44.9	190.4
Mechanical - Plant Systems	M3		20.0%	30.0%				7.0%
Ground source heat nump with central heat nump chiller	M3e		20.070	30.070				7.070
Chiller heat recovery	M3f							
Domostic Hot Water	14/				E0.0%			6 10/
					30.0%			0.1/0
Low Jow Jixlures (Showers, lovs, shiks)	VVD							
Wastewater beat recovery	VVC							
Subtotal from Mechanical Plant and DHW systems (nercentage)	we	0.0%	20.0%	30.0%	50.0%	0.0%	0.0%	13 1%
Reduced FUI from Energy Conservation Measures (kBTU/SE)		16.6	33.4	20.6	15.0	27.7	44.9	158.2
Final Energy Use Breakdown as Percentage of Baseline Use		7%	14%	8%	6%	11%	18%	36%
		,,,,	2170	0,0	0,0	11/0	20/0	00/0
Building Operating F	actor 0.90			249.2	CBECS Baselin	ne EUI (kBTU/sf)		
Impact of Interactive ECM ef	fects 1.05			60%	target reduct	ion from CBECS		
· · · · ·				Achievement:	TARGET RED		т	
Total Reduced FUI (kBT	1/sf) 148 0			41%	nercent redu	ction from CBECS		
Total Neduced Lot (Kb)	0/31/ 140.0			40%	percent redu	ction from Norm	, alized Baseline	Blde
Total reduced aper	muuco (k)M/b)	7 906 164		4070	percentredu		unzeu busenne	Bidg
Total reduced eller	gy use (kvvii)	7,800,134						
Number of emotelies a		27.640						
Number of crystaline p	anels needed	27,640						
Total ki	N of PV array	5666						
PV Panel Analysis:								
From RETScreen 4-1: method 2, 2% misc losses, 90% inverter efficiency, assumes San	iyo-	kWh ner	Total papels	Input Area				
205 panel, facing South (azimuth 0°)	angle	nanel	needed at °	(SE)	# of Panels			
		Patier	neeueu at	(35)		4		
	0°	252.778	30882	44,700	3584	_		
	15°	272.61	28635		0	4		
optimal a	ngle: 35.0°	286.98	27202	300,000	24056	-		
	45°	284.06	2/481		0	-		
	90°	205.17	38048		0			

Total kWh = 7,809,547

### LIVING BUILDING STRATEGIES NARRATIVE

- D Design Massing & Orientation
- E1 Envelope Glazing & Shading
- E2 Envelope Walls & Roof
- L1 Lighting Daylighting
- L2 Lighting Power Density & Controls
- M1 Mechanical Widen Temperature Setpoints
- M2 Mechanical Distribution & Ventilation
- M3 Mechanical Plant Systems
- M4 Mechanical Schedule & Load Shifting
- P Plug Loads
- PV Photovoltaic
- W Water
- 0 Other

### **Design - Massing and Orientation**

**D1: Idealized Massing / floor plan:** Several reference buildings did not meet the Civilized Environment prerequisite with work spaces located more than 30' from the exterior wall. Buildings which required redesign were a) elongated to make a long, thin building if site conditions allowed or b) reorganized to be donut shaped with an atrium in the center or c) light shafts were added to bring light and ventilation to areas for which it was functionally required. These changes generally resulted in a reconfiguration of the floor plate and thus added skin to the building.

**D1A: Operable Windows:** were assumed to be 8-10 sf awning vent panes. They are manually operated without actuators or position switches.

**D2: Idealized Roof Shape and Orientation:** To maximize solar potential and daylight aperature orientation the roof shape and orientation of several buildings was redesigned. This change resulted in the following:

**D2A: Added Wall/Skin for Modified Design:** represents the net change in the skin as needed to enclose the added square footage in the modified design. These costs include the entire skin assembly from interior finish to exterior finish and structure to match the original building.

**D2B: Modifications of Roof Structure and Roofing:** reflect the changes made to the structural system, size and details when changing from a flat roof to a sloped shed roof. The structural system was changed from a wide flange steel system to an open-web joist structural system at the roof. The overall size of the roof is increased as a result of both the angle and overhangs being introduced. Credits include removal of the parapet and associated sheetmetal flashings and caps.

**D3: Floor plan Modifications for Daylighting:** Several strategies were employed to improve the daylighting in buildings both to reduce energy usage of the lighting and to improve the access for all occupants to light and air. The daylighting rule of thumb "to achieve effective distribution of light from unilateral daylighting, room depth should not exceed about 2.5 H, where H is the window height." Buildings that did not meet this basic rule were modified first by raising the window height, reducing the depth of the room, or by increasing the floor to floor height.

**D3A: Raise Floor to Floor Heights**: This was done as a last resort only if the daylighting rule of thumb was not achievable by any other means.

**D3B: Replace Roofing with Glazed Skylight:** represents the net cost or credit calculated by deducting the existing roofing assembly costs from the skylight costs. Pricing was based on an aluminum, pre-engineered, single-pitch skylight unit in most cases. In some climates, a more expensive, sawtooth skylight was included

**D3C: Reallocation of Glazing:** was done to move glazed areas of the building skin from the East side of the building to the South side, increasing the solar impact and daylight harvesting. It was assumed in the default scenario that there is a net zero cost impact since the existing skins are only changing locations on the building. Costs and credits in this category represent a net change in glazing as modified in the Living Building design for energy performance and / or light penetration into the space.

**D4: Floor Plan Renovation:** segregation use as classroom/office to maximize reuse of energy. Floor plans were revised using Living Building prerequisites as an additional criteria for space programming to optimize energy use and daylighting opportunities.

### Envelope - Glazing & Shading

**E1A: Improved Glazing Costs:** were developed by identifying the price difference between the glazing used in the actual project, and those identified in the Energy Matrix to achieve the performance levels required for that project. No credits were assigned if the target efficiency levels were below those actually installed in the base building. See appendix for target glazing valves.

**E1B:** Add Effective Shading Devices: Different types of shading devices were added in different areas depending on the orientation of the windows and the anticipated sun exposure.

**Horizontal Exterior Shading Device:** for this building type were extruded aluminum horizontal sun shades manufacturers. Where applicable, a credit was provided to remove existing shading devices on non-critical facades of the building. Where PV panels were identified as the shading surface for the sun shade, only the cost of structural outriggers to support the PV panels was included.

**Vertical Exterior Shading Devices:** were included in several different styles and configurations. Some of these vertical devices were wall hung elements that were to be installed adjacent to particular window openings. In other strategies, there are entire fin walls designed to run the full height of a curtainwall from the ground. An additional configuration included shading elements to be hung from an engineered curtainwall system.

**Trees for Shading:** were included in the modified design to provide natural shading. Trees were deciduous to allow for solar heating in the cooler seasons.

E1C: PV Shading (Glazing): See E1B above.

**E1D: Reduce glazing to 30%:** Where a building type exceeded the recommended glazing percentage for a specific climate, the building was redesigned to achieve a reduction in the glazing area. Typically, reduced glazing was accomplished by substituting glazed curtain wall for a framed, insulated, and clad section across the percentage indicated.

E1E: Reduce glazing to 40%: See E1D above.

Insert chart of ideal glazing

**E1F: High Performance Residential Glazing:** The following glazing types were incorporated into the residential projects to improve energy performance.

E1G: Insulated Panels for Glazing (Thermal Window Shades): Investigated, but not used.

### **Envelope - Walls and Roof**

**E2A: Shaded Roof from Solar Panels** - No construction cost impact (solar panel cost considered elsewhere).

**E2B: Optimize Insulation to Core Performance Guide** - See insulation levels required for each climate zone

Portland	Walls:	R-13 stud + R-7.5 ci Roof R-25
Phoenix	Walls:	R-13 stud + R-5 ci Roof: R-20
Atlanta	Walls:	R-13 stud + R-5 ci Roof: R-20
Boston	Walls:	R-13 stud + R-10 ci Roof: R-35

E2C: PV Mount AboveRoof to Allow for Shading: See E2a above.

**E2D: Change Skin to Highly Reflective Siding:** included costs to remove the exterior skin cladding as originally designed and replace it with a regionally-appropriate built-up finish (light color).

**E2E: Move Vapor Barrier to Outside of Building:** represents the cost to clad the framing which was previously on the interior of the concrete/brick mass. The high-mass concrete/masonry wall was redesigned to the interior side of the wall to better transfer the stored heating/cooling into the space.

E2F: Advanced Framing: Investigated, but not used

**E2G: Double envelope south face**: Solar chimney was implemented in the Boston single-family residence.

E2H: Straw Based SIPS: Investigated, but not used

**E2I: Optimize Insulation Residential**: Regionally appropriate insulation methods were applied for the single family residences. Base building was designed with Insulated Concrete Forms (ICF).

**E2J: Infill Spandrel Panel with Framing and Insulation:** includes costs to frame, insulate and drywall finish selected areas on the interior where curtainwall was previously designed.

### Lighting - Daylighting

**L1A: Remove Ceiling, Raise Window Head, Relocate Shading Device**: to act as light shelf No Construction cost impact Exposed Ceilings were represented by the credit for removing the suspended ceiling tile and grid, and adding the cost to paint the structure above with a matte finished light color.

**L1B: Top Daylighting with Skylights:** Occurs in some scenarios in conjunction with the addition of an atrium space.

**L1C: Continuous Daylighting Controls:** are provided through the use of sensors and dimming ballasts at light fixtures within 25' of the perimeter wall in an open office environment.

**L1D: Add Light Shelf:** Provide light shelf on interior of space with exterior component to also shade glass. Interior light shelves were added to the windows along the south side of the building to help reflect the incoming light deeper into the space. The product included in this cost is similar to the combination aluminum and polycarbonate lightshelves currently available from several manufacturers.

**L1E: Heliostat (Tracking Mirror above Atrium):** is a series of mirrors installed on the roof to allow natural light to be selectively introduced into the interior space depending on the desired light levels.

**L1F: Glass Partitions:** were added to the modified design as a replacement separation between public and private spaces. This was done to increase the light penetration from the central skylight above into adjacent interior spaces. Costs reflect the replacement of standard interior partition wall framing and finished gypsum board with a butt-glazed and caulked glass panel system captured at the head and sill by aluminum channel. Replaced sections vary in elevation based on the design criteria. This revision also includes costs to add deluge fire sprinklers at rated partitions.

**L1G: Add Glazed Clerestory:** A section of roof was reconfigured to allow for clerestory glazing to provide natural daylighting opportunities.

L1H: Relocate Clerestory Clerestories: were relocated to correspond to skin condition.
# Lighting – Power Density & Controls

**L2A: Efficient Fixture Optics:** are incorporated in the design through the use of light fixtures with advanced optical performance. Fixtures similar to the Ledalite Vectra 4' fixture were used for cost estimating purposes.

**L2B: Individual Occupancy Sensors and Dimming Controls:** are provided in closed offices and and other low occupancy spaces such as conference rooms

**L2C: Individual Light Level Control and Dimming:** at "open" office areas are employed through the use of a fixture similar to the Ledalite Edapt 4' fixture and includes individual control at each workstation.

**L2D: Light Colors on Walls and Ceiling Surfaces:** provided by paint with a minimum light reflectance of 80% for walls and 90% for ceilings was assumed. No costs were added for this strategy.

**L2E: Occupancy Sensors for transient lighting in corridors, stairs, and bathrooms:** achieves energy savings during unoccupied time frames.

**L2F: Dimmable Direct/Indirect fixtures:** includes the premium cost to provide daylighting control with dimmable ballasts in classroom light fixtures within 15' of the exterior glazing, while providing local control of nearest lighting at teaching wall.

**L2G: Patient Bedlight with Separate Switching for Ambient/Task:** Use fixture that allows for increase lighting on demand for examination purposes, but provides reduced lighting for patient use.

**L2I: Dual Day/Night Light Levels:** in corridors are achieved through the use of occupancy sensors wired to a secondary ballast in the light fixtures, which turn a portion of the fixture off during periods of no traffic, and some fixtures completely off at this time.

**L2K: Provide Hardwired Compact Fluorescent Fixtures:** in all spaces in lieu of incandescent options for residential building occupancies where not required by code.

**L2L: Motion Sensors for Exterior Lighting:** are incorporated to reduce energy costs when exterior traffic is not occurring.

**L2M: Egress Lighting on Occupancy Sensors:** becomes a proactive measure to reduce energy costs during low peak occupancy hours.

**L2N: Stairwell Lighting:** on daylighting sensors are incorporated to reduce energy costs when stairs are located next to the exterior of the building or an atrium. The cost estimate includes the premium to provide sensors and dimming ballasts.

# Mechanical – Widen Temperature Setpoints

#### M1A: Widen Set Point Temperatures (expanded ASHRAE 55): Widened

acceptable temperature and humidity set points allows for reduced mechanical equipment sizing (central plant, as well as distribution system) This was applied for all building types and regions except for the majority of the hospital environment.

# Mechanical - Plant Systems

**M2A: Radiant heating/Cooling with Dedicated Outside Sir System (DOAS):** An in-slab, radiant floor heating & cooling system will be provided. Displacement ventilation will be provided by a heat recovery air handler providing 100% outside air, tempered, and dehumidified where climate appropriate (assume air volume of 0.1-0.4 CFM/SF conditioned area, depending on the region). The air handler will have a changeover hydronic heating/ cooling coil, supply and exhaust fan with VFD, and MERV 13 filtration. Air will be distributed through a galvanized steel duct system, and delivered low in space (displacement ventilation), using low-velocity diffusers.

**Topping Slab for Underfloor Radiant System:** includes the cost to thicken the floor slab for installation of radiant floor tubing for use with the ground source heating and cooling strategy. The existing superstructure was assumed to be sufficient to support this added weight.

**Eliminate Raised Access Floor:** For some buildings the existing raised access floor system was removed. All work associated with the raised access floor was removed in favor of the radiant HVAC system. Floor to floor heights were not reduced based on corollary daylighting benefits. It was assumed that the revisions to any other systems (ie low-voltage) relocated from under the access floor were cost-neutral.

**M2B: Energy Recovery Ventilation:** The air handler (described in M2a) will be equipped with an energy recovery wheel section. Relief/exhaust air will be recovered as it runs through the heat exchanger to preheat and precool the incoming outside air. ERVs for residential will have changeover heating/cooling coils only where required by climate, and will be central (one central ERV serving multiple units) constant volume units.

**M2C: Demand Based Ventilation Carbon:** dioxide sensors will be used to vary outside air rates supplied by the displacement system.

**M2D:** Minimize Carpet (Insulates Against Radiant System): Carpet Reduction costs were calculated by crediting the cost of carpeting for all public spaces, and replacing that flooring covering with a concrete sealer/densifier similar to RetroPlate. The assumption was that a standard concrete dustproofing finish would not be acceptable for long-term maintenance. This strategy eliminates the attenuating factor the carpet has on the efficiency of the in-floor radiant heating and cooling system.

**M2E: Operable Windows:** were assumed to be 8-10 sf awning vent panes. They are manually operated without actuators or position switches. (already in D1A)

**M2F: Fan assisted Natural Ventilation:** Additional exhaust capacity (assume up to 0.4 CFM/SF) will be available to be activated manually when outside air conditions are suitable for natural ventilation and operable windows are open. The HVAC system will be disabled during this mode.

**M2G: Night Flush** No construction cost impact. Night flush to precool the space will be accomplished with the radiant and fan system.

**M2H: High Mass Concrete Inside Insulation:** is a strategy that moves concrete elements of the exterior wall to the interior of the face of the wall assembly providing better coupling for thermal transfer. Pricing for this strategy includes additional costs for a highly-reflective exterior cladding over the existing framing and insulation that would be moved to the exterior of the building. The concrete itself was already included in the baseline as a stem wall or shear wall element.

**M2I: Chimney:** (80sf per 1000 sf) A solar chimney was investigated but not utilized.

**M2J: Eliminate Cooling:** Mechanical cooling is not provided for the educational and single family residences. This was done to reduce the energy usage which drove the renewable system size. This helped reduce the overall building costs.

**M2K: Displacement Ventilation Delivery for DOAS Air Supply**: to be low in the space (near floor level, but not underfloor) using low-velocity diffusers.

M2L: Solarwall Mechanical Screen or Solar Duct (preheat air): - A solar wall screen was used at the elementary school to preheat the ventilation air in cold and mild climates.

**M2M: Optimize Fan Systems (Fan Wall):** Provide FanWall system for the hospital air handler (see FanWall by Huntair)

**M2N: Radiant Ceiling Panels for Heating/Cooling:** For existing buildings, one option, which was investigated but not used, is radiant ceiling panels for heating and cooling (assume radiant panel coverage is approximately 1/2 of total ceiling area).

**M20: Radiant Heating/Cooling:** For existing building only (complex mixed use renovation); use topping slab to install radiant floor heating and cooling system, rebuild stairs

M2Z: Ceiling Fans that are "Casablanca" Style Fans, and Window Box Fans: that are installed through window openings are employed to reduce artificial air conditioning energy costs.

# Mechanical - Plant Systems

**M3A: Ground Source Heat Pump System**: Provide distributed ground source water to water heat pump. Ground source system will be vertical closed loop field of ~200 feet deep boreholes each with Polyethylene pipe (two pipes per borehole connected by U-shape elbow at bottom), filled with bentonite grout surrounding piping. All vertical pipes connect to buried horizontal main that carries fluid to building heat pump.

**M3B: Cascading Chilled Water System:** Chilled water from ground source heat pump systems is routed first to the air handling unit chilled water coils for dehumidification of ventilation air (using the lowest chilled water temperature), and the warmer chilled water is then routed to radiant slabs/panels (higher chilled water temperature will increase the system efficiency and help to avoid condensation on radiant slab/panels)

**M3C: Solar Thermal (Evacuated Tubes Heating System):** Solar thermal heating water panels are used for a portion of the Heating and DHW Plant at the hospital due to the large demand for energy.

**M3D:** Absorption Chillers using Solar Thermal: An absorption chiller with solar thermal input was investigated but not utilized. The heat source for the absorption chiller is the hot water from the solar thermal panels.

**M3E: Ground Source Heat Pump with Central Heat Pump Chiller:** Closed loop vertical well system (as for M3a) but use single central heat pump chiller for heating and chilled water (instead of multiple distributed water to water heat pumps)

**M3F: Chilled Heat Recovery**: The heat pump chiller at the hospital is used to capture the waste heat during the cooling mode for domestic hot water.

# **Plug Loads**

**PA: Occupancy Sensor controlled plug loads:** are incorporated through the use of portable power strips (with motion sensors) in work spaces where normal activity assumes movement in and out of the individual workspace.

**PE: Energy Efficient Transformers:** are included where their long term efficiency will provide lower energy costs and reasonable payback periods.

# Photovoltaic

**PV1: Photovoltaic (PV) Panels and Infrastructure:** is the design-build cost for the photovoltaic array providing electricity to the building. The size of array was determined by the required load for the building as calculated in the Energy Strategies.

**PV2: Added Structure for Roof Mounted PV Panels:** (where required) represents the costs, beyond typical pedestal mounted installation, to secure PV panels to the adjacent structure.

**PV3: Added Structure for Mounting PV Panels to Adjacent Parking Structure** represents the costs to install the PV panels atop a structure that provides shading over the parking areas.

# Water Strategies

**W1: Remove Storm Drainage Connection to Public:** was a credit provided since all storm water would be treated and handled on site. The credit is zero because this line item also includes the addition of a sewer meter for verification purposes. Credits for removing connections to domestic water, sanitary sewer and fire water were not taken with the assumption that the jurisdictions would require them for emergency situations.

W2: Rainwater Containment: costs were calculated based on an underground concrete containment box (6" thick walls) with fluid-applied waterproofing membrane on the interior sides and bottom of the structure. It was assumed that the slab-on-grade would constitute the lid once structurally engineered for the span. Where FRP containment was identified for smaller tanks, material and installation costs were obtained from local subcontractors.

**W3: Biological Bioreacto**r: is the design-build cost for the system to treat all water prior to discharge on-site. This system also is used to treat greywater and blackwater for re-use for certain building types as indicated on the Rainwater Matrix.

**W4: Membrane bioreactors** proposed combine "active aeration" together with "passive contact." The primary treatment section of the bioreactor is composed of multiple rotating drums with large surface areas. The effluent is drawn inside the drums through holes on its periphery surface and passes over a series of internal surfaces. It is the combined effect of being mixed with air and passing over bacterial surfaces which allow for high capacity treatment with minimal power consumption and small size footprint. These bioreactors should be inspected weekly for proper operation and possible biomass growth. Monthly greasing of the main bearings and other main components is recommended. Each bioreactor will retain approximately three months of bio-sludge which must be removed. The resulting sludge can be further processed to produce dry solids which can be used for fertilizer.

**W4: Stormwater Retention/Building Discharge:** includes the costs associated with building a retention area with landscaped swales for the water to collect upon discharge from the building's treatment system. The system is sized to detain the water long enough for it to recharge into the site aquifer.

### W5: Additional Area for Water Collection:

**6' Roof Overhang and Structure for Water Collection:** for projects where a small amount of additional area was needed to meet the water usage budget and 6' overhang was added to increase water collection surface. The overhang was designed to double as a shading device.

**Rain Harvesting Canopy:** for projects where additional area was needed to met the water usage budget retractable canopies where designed to capture water during storm events.

Water Collection on Vertical Surfaces / Top of Roof: represents the costs to install various areas of water collection around the perimeter of and atop the high-rise building type. Costs reflect structural outriggers and catchment surface for several tiers of horizontal collection around the perimeter, and operable surfaces attached to vertical structural elements to capture precipitation from cross-winds.

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**W6: Plumbing Fixtures:** will be served with a greywater system for flush water which is supplied by way of a rain harvesting system (Roof Washer). All plumbing fixtures are low flow with optical sensors.

W7: Composting Toilets: were implemented on the single family residence building type.

## Other

**O1: Wind Turbines**: were removed from the base cost of the high rise building in all climates to reflect the LEED Gold building. They were then added back into the Portland and Boston designs for the Living Building.

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# PREREQUISITE SUMMARY

As the project commenced, the team analyzed each Living Building Challenge prerequisite in order to determine which ones would have cost implications for the study. This section of the report provides a brief summary of assumptions related to each prerequisite of the Version 1.2 Living Building Challenge.

### **1** – Appropriate Site Selection

All sites selected met this criteria, therefore no costs were associated with this prerequisite.

### 2 - Limits to Growth

All sites selected met this criteria, therefore no costs were associated with this prerequisite.

### 3 - Habitat Exchange

All projects accounted for this cost at the same rate, \$5.00/acre/year. The cost was set based on a 100-year commitment to programs available through the Nature Conservancy's "Adopt an Acre®" program.

### 4 - Net Zero Energy

Costs for all proposed energy improvements were added to the base costs, with redundant systems replaced or eliminated in the Living Building redesigns subtracted from the base cost estimate. Other on-site energy systems such as bio-fuels, bio-gas, geothermal,or wind were not considered because of prohibitions outlined in the Living Building Challenge or due to resource limitations too complex to deal with in a comparative review.

The cost of photovoltaic's (PV) and installation was added to the Owner & Design Build Costs at a sliding scale rate as follows:

Systems	< 10 kW =	\$9.00 / Installed Watt
Systems	> 10 kW but < 0.5 MW =	\$8.50 / Installed Watt
Systems	> 0.5 MW =	\$7.50 / Installed Watt

Much of the work associated with this prerequisite was determining the energy conservation strategies each building type and climate city would employ, and the design changes necessary to achieve the estimated resultant energy savings. A target of 50%-65% better than the baseline building was established as a goal, with the hospital at the low end of the scale and the single family residence expected to achieve the greatest percentage energy savings. PV panels were added to supply the remaining energy first to the building roofs, with outriggers that double as sunshades on the south and west. If energy usage was still not accounted for, canopies over the parking lot or ground mounted PV-in the case of the hospital - was added. Lastly of the site did not have enough area, parking garage roofs were used for additional pv area - but only after the parking garage energy use was also accounted for in the net zero equation. See Description of Net Zero Energy strategies for additional information.

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### 5 - Materials Redlist

For the purposes of the cost study, it was assumed that Redlist free products would be available for all products currently containing Redlist materials. (The purpose of this study was not to determine market availabilities). Specific materials addressed directly in the cost estimating include PVC waste and vent piping, PVC site electrical raceways and PVC roofing. An added cost of 1.5% of direct construction cost was added to the base building to account for increased costs due to substitution of materials which did not meet the Redlist

#### 6 - Construction Carbon Footprint

The project's construction carbon footprint was estimated using the Mithun2 calculator for each climate city and building type. \$11/ton was used as an offset cost based on the average pricing received from several high-quality offset providers including the Climate Trust. Carbon offsets were priced using reduction programs, not sequestration.

#### 7 – Responsible Industry

The costs to meet this prerequisite only include the provision of 100% FSCcertified wood on the project. Where the value of the wood products was known, a premium was applied to upgrade to certified wood. This premium was proportionately higher in regions other than Portland due to the lack of availability of FCS certified wood. Where the costs for the wood are dependent on a yet unbuilt tenant improvement, an estimate was made of the cost of woodrelated work and the same premiums were applied. The additional costs for this prerequisite were discounted by slightly more than half for projects achieving LEEDv2.2 credit MRc7 in recognition the fact that some of the costs already included in the baseline. A straight 50% factor was not used in order to account for the premiums for the temporary wood (e.g. concrete formwork) that none of the LEED baseline projects included. It should be noted that most of the building types larger other than the single family residence and multi-familly residential use very little wood, and so the effect of this prerequisite on overall pricing is somewhat minimal.

#### 8 – Appropriate Materials/Service Radius

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. The premium was increased to 12% for Phoenix due to lack of secondary market cities within the innermost 250 mile radius. In contrast, Portland, Boston, and Altanta all have other substantual secondary markets within 250 miles of the base city.

#### 9 - Construction Waste Management

All of the baseline projects in Portland achieved or are projected to achieve construction waste management levels equal to or in excess of those required by the Living Building Challenge. Due to the number of LEED projects receiving the exemplary performance credit for construction waste management, no cost increase was added for this prerequisite in Portland. However, in Atlanta and Phoenix a 15 % increase was added for that section of the project budget, and in Boston a 12.5% increase was anticipated to achieve the LEED Gold baseline. The single family residential percentages were increased, in all climates, to

account for its significantly smaller scale. For the renovation project, additional items to be diverted include existing light fixtures, mechanical equipment, etc., resulting in additional premiums of 10% for Portland, 15% for Phoenix and Atlanta and 12.5% for Boston for the mixed use renovation building type.

## 10 - Net Zero Water

Costs for all proposed features required to achieve Net Zero water were added to the base construction. Rainfall data available from NOAA records was used to determine the amount of rainwater available using five average years of data. Similar to the Net Zero Energy prerequisite, conservation strategies were applied first. The following water strategies were applied in the following order:

- 1) rainwater storage and treatment,
- 2) greywater reuse for non-potable uses,
- 3) blackwater reuse for non-potable uses and
- 4) blackwater reuse for potable use.

Tanks, treatment and pumps were assumed to be co-located in existing structures. See net zero water strategies description for additional information.

## 11 - Sustainable Water Discharge

The sustainable water discharge strategy was directly linked to the net zero Water strategy employed. In buildings where all rainwater was collected and membrane bioreactors were used, it was assumed that no additional storm water or building water was needed. In other projects, strategies included permeable asphalt, swales, dry wells or other storm water management techniques to manage the building water discharge.

# **12 – Civilized Environment**

Several of the base projects required redesign so that every occupiable space is located within 30 feet of an operable window. For some buildings additional costs were also added to make the existing fixed windows operable.

### 13 - Healthy Air / Source Control

Costs for this prerequisite were assumed to have been met by all projects achieving the LEED Gold baseline level.

# 14 - Healthy Air / Ventilation

Costs for this prerequisite were assumed to have been met by all projects achieving the LEED Gold baseline level.

# 15 - Beauty and Spirit

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

### **16** – Inspiration and Education

A lump sum cost, based on gross square footage, was added to each building type for an instructional signage program to convey the sustainability message of the project.