Sustainable Design, Construction and Operation of a Residential High-Rise Building in San Francisco

A 2011 Group Project Final Report

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Executive Summary

Buildings in the U.S. account for 40% of primary energy use, 72% of electricity use, 13% of potable water consumption, and 39% of CO_2 emissions (The U.S. Green Building Council, 2011). In response to the impact of the built environment, the city of San Francisco has instituted stringent green building codes, requiring all new construction high-rise buildings to achieve LEED Gold certification. Our client, the ADCO Group, a privately owned real estate development company, plans to construct a luxury condominium tower in San Francisco's Cathedral Hill neighborhood.

This report addresses the environmental impacts of the ADCO Group's proposed condominium tower in San Francisco. Our analysis considers water and energy usage, accounting for environmental impacts over the long-term occupancy of the building. The goals of our project are to increase the energy and water performance of the building and to justify an integrated building design process. These goals will help our client with their overarching objective of achieving LEED Gold certification or better.

Within these goals, we had to respond to three significant drivers. Firstly, we needed to provide recommendations that fit within the financial feasibility of the client's budget. Secondly, we had to ensure that our recommendations would sustain the transfer of ownership from ADCO to individual condo owners. By transfer of ownership, we mean that ADCO will no longer have a stake in the building after all of the units are sold. Lastly, we had to assure the long-term performance of our recommendations.

In our initial literature reviews and conversations with building experts, we identified a hierarchy to approach our analyses. We prioritized energy and water reduction in this order:

1. Load Reduction: reducing the building's demand for energy and water.
2. Efficiency measures: installing more efficient appliances and equipment.
3. Renewables: using alternative sources of energy.

To reduce the energy load of the building, we first analyzed the building envelope for passive heating and cooling potential, which can reduce the energy required to heat and cool the building's interior. The main factors affecting passive design include: latitude of the building site, orientation to the sun, window placement and design, use of properly-sized overhangs, and insulation.

Using these passive design parameters and local temperature data, we performed a series of energy models. The energy models simulate the energy flows through a building, both electrical energy and the transfer of heat energy. We modeled these energy flows as follows:

1. We used hourly solar radiation for the site and a slope factor algorithm to model the quantity of solar energy that would strike each face of the proposed building throughout the year.
2. We analyzed local air temperature data to identify the heating and cooling loads of the proposed building throughout the year.

3. To model the more complex interactions that occur once the solar energy and outside air temperature affects the interior of the building, we used the eQUEST software package. With this software we were able to model the energy consumption of the building in response to changes in the envelope design.

The results of our energy models show that window type is the most crucial element for energy performance in a high-rise building with an 80% glass envelope. Specifically, our models show that using low solar heat gain glass is the most important factor in reducing annual energy consumption for the proposed building. Looking at insulation of the envelope, our models show that increasing exterior-wall insulation beyond R-13 in a building with an 80% glass façade has an insignificant effect on reducing heating and cooling load in San Francisco's mild climate.

Our analysis next considers building monitoring and automation systems (BMAS), which are important tools to manage the energy demand of modern high-rise buildings. These systems monitor and control the central energy loads of the building, such as common area lighting, elevators, and heating and cooling systems. However, traditional BMAS do not address the energy efficiency opportunities in individual condominiums. As such, we investigated the feasibility of expanding the BMAS to include submeters, load controllers and dashboards within each unit. To analyze the costs and benefits of in-condo BMAS, we created six design scenarios, each with a different mix of submeters, loads controllers, and with or without an energy dashboard. Using price quotes from electrical contractors, we estimated the total cost of the six energy monitoring scenarios.

Our analysis shows the energy savings required are easily achievable for several of the BMAS scenarios. The monitoring scenario, identified as Scenario 3 in our report (4 submeters, 3 load controllers, and a dashboard), offers the most potential benefits without significant added costs. The 16.1% energy savings required for a 10-year payback under this scenario may be easily achievable given the monitoring system's behavior-changing capabilities.

In addition to reducing the energy load of the building, we also focus on ways to reduce the water load. We first calculated baseline water usage using the Federal standard for fixture efficiency. We then calculated the projected water savings from replacing conventional fixtures with more efficient alternatives. We found that by installing more water efficient fixtures and appliances standard within each of the units, we could drastically reduce the building's water usage for a minimal upfront investment.

To determine future water use and savings, we used an average annual increase in water rate of 11% and a 10-year projection into building operations. We modeled four possible scenarios. The 10-year values of investment are both positive and approximately equal for Scenarios 1 and 2; however, the addition of Energy Star appliances in Scenario 2 adds a degree of energy efficiency that justifies the added costs.

With the assumption that Scenario 2 will be implemented, we then examined the viability of adding monitoring systems into the units. Based on literature review that shows 4 - 20% of reduction in consumption from monitor feedback, we modeled a 4%, 12%, and 20%

reduction in addition to efficiency gained from Scenario 2 appliances, given the assumption that Scenario 3 would achieve the lowest value due to its lack of dashboard inclusion, and Scenario 4 would yield greater reduction from having dashboard feedback. We found that all three models yielded positive values of investment, indicating that the installation of a monitoring system would be a worthwhile investment. Additionally, the monitoring and dashboard system could act dually as an ongoing maintenance system to detect and locate water leaks. As many household water leaks can go undetected for long periods of time and result in high material and mechanical damage costs, this ability to identify water leaks is another added benefit of installing a monitoring system.

Based on energy modeling, energy and water monitoring and financial analyses, we provide the developer with site-specific recommendations for green building technologies with the highest environmental value per cost of implementation and the highest likelihood of use by future owners.

Lastly, we recommend that ADCO pursue an integrated building design process. In a conventional design process, each team member works independently, which limits opportunities for integration and synergy. Integrated building design, however, brings the developer, architect, engineer, and contractor together at the earliest stages of a building's life, resulting in a collaborative design process and a building system that performs optimally. Integrated building design will speed the learning curve for future green building projects, both for our client and for other developers seeking to reduce the long-term environmental footprint of large buildings.

Problem Statement

"Green" buildings are maturing as a financially viable strategy for reducing human consumption of energy, water, and materials. Their utility is well proven for owner-occupants, whose long-term involvement in a project provides the foundation for fundamental behavior shifts and ultimately a successful return on investment. However, the emerging challenge for green building construction projects is to carry on this success in situations where ownership is transferred. Our project, the proposed 1481 Post Street condominium tower in San Francisco, represents this challenge: the developer intends to develop a green property, but will exit the project once the units are sold. Within this constraint, the developer must budget its green investments in the building efficiently to sell the units at a price that the market can bear. To help address this problem, the developer has sought the involvement of the Bren School.

This Bren School thesis project analyzes potential green building processes and technologies for the 1481 Post Street development, and identifies their potential costs, benefits, and trade-offs. Based on these analyses, we provide the developer with site-specific recommendations for green building technologies—appropriate for the location—with the highest environmental value per cost of implementation, and the highest likelihood of use by future owners over multiple changes in ownership. Additionally, we recommend reproducible processes that will speed the learning curve for future green building projects, both for our client and for other developers seeking to realize a meaningful reduction in the long-term environmental footprint of large buildings.

Project Background

Client

Our client, the ADCO Group, a privately owned U.S. real estate and merchant banking company, intends to build a 36-story, 231-unit high-rise condominium building at 1481 Post Street in San Francisco. ADCO is currently preparing an environmental impact report to be reviewed by the City Planning Commission before moving to the construction phase. The ADCO Group has enlisted our help with the identification and analysis of sustainable design elements for this proposed building, and has specified the goal of meeting or exceeding LEED Gold certification. The client's overarching goal in bringing the Bren School to this project is establishing 1481 Post Street as a paradigm for environmental stewardship and a hallmark sustainable building in the San Francisco skyline. This development will also be the first LEED certified building for ADCO's new construction projects in San Francisco.

1481 Post St: Location and Climate

Located in San Francisco's Cathedral Hill neighborhood, the proposed residential high-rise is situated along a major transit corridor within a 20-minute walk to Union Square, Civic Center, Pacific Heights, and the Fillmore Center. This convenient siting creates a walkable community surrounded by a diversity of amenities, an integrated and lively streetscape, and less need for personal car use (Dumreicher, Levine, & Yanarella, 2000). High-rise buildings like 1481 Post Street present the crucial economy of scale needed for high-efficiency technologies that are typically out of reach for individual homeowners. High-rise residential buildings also provide the opportunity for efficient bundling of building services such as energy and water.

San Francisco has a temperate climate with limited seasonal temperature variability. The coastal city is subject to cool marine air and persistent fog in the summertime, which can burn off on the warmer bay side of the city, creating conditions for a thermally driven sea breeze. Wintertime weather is temperate, with average maximum temperatures between 45 and 60°F (Null, 2005). Spring and Fall experience the most cloud-free, high-pressure conditions, resulting in some of the warmest days. Rainfall in San Francisco averages an annual 20.11 inches in an average of 63 days of the year. This combination of weather patterns creates opportunities for green building elements to be explored in our analysis.

San Francisco's Green Building Regulations

Buildings account for roughly 40% of total energy consumption in the United States, and the percentage is even higher in densely urbanized cities (The U.S. Green Building Council, 2011). Federal, state and local governments are increasing regulation of buildings' energy and water consumption, with the strongest involvement on the regional scale. San Francisco, in particular, has developed a stringent set of sustainable building requirements for new construction projects. New high-rise residential construction projects in the city are required to meet LEED Silver certification today and LEED Gold status by 2012. These strict building requirements call for new high-rise residential buildings to meet specific load reduction goals, supporting the city's aggressive goal to reduce greenhouse gas emissions in 2012 by 20% below 1990 emissions (The San Francisco Board of Supervisors, 2008). San Francisco's building codes are some of the most stringent in the country and supersede California state building standards including the new CALGreen building code, effective January 2011 (Department of Building Inspection, 2011). These green building codes present another constraint for our project: the minimum level of performance in LEED's environmental impact categories is fixed at the Gold level, so we consider that minimum as our baseline upon which to analyze potential improvements. The following table lists all possible attainable LEED v3 category titles and the range of LEED points that the building will be eligible for per our recommendations and ADCO's proposed interests. This evidence clearly demonstrates, that even at minimum, the building will clearly meet the 60 points necessary for LEED NC Gold certification. For more information on specified recommendations and relevant credits, please refer to Project Manual Recommendations.

Table 1 - Possible LEED Points Attainable with ADCO's Existing and Team SFHighRise's Proposed Recommendations

LEED Category	Shorthand	Category Title	Number of Possible Points	Evidence
Sustainable Sites	SSp1	Construction Activity Pollution Prevention	N/A	Prerequisite
Sustainable Sites	SSp2	Environmental Site Assessment	N/A	Prerequisite
Sustainable Sites	SSCr1	Site Selection	1	Developing on Existing Site
Sustainable Sites	SSCr2	Development Density and Community Connectivity	5	Existing Amenities and Services located within ½ mile of site
Sustainable Sites	SSCr4.1	Alternative Transportation – Public Transportation Access	6	Existing proximity to numerous San Francisco Muni bus lines within ¼ mile of site
Sustainable Sites	SSCr4.2	Alternative Transportation – Bicycle Storage and Changing Rooms	1	Site will provide covered storage facilities for securing bicycles for 15% of more of building occupants
Sustainable Sites	SSCr4.3	Alternative Transportation – Low-Emitting and Fuel Efficient Vehicles	3	Very likely that site will provide preferred parking for low-emitting and fuel-efficient vehicles for 5% of the total vehicle parking capacity on-site
Sustainable Sites	SSCr4.4	Alternative Transportation – Parking Capacity	2	Parking capacity likely to meet but not exceed minimum local zoning requirements and will include a car-share program
Sustainable Sites	SSCr5.1	Protect or Restore Habitat	1	Likely that site will contain local vegetation that will cover 50% of the site (excluding the building footprint) or 20% of the total site area

Sustainable Sites	SSCr5.2	Maximize Open Space	1	May be likely that the site will reduce the development footprint and/or provide open vegetated space, exceeding local zoning requirements by 25%
Sustainable Sites	SSCr6.1	Stormwater Design – Quantity Control	1	Likely that the site will have a stormwater management plan that results in a 25% decrease in the volume of stormwater runoff from the 2-year 24-hour design storm
Sustainable Sites	SSCr6.2	Stormwater Design – Quality Control	1	May be likely that there will be a stormwater management plan promoting the infiltration, capture, and treatment of stormwater runoff from 90% of the average annual rainfall
Sustainable Sites	SSCr7.1	Heat Island Effect – Nonroof	1	Proposed parking garage to be subterranean and site may use hardscape materials with an SRI of at least 29
Sustainable Sites	SSCr7.2	Heat Island Effect – Roof	1	Very likely that roof will either contain a vegetate roof and/or a high-albedo roofing material
Sustainable Sites	SSCr8	Light Pollution Reduction	1	May be likely to reduce light pollution of interior lighting and very likely to reduce light pollution on-site of exterior lighting
Water Efficiency	WEp1	Water Use Reduction	NA	Prerequisite
Water Efficiency	WECr1	Water Efficient Landscaping	2	Very likely that site will use 50% less water from a calculated midsummer baseline case
Water Efficiency	WECr2	Innovative Wastewater Technologies	2	Very likely that wastewater will be reduced by 50% with the installation of water-conserving fixtures and energy / water monitoring systems
Water Efficiency	WECr3	Water Use Reduction	2 – 4	Very likely that the building will use 30 – 40% less water than the baseline calculated for building (not including irrigation)
Energy and Atmosphere	EAp1	Fundamental Commissioning of Building Energy Systems	NA	Prerequisite
Energy and	EAp2	Minimum Energy	NA	Prerequisite

Atmosphere		Performance		
Energy and Atmosphere	EAp3	Fundamental Refrigerant Management	NA	Prerequisite
Energy and Atmosphere	EACr1	Optimize Energy Performance	1 – 19	Very likely that the building will demonstrate a percentage improvement in the proposed building performance rating compared with the baseline building performance rating between 12 and 48%
Energy and Atmosphere	EACr2	On-Site Renewable Energy	1 – 7	Very likely that the building will have either building integrated photovoltaic systems or solar thermal heating for a proposed pool on-site, but unlikely that this will 13% of total building energy consumption
Energy and Atmosphere	EACr3	Enhanced Commissioning	2	Very likely that a CxA will continue to commission the building post-construction and will play a role in the proposed energy monitoring system
Energy and Atmosphere	EACr4	Enhanced Refrigerant Management	2	Very likely that building will use refrigerants that minimize both ozone depletion and global climate change
Energy and Atmosphere	EACr5	Measurement and Verification	3	With CxA, very likely that a measurement and verification (M&V) plan will be implemented post-construction
Materials and Resources	MRp1	Storage and Collection of Recyclables	NA	Prerequisite
Materials and Resources	MRCr2	Construction Waste Management	1 – 2	Very likely that the site will recycle and/or salvage nonhazardous construction of demolition debris (between 50 and 75%)
Materials and Resources	MRCr3	Materials Reuse	1	Very likely that salvaged, refurbished, or reused materials, will constitute at least 5% of the total value of materials on the project
Materials and Resources	MRCr4	Recycled Content	1 – 2	Very likely that the building will use materials with recycled content (at least 10 – 20% of

				total materials costs)
Materials and Resources	MRCr5	Regional Materials	1 – 2	Very likely that building will use building materials extracted, harvested, or recovered, as well as manufactured, within 500 mils of the project site (between 10 – 20% of total material costs)
Materials and Resources	MRCr6	Rapidly Renewable Materials	1	Very likely that the building will use building materials and products (at least 2.5% of total costs for all materials)
Materials and Resources	MRCr7	Certified Wood	1	Likely that the building will use a minimum of 50% (cost) of wood-based materials and products that is Forest Stewardship Council certified
Indoor Environmental Quality	IEQp1	Minimum Indoor Air Quality Performance	NA	Prerequisite
Indoor Environmental Quality	IEQp2	Environmental Tobacco Smoke (ETS) Control	NA	Prerequisite
Indoor Environmental Quality	IEQCr1	Outdoor Air Delivery Monitoring	1	Will contain CO2 monitors and monitor outdoor airflow
Indoor Environmental Quality	IEQCr2	Increased Ventilation	1	Very likely that the building will increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 20% compared to an ASHRRAE Standard 62.1-2007 baseline
Indoor Environmental Quality	IEQCr3.1	Construction Indoor Air Quality Management Plan – During Construction	1	Very likely that there will be an IAQ management plan for the construction and preoccupancy phases of the building
Indoor Environmental Quality	IEQCr3.2	Construction Indoor Air Quality Management Plan – Before Occupancy	1	Very likely that there will be an IAQ management plan and that will it be implemented after all finishes have been installed and cleaned
Indoor Environmental Quality	IEQCr4.1	Low-Emitting Materials – Adhesives and Sealants	1	Very likely that all adhesives, sealants, and sealant primers will meet LEED v3 requirements
Indoor Environmental Quality	IEQCr4.2	Low-Emitting Materials – Paints and Coatings	1	Very likely that paints and coatings used on the interior of the building will comply with

				LEED v3 requirements
Indoor Environmental Quality	IEQCr4.3	Low-Emitting Materials – Flooring Systems	1	Very likely that flooring will meet LEED v3 requirements
Indoor Environmental Quality	IEQCr4.4	Low-Emitting Materials – Composite Wood and Agrifiber Products	1	Very likely that wood and agrifiber products used in the building will not contain urea-formaldehyde resins
Indoor Environmental Quality	IEQCr5	Indoor Chemical and Pollutant Source Control	1	Very likely that the building will minimize the control and entry of pollutants into the building and later cross-contamination of regularly occupied areas
Indoor Environmental Quality	IEQCr6.1	Controllability of Systems – Lighting	1	Very likely that building occupants will be given to 90% of total occupants for individual lighting tasks needs and preferences
Indoor Environmental Quality	IEQCr6.2	Controllability of Systems – Thermal Comfort	1	Very likely that 50% of the building will be able to control temperature in the building
Indoor Environmental Quality	IEQCr7.1	Thermal Comfort – Design	1	Very likely that the heating, ventilation, and air conditioning systems will meet ASHRAE Standard 55-2004
Indoor Environmental Quality	IEQCr7.2	Thermal Comfort – Verification	1	Very likely that a thermal comfort survey will be distributed to building tenants post-occupancy
Indoor Environmental Quality	IEQCr8.1	Daylight and Views – Daylight	1	Most, if not all, units will have open daylight
Indoor Environmental Quality	IEQCr8.2	Daylight and Views – Views	1	Most, if not all, units will have open views
Innovation in Design	IDCr1	Innovation in Design	1 – 2	1) Building Monitoring Systems 2) Exemplary Performance
Innovation in Design	IDCr2	LEED Accredited Professional	1	At least 1 principal participant will be e LEED Accredited Professional
		Max. Total Points	**93**	
		Min. Total Points	**62**	
		Points needed for Gold	**60**	

Project Significance

The Role of Buildings in California's Energy and Water Challenges

The growing population in California continues to increase the demand for electricity at a rate of 2% per year (Brown & Koomey, 2002). This increasing demand brings a suite of drawbacks including service interruptions, new power plant construction and operation, and reliance on out-of state power. Buildings are a large contributor to this demand for electricity. Space heating accounts for 27% and space cooling accounts for 11% of the energy consumed in residential buildings in the United States. Including water heating (13%), these systems account for 51% of residential energy consumption (The Energy Information Administration, 2009). Sustainable and efficient innovative building design can significantly reduce overall energy consumption and simultaneously improve indoor air quality (ASHRAE, 2009).

These same building designs will also be crucial in helping California meet the Global Warming Solutions Act of 2006 (Assembly Bill 32), which sets an economy-wide cap on California greenhouse gas emissions at 1990 levels by no later than 2020. This aggressive goal represents approximately an 11% reduction from current emissions levels and nearly a 30% reduction from projected business-as-usual levels in 2020 (California Energy Commission, 2008). A building that invests in upfront load-reduction, efficient operating systems, and user-based incentives to reduce electricity consumption will pay dividends as utility prices rise.

In LEED v3, the new LEED rating system, the US Green Building Council has emphasized the importance of HVAC design by increasing the weighting of Energy and Atmosphere (EA). The EA section of version 3 is now weighted as 35% of total possible points, whereas the EA section in version 2.2 was 25% (The U.S. Green Building Council, 2009). This new weighting highlights the increasing importance of energy use reduction and efficiency, and the significant role of innovative HVAC design in achieving these goals.

Droughts in California are often persistent and policymakers strive to prescribe realistic and viable regulations toward water conservation. Some examples include AB 1420, which allows awarding of grants and loans only to projects contingent on compliance of best water management practices, and SBX 77, which requires a 20% reduction and reporting of urban water use (Inland Empire Utilites Agency, 2010). In addition to this top-down approach, bottom-up efforts from individual residents will also be necessary to reduce water consumption. California residential water use accounts for 54% of total urban water use, a number projected to reach 58% by 2020 (Irvine Ranch Water District, 2010). Approximately 20% of California's annual energy consumption is used just to transport water (California Energy Commission, 2005). The conservation of water is imperative to sustain the state's projected growing population and its environment; efficiently designed and operated buildings will play an important role in managing this valuable resource.

The Role of Homeowners in Resource Conservation: Behavior and Incentives

Homeowners are the beneficiaries of reduced energy and water bills provided by efficient buildings; they can also be the driver of a building's long-term sustainability since they are responsible for real-time demand and consumption. There is recent evidence suggesting that tenants are not provided enough information to optimally operate the buildings they occupy, at the level of performance intended by the building's designers (Hammerstrom 2007; Wilson 2008; Appelbaum, 2010). Achieving energy and water reductions will require educating building tenants on how to optimally use the facilities they inhabit. For example, multiple studies have found that providing tenants with real-time information of their energy and water usage has led to reductions of 4 to 20% (Hayes, and Cone, 1981; Hammerstrom 2007; Wilson 2008). Tenants must be incentivized to help retain the building's sustainable purpose and benefits over the course of numerous ownership transfers.

Project Goals

Fixed Parameters

When we started this project, ADCO had already been in discussion with a group of architects to design the building and some decisions had been fixed prior to our involvement. It was important that we work around these finalized decisions, or fixed parameters, to identify areas where we could have the greatest impact, and avoid putting too much effort toward aspects of the building we had no control over.

ADCO had a site in mind for the project from the beginning, and they had worked with the architects to develop an initial sketch-up of the way the building would orient. Neither the site nor orientation of the building would change; therefore we did not spend time examining sustainable options in those areas, despite the heavy weights LEED assigns to site selection.

ADCO prefers an 80% glass exterior for the building's façade; this preference is based on their years of experience selling luxury condominiums. While this might pose challenges in terms of energy efficiency, it allows the developer to remain competitive in the San Francisco high-end condominium market, where glassy façades are the norm, and buyers expect a "wow factor" of views and light. The proposed building incorporates stone cladding into its façade. This reduces the overall use of glass to a degree, and differentiates the building from the competing condominium towers such as One Rincon, One Hawthorne, and Infinity, which all exhibit a glass curtain wall appearance.

Upon our initiation into the project, our client and the architects were in the middle of developing and designing the envelope of the building. As this stage was both current and important, we decided that we would sync our research with theirs and also focus most of our efforts in designing an economical and efficient envelope for the building. For this reason, and due to the heavy glazing of the building design, it made sense to focus much of our research toward windows and insulation within the scope of energy efficiency.

Goal #1: Long Term Energy and Water Performance

We examine and recommend efficient energy and water options and potential usage monitoring mechanisms to ensure sustained energy and water performance throughout the building's operation.

Goal #2: Key Processes to a Front Loaded Design

We examine and recommend an integrated building design process to ensure future projects undertaken by our client can maximize the economic benefits of a front loaded design.

Project Drivers

Our analysis responds to three project-specific drivers. First, ensure that our recommendations are financially feasible against the client's budget, resulting in units with a sale price that the market could bear. Second, ensure that our recommendations sustain the transfer of ownership from ADCO to individual condo owners, since ADCO will no longer have a stake in the building after all of the units are sold. Third, assure the long-term performance of our recommendations such that the occupants are equipped with the tools necessary to operate the building as efficiently as it was designed to perform.

Methods

We collected data for this project using the following methods: original analysis, case study and published literature review, interviews with industry professionals and scientists, research into future policies, and relevant green building conference and seminars.

In talking to building experts, we identified an overarching hierarchy to approach our analysis to energy and water conservation. We prioritized conservation in this order:

1. **Load Reduction**. The most cost-effective, long-term savings result from reducing the building's upfront demand for energy and water, through an initial design that optimizes the building's siting, dimensions, orientation, envelope, and mechanical systems.
2. **Efficiency measures**. The next most cost-effective strategy is to select efficient appliances, fixtures, and mechanical systems that reduce waste from end-use energy and water flows.
3. **Renewables**. On-site power generation is typically the least cost-effective way to offset electricity use; photovoltaic and wind power are expensive, per unit of generated electricity, and produce a small fraction of a building's demand in typical urban settings. Therefore this is ranked last in our hierarchy of analysis, after the first two had been thoroughly considered.

This hierarchy drove our methodical approach to cost-benefit analyses of building technologies. The primary criterion for our analysis, allowing for variable comparison across disparate platforms, was marginal environmental benefit per cost of implementation and upkeep. In the numerator of this metric, we estimated the cost of installation and upkeep versus a baseline cost defined as the least expensive way to meet code. These costs were based on interviews with contractors, vendors, and other industry professionals. In the denominator, we looked at units of offset energy (or water) versus the baseline usage defined as the minimum performance needed to achieve the LEED Gold standard mandated by the city. In comparing this metric for different applications, we also weighed the importance of marketability and buyer appeal, and likelihood of use.

Analysis I: Water

1481 Post Street will consist of 231 units of various configurations. Assuming each full bathroom has one toilet, shower and lavatory faucet; and each half bathroom has one toilet and lavatory faucet, the building will have 592 toilets and lavatory faucets, 397 showers, and 231 kitchen sinks, dishwashers and clothes washers. By recommending fixtures and appliances that are more efficient than their conventional counterparts, we can save the building a significant amount of water. Additionally, we have made recommendations regarding the building's landscape, which typically accounts for ¼ of a building's water usage.

Importance of Water Conservation

A recent government survey showed that at least 36 states are anticipating local, regional, or statewide water shortages by 2013 (The United State Environmental Protection Agency, 2010). California, in particular, faces some of the most challenging water issues in the country, and balancing water supply and demand is a perennial problem.

Buildings in the United States account for 13% of the potable water consumption and this percentage is likely to increase as residential construction is expected to grow over the decade to meet the needs of a growing population (The U.S. Green Building Council, 2010). As a result, sustainable building practices that reduce water demand and employ water conservation strategies are integral for new construction projects nationwide.

Currently, the average American uses 100 gallons of water per day and 70% of this water is for indoor use. The toilet, shower and clothes washer are some of the biggest water consumers, typically comprising 30%, 19% and 25% of total indoor water use respectively (Aquacraft, 1999). By installing water efficient fixtures as standard within each residence and incorporating water conservation strategies early on in the design process, building developers can play an integral role in reducing water demand within their buildings.

Snapshot of Indoor Water Usage

We calculated baseline water usage using Federal standard fixture efficiency from EPACT 2005 and average occupant usage from the LEED 2009 for New Construction & Major Renovation Ratings System Reference Guide. The indoor water fixtures we analyzed were: toilet, shower, lavatory faucet, kitchen sink, clothes washer, and dishwasher. We then calculated the projected water savings from replacing conventional fixtures with WaterSense fixtures and Energy Star appliances. We determined annual water savings per household for different water efficiency scenarios. For an average unit in the 1481 Post Street building, based on San Francisco's average household size of 2.4 people, the resulting savings came to approximately 10,100 gallons per year. For the building as a whole, the savings reached 2.35 million gallons per year, increasing water efficiency by 20% (See Figure 1).

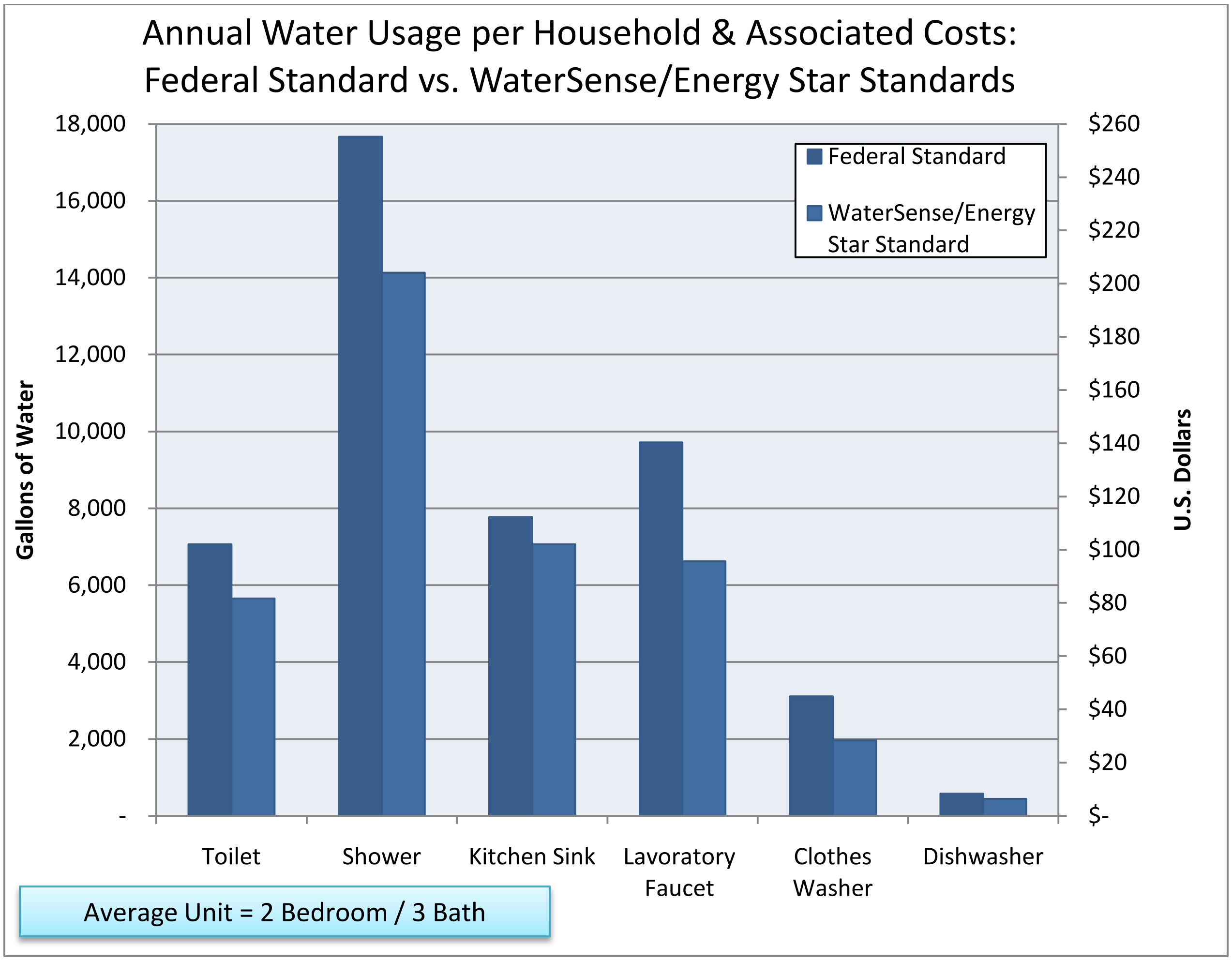

Figure 1 – Annual Water Use per Household (in gallons on the primary y-axis and U.S. dollars on the secondary y-axis)

Compared to the cost of the baseline fixtures, the cost for upgrading to efficient fixtures is about $134,000 for the whole building. Some of this cost may be recouped during the selling process through a marketing premium or increased sales performance as a result of "green" differentiation. Above-baseline water savings is a tangible environmental metric appealing to many Californians, and more importantly, the projected per-household water bill savings can be marketed to buyers. With water prices expected to rise significantly in the state, these annual savings will increase, and the building's built-in efficiency can be marketed to potential buyers as a degree of insurance against future water price shocks.

Future of Indoor Water Usage

We obtained historical water rate data from a neighboring building owned and operated by ADCO in San Francisco. These data provide us with a monthly dollar/gallon rate of water use for the last six years (2005-2010). With this information, we first average the annual water rate, and after determining the rate of change from year to year, determined what the average annual change of rate was. The average rate of increase in water rate was 11% annually (See Figure 2). We then use this rate to project 10 years into the project life, starting with 2014, when the building is expected to become operational.

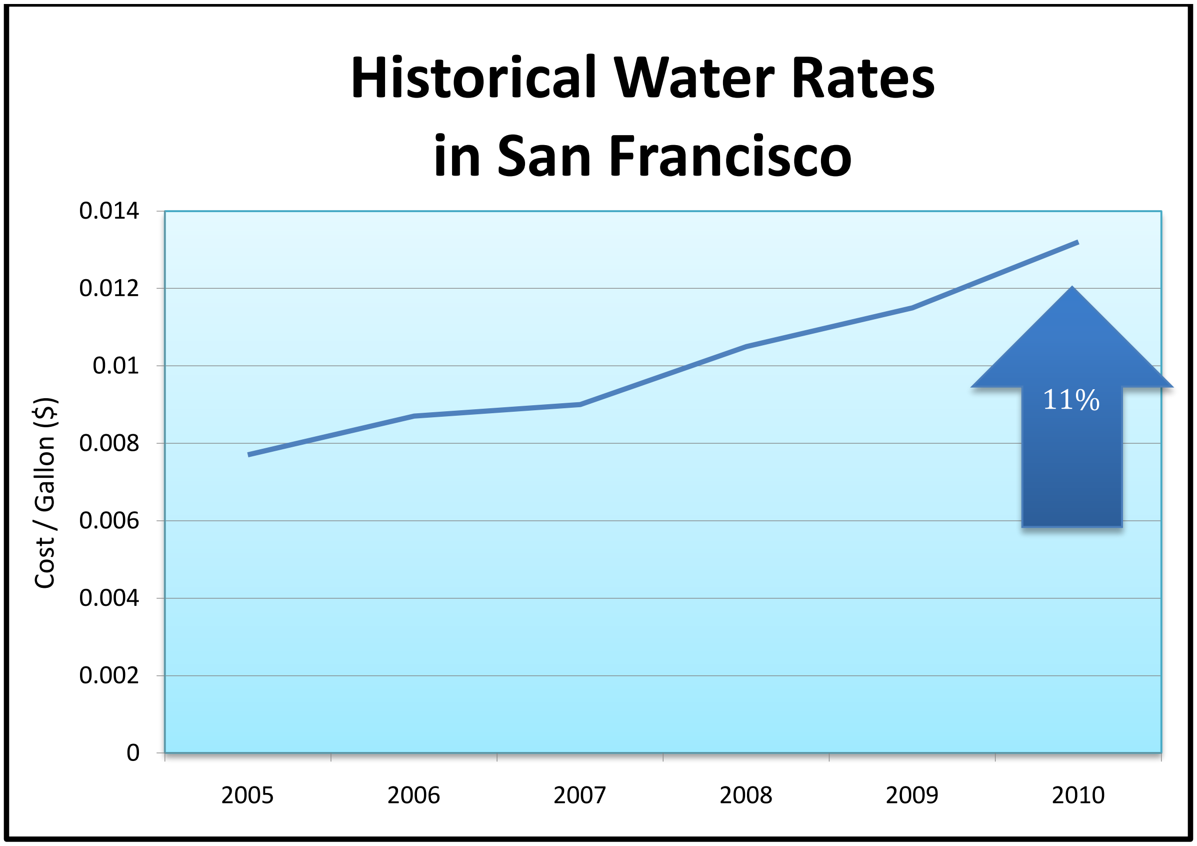

Figure 2 - Historical Water Rates in San Francisco (2005 - 2010)

Scenario Design for Indoor Water Use Savings

We used four different scenarios to examine water use consumption and reduction (See

Table 2). These scenarios are designed to assist ADCO in identifying areas of improvement and guide them toward the most economical and impactful options to maximize water savings. The scenarios are outlined in the table below and include WaterSense fixtures, Energy Star appliances and building monitoring systems. We examined the feasibility of expanding the standard building automation system into individual monitoring systems in each unit. This advanced building monitoring and automation system (BMAS) could submeter water loads, and the added unit dashboards could give occupants detailed information about their usage patterns.

Table 2- Scenarios for Indoor Water Use

Scenario	Total Costs ($)	System Description (Whole Building)
1	71,400	WaterSense efficient toilets lavatory faucets, kitchen faucets, and showers
2	134,000	Scenario 1 and Energy Star dishwashers and clothes washers
3	338,000	Scenario 2 and a Monitoring System without dashboards
4	389,000	Scenario 2 and a Monitoring System with dashboards in each unit

Once the scenarios were decided, we continued with calculations to determine all WaterSense and Energy Star fixtures or appliances' individual water savings capacity in terms of gallons and dollars. The results were compared to a baseline of conventional fixtures and aggregated to demonstrate potential water savings within the whole building. The savings in gallons were then translated into savings in dollars across the first 10 years of the building's operations, adjusted for each year's expected water price. This was done by considering a discount rate of 5% and using the previously calculated 11% of annual increase in water rates in San Francisco.

Findings

In Scenario 1, with only our WaterSense appliances in place, the building could achieve up to a 21% reduction in water use compared to the baseline. The upfront, added investment of $71,400 for these appliances will break even by the building's third year in operation. At the end of 10 years, the building will see a savings of over $420,000 in water utility costs.

In Scenario 2, with all of our WaterSense and Energy Star appliances in place, the building could achieve up to a 21.8% reduction in water use compared to the baseline. Economically, this means that the upfront, added investment of $133,770 will break even by the building's fourth year in operation. By the end of 10 years, the water savings will translate into $481,820. Compared to Scenario 1, Scenario 2's upfront, added investment is $62,370 greater and yields an increase of $61,369 in payback at the end of 10 years and an increase in water efficiency of 1.1%.

With all these considerations, the Net Present Value (NPV) for Scenario 1 is $349,051 and for Scenario 2 is $348,050. While these values are approximately equal, the investment in the added Energy Star appliances in Scenario 2 carry value beyond water savings. The energy savings of around 37% from the Energy Star clothes washer and around 10% from the Energy Star dishwasher are also important considerations for investment (See Figure 3).

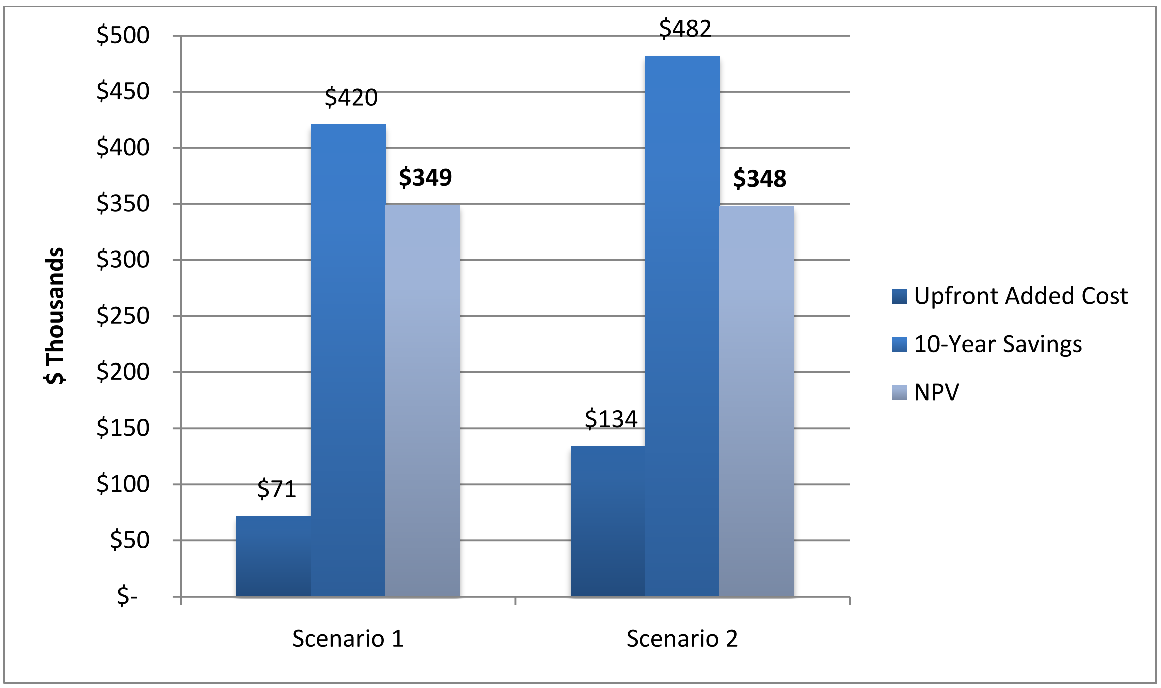

Figure 3 - Net Present Value Results for Indoor Water Use

In Scenario 3, we examined the potential of adding a monitoring system without dashboards along with Scenario 2's combination of appliances. The upfront cost for the monitoring system was calculated with the assumptions that 1) we will only need one submeter per unit to measure water loads, 2) water will bear 10% of the total system cost for engineering, software, server, maintenance, and dashboards, and 3) the low maintenance cost will not be adjusted for inflation or discounting over time. Given this, we calculated that the monitoring cost without dashboards is $203,250. For Scenario 4, we added an individual dashboard in each unit for real-time occupant feedback information. Given the same assumptions as Monitoring 1, plus the added cost of the dashboard units, the total monitoring cost with dashboards is $208,851. Assuming these monitoring systems will be added in after the installation for the Scenario 2 fixtures, the cumulative total costs for Scenarios 3 and 4 are $337,620 and $387,632, respectively.

To calculate the NPV for Scenarios 3 and 4, we again projected 10 years into the building's operation, starting in 2014. We used Scenario 2 as baseline to compare the added costs of monitoring system Scenario 3 and 4. When we analyzed the NPV of Scenarios 3 and 4, assuming that the monitoring systems led to no additional water savings, we still found a positive NPV of $143,494 for Scenario 3, and an NPV of $93,482 for Scenario 4 (See Figure 4).

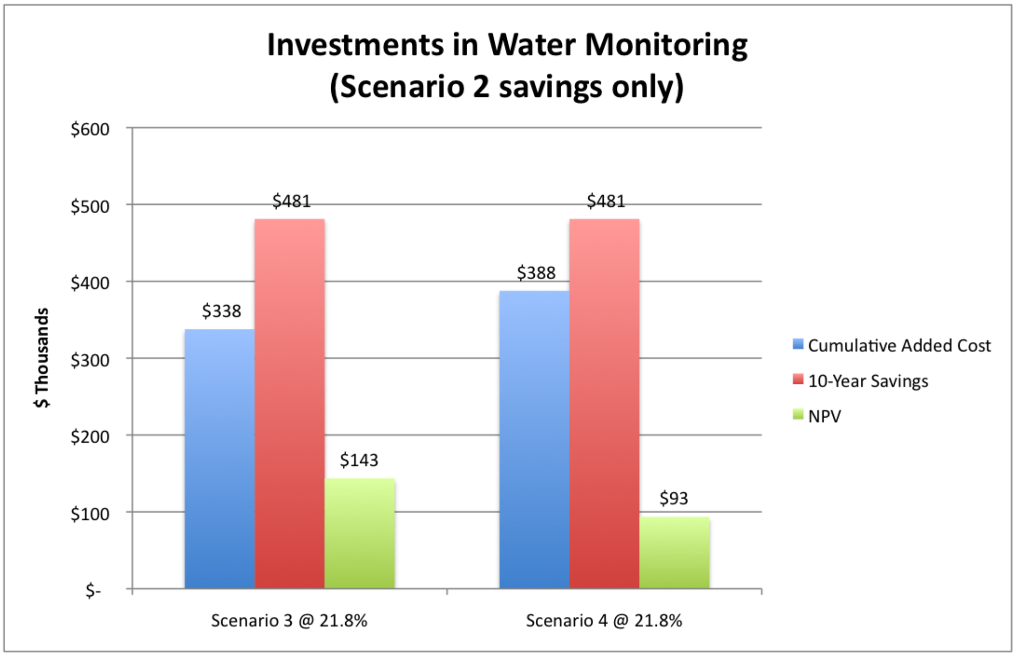

Figure 4 - Investments in Water Monitoring without Energy Monitoring Systems

From various literature reviews we found that providing occupants with feedback information on energy and water usage, through the use of monitoring systems and dashboards, effectively alters occupant behavior, leading to 4-20% reduction in consumption (Darby, 2006; Wilson, 2008). We tested the effect of this behavior modification by quantifying its resulting water savings potential, and examining how the NPVs would change if this behavior change were taken into consideration. Since Scenario 3 does not include a dashboard, we took the low end of the quoted range and assumed a 4% reduction from behavior modification. For Scenario 4, we took an average of the quoted range, a 12% reduction, as well as the high end of the quoted range, a 20% reduction, and added them to the baseline of Scenario 2. Given these new rates of reduction, we determined that the NPV from Scenario 3 would be $214,116. The two NPVs for Scenario 4 at 12% and 20% reduction are $300,935 and $428,938, respectively (See Figure 5).

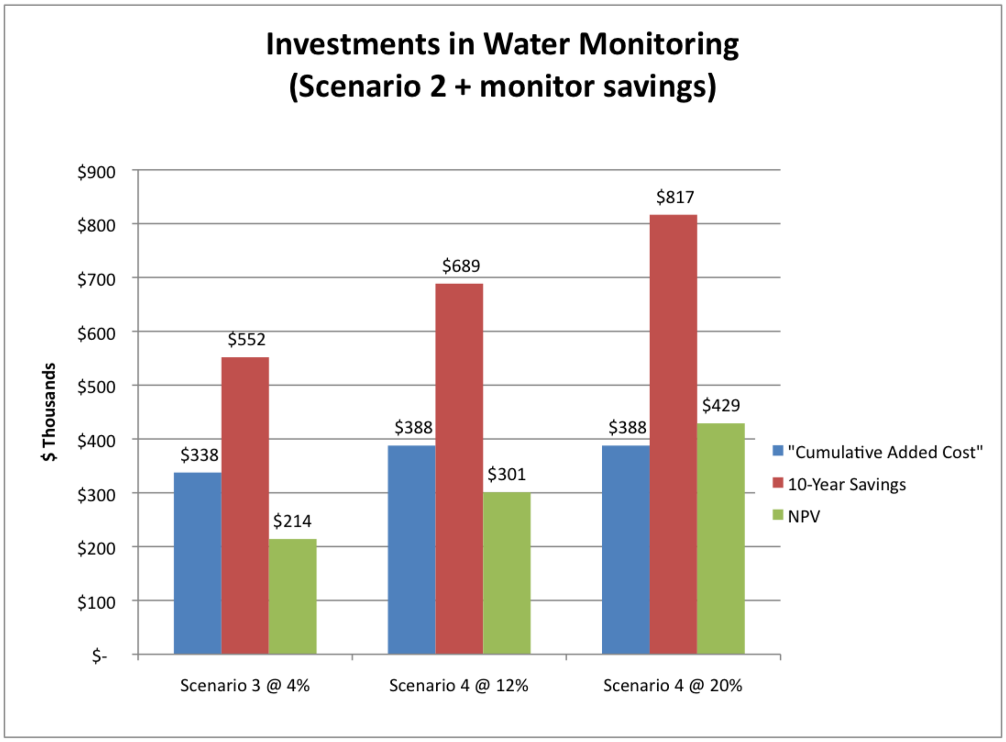

Figure 5 - Investments in Water Monitoring with Energy Monitoring Systems

The positive NPVs are strong indicators that the monitoring system is a worthwhile investment, given a 10-year payback period. The potential to achieve an additional 12- 20% water savings through the installation of dashboards justifies the investment in Scenario 4 over Scenario 3. Based on past empirical data and the highly environmentally aware populace in San Francisco, we believe that the use of monitoring and dashboard systems can achieve high percentages of reduction.

In addition to incentivizing positive occupant behavior, monitoring systems can also act as ongoing maintenance systems that provide indicators when a part of the system is malfunctioning. A common example in household malfunction is water leaks. By the time they are detected, water leaks can result in unexpectedly high expenses for repairs in damaged materials and parts. A home equipped with a monitoring system could prevent such a leak from persisting undetected. The occupant may easily determine from the monitoring system that there is an unusually high load of water being expelled in the household, and may identify where the leak is located. This preventative method of damage control is another important benefit of installing monitoring systems in every unit.

Recommendations for Indoor Water Usage

Our group recommends the following to reduce indoor water use:

- Installation of WaterSense certified toilets, showerheads, and bathroom and kitchen faucets in all building units and building common areas (including the lobby and fitness center).

- Installation of Energy Star rated clothes washers and dishwashers standard in all building units and building common areas.
- Based on our NPV calculations, projected savings in water consumption and projected water price increase, the investment in an added monitoring system with individual unit dashboards is recommended.

Outdoor Water Use

While increasing the efficiency of some of the largest water consuming fixtures will result in significant savings, indoor water use is only part of the problem. To fully address the water usage of a building, we need to consider ways to reduce outdoor water usage, which on average accounts for 25% of a building's water usage.

Significance

Landscape irrigation is a significant component of outdoor water use. Improved landscape design and maintenance can greatly reduce or even eliminate the need for potable water use outdoors. Additionally, well-planned landscapes can reduce stormwater, taking pressure off of a city's sewer system, and minimizing runoff polluted with chemicals from entering our water system.

As part of their environmental impact report (EIR), ADCO must develop a landscape plan. While they need to complete the design of the base of the building before they can draw up this landscape plan, our recommendations for landscape design will reduce outdoor water usage.

Recommendations for Outdoor Water Usage

Our group recommends the following to reduce outdoor water use:

1. Xeriscaping is a landscape technique that reduces/eliminates the need for irrigation. Common xeriscape strategies include planting native and adaptive plants that require less water, pesticides and fertilizer.
2. Efficient Irrigation Technologies can reduce the amount of water used for irrigation.
    a. Drip irrigation is 90% efficient compared to conventional sprinklers, which are only 60% efficient, as they lose a lot of water to wind.
    b. Another efficient irrigation technology that we recommend employing is the use of reclaimed water. Reclaimed water for irrigation purposes can drastically reduce the pressure on municipally supplied potable water. Sources of reclaimed water include: captured rainwater, graywater, or municipally supplied reclaimed water. The latter option is not currently used in San Francisco; however, the infrastructure exists and may be used in the future.
3. Stormwater Management is a problem in urban areas with significant impervious areas. Impervious materials prevent the infiltration of water after a storm; water instead rushes offsite. This runoff is a significant threat to water quality due to contamination with chemicals. In response, we recommend the following:

a. The minimization of stormwater runoff through increased vegetated surfaces on the ground level, permeable pavers where appropriate, and runoff-capturing landscape features such as rain gardens or bioswales.
b. The installation of the greatest percentage of greenery possible on the roof of the building. A vegetated roof will slow down the runoff rate as the plants absorb the water and reduce the burden on the municipal stormwater system.
c. The inclusion of green walls or vegetated structures attached to vertical surfaces that can slow runoff rates and provide aesthetic interest.

Analysis II: Energy Load Reduction - Envelope

Passive Design Principles

The most important factors in reducing the energy load of a building are the following:

1. Orientation of the building faces to the sun.
2. Design of the building's exterior (also referred to as the building envelope) (Johnston & Gibson, 2010).

As previously mentioned, when our team joined this project, a fixed parameter was the orientation of the building due to constraints of property boundaries and shadow studies. However, the envelope design had not yet been finalized, allowing us the ability to influence the design of this important factor toward achieving our goal of reducing energy load.

The amount of energy required to heat and cool the building's interior to a comfortable temperature year-round can be minimized by designing the envelope for passive heating and cooling. Passive heating and cooling are accomplished by designing the building to maximize solar heat gain in the winter and minimize the solar heat gain in the summer. Passive heating and cooling can be accomplished via the following design principles:

- Careful placement and design of windows.
    - For example, for buildings in the northern hemisphere, include a relatively large quantity of windows on the south-facing side to maximize solar heat gain in the colder months.
- Use of properly-sized overhangs.
    - Provides shade from the higher sun angle in the summer, while still letting the lower-angle winter sun into the interior. (Because of this relationship, passive heating and cooling may be more properly referred to as "passive heating and summer shading.") (Johnston & Gibson, 2010)
- Both of the above principles combined with an airtight envelope and high levels of insulation throughout.

Solar Load Calculations

The first step in passive design is to determine how much solar energy would strike each face of a proposed building throughout the year. Such calculations can be used in an iterative process to tune the design of the building faces to optimize passive heating and cooling.

Data Acquisition

Prior to conducting data processing to model the solar load received by the individual building faces at the 1481 Post Street site, we needed to obtain actual weather data for the location. Specifically, we needed to find data for direct-beam insolation, as well as cloud cover, for each day of the year. Our goal was to then determine "representative sunny days" and "representative cloudy days" for each month of the year, from which we could then model direct-beam, solar load on the building faces for various points throughout the year.

To obtain data with a sufficient sampling rate for our analysis, we investigated data sets compiled by the National Renewable Energy Laboratory (NREL). NREL's National Solar Radiation Database included data at the high degree of resolution we required (National Renewable Energy Laboratory, 2011a). For the years 1991 – 2005, insolation and cloud-cover data for the San Francisco Airport had been collected for every hour of each day of the year (National Renewable Energy Laboratory, 2011b).

The insolation was not measured directly, but rather calculated from theoretical clear-sky radiation and observed cloud cover recorded hourly from a combination of geostationary satellites and a meteorological station at the San Francisco Airport (SFO). While the NREL data was for South San Francisco as opposed to downtown San Francisco, we were unable to locate a another dataset with a similarly high degree of resolution for a site closer to 1481 Post Street. We determined that the NREL data for SFO should be sufficient for our purposes of calculating relative differences in solar load on the various building faces.

Data Processing

We decided to use the 2005 dataset, since this was the most current. Within the dataset, two methods had been used to collect and model insolation data: SUNY and METSTAT (Renne et al., 2008). We chose the SUNY data for our calculations, as the SUNY model is:

- More modern than the METSTAT model.
    - SUNY "uses Geostationary Operational Environmental Satellite (GOES) imagery to estimate solar radiation" (Renne et al., 2008, p. 4).
- A higher resolution.
    - The SUNY model incorporates "virtually seamless" satellite images of cloud cover rather than "scattered and sometimes sparse point-source ground-based meteorological observations" (Renne et al., 2008, p. 7)
- More accurate.
    - SUNY does not have the problem that METSTAT does of the increased possibility of errors due to modifying cloud-cover data to calibrate the data (Renne et al., 2008).

Algorithm

Because almost all available solar radiation data are from measurements on leveled instruments, we calculate the ratio of direct-beam-solar radiation on a slope to the direct-beam-solar radiation on level ground. This "slope factor" *SF* is the following:

The "slope" for 1481 Post Street is 90°, which represents the vertical building faces that are perpendicular to level ground. The slope factor algorithm is able to account for the following:

- Precise latitude of the building site.

- Azimuth of each building face (the angle between each building face and true east-west. As by climatological convention, an azimuth of 0° is south, with positive azimuths counter-clockwise and negative azimuths clockwise).
- The continuous variation in solar zenith angle throughout each 24-hour cycle, for each day of the year.
- The continuous variation in solar azimuth throughout each 24-hour cycle, for each day of the year.

The following were our inputs into the slope factor algorithm:

- Precise latitude of building site: ~37.79°
- Slope of building faces: 90°
- Azimuth of southern building face: 9.25°
- Azimuth of northern building face: -170.75°
- Azimuth of eastern building face: 99.25°
- Azimuth of western building face: -88.75°

Note: Our analysis did not account for shadows cast by the buildings neighboring the site.

Data Preparation

Our team aggregated the hourly insolation data for each day of the year into daily totals. Our goal was to define "representative sunny days" and "representative cloudy days" based on a comparison of the daily insolation totals throughout the year.

The NREL dataset contained global insolation (G), direct-beam insolation (I), and diffuse insolation (D). The direct-beam insolation in the dataset did not account for the continuously changing zenith angle throughout each 24-hour cycle. The relationship between global, direct and diffuse radiation is as follows:

where ϑ is the zenith angle.

To derive values for direct-beam insolation that account for the continuously changing zenith angle, we subtracted diffuse insolation from the global insolation (the global insolation values incorporated the changing zenith angle). We could then use the calibrated, daily, direct-beam insolation as the focus of our analysis.

To define "representative sunny days" and "representative cloudy days," we compared the daily, direct-beam insolation totals for each month of the year. Simply taking the minimum and maximum daily, direct-beam insolation totals for each month would not be a good measure. These extremes occur infrequently, and designing a building's envelope and HVAC systems around such infrequent extremes would result in lower efficiency (ASHRAE, 2009). Therefore, we defined one "representative sunny day" and one "representative cloudy day" for each month as follows: We defined the representative sunny day for a particular month as the

75th percentile of the total daily insolation values for that month. Similarly, we defined the representative cloudy day for a particular month as the 25th percentile of the total daily insolation values for that month.

Using the calculated 75th and 25th percentiles for each month, we then manually matched these hypothetical, representative values with the closest-matching data points. For example, the 75th percentile of daily direct-beam insolation for the month of December was 1391.75 Wh/m^2, and the closest-matching data point was 1393 Wh/m^2 and occurred on December 10. Therefore, our representative sunny day for the month of December was December 10. In the rare instances where the calculated 25th or 75th percentile fell on the exact midpoint between two data points, we selected the data point with the higher direct-beam insolation.

Application of Slope Factor to the Processed Solar Data

Once we had calculated a representative sunny day and a representative cloudy day for each month, it was then time to multiply the daily direct-beam insolation by the matching slope factor. To facilitate this process, we modified the MATLAB scripts to output to an Excel file the slope factors for each day of the year.

Addition of Diffuse Insolation

After calculating the slope-adjusted, direct-beam solar loads for each building face, we added back in the diffuse insolation component that we had removed earlier for compatibility with the slope-factor algorithm. The addition of the diffuse component for each day provided us with a better picture of the total insolation occurring on the different building faces throughout the year.

where I is the direct-beam insolation, ϑ is the zenith angle, SF is the slope factor for the building face, and D is the diffuse insolation. Each building face is a vertical wall and thus is exposed to one half of the total daily diffuse insolation.

Note: This assumes that diffuse insolation is the same in all directions.

Therefore, after combining our pre-processed data with the outputs from the slope-factor algorithm, followed by a number of post-processing steps including the addition of diffuse insolation, the result was the total daily solar load for each building face. As explained earlier, we calculated these total daily solar loads for one representative sunny day per month and for one representative cloudy day per month. See Figure 6 for a summary of the data-processing steps used to calculate the total daily solar loads for each building face.

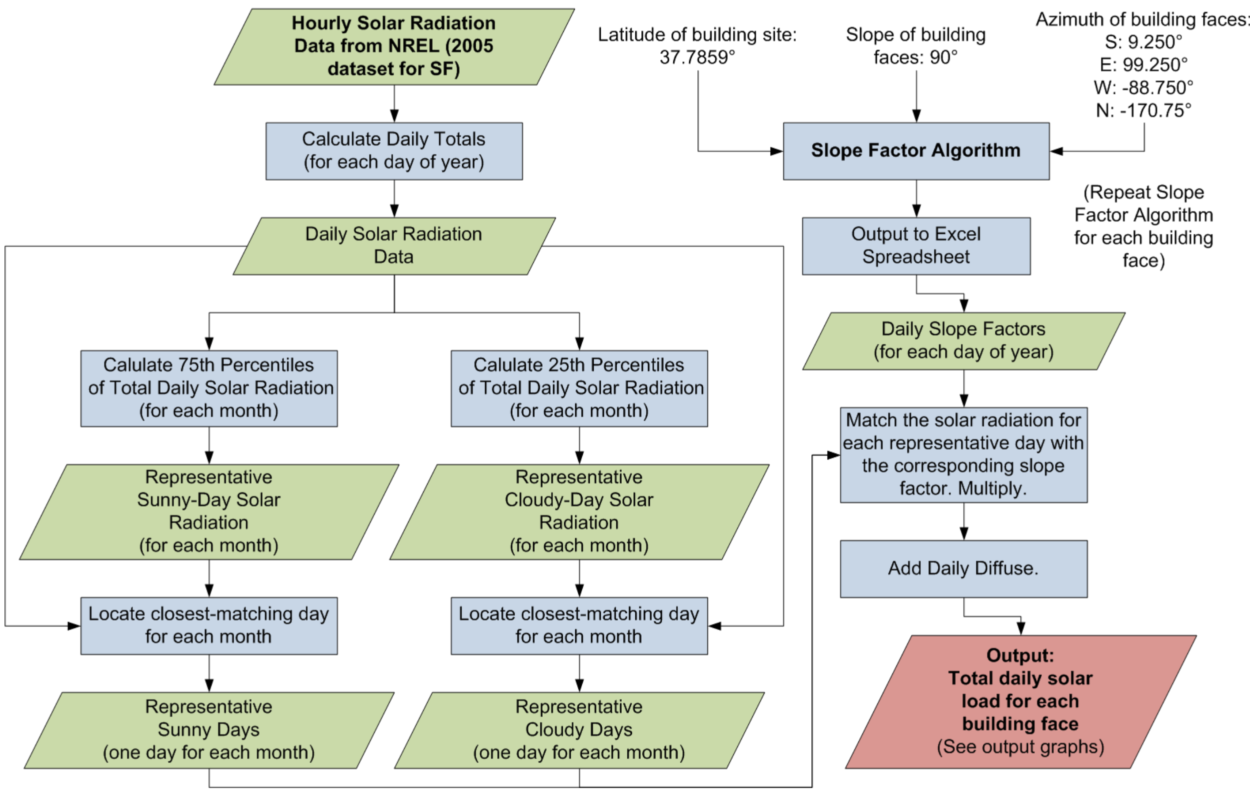

Figure 6: Solar Load Calculations – Process

Findings & Recommendations

Plots for the total daily solar loads for each building face are contained in Figure 7, Figure 8, Figure 9, and Figure 10. A quick examination of the graphs reveals that the northern face of the building receives relatively little insolation throughout the year. This is especially apparent when examining the representative sunny days. The northern face only ever receives as much solar energy as the southern face in June. During all other months, the southern, eastern, and western faces receive far more insolation on sunny days than the northern face, with the southern face receiving the greatest solar load.

Because of the differences in solar load for each building face, we can infer some preliminary conclusions. Windows on the northern face do not require as low of a solar heat gain coefficient (SHGC) as windows on the other building faces. This would help reduce the cost of the windows for the northern side of the building and also allows for a sufficient amount of daylight to enter on the northern side. Because of the surplus of insolation on the southern face, the SHGC of the windows on this side should be lower to prevent the rooms from overheating in the summer months.

For the eastern and western faces of the building, we can see that the total daily solar loads are very similar to each other for a given day. However, it is not as simple as this. Because the sun rises in the east, the majority of the solar insolation on the eastern face occurs in the morning. This creates a morning heating effect on the eastern side. Subsequently, on the western face, the majority of the solar insolation occurs in the afternoon and evening. This creates an afternoon heating effect on the western side.

The highest amounts of daily insolation strike the eastern and western faces in the hottest summer months. This is undesirable, and if unmitigated, will increase cooling costs in the summer. In other words, the natural solar loads on the eastern and western faces are approximately 180° out of phase with what would be desirable for passive heating and cooling. To mitigate this, we recommend using windows with a low SHGC for the eastern and western building faces. The SHGC for these windows can be comparable to that of the southern windows.

Overall from the four graphs, one can very clearly see that each building face receives a different amount of insolation than the other building faces throughout the year. These calculations reveal that one cannot optimize the design of a building absent of its site characteristics. Quantifying optimal values for SHGC for our design requires the use of more-sophisticated algorithms. So far, we've calculated the amount of solar energy that strikes each *exterior* building face throughout the year. To model the more complex interactions that occur once the solar energy reaches the *interior* of the building, we turn to energy modeling.

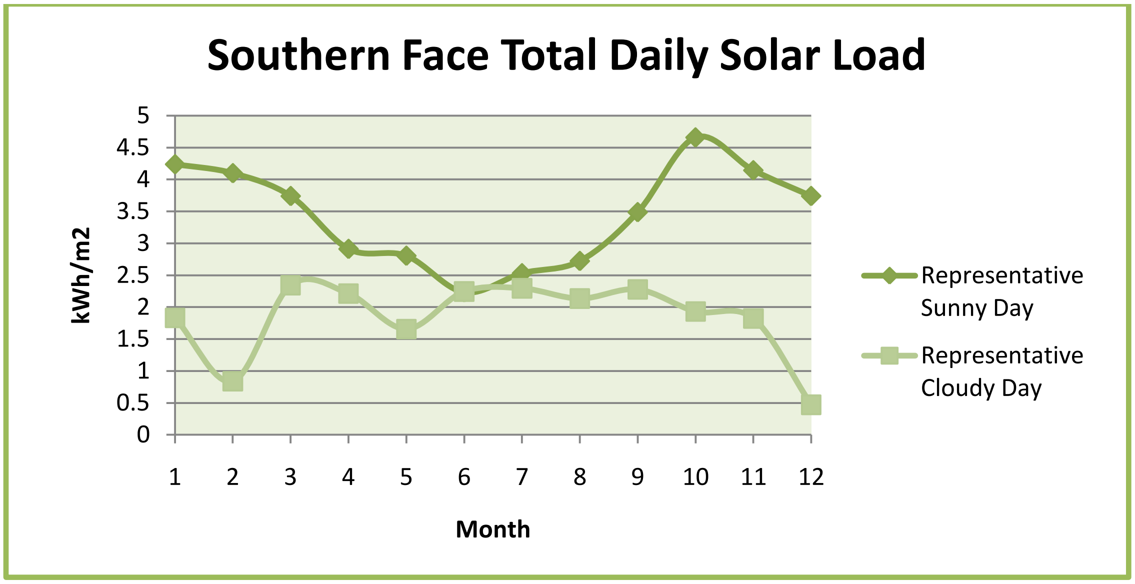

Figure 7

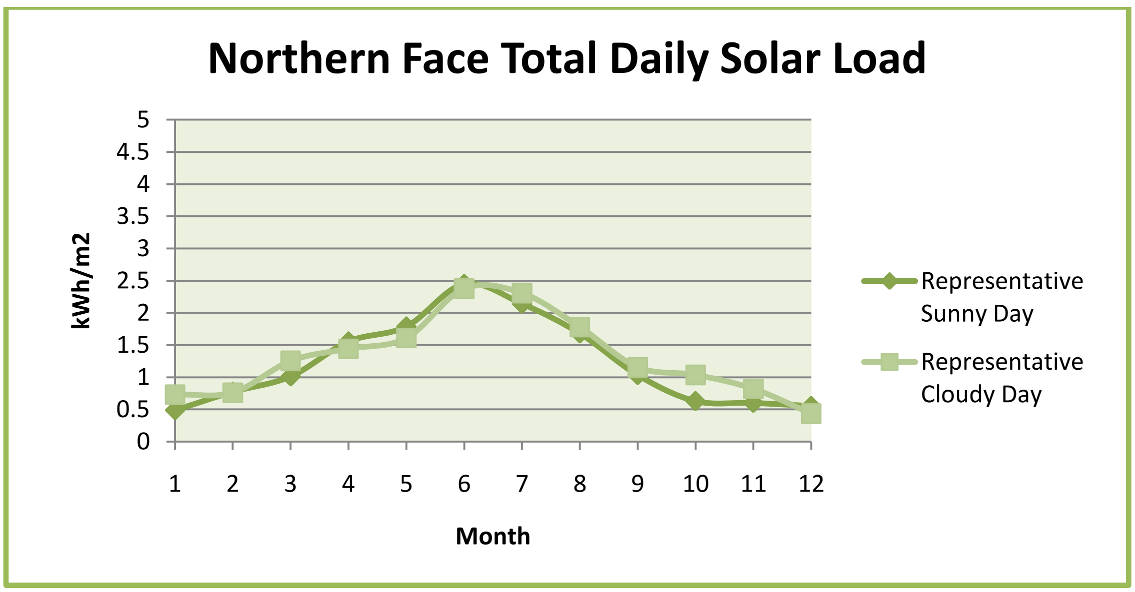

Figure 8

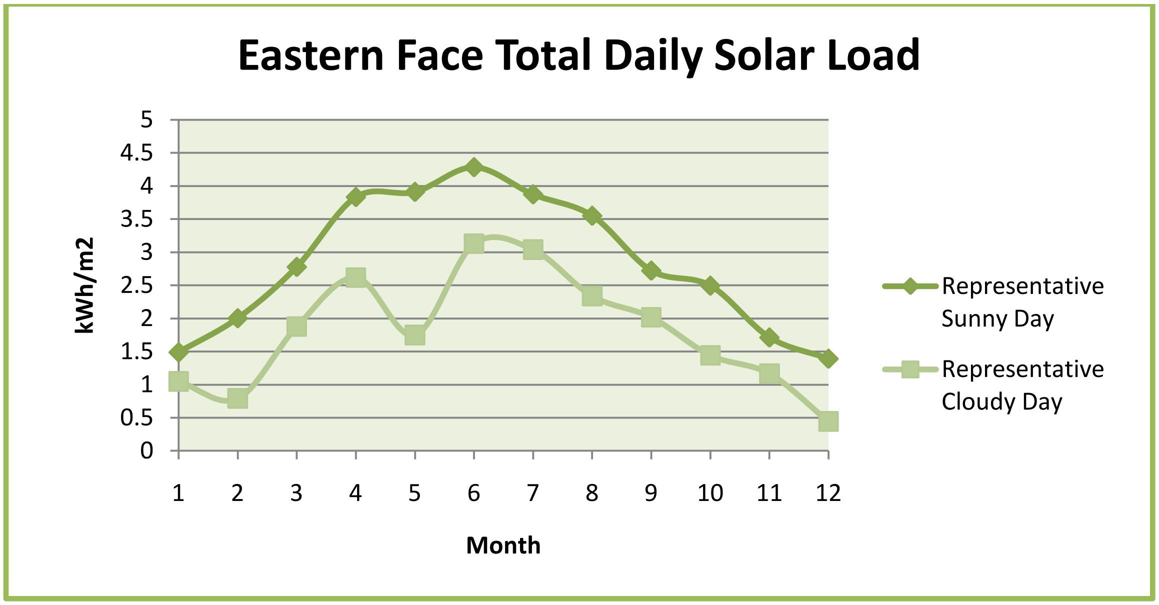

Figure 9

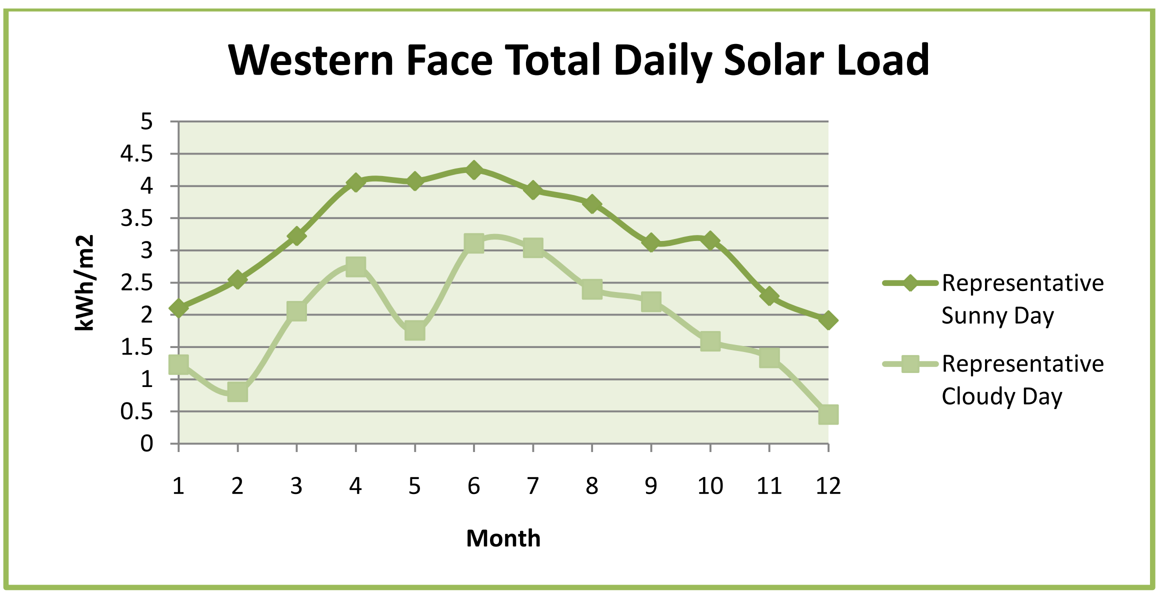

Figure 10

Air Temperature Analysis

Another important climatic effect related to building energy performance is outside air temperature. Outside air temperature has an effect on indoor air temperature, and therefore building energy performance, due to conductance. Conductance is the transfer of heat from one molecule to another, and the performance of a building envelope is in part due to its ability to resist this heat transfer. Building envelopes act as a partial thermal barrier between conditioned indoor air temperature, and unconditioned outdoor air temperature. To optimize building performance of the proposed high-rise through envelope design, it is important to analyze outside temperatures of the building site. The results of this analysis will also aid in the design of the mechanical systems required to maintain indoor air at a comfortable temperature.

We analyzed San Francisco climate data to better understand the building performance interactions related to temperature. We used a temperature dataset provided by NOAA's National Weather Service Forecast Office, which reports hourly dry-bulb temperature measurements over the course of the entire year from the San Francisco Airport (NOAA, 2010). Using this dataset, we estimated the monthly heating and cooling hours experienced in San Francisco.

To calculate the heating and cooling hours, we assumed that 1) any outside air temperature below 65° F (heating threshold) is below comfortable temperature, and requires heating and 2) any outside air temperature above 75 degrees Fahrenheit (cooling threshold) is above comfortable temperature and requires cooling. Using this metric, we calculated the number of degrees Fahrenheit above or below the heating or cooling threshold for each hour, and aggregated the hourly totals for each month of the year.

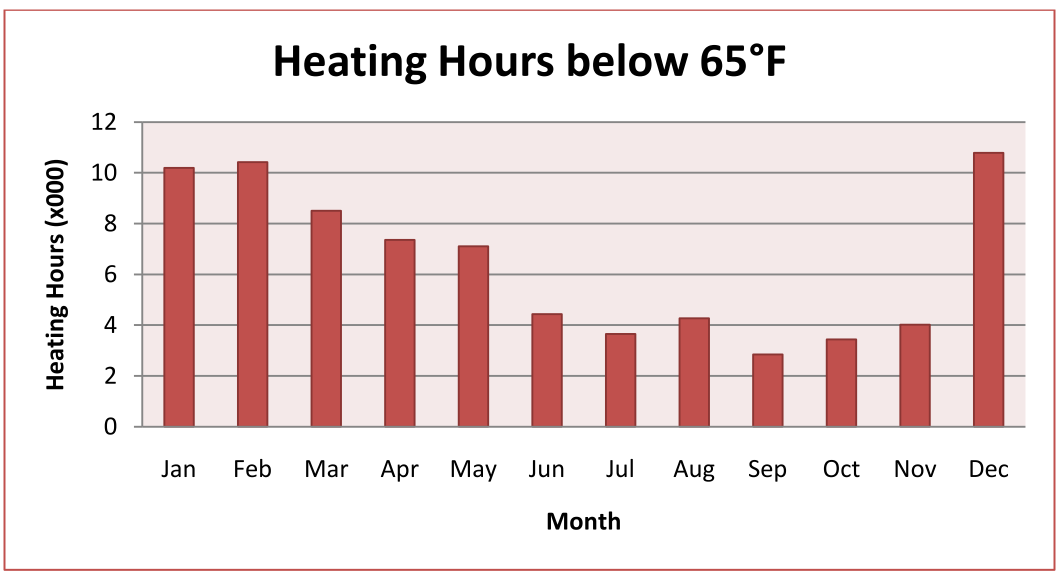

Figure 11 - Heating Hours below 65° F (2009 - 2010)

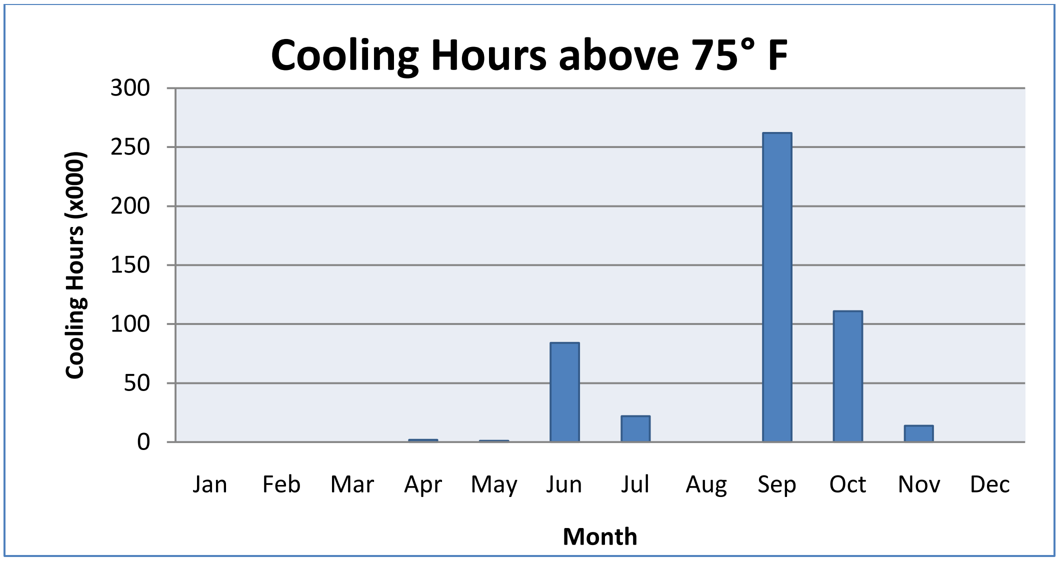

Figure 12 - Cooling Hours above 75° F (2009 - 2010)

As evident in the previous figures, the total heating hours are significantly greater than the total cooling hours. Given the interaction between indoor and outdoor air temperature, this means that indoor air temperature will have to be warmed to a comfortable level much more than it will have to be cooled to a comfortable level. It becomes clear that the heating loads will be much more significant than the cooling loads based on this analysis. In addition, the data also shows that there is not considerable temperature variability throughout the year. While there is some change in total heating and cooling hours for each month of the year, this change is not very pronounced.

This temperature data analysis is an important design tool, and can be used in conjunction with the solar load calculations to identify design solutions that optimize building energy performance. For example, in the summer, there is a combination of relatively high solar loads on all building faces, and high outside air temperature (above the cooling threshold), resulting in the overheating of indoor air space by both radiation and conductance. To avoid the need for excessive mechanical cooling, it would be beneficial to add envelope design features that block solar radiation during times above the cooling threshold. Similarly, during months with high heating hours, it will be beneficial to design the envelope to maximize the absorption of incoming solar radiation, as there will be demand for warmth. The assessment of both solar radiation and temperature is necessary when designing both the building envelope and the internal mechanical systems.

Energy Modeling

Working from the preliminary design renderings from the architectural team and in conjunction with the consulting mechanical engineer, we constructed an energy model of the proposed structure. At the recommendation of the mechanical engineer, we used the eQUEST modeling suite, as this runs the more-current DOE 2.2 engine and is also ideal for modeling changes in envelope parameters.

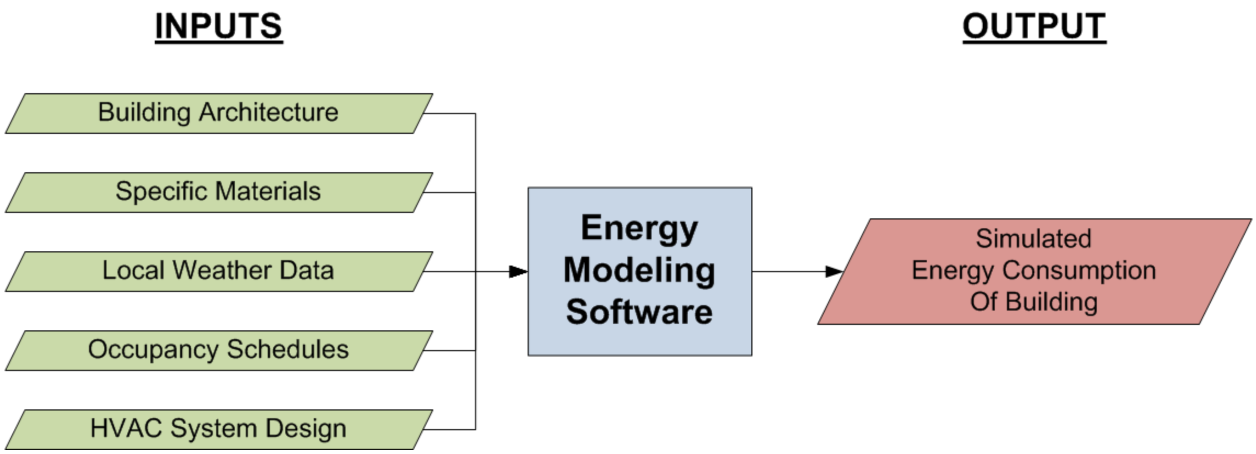

Figure 13 – Simplified Flow of the Energy Modeling Process

The first step was to design an architectural model of the structure within eQUEST. This consisted of entering parameters such as site location, orientation, envelope and foundation materials and design, and predicted usage patterns of the future occupants. The second major step was to create a preliminary system to model heating, ventilation, and air conditioning (HVAC) (See "Energy Model Specification for Baseline" in the Appendix for a complete specification of our baseline architectural and HVAC models in eQUEST).

The combined architectural and HVAC model provided us with the necessary tools to quantify the energy performance of various envelope design scenarios. These design scenarios enabled us to model the tradeoffs between investments in insulation and investments in glazing.

Our baseline model includes R-13 insulation in the exterior walls and Solarban 60 windows with argon fill (see Energy Model Specification for Baseline for a complete specification of our baseline energy model). The annual heating and cooling loads for our baseline model are depicted in Figure 14 and Figure 15. As you can see from the figures, the heating loads dominate throughout the year, while cooling loads are relatively small in San Francisco's mild climate. Envelope design significantly affects heating and cooling loads. By designing the envelope to minimize these loads, the building's HVAC systems can be significantly reduced in size, reducing inefficiencies and capital costs.

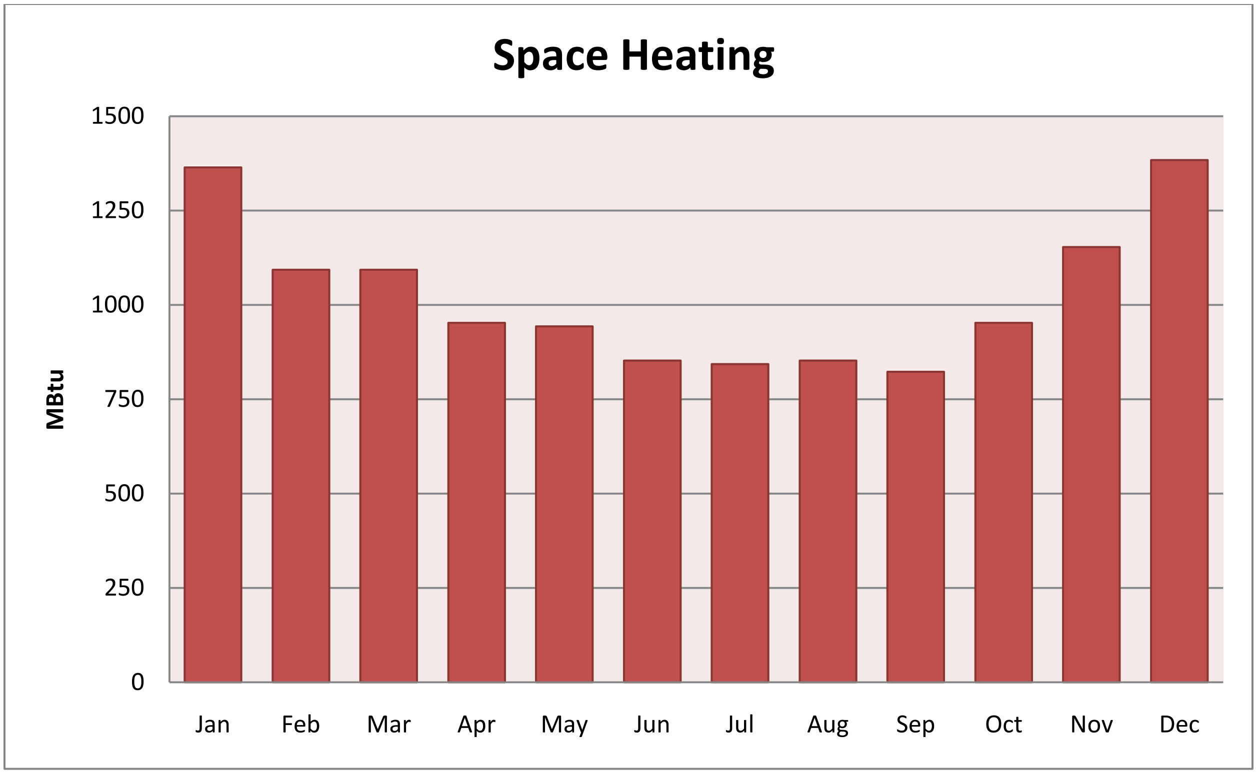

Figure 14 - Baseline Monthly Heating Loads

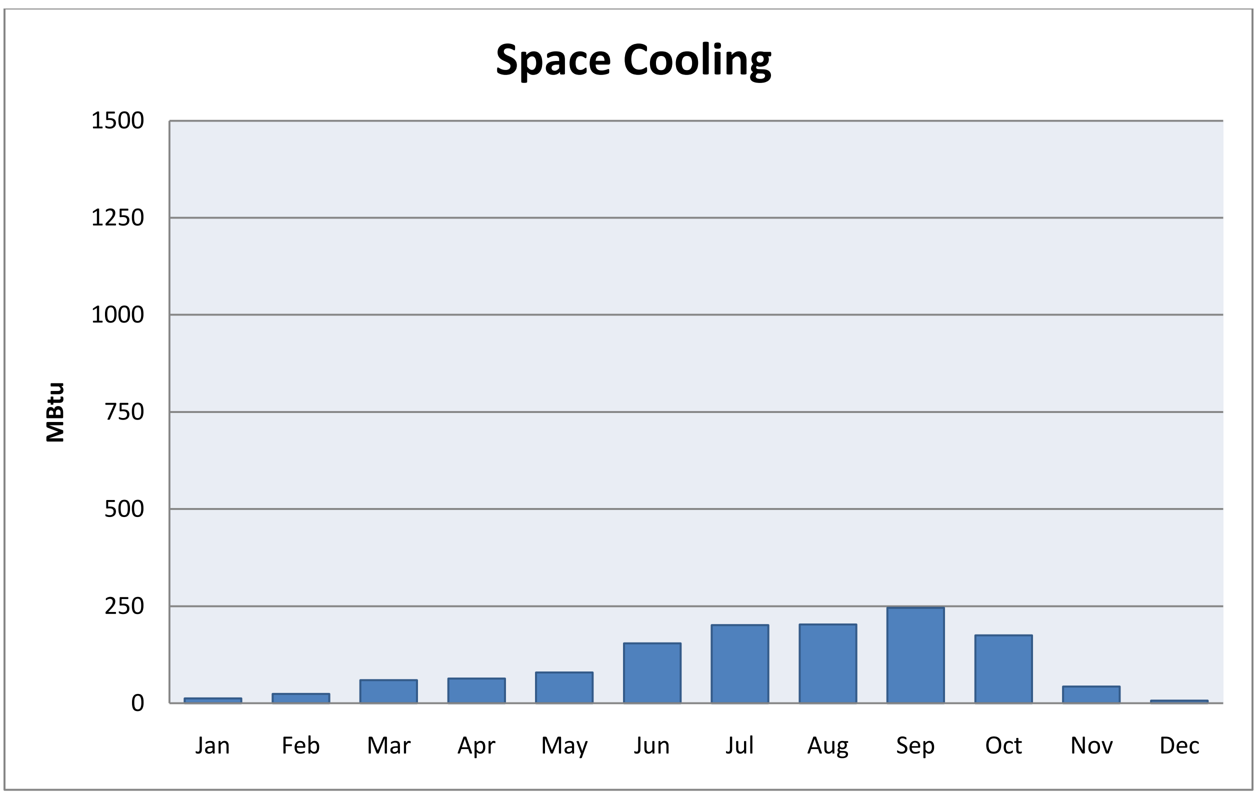

Figure 15 - Baseline Monthly Cooling Loads

Once we had constructed a baseline model that produces realistic outputs for heating and cooling loads throughout the year, then we began modeling different design scenarios.

Insulation

For the first set of scenarios, we increased the amount of insulation in the exterior walls, holding all other design parameters constant. The left graph of Figure 16 depicts the total annual heating and cooling energy consumption per square foot versus increasing insulation amounts. The graph to the right depicts the total cost per square foot to purchase and install the different insulation amounts.

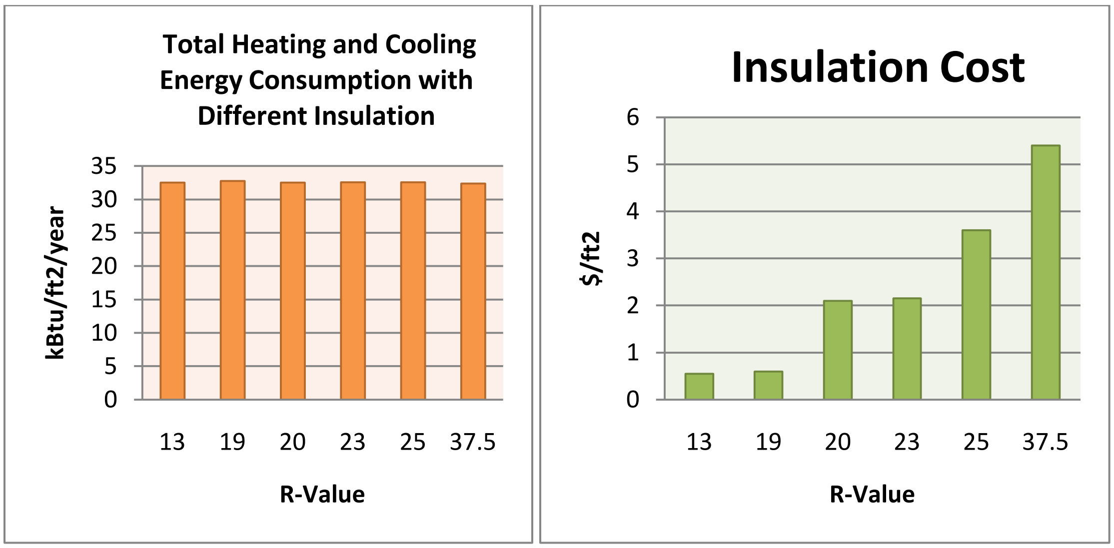

Figure 16 – Performance vs. Cost (Insulation)

Note: We obtained the cost information for the insulation from conversations with contractors in the San Francisco area (see Table 3 for a summarized list).

Table 3 – Insulation Costs Obtained from Private Contractors

R-Value	Insulation	Cost ($ / sq ft)
13	Fiberglass Batt (4”)	0.55
19	Fiberglass Batt (6”)	0.6
20	Blown in Cellulose	2.1
23	Blown in Fiberglass	2.15
25	Polyurethane Spray Foam (4“)	3.6
38	Polyurethane Spray Foam (6”)	5.4

Insulation is measured in terms of R-value. The greater the R-value, the greater the resistance to heat flow through a material. Reducing the annual heating and cooling load is our goal; however, our models do not show this to occur in response to investments in more insulation. This is due to two main factors:

1. Our building's envelope is dominated by 80% glass, making any perceived improvements from increased insulation insignificant, when viewed at the level of the overall building system.
2. The annual climate in San Francisco is relatively mild. The difference between outdoor temperature and comfortable indoor temperature in San Francisco is not as extreme as in an extremely hot or cold climate.

Recommendations

Therefore, increasing exterior-wall insulation beyond R-13 in a building with an 80% glass façade has an insignificant effect on reducing heating and cooling load in San Francisco. We recommend that the developer invest only in the minimum amount of insulation for the exterior walls required by code, which in San Francisco is R-19. Anything beyond this would not be cost-effective.

Windows

For the second set of scenarios, we increased the performance of various window parameters, including solar heat gain coefficient (SHGC) and U-value. The SHGC "measures how well glass blocks heat in sunlight... The SHGC is the fraction of solar radiation admitted through a window (both directly transmitted and absorbed) and subsequently released inward" (Johnston & Gibson, 2010, p. 25). U-value, on the other hand, is the inverse of R-value. So while R-value measures how well a material resists thermal conductivity, U-value measures how well a material *conducts* the heat transfer. Therefore, a higher U-value means a lower R-value. In the United States, U-value is measured in Btu/(h*ft^2*°F) while R-value is measured in h*ft^2*°F/Btu.

The left graph of Figure 17 depicts the total annual heating and cooling energy consumption per square foot versus differences in SHGC and U-value. The graph to the right depicts the total cost per square foot to purchase and install the different window technologies.

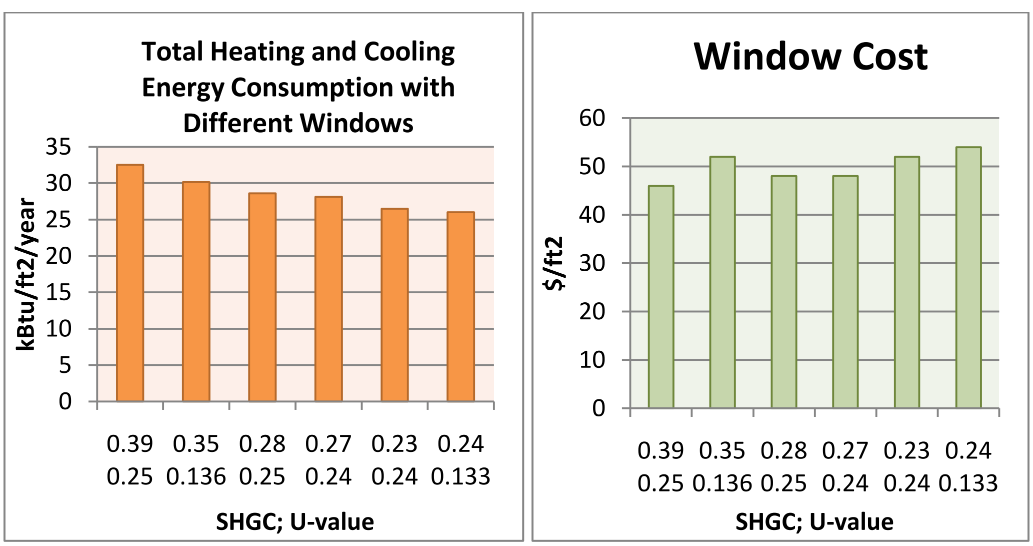

Figure 17 – Performance vs. Cost (Windows)

Note: We obtained the cost information for the windows from conversations with contractors in the San Francisco area and from conversations with window manufacturers.

Our models show that reductions in annual heating and cooling loads correspond to decreases in SHGC. In contrast, decreasing U-value of the windows has little effect on reducing heating and cooling loads. In San Francisco's relatively mild climate, decreases in SHGC dominate the effect on reducing heating and cooling loads.

Recommendations

Therefore, decreases in U-value below 0.25 have an insignificant effect on reducing heating and cooling load in San Francisco. Investments in triple-pane windows or suspended film—both of which reduce U-value—would not be cost-effective for this project. We recommend that the developer focus instead on obtaining windows with a low SHGC. Based on the results of the solar load calculations that we conducted earlier, windows on the northern face do not require as low of a SHGC as windows on the other building faces. For example, a SHGC of 0.27 would suffice for north-facing windows, while a lower SHGC in the range of 0.24 down to 0.23 or lower is recommended for the southern, western, and eastern faces. This would help reduce the cost of the windows for the northern side of the building and allow for increased investment in low SHGC for the windows on the southern, western, and eastern building faces, where a reduced SHGC would have the greatest impact on reducing heating and cooling loads.

Overhangs

For the third set of scenarios, we added overhangs of various sizes and configurations to the building, holding all other design parameters constant. We modeled the effects on annual heating and cooling loads of including overhangs ranging from 1 ft to 5 ft in depth, in 1-ft increments. We modeled the effects of each of these five different overhang sizes for each of the following four configurations:

1. Overhangs on all sides.
2. Overhangs on S, W, & E sides only.
3. Overhangs on S & W sides only.
4. Overhangs on S side only.

The results are depicted in Figure 18. Note: For each building face that includes overhangs, our models assume one overhang per floor-to-ceiling window, installed flush with the top of the window area.

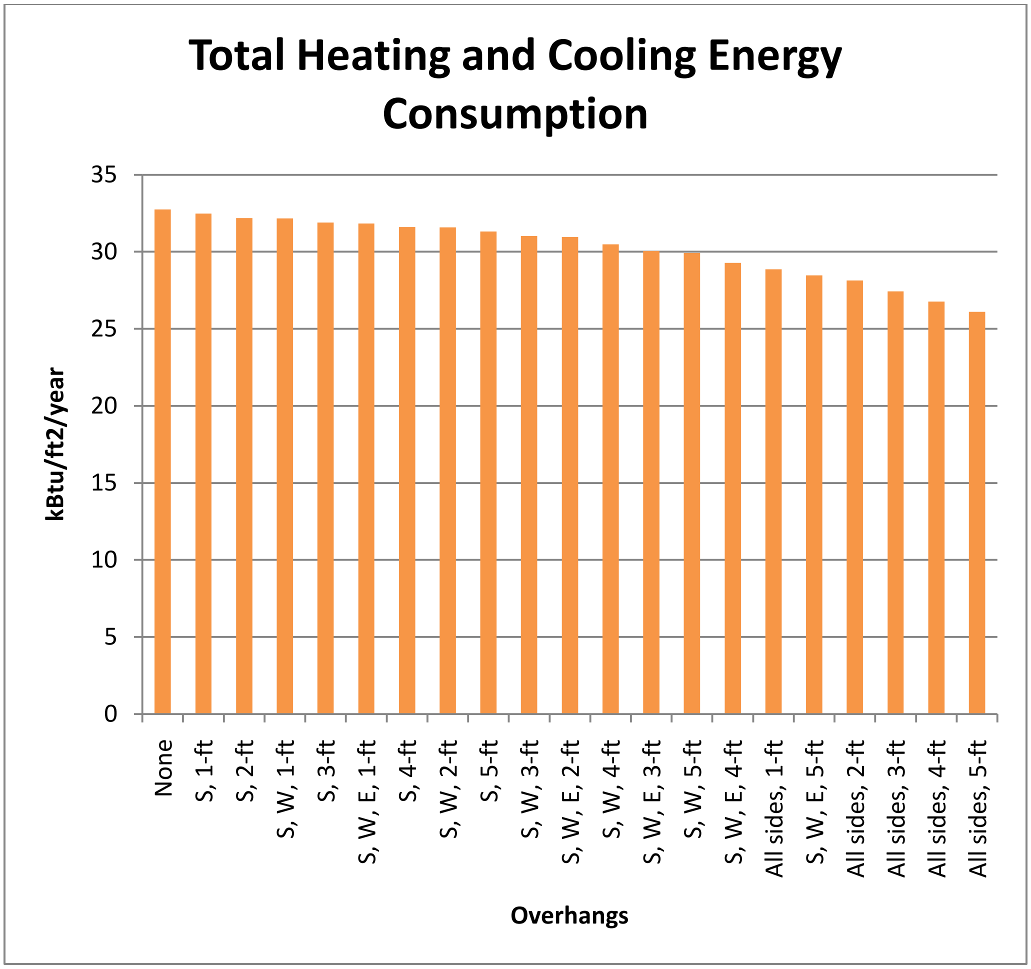

Figure 18

Our models showed that for each particular overhang depth, including overhangs on all sides of the building resulted in lower total heating and cooling consumption throughout the year than including overhangs on only the S, W, & E sides. Additionally, scenarios with overhangs on the S, W, & E sides performed better for a given overhang depth than scenarios with overhangs on only the S & W sides. And scenarios with overhangs on the S & W sides performed better for a given overhang depth than scenarios with overhangs on only the S side. In general, for a given overhang depth, the greater the number of building faces with overhangs installed, the greater the reduction in total heating and cooling consumption annually (see Figure 19).

Our models also showed that for a given combination of building faces that included overhangs, the greater the overhang depth, the greater the reduction in total heating and cooling consumption annually.

From Figure 18, you will notice that installing 5-ft overhangs on the S, W, & E sides reduces total heating and cooling costs to a level between those of installing 1-ft overhangs on all sides and installing 2-ft overhangs on all sides. Assuming a constant cost per unit area of overhang material, installing 2-ft overhangs on all sides would require only 54% of the cost of installing 5-ft overhangs on only the S, W, & E sides. And yet the energy savings over baseline are still roughly the same (13% compared to 14%) for both scenarios. So in this case, installing 2-ft overhangs on all sides provides approximately two times the utility per dollar than installing 5-ft overhangs on only the S, W, & E sides.

Further, installing 3-ft overhangs on all sides would require only 81% of the cost of installing 5-ft overhangs on only the S, W, & E sides. And yet the energy savings over baseline would increase to 16.2%.

Going in the other direction, installing 1-ft overhangs on all sides would require only 27% of the cost of installing 5-ft overhangs on only the S, W, & E sides. And yet the energy savings over baseline are still roughly the same (12% compared to 13%) for the two scenarios. So in this case, installing 1-ft overhangs on all sides provides approximately four times the utility per dollar than installing 5-ft overhangs on only the S, W, & E sides.

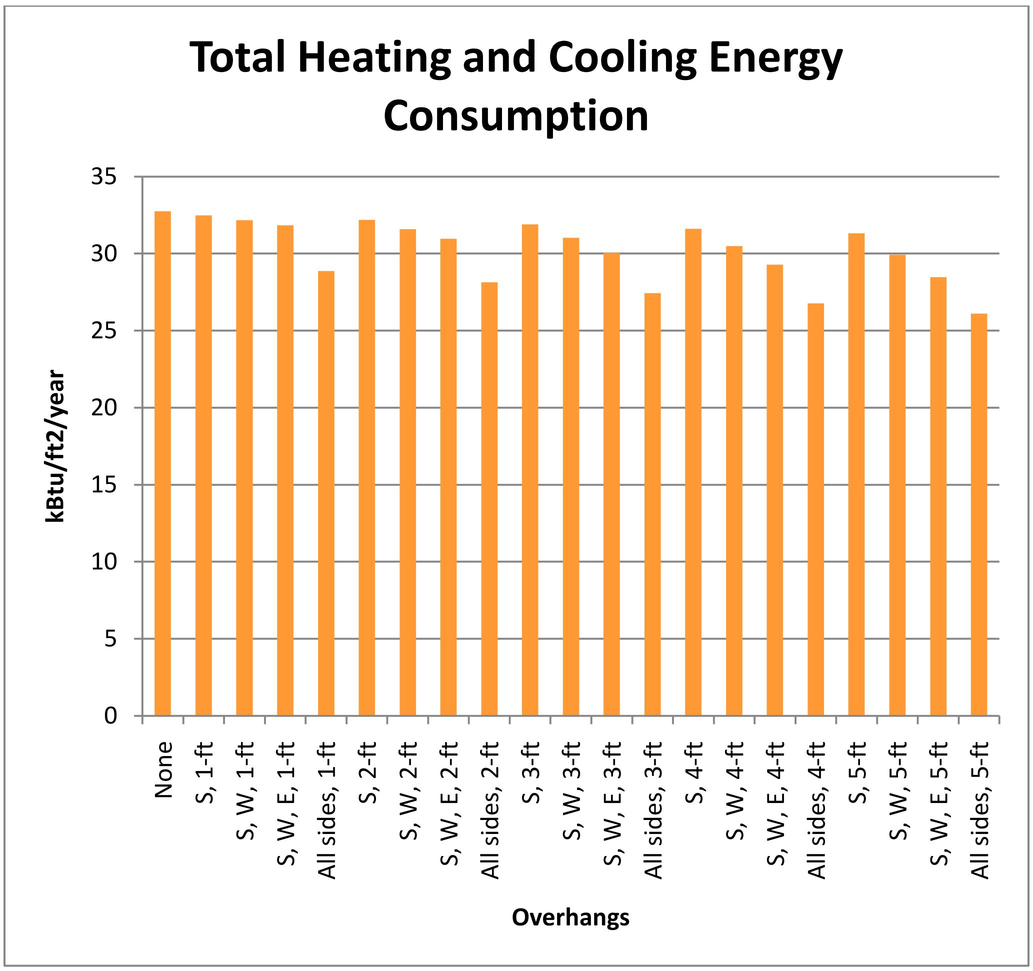

Figure 19

Recommendations

Therefore, installing smaller overhangs on all of the building faces provides more utility per dollar than installing larger overhangs on only a subset of the building faces. Our analysis showed that installing 1-ft overhangs on all sides was the most cost-effective scenario, as it provided approximately four times the utility per dollar than installing 5-ft overhangs on only the S, W, & E sides. Installing 2-ft overhangs on all sides was the second-most cost-effective scenario, as it provided approximately two times the utility per dollar than installing 5-ft overhangs on only the S, W, & E sides. We therefore recommend that the developer investigate the feasibility of incorporating 1-ft to 2-ft overhangs on all sides. As stated earlier, our models assumed one overhang per floor-to-ceiling window, installed flush with the top of the window area.

Electrochromic Windows

Electrochromic (EC) windows are an emerging technology that allows the transparency level of the glass to be altered. While currently price-prohibitive for a high-rise structure at approximately $200 per square foot (not including installation), a staff scientist that we met with at the Lawrence Berkeley National Laboratory (LBNL) explained that a mature market for EC windows may exist by the time of construction for the 1481 Post Street Project. If that is the case, in 2013-2014 we could see a cost of $50-$100 per square foot for EC windows (not including installation).

Our team decided to model the effect on annual heating and cooling load of using EC windows compared to our baseline model. Our models showed that relying on occupants to manually turn on and off the EC windows resulted in higher energy consumption in the majority of cases. This could be due to the following: If the occupants leave their EC windows tinted in the early morning while the sun is rising, they miss out on passive heating. If they forget to tint their EC windows on a hot summer day when they go to work, they miss out on the shading effect toward decreasing cooling loads later in the day. However, if they do tint their EC windows when they go to work, but it is a colder day, they again miss out on passive heating.

Recommendations

What our models indicate is that for electrochromic windows to be effective at reducing heating and cooling loads for the proposed high-rise, the electrochromic windows need to have the option of being controlled by an automation system. At a minimum, such an automation system should combine a programmed solar schedule with a sensor for outdoor temperature. The system would also need to interface with the HVAC controls to prevent the two systems from working against each other. Digital logic within the automation system could then, for instance, decrease the transparency of the windows if the outdoor temperature is hot (beyond a certain threshold value) and the sun is also within line-of-sight of the windows. At the same time, the system would interface with the HVAC system to ensure that the air conditioning does not turn on prematurely. Building automation systems are discussed in greater detail later in the next section of this report.

Analysis III: Energy Use Reduction – Monitoring Systems

As standard for a modern high-rise building, 1481 Post Street will contain a building automation system (BAS), a built-in network of electronic control devices connected to a central operator. The BAS allows the building manager or engineer to have centralized control of mechanical, HVAC, and electric systems, and it orchestrates building-related systems to work together efficiently and at levels dictated by occupant needs. In a residential high-rise, the BAS will control common-area lighting, elevators, security and fire systems, and HVAC equipment including chillers, boilers, pumps and air handling units. The BAS can be programmed to switch off energy-using components when they are not in use, to reduce waste.

BAS is a standard component for a high-rise building, and is an important factor for driving energy efficiency in common areas and central systems; however, it does not allow for efficiency improvements within individual condominiums. Our research investigated the feasibility of expanding the monitoring system into each individual condo unit. Inside each unit, advanced building monitoring and automation systems (BMAS) would submeter energy and water loads, giving occupants detailed information about their usage patterns.

Objective

Our goal was to quantify the costs and potential benefits of various advanced building monitoring and automation systems (BMAS) designed for the proposed high-rise condominium structure.

Scope

Our analysis of advanced building monitoring and automation systems included:

- Interviews with electrical contractors and suppliers to estimate the BMAS costs.
- Estimation of annual energy costs of 1481 Post Street based on energy performance output of the eQUEST energy model.
- Projections of future energy prices, market trends and relevant policies
- Creation of a cost benefit analysis model to compare the added system costs to the potential energy cost savings accrued over a period of ten years from the purchase date.
- Research into the effectiveness of BMAS in reducing energy consumption through literature review, case studies, and interviews with building science experts.

Significance

Energy load reductions can be significant through passive solar design, selection of high performance envelope materials, and use of efficient technologies integrated into the design and construction of the project. These features do not, however, guarantee the long-term operational performance of the building.

Building monitoring and automation systems ensure ongoing energy performance by providing the occupant and building operator with access to real time energy data and enhanced system control. Case studies and literature review demonstrated the effectiveness of building monitoring systems in reducing energy consumption through occupant behavior modification, and continued verification of system performance. Given the potential role of monitoring systems in long-term building performance, our team found it critical to analyze the implications of this technology at 1481 Post Street.

Recommendation

Our group recommends that ADCO consider the installation of advanced monitoring and dashboard systems that allow operators and condominium owners to track, monitor, and effectively manage the use of energy and water at 1481 Post Street. The electrical design should allow for digital submetering so that electricity consumption is transparent and categorized by use. We recommend that the unit water meters have digital capabilities allowing for the integration of both water and energy data in the building automation system and visual display units.

Methods

Identification and Cost of System Components

The first step was to estimate the costs of various building monitoring and automation scenarios. Inquiries were sent to a list of contacts through the San Francisco Electrical Contractors Association. As a result of this inquiry, our team came in contact with several electrical contractors and specialty suppliers with proven experience in monitoring and automation systems. Based on dialogue with suppliers and contractors, we compiled a detailed list of all the necessary components required for the systems. The main components include individual load submeters, controllers, low voltage cable, dashboard screens, a central server, and a software package.

The submeters measure the energy and water use of each circuit or load. We assume that the building will not have natural gas in each unit due to an early design decision by the developer, so we did not include gas submeters. Natural gas will be used in the building system, however, so we included it in our cost estimates. The electrical submeters are solid-state current-transformers, and water submeters are positive displacement impeller type with a digital pulser. Electrical load controllers consist of a central module and single circuit timer and triggering element. The load controller operates in conjunction with the submeters and adjusts loads by responding to usage patterns and price signals from the utility. The data received from each submeter can be displayed on a dashboard, which is an LCD screen installed in a convenient location within the condominium. The entire monitoring and automation system requires a central server and software package for the user interface and access to system controls.

Submeters and load controllers can be installed for the major loads only, or they can be installed for every load in the condominium. For example, the BMAS could monitor only the HVAC system and lighting loads, or it could monitor and control up to fifteen loads in each condominium. Given the range of options and added costs of each component, it was clear that monitoring and automation systems could have much different levels of sophistication, with a large range in total costs.

BMAS Scenario Design

Given the numerous design options, we created six BMAS scenarios to represent the range of sophistication and costs possible for the project. The low-level scenario assumes three submeters, without controllers or a dashboard installed. The high-level scenario assumes ten submeters, controllers, and a dashboard installed. Each scenario requires baseline investments in the central server and software package, in addition to a monthly software and maintenance fee. Several assumptions are made regarding these cost estimations: 1) When the monitoring system includes water submetering, we allocate 90% of the cost of the central components (central server, software, design, engineering and maintenance) to energy, 2) the maintenance costs are not be adjusted for inflation or discounting over time, and 3) central server and software costs are the same across all monitoring scenarios. The expected whole-building system costs for each scenario are outlined in Table 4.

Table 4 - BMAS Scenarios

Monitoring Scenario	Total Costs ($)	System Description (Per Unit)*
1	826,000	3 Submeters
2	1,049,000	4 Submeters; Dashboard
3	1,221,000	5 Submeters; 3 Controllers; Dashboard
4	1,395,000	6 Submeters; 3 Controllers, Dashboard
5	1,880,000	8 Submeters; 5 Controllers; Dashboard
6	2,355,000	10 Submeters; 7 Controllers; Dashboard

*Standard Feature across all scenarios: Central Server and Software

After compiling cost estimations of various BMAS scenarios, the next step is to identify the cost savings required to justify the upfront investment. We begin this by reviewing current energy rates and making approximations of future escalations.

Estimation of Future Energy Prices

To estimate the escalation rates, we examine thirty years of cost data from the Energy Information Center, where historic electricity and gas rates are listed for both California and Pacific Gas and Electric, the local utility provider.

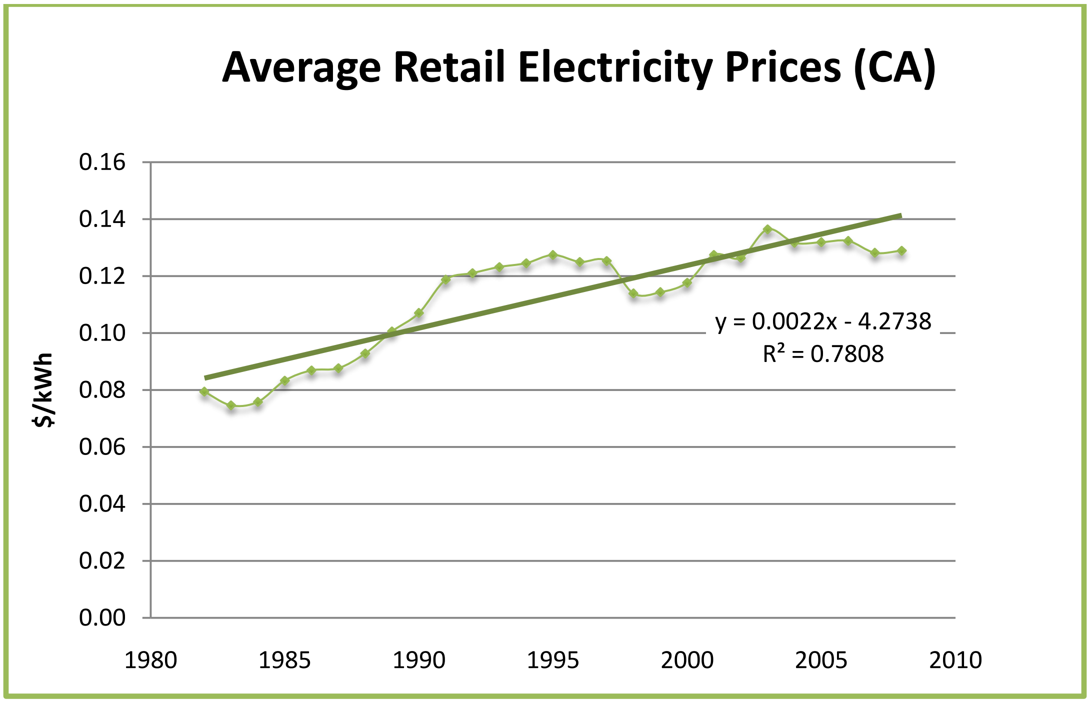

Figure 20 - Average Retail Electricity Prices in California (PG&E)

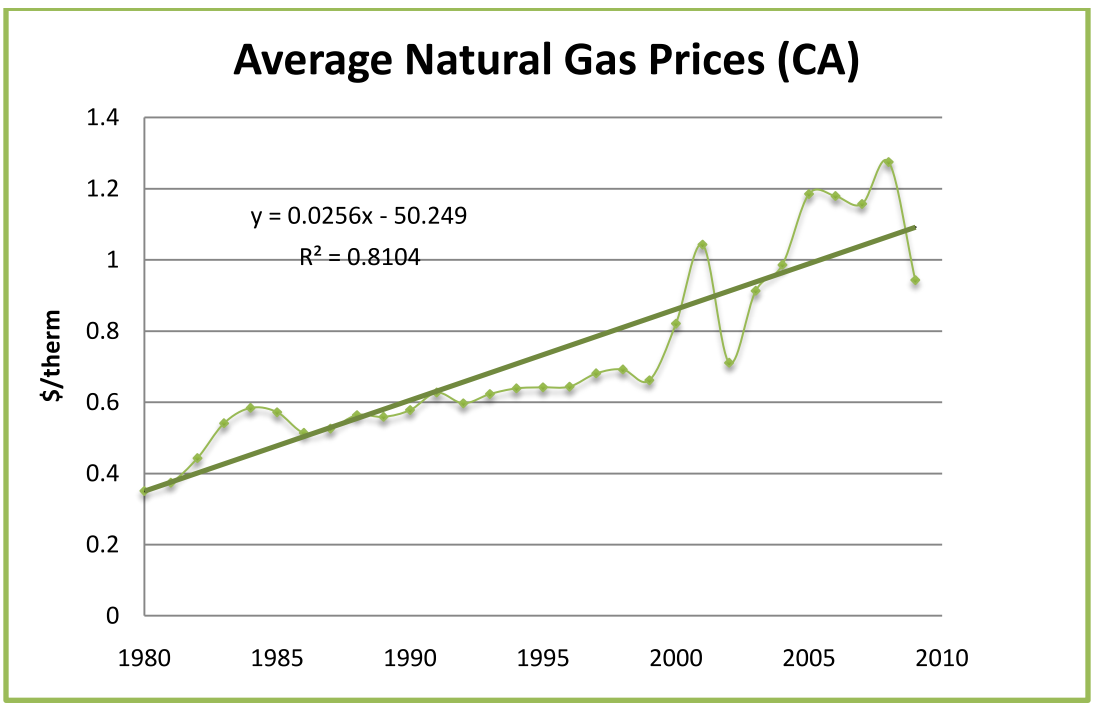

Figure 21 - Average Natural Gas Prices (PG&E)

Using these historic data, we can estimate annual price escalations for natural gas and electricity through linear regression analysis. The data show a 2.2% annual increase in the price of electricity and a 2.56% annual increase in the price of natural gas. Our team accessed energy prices from utility bills of ADCO's existing high-rise apartment building, Cathedral Hill Plaza. Using cost data from the five most recent years, we made assumptions of the current electricity and gas rates of 1481 Post Street. The average electricity rates were $0.14/kWh and natural gas rates were $0.90/therm. We used this data to establish baseline energy rates, so that we could estimate the rates over a ten-year period, beginning in 2014, when the building is expected to become operational.

Comparison of Upfront Investment to Potential Operational Savings

The next step was to compare the upfront investment in the various BMAS scenarios to the potential savings from energy cost reductions. We created a cost benefit analysis model where we could identify the savings required for the investment to pay off. In other words, we quantified the system effectiveness required for each BMAS scenario to break even in ten years; this would occur when the Net Present Value (NPV) equals zero.

We used the energy performance output of our baseline eQUEST model to quantify annual energy costs. From these baseline energy costs, we could calculate the annual reductions required to justify a ten year payback. We assumed that the BMAS scenarios would equally affect electricity and natural gas usage for the building. While the individual units do not have natural gas load, the natural gas boilers run the HVAC system, which are submetered and controlled under the monitoring scenarios.

Aside from the previously stated assumption for BMAS system costs, projected building energy consumption, estimated electricity and gas price and escalation rates, we also assumed a discount rate of 5%. Using this information, we were able to calculate the level of effectiveness required for each scenario to pay off in ten years.

Results

Table 5 –Building Monitoring Automation System (BMAS) Scenario Results

Monitoring Scenario	Total Cost ($)	Energy Savings (%)
1	825,750	10.9
2	1,049,000	13.8
3	1,221,000	16.1
4	1,395,000	18.3
5	1,880,000	24.7
6	2,354,000	31.0

The analysis shows that for the lowest level of monitoring, which includes three submeters and no controllers, a 10.9% reduction in energy costs is required for the upfront investment to pay for itself in ten years. The highest level of monitoring, where 10 loads are submetered, 7 loads are controlled and a dashboard unit is installed, requires a 31% reduction in energy costs for the upfront investment to pay for itself in ten years.

While the high level scenario required likely unattainable levels of savings to have a ten-year payback, several other scenarios required more attainable levels of savings. Given this range of cost savings necessary for the ten year payback, our team investigated the potential benefits of these systems to provide justification that this level of energy saving is, in fact, achievable.

Qualitative Analysis of Expected Benefits

Usage Reduction through Behavioral Modification

BMAS give occupants the ability to view and change their consumption patterns. This information is relayed to the occupant through dashboards, or displayed through web-connected software, where loads are broken out separately – for example, into lighting, appliances, heating, and cooling. BMAS allows occupants to not only analyze their usage patterns, but also to compare themselves to other building occupants. Behavioral modification through self-audit and social feedback is augmented with the use of software programs customized for each condominium, with varying degrees of automation. This customization will consider the unit-specific environmental conditions and use strategies to maximize occupant engagement.

We researched a number of case studies that looked at the effect of this visual feedback on occupant behavior. From multiple studies, we found that access to real time data led to decreases in energy consumption between 4-20% (Hayes & Cone, 1981) (Wilson, 2008). A 2007 study by the Pacific Northwest National Lab found a 10% to 15% reduction in energy consumption due to monitoring (Hammerstrom, et al., 2007). This empirical evidence suggests that monitoring systems are a successful tool for improving occupant behavior.

Cost Savings through Continuous Commissioning

Monitoring systems are also an important tool for commissioning. Commissioning is roughly equivalent to a tune-up: it's the process of verifying that a building's energy systems are performing as they were intended to. Monitoring systems enable commissioning on a continual, real-time basis. This practice has been referred to as the single-most cost-effective strategy for reducing energy and maintenance cost in buildings today (Mills, et al., 2004). A 2009 study from the Lawrence Berkeley National Lab found that commissioning increased median whole building energy savings by approximately 13% for new construction projects (Mills, 2009).

LEED has been criticized for awarding credentials to newly constructed buildings without proof of performance. A monitoring system that extends throughout individual condominiums, in addition to the BAS in the common areas, will collect a robust data profile of the building's performance, and continuously identify areas needing improvement. This "continuous commissioning" will help facilities managers maintain the functionality of building mechanical systems engage occupants in identifying in-unit inefficiencies.

Continuous commissioning can lead to cost savings for the building in three ways: 1) through maintaining efficiency levels at optimal performance, leading to reduced energy use, 2) through early detection of potential leaks or malfunctions, identified by real-time feedback discrepancies, and 3) through increasing the lifetime of critical building systems, leading to less long-term capital input (Mills, et al., 2004). These savings take the form of reduced utility and maintenance bills, and avoided capital costs for repairs or retrofits, both of which can result in lower HOA fees for owners.

Monitoring-driven cost savings will benefit condo owners – but can the significant upfront cost be justified to the developer, who will transfer ownership of the building? Our research suggests that it can; we found that measured energy performance is a marketable value that will lead to a property price premium. A 2010 study by UC Berkeley and the University of Maastricht concluded that energy improvements translated to higher rents and sales prices for Energy Star-rated commercial buildings: for a $1 per square foot reduction in energy costs, building owners saw a sales premium of 4.9% (Eichholtz, Kok, & Quigley, 2009). We referred to this metric when calculating cost-benefit scenarios for monitoring systems in the analysis that follows.

Integration with Time-Variant Utility Pricing

An additional marketing benefit of the building monitoring system is its adaptability to time varying utility rates. PG&E is rolling out smart meters to its customers in the Bay Area, including all of San Francisco by 2012. Smart meters are a tool for the utility company to pass a varying rate structure to its customers, but for customers to benefit, they must be prepared to respond to these varying rates in real time.

The optimal tool for dealing with these complex price structures is a monitoring system, which helps occupants shift their energy use from peak hours to off-peak hours. We recommend investing in a multi-circuit system, which breaks out the different energy loads and automatically adjusts in response to price signals from the utility. This will prepare building occupants for future price volatility and offer a degree of protection from future increases in the price of electricity.

Digital Appeal: Linking Building Monitoring with High Tech Trends

Due to the increasing adoption of modern digital devices, ADCO's investment in digitally integrated monitoring is likely to be well received by prospective buyers. Market research has shown that smart-phone ownership will surpass that of feature phones by 2011 (Javelin Strategy, 2010). Advanced monitoring systems will allow occupants to couple energy and water usage with modern digital devices, which will be a significant selling point to a digitally inclined audience. Additionally, the growing popularity of social networks is leading to the formation of energy and resource use comparison platforms. Monitoring systems are compatible with rewards-based tracking sites such as EarthAid.net, and voluntary home energy scoring systems recently announced by the Department of Energy.

Technology and monitoring, communicated in the form of a “Smart Condo,” could be the primary tool for conveying this building’s green message to the public. In the past, some condominium constructions, such as those in Battery Park City, have used visible solar PV or other renewables as their green manifesto. Today’s buyers are technologically sophisticated, especially in San Francisco, and they know that a solar panel is only part of a larger green building system. Green technology in the form of monitoring may be a meaningful and engaging way to market to potential buyers in San Francisco and Silicon Valley; in fact, smart technology could be a strong differentiating marketing tool for the 1481 Post Street project.

Anticipation of Potential Energy Reporting Regulation

The Energy Star program is based on the measured energy performance of commercial spaces, and reveals the actual energy performance, as opposed to the modeled energy performance criteria of LEED-NC. A recently passed San Francisco City ordinance requires that the Energy Star score of existing commercial buildings be reported to the city for public display (The Planning Department of San Francisco, 2009). Additionally, State Assembly Bill 1103 will require the commercial Energy Star score to be reported to the buyer before transfer of ownership (Eggert & Byron, 2007).

While both the state and city initiatives are directed at commercial buildings, there is the possibility of an energy disclosure initiative for residential properties in the future. Investments in advanced building monitoring will offer condominium owners an element of insurance, in the event that San Francisco pushes forward with increasingly progressive green building performance regulation. The pre-installation of advanced monitoring ensures condominium owners will be equipped to adapt to future energy reporting requirements, as energy use will already be transparent and in reportable form.

Value of Data Sharing

We recommend setting up a formal data-sharing relationship between the HOA and the developer, using building monitoring systems to relay categorized building performance information to ADCO from the HOA or building maintenance company. From ADCO’s perspective, this will help with planning future green buildings: knowing what worked, and where to allocate investments in the future projects. From the HOA’s perspective, this will help buyers maintain their investment by allowing for continuous optimization of energy performance, and by quantifying utility savings as a marketing tool for a second sale.

Conclusions & Recommendations

The potential for energy savings is substantial for all BMAS scenarios. Each system has the ability to improve occupant behavior and increase building performance transparency to optimize efficiencies. Given the range of options, and the levels of savings required for these options, it became clear that highest level scenario does not have the proven track record to achieve over 30% savings. While the lowest level scenario 1 required approximately 11% savings, this system lacked the controller capabilities inherent in scenarios 3-6. Scenario 3 required 16.1% savings to achieve a ten-year payback, but has a number of important features that will ensure long-term operational performance of the building.

Based on our research, load controllers and dashboards were important additions to BMAS as they provided a range of benefits for long-term operational performance. The dashboards further engage occupants in understanding their usage to create behavior modifications, and the load controllers can adapt to dynamic energy pricing scenarios imposed by Pacific Gas and Electric in the near future. Our research showed that Scenario 3, which contains 5 submeters, 3 load controllers, and a dashboard, offered the most potential benefits without significant added costs. The 16.1% savings required for a ten year payback may be easily achievable given the advanced capabilities.

Integrated Building Design

The Practice of Integrated Building Design

In researching case studies of existing green buildings and speaking with industry professionals, we found strong consensus of the importance of a process known as Integrated Building Design (IBD). IBD refers to a collaborative process between the decision-makers and technical experts involved in a building's design, to reach performance goals within budget.

Specifically, IBD advocates early or "front-loaded" design meetings between the developer, architect, engineer, and contractor. These design meetings, known as charrettes, establish building performance goals in the presence of experts from each stage of the building process. Since each participant "owns" a stage in the building's creation, the charrette is a crucial opportunity to share knowledge, agree on feasibility and streamline the project's budget and schedule.

According to the U.S. Green Building Council, integrated design produces higher quality buildings than the commonly used linear design process (The U.S. Green Building Council, 2009). In the linear process, a developer hires an architect, who passes off the building design to an HVAC engineer, who then designs the mechanical systems for the structure, which is next bid out to a contractor. Such a linear process misses the opportunities for collaboration along the way, resulting in an increased probability of mistakes or inefficiencies that add cost and time to the project's budget. A building is a classic example of system dynamics, with multiple interconnected variables that change at different rates; for example, a variation in the envelope design will affect the HVAC and lighting requirements, which may propagate cost increases or savings at different magnitudes. The integrated building design process takes advantage of system dynamics to optimize building variables with the expertise of a multidisciplinary design team.

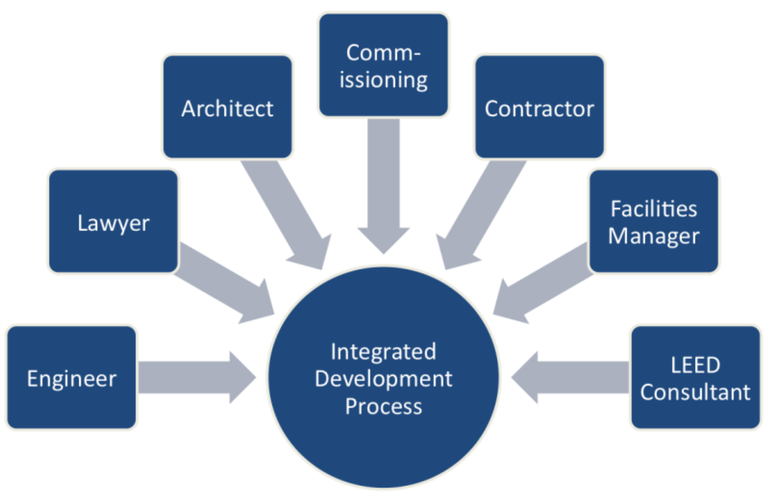

Figure 22 - Integrated Building Design

An integrated design process may redistribute some costs to earlier stages of the building project, since professionals at the charrettes will be paid for their time; however, the increased upfront costs are likely to be absorbed by budget shifts or outweighed by avoidance of midstream change orders. The USGBC's "Cost of Green in NYC" report, which examines the financial histories of recent LEED certified condo buildings in New York City, explains that an integrated design team will adaptively budget for a higher-quality building without an overall increase in cost. The report states that "LEED project teams simply make different choices about how to spend the monies available to them; they reallocate funding within the project budget to accommodate green measures (Urban Green Council, 2009)." For a detailed financial analysis of recent green buildings, both in cost and sales premium, see the section of this report entitled Economic Benefits of Green Buildings.

A developer interested in learning more about green buildings may also seek input from third-party building experts and building scientists, as part of the integrated design process; funded specialists may be available for knowledge-sharing through universities, national laboratories, city agencies, utilities, non-profits, think tanks, and professional organizations such as USGBC. These specialists may join the charrette during the design phase, at no cost or low cost, to promote sustainability. Additionally, a developer may become aware of pilot programs or incentives for energy and water efficiency by meeting with decision makers from the city's utility company. Increased information gathering at the onset of the project represents a time commitment for the developer, but as with other upfront investments in the integrated building design process, the investment is likely to pay off with a higher quality product.

IBD in Practice – The 1481 Post Street Project

We strongly recommend that our client approach the 1481 Post Street project with an integrated design strategy. During our involvement in this project, we were able to demonstrate the positive changes to the design that occurred when the developer, architectural team and engineers collaborated at an earlier stage than was projected.

Our goal was to assess the feasibility of energy-efficient envelope changes, before the final exterior design was locked in by the architect. As part of a multi-variable system, changes to the envelope would have cascading effects on the HVAC and other mechanical systems of the building, which required the input of a mechanical engineer as well as the architect and developer. To move forward with our analysis, we requested that the developer host a meeting between the architect and mechanical engineer (MEP). The architect had been contracted for the project, however at that stage of the building entitlement process; it was not cost-effective to retain a full-time MEP. The solution was to hire the MEP on an hourly consultant basis.

In the resulting design charrette between the developer, architectural team, and consulting MEP, we discussed options for resizing the HVAC system based on changes to the building envelope. The MEP gave us critical information needed to begin the energy modeling process which would analyze these multi-variable options and their potential costs and benefits. We also discussed the feasibility of substituting limestone cladding with pre-cast recycled concrete, to reduce the building's usage of virgin mined material. Common goals were uncovered at the charrette: the architects and MEP agreed that the concrete was a feasible substitute, and the developer commented that past projects had experienced undesirable limestone staining due to exposure to the elements. While limestone would be necessary to convey the building's aesthetics at ground level, it was agreed that concrete would be a beneficial substitute, for multiple reasons, above the ground floors.

When our team's involvement with the project ends, we recommend that our client continue to invest in design charrettes to identify opportunities for reducing the building's environmental impact and increasing its success as a high-performance system of functioning parts. We recommend involving contractors in the next round of charrettes, to better refine the feasibility and cost-effectiveness of the options proposed by the Bren team, and by future green building consultants that may work on the project.

We are confident that an integrated building design process will help to crystallize our client's strategy for going "green" in the 1481 Post Street and future building projects, resulting in a well-defined approach to environmental impact reduction and a streamlined budget and construction schedule. A defined strategy will likely result in higher performance towards the project's stated environmental goals, and a value proposition that can be credibly marketed to potential buyers.

Economic Benefits of Green Buildings

Developers and Green Buildings

Compared to a non-certified building in the same location, a green-certified residential building can result in lowered costs and/or increased revenue for the developer. First, costs can be reduced through government incentives including rebates, tax credits, coverage of third-party labor, and other financial programs designed to reward builders for achieving energy- and water-saving goals. Second, revenues can be increased through certification as a LEED- or Energy Star-certified project, since these rating programs have been shown to increase sale and rental prices for large commercial buildings (including multi-family).

To realize a net economic benefit from a green building, a developer would need to calculate that the spread between any increases in costs due to green building practices is exceeded by the cost savings or revenue derived from incentives and projected marketing benefits.

Cost of Green Building Practices

Recent literature estimates that the cost of building "green" has dropped to a negligible level, compared to its level during the industry's emergent years. In 2003, when green building was a more nascent phenomenon for developers and builders, the estimated LEED cost premium was rather significant: as high as 2.5% for Certified, 3.3% for Silver, 5.0% for Gold, and 8.5% for Platinum (Syphers, Baum, Bouton, & Sullens, 2003). As of 2011, as the green building industry has matured, technical knowledge and product availability has increased to a more robust economy of scale. Recent studies have documented that the green premium is much less than initially feared.

Specifically, the cost of LEED was deemed "insignificant" in a 2009 report, "Cost of Green in NYC," published by the U.S. Green Building Council in conjunction with the Urban Green Council; Davis Langdon, a construction cost management consulting firm; and the New York State Energy Research and Development Authority (NYSERDA). The paper compared new LEED-certified high-rise luxury residential buildings in New York City, built within the prior two years of 2009, against their non-certified counterparts. The paper found the following range in cost per square foot for construction of buildings at increasing levels of LEED certification:

Table 6 - USGBC, Cost of Green in NYC, 2009

Table 3:
CONSTRUCTION COSTS: HIGH-RISE RESIDENTIAL ($/SF)

	ALL	LEED	NON-LEED	CERT	SILVER	GOLD	PLAT
AVERAGE	438	440	436	315	467	433	463
MEDIAN	431	439	407	315	439	440	463

The data reveal that there is no linear correlation between the four increasing LEED certification levels and cost; rather, cost varies on a project-by-project basis. Averaging the costs of all certified projects together results in a difference of less than 1% compared to the non-certified projects ($440/sq ft LEED versus $436/sq ft non-LEED, representing a 0.9% difference in cost). The study also presents the same data broken down by project:

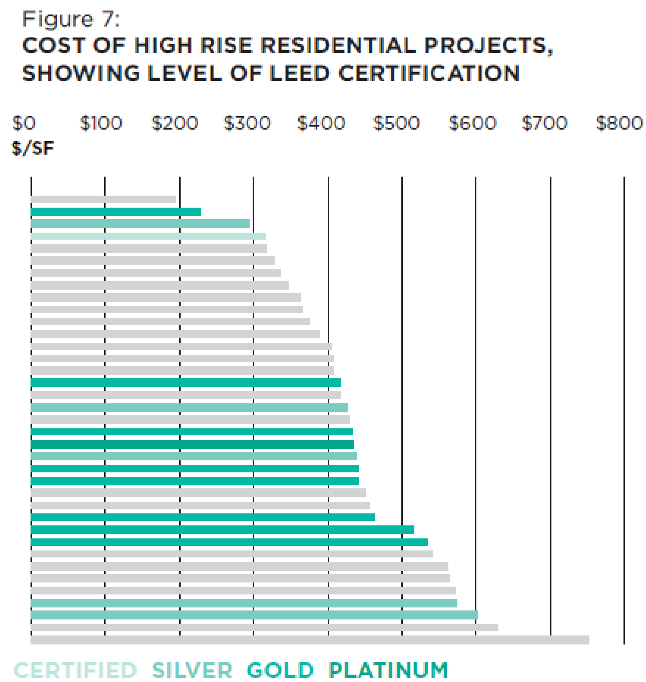

Figure 23 - USGBC, Cost of Green in NYC, 2009

The data fail to demonstrate a correlation between increased LEED certification level and cost. It should be noted that the above data quantifies construction costs, without the addition of "soft costs:" LEED design fees, LEED direct fees, and commissioning fees. These soft fees are reported separately, with the following values:

Table 7 - USGBC, Cost of Green in NYC, 2009

Table 4:
LEED FEES: ALL NEW CONSTRUCTION PROJECTS ($/SF)

	LEED DESIGN	LEED RELATED	CX
AVERAGE	1.47	0.59	2.35
MEDIAN	0.56	0.30	1.55

Added to the construction costs, these soft fees increase the difference between LEED and non-LEED projects: by an additional 1% when adding the averaged soft costs ($440 sq ft + $4.41 sq ft for LEED versus $436 sq ft for non-LEED), or by an additional 0.5% when adding the median soft costs ($440 sq ft + $2.41 sq ft for LEED versus $436 sq ft for non-LEED). The study recommends the median value as more accurate, since the average value is skewed by a few outlying data points representing projects whose soft costs were disproportionately high.

Even factoring in soft costs, the "Cost of Green in NYC" study asserts that LEED certification does not significantly add to the cost of construction for luxury high-rise buildings. The report's authors conclude that:

> "The analysis of New York City residential buildings found no statistically significant difference in construction costs between LEED and non-LEED buildings. LEED projects do not dominate the high end of building costs. In other words, compared to other factors influencing construction costs, LEED is insignificant…. This is not to say that LEED certification is without direct costs; LEED buildings often require the use of higher cost materials, systems, and construction processes. Why is it, then, that we find no difference in construction costs between LEED and non-LEED buildings? Anecdotal evidence suggests several reasons for this lack of cost differential. Firstly, LEED project teams simply make different choices about how to spend the monies available to them; they reallocate funding within the project budget to accommodate green measures….In summary, although the measures typically used to achieve LEED can have associated costs, those costs are not significant or prohibitive. The construction cost analysis shows that high-rise residential projects achieve LEED within budget parameters, and within budgets comparable to non-LEED projects (Syphers, Baum, Bouton, & Sullens, 2003)."

This study provides a compelling analysis that LEED-certified luxury high-rise residential buildings do not necessarily carry a construction cost premium, and in fact, some projects very similar in scope to 1481 Post Street have cost less than their non-LEED competitors. As mentioned by the authors of the USGBC study quoted above, an adaptive design process – in which budgets are reallocated adaptively through an ongoing communication between developers, architects, engineers, and contractors working towards the same goals for building performance – can effectively erase or minimize the "green" cost premium.

The USGBC study echoes the important point that green building is an intrinsic process, and not a "luxury" addition that carries a separate price tag. In his 2008 paper, "Delivering Sustainable Tall Buildings," Michael Deene, Operations Manager at Turner Construction Company, New York, comments that "luxury tends to be superficial and market driven and must show an immediate return (2008)." What the USGBC and other recent studies have shown is that LEED certification is not simply a luxury attached to a building for mark-up; rather it's a process-based collaboration between developers, architects, and builders that increasingly results in a better product – defined in terms of resource efficiency and improved human comfort – for the same (or lower) price.

Incentives from Government Agencies

A green building's costs can be partially offset by government incentives designed to reward builders for achieving environmental goals including energy, water, and resource conservation. Many incentives are performance-based, meaning a builder will receive higher tiers of payment for higher realized levels of energy, water, or resource efficiency. Incentives come from federal, state, and city government agencies, utilities, and multi-departmental entities that share delivery of funds or dispense them through third-party agents. Due to the decentralized structure of the funding sources, it can be time-consuming to aggregate and analyze the available funds.

The Bren team has identified the followed entities as potential funding sources for the project at 1481 Post Street in San Francisco.

a) SF Environment's Energy Watch Program

b) SF Green Finance/PACE Funding

c) California Multifamily New Homes Program, via Heschong Mahone Group (HMG)

d) Rebates for renewable power installation: 1) CSI/PG&E's Solar Thermal initiative; 2) CEC/PG&E's GoSolar California (solar PV); 3) PG&E/CEC's Emerging Renewables Program (wind and fuel cells); 4) CA Revenue and Taxation Code's Tax Exclusion for Solar Energy Systems (all solar).

e) PG&E Savings by Design and Demand Response programs

f) Waste/Recycling incentives

Marketing Benefits of Green Buildings

The primary return on investment for many green building technologies is in the form of long-term savings on utility bills for occupants of the units. Hence, for the builder of a luxury condominium project, some green investments may present a challenge, since the beneficiary of the investment will be the buyer, not the builder. Since the builder does not realize these savings, other means of payback can be considered to justify the potential cost premium.

Buyer Expectations and Competition

The first consideration is the robust market trend towards green building practices: the phenomenon may have become popular enough to reach the tipping point, at which buyers expect a degree of "green-ness" as a baseline. An entry-level green certification may soon be essential to remain competitive in the building industry, as the percentage of developers dedicated to green building practices is poised to become the majority in the next few years. According to the "Global Green Building Trends" report published by McGraw-Hill in 2008, by the year 2013, 53% of responding firms expect to be largely dedicated to green building (on over 60% of their projects), up from 30% in 2008 (2009).

A 2008 report by CoStar, a commercial real estate information company (2008), lists the firms as of 2007 with the largest commitment (measured in square feet) to green office building construction:

Table 8 - Miller, Spivey, and Florance, Does Green Pay Off, 2008

Exhibit 13: Leading Developers of Green Office Buildings as of Second Quarter 2007

	Developer	# Bldgs	Square Feet	% of Total
1	Hines	39	26,374,642	17.7%
2	Vornado/ Charles E. Smith Commercial Rea	14	4,750,018	3.2%
3	The Durst Organization	3	2,703,267	1.8%
4	Shorenstein Company, LLC	3	2,444,010	1.6%
5	Opus Northwest Corporation LLC	4	2,346,632	1.6%
6	John Hancock Real Estate Finance Group	2	2,171,881	1.5%
7	The Durst Organization/Bank of America	1	2,118,441	1.4%
8	Trammell Crow Company	7	2,092,713	1.4%
9	Texas Eastern Corporation	2	2,086,307	1.4%
10	Maguire Properties	3	2,019,629	1.4%

On the consumer side, the 2008 McGraw-Hill report also surveyed a representative sample of one million American households, and found that:

- 70% of buyers are either more or much more inclined to purchase a green home over a conventional home in a down housing market.
- More than 80% of respondents said they believe that green homes are not just more economical, but offer better and healthier places to live (USGBC and McGraw Hill Construction, 2008).

Due to this trend in buyer and industry sentiment, a condominium project without third-party verified green certification (such as LEED or GreenPoint) risks being out-competed by a builder with a more visible green commitment. As Jeff Blau, President of Related Companies, a prominent New York luxury real-estate developer, comments on his firm's stance, "Building green is no longer just an option that we consider, but as a leading developer, it is a responsibility that we embrace. In this difficult economic environment, we all need to be more vigilant than ever to reinforce our commitment to building green (Urban Green Council, 2009)."

Municipal and state mandates are another, overriding driver of green certification. As San Francisco will require LEED Gold Certification for new permit applications for high-rise residential building starting in 2012, the marginal costs of achieving LEED certification up through the Gold level falls to zero, since there will be no alternative. With LEED Gold as the baseline, a jump to Platinum may become the differentiating factor that gives a green builder the competitive advantage.

Existence of the Green Premium – Empirical Evidence

In 2009, for the first time, a large-scale university research study compared price points for certified green buildings against non-certified control buildings. This study was conducted by economists Piet Eichholtz, Nils Kok, and John M. Quigley, in association with Maastricht University, the Netherlands, and UC Berkeley's Center for the Study of Energy Markets (CSEM), a program of the University of California Energy Institute. In the study, entitled "Doing Well by Doing Good? Green Office Buildings," the authors state that,

> "This paper provides the first credible evidence on the economic value of the certification of "green buildings" – value derived from impersonal market transactions rather than engineering estimates. For some 10,000 subject and control buildings, we match publicly available information on the addresses of Energy Star and LEED-rated office buildings to the characteristics of these buildings, their rental rates and selling prices. We find that buildings with a "green rating" command rental rates that are roughly three percent higher per square foot than otherwise identical buildings – controlling for the quality and the specific location of office buildings. Ceteris paribus, premiums in effective rents are even higher – above six percent. Selling prices of green buildings are higher by about 16 percent (2009)."

In 2010, the authors revisited their analysis in a follow-up study entitled, "The Economics of Green Building." Their updated findings, which now included data from the recession-affected year 2009, reported the same premium for rents, at 3% higher for an office building registered with LEED or Energy Star, and a higher premium for effective rents, at almost eight percent. For selling prices, the premium for a green building relative to comparable non-certified buildings nearby is slightly lower, at about 13 percent.

These studies concerned the market for large commercial buildings, including multi-family. The papers make the important leap from anecdotal to empirical evidence that green-certified buildings do indeed financially outperform their non-certified counterparts, in terms of building value and rental rates.

The scope of the 2010 research – analyzing sales and rent data for a sample of 21,000 rental buildings and 6,000 buildings which were sold, including a total of 2,700 green-certified properties – provides statistically compelling evidence of consumers' willingness-to-pay for green-labeled commercial property. The two labels considered were Energy Star and LEED. The study suggests that buyers and investors respond positively to multiple variables contained within the green-building umbrella: a lower risk premium, possibly represented by the insurance against future energy price increase, the prospect of charging higher rents, and the intangible effect of a green-certification label. Renters respond to the promise of lower utility bills and higher employee satisfaction.

Relative Performance of Green Buildings in a Recession

The Eichholtz et al 2010 study also investigates price dynamics of Energy Star and LEED rated buildings during the decline of property values which accompanied the 2008 U.S. recession. This decline coincided with an increase in the supply of green buildings during 2007-2009. The study finds that green buildings performed well, despite increased supply in the face of stagnant or plummeting demand. According to the authors,

> "recent downturns in property markets have *not* significantly affected the rents of green buildings relative to those of comparable high quality property investments; the economic

> premium to green building has decreased slightly, but rents and occupancy rates are still higher than those of comparable properties."

The study reports that rents for green buildings were 4.1% higher than non-green buildings in the pre-recession year of 2007, dropping to 1.2% higher during the height of the recession in 2009. During the recession, rents for green buildings declined along with rents for non-green buildings, but a premium for green buildings remained.

Higher Occupancy Rates and Faster Absorption Rates of Green Buildings

The Eichholtz et al 2010 study also analyzes the metric of effective rent, defined as rent multiplied by occupancy rate, which can be a useful tool for measuring the total returns to a property owner. Compared to nearby control buildings, green-certified buildings were found to have effective rents of almost eight percent higher for the study period. The increase between the rent and effective rent statistic reflects the higher average occupancy rates in green buildings. During the economic downturn, effective rents for green buildings maintained their premium over non-green buildings, decreasing by 5.1% versus 7.5% for non-green buildings (2010).

A parallel 2008 study by Norm Miller, Jay Spivey and Andy Florance of CoStar, a commercial real estate information company, reports similar findings that LEED-certified or Energy Star-rated commercial buildings command higher sale prices (10% higher for LEED, 6% higher for Energy Star), as well as uniformly higher occupancy rates and rent prices. Also concurring with the Berkeley/Maastricht study, operating expenses based on energy costs were shown to be significantly lower for Energy Star-rated buildings (70% lower) than for non-green counterparts, a tangible benefit of interest to buyers or tenants. Additionally, the CoStar study mentions that green buildings may sell or rent at a faster rate: "We did not have data on absorption rates but casual surveys suggest much faster absorption rates for LEED certified buildings. Although empirical data would be preferable, we will cautiously add this finding to our list of potential economic benefits for developers of green building projects. With faster absorption rates, developers reduce carrying costs for unsold units and receive a quicker return on investment (2008)."

Summary

The Eichholtz et al studies provide a statistically robust benchmark for estimating the market's willingness-to-pay for a green-certified building as of 2010: approximately 3% higher for rent, 8% higher for effective rent, and 13% higher for the building sale price, based on transaction data between 2004 and 2009. The studies also reveal better performance of green buildings during a significant economic downturn, and higher occupancy and absorption rates. Comparing these figures to the USGBC's "Cost of Green in NYC" statistics, which state that LEED-certified buildings on average cost 2% less than their non-certified counterparts, including soft costs, the percentage spread is robust. The analyses presented in these studies are a compelling argument that green building is now an economically favorable choice for developers.

Homeowner's Association and Building Management

Incorporating green building practices at the pre-design phase for a building sets the project direction over a building's lifetime. The ADCO Group therefore bears responsibility for ensuring the design and construction of the building is optimal for projected energy and water usage. However, once construction is completed, all units will be available for sale. Our client has expressed that it will hold no legal or financial responsibility once the building achieves full occupancy.

To guarantee that the building continues to perform as efficiently as it was designed, a well-structured, self-governing Homeowner's Association (HOA) will oversee the continued performance of the building. HOAs, most of which are for condominiums, are officially recognized as common interest developments (CIDs) in California. CIDs are characterized by the individual ownership of a house or condominium coupled with the shared ownership or right to use common areas (Johnston and Johnston-Dodds 2002). California Civil Code section 1350 governs CIDs, allowing for the creation of HOAs and the enforcement of agreed Codes, Conditions, and Restrictions (CC&Rs). The California Department of Real Estate oversees and enforces Section 1350 and the Subdivided Lands Law once CIDs establish CC&Rs and related bylaws. It is important to note that once sales have begun, the jurisdiction of the department is limited to the approved public report and does not involve itself in association disputes.

In 2002, 34,000 CIDs existed in California, comprising about 8 million people or 24% of the state's population (ibid). Of that, 65% of are condominium developments, including multifamily units. We believe that the ADCO Group can pursue this management practice, with stipulations for information sharing on the continued energy and water consumption of the building. This serves two purposes:

It ensures that the developer has access to marketing material that will highlight their first efforts with green building practices. This genuine long-term interest will foster a healthy rapport with numerous stakeholders within and beyond the development.

Under LEED v3 for New Construction one of the Minimum Program Requirements states that "all certified projects must commit to sharing with USGBC and/or GBCI all available actual whole-project energy and water usage data for a period of at least 5 years" (2008). The same requirement applies under LEED v3, were the building to pursue certification for Existing Buildings.

In consultation with property managers in San Francisco, our team learned it would be best to provide soft recommendations including, but not limited to the following:

- A mandatory Orientation where the hired property manager or the ADCO Group will tour future tenants through a sample unit and review:
    - Highlights of unique "green" features (i.e. Energy Dashboards)
    - Proper use and maintenance of said "green" features
    - Local, state, and federal resources for improving the environmental performance of their units

- Operating cost ledger items that include the following suggested “green” features for a proposed HOA:
  - Building insulation operating costs (See Appendix: Project Manual – Insulation)
  - High-performance window operating costs (See Appendix: Project Manual – Windows (Fenestration)
  - Individual plumbing and water fixture installation and operating costs (See Appendix: Project Manual – Plumbing and Water Fixtures)
  - Common area water efficient technologies operating costs (See Appendix: Project Manual – Water-efficient landscaping)
  - Monitoring System installation and operating costs (See Appendix: Project Manual – Monitoring system)
- Environmental subcommittee
  - Works in tandem with the building management staff to identify and educate tenants about green features in the building
  - Host workshops in conjunction with private and/or local environmental programs that promote a “green” lifestyle

Recommendations for a Bird-Safe Building

The 1481 Post Street project can take simple steps to reduce the likelihood of fatal bird strikes against its façade. Buildings, especially those with large windows and a high percentage of glass in the envelope, represent a biologically significant threat to bird populations; in the U.S., it is estimated that up to one billion birds are killed per year by flying into building windows (Klem, 2009).

The primary drivers of building-related bird fatalities are window reflectivity, window transparency, and night lighting. Reflective windows kill birds when they reflect vegetation, sky, or a perceived passageway, causing birds to fly into them. Transparent windows can present a fatal attraction when they offer a sight-line through a structure, out to the other side. The ground level and bottom few stories of a building are the most hazardous, due to their proximity to surrounding vegetation. Night lighting, particularly in tall buildings, can disorient nocturnally migrating birds and cause them to collide with the building (San Francisco Planning Department, 2010).

In October 2010, the San Francisco Planning Department proposed a document – "Standards for Bird-Safe Buildings" – that would recommend bird-safe measures for San Francisco buildings. Decision has not been reached on the draft document, but if accepted, San Francisco would not be the first city in North America to adopt bird standards. Chicago, through its county government, passed an ordinance in 2008 requiring that all new buildings and major renovations incorporate design elements to reduce the likelihood of bird collisions. Similar, mandatory regulation has passed in Toronto (ibid).

The following recommendations are adapted from the public review draft of the 2010 "Standards for Bird-Safe Buildings" document. The document represents up-to-date scientific research on bird mortality from buildings in urban areas; it was co-written by the American Bird Conservancy scientific staff, and was based on guidelines published by the New York City Audubon Society in 2007. Observing the document's minimal guidelines would remove significant hazards for birds at the 1481 Post Street site, and result in compliance with the standards as they appear in the October 2010 draft document. Compliance at the minimal level would qualify 1481 Post Street as a "Bird Safe Building" under the proposed certification, and the building could be marketed as such. Incorporation of bird-safe building design may also be eligible for a LEED point under V3's Innovation and Design category.

Windows

The greatest danger to birds comes from unarticulated, highly-glazed buildings adjacent to water, wetlands, or green open space larger than one acre. 1481 Post Street is not adjacent to any of these bird attractants, and its façade has a favorable degree of articulation due to limestone cladding and extensive window mullions. However it has an overall 80% glass façade, and adjacent street trees and landscape vegetation which will reflect in the glass at lower levels. The following is recommended to mitigate bird strikes:

- Reduce glass reflectivity: no glazing on building shall have a "Reflectivity Out" coefficient exceeding 30%.

- Treat or select glass with a "visual noise barrier" for at least 95% of the collision zone, defined as the ground floor up to 40 feet. A visual noise barrier is defined as fritting, permanent stencils, frosted glass, exterior screens, UV patterns visible to birds, or an equivalent treatment approved by a qualified biologist. Notes: As of 2010, the German company Arnold Glas produces Ornilux, a specialty glass with UV patterns visible to birds, but not to humans, available in low-e and insulated configurations; the glass is distributed in the U.S. by Roeder Windows & Doors of Ventura, CA. Building-integrated photovoltaic glass, such as Pythagoras glass, may also qualify as a visual noise barrier.

Based on the current renderings of 1481 Post Street, it appears to be free of "bird traps" listed in the document, such as glass courtyards, glazed passageways, transparent building corners, and clear sight lines through the building. However, we recommend consulting the "Standards for Bird Safe Buildings" document to learn more about preventing the inadvertent design of "bird traps."

Night Lighting

Night lighting on tall buildings can disorient and "trap" nocturnally migrating birds, causing death due to collision or exhaustion (Klem, 2009). Fatalities increase during inclement or foggy weather, and during the birds' spring and fall migration seasons. The following is recommended to mitigate lighting-related bird deaths at 1481 Post Street:

- Avoid uses of uplighting that spills light into the night sky, including upward-facing spotlights on roof; instead, use shielded lighting that is aimed downwards at the targeted area.
- Avoid the use of red-colored lighting; instead, use blue or green lighting.
- Participate voluntarily in San Francisco's "Lights Out for Birds" program, administered by PG&E, SF Environment, and Golden Gate Audubon Society. In this program, owners of tall buildings turn off upper lights at night during the spring migration (February 15 to May 31) and fall migration (August 15 to November 30). For 1481 Post Street, this would likely involve turning off upper exterior and roof decorative lighting during these periods.
- Lastly, we recommend distributing the San Francisco Bird-Safe Building Standards to apartment buyers, to educate them about the role they can play in reducing bird collisions.

Conclusion

To address the impacts of the built environment, our goals for this project were to increase the energy and water performance of the 1481 Post Street building and to justify an integrated building design. Throughout the project, we analyzed potential green building processes and technologies for the proposed tower and identify their estimated costs, benefits, and trade-offs. Based on energy modeling and financial analyses, we provide the developer with site-specific recommendations for green building technologies with the highest environmental value per cost of implementation and the highest likelihood of use by future owners.

The results of our energy modeling show that optimizing the building's envelope, specifically choice of glass, is critical to energy performance. For windows, our models show that low solar heat gain is the most important factor in reducing annual energy consumption for the proposed building. Our models also show that increasing exterior-wall insulation beyond R-13 in a building with an 80% glass façade has an insignificant effect on reducing heating and cooling load in San Francisco's mild climate.

Additional analysis examined potential energy savings from building monitoring and automation system (BMAS) scenarios. Analyzing case studies of monitoring systems and utility rate projections, we identified a number of important benefits to BMAS that integrates submeters, load controllers and dashboards. We recommend Scenario 3, which contains 4 submeters, 3 load controllers, and a dashboard, as it offers the most potential benefits without significant added costs. The 16.1% energy savings required for a 10-year payback under this scenario may be easily achievable given the monitoring system's behavior-changing capabilities.

We then continued our analysis to determine cost-effective methods to achieve greater water savings. We find a reasonable return on investment for water efficient fixtures and individual unit energy/water monitoring systems designed to reduce consumption. Our modeled scenarios, which show the 10-year values of investment in water efficiency measures, are both positive and approximately equal for Scenarios 1 and 2; however, the addition of Energy Star appliances in Scenario 2 adds a degree of energy efficiency that justifies the added costs. Therefore, we recommend the installation of WaterSense fixtures and Energy Star appliances standard within each of the units. Continuing the water analysis with the assumption that Scenario 2 will be implemented, we then examined the viability of adding water monitoring systems into the units. Our models yielded positive 10-year values, indicating that the installation of a monitoring system would be a worthwhile investment.

Lastly, we recommend that ADCO pursue an integrated building design process. Integrated building design brings the developer, architect, engineer, and contractor together at the earliest stages of a building's life resulting in a collaborative design process and a building system that performs optimally.

Our recommendations for increased energy and water efficiency, monitoring systems, and the integrated building design process will help ADCO reduce the environmental impact of this building. This project will be a useful tool for both our client and for other developers seeking to reduce the long-term environmental footprint of future building projects.

Acknowledgements

The SFHighRise Team expresses the deepest gratitude to the following individuals and institutions for their invaluable support and guidance throughout the entire group project process. First, we would like to thank the faculty and staff at the Bren School for Environmental Science and Management for teaching the necessary skills sets to solve real-world environmental problems and supporting administrative and logistical work related with the group project process. We are grateful to Yardi Systems for their financial support to the Bren School, which made part of our group project funding possible. Additionally, we greatly appreciate the financial assistance that the Bren School provided for SFHighRise group members Allan Robles and Fiona Teng for attending the 2010 US Green Building Council's Greenbuild Conference in Chicago, IL. Second, the team would like to thank the ADCO Group for the opportunity to solve a real world environmental problem and in the process gain both professional and personal growth. We thank the ADCO Group as well for the invaluable summer work experience offered to two members of the project, and for their generous financial contribution to project expenses. There are also numerous industry professionals that provided us with tangible advice that have made our analyses and recommendations more robust. Lastly, we would like to personally thank our faculty advisor, Dr. Jeff Dozier, whose wisdom and years of professional and academic experience consistently turned ADCO's environmental problem into an opportunity for realized solutions.

<u>Academic and Industry Acknowledgements</u>

Dr. Jeff Dozier – Professor at the Bren School for Environmental Science and Management

Ms. Linda Corso – VP of Operations at the ADCO Group, Inc. (San Francisco)

Mr. Eric Grossberg – Managing Director at the ADCO Group, Inc. (New York City)

Ms. Maherah Silmi – Property Manager for the Cathedral Hill Plaza Apartment Complex

Dr. Christopher Costello – Professor at the Bren School for Environmental Science and Management

Mr. Jordan Sager – LEED Portfolio Manager at UC Santa Barbara's Facilities Management Department

Mr. John Campanella – President at Bermant Homes

Mr. Bryan Henson – General Manager at Allen Associates

Ms. Lindsey Taggart – Building Environmental Specialist at the Santa Barbara Community Environmental Council

Mr. Steve Taylor – Principal at Taylor Engineering

Mrs. Robin Bass – Senior Associate, Huntsman Architectural Group

Dr. Eleanor Lee – Staff Scientist, Lawrence Berkeley National Laboratory

Mr. Andrew De Coriolis – Customer Programs Manager at Lucid Design Group

Mr. Carey Vandenberg – CEO of Agilewaves, Inc.

The SPUR Association of San Francisco

Mr. Michael Willis – President at Michael Willis Associates

Mr. Sanjeev Malhotra – Design Director at Michael Willis Associates

Mr. Howard Leist – Director of Design, SLCE Architects, LLP

Mr. Bill Burke – Architect, PG&E Pacific Energy Center

We'd like to thank the organizations that have made this project process financially viable:

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Appendix

Energy Model Specification for Baseline

The following specification enables the baseline energy model used in our analysis to be replicated. The specification also provides transparency of the assumptions used in our analysis.

Architectural Model

- Project and Site Data
    - **General Information**
        - Code Analysis: California Title 24
        - Building Type: Multifamily, High-Rise (interior entries)
        - Code Vintage: 2010 – 2012
        - Building Location and Jurisdiction
            - Location Set: California (Title 24)
            - Region: Oakland Area (CZ03)
              Note: Closest option to San Francisco.
            - Jurisdiction: CA Title24
                - City: San Francisco CO
                  Note: "CO" means "City/County Office"
        - Utilities and Rates
            - Electric
                - Utility: PG&E (CA)
                - A1(1) (kWh charges only, < 499kW, single-phase service)
                  Note: A1(1) was the closest electric rate available in eQUEST to the rate specified to us during a phone conversation with a PG&E representative.
            - Gas
                - Utility: PG&E (CA)
                - Rate: GNR-1 (buildings with < 20800 therms/mo)
        - Other Data
            - Analysis Year: 1991
            - Usage Details: Hourly Enduse Profiles
            - Prevent duplicate model components: TRUE
    - **Compliance Analysis Settings**
        - Includes DHW: TRUE
    - **Season Definitions**
        - Description of Seasons: Typical Use Throughout Year
        - Number of Seasons: 1
          Assumption: Residents occupy the building the same number of hours per week year-round.
        - Season #1
            - Label: Entire Year
- Shell Component – Bldg Envelope & Loads 1

- **General Shell Information**
  - Shell Name: Bldg Envelope & Loads 1
  - Building Type: Multifamily, High-Rise (interior entries)
  - Specify Exact Site Coordinates: FALSE
    Note: X, Y, and Z here are NOT dimensions of the building; they are offsets of the building origin from 0, 0, 0. Modifying the origin was not necessary for this analysis.
  - Areas and Floors
    - Building Area: 414,054 ft^2
      Note: For the purposes of this energy model, assume that Floor 1 has 11,655 ft^2 of conditioned space. Therefore, the total building area is equal to (Floor 1 ft^2) + (total gross ft^2 for floors 2 thru 36) = (11,655 ft^2) + (402,399 ft^2) = ***414,054 ft^2****.*
    - Number of Floors:
      - Above Grade: 36
      - Below Grade: 0
        Assumption: Any floors below grade would be unconditioned parking garage.
    - Use Floor Multipliers: TRUE
  - Other Data
    - Shell Multiplier: 1
    - Daylighting Controls: No
      Note: Indicates whether automatic daylight-sensing/dimming lighting controls will be used in the base case model.
    - Usage Details: Hourly Enduse Profiles
    - Prevent duplicate model components: TRUE
    - Component Name Prefix: EL1
- **Building Footprint**
  - Footprint Shape: Rectangle
  - Zoning Pattern: Perimeter / Core
  - Building Orientation
    - Plan North: North
  - Footprint & Zoning Dimensions
    - *Notes*
      - *For floors 2 – 36, the outer building dimensions were as follows (as per the SLCE renderings dated September 21, 2010):*
        - *X: 118.0 ft*
        - *Y: 110.0 ft*
      - *If the building were a true rectangle, the square footage per floor for floors 2 – 36 would be X * Y = 118.0 ft * 110.0 ft = 12,980 sq ft.*

- *However, due to the slight curvature of the building faces, the actual square footage per floor is significantly less.*
- *For floors 2 – 36, the average gross square footage per floor is 11,552.6 ft^2.*
  - *This is 11% fewer sq ft than that calculated by a 118 ft x 110 ft rectangle.*

- *To make our energy model more accurate, we will calculate the footprint dimensions of a hypothetical, truly-rectangular building that has the same square footage per floor as the actual curved building, while at the same time preserving the same aspect ratio of 110/118 = 0.9322 (or 118/110 = 1.0727).*
  - *These dimensions are as follows:*
    - ***X: 111.50 ft***
    - ***Y: 103.61 ft***

- Perimeter Zone Depth: 29.73 ft
  Note: Use the average of the two perimeter zone depths. To calculate an average perimeter zone depth for our hypothetical, truly-rectangular building that has the same square footage per floor as the actual curved building, we need to do the following:
  1. *Subtract the core dimensions from the hypothetical, rectangular building dimensions and then divide by two:*
     (111.5 ft – 42.5 ft) / 2 = 34.5 ft
     (103.6 ft – 53.67 ft) / 2 = 24.965 ft
  2. *Take the average:*
     (34.5 ft + 24.965 ft) / 2 = 29.7325 ft ~= ***29.73 ft***
- Specify Aspect Ratio: TRUE
- X1: 111.50 ft
- Y1: 103.61 ft

- Floor Heights
  - Flr-To-Flr: 11.3 ft
  - Flr-To-Ceil: 10.0 ft
- Roof, Attic Properties
  - Pitched Roof: FALSE
  - Attic Above Top Fl: FALSE

- **Building Envelope Constructions**
  - Roof Surfaces
    - Construction: 8 in. Concrete
    - Ext Finish / Color: Concrete (no ext finish); White, semi-gloss
    - Exterior Insulation: 5 in. polyisocyanurate (R-35)
    - Add’l Insulation: no LtWt Conc Cap
  - Above Grade Walls

            - Construction: Metal Frame, 2x6, 16 in. o.c.
            - Ext Finish / Color: Glass, spandrel; ‘Medium’ (abs=0.6)
            - Exterior Insulation: 1/2in. fiber bd sheathing (R-1.3)
            - Add’l Insulation: R-13 batt
            - Interior Insulation: (no board insulation)
        - Ground Floor
            - Exposure: Over Parking Garage
            - Construction: 8 in. Concrete
            - Ext/Cav Insul: 2 in. polyisocyanurate (R-14)
            - Interior Insul.: (no board insulation)
            - Cap & Finish: - no concrete cap -; Ceramic/Stone Tile
            - Slab Penetrates Wall Plane: TRUE
                - Slab Edge Insul.: (no board insulation)
                - Slab Edge Finish: (none)
    - **Building Interior Constructions**
        - Ceilings
            - Int. Finish: Drywall Finish
            - Batt Insulation: R-13 batt
        - Vertical Walls
            - Wall Type: Frame
            - Batt Insulation: R-13 batt
              Note: We included insulation between the interior walls, because the interior walls in our eQUEST model separate the different thermally-controlled zones on each floor. R-13 was the maximum available.
        - Floors
            - Int. Finish: Ceramic/Stone Tile
              Note: Closest option to hardwood flooring.
            - Construction: 8 in. Concrete
            - Concrete Cap: (no concrete cap)
            - Rigid Insulation: (no board insulation)
            - Slab Penetrates Wall Plane: TRUE
                - Slab Edge Insul.: (no board insulation)
                - Slab Edge Finish: (none)
    - **Exterior Doors**
        - Door Type 1: Air Lock Entry (glass)
            - Ht (ft): 7.0
            - Wd (ft): 6.0
            - Construction: (specify properties)
                - Auto Select Minimally Code Compliant Door Properties: FALSE
                - Specification Methods
                    - Conductance: NFRC Ufactor

        - Solar Transmit.: NFRC SHGC
      - Product Description
        - Product Type: Closed Revolving Door or Air Lock Door
        - Number of Panes: Double
        - Frame Type: Alum w/ Brk
        - Door Sill Has Thermal Break: TRUE
        - Glass Tint: Clear Glass
        - Low-E Coating: 0.2 < e <= 0.4
        - Air Space: >= 1/2 in.
        - Gas Fill: Argon
      - Performance Data
        - NFRC Ufactor: 0.340
        - NFRC SHGC: 0.390
        - Visible Transmittance: 0.450
    - Frame Type: Alum w/ Brk
    - Frame Wd (in): 6.0
  - Door Type 2: Opaque
    - Ht (ft): 6.7
    - Wd (ft): 3.0
    - Construction: Steel, Polyurethane core w/ Brk

Note: Whenever we tried to incorporate doors into the model, eQUEST included them on every floor, even though we only specified them for Floor 1. Specifying that this was a high-rise with interior entries did not prevent any ground-floor, exterior door from being duplicated on every floor. This issue interfered with proper window placement on the higher floors. To correct for this, we set all door quantities to zero.

- **Exterior Windows**
  - Window Area Specification Method: Percent of Gross Wall Area (floor to floor)
  - Window Type 1
    - Glass Category: (specify properties)
      - Auto Select Minimally Code Compliant Door Properties: FALSE
      - Specification Methods
        - Conductance: NFRC Ufactor
        - Solar Transmit.: NFRC SHGC
      - Product Description
        - Product Type: **Fixed** Window
        - Number of Panes: Double
        - Frame Type: Alum w/ Brk, **Curtain**, Ins Spacer
        - Glass Tint: Clear Glass
        - Low-E Coating: 0.2 < e <= 0.4

- Air Space: >= 1/2 in.
- Gas Fill: Argon

o Performance Data
Note 1: Values obtained from the "DOE2 Glass Library.xls" (available via the eQUEST Help menu).
Note 2: Values are for Solarban 60 Clr/Arg/Clr 3 (Ufactor: 0.34 (U-Value: 0.25); SHGC: 0.39; VT: 0.45)
- **NFRC Ufactor: 0.340**
- **NFRC SHGC: 0.390**
- **Visible Transmittance: 0.450**

- Frame Type: Alum w/ Brk, **Curtain**, Ins Spacer
- Frame Wd (in): 6.00
- Window Dimensions, Positions and Quantities
  - o Typ Window Width (ft): 8.00
  - o Window width to take precedence over % window inputs: TRUE
  - o Window Ht (ft): 10.00
  - o Sill Ht (ft): 0.00
  - o % Window (floor to floor, including frame) North: **60.0**
  - o % Window (floor to floor, including frame) South: **60.0**
  - o % Window (floor to floor, including frame) East: **60.0**
  - o % Window (floor to floor, including frame) West: **60.0**

▪ Window Type 2
- Glass Category: (specify properties)
  - o Auto Select Minimally Code Compliant Door Properties: FALSE
  - o Specification Methods
    - Conductance: NFRC Ufactor
    - Solar Transmit.: NFRC SHGC
  - o Product Description
    - Product Type: **Operable Window**
    - Number of Panes: Double
    - Frame Type: Alum w/ Brk, **Oper**, Ins Spacer
    - Glass Tint: Clear Glass
    - Low-E Coating: 0.2 < e <= 0.4
    - Air Space: >= 1/2 in.
    - Gas Fill: Argon
  - o Performance Data
    Note 1: Values obtained from the "DOE2 Glass Library.xls" (available via the eQUEST Help menu).
    Note 2: Values are for Solarban 60 Clr/Arg/Clr 3 (Ufactor: 0.34 (U-Value: 0.25); SHGC: 0.39; VT: 0.45)
    - **NFRC Ufactor: 0.340**

- **NFRC SHGC: 0.390**
- **Visible Transmittance: 0.450**
- Frame Type: Alum w/ Brk, **Oper**, Ins Spacer
- Frame Wd (in): 6.00
- Window Dimensions, Positions and Quantities
  - Typ Window Width (ft): 8.00
  - Window width to take precedence over % window inputs: TRUE
  - Window Ht (ft): 10.00
  - Sill Ht (ft): 0.00
  - % Window (floor to floor, including frame) North: **20.0**
  - % Window (floor to floor, including frame) South: **20.0**
  - % Window (floor to floor, including frame) East: **20.0**
  - % Window (floor to floor, including frame) West: **20.0**

- **Exterior Window Shades and Blinds**
  Note: For the baseline model, these features are not included.
- **Roof Skylights**
  - Skylit Rooftop Zones: None
- **Building Operation Schedule**
  - Entire Year 1/1-12/31
    - Use: Daytime Unoccupied, Typical Use
    - Mon – Fri:
      - Leave At: 7 am
      - Return At: 5 pm
    - Sat – Sun & Hol:
      - Leave At: 9 am
      - Return At 4 pm
- **Activity Areas Allocation**
  Note: Each individual unit will contain its own washer and dryer, so we removed the 7% laundry area per floor, and added it to the Residential area per floor. (In other words, we incorporated the laundry area per floor into the residential area per floor.)
  - Area Type 1: Residential (Multifamily Dwelling Unit)
    - Percent Area (%): 77.0
    - Design Max Occup (sf/person): 200
    - Design Ventilation (CFM/per): 30.00
    - Assign First To Zone(s): Per
  - Area Type 2: Corridor
    - Percent Area (%): 16.0
    - Design Max Occup (sf/person): 100
    - Design Ventilation (CFM/per): 15.00
    - Assign First To Zone(s): Cor
  - Area Type 3: Storage (Conditioned)

- Percent Area (%): 7.0
- Design Max Occup (sf/person): 333
- Design Ventilation (CFM/per): 50.00
- Assign First To Zone(s): Cor

- Area Type 4: Laundry
  - Percent Area (%): 0.0
  - Design Max Occup (sf/person): 0
  - Design Ventilation (CFM/per): 0.00
  - Assign First To Zone(s): (blank)
- Occupancy Profiles by Season
  - Entire Year: EL1 Occup Profile (S1)

- **Non-HVAC Enduses to Model**
  - Interior Enduses (contributing to space loads)
    - Interior (ambient) Lighting: TRUE
    - Cooking Equipment: TRUE
    - Miscellaneous Equipment: TRUE
    - Self-Contained Refrigeration: TRUE
  - Exterior Enduses (not contributing to space loads)
    - Exterior Lighting: FALSE
    - Domestic Hot Water: TRUE; Model DHW Equipment with Seasonal Profiles
  - Laundry Facilities
    - Location of Equipment: In-Unit
    - # Dwelling Units per Floor: 7 units/floor
      Note: (231 units) / (35 residential floors) ~= 7 units / floor.
    - Laundry Loads / Unit / Wk: 7.5 loads/unit/week
      Note: According to DOE, residential clothes washers have an annual average usage of 392 cycles per year.
      (392 cycles/year) / (52.14 weeks/ year) ~= 7.5 cycles/week
    - Washer Type: Vertical Axis
    - Dryer Fuel: Electricity
- **Interior Lighting Loads and Profiles**
  - Lighting (W/SqFt)
    - Area Type 1: Residential (Multifamily Dwelling Unit): 0.50
    - Area Type 2: Corridor: 0.60
    - Area Type 3: Storage (Conditioned): 0.60
    - Area Type 4: Laundry: 0.00
  - Multipliers on above intensities: 1.00
  - Interior Lighting Hourly Profiles by Season
    - Entire Year
      - Ambient: EL1 InsLtg Profile (S1)
- **Cooking Loads and Profiles**
  - Area Type 1: Residential (Multifamily Dwelling Unit)

            - Electric Equipment Load (W/SqFt): 0.05
        - *Notes:*
            - *We did not include any gas cooking in model (as per consulting mechanical engineer).*
            - *Electric cooking loads:*
                - *Electric cooktop: 234 kWh/year*
                - *Electric oven (non-self-cleaning): 274 kWh/year*
                - *Microwave: 165.8 kWh/year*
            - *Derivation of electric cooking load in Watts per ft^2:*
                - *Total electric cooking load = (234 kWh/year) + (274 kWh/year) + (165.8 kWh/year) = 673.8 kWh/year*
                - *Average ft^2 per condo unit = (325,450 total net residential ft^2) / (231 total units) ~= 1,409 ft^2*
                - *(673.8 kWh/year) / (8760 h/year) = 0.076918 kWh/h = 76.918 W*
                - *(76.918 W) / (1409 ft^2) =* ***0.05459 W/ft^2***
        - Cooking Equipment Hourly Profiles by Season
            - Entire Year: EL1 CookEq Profile (S1)
    - **Self-Contained Refrig Loads and Profiles**
        - Area Type 1: Residential (Multifamily Dwelling Unit)
            - Refrig Equip Load (W/SqFt): 0.14
                - *Assumption 1: 615 Watt refrigerator.*
                - *Assumption 2: Compressor runs 7.7 h/day.*
                - *Derivation of electric cooking load in Watts per ft^2:*
                    - *(615 W)(7.7 h/day) = 4735.5 Wh/day*
                    - *(4735.5 Wh/day) / (24 h/day) = 197.3125 W*
                    - *(197.3125 W) / (1409 ft^2) =* ***0.1400 W/ft^2***
            - Refrig Equip Sensible Ht (frac): 1.00
        - Self-Contained Refrigeration Equipment Hourly Profiles by Season
            - Entire Year: EL1 S-C Refrig Profile (S1)
    - **Miscellaneous Loads and Profiles**
        - Area Type 1: Residential (Multifamily Dwelling Unit)
            - Electric Load (W/SqFt): 0.30
            - Electric Sensible Ht (frac): 1.00
        - Miscellaneous Equipment Hourly Profiles by Season
            - Entire Year: EL1 Misc Profile (S1)
    - **Domestic Water Heating Hourly Profiles**
        - DHW Hourly Profiles by Season
            - Entire Year: EL1 DHW Profile (S1)
- <u>DHW Equipment</u>
    - **Residential Domestic Water Heating**
        - Heater Specifications
            - Heater Fuel: Electricity

            - Efficiency Spec.: Standby Loss
            - Heater Type: Storage
            - Hot Water Use: 16.84 gal/person/day
            - Input Rating: 1,607.9 kW
        - Storage Tank
            - Tank Capacity: 17,968 Gal
            - Insulation R-value: 25.0
            - Standby Loss: 0.00 %/hr
        - Water Temperatures
            - Supply Water: 110.0 °F
            - Inlet: Equals Ground Temperature
        - Pumping
            - Recirculation %: 0.0 %
- <u>Correction of Occupancy per Zone</u>
  Note: The default eQUEST values for "Number of People" per zone is unrealistically high. Based on an average household size for San Francisco of 2.42 individuals (MTC-ABAG Library, 2011)*, the number of people per zone in our model should be 3.88 for perimeter zones, and zero for core zones.*
    - Go to Detailed Data Edit -> Internal Loads -> EL1 Ground Flr (or any other floor) -> EL1 South Perim Spc (or any other zone) -> Spreadsheet -> Display Mode: Occupancy -> Number of People
    - For all twelve of the defined perimeter spaces, correct the value for "Number of People" to 3.88.
    - For all three of the defined core spaces, correct the value for "Number of People" to 0 (zero).

  Note: The above corrections are lost every time you enter Wizard Data Edit mode.

HVAC Model

Designing an HVAC model that provides realistic heating and cooling loads for the proposed structure throughout the year is critical To receive meaningful output from the energy model. The most difficult-to-design component of our energy model was an HVAC model that produced realistic heating and cooling loads throughout the year for the climate. The large size of the proposed structure at 1481 Post Street added to the complexity.

Based on data collected for an existing high-rise building next to the proposed building site, a realistic annual heating and cooling load for the climate and building type should fall roughly between 50 kBtu/ft^2/year and 100 kBtu/ft^2/year (for the baseline design). After experimentation with the majority of HVAC system types offered in eQUEST, and after experimenting with different configurations of these systems combined with iterative tuning of the parameters, we obtained an HVAC model that produces a realistic annual heating and cooling load of 71 kBtu/ft^2/year for the baseline design.

The annual heating and cooling loads for our baseline model are shown in Figure 24 and Figure 25. Figure 26 depicts the total energy consumption of the baseline model over the year.

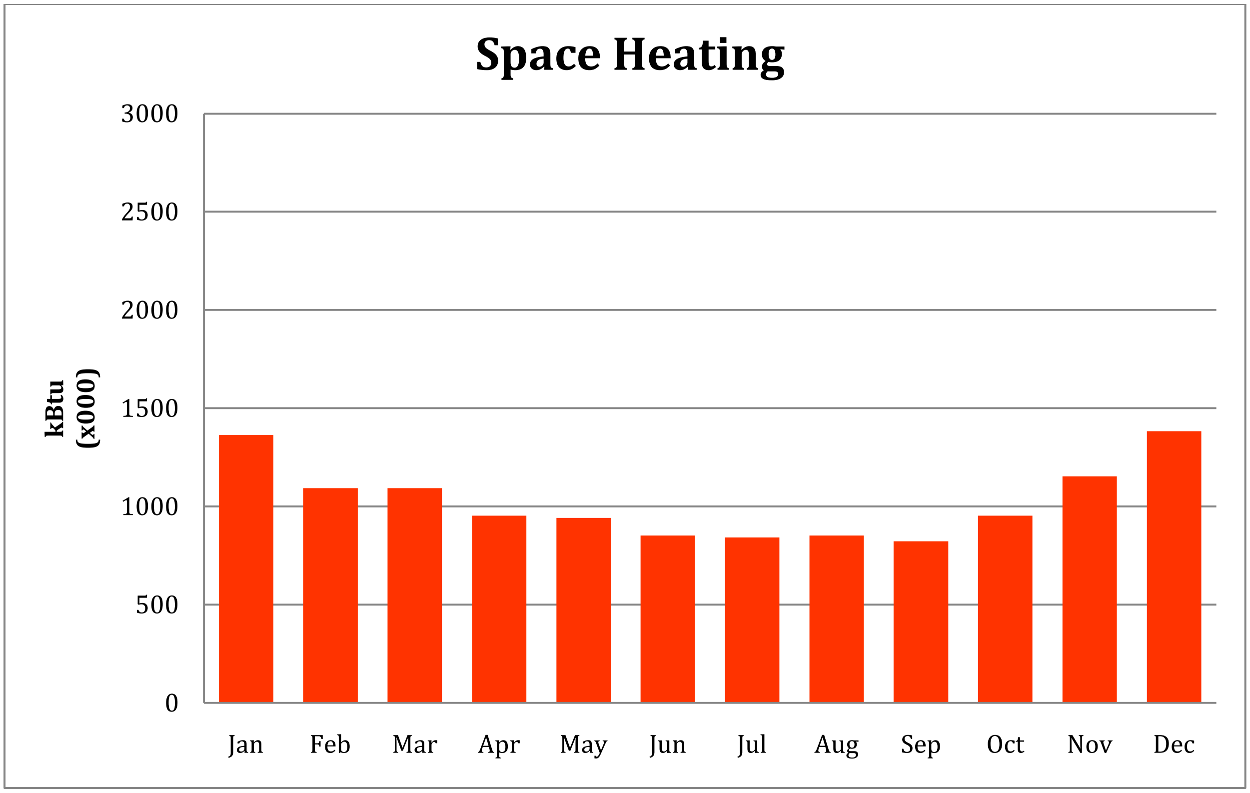

Figure 24: Baseline Monthly Heating Loads

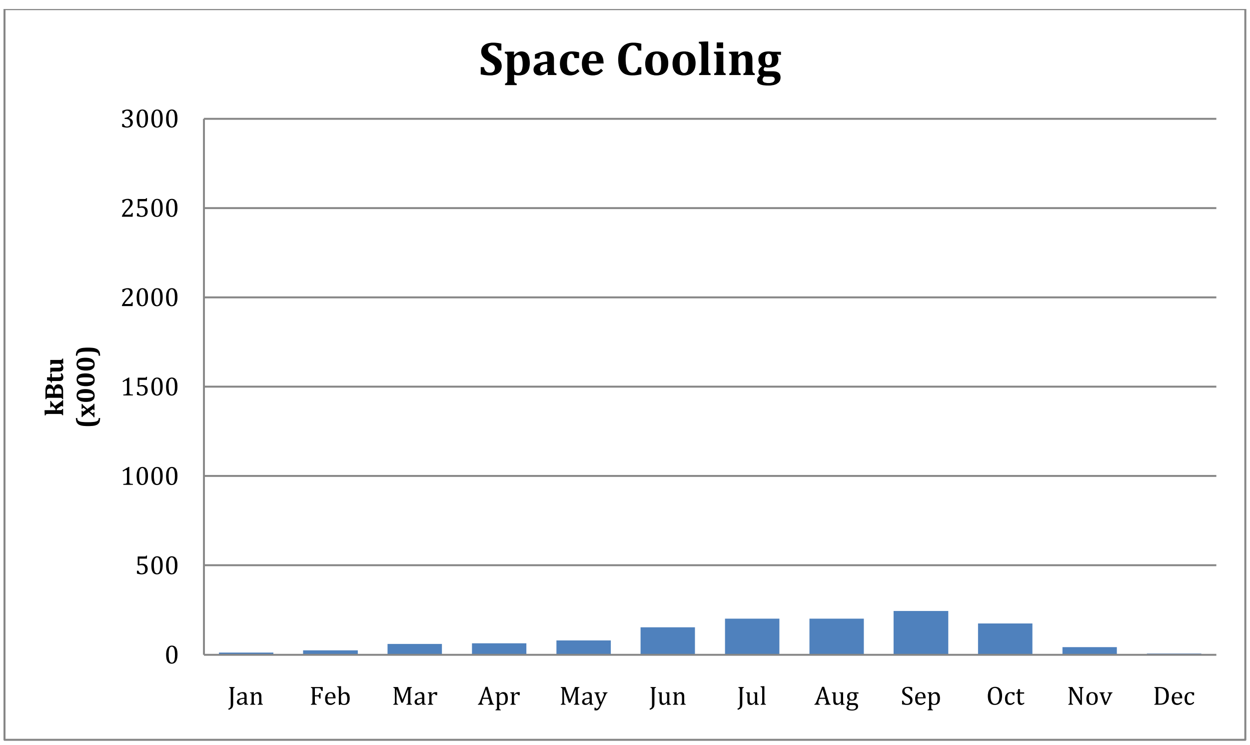

Figure 25: Baseline Monthly Cooling Loads

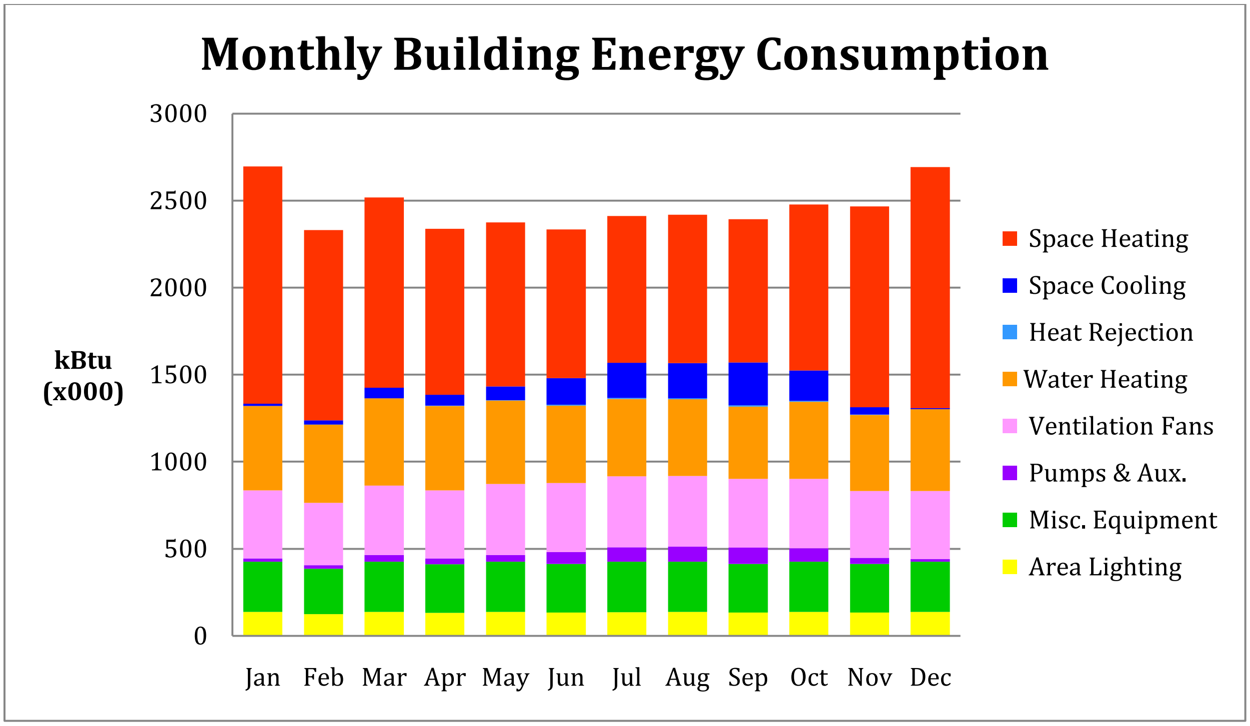

Figure 26: Baseline Monthly Energy Consumption

Below is the specification for the baseline HVAC model used in our analysis.

- Air-Side System Type
    - **HVAC System Definition**
        - Cooling Source: Chilled Water Coils
        - Heating Source: Hot Water Coils
        - System Type: Multizone Air Handler with HW Heat
        - System per Area: System per Floor
        - Return Air Path: Ducted
        - Prevent duplicate model components: TRUE
    - **HVAC Zones: Temperature and Air Flows**
        - Seasonal Thermostat Setpoints:
            - Occupied (°F)
                - Cool: 78.0
                - Heat: 68.0
            - Unoccupied (°F)
                - Cool: 78.0
                - Heat: 68.0
        - Design Temperatures
            - Indoor
                - Cooling Design Temp: 75.0 °F
                - Heating Design Temp: 72.0 °F
            - Supply

        - Cooling Design Temp: 55.0 °F
        - Heating Design Temp: 95.0 °F
    - Air Flows
      - Minimum Design Flow: 0.50 cfm/ft2
      - VAV Minimum Flow for Core: 100.0%
      - VAV Minimum Flow for Perimeter: 100.0%
  - **HVAC System Fans**
    - Supply Fans
      - Dual Fan: TRUE
      - Power & Mtr Eff: 4.00; in. WG; Premium
      - Fan Flow & OSA: Auto-size Flow (with 1.15 safety factor)
      - Fan Type: Variable Speed Drive
    - Return Fans
      - Return: TRUE
      - Power & Mtr Eff: 1.33; in. WG; Premium
      - Fan Flow: Auto-size
      - Fan Type: Variable Speed Drive
    - Heating Fans
      - Power & Mtr Eff: 2.00; in. WG; Premium
      - Fan Flow: Auto-size
      - Fan Type: Variable Speed Drive
  - **HVAC System #1 Fan Schedules**
    - Cycle Fans at Night: No Fan Night Cycling
    - Operate fans 0 hours before open and 0 hours after close.
    - Entire Year 1/1-12/31
      - Mon – Fri:
        - On At: 5 pm
        - Off At: 7 am
      - Sat – Sun & Hol:
        - On At: 4 pm
        - Off At: 9 am
  - **HVAC Zone Heating, Vent and Economizers**
    - Zone Heat Sources & Capacities / Delta T
      - Baseboards: - none –
    - Economizer(s)
      - Type: Drybulb Temperature
      - High Limit: 75.0 °F
  - **HVAC System Hot/Cold Deck Resets**
    - Cold Deck Reset(s)
      - Type: Outside Air Reset
      - Outside Hi/Low: 62.0 °F; 55.0 °F
      - Supply Min/Max: 55.0 °F; 60.0 °F
    - Hot Deck Reset(s)

- Type: Outside Air Reset
- Outside Hi/Low: 70.0 °F; 0.0 °F
- Supply Min/Max: 80.0 °F; 95.0 °F

- <u>CHW Plant Equipment</u>
  - **Cooling Primary Equipment**
    - Chilled Water System
      - CHW Loop:
        - Head: 56.6 ft
        - Design DT: 12.0 °F
      - Pump Configuration: Single System Pump(s) Only
      - Number of System Pumps: 1
      - CHW Loop Flow: Variable
      - Pump Control: Single Speed
      - Motor Efficiency: Premium
      - Estimated CHW Load: 415,891 ft^2 Served x Size Factor: 1.20 / 480 ft2/ton = 1,039.7 tons.
      - Chillers
        - Chiller Type: Electric Centrifugal Hermetic
        - Condenser Type: Water-Cooled
        - Compressor: Constant Speed
        - Chiller Counts & Sizes: 2; Auto-size; >=300 tons
        - Chiller Efficiency: 0.676 kW/ton
  - **Primary Equipment Heat Rejection**
    - Water-Cooled Condenser / Cooling Tower
      - Cnd. Water Loop:
        - Head: 61.6 ft
        - Design DT: 10.0 °F
      - Condenser Configuration: Open Tower
      - Temperature Control: Fixed
      - Setpoint: 85.0 °F
      - Capacity Control: Variable Speed Fan
      - Fan Efficiency and Type: Premium; Centrifugal
  - **Chilled Water System Control and Schedule**
    - Setpoint is: OA Reset
    - CHW Min Temp: 44.0 °F
    - CHW Max Temp: 54.0 °F
    - Entire Year 1/1-12/31
      - Mon – Fri:
        - On At: 5 pm
        - Off At: 7 am
      - Sat – Sun & Hol:
        - On At: 4 pm
        - Off At: 9 am

- HW Plant Equipment
    - **Heating Primary Equipment**
        - Hot Water System
            - HW Loop:
                - Head: 41.6 ft
                - Design DT: 30.0 °F
            - Pump Configuration: Single System Pump(s) Only
            - Number of System Pumps: 1
            - HW Loop Flow: Variable
            - Pump Control: Single Speed
            - Loop Pump:
                - Motor Efficiency: Premium
        - Boilers
            - Boiler Type / Fuel: Condensing HW Boiler; Nat. Gas
            - Boiler Count / Output: 3; Auto-size; >2,500 kBtuh
            - Boiler Efficiency: 93.0%
                - *Note: As per consulting mechanical engineer.*
    - **Hot Water System Control and Schedule**
        - Setpoint is: OA Reset
        - HW Max Temp: 140.0 °F
        - HW Min Temp: 120.0 °F
        - Operation: Demand
        - Entire Year 1/1-12/31
            - Mon – Fri:
                - On At: 5 pm
                - Off At: 7 am
            - Sat – Sun & Hol:
                - On At: 4 pm
                - Off At: 9 am

Monitoring Cost Breakdown Scenarios

Table 1: Monitoring Scenario 1 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
Hardware	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeter	300	450	750
	Total hardware cost per unit	900	1,350	2,250
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database per unit			324.68
Design and Operation	Engineering/design per nit			90
	Maintenance/Operation Costs per unit			810
Total	**Total Cost Per Unit**			**3,574.68**

Table 2: Monitoring Scenario 2 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
Hardware	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeter	300	450	750
	Appliances submeter	300	450	750
	Dashboard			194.85
	Total hardware cost per unit	900	1,350	2,444.85
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database cost per unit			292.21
Design and Operation	Engineering/design cost per unit			90
	Maintenance/operation cost per unit			810
Total	**Total Cost Per Unit**			**4,541.18**

Table 3: Monitoring Scenario 3 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
Hardware	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeyer	300	450	750
	Appliances submeter	300	450	750
	Dashboard			194.85
	HVAC controller	150		300
	Lighting controller	150		150
	Appliances controller	150	450	150
	Total hardware cost per unit	1,650	2,250	4,094.85
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database cost per unit			292.21
Design and Operation	Engineering/design cost per unit			90
	Maintenance/operation cost per unit			810
Total	**Total cost Per Unit**			**5,287.06**

Table 4: Monitoring Scenario 4 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeter	300	450	750
	Range submeter	300	450	750
	Major appliances submeter	300	450	750
	Dashboard			194.85
	HVAC controller	150		300
	Lighting controller	150		300
	Appliances controller	150	450	300
Hardware	Total hardware cost per unit	1,950	2,700	4,844.85
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database per unit			292.21
Design and Operation	Engineering/design per unit			100
	Maintenance/operation cost per unit			900
Total	**Total Cost per unit**			**6,037.06**

Table 5: Monitoring Scenario 5 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeter	300	450	750
	Range/oven submeter	300	450	750
	Dishwasher submeter	300	450	750
	Kitchen appliances submeter	300	450	750
	Other appliances submeter	300	450	750
	Dashboard			194.85
	HVAC controller	150		300
	Lighting controller	150		300
	Dishwasher controller	150		300
	Kitchen appliances controller	150		300
	Other appliances controller	150	750	300
Hardware	Total hardware cost per unit	2,850	3,900	6,944.85
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database cost per unit			292.21
Design and Operation	Engineering/design cost per unit			90
	Maintenance/operation cost per unit			810
Total	**Total Cost per unit**			**8,137.06**

Table 6: Monitoring Scenario 6 Cost Breakdown

Category	Description	Material Cost ($)	Installation Cost ($)	Total Cost ($)
	HVAC submeter	300	450	750
	Lighting submeter	300	450	750
	Plug loads and appliances submeter	300	450	750
	Range/oven submeter	300	450	750
	Dishwasher submeter	300	450	750
	Kitchen appliances submeter	300	450	750
	Refrigerator submeter	300	450	750
	Washer submeter	300	450	750
	Dryer submeter	300	450	750
	Dashboard			194.85
	HVAC controller	150		293
	Lighting controller	150		293
	Plug loads controller	150		293
	Dishwasher controller	150		293
	Kitchen appliances controller	150		293
	Refrigerator controller	150		293
	Other appliances controller	150	1,000	293
Hardware	Total hardware cost per unit	3,750	5,050	8,994.85
Software and Database	Building central server			45,000
	Building software			22,500
	Software/database per unit			292.21
Design and Operation	Engineering/design per unit			90
	Maintenance/operation costs per unit			810
Total	**Total Cost per unit**			**10,190.90**

Project Manual Recommendations

The 1481 Post St Project Team will require a project manual for prospective general contractors, which outlines bidding requirements, sample documents, conditions of the contract, and building specifications for proper LEED submittals. It is pertinent that the professional chosen to draft up the manual prescribe explicit LEED requirements for the 1481 Post St Project to meet LEED for New Construction (NC) Gold. Below, we are making recommendations under the following categories: LEED Gold (sufficient requirements), Beyond LEED (marginal recommendations to improve the marketability and reputation of the project), and Regional Credits (easily achieved credits that increase the rating of the building while mitigating impacts specifically to San Francisco). Note that:

- The recommendations for LEED sections are for insertion into the overall Project Manual; the recommendations are not meant to be exhaustive.
- The architect(s) and/or LEED AP who compose the Project Manual should provide in explicit detail sufficient LEED requirements to ensure the 1481 Post St Project meets LEED NC Gold certification.
- The recommendations listed in this document can help the project in the following three ways:
    - Some of the recommendations can have a large impact toward earning a significant percentage of LEED points toward LEED NC Gold.
    - Secondly, some of the Project Manual LEED sections written below encompass the wider recommendations we have made to go "beyond LEED." Areas in which the project goes beyond LEED may serve as marketing potential for the project to increase selling rates.
    - We have also included a section on achieving the maximum amount of Regional Credits and Points for the 1481 Post St Project.

Recommended Sections

Concrete

For all CSI sections under Division 03 and/or any other sections pertaining to Concrete, we recommend the following LEED verbiage to be inserted into the Project Manual:

- Materials and Resources Credit 4 (MRc4): Recycled Content
    - When possible reuse the concrete from demolition at the site.
    - Please provide the following information for LEED submittal: (1) % postconsumer content (by weight), (2) % pre-consumer content (by weight), and (3) total material cost.
    - If possible, use 10% to 20% recycled content (even higher concentrations are strongly recommended).
- Materials and Resources Credit 5 (MRc5): Regional Materials
    - Use only concrete that has been extracted from the earth from a site no further than 500 miles from the 1481 Post Street building site. Any manufacturing or processing must also have been within a 500-mile radius from the building site.
    - When possible, reuse the concrete from demolition at the site.

    - Please provide the following information for LEED submittal: (1) name of manufacturer, (2) address of manufacturer, (3) cutsheets that document the extraction location, and (4) total material cost.
- List of Local Vendors
    - Allied Concrete Redy Mix: San Francisco Batch Plant
        - 450 Amador Street, San Francisco, CA
        - (415) 282-8117
    - Pacific Supply
        - 1735 24th Street, Oakland, CA
        - http://pacificsupply.paccoast.com/
        - (916) 971-2301

Structural Steel

For all CSI sections under Division 05 and/or any other sections pertaining to Structural Steel, we recommend the following LEED verbiage to be inserted into the Project Manual:

- Materials and Resources Credit 4 (MRc4): Recycled Content
    - Use structural steel composed of 60% recycled content (or more). Please provide the following information for LEED submittal: (1) % postconsumer content (by weight), (2) % preconsumer content (by weight), and (3) total material cost.
- Materials and Resources Credit 5 (MRc5): Regional Materials
    - Use only structural steel that has been extracted from the earth from a site no further than 500 miles from the 1481 Post Street building site. Any manufacturing or processing must also have been within a 500-mile radius from the building site.
    - Please provide the following information for LEED submittal: (1) name of manufacturer, (2) address of manufacturer, (3) cutsheets that document the extraction location, and (4) total material cost.
- List of Local Vendors
    - Armstrong Steel Corporation
        - 268 Bush Street, San Francisco
        - 1(800) 480-3045
        - http://www.armstrongsteelbuildings.com/
    - Detail Ironworks
        - 1415 Donner Avenue, San Francisco
        - (415) 822-8896
    - Gilmore Steel Inc
        - 1021 45th Avenue, Oakland
        - (510) 261-5900
        - www.gilmoresteel.com
    - MJB Steel Products Co
        - 2245 McKinnon Avenue, San Francisco, CA
        - (415) 282-8710
    - Owa Steel , Inc.
        - 1483 Donner Avenue, San Francisco

        - (415) 822-7128
    - Tom's Metal Specialists
        - 1416 Wallace Avenue, San Francisco
        - www.tomsmetal.com/home-page
        - (415) 822-7971

Insulation

For all CSI sections under Division 07 and/or any other sections pertaining to Insulation, we recommend the following LEED verbiage to be inserted into the Project Manual:

- Note: We recommend that the developer invest only in the minimum amount of insulation for the exterior walls required by code, which in San Francisco is R-19. Anything beyond this would not be cost-effective.
- Materials and Resources Credit 4 (MRc4): Recycled Content
    - Please provide the following information for LEED submittal: (1) % postconsumer content (by weight), (2) % preconsumer content (by weight), and (3) total material cost.
    - We recommend the following percentages for recycled content.
        - Cellulose Insulation: 95% postconsumer
- Materials and Resources Credit 5 (MRc5): Regional Materials
    - Use only insulation products for which the vast majority of the product has been extracted from the earth from a site no further than 500 miles from the 1481 Post Street building site. Any manufacturing or processing must also have been within a 500-mile radius from the building site.
    - Provide the following information for LEED submittal: (1) name of manufacturer, (2) address of manufacturer, (3) cutsheets that document the extraction location, (4) total material cost, and (5) cutsheets that document the percentage regionally extracted (by weight).
- Energy and Atmosphere Credit 1 (EAc1): Optimize Energy Performance
    - Due to the size of the building, a whole building energy simulation is required under EA Prerequisite 2.
    - To earn EAc1 for this project, the whole building simulation must exceed a minimum of 12% above the ASHRAE baseline Standard 90.1-2007 (for 1 LEED point). A range of compliant path options is available extending up to 48% or higher (for up to 19 LEED points).
- Energy and Atmosphere Credit 3 (EAc3): Enhanced Commissioning
    - Due to the size of the building, a whole building energy simulation is required under EA Prerequisite 2.
    - The commissioning agent (CxA) must be independent of the design and construction and must be brought on prior to the start of the construction documents phase.
- List of Local Vendors
    - CWInsulation.com
        - PO Box 22422, San Francisco
    - West Coast Insulation and Fireplaces

        - 121 Beech Street, Redwood City
- Beyond LEED
    - Flame Retardants – Use insulation deemed safer for human health (if available). For example, use insulation that does not contain phthalates and halogenated flame retardants, including, but not limited to, the following:
        - Hexabromocyclododecane (HBCD)
        - Penta, octa, and decabromodiphenyl ethers
        - Tetrabromobisphenol-A (TBBPA)
        - Tris(2-chloroisopropyl) phosphate (TCPP)
        - Tris(2-chloroethyl)phosphate (TCEP)
        - Dechlorane Plus
    - Insulation, gypsum board, wall coverings, and acoustical ceiling systems must meet the testing and product requirements of the California Department of Health Services *Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers, including 2004 Addenda*.
        - Note: This requirement goes beyond LEED NC to the even stricter air quality requirements of LEED for Schools. (Refer to the IEQc4.6 section of the *LEED Reference Guide for Green Building Design and Construction, 2009 Edition* for more details.
    - Use of materials safer for human health can be marketed to potential condo buyers to increase selling rates.

Windows (Fenestration)

For all CSI sections under Division 08 and/or any other sections pertaining to Windows (Fenestration), we recommend the following LEED verbiage to be inserted into the Project Manual:

- Note: We recommend that the developer focus on obtaining windows with a low SHGC. Windows on the northern face do not require as low of a SHGC as windows on the other building faces. For example, a SHGC of 0.27 would suffice for north-facing windows, while a lower SHGC in the range of 0.24 down to 0.23 or lower is recommended for the southern, western, and eastern faces.
- Materials and Resources Credit 4 (MRc4): Recycled Content
    - Please provide the following information for LEED submittal: (1) % postconsumer content (by weight), (2) % preconsumer content (by weight), and (3) total material cost.
    - If possible, use 10% to 20% recycled content (even higher concentrations strongly recommended).
- Materials and Resources Credit 5 (MRc5): Regional Materials
    - Use only window products for which the majority of the building materials (especially glass) have been extracted from the earth from a site no further than 500 miles from the 1481 Post Street building site. Any manufacturing or processing must also have been within a 500-mile radius from the building site.

    - Provide the following information for LEED submittal: (1) name of manufacturer, (2) address of manufacturer, (3) cutsheets that document the extraction location, (4) total material cost, and (5) cutsheets that document the percentage regionally extracted (by weight).
- Energy and Atmosphere Credit 1 (EAc1): Optimize Energy Performance
    - Due to the size of the building, a whole building energy simulation is required under EA Prerequisite 2.
    - To earn EAc1 for this project, the whole building simulation must exceed a minimum of 12% above the ASHRAE baseline Standard 90.1-2007 (for 1 LEED point). A range of compliant path options are available extending up to 48% or higher (for up to 19 LEED points).
    - Also, the project requires modeling fenestration location and its properties: (1) U-value, (2) solar heat gain coefficient, and (3) transmittance as shown on proposed architectural designs. Note: Refer to Table 5.5-3 of ASHRAE 90.1-2007 for determining the maximum U-factors for the baseline building.
- Energy and Atmosphere Credit 3 (EAc3): Enhanced Commissioning
    - Due to the size of the building, a whole building energy simulation is required under EA Prerequisite 2.
    - The commissioning agent (CxA) must be independent of the design and construction and must be brought on prior to the start of the construction documents phase.
- Indoor Environmental Quality Credit 6/6.2 (IEQc6/6.2): Controllability of Systems--Thermal Comfort.
    - Recommended minimum of 1 *Operable Window* per exterior room (larger rooms such as Bedrooms and Living Rooms).
- Indoor Environmental Quality Credit 2 (IEQc2): Increased Ventilation
    - Potential for this credit given the energy modeling under EA Prerequisite 2 and incorporation of a minimum of 1 Operable Window per exterior room (larger rooms such as Bedrooms and Living Rooms).
- Indoor Environmental Quality Credit 8.1 (IEQc8.1): Daylight and Views—Daylight
    - Potential for this credit given the large percentage of window area. (Refer to the IEQc8.1 section of the *LEED Reference Guide for Green Building Design and Construction, 2009 Edition* and LEED-Online to facilitate calculations.)
- Indoor Environmental Quality Credit 8.2 (IEQ 8.2): Daylight and Views—Views
    - Potential for this credit given the large percentage of window area. (Refer to the IEQc8.2 section of the *LEED Reference Guide for Green Building Design and Construction, 2009 Edition* and LEED-Online to facilitate calculations.)

Plumbing & Water Fixtures

For all CSI sections under Division 22-41-00 and/or any other sections pertaining to Plumbing and Water Fixtures, we recommend the following verbiage to be inserted into the Project Manual:

- WaterSense certified toilets, showerheads, and bathroom and kitchen faucets shall be used in all building units and building common areas.

    - Dual-flush toilets with an average of 1.3 gal/flush (gpf) or lower shall be used in all building units and building common areas.
    - For the common areas, lavatory faucets shall have a flow rate of no higher than 0.5 gal/min (gpm).
    - For living spaces, flow rates shall be no higher than 1.5 gpm for lavatory faucets, 2.0 gpm for kitchen faucets, and 2.0 gpm for showerheads.
- Water Efficiency Prereq 1 (WEp1): Water Use Reduction
    - Please provide the following information for LEED submittal: (1) projected number of occupants, and (2) manufacturers' data showing water consumption rates, manufacturer, and model of each fixture and fitting.
    - Note: The "Analysis I: Water" section of this report may be submitted to satisfy the first requirement.
- Water Efficiency Credit 3 (WEc3): Water Use Reduction
    - Please provide the following information for LEED submittal: (1) projected number of occupants, and (2) manufacturers' data showing water consumption rates, manufacturer, and model of each fixture and fitting.
        - Note: The "Analysis I: Water" section of this report may be submitted to satisfy the first requirement.
    - Potential for Credit 3.2: 40 % Reduction via combination of WaterSense fixtures (20% reduction) plus monitoring systems (additional 20% reduction).

Water-Efficient Landscaping

For all CSI sections under Division 32 pertaining to Water-Efficient Landscaping (including 32-12-43 Porous Flexible Paving; 32-14-44 Porous Unit Paving, Precast Concrete; 32-14-45 Porous Unit Paving, Plastic; 32-80-00 Irrigation; and 32-93-03 Native Plants and Seeds), we recommend the following verbiage be inserted into the Project Manual:

- Xeriscaping shall be used to reduce the need for irrigation. Common xeriscape strategies include planting native and adaptive plants that require less water, pesticides and fertilizer.
- Drip irrigation shall be used for all cases where irrigation is necessary (for example, in planting beds).
- Reclaimed water (including captured rainwater, graywater, or municipally supplied reclaimed water) shall be utilized when possible as a source of irrigation.
- Minimize the percentage of hardscape area on the site boundary. In cases where hardscape is necessary, consider use of porous paving.
- Recommendation that roof coverings shall be green (vegetated) where possible. A vegetated roof will slow down the runoff rate as the plants absorb the water and reduce the burden on the municipal stormwater system.

  Potential LEED Credits:
- Water Efficiency Credit 1 (WEc1): Water Efficient Landscaping
- Sustainable Sites Credit 5.2 (SSc5.2): Maximize Open Space
- Sustainable Sites Credit 6.1 (SSc6.1): Stormwater Design – Quantity Control
- Sustainable Sites Credit 6.2 (SSc6.2): Stormwater Design – Quality Control
- Sustainable Sites Credit 7.1 (SSc7.1): Heat Island Effect, Non-Roof

- Sustainable Sites Credit 7.2 (SSc7.2): Heat Island Effect, Roof

Monitoring Systems

For all CSI sections under Divisions 27 Communication, 26 Electrical, and 33 Utilities pertaining to Monitoring Systems (including 27-42-19 Public Information Systems; 26-09-00 Instrumentation and Control for Electrical Systems; 26-27-13 Electricity Metering; 33-12-33 Water Utility Metering; and 33-51-33 Natural-Gas Metering), we recommend the following verbiage to be inserted into the Project Manual:

- The Monitoring System selected for the project should include the following minimum requirements:
    - Separately monitor a minimum of 5 different loads including HVAC, lighting, dishwasher, misc. plugs & major appliances, and water.
    - Display a minimum of the above information in real-time via a wall-mounted dashboard.
    - Controllability of a minimum of 3 load types including HVAC, lighting, and dishwasher.
    - BACnet compliant components for interoperability and compatibility with future technologies.
    - Ability to interface with the Smart Grid and obtain time-variant pricing data and schedules.
    - Interface with the central building automation system (BAS).
        - This will enable the HOA to subdivide a master PG&E bill to individual tenants that accurately reflects individual unit use.
        - This will also facilitate building performance tracking and information sharing between the HOA and the ADCO Group.
            - This will in turn facilitate EAc5.
        - Innovation in Design Credit (ID)

Indoor Environmental Quality

For all CSI sections pertaining to interior building materials (with the exception of electrical and plumbing systems), we recommend the following LEED verbiage to be inserted into the Project Manual. Note: interior building materials refer to any materials inside of the weatherproofing system.

- Indoor Environmental Quality Credits 4.1 & 4.2 (IEQc4.1 & IEQc4.2)
    - Please provide the following information for LEED submittal: (1) Material Safety and Data Sheet (MSDS) for each material (especially all materials involving paints, sealants, adhesives, and coatings) and (2) ensure that the product VOCs do not exceed the requirements listed below:
        - South Coast Air Quality Management District (SCAQMD) Rule # 1113 (effective January 1, 2004)
            - Note: This is the most straightforward standard to follow. (Refer to Table 1 in the IEQc4.2 section of the *LEED Reference Guide for Green Building Design and Construction, 2009 Edition* to facilitate meeting this standard.)

        - South Coast Air Quality Management District (SCAQMD) Rule # 1168 (effective July 1, 2005).
        - Green Seal Standard for Commercial Adhesives GS-36 (effective October 19, 2000).
        - Green Seal Standard GS-11, Paints, 1st Edition (effective May 20, 1993).
        - Green Seal Standard GC-03, Anti-Corrosive Paints, 2nd Edition (effective January 7, 1997).
    - Note: Refer to the IEQc4.1 and IEQc4.2 sections of the *LEED Reference Guide for Green Building Design and Construction, 2009 Edition* to facilitate meeting the standards listed above.
- Beyond LEED
    - Flame Retardants – When required to use products containing flame retardants, use products deemed safer deemed safer for human health (if available). For example, use products that do not contain phthalates and halogenated flame retardants, including, but not limited to, the following:
        - Hexabromocyclododecane (HBCD)
        - Penta, octa, and decabromodiphenyl ethers
        - Tetrabromobisphenol-A (TBBPA)
        - Tris(2-chloroisopropyl) phosphate (TCPP)
        - Tris(2-chloroethyl)phosphate (TCEP)
        - Dechlorane Plus
    - Use of materials safer for human health can be marketed to potential condo buyers to increase selling rates.

Regional Priority (RP) Credits

- RP credits are based on project location to focus on local environmental issues. For a given project location, there are 6 different RP credits to choose from. A maximum of 4 of the 6 credits may be used to be towards the additional RP credits. For each credit submitted under RP, the project will receive LEED points for both the standard LEED credit itself as well as 1 additional point for every RP credit. Also, the project is eligible for one bonus LEED point if the project achieves 4 of the 6 Regional Priority Credits.
- Sustainable Sites Credit 5.2 (SSc5.2)
    - Reduce the development footprint and/or provide vegetated open space within the project boundary such that the amount of open space zoning exceeds local zoning requirements by 25%. According to the San Francisco, California Building Code Sec 135, RC-3 units must attain 60 sq ft of usable open space for each dwelling unit or about 13,860 sq ft. Exceeding this by 25% will require an open space of at least 17,325 sq ft.
- Water Efficiency Credits 2 & 3 (WEc2 & WEc3)
    - Reduce potable water use for building sewer conveyance by 50% through the use of water-conserving fixtures or non-potable water.
- Energy & Atmosphere Credit 2 (EAc2)
    - Use on-site renewable energy systems to offset building energy costs such as passive solar heating for the 1st floor pool.

- To be eligible for this credit, ADCO may only require meeting the minimum 1% on-site renewable energy requirement for two (2) and points and seven (7) if it achieves 13%.

- Indoor Environmental Quality Credit 8.1 (IEQc8.1)
  - Provide building occupants with a connection between indoor spaces and the outdoors though the introduction of daylight and views into the regularly occupied bedrooms and commons areas. We believe that with an all glass façade, this should be easily achievable to attain the 75% required for the total building.
- Beyond LEED
  - We recommend submitting for RP credit those RP options for the site that are more difficult to achieve thus incentivizing to incorporate all 6 RP credits to maximize regional considerations specific to San Francisco.

Homeowner's Association

For any CSI Divisions pertaining to long-term tenant operations and maintenance, we recommend the following verbiage to be inserted into the Project Manual:

- Energy and Atmosphere Credit 5 (EAc5): Measurement and Verification
  - Develop and implement a measurement and verification plan consistent with Option D: Calibrated Simulation (Savings Estimation Method 2) as specified in the *International Performance Measurement and Verification Protocol (IPMPV) Volume III: Concept and Options for Determining Energy Savings in New Construction, April 2003*.
  - The M&V period must cover at least 5 years of post-construction occupancy.