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

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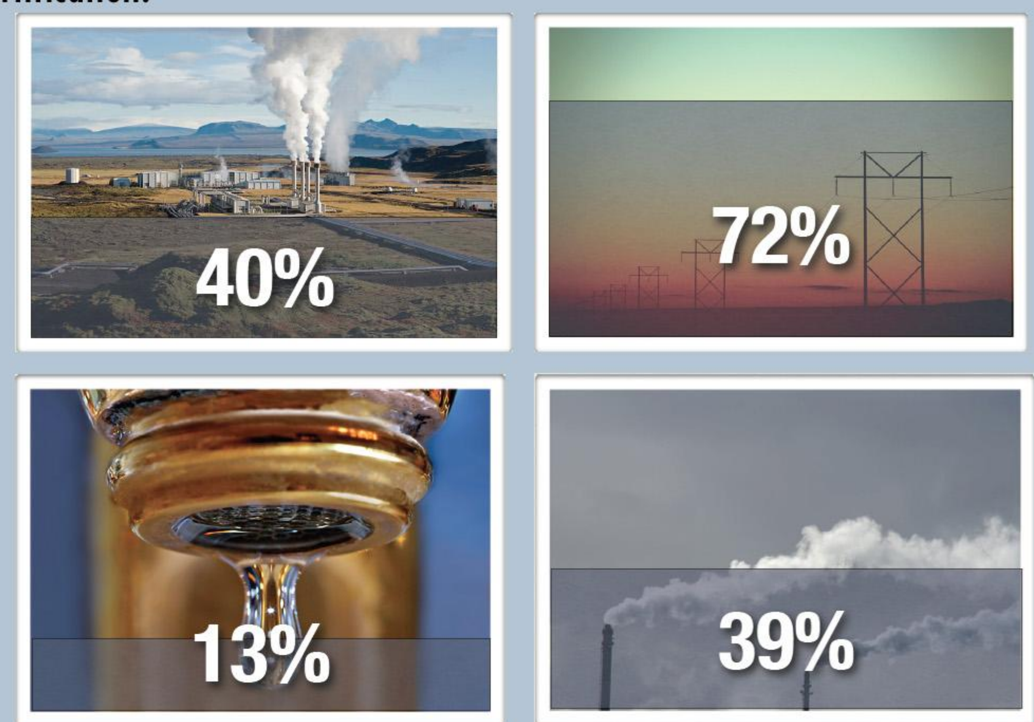
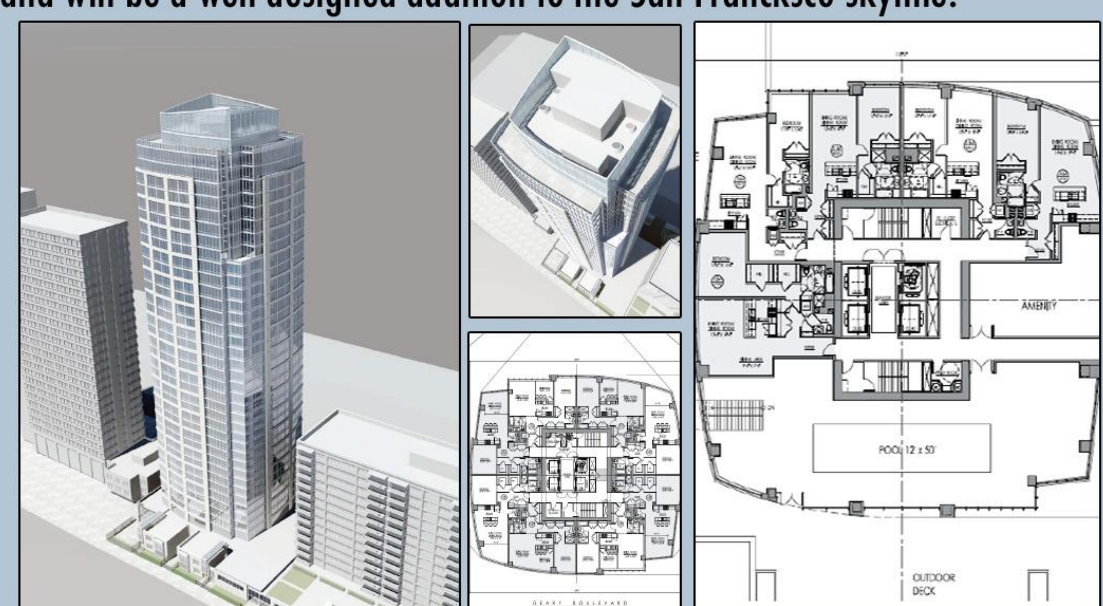
The Project

Buildings in the United States account for 40% of our primary energy use, 72% of electricity use, 13% of potable water consumption, and 39% of carbon dioxide emissions. 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. The 36 story high structure will house 231 units and will be a well designed addition to the San Francksco skyline.



Project Goals

The goals of our project were 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:

1) We needed to provide recommendations that fit within the financial feasibility of the client's budget.

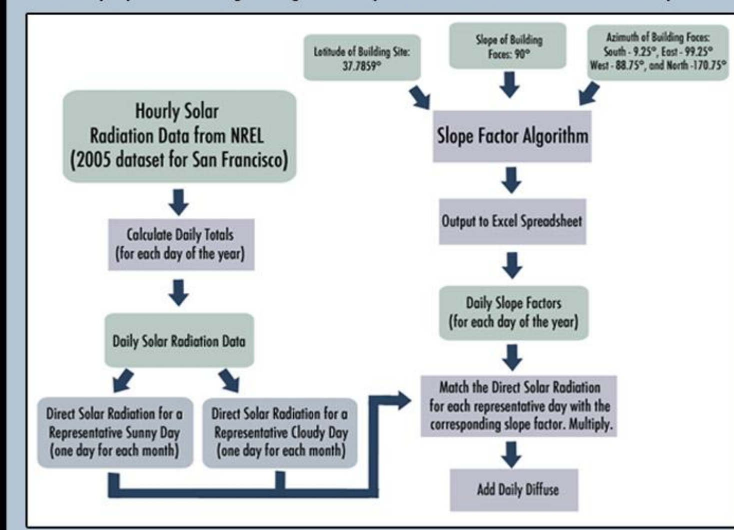
2) Ensure that our recommendations would sustain the transfer of ownership from ADCO to individual condo owners, as ADCO will no longer have a stake in the building after all of the units are sold.

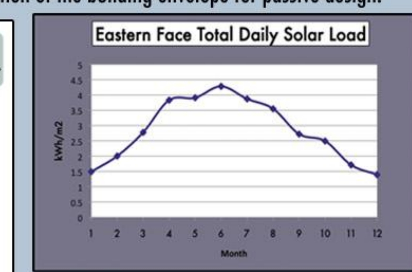
3) Assure the long-term performance of our recommendations.

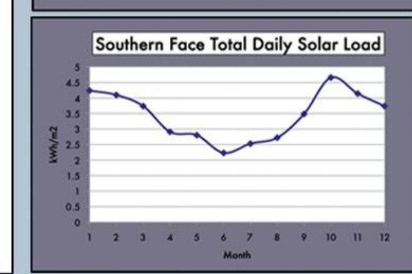
Energy Modeling

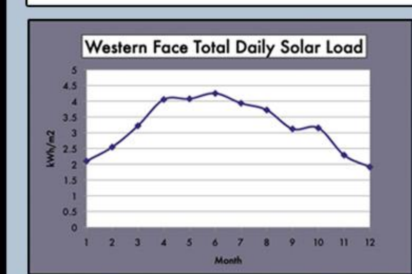
Energy modeling is the process of simulating how energy will flow through a building, whether that process is via electrical energy or the transfer of heat energy. We calculated energy flows as follows:

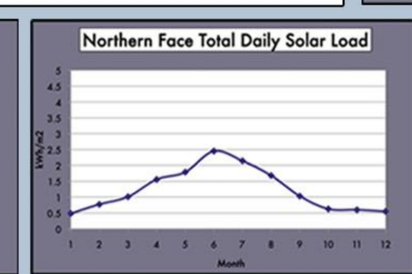
1) Using hourly solar radiation for the site and a slope factor algorithm, we modeled the quantity of solar energy that would strike each face of the proposed building throughout the year. This critical calculation allows optimization of the building envelope for passive design.











$$SF = \frac{\text{daily integrated direct solar radiation on a slope}}{\text{daily integrated direct solar radiation on level ground}}$$

2) To model the more complex interactions that occur once the solar energy reaches the interior of the building, we used the eQUEST software package to predict the energy consumption of the building in response to changes in the envelope design.

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 loads in San Francisco's mild climate. For windows, our models show that low solar heat gain is the most important factor in reducing annual energy consumption for the proposed building.

Energy Monitoring

Building monitoring and automation systems (BMAS) are important features of modern high-rise buildings. These systems monitor and control the central energy loads, such as common area lighting, elevators, and heating and cooling systems. However, traditional BMAS do not address the energy efficiency opportunities in individual units. 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 advanced building monitoring and automation systems (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.

From this estimation of total upfront cost and estimated annual energy costs, we identified the 10-year energy savings that would justify this initial investment. Our analysis shows the energy savings required are easily achievable for several of the BMAS scenarios.

In 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. Our research shows that Scenario 3 (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 may be easily achievable given the advanced capabilities.

Recommendations

1) 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

2) Invest in an Advanced Building Monitoring System that contains 5 submeters (including energy and water), 3 controllers, and a visual dashboard for each individual unit. This will assist condo owners with behvarior modification and post-occupancy comissioning of the building

2) Install WaterSense certified toilets, showerheads, and bathroom and kitchen faucets, in all building units and building common areas (including the lobby and fitness center)

3) Install Energy Star rated clothes washers and dishwashers standard in all building units and building common areas

4) Use xeriscaping, efficient irrigation technologies, and vegetated surfaces (roof and non-roof) to minimize outdoor water consumption and mitigate stormwater runoff

5) Use San Francisco building code R-19 Insulation for the building's exterior wall, as anything above this is cost-ineffective

6) Install double-paned low-e exterior building windows that contain a low Solar Heat Gain Coefficient (SHGC), between 0.23 and 0.25 (contingent on building side)

Water

To reduce the water load in the building, we 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 indoor water usage for a minimal upfront investment.

To determine future water use and savings, we factored an average annual increase in water rate of 11% and a 10-year projection into building operations. We modeled four possible scenarios:

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 dashboards, and Scenario 4 would yield greater reduction from having dashboard feedback.

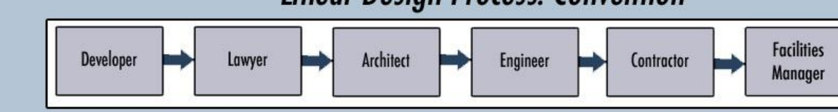
The 10-year values of investment are both positive and approximately equal for Scenarios 1 and 2; however, the addition of Energy Star appliances in Scenario 2 adds a degree of energy efficiency that justifies the added costs.

We found that all three models yielded positive values of investment, indicating that the installation of a monitoring system would be a worthwhile investment.

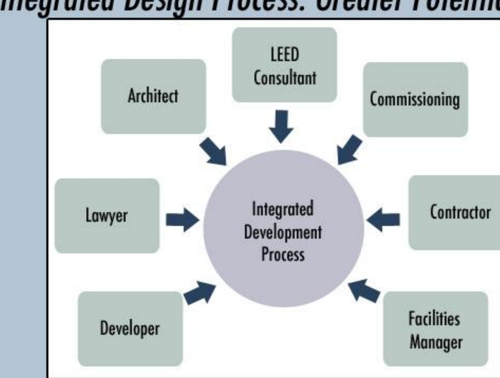
Integrated Building Design

In researching case studies of existing green buildings and speaking with industry professionals, we found strong consensus of the importance of Integrated Building Design (IBD) in lieu of the conventional linear design process. 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.

Linear Design Process: Convention



Integrated Design Process: Greater Potential Savings



IBD advocates front-loaded design meetings, known as charettes, between the developer, architect, engineer, and contractor. 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.

Conclusion

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 learning tool for both our client and for other developers seeking to reduce the long-term environmental footprint of future building projects.

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