Targeting 100! A Roadmap for Meeting the 2030 Challenge in Healthcare across the United States

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ABSTRACT

Healthcare buildings account for less than 1% of all commercial buildings and 2% of all commercial floor space, yet they account for over 5% of commercial building energy consumption. While healthcare represents a monumental opportunity for reducing overall commercial energy consumption, changing the norm for how these facilities are designed is a challenge. Targeting 100! was developed to encourage the incorporation of energy efficiency into healthcare industry building design by providing evidence for the successful implementation of deep energy reduction strategies. It extends previous research based in the Pacific Northwest to a national scale, addressing the nation's six largest cities and most diverse climate zones. The Targeting 100! energy goal for acute care hospitals (based on the 2030 Challenge) is an EUI of 100 KBtu/SF Year, with little to no additional up-front cost for construction. Strategies for achieving this goal rely on architectural, building mechanical and plant systems integration. Based on today's codes and standards for energy and health, Targeting 100! provides a roadmap that can be immediately implemented in hospitals that are being designed today. This paper documents systems strategies, parametric energy modeling, and cost modeling that show it is possible to achieve a 60% or greater energy reduction for acute care hospitals with little additional capital investment in the largest and most diverse cities across the U.S.

Hospital Energy Use

Healthcare infrastructure represents a monumental opportunity for energy reduction nationwide. The building sector consumes approximately 50% of the total energy used in the U.S. (Architecture 2030 2011). Healthcare buildings account for less than one percent of all commercial buildings, and two percent of all commercial floor space, yet account for 5.5% of commercial building energy consumption (EIA 2012). This figure has increased since 2003, when healthcare consumed 4.3% of the total delivered energy within the building sector (EIA 2003).

The U.S. spends approximately $40 million monthly on healthcare construction (US Fed Res MO 2014). Most of this construction is being designed at code minimum energy standards. At a time where healthcare reimbursements are decreasing for many healthcare organizations, reducing spending on energy can be an effective way to bolster bottom lines. Reducing energy use also has a direct impact on carbon emissions, and thus an impact on environmental health. As institutions whose missions are to "first do no harm," reducing the environmental and health burden of energy consumption should be a fundamental priority for healthcare organizations. The cycle of planning, design, and constructing new hospitals can take seven to ten years from pro-forma to operational completion. To make an impact as soon as possible, it is very important to develop strategies for radically reducing energy use today, which will impact implementation now and into the future.

Energy Goal Setting

With a greater focus on the environmental and cost impacts of our infrastructure, energy use and thereby carbon emissions are at the core of many efforts to make buildings more sustainable. Many sustainability programs target energy performance in building infrastructure, such as the United States Green Building Council's Leadership in Energy and Environmental Design (USGBC, LEED), the International Living Future Institute's Living Building Challenge, and Architecture 2030's 2030 Challenge. These are also systems that have been adopted by state and federal governments, the United States Congress of Mayors, the American Institute of Architects, and many owners and project teams.

In order to reduce energy use it is imperative to first establish reasonable and testable goals for energy reduction. To set these goals for healthcare facilities, it is helpful to understand how much energy is used by existing hospitals. Annualized energy use for buildings is often reported as an Energy Use Index or EUI. The EUI for a building is the total amount of energy used (most commonly electricity and natural gas) per unit of floor area, measured on an annual basis. Building EUIs are often reported in units of KBtu/Square Foot Year. This is a way of comparing different buildings to each other, much like comparing different cars to each other using a miles per gallon rating. For EUI, a low score means that less energy is being used and a high score means that more energy is being used.

The 2030 Challenge is a progressive goal where in 2010-2015 the goal is a 60% energy reduction, and in subsequent years the goal becomes incrementally more aggressive ultimately aiming for carbon neutrality by the year 2030. The goal is based in fossil fuel reduction, however since many municipalities generate electricity via carbon emitting sources, electricity use is also factored in to the energy use reduction goals. Compliance with the 2030 Challenge is measured by comparing a building's modeled energy performance to the energy use of a median performing building of the same type and climate zone as recorded in a national building database. Target Finder is a web interface used to identify energy information from the database, normalizing for building typology, climate, size, use, etc. (Target Finder 2014). For many building types Target Finder accesses the CBECS dataset. For hospitals, the dataset used today is based on a 2010 survey of approximately 300 hospitals nationally. Through Target Finder, the median building of similar type and size as well as climate region can be determined.

The United States Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS) is a separate national database of building operational energy use that provides a reference to how much energy buildings consume by climate zone and by building use type. The average energy use index (EUI) for hospitals surveyed by CBECS in the United States is 249 KBtu/SF Year (EIA 2003).

Targeting 100!

On average, hospitals in the U.S. use about 250 KBtu/SF Year. The 2030 Challenge goal for 2010-2015 is a 60% reduction from operational baseline - A 60% energy reduction from that average indicates a site energy use index (EUI) of less than 100 KBtu/SF Year – this is the number from which Targeting 100! derives its name. While regional variations in this average are seen in the Target Finder data set, an EUI of 100 KBtu/SF Year was used as the common goal for all of the study cities. Climate is not a large factor in the baseline energy use in hospitals; typical hospitals built today are largely internally load dominated, so climate has little effect on their overall annual energy use profiles.

Targets of Opportunity for Energy Reduction

There are several reasons why hospitals are such large energy consumers -- they are densely occupied, operate 24 hours per day, seven days a week, and house a lot of energy-consuming equipment. This research, however, has uncovered some of the less obvious reasons why hospitals are large energy consumers. One of the biggest uses of energy within hospitals is re-heat. Internal requirements typically dictate that air be very cool in some areas of the hospital, especially in areas such as surgery suites. In typical hospital heating, ventilation and air conditioning (HVAC) systems, incoming air is delivered by a multi-zone overhead ducted system. The space needing the coolest air (such as surgery) determines the temperature of the air traveling through an entire zone. All spaces needing warmer air (for example, offices, exam rooms, and patient rooms) require the air to be re-heated at the delivery point. Because of this design, a hospital's fresh air is first cooled on intake and then delivered to interior spaces, and is ultimately reheated to the correct temperature for each space. Both changes in temperature (cooling and heating) commonly require energy. An appropriate analogy is driving with the accelerator engaged and using the brake to adjust the speed. This phenomenon drives hospital energy use making hospitals internally load dominated rather then driven predominantly by envelope conditions.

Benchmarking Energy Use of an Operational Hospital

As part of the effort to correctly characterize how hospitals actually use energy, this team worked closely with Legacy Salmon Creek Medical Center (LSCMC), a state-of-the-art operational healthcare facility located in Vancouver, WA. Designed by Zimmer Gunsul Frasca Partnership and Affiliated Engineers, Inc., it exemplifies sound engineering and architectural design, and performs better than the average hospital in the United States today. As a relatively new facility, it provided a good foundation for the team to determine how a hospital uses electricity and natural gas for its complex operations. The detailed data collection and analysis from this study hospital confirmed some of our understandings of how hospitals use energy, and provided data to show that some of our previous assumptions needed either modification or correction. These data provide detailed information for energy modeling simulations including calibrated diversity and load profiles.

This detailed monitoring study helped confirm that re-heat is the largest end-use of energy in the hospital, consuming over 40% of the hospital's energy. The study also provided data on the energy use patterns of many building systems. Heating energy for service hot water was less than 2% of the total, and was mostly related to cooking activities with peaks three times during a typical day. As hospital patients' conditions become more acute, fewer showers are taken at the hospital, representing less energy consumed for this end use. Similarly, patient room lighting was observed to use much less energy than expected compared to their connected load, whereas general lighting followed a more expected schedule of operations.

Imaging equipment, notably MRI machines, were long thought to be large energy users. But study results indicate all imaging equipment accounts for less than 1 percent of energy use. Elevators represent a similar load, utilizing less than 1% of the total energy in the hospital. This information helped the study team to focus on larger energy users, rather than devoting time and effort to areas that would result in very small relative gains. It also enabled the development of more predictive energy models for Targeting 100! that match actual acute care hospital patterns of use.

Study Design

For this analysis hospital prototype models were developed to a schematic level of design and analyzed with energy and cost models. Integrated architectural, building mechanical and plant systems were evaluated through bundled load reduction and energy performance solutions using six representative cities for climate and cost information. Two Architectural Schemes were developed, one that exemplifies a "typical" hospital (Scheme A) and the other with a more articulated form, allowing for greater opportunities for connections outside (Scheme B). Both are 225-bed, 477,000 SF hospital prototypes that are equal in square footage, program, and approximate footprint.

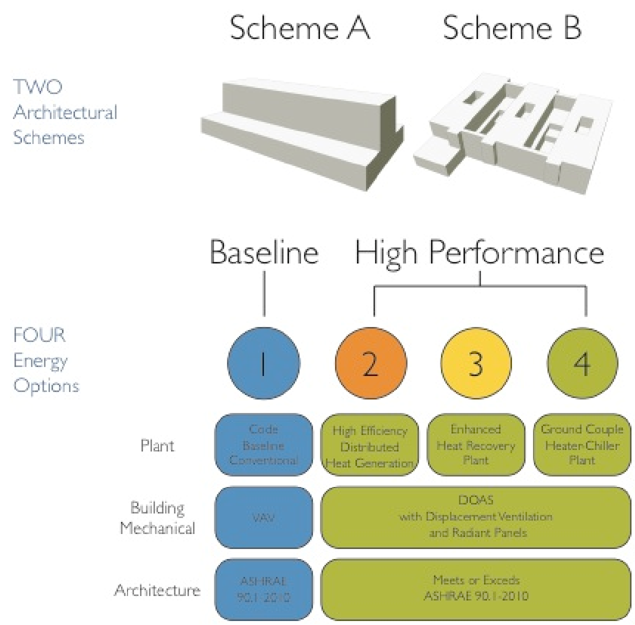

Figure 1. Study design. Two architectural schemes and four energy options were evaluated with energy and cost modeling. *Source*: University of Washington Integrated Design Lab 2013.

For each Architectural Scheme, four Energy Options were developed. The baseline Energy Option uses the American Society of Heating, Refrigeration, and Air-Conditioning Engineer's (ASHRAE) standard 90.1 2010, a United States-based energy standard, as its "common practice" assumption. Three high performance options were compared to this baseline option. The three high performance options were conceived of as bundles of efficiency strategies that also fully comply with energy and health related codes in the United States. These three high performance options only vary at the central plant level, where one has a full ground source heat pump, one has a heat recovery chiller in lieu of the ground source heat pump system, and the third uses a high performance distributed heating system.

The emphasis was on integrated—or bundled—strategies that work in concert with each other to achieve a drastically reduced energy profile. The team took a similar approach with the cost models, where an integrated approach meant that cost deductions were taken in some areas, which helped to offset the cost additions in other areas.

Six of the most highly populated and climatically diverse ASHRAE climate regions of the U.S. were chosen for this study. The most populous cities within those regions serve as the basis for weather and construction cost data: Chicago (Climate Zone 5A), New York (4A), Seattle (4C), Los Angeles (3C), Houston (2A), and Phoenix (2B). Four energy models were developed for each city using EQuest DOE2 energy modeling software. Similarly, detailed cost models were developed for each energy option in each of the six study cities.

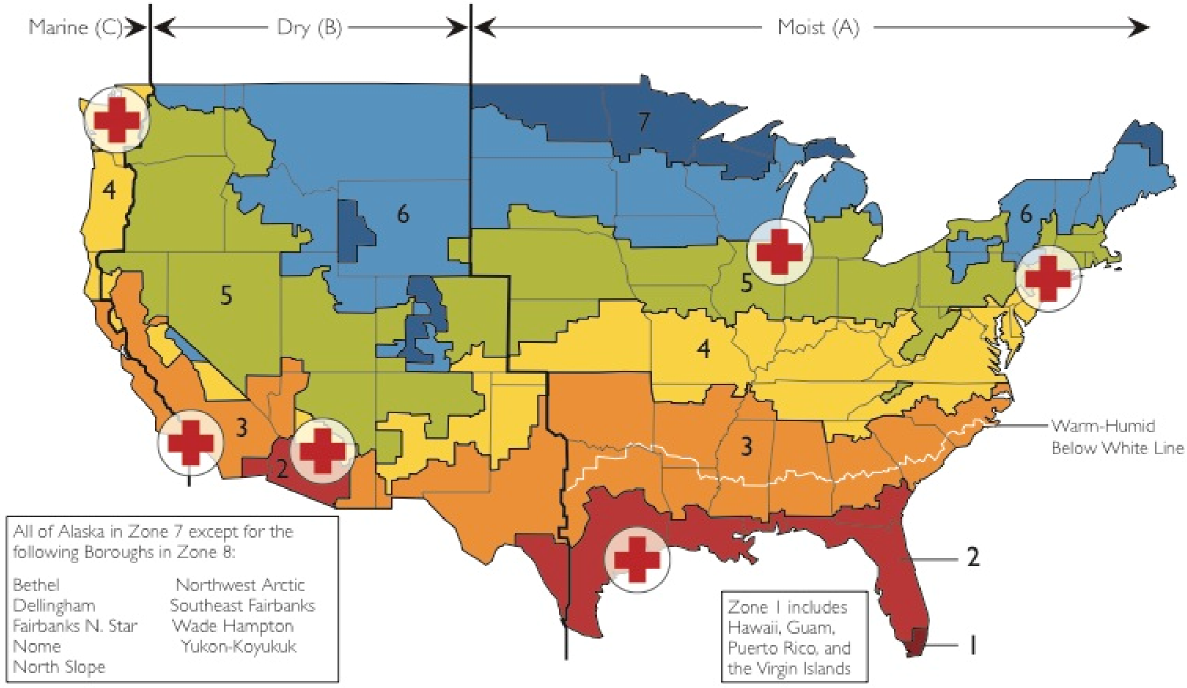

Figure 2. Six cities were evaluated that represent the largest cities in the most diverse climate regions in the U.S. *Source*: University of Washington Integrated Design Lab 2013.

Load Reduction and Chosen Strategies

Aggressively reducing external climate-dependent loads and internal loads is the first step of an integrated approach to significantly decreasing annual energy use, first cost of construction, and ultimately annual energy costs. A simultaneous focus on both peak loads and whole building annual energy loads is important for solving the energy and cost equation. Smaller peak loads mean smaller plant equipment, which translates to lower capital cost investments; lower overall load profiles allow for flexibility in ventilation system choice and mean significantly reduced annual energy use profiles for heating and cooling which translate to annualized energy savings.

Highly coordinated architectural and building mechanical systems strategies achieve large load reductions. For example, dynamic exterior shading on the envelope significantly reduces solar heat gain, enabling a decoupled approach to the building heating, cooling, and ventilation systems. Decoupling heating and cooling from ventilation of rooms enables much lower whole building load profiles and significantly reduced peak loads. Shifting from all-air systems to a hybrid of air and water-based systems also provides the opportunity for more flexibility in the allocation of systems in the plenum spaces, or enables the project to reduce the overall floor-to-floor height.

This also brings synergistic benefits where the height of the building and the coordination of the mechanical space translate to additional cost. Lower and more balanced loads enable smaller and more efficient plant equipment such as a ground-source heat pump plant that is reasonably sized and has an annual balance between heating and cooling profiles. All of the systems in this example, from architectural exterior dynamic shades to building mechanical de-coupling to highly efficient plant systems, are intertwined; each relies on the other to provide an effective and energy efficient integrated system.

More details on specific architectural, building mechanical, and central plant strategies can be found by accessing the Targeting 100! tool, located at www.idlseattle.com/t100.

Integrated Design and Integrated Systems

The integrated nature of both the project team structure and the technical solutions required are keys to successfully meeting Targeting 100! goals at a hospital. While the technology and innovations are available now under current codes, they are not common practice in the U.S. healthcare market. Many of the solutions work in synchrony, where energy savings can aid in first cost of construction savings. While conceived here as bundles of architectural, building mechanical, and plant systems, an integrated approach to design means that all professionals from design to operation must provide insight and expertise in all of these categories from the beginning of project development. Having a project team structure and culture that enables cooperative decision making with key stakeholders is essential for driving deep energy savings along with low first costs.

The schematic mechanical designs, energy models and cost estimates in this study are for a snapshot of strategies that accomplish the goal of achieving the 2030 Challenge. These strategies are a conceptual framework for this work, and can be seen as one solution for achieving this goal. However, there are a range of strategies that would be suitable for achieving the goal of reaching the 2030 Challenge. Strategies were identified through previous research efforts of this group and through the team's expertise. Instead of parametrically analyzing each of the energy strategies individually or comparing groups of strategies side by side, three high-performance code compliant paths were modeled as integrated packages and compared to a Code Baseline model.

Design decisions for architectural systems, mechanical systems, and plant systems are intricately intertwined where they necessarily support each other; therefore, various components cannot be replaced or value engineered out of the projects without affecting the energy results overall. This is especially true in hospital buildings, where a small change in one system tends to ripple throughout the building's myriad of systems, especially in highly energy efficient designs. After several years of research we have come to realize that significant energy savings are only possible through close and continuous integrated efforts from the earliest stages of project planning, with involvement from core planning, design, construction and facility operation team members.

This integrated approach creates a re-formulated set of architectural, mechanical and plant systems that are developed from a holistic performance-based project perspective. Interaction between all disciplines, including ownership, design, engineering, energy modeling, utility and construction teams is integral in producing the most energy efficient, highest quality outcome. The focus of this research effort has been to assess the whole-building performance of eight distinct hospital designs in each study city. Targeting 100! considers each of the designs to be an integrated whole, or a bundled set of strategies per hospital design option within each architectural scheme.

Energy Outcomes

Based on these integrated bundles of schematic architectural, building mechanical, and plant system designs, Targeting 100! is able to achieve a 60% reduction in energy use compared to average operational hospitals, thus meeting the 2030 Challenge goal for 2010-2015. Targeting 100! also achieves the goal of reducing energy to 100 KBtu/SF Year across all six study cities. The major energy end use reduction was in heating energy, specifically re-heat energy. This was expected, as heating energy was identified as the single largest energy load, and therefore the best target of opportunity for energy savings. The key moves to decreasing the heating load and overall energy footprint were 1) first reducing loads on the envelope through solar control; 2) de-coupling of space tempering and ventilation for most spaces using supplemental radiant sources for heating and cooling rather than fully relying on air-transport for tempering during peak conditions; 3) using displacement ventilation with 100% Outside Air to deliver required air changes in most spaces; 4) turning down air changes in highly regulated areas while un-occupied; and 5) using efficient, right sized central plant approaches with maximum heat recovery.

This de-coupled and de-centralized scheme of heating, cooling and ventilating systems acting in close coordination with solar heat gain load reductions, heat recovery from significant powered or heated energy sources, and a large ground source heat pump system (or distributed heating system, or heat recovery chiller) significantly reduces the energy demands for ventilation, space heating, cooling and water heating.

Hospitals have a reputation for being less than ideal environments for patients to heal and staff to work. Designers, researchers and health professionals have long recognized that healthy, healing interior environments are imperative for patients, but are now coming to realize that such high quality interior environments are equally important for staff who work in these critical care settings. Thus it is crucial to incorporate high interior environmental quality attributes such as abundant daylight, fresh air, views of the outdoors, and the greatest opportunities for individual personal control of light, temperature and fresh air into new hospital developments. It is also important for hospital owners and designers to understand both the energy and cost implications of these design decisions. High performance projects, such as Targeting 100!, address both energy efficiency and improved indoor environmental quality.

The Targeting 100! architectural Scheme B was developed with these both energy and indoor environmental quality in mind. The overall energy results between Scheme A and Scheme B were surprisingly similar. While maintaining a 30 percent window-to-wall ratio for both architectural schemes, the more articulated version has nearly double the actual window area due to its overall increased surface area. The major difference in energy profiles between the schemes was in electric lighting – the articulated scheme demands less energy for electric lighting due to more potential for daylighting. On a whole building basis, the more articulated scheme does not come at an energy penalty from an increased exterior surface area or overall glass area. This finding makes sense in light of internal load profile of hospitals that is mainly driven by HVAC systems, thus the envelope does not drive the overall EUI. The envelope does have a significant impact on peak loads, which were a major point of analysis and strategy development as discussed above. The configuration of Scheme B paired with the energy results show that it is possible to build a hospital with many opportunities for natural light views without paying an energy penalty. This energy result does not reflect the potential for higher interior environmental quality through greater connection to daylight, potential for views and connections to the exterior environment that the more articulated scheme enables. Although these qualities were not quantified in this study, it is recognized that attributes like these boost interior environmental quality and thereby promote health, healing, and productivity.

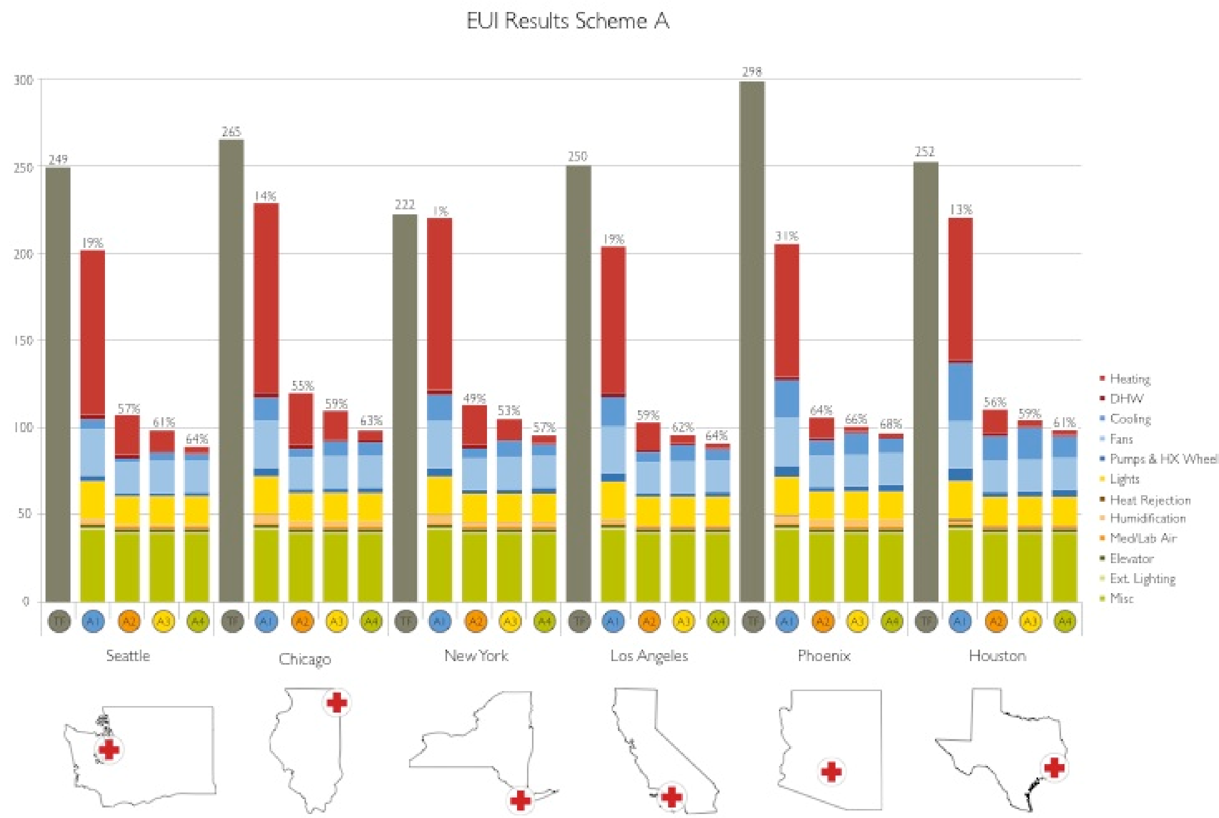

Figure 3. Energy Results for Scheme A. These results show a comparison of the annual energy use profiles in one architectural scheme compared to a Target Finder baseline. Percent reductions indicated are reductions from this baseline. Energy end-uses are indicated in the stacked colors in the bar. Two major conclusions that can be drawn here are that 1) it is possible to meet the 2030 Challenge with a 60% energy reduction in each city, and 2) the major target of opportunity, re-heat energy, was dramatically reduced in all three high performance energy options in all cities. *Source*: University of Washington Integrated Design Lab 2013.

Environmental impacts

Reducing energy consumption in hospitals has a direct relationship to reduced carbon emissions, reduced greenhouse gases, and improved air quality. Emissions associated with energy generation, especially in areas using coal as a primary source of electricity generation, are sources of reduced air quality and contribute to increased incidence of asthma and have other deleterious health consequences (WHO 2009). As institutions whose missions are founded in preserving and maintaining human health, and institutions that use over 5% of all energy consumed in the commercial sector, hospitals have a vast potential for mitigating deleterious CO_2 emissions. Numerous organizations have begun to recognize the connection between environmental health, energy efficiency, and the role that hospitals have to play within these sets of issues.

Environmentally, the level of annual energy savings for one Targeting 100! hospital (calculated as a national average) is equivalent to saving 5,000 tons of carbon from entering the atmosphere annually (EPA 2013). This would be equivalent to planting 3,400 acres of forests, taking 850 passenger cars off the road, or removing 600 households from the grid (RECS 2009; EIA 2013).

First Cost Outcomes

Throughout the six study regions, the capital cost implications of implementing the most energy efficient energy option (Option 4) were on average a three percent incremental cost premium compared to baseline when including potential utility incentive rebates. The other two high performance options (Options 2 and 3), while not yielding as much energy savings, show on average a two percent incremental cost premium compared to baseline energy assumptions. The integrated nature of Targeting 100! creates complementary savings in energy and capital construction costs; cost savings in some categories can offset incremental cost increases for energy improvements in other areas. For example, reduced cooling loads were realized by adding exterior shading systems – in this case motorized retractable louver shades—which in turn reduced the size and first-cost of the cooling system. De-coupled systems concepts also reduced loads, having a large beneficial impact on primary ventilation duct sizing, thus creating more area within the ceiling plenum to either increase flexibility in systems coordination or reduce the floor-to-floor height on patient floors by a minimum of one foot. Cost savings realized by reductions in floor height and ventilation ducting help offset the increased cost for other energy efficiency improvements, such as increased piping costs caused by more primary heating and cooling being performed by water-based systems rather than air-based systems. These integrated building and systems strategies work in concert to achieve energy and cost savings, making a bundled holistic approach to whole building energy efficiency essential.

Architectural, mechanical and cost models are based on schematic level considerations. On any specific project, budget fluctuation is common at this stage; it is reasonable to assume that this modest capital cost differential between the code baseline building and the Targeting 100! high performance building options are within a reasonable range for the project to shift budget priorities to accommodate these costs; therefore, at a schematic stage of development, a 3 percent increase in capital cost could be considered "cost-neutral."

Additionally, some forward thinking hospital organizations are investing in incremental capital cost strategies that meet an acceptable rate of return. These programs emphasize that reasonable increases in first cost for strategies that yield long-term energy savings are a good investment; these investments reduce risk, bring greater stability to the organization's bottom line, reduce future liabilities, and reduce the organization's overall environmental footprint.

In many regions, utility incentive programs can reduce the incremental capital cost outlays through electric and gas utility incentive programs that fund energy efficiency projects. For this analysis, it was estimated that an integrated whole-building energy utility incentive for this level of energy efficiency savings could support the first-cost of energy efficiency strategies at a value of approximately $4/SF. With this level of incentive, the total cost premium for energy efficiency strategies that meet the 2030 Challenge goal would be reduced from approximately four percent to approximately three percent of the total project cost.

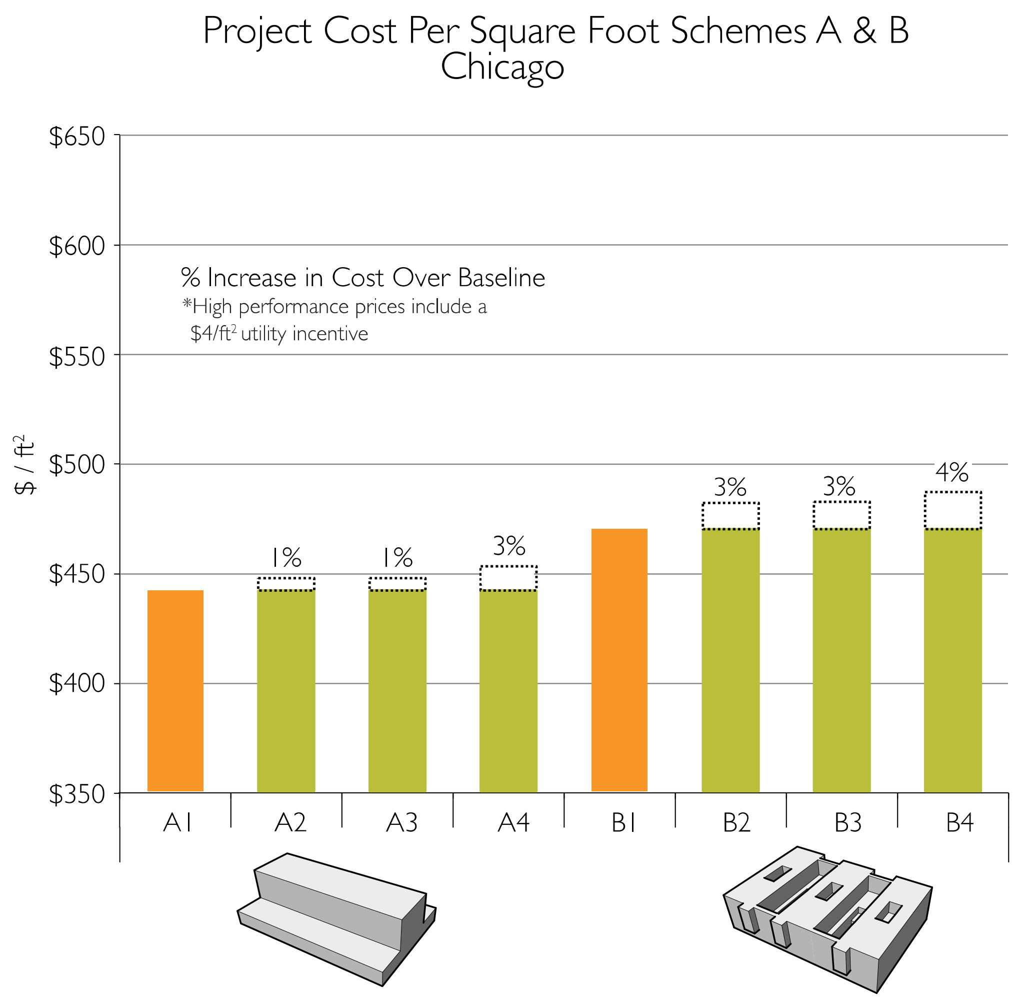

Figure 4. Cost results for Scheme A and B based in Chicago. This figure is representative of the cost modeling results. Where the overall cost per square foot varied by city, the percent increase of first cost is similar city to city showing a three percent cost increase for the most energy efficient Option 4 and on average, a two percent cost increase for the other two high performance options, Option 2 and 3. *Source*: University of Washington Integrated Design Lab 2013.

Increasing the amount of building envelope in the more articulated architectural option (Scheme B) yields approximately 6 percent increase in capital cost compared to the more simplified architectural option (Scheme A). This analysis has not attempted to analyze the quantitative or qualitative benefits of creating a more perforated hospital, such as increased daylight and its effect on staff productivity and retention or patient healing. The potential benefits associated with these quality building attributes may more than pay back the higher capital investment required to increase the building's envelope.

Operational Energy Costs

Energy costs are often seen as fixed costs – those that are steady and have a static effect on the basic budget of a hospital. More sophisticated organizations see energy costs as malleable where reductions can positively affect the financial outlook of the organization. For a typical hospital in the United States, an energy bill can be between $2-4 Million USD depending on the building size and specific locale. While that is not a large percentage of the overall operational budget, these savings can be re-framed as net income that would otherwise require services or gross revenue to generate (BetterBricks 2014).

To demonstrate this idea, a typical Targeting 100! hospital saves 60% on energy, and 35% on annual utility costs translating to an average of $575,000 in annual utility savings. For a hospital that operates in a 2% profit (or Net Operating Income) environment, a net savings of $1 is equivalent to $50 of gross revenue. In those terms, saving $570,000 annually on energy is equivalent to $28.5 Million USD of gross revenue. That is, the hospital would have to deliver an equivalent of $28.5 Million USD of services annually to reflect the same $570,000 to their bottom line. To achieve these utility savings, the hospital has not had to render patient services, yet has netted a significant amount of capital that can be invested back into the organization.

Instead of simple payback, energy efficiency can be thought of as an ongoing revenue stream over the lifetime of that investment that actually exceeds what the organization can get in relationship to making investments in other medical related practices and disciplines at the hospital. While hospital budgets are getting tighter and reimbursements are decreasing, energy savings can be viewed as an ongoing, high yield, low risk investment or revenue stream that helps provide stability for the organization.

Peer Review Stakeholders

Targeting 100! is grounded in the local realities of hospital design, construction and operation in each region. The UW's research team met with over 200 stakeholders in a series of workshops held in each of the six study regions with the goal of getting on-the-ground feedback on the project's preliminary findings and on the best region-specific approaches to achieve deep energy savings and balanced capital investment.

These collaborations ground the research in the realities of design, construction and operation of hospitals today in order for it to have the most impact. The feedback of key stakeholders was critical for understanding the applicability of the models and gathering the best approach to meeting the load reduction, energy efficiency, and cost goals in each climate region and representative city.

Partners and Research Team

The University of Washington Integrated Design Lab (UW IDL) began this research in 2006, supported by the Northwest Energy Efficiency Alliance's BetterBricks Initiative and The US Department of Energy through the American Recovery and Reinvestment Act.
The University of Washington's Integrated Design Lab collaborated closely with three industry leaders that were part of the project team: SOLARC Architecture & Engineering, TBD Consultants, and NBBJ.

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