Targeting 100!

Envisioning the High Performance Hospital: Implications for A New, Low Energy, High Performance Prototype

Executive Summary

University of Washington's
Integrated Design Lab

with support from

Northwest Energy
Efficiency Alliance's
(NEEA) BetterBricks
Initiative

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ABSTRACT

Cost control, maintaining quality healing and working environments, and more sustainable, energy efficient operations are topics of many conversations in healthcare today. The University of Washington's Integrated Design Lab, in collaboration with a team of experts in design, engineering, operations and hospital ownership have developed research directed at much higher performing buildings – targeting both energy performance and interior environmental quality, for little capital investment.

This research provides a conceptual framework and decision-making structure at a schematic design level of precision for hospital owners, architects and engineers. It offers access to design strategies and the cost implications of those strategies for new hospitals to utilize 60% less energy.

Two acute care hospital prototypes have been developed at a schematic level of architectural and mechanical systems detail. These two prototype architectural schemes and six energy performance options have been modeled for energy use and cost of construction. Both architectural schemes were able to achieve more than a 60% reduction in energy use from typical operational examples, meeting the 2030 Challenge for 2010. This research and design exercise has shown that there is little cost implication for high levels of energy efficiency with an overall premium of approximately 2% of the total project cost, a premium reconcilable through the prioritization of project specific goals and outcomes at the schematic design phase, or easily recaptured in a short-term simple return on investment.

The report of this project is designed as a tool and frame of reference for moving energy efficiency goals forward in project teams, providing a path towards achieving 2030 Challenge energy goals, and providing evidence that these goals do not require substantially increased project capital commitment.

EXECUTIVE SUMMARY

PROJECT RATIONALE

Energy + Interior Environmental Quality: Buildings in healthcare use an immense amount of energy; approximately 4% of all energy consumed in the United States today, including all of the energy used by industry, transportation and building sectors[1]. Hospitals are responsible for an enormous amount of greenhouse gas emissions; one average sized hospital emits approximately 18,000 tons of carbon dioxide into the atmosphere annually. Thus, the fields of hospital design, construction and operation offer a great opportunity for energy resource acquisition.

Hospitals also 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.

Energy Goal Setting: In order to reduce energy use it is imperative to first establish reasonable and testable goals for energy reduction. To set these goals, it is helpful to understand how much energy current hospitals use, and then develop reasonable energy reduction targets. 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 by the building, most commonly electricity and natural gas, per square foot of floor area, metered on an annual basis. Buildings' EUI are often reported in units of KBtu/SF·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. The U.S. Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS)[2] is a 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 Puget Sound climate region is 270 KBtu/SF·Year. A second database of 12 regional Pacific Northwest hospitals has been developed by the Northwest Energy Efficiency Alliance, which verifies the operational energy use that CBECS reports. It confirms a comparable operational EUI for similarly sized regional hospitals, at 263 KBtu/SF·Year[3].

Targets of Opportunity: What are the largest targets of opportunity for energy savings in Puget Sound hospitals? A survey of the operational energy use data concluded that over 50% of the energy used in a hospital is used for the heating of either spaces or hot water. This comes as quite a surprise, and quite an irony, since an EQuest simulation of a baseline ASHRAE 90.1, 2004 code compliant 225 bed hospital in the Puget Sound found that hospitals generate enough heat from internal mechanical or electrical sources to need no additional heat until the outside temperature reaches below 20 degrees. This is of particular note given that it rarely reaches below that temperature; the 99% design low temperature condition is 28.4 degrees F.

The knowledge of these energy demand profiles and climate conditions helped guide an integrated building systems approach in this research. Heating as the predominant energy load became the largest target of opportunity for energy reduction, specifically re-heat energy. Simplified, re-heat is a process used in building systems where outside air is all cooled to a common low temperature, often dictated by the perimeter zones or the hottest areas within the building. Then, when this over-cooled air is re-distributed through the building, in most cases it is re-heated to a more comfortable temperature. The process of cooling then re-heating the air back to a comfortable temperature is a severely energy intensive process. The knowledge of high energy demands on the heating side, coupled with the low thermal balance point temperature of this building type, made the heating systems a first priority for the application of energy efficiency strategies. However, to achieve significantly reduced energy use in hospitals, a complete re-assessment of all systems is required.

STUDY FRAMEWORK: THE 2030 CHALLENGE FOR 2010

What is the 2030 Challenge? The 2030 Challenge is an energy goal that is being adopted by architects, engineers and owners in an effort to greatly reduce energy consumption and greenhouse gas emissions in buildings. It is a progressive goal where every five years a greater reduction in energy use is targeted. For new buildings being designed for operation between 2010-2015, the goal is a 60% reduction from standard operational energy use and by 2030 the goal is to reach net zero annual energy demand. Compliance with the 2030 Challenge is measured by a building's modeled energy performance compared to operational energy use for a median performing building of the same-type and climate zone. Operational energy performance is determined by comparison to the Commercial Building Energy Consumption Survey from 2003 (CBECS), a national database that houses information on different building types in various climate zones. Target Finder is a web interface used to identify energy information from the CBECS database normalizing for building typology, climate, size, use, etc[4].

A 2030 Challenge Hospital, At What Cost? The research question for this project was whether the research team could design a hospital that met the 2030 Challenge, a 60% reduction in energy use, at little additional capital cost to the owner. In order to meet this energy goal in the Pacific Northwest, a project must have a simulated energy performance of less than 108 KBtu/SF year, a 60% reduction from 270 KBtu/SF·Year, the average operational EUI for hospitals in the Seattle climate region as documented by Target Finder and used as the baseline reference for Architecture 2030. The project team set an EUI of 100 for its goal, thus creating the title "Target 100."

Two Architectural Schemes, Three Energy Options: In this study, two architectural hospital prototypes were developed to a schematic level of detail. One prototype, "Scheme A," has a post-war hospital form with a five-story patient room tower centered atop a two-story tall and very deep-plan block of diagnostic and treatment (D&T) spaces. The other prototype, "Scheme B," has a thinner, more articulated D&T base platform, allowing greater potential for daylight, views and natural ventilation at all floors for all hospital functions. Both architectural prototypes were developed with three energy options: 1, 2, and 3. Option 1 is an energy code compliant baseline, Option 2 targets a 60% reduction from typical operational hospitals in the Pacific Northwest (named "Target 100," since they target 100 KBtu/SF·Year). At the central plant level, Option 2 utilizes an extensive ground-source heat pump plant as a major energy reduction strategy. Option 3 also targets an EUI of 100, but utilizes a more conventional heat recovery plant at the central plant level. Thus, three conceptual mechanical Options 1, 2, and 3 were developed for each architectural Scheme A and B. Subsequently, six energy models were developed and analyzed for these two architectural schemes. Similarly, cost models were developed and the first cost of construction was determined and compared between the six options[5].

Looking to Scandinavia: Achieving the 2030 Challenge is a monumental achievement for hospital projects, and one that has not yet been achieved in practice in the U.S. Other countries, especially regionally in Scandinavia, have been achieving greater energy performance with high interior environmental quality for several decades. Many of the strategies that were employed in the Target 100 options are referenced from recent University of Washington research on Scandinavian hospitals[6]. Looking at overall energy use in these countries and the mechanical strategies used to attain this level of energy efficiency provided a valuable trajectory for this research. Scandinavian countries consistently use half to one quarter the amount of energy in their healthcare facilities than is used in the U.S. They implement this level of efficiency using mechanical strategies that are possible to incorporate into our North American healthcare facilities today. In concert with energy efficiency, human connections to the outside environment via the abundant use of daylight, views and the opportunity for fresh air from operable windows are prevalent throughout these facilities. Since these countries have light and weather climate conditions similar to the Pacific Northwest, they provided a helpful framework for this research. Although there are cultural distinctions that make each country's hospital environment unique, there are many lessons that can be learned from Scandinavia, and applied to hospital design in the U.S.

How Can a Hospital Achieve the 2030 Challenge? In order to achieve a 60% reduction in energy use, an entire re-evaluation of many of the architectural systems, building systems and mechanical systems must take place. Adhering to a code-compliant path, following relevant mechanical, architectural and health related guidelines, the following building and mechanical concepts were found to be integral to achieving a high performance, Target 100 hospital design that achieves the 2030 Challenge:

The 2030 Hospital Integrates:

- Full **Project Team** and **Project Design Integration**.
- **Goal Setting, Energy Modeling, and Benchmarking**: Attention to designing to an energy goal, continuously verifying design performance through all stages of project schematic design through operations and maintenance.

Architectural Systems

- **Daylighting**: increase interior environmental quality and decrease electric lighting use.
- **Solar Control**: minimize peak loads for cooling and increase thermal comfort.
- **High Performance Envelope:** balance heat loss and radiant comfort with thermal performance.
- **Building Form and Orientation**: maximize the form of the building in relationship to the outside environment.

Building Systems

- **De-centralized, De-coupled Systems**: separate thermal conditioning from ventilation air.
- Optimized **Heat Recovery** from space heat and large internal equipment sources.
- Advanced HVAC and lighting **Controls:** turn off what is not in use.

Plant Systems

- **Advanced Heat Recovery** at the central plant with **Heat Pumping** or enhanced heat recovery chillers and highly efficient boilers.

Some of these concepts are major departures from standard design practice, but must be addressed to achieve high quality, low energy healthcare designs that incur little upfront additional capital cost investment.

It is critical to recognize that the strategies employed in this research study are ***one*** integrated solution. They represent a snapshot of strategies that were bundled to accomplish the goal of achieving the 2030 Challenge. These strategies are a conceptual framework for this study, 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. A framework of Architectural Systems, Building Systems and Plant Systems can help conceptualize the categories that efficiency strategies bridge.

OVERALL ENERGY AND COST RESULTS

Energy Outcomes: Based on a highly integrated bundle of schematic architectural, building systems, and plant system designs described above and detailed in the final report and appendices, both architectural schemes A & B were able to achieve more than a 60% reduction in energy use from the 2030 baseline operational examples described in CBECS, thus meeting the 2030 Challenge goal for 2010. 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 were the decoupling of space tempering and the ventilation of most spaces; fluid rather than air-transport of heat and cooling for peak conditions; and the final distribution of heating and cooling to each space via a bundle of decentralized systems such as radiant panels, chilled beams and fan coil units. This decoupled and decentralized scheme of heating, cooling and ventilating systems acting in close coordination with heat recovery from most every significant powered or heated energy source and a large ground source heat pumping system reduces the required energy use for heating (space and water) by 92%, and reduces the overall energy use for the building by just over 60%, to an overall EUI of 100 KBtu/SF·Year. A second option, with a centralized heat recovery plant in place of the ground source heat pump system, was also found to be highly effective, reducing the overall energy consumption by just under 60%. Domestic hot water heating energy, cooling load reductions, and lighting power reductions through daylighting strategies were other areas of focus where significant energy savings were achieved.

Integrated Team, Integrated Systems: Achieving results with such a dramatic reduction in overall energy use requires an integrated approach where engineering, architectural, construction contracting, ownership and utility groups all work together to achieve highly bundled and integrated, commonly held goals. This project has focused on a bundled or holistic approach to energy reduction and quality improvement, and the overall cost implications of these strategies.

One result of this highly integrated, high performance design is a large change in the dominant fuel source. The typical fuel split in hospitals is approximately 40% for electricity and 60% for natural gas (mainly for heating). The relationship between the demands for electricity and natural gas changes significantly in the Target 100 Options; there is a large reduction in natural gas consumption, and a modest reduction in electricity consumption with a fuel split of approximately 82% electricity and 18% natural gas.

COST ANALYSIS

Synergistic Savings: Given potential utility incentives, there is a 1.7% capital cost investment required to implement energy efficiency measures that achieve the 2030 Challenge for 2010. The integrated nature of building and systems create complementary savings in both energy and cost; cost savings in some categories paid for incremental energy improvements in other areas. For example, reduced cooling loads were realized by the addition of retractable louver shades, thereby reducing the first-cost of the cooling system. De-coupled systems concepts also reduced loads having a major impact on primary ventilation duct sizing, creating room in the ceiling plenum to drop the floor-to-floor height on patient floors by one foot. Cost savings realized by floor height reductions and reductions in ventilation ducting offset the increased cost for other energy efficiency improvements. These integrated building and systems strategies work in concert, thereby this effort has been approached as a bundled set of whole building strategies in a holistic analysis[7].

Cost Outcomes: The cost implications of the energy efficiency options was an overall premium of about 2.7% of the total project cost without any utility or other incentives. A schematic approach to understanding the range of possible utility incentives, in discussion with regional gas and electric utility efficiency engineers, yielded a potential whole building incentive that could subsidize first-cost of energy efficiency strategies at a value of approximately $4/Sq.Ft., or approximately $2.1 million. With this potential incentive, the total cost premium for energy efficiency strategies that meet the 2030 Challenge goal would be approximately 1.7% of the total project cost. It is important to consider that these architectural, mechanical and cost models are at a schematic level of design, thus this low percent difference between the code baseline energy option and the Target 100 energy option give great promise for the ability for new hospital projects to incorporate significant energy efficiency in their design at relatively low first-cost.

The Cost of a Highly Articulated Form: The cost of the change in architectural form, from Scheme A to Scheme B, was greater than the premium for energy efficiency. The change in form incurred an incremental cost of 8.4% with increases in cost for exterior surface, building envelope and greater articulation of the perimeter. There is a cost premium for the overall increase in surface area for Scheme B; however, the increased building perimeter improves the potential benefit of connectivity between the interior and exterior environment. Development of hospitals with better direct connection to daylight, view and potential for access to nature must be weighed with the benefits obtained from patient healing, staff well-being, productivity, satisfaction and retention in a hospital that has much higher interior environmental quality. Although this study's focus was not on the economic benefit that can be recaptured from better work environments and healing environments, this has been the subject of other studies, and can far outweigh the small increase in capital cost investment required to provide a superior quality building.

Simple payback: It was found through this work that the Target 100 energy options would save between $700,000 and $850,000 annually on total energy costs compared to newly constructed, energy code compliant options based on simple Puget Sound Energy non-negotiated rate structures. Based on these savings, the initial capital cost investment would take less than eight years to recover. If whole building utility incentives were available, the investment would take less than five years to recover. These figures are not taking into account the time-value of money, escalation or capitalization rates, therefore they are the most conservative, simple payback estimates. It is worthwhile to note that these savings are compared to other newly constructed hospitals, whose operational energy use is also lower than typical energy use of average existing infrastructure today. If these savings are compared to a similarly sized, average operational hospital today, the Target 100 hospital would save over $1M on utility bills, annually.

Putting Energy Savings Into the Operational Budget: The savings accrued by the energy efficiency strategies are significant, especially if considered as part of the net operating income for the hospital. In a 4% operating environment, it takes $25 of gross revenue to generate $1 of net operating income. That is, $25 worth of services must be provided to yield $1 of profit, or net-operating income. Energy savings can be viewed as an ongoing, high yield, low risk investment or revenue stream that does not require services to provide income to the bottom line of the hospital. In order to accrue $700,000-$850,000 of net operating income, (the savings achieved annually on energy bills) $18,000,000-$21,000,000 worth of services would have to be delivered annually.

Carbon and Beyond: If looked at from a carbon perspective, adopting these strategies would save 7,800 tons of carbon[8] entering the atmosphere annually (based on national electrical source assumptions). If only one project attains this goal it would be equivalent to taking over 1,300 passenger cars off the road[9] or planting over 300,000 trees[10]. This is a monumental amount of carbon savings – and it is an attainable, affordable goal that can be achieved if a commitment is made early by a motivated and dedicated integrated design, construction and ownership team.

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[1] EIA, 2006 Energy Information Administration (EIA), Commercial Buildings Energy Consumption Survey (CBECS): Consumption and Expenditures Tables. "Table C3A". US Department of Energy, 2006.

Architecture 2030. "The 2030 Challenge". http://www.architecture2030.org/2030_challenge/index.html.

CBECS 2006 estimates energy consumption of all healthcare buildings at 594 trillion Btu of 6,523 trillion Btu for all buildings, thus 9% of all buildings' energy use. Architecture 2030 estimates that buildings use 48% of all source energy in the U.S. with industry and transportation sharing the remaining energy. Therefore, healthcare uses 4% of all site energy in the U.S.

[2] EIA, 2003 Energy Information Administration (EIA), Commercial Buildings Energy Consumption Survey (CBECS). US Department of Energy, 2003.

[3] Burpee, Heather, Hatten, M., Loveland, J., and Price, S. "High Performance Hospital Partnerships: Reaching the 2030 Challenge and Improving the Health and Healing Environment." Paper presented at the annual American Society for Healthcare Engineering (ASHE) Conference on Health Facility Planning, Design and Construction (PDC). Phoenix, AZ, March 8-11, 2009.

[4] http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

[5] All energy options maintain Washington State Health and Energy code compliance.

[6] Burpee, Heather, Hatten, M., Loveland, J., and Price, S. "High Performance Hospital Partnerships: Reaching the 2030 Challenge and Improving the Health and Healing Environment." Paper presented at the annual American Society for Healthcare Engineering (ASHE) Conference on Health Facility Planning, Design and Construction (PDC). Phoenix, AZ, March 8-11, 2009.

[7] Cost estimates for the project are based in the Seattle, Washington construction market and were priced at fair market value for the Winter of 2010. They are first cost of construction estimates and do not include land acquisition, site work, or professional fees.

[8] Hatten, M., and J. Jennings. "2009 AIA Portland Design Awards CO_2 Calculator." 2009.

[9] United States Environmental Protection Agency. "Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks" http://www.epa.gov/oms/consumer/f00013.htm.

[10] Trees for the Future: "How to calculate the amount of CO2 sequestered in a tree per year" http://www.treesftf.org/resources/information.htm#agfotech. Tree offset calculation is based on a tree planted in the humid tropics absorbing on average 50 pounds of carbon dioxide annually over 40 years.