Target 100: Re-Envisioning Today's Hospital Prototype for Greatly Improved Energy Efficiency, Human Well-Being and Performance

Joel Loveland and Heather Burpee, University of Washington Integrated Design Lab
Mike Hatten, Solarc Architecture & Engineering
Duncan Griffin, NBBJ Architecture

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 utilizing 60% less energy and don't require substantially increased project capital commitment.

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.

Introduction to the Project and Project Team

Funded by the BetterBricks Program of the Northwest Energy Efficiency Alliance, the University of Washington's Integrated Design Lab with the collaboration with Solarc Architecture and Engineering, TBD Consultants, Cameron McAllister, NBBJ Architects, Mahlum Architects, and Mortenson Construction has developed a body of work that encompasses:

1. Knowledge about the actual operational energy-use characteristics of hospitals in the Pacific Northwest and abroad,
2. Building architectural systems, building mechanical systems and central plant systems design strategies for radically reducing energy use in the hospital sector to meet the 2030 Challenge for 2010,
3. Two prototype hospital configurations that meet the 60% energy reduction goal for the 2030 Challenge, for 2010-2015,
4. Cost implications for these prototype hospital designs.

As part of this work, the group has developed an overall strategy for reducing energy in hospitals by more than 60% in the Pacific Northwest, and these architectural, mechanical and central plant strategies provide a road-map to even greater energy savings. The study of Scandinavian hospital designs illustrate that achieving these aggressive energy goals is possible while simultaneously creating superior interior environmental qualities for patient care and staff retention, and they serve as a model for this work.

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 (EIA, 2006). 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' EUIs 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. Department of Energy's Commercial Building Energy Consumption Survey [CBECS] (EIA, 2003) 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 the Electrical Power Research Institute and incorporated into 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 that verifies the operational energy use that CBECS reports. It confirms a comparable operational EUI for similarly sized regional hospitals, at 263 KBtu/SF,Year (Burpee et al, 2009).

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 spaces or secondarily of 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. Re-heat is a process used in building systems where outside air is all cooled to a common low temperature, often dictated by the hottest areas within the building zone. Then, when this cooled air is distributed through the larger building zone, in most cases it is re-heated to a more comfortable temperature in spaces such as patient rooms where less cooling is commonly required. The process of cooling then reheating the air back to a comfortable temperature is an 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 a significant reduction of energy use to meet the 2030 Challenge in hospitals, a complete re-assessment of all systems is required.

Study Framework: The 2030 Challenge for 2010

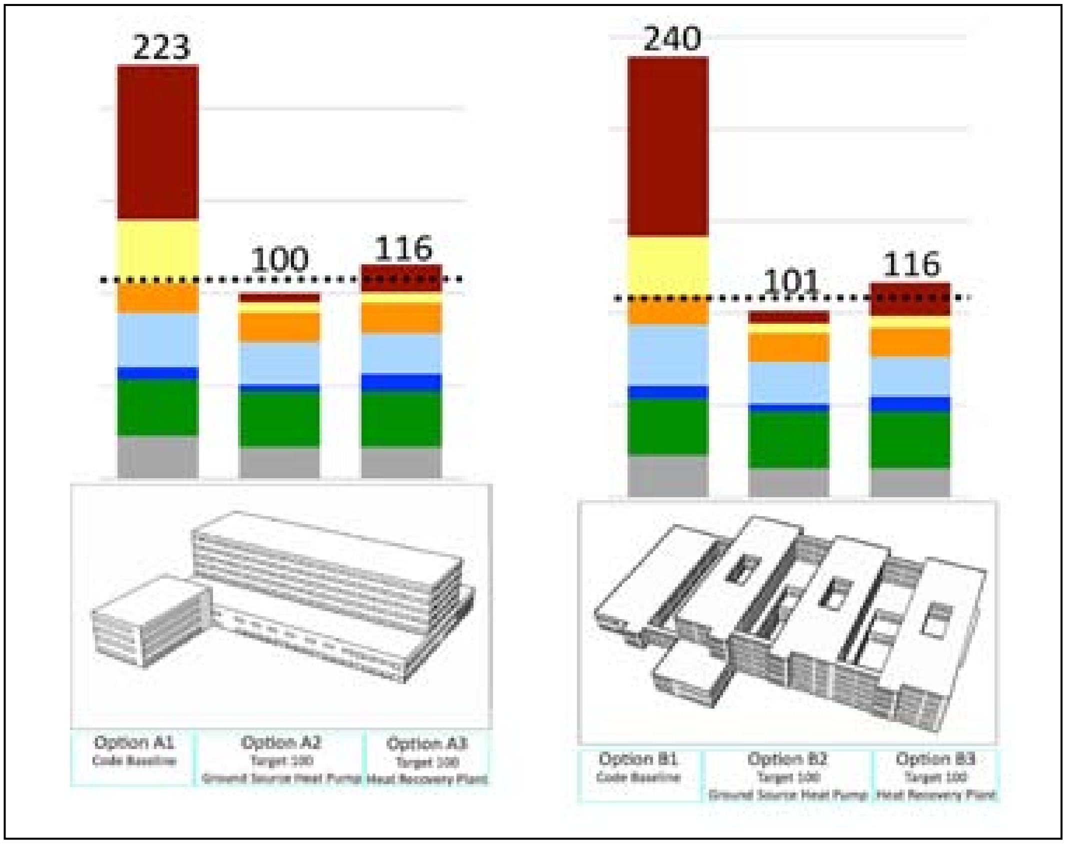
What Is the 2030 Challenge?

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 CBECS from 2003, 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 (U.S. Departments of Environmental Protection and Energy, 2010).

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."

Figure 1. Target 100 Energy Performance, Meeting the 2030 Challenge and Efficiency Improvements Relative to a Code Baseline



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. Figure 1 above illustrates the two architectural schemes and energy performance options.

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 eQuest 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. All energy options comply with Washington State Health and Energy codes.

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 (Burpee et al, 2009). 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?

The Target 100 hospital design achieves the 2030 Challenge by taking advantage of an early integration of design, construction and operations team members in the processes of energy goal setting, energy modeling and energy benchmarking. This process is best characterized by close attention to designing to an energy goal, continuously verifying design performance through all stages of project, from schematic design through post-occupancy operations and maintenance. 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 an energy and health 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.

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 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

The Schematic Nature of this Project

This project is a proof of concept exercise, which investigated how to design a hospital that meets the 2030 Challenge, as well as the first cost implications of these design decisions as compared to a conventional approach. The energy and cost estimates were based on a schematic level design precision of understanding. As with any building project, these modeled estimates will evolve with greater precision as the project approaches greater completion. Within that framework, the precision of these numbers, while stated quite precisely, we know them to be very adjustable within a margin of +/- 10% at this stage of design. Therefore differences in cost within that margin are commonly considered amenable to internal capital cost adjustments in order to maintain cost control within maximum allowable (capital) cost limit.

The bases of the assumptions for this project are made as explicit as possible so that others can follow the logic of the work reported in this paper. This team has a strong basis in practice and research, with knowledge and expertise that guided the process ensuring a plausible foundation and results. Ultimately, the outcome is a tool that can be referenced as a framework for the energy implications and first costs associated with overarching design decisions that approach the 2030 Challenge goals for 2010, without impinging on any current Washington State Energy or Health related codes. If health and safety codes are re-evaluated with both safety and energy in mind, and this research were undertaken in a non-code compliant path, an even greater energy savings might be achieved. In that way, this project is a stepping-stone to future work for even further reduced energy consumption in this typology.

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, and was a substantial area of focus in the re-evaluation of the mechanical systems design.

The key moves to decreasing the heating load were the decoupling of the tempering and ventilation of most spaces; the utilization of fluid rather than air-transport of heat and coolth for peak heating and cooling; 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%, or 120 KBtu/SF,Year. Figure 1 illustrates the energy performance of the prototype options.

Heating Strategies

De-coupled zonal heating and cooling systems with dedicated outside air and heat recovery. The de-coupled system concept eliminates reheat loads that in most conventional overhead ducted systems, result in the majority of heating energy use in regional hospitals. Reheat loads are a special energy problem in overhead ducted systems in hospitals because of the applicable state codes and standards that dictate minimum air circulation rates in many of the spaces. For example, minimum circulation rate requirement in patient rooms is six air changes per hour (about 1 cf/m,sq.ft.). Much of the time the cooling load in patient rooms requires much less than this minimum flow rate, resulting in a “system-imposed” reheat load for many hours throughout the year. Dedicated outside air systems can be sized to provide the minimum fresh air rates (2 ACH in patient rooms) and thus can be much smaller than central overhead ducted systems. The ventilation air is still tempered (typically introduced at about 62 deg. F to 68 deg. F using heat recovery from the exhaust air for most conditions), but it may not provide the primary source of cooling or heating to the room. Room cooling and heating is provided by zonal heating and cooling systems. These systems, physically located in or near the space they are serving, can take many forms. Four-pipe fan coils were defined for the “Target 100” systems, allowing code-dictated minimum air circulation rates to be maintained without imposed reheat loads. In European Hospitals, zonal systems include radiant heating and cooling, chilled beams, as well as fan coil units.

Optimized heat recovery from multiple internally generated sources including. Improved ventilation heat recovery with 65% effectiveness for areas with 100% outside air requirements and 70% minimum effectiveness for the dedicated outside air systems.

Advanced controls for ducted VAV systems serving surgery suites and emergency department zones. Significant heating energy use reductions can be achieved in “conventional” ducted VAV systems by significantly reducing total system flow rate during periods when the spaces served by the system have little or no occupancy. Almost all systems serving surgery suites experience this condition. By using occupancy sensing controls, VAV terminal units can be positioned to an “unoccupied” minimum air flow position, allowing variable frequency drives (VFDs) to slow fan speed, and dramatically reducing (if not eliminated) reheat loads for unoccupied zones. Efforts to aggressively reset supply air temperatures, especially during unoccupied periods, can work effectively in combination with occupancy sensor controls, to reduce energy use associated with reheat. A more basic form of the “advanced control” concept can apply to entire systems where all zones are unoccupied for discrete periods, and the entire fan system can be de-energized during the unoccupied period. The laundry might represent one such system.

Modular ground-coupled heat pump plant. The heat pump-based plant generates heat for space and potable water heating with a coefficient of performance often in excess of 4.0 (compared to a conventional steam plant that may operate at an “equivalent” efficiency of 0.8). In terms of heat generation, a heat pump-based plant is about 5 times as efficient as a conventional fossil fuel-fired plant. This concept employs integral heat recovery in the form of heat recovery chillers, and is often operating to meet the cooling loads imposed by the zonal cooling systems (that are not typically equipped with outside air economizers). The heat rejected from the chillers heats condenser water to 115 to 120 deg F, and is used to meet space heating and much of the potable water heating loads (that remain after reheat loads have been virtually eliminated). When there is insufficient heat to recover due to minimal cooling loads, the heat pump plant extracts heat from the thermal mass of the earth via water circulated through a piping arrangement in contact with the ground. When insufficient heating load exist to use all of the waste heat from cooling the spaces in the hospital, the excess heat is rejected to the earth through the same piping arrangement.

Reduced piping system losses. The heat pump-based plant works with a low temperature heating water distribution system. Supply water temperature is typically delivered to heat exchangers at 115 to 120 deg F. Return water temperature ranges from 95 to 100 deg F. There is no steam distribution involved. Compare this to the typical plant in the Baseline Energy Model that has several large steam boilers with high pressure steam distribution, steam pressure reducing valves, numerous steam traps, steam-to-hot water heat exchangers, and heating water piping with heating water supply temperatures of 180 deg F. The distribution system losses associated with a central steam system can be significant, especially over time as traps fail and piping and valves begin to leak. These losses are virtually eliminated in the low temperature heat pump plant.

Water Heating

Energy demand for service hot water is also reduced over 75% from the Baseline Energy Option to the Target 100 Option; from a Baseline Energy End Use representing just over 10% of the total energy consumption, to an end use comprising about 3% in the Target 100 Schemes. The 75% reduction in potable water heating energy is achieved with these three primary strategies:

Shower waste-water heat recovery. A dedicated shower drain system is proposed for the Target 100 options that allow the installation of a centralized gravity film heat exchanger system that can preheat incoming cold water using the warmth leaving drain water. Overall heat recovery effectiveness is at least 50% resulting in a 50% reduction in the load that showers impose on the potable water heating system.

Primary heat generation from heat pump plant. The primary source of heat to meet potable water heating loads is provided by the modular heat pump plant, via water-to-water heat exchangers that can heat incoming cold water to about 115 deg F. Primary water heating coefficient of performance is expected to be at least 3.5 (i.e., 3.5 units of heat delivered for every unit of electric heat input).

Secondary heat generation from high efficiency gas-fired water heater. Condensing, modulating gas-fired water heaters provide the final heating for the potable hot water system, from 115 deg. F up to the final hot water temperature setpoint of 120 deg. F. Final water heating efficiency is expected to average at least 90%.

Space Cooling

Space cooling represents a modest overall energy end use. Overall chiller efficiency is predicted to be slightly improved with the Target 100 Option. This is due to improved matching of chiller/heat pump capacity to actual load, resulting in improved part load efficiencies. However, the annualized cooling load is higher in the Target 100 Energy Option, resulting in a predicted increase in cooling energy end use. Note that peak loads are reduced in the Target 100 Option, and the peak efficiency of the Target 100 Energy Option (COP=4.50) is not quite as good as the Baseline Energy Option 1 (COP=6.10).

Lighting

Interior and exterior lighting is a significant energy end use that represents between 12% to 17% of the overall building energy usage. Options A2 & 3 are predicted to use about 27% less energy for lighting than Option A1. The reduction in lighting energy use is achieved by employing the following design strategies:

Ultra-efficient interior electric lighting. A combination of refined design criteria, maximum efficacy light sources, and additional installation of occupancy sensor controls on interior lighting is projected to reduce overall connected load from 1,248 watts/SF to an effective 0.993 watts/SF.

Daylighting controls. A combination of manual and automatic controls in selected perimeter daylight zones are projected to result in a 9% reduction in interior lighting annual energy use.

Efficient exterior lighting. A combination of refined design criteria and maximum efficacy light sources is projected to reduce overall connected load from 20 kW to 16 kW.

Other Major Outcomes

Floor-to-floor height reduction. De-coupled system concepts also have an impact on air duct sizing in the hospital. In this project this had a significant impact changing the main ventilation ducts (exiting a vertical riser shaft) from 22” diameter (typical) to 12” diameter. In addition, a 20” diameter return duct main was eliminated. Duct sizing, especially large centralized return ducts, primarily influence the floor to floor height of hospitals. When the air-side tempering is decreased, these duct size reductions allows the patient care floors to be comfortably lowered from 15’ to 14’ floor-to-floor.

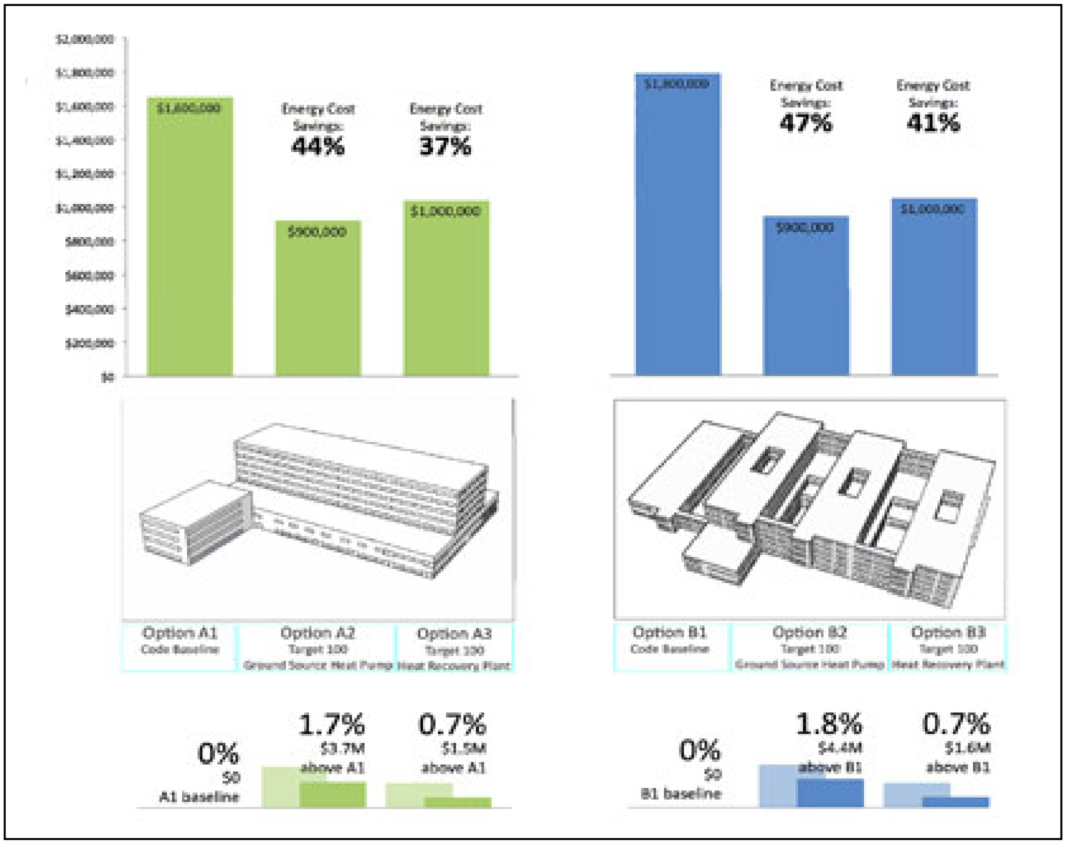
Cost Outcomes

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.

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.

Figure 2. Parametric Prototype Hospital Schemes and Energy Options with Their Respective Energy Savings and Capital Costs Including Utility Efficiency Incentives



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. 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.

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 wellbeing, 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.

Conclusions

A design, construction and ownership team has an excellent chance to build a large hospital that is greatly more energy efficient, 60% better than commonly operating large Puget Sound hospitals today, with little to no extra capital cost to the owner. As a group, we had hoped that designing a hospital that meets the 2030 Challenge with a form that has the ability to better connect to the outside environment would be a cost neutral proposition. We are disappointed that there is a significant but less than 10% difference in cost between Schemes A1 and B2, but this provides future study for where these differences occur how to minimize these increases in cost.

The future for this study is to identify areas where cost can be reduced further in Scheme B2 to be more equitable to Scheme A1, and to increase confidence in these systems' reliability from an energy perspective, cost perspective, and implementation perspective. That is our challenge -- how to bring this cost difference more in line, identifying the big pieces that have cost influence and understanding both the cost and energy implications of the decisions. Overall, we are interested in providing high quality healthcare environments with significantly reduced energy use, and no additional capital cost for the project.

References

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.

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

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

U.S. Department of Environmental Protection and the U.S. Department of Energy, 2010. http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder